DOE/MC/14522-1

PROCEEDINGS OF THE 2ND SYMPOSIUM ON VALVES FOR COAL CONVERSION AND UTILIZATION

Symposium Held October 15-17, 1980

January 1981

Work Performed Under Contract No. AM21-80MC14522

TRW Energy Systems Group
Morgantown, West Virginia

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DOE/MC/14522-1
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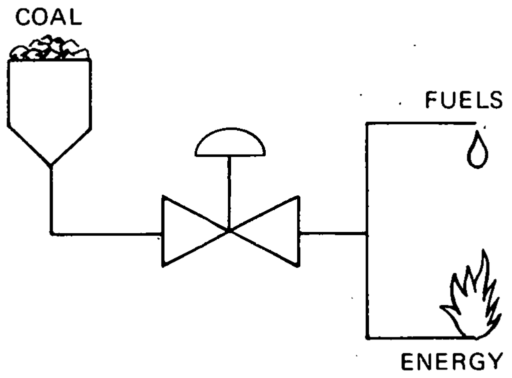

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In Cooperation with the
Valve Manufacturers Association

January 1981

TRW Energy Systems Group
918 Chestnut Ridge Road, Suite 12
Morgantown, West Virginia
David A. Maxfield, Editor

Prepared for

U.S. Department of Energy
Morgantown Energy Technology Center
Collins Ferry Road
Morgantown, West Virginia
John F. Gardner, Project Manager
under
Contract No. DE-AB21-80MC14522

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Preface

The objectives of the *Second Symposium on Valves* for Coal Conversion and Utilization were:

- To inform the valve industry of the application requirements and needs for severe-service valving in the emerging synthetic-fuels technologies.
- To establish the state of the art with valving in these severe-service applications by discussing user experience.
- To establish a forum for technical information interchange between valve manufacturers, users, specifiers, and the Government relative to the severe-service valves required for coal conversion.

These objectives were successfully achieved, as was evidenced by the enthusiastic participation of the 300 registrants and the many favorable comments received.

The *Symposium* program consisted of the presentation of 15 papers on a wide range of topics related to valves for coal-conversion service and two panel discussions—one on block valves and one on throttle valves. The presentations—made by experts in the coal-conversion field—were excellent with active audience participation during the question-and-answer sessions. Hopefully, the exchange of information that took place among participants during the *Symposium* and during follow-up exchanges will result in a better understanding for all participants—valve manufacturers, users, and specifiers—of the many problems that are inherent in the multitude of processes involved in the emerging coal-conversion industry.

As was brought out in several *Symposium* papers, the instability of many Middle East oil-producing nations is providing added incentive for the United States to develop alternative fuel-producing systems and plants. Cooperation among Federal and State governments, valve manufacturers, and peripheral industries can greatly enhance our nation's ability to meet the challenge of building the necessary facilities for converting coal into liquid and gaseous fuels for utilization as substitutes for foreign-imported fossil fuels.

The *Proceedings of the 2nd Symposium on Valves for Coal Conversion and Utilization* has been published to provide reinforcement to the oral presentations and panel discussions and to encourage even greater cooperation among the various members of the valve community in solving the valve-related problems that are inherent in coal conversion and utilization. The main body of the *Proceedings* is divided into 20 separate sections. Section 1 consists of the opening remarks by John F. Gardner (Symposium Program Chairman and Project Manager, Valve Testing and Development Projects, U.S. Department of Energy, Morgantown Energy Technology Center) and Jerome O. Hendrickson (President, Valve Manufacturers Association). Sections 2 through 16 provide the 15 *Symposium* papers grouped, where possible, by specific topical categories (e.g., keynote, direct liquefaction, gasification, etc.). Sections 17 and 18 are respectively devoted to the panel discussions on valves for blocking and throttling service in coal conversion. Section 19 presents the paper on "Critical Valve Specifications and METC Valve-Testing Projects" by John F. Gardner, and the final section, Section 20, is reserved for the *Symposium* closing remarks by John Gardner and Donn Hammitt (Technical Committee Chairman, Valve Manufacturers Association, and Manager, Control Valve Research and Engineering, Fisher Controls Company).

In addition to this "Preface" and the "Acknowledgments," the front matter of the *Proceedings* includes two cross-reference indexes—one that lists the presentations in alphabetical order of the presenters and one that lists the presentations in order of specific topics of the various presentations. Finally, to encourage future exchanges of information, the front matter also includes a list of the chairmen and speakers, as well as list of all *Symposium* registrants, including mailing addresses and company/institution affiliations.

Acknowledgments

Anyone who has ever worked "behind the scenes" at a conference similar to the *2nd Symposium on Valves* knows that the success or failure of such a program is the result of many people working together on a myriad of tasks, ranging from the writing of talks to the preparation of name tags and signs. Unfortunately, space does not permit the acknowledgment of the scores of individuals who contributed to the success of our *Symposium.*

However, I do wish to give special recognition to the speakers and panel members for their excellent contributions to the overall program. In addition, their employers also deserve recognition for cooperating in making available their time and talents.

The Valve Manufacturers Association (particularly Carl Novak and Jerry Hendrickson) and its Technical Committee (Richard Handschumacher, Bill Knecht, Greg Kurkjian, and Donn Hammitt, Chairman) have given their full support to every phase of the *Symposium.* Their assistance in planning and their feedback on the needs of the valve industry contributed immeasurably to the *Symposium's* ultimate success.

Dave Maxfield, Gordon Sine, and Diane Watson of the TRW Energy Systems Group performed an outstanding job in coordinating the *Symposium* and publishing this *Proceedings.* Furthermore, Virginia Harris and Barbara Starn, also of TRW, and Pam Stasia of METC deserve much credit for their valuable assistance in the preparation for the *Symposium* and the publishing of the *Proceedings.*

My coworker, Don Freeburn, and the management of the Morgantown Energy Technology Center have provided vital encouragement and support since this project's conception.

Finally, a special thanks is due to all 300 of you who attended for your contributions in making the *2nd Symposium on Valves for Coal Conversion and Utilization* a success.

John F. Gardner, P.E.
General Chairman

Cross-Reference Index of Presentations in Alphabetical Order of Presenters

Cross-Reference Index of Presentations by Specific Topic

List of Chairmen and Speakers

Carl Ackerman
PAMCO
Solvent Refined Coal Plant
P.O. Box 199
DuPont, WA 98327
206/964-8155

Richard Basile
EXXON Coal Liquefaction Plant
EXXON USA
5011 Baker Road
Baytown, TX 77520
713/424-3521

Kirit J. Bhansali, Metallurgist
National Bureau of Standards
Washington, D.C. 20234
301/921-2974

Neil Bond
Ashland Synthetic Fuels, Inc.
Old Rt. 3 and I-64
Catlettsburg, KY 41129
606/739-8621

David K. Christensen
General Electric Company
Bldg. 2, Room 328
1 River Road
Schenectady, NY 12345
518/385-2745

F. Don Freeburn, Chief
Component Development Projects Branch
Morgantown Energy Technology Center
U.S. Department of Energy
Morgantown, WV 26505
304/599-7746

John Gardner, Project Manager
Valve Testing and Development Projects
Morgantown Energy Technology Center
U.S. Department of Energy
Morgantown, WV 26505
304/599-7125

Donn Hammitt, Manager
Control Valve Research and Engineering
Fisher Controls Company
P.O. Box 190
Marshalltown, IA 50158
515/754-3446

Richard Handschumacher
Vice President, Engineering
ITT Grinnell Valve Co., Inc.
260 West Exchange Street
Providence, RI 02901
401/831-7000

Dan Heister
Rockwell Energy Systems Group
8900 DeSoto
Canoga Park, CA 91304
213/341-1000 x 1332

Jerome Hendrickson
Valve Manufacturers Association
6845 Elm Street, Suite 711
McLean, VA 22101
703/893-4400

Mike Kaden, Engineering Director
International Energy Agency
Grimethorpe North Barnsley
S. Yorkshire S727AB ENGLAND
44-226-713-486

John E. Kelley, Metallurgist
U.S. Bureau of Mines
Albany Metallurgy Research Center
P.O. Box 70
Albany, OR 97321
503/967-5896

Warren Lester, PDU Plant Engineer
Westinghouse Electric Corporation
Advanced Coal Conversion Department
Waltz Mill Site, Box 158
Madison, PA 15663
412/722-5509

William R. Miller, Assistant Engineering Manager
Ashland Synthetic Fuels, Inc.
P.O. Box 391
Ashland, KY 41101
606/739-8621

Steve O'Toole, Engineering Superintendent
PAMCO
Solvent Refined Coal Plant
P.O. Box 199
DuPont, WA 98327
206/964-8115

Robert J. Platt
EXXON Research and Engineering Company
Engineering Technology Department
P.O. Box 101
Florham Park, NJ 07932
201/765-0100

Frank Plut
Stearns-Roger, Inc.
P.O. Box J
Homer City, PA 15748
412/479-9081

Gary Qualls
Ashland Synthetic Fuels
P.O. Box 391
Ashland, KY 41101
606/739-8621

Dan Trapp, General Manager
Procurement
Fluor Engineers and Constructors
3333 Michelson Drive
Irvine, CA 92730
714/975-2000

William O. West, Area Engineer
DRAVO Corporation
One Oliver Plaza (TAC-10)
Pittsburgh, PA 15222
412/566-3000

Ian G. Wright
Battelle-Columbus Laboratories
505 King Avenue
Columbus, OH 43201
614/424-6424

Kamel S. Youssef, Acting Director
Office of Engineering and Component Management
Major Projects Management, Office of Fossil Energy
U.S. Department of Energy
Washington, D.C. 20545
301/353-5573

Michael Zabetakis, Director of Research
Bituminous Coal Research
350 Hockbey Road
Monroeville, PA 15146
412/327-1600

List of Symposium Registrants

Carl D. Ackerman
P & M Coal Mining
P.O. Box 199
DuPont, WA 98327

R.L. Acree
Gulf Science & Tech.
P.O. Box 2038
Pittsburgh, PA 15230

Robert M. Adams
Pacific Ives
3201 Walnut Ave.
Long Beach, CA 90807

Gary M. Akerley
Hitachi Metals
236 Old New Brunswick Rd.
Piscataway, NJ 08854

Robert R. Anglemier
Daniel Industries
19191 Hempstead Hwy
Box 40421
Houston, TX 77040

Oscar C. Backstrom
Zimmerman and Jansen
P.O. Box 9506
Pittsburgh, PA 15223

R.A. Bajura
West Virginia Univ.
College of Engineering
Morgantown, WV 26506

Paul Barbieri
Components & Controls, Inc.
P.O. Box 437
491 Washington Ave.
Carlstadt, NJ 07072

Ted Barker
Gray Tool Co.
P.O. Box 2291
Houston, TX 77001

Richard J. Basile
Exxon
5011 Baker Rd.
Baytown, TX 77520

Samir Basilious
Foster-Wheeler
110 S. Orange Ave.
Livingston, NJ 07039

David N. Bauer
Lorda Industries
8333 S.E. Pine Cir.
Hobe Sound, FL 33455

John Bazan
Foster-Wheeler
12 Peach Tree Hill Rd.
Livingston, NJ 07039

J.P. Beala
Velan Engineering LTD
255 Migneron St.
St. Laurent, PQ
Quebec H4T 1W8 CANADA

Marvin Beasley
Gray Tool Co.
P.O. Box 2291
Houston, TX 77001

Brian L. Belding
Cameron Iron Works
P.O. Box 1212
Houston, TX 77001

F.A. Bensinger
Anchor/Darling
701 First St.
Williamsport, PA 17701

Bruno Bertocci
Rowe-Price
100 East Pratt St.
Baltimore, MD 21202

Joe Betz
Mine Safety Appliance
Evans City, PA 16033

Kirit J. Bhansali
National Bur. of Stds.
Gaithersburg, MD 20760

David L. Bialosky
Standard Oil Co.
Midland Bldg.
Cleveland, OH 44115

Jack L. Bigus
Airesearch Mft.
111 So. 34th St.
Box 5217
Phoenix, AZ 85010

T.P. Blom
Koninklijke
Shell Laboratorium
Badhuisweg 3
Amsterdam
THE NETHERLANDS

Charles H. Bodamer
Int. Coal Ref. Co.
P.O. Box 2752
Allentown, PA 18001

Efrem Bolisay
System Development Corp.
7929 Westpark Dr.
McLean, VA 22102

Neil Bond
Ashland Synthetic
Old Rt. 3 and I-64
Catlettsburg, KY 41129

James E. Bonerigo
ICRC
P.O. Box 2752
Allentown, PA 18001

Leonard Bosh
Contromatics
222 Roberts St.
E. Hartford, CT 06108

Armand R. Bosso
Stearns-Roger
4500 Cherry Creek Dr.
Box 5888
Denver, CO 80217

Robert Boulden
Ladish
Cudahy, WI 53110

Jeffrey M. Bowman
Fabri-Valve
P.O. Box 2713
Portland, OR 97208

R.A. Bradley
Oak Ridge National Labs
P.O. Box X
Oak Ridge, TN 37830

N. Bragadir
Anchor/Darling
701 First St.
Williamsport, PA 17701

J.R. Brinkley
WKM Valve
16500 South Main
Missouri City, TX 77459

J.W. Bromage
Crane Co.
203 Hampshire St.
Indian Orchard, MA 01151

Bob Brown
Duriron Co., Inc.
Valve Division
Cookville, TN 38501

Earl H. Brown
Westinghouse N.E.D.
5538 Fera Drive
Bethel Park, PA 15102

Robert L. Bunting
Everlasting
P.O. Box 398
Cranford, NJ 07016

Jim Burke
Cameron Iron Works
P.O. Box 1212
Houston, TX 77001

Charles Butto
C.F. Braun
1000 S. Fremont
Alhambra, CA 91802

N. Byars
West Virginia Univ.
College of Engineering
Morgantown, WV 26506

James A. Campbell
Red Valve Co.
500 N. Bell Ave.
Carnegie, PA 15106

Raymond E. Cellemme, Jr.
ITT Grinnell
260 W. Exchange St.
Providence, RI 02901

A.N. Chen
Standard Oil of CA
555 Market St.
San Francisco, CA 94105

Dipak Choudhuri
Air Products & Chemicals
P.O. Box 538
Allentown, PA 18105

David K. Christensen
General Electric
Bldg 6-238
1 River Road
Schenectady, NY 12345

Norman V. Cleary
Stanley Berg, Inc.
P.O. Box 4500
Pittsburgh, PA 15205

Edward S. Cline
Kennametal, Inc.
L Lloyd Avenue
Latrobe, PA 15650

Christopher Clow
Clow Corporation
40 Chestnut Ave.
Westmont, IL 60559

D.W. Collins
Union Carbide
P.O. Box Y
Bldg 9201-3, MS-8
Oak Ridge, TN 37830

Earl Collins
Jet Propulsion Lab
MS 171-301
4800 Oak Grove Dr.
Pasadena, CA 91103

Nancy Condon
Pacific Valves
3201 Walnut Ave.
Long Beach, CA 90807

James W. Conrad
FACE, Inc.
Carnegie, PA 15205

William P. Coppin
Maxon
201 East 18th St.
Muncie, IN 48302

Bernard Cox
UOP/SDC
P.O. Box 4052
Catlettsburg, KY 41129

Gary Crossland
Lummus Co.
1515 Broad St.
Bloomfield, NJ 07055

O.J. Cummins
Duriron Co., Inc.
Valve Division
Cookville, TN 38501

Richard M. Curlee
Sandia Laboratories
Process Research Div.
P.O. Box 5800
Albuquerque, NM 87185

Tom L. Dahl
Union Carbide
P.O. Box 7
Nuclear Division
Oak Ridge, TN 37830

C.A. Dally
Dally Engineering
1200 Century Bldg.
Pittsburgh, PA 15222

Robert G. Davenport
Kamyr Valves
145 Murray St.
Glens Falls, NY 12801

Warren Davis
Ladish Co.
Cudahy, WI 53110

John Demchek
FACE, Inc.
Carnegie, PA 15205

Robert DeWitt
Monsanto
Mound Laboratory
Box 32
Miamisburg, OH 45342

Olavo C. Dias
Mechanical Tech., Inc.
2731 Prosperity Ave.
Fairfax, VA 22031

Jim Dodd
Wyle Laboratories
2361 Jeff. David Hwy
Arlington, VA 22202

Frank Dowling
Ladish Co.
Cudahy, WI 53110

D.J. Easton
Everlasting
70 Myrtle St.
Cranford, NJ 07016

John Egnew
Fisher Controls
205 S. Center St.
Marshalltown, IA 50158

William A. Ellingson
Argonne Nat. Lab.
Bldg 212
9700 S. Cass Ave.
Argonne, IL 60439

Rudi Everts
Shell International
CaralyBylandtlaan 23
The Hague
NETHERLANDS

Richard J. Faix
Westinghouse Elec.
Box 158
Madison, PA 15642

J.M. Farrell
Veland Engineering Ltd.
255 Migneron St.
St. Laurent, PQ Quebec
H4T1W8 CANADA

Frank Finch
LASL Corp.
Los Alamos, NM 87545

Vincent Fisher
FACE, Inc.
P.O. Box 4539
Pittsburgh, PA 15205

Roger Fix
Fisher Controls
205 S. Center St.
Marshalltown, IA 50158

Thomas W. Flaherty
ICRC
P.O. Box 2752
Allentown, PA 18001

Jonathan R. Fleming
Foster-Miller
350 Second Ave.
Waltham, MA 02154

Jack Forbes
Scientific Design
Two Park Avenue
New York, NY 10016

Lawrence Fox
Fox Valve
2 Great Meadow Lane
East Hanover, NJ 07936

Bob Fraser
Wormser Engineering
212 S. Main
Middleton, MA 01949

F. Don Freeburn
Morgantown Energy
Technology Center
U.S. Dept. of Energy
Morgantown, WV 26505

Helmut Freese
UGDE GmbH
Deggingstr. 10-12
4600 Dortmund 1 GERMANY

Donald I. Frelin
Stearns-Roger, Inc.
P.O. Box J
Homer City, PA 15748

Walter P. Gadient
Sulzer
200 Park Avenue
New York, NY 10017

Frank Galligani
Materials Development Corp.
81 Hicks Ave.
Medford, MA 02155

Ing. Max Gappisch
Argus Gesellschaft mbH
Goethestrabe 15
Ettlingen
WEST GERMANY 7505

John F. Gardner
Morgantown Energy
Technology Center
U.S. Dept. of Energy
Morgantown, WV 26505

Robert A. Genier
Atwood and Morrill
285 Canal St.
Salem, MA 01970

J.A. (Tony) George
Xomox Corp.
4444 Cooper Rd.
Cincinnati, OH 45242

William Goglia
Crane Co.
300 Park Avenue
New York, NY 10022

Ricardo Gonzalez
Worcester Controls
125 Hartwell St.
West Boylston, MA 01583

Edwin F. Goodwin
Mitre
1820 Dolley Madison
McLean, VA 22102

Louis Grass
Stearns-Roger
P.O. Box 5888
Denver, CO 80217

Lee R. Griffith
EG & G Sealol
P.O. Box 2158
Providence, RI 02905

Art Gross
Kast Metals Corp.
P.O. Drawer 6611
Shreveport, LA 71106

Larry A. Groves
Stearns-Roger
4500 Cherry Creek Dr.
Box 5888
Denver, CO 80217

Kerry F. Gunn
Exxon Research
P.O. Box 4255
Baytown, TX 77520

Raymond J. Haerry
ICRC
P.O. Box 2752
Allentown, PA 18001

C. Hales
IIT Research Inst.
10 W. 35th St.
Chicago, IL 60616

Donn Hammitt
Fisher Controls
205 S. Center St.
Marshalltown, IA 50158

R.A. Handschumacher
ITT Grinnell
260 W. Exchange St.
Providence, RI 02901

C.R. Harper
Consolidated Controls
2338 Alaska Ave.
El Segundo, CA 90245

Thomas A. Hartman
Hartman Valve
700 Capac Ct.
St. Louis, MO 63125

W.F. Hatter
Gulf Science & Tech.
P.O. Box 2038
Pittsburgh, PA 15230

Gary Hayler
MCC Center Line
1007 E. Admiral Blvd.
Tulsa, OK 74101

Dan Heister
Rockwell
8900 DeSoto
Canoga Park, CA 91304

Bill Henderson
Babcock and Wilcox
2567 S.E. Main St.
Irvine, CA 92714

Jerome Hendrickson
Valve Manufacturers
6845 Elm St., Ste 711
McLean, VA 22101

Rick Henry
Stanley Berg, Inc.
108 Rosslyn Road
Carnegie, PA 15106

Leroy Herr
Kieley and Mueller
64 Genung St.
Middletown, NY 10940

L. Herriott
West Virginia Univ.
College of Engineering
Morgantown, WV 26506

Heinz K. Hetz
Yarway
Blue Bell, PA 19422

Ken Higuchi
General Atomic
P.O. Box 81608
San Diego, CA 92138

B.P. Hilterman
Kerotest Mftg. Co.
2525 Liberty Ave.
Pittsburgh, PA 15222

Alberto L. Hinojosa
Daniel Industries
P.O. Box 40421
Houston, TX 77040

Ron Hornyak
R-P & C Valve
8150 West Ridge Rd.
Fairview, PA 16415

Robert W. Howe
Standard Oil
P.O. Box 400 MS B 4
Naperville, IL 60566

Jack Hubacher
TRW Energy Systems
8301 Greensboro Dr.
McLean, VA 22102

Istvan Hukvari
Clow
40 Chestnut Ave.
Westmont, IL 60559

David J. Hunter
Xomox Corp.
4444 Cooper Rd.
Cincinnati, OH 45242

Roger Hurd
Zimpro
Rothschild, WI 54474

H.C. Hutton
Anvil Products
P.O. Box 207, Rte 11 N.
Greencastle, PA 17225

Rand Huzenlaub
Tapco International
14309 Sommermeyer
P.O. Box 40472
Houston, TX 77040

Benjamin Johnson
Ralph M. Parsons
100 W. Walnut Ave.
Pasadena, CA 91124

C.J. Johnston
Walworth Co.
Huff Ave.
Greensburg, PA 15601

Mike Kaden
Int. Energy Agency
Grimethorpe, N. Barnsley
S. Yorkshire S727AB
ENGLAND

S.J. Kalian
Corning Glassworks
HPBB2
Corning, NY 14830

Dhiru Kapadia
General Valve
601 S. Placentia Ave.
Fullerton, CA 92631

Bob Kaufman
Mogas Machine
P.O. Box 11687
Houston, TX 77016

John E. Kelley
Albany Metallurgy
Research Center
Box 70
Albany, OR 97321

John Kendrick
W.A. Stoeltzing
P.O. Box 12892
Pittsburgh, PA 15241

Les Kenney
SII Willis
Box 7367
Long Beach, CA 90807

Robert E. Kessler
Dresser
Bradford, PA 16701

Raymond K. Kim
Babcock and Wilcox
Box 835
Alliance, OH 44601

K.K. Kirkham
Standard Oil of CA
P.O. Box 1272
Richmond, CA 94802

Stephen C. Kline
P & M Coal Mining
P.O. Box 3396
Englewood, CO 80155

Adolph Kobres, Jr.
Exxon Research
P.O. Box 101
Florham Park, NJ 07932

Quentin V. Koecher
Custom Controls
Box 368
Bellaire, TX 77401

Robert Koester
Wm. Powell Co.
2503 Spring Grove Ave.
Cincinnati, OH 45214

Donald Krastman
PETC/DOE
P.O. Box 10940
Pittsburgh, PA 15236

Richard L. Lawson
Copes-Vulcan
P.O. Box 5-7
Lake City, PA 16423

Swenam Lee
PETC/DOE
P.O. Box 10940
Pittsburgh, PA 15236

W.M. Lee
AiResearch Manufac.
111 S. 34th St.
Phoenix, AZ 85010

Dennis R. Lennon
ICRC
P.O. Box 2752
Allentown, PA 18001

Warren Lester
Westinghouse Elec.
Box 158
Madison, PA 15663

James W. Lindstrom
Koppers
Koppers Co.
Pittsburgh, PA 15219

E.L. Long, Jr.
Oak Ridge National Labs
Box X
Oak Ridge, TN 37830

Dan Lorden
Stoody Co.
208 Burnam Wood Dr.
Mt. Laurel, NJ 08054

Jerry D. MacAfee
Jamesbury Corp.
640 Lincoln St.
Worcester, MA 01605

Stanley E. Machowski
Posi-Seal International
Route 49 and U.S. 95
No. Stonington, CT 06359

E. Dennis Malloy
Colt Industries
602 N. 10th St.
Camden, NJ 08101

William F. Mangels
Stone and Webster
One Penn Plaza
250 W. 34th St.
New York, NY 10119

Al Mariconda
Yarway Corp.
Bluebell, PA 19422

Kenneth Marion
MARPAC
1900 Dempster St.
Evanston, IL 60204

Al Mark
Jet Propulsion Lab
4800 Oak Grove Dr.
Pasadena, CA 91103

Robert E. Martin
Jet Propulsion Lab
4800 Oak Grove Dr.
Pasadena, CA 91103

T.A. Mateya
Rockwell International
400 N. Lexington Ave.
Pittsburgh, PA 15208

Yosh Matsumae
Tomoe Valve Co.
16631 Busby Lane
Huntington Beach, CA 92647

David A. Maxfield
TRW Energy Systems
918 Chestnut Ridge, #12
Morgantown, WV 26505

Victor May
Texaco, Inc.
Box 1608
Port Arthur, TX 77640

John T. McCabe
Mechanical Tech.
968 Albany-Shaker Rd.
Latham, NY 12110

R.H. McCutchan
Tapco International
P.O. Box 40472
Houston, TX 77040

William D. McIlroy
Anvil Products
Box 67
Allison Park, PA 15101

Mr. McKinnon
Babcock and Wilcox
2567 S.E. Main St.
Irvine, CA 92714

William N. McLean
Crane Co.
4100 S. Kedzie Ave.
Chicago, IL 60632

William J. Medwig
Rockwell International
70 S. Orange Ave.
Livingston, NJ 07039

John Meek
IGT
4201 W. 36th St.
Chicago, IL 60632

Michael E. Miles
Jamesbury Corp.
640 Lincoln St.
Worcester, MA 01605

Alfred E. Miller, Jr.
Koppers
Koppers Co.
Pittsburgh, PA 15219

David Miller
ICG Group
Room 3732, 55 E. Monroe
Chicago, IL 60603

Gerald A. Miller
Dresser Ind.
1702 McGaw
Irvine, CA 92713

William A. Miller
Ashland Synthetic
P.O. Box 391
Ashland, KY 41101

David Milligan
Hydrocarbon Research
P.O. Box 6047
Lawrenceville, NJ 08648

Les Mills
SOHIO
313 Midland Bldg.
Cleveland, OH 44115

Oliver W. Misel
Curtiss-Wright
One Passaic St.
Wood-Ridge, NJ 07075

Dilip Mistry
Ingersoll-Rand
Box 301
Princeton, NJ 08540

K.L. Moan
MARPAC
1900 Dempster St.
Evanston, IL 60204

V. Louis Mogas
Mogas Machine
P.O. Box 11687
Houston, TX 77016

Jerry Morgenroth
XOMOX
4444 Cooper Road
Cincinnati, OH 45242

Richard A. Mueller
Cities Service
P.O. Box 300
Tulsa, OK 74102

William J. Muench
General Machine Co. of NJ
55 Evergreen Ave.
Newark, NJ 07114

E.J. Murphy
ITT Grinnell
260 W. Exchange St.
Providence, RI 02901

Mikimaro Nakamishi
Tomoe Valve Ltd.
3-11-11, Shimmachi
Nishi-ku, Osaka 500
JAPAN

William Nicholson
C.F. Braun
1000 S. Fremont
Alhambra, CA 91802

John E. Notti
General Valve
601 S. Placentia Ave.
Fullerton, CA 92631

Carl Novak
VMA 6845 Elm Street
Suite 711
McLean, VA 22101

Jeff Olson
Standard Oil Co.
Amoco Research Ctr.
P.O. Box 400
Naperville, IL 60566

Roger Orio
Dresser Europe
527 Avenue du General DeGaulle
92140 Clamart
FRANCE

Robert H. Osthues
Worcester Controls
125 Hartwell Street
West Boylston, MA 01583

Steven L. O'Toole
P & M Coal Mining
P.O. Box 199
DuPont, WA 98327

A.R. Padhye
WVU
Mechanical Engineering
Morgantown, WV 26506

David M. Palmieri
Rockwell International
390 North Lexington Ave.
Pittsburgh, PA 15208

George A. Pappaioanou
Union Carbide
1500 Polco St.
P.O. Box 24184
Indianapolis, IN 46224

Nick R. Parekh
Mobil Oil
P.O. Box 1026
Princeton, NJ 08540

Alexander Patton
G&W Fluid Systems
25 Graystone St.
Warwick, RI 02886

Herm Paul
Continental Disc
3407 NW 58th Terr.
Kansas City, MO 64151

Wendell Paulson
Zimpro
Rothschild, WI 54474

Doug Peterson
Conspray Construction
111 W. Dyer Rd., Ste B
Santa Ana, CA 92707

M. Petro
Mine Safety Appliance
Evans City, PA 16033

Kenneth A. Phy
Catalytic, Inc.
Centre Square West,
1500 Market St.
Philadelphia, PA 19102

William E. Pietrucha
VMA
6845 Elm Street, Ste 711
McLean, VA 22101

John S. Platou
Cameron Iron Works
P.O. Box 1212
Houston, TX 77001

Donald E. Platt
Contromatics
222 Roberts St.
E. Hartford, CT 06108

Robert J. Platt
Exxon Research
180 Park Ave., Box 101
Florham Park, NJ 07932

Frank Plut
Stearns-Roger, Inc.
P.O. Box J
Homer City, PA 15748

Eric Porteous
Albert Pipe
101 Varick Avenue
Brooklyn, NY 11237

H.A. Posner
Worcester Controls
125 Hartwell St.
West Boylston, MA 01583
Attenton: G. DeMarco

Gary E. Qualls
Ashland Synthetic Fuels, Inc.
P.O. Box 391
Ashland, KY 41101

George B. Rabe
Foster-Wheeler
2 Fairway Trail
Sparta, NJ 07871

Larry Radcliffe
Department of Energy
Box E
Oak Ridge, TN 37716

A.T. Radhakrishnan
Exxon Research
P.O. Box 101
Florham Park, NJ 07932

Erik Randich
Sandia National Labs
P.O. Box 5800
Albuquerque, NM 87185

Heinz Rath
GkT-GmbH
Postfach 10 22 51
D-4300 Essen GERMANY

F.H. Redwino
USS Oilwell
2001 North Lamar St.
Dallas, TX 75221

Carleton L. Reed
Masoneilan International
63 Nahatan Street
Norwood, MA 02062

Frank Rerecich
Marotta Scientific
Boonton Avenue
Boonton, NJ 07005

Mohammad Riaz
Borg-Warner
7500 Tyrone Avenue
Van Nuys, CA 91409

John A. Richards
Conspray Construction
Systems
111 W. Dyer Rd., Suite B
Santa Ana, CA 92707

John W. Richardson
Dresser, Inc.
P.O. Box 1430
Alexandria, LA 71301

Robert L. Riegel
Pacific Valves
3201 Walnut Avenue
Long Beach, CA 90807

A.M. Ritter
Fetterolf Corporation
P.O. Box 156
Fairview, PA 19409

Vernon E. Robbins
Hills-McCanna
400 Maple Avenue
Carpentersville, IL 60110

Glenn W. Robinson
International Coal
Refining Co.
P.O. Box 2752
Allentown, PA 18001

Lawrence W. Rohal
WKM Division
P.O. Box 2117
Houston, TX 77001

Dennis Romich
Babcock and Wilcox
P.O. Box 1260
Old Forest Road
Lynchburg, VA 24505

B.J. Rooney
Rockwell International
400 N. Lexington Ave.
Pittsburgh, PA 15208

Don Routh
Marotta Scientific
Boonton Avenue
Boonton, NJ 07005

I. Rozalsky
Shell
Westhollow Research Center
P.O. Box 1380
Houston, TX 77001

Wolfhard Ruddeck
RHEINISCHE
BRAUNKOHLENWERKE
AKTIENGESELLSCHAFT
Stuttgenweg 2
5000 Koln 41
GERMANY

Frank Ruiz
Dow Chemical
Louisiana Division
Plaquemine, LA 70764

Robert S. Ruscitti
Copes-Vulcan
P.O. Box 577
Lake City, PA 16423

Alberto Sagues
University of Kentucky
Kentucky Center for Energy
Research Lab
P.O. Box 13015
Lexington, KY 40583

Gordon A. Sargent
University of Kentucky
Metallurgical Engineering
763 Anderson Hall
Lexington, KY 40506

Fred Sarvey
John Mohr and Sons
3200 E. 96th Street
Chicago, IL 60017

Donald E. Schneider
Hamilton Foundry
1551 Lincoln Avenue
Hamilton, OH 45011

Robert Schnerstein
ETEC
P.O. Box 1440
Canoga Park, CA 91304

E.F. Schoenweis
Rockwell International
400 N. Lexington Avenue
Pittsburgh, PA 15208

Fritz O. Seger
SII Willis
2508 Palm Drive
Long Beach, CA 90807

Joan Carol Seibert
Hydrocarbon Research
Franklin Corner Road
Lawrenceville, NJ 08648

Michael Shackleton
Acurex Corporation
485 Clyde Avenue
Mountain View, CA 90402

Dennis J. Shallenberger
Kennametal
1 Lloyd Avenue
Latrobe, PA 15650

Don Shegrud
Continental Disc
3407 NW 58th Terr.
Kansas City, MO 64151

S.N. Shields
Walworth Co.
P.O. Box 1103
Greensburg, PA 15601

William H. Simendinger
The Lunkenheimer Company
Beekman and Waverly Sts.
Cincinnati, OH 45214

Gordon C. Sine
TRW Energy Systems
918 Chestnut Ridge Rd., #12
Morgantown, WV 26505

C.A. Siver
Conval, Inc.
Field and Billings Road
Somers, CT 06071

S.R. Skaggs
Los Alamos Laboratories
P.O. Box 1663
Los Alamos, NM 87545

Gary B. Slay
Pressure Products
900 Louis Drive
Warminster, PA 18974

Joseph W. Slusser
Air Products and Chem.
P.O. Box 538
Allentown, PA 18105

Henry Sonderregger
ITT Grinnell
260 West Exchange St.
Providence, RI 02901

Terry Staeth
Hills-McCanna
400 Maple Avenue
Carpentersville, IL 60110

James M. Staley
TRW Mission
P.O. Box 40402
Houston, TX 77040

Wayne Stalnecker
Fairchild-Stratos
1800 Rosecrans Avenue
Manhattan Beach, CA 90266

J.A. Stares
Masoneilan
63 Nahatan St.
Norwood, MA 02062

K.L. Steffan
Stearns-Roger
4500 Cherry Creek Dr.
Box 5888
Denver, CO 80217

Robert D. Stewart
Crosby Valve
Wrentham, MA 02093

Robert Stuhlfauth
Clow Corporation
5001-A Greentree
Exec. Campus
Marlton, NJ 08053

George R. Sweitzer
General Machine Company
of New Jersey
55 Evergreen Avenue
Newark, NJ 07114

Bill Swift
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439

Al Swing
Fluor E & C
3333 Michelson Drive
Irvine, CA 92730

Matt Symalla
Dezurlk
251 Riverside
Sartell, MN 56377

Tatsuyuki Tanaka
Kubota, Ltd.
50 Rockefeller Plaza,
Room 1214
New York, NY 10020

Donato R. Telesca
Enviro Control
1 Central Plaza
11300 Rockville Pike
Rockville, MD 20852

J.E. Thompson
USS Oilwell
2001 North Lamar St.
Dallas, TX 75221

M.L. Torti
Norton Company
Worchester, MA 01605

Dan Trapp
Fluor Eng. & Constructors
3333 Michelson Drive
Irvine, CA 92730

Paul Tremblay
Foster-Miller
350 Second Ave.
Waltham, MA 02154

Richard M. VanBuskirk
Robbins and Myers
1345 Lagonda Avenue
Springfield, OH 45501

Ross Vandever
Orbit Valve Co.
7500 Interstate Drive
Little Rock, AR 77219

Dale H. VanHorne
R-P & C Valve
8150 West Ridge Road
Fairview, PA 16415

M.M. VanKessel
Koninklijke Shell-
Laboratorium
Badhisweg 3, Amsterdam
THE NETHERLANDS 1031 CM

Martin Verhoeff
Denver International B.V.
Balsebaan 48, Bergen
Op Zoom
HOLLAND

D.J. Vermeer
Ocean Minerals Co.
P.O. Box 4531
Mountain View, CA 94040

James Voss
Hamilton Foundry
1551 Lincoln Avenue
Hamilton, OH 45011

N. Wayne Walkup
McCartney Manufacturing
635 W. 12th St.
Baxter Springs, KN 66713

H.A. Waller
Consolidated Controls
2338 Alaska Avenue
El Segundo, CA 90245

John V. Walsh
Jet Propulsion Lab
4800 Oak Grove Drive
Pasadena, CA 91103

John Webbley
Ajax Magnathermic
Warren, OH 44482

Dianne Weitzel
Jet Propulsion Lab
4800 Oak Grove Drive
Pasadena, CA 91103

Harold West
Superior Hard Surfacing Co.
3209 West 21st St.
Tulsa, OK 74107

William O. West
Dravo
One Oliver Plaza (TAC-10)
Pittsburgh, PA 15222

Peter Williams
Whitey Company
318 Bishop Road
Highland Heights, OH 44143

Tim Williams
Guelph Engineering
10 Kingsmill Ave., Box 98
Guelph, Ontario
CANADA

Galen Wilkie
Fisher Controls
205 South Center Street
Marshalltown, IA 50158

Albert Wilson
UOP/SDC
7929 W. Park Drive
McLean, VA 22102

Frank Wilson
GPE Controls
6511 West Oakton St.
Morton Grove, IL 60053

Wallace E. Wood
Allis Chalmers
P.O. Box M-93
York, PA 17403

Ian G. Wright
Battelle-Columbus
505 King Avenue
Columbus, OH 43201

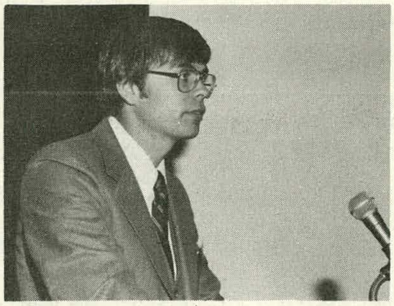
Frederick Wyant
Westinghouse
Box 158
Madison, PA 15663

Kamel S. Youssef
Department of Energy
Washington, D.C. 20545

Michael Zabetakis
Bituminous Coal Research
350 Hockbey Road
Monroeville, PA 15146

Program Chairmen . . .

Seated (left to right): David A. Maxfield, R.A. Handschumacher, Jerome O. Hendrickson, and Carl Novak. **Standing (left to right):** John F. Gardner, Donn Hammitt, and F. Don Freeburn.



Section 1

Opening Remarks for Second Symposium on Valves For Coal Conversion And Utilization

John F. Gardner, Project Manager,
Valve Testing and Development Projects,
U.S. Department of Energy,
Morgantown Energy Technology Center

and

Jerome O. Hendrickson, President,
Valve Manufacturers Association

October 15, 1980—8:30 a.m.

GARDNER: We would like to welcome you to Morgantown and the Second Symposium on Valves for Coal Conversion and Utilization. We have aimed this Symposium at the needs of valve manufacturers. We hope that this Symposium provides an exchange of information from the users to the manufacturers in such a manner that in the future we can successfully procure reliable valves for the emerging coal-conversion industry. This is needed so that we have a new, sound, and secure industry in the United States, helping us to become self-sufficient in our energy needs.

This program has come about through the gentle nudging and then shoving of the Valve Manufacturers Association. They have requested that we follow up on what was done here in 1977—the Workshop on Valves for Solids-Handling Service in Coal Conversion. We also hope that this Symposium provides a mechanism for the Department of Energy to identify needs for research and development that may or may not be able to be handled on an individual basis by valve-manufacturing concerns or through our various contract work forces in the process technology area. We hope that we can identify these needs for component development and carry those needs forth into fully implemented programs.

What we have tried to do is give you a representative cross section of coal-conversion processes that we feel will become commercial in the future. You probably will see valve specifications coming our in the next 6 months to 5 years from archetect/engineers and the industrial partners for these processes. These processes are of the type that DOE is supporting in the area of demonstration. Such processes will be commercial ventures in the future by the private sector.

We will have a gentleman here from Fluor talking about the existing indirect-liquefaction SASOL technology. You will hear some very interesting papers this morning in the area of direct coal liquefaction and the processes and valve requirements associated with each of those different processes. The program will move from the direct-liquefaction area into that of pressurized fluid-bed combustion or direct utilization of coal. The program goes international in this area in that we have a speaker here from the International Energy Agency, Grimethorpe, England, and a representative from an American firm working in the area of pressurized fluidized beds. We will round out the day with an entrained-gasification presentation, the application there being generic to the entrained-gasification process of which the Bi-Gas and Texaco processes would be representative. Tomorrow, we will continue with our gasification discussions, both in terms of existing technology and what we would consider to be second-generation technology.

We will whet our appetites right after lunch tomorrow on the area of materials for valves in coal-conversion services. Tomorrow afternoon, we will be broken out into two separate groups for panel discussions. Both of these panel discussions will go on concurrently. One group will remain here in this room. The second group will go on to another conference room. The two areas for panel discussions will be blocking valves and throttling valves for coal-conversion service.

Friday morning, we will try to wrap up with more discussion on materials for severe-service valves. Additionally, a short overview will be presented on where we have gone with the DOE test/development programs in the valve area.

We would hope that all those present will attempt to receive maximum benefit from the Symposium. That will only happen through your active participation. Question-and-answer periods are going to be available following each speaker's presentation and, of course, you will have the panel discussions tomorrow for open discussion between all of the presenters here and you, the audience. We would hope that you would actively participate and thereby maximize the benefit derived from this Symposium.

Most of our speakers, with a few exceptions, will be available for the full program. Speakers will be available over lunch or during the breaks or the evening banquet tonight for you to have informal discussions on a problem area that you may see within your valve-manufacturing area or in a related process area.

At the request of many management and marketing people in the country, we have asked all of the presenters to try to identify quantities of valves required in their plants. We have asked for their viewpoint on where coal conversion is going to go in the future. Both a DOE and a private industrial viewpoint of the future of coal conversion will be provided so you can return to your company with some insight into the future of coal and the emerging coal-conversion industry.

We should now take care of a couple of important items in the area of operational mechanics. First, your badge is your meal ticket for all luncheons and the evening banquet. Do not lose it. Second, we are going to ask all our speakers to repeat questions from the audience so that they can correctly be transcribed into the minutes of the Symposium. We intend to publish proceedings for the Symposium. Those who were with us in '77 know that it took quite a long time. We hope to have that shortened greatly for this, the Second Symposium on Valves.

At this point, I would like to introduce my friend, Jerry Hendrickson, President of the Valve Manufacturers Association. I would like to say thanks to Jerry for his active support of this Symposium; to Carl Novak, the Executive Secretary of VMA, and to the VMA technical committee for their assistance in guiding the formation of the program itself, with special thanks to Dick Handschumacher, Donn Hammitt, and Bill Knecht. Thanks also to my support group, TRW Energy Systems Group here in Morgantown, and especially to Dave Maxfield, who served as the coordinator for the Symposium program.

And lastly, I would like to express my appreciation to Morgantown Energy Technology Center management and the management of DOE Headquarters from the Office of Engineering Support for their active encouragement to conduct this Second Symposium on Valves. With that, I will turn the podium over to Jerry Hendrickson, President of the Valve Manufacturers Association.

HENDRICKSON: We are very grateful to be with you as early as 8:30 to see the capacity of this room filled. I think it's a great tribute to the liaison work that goes on between the fine government representatives of the Department of Energy as exemplified by our Chairman, John Gardner, and members of his fine support team. It's been a real pleasure to work, since 1977, to develop a Second Symposium on Valves for Coal Conversion and Utilization.

Yesterday, when Carl Novak and I were coming to this beautiful spot in Morgantown, we took the plane into Pittsburgh and drove down. There are detours, of course, those of you who have made the run will know, but I think the important thing to Carl and me was to notice a sign as we came closer to this garden spot where we are today. And this big, blue-bordered sign said, "Welcome to wild and wonderful West Virginia." We have been here for 12 hours. We haven't noticed any of the wildness, maybe it's the steadiness and stability of this group—it has been very tame. Last night as Carl and I went through the hotel, which we always do to get acquainted, we noticed that there was a great deal of attention on the World Series. We observed that the Phillies did win, 7 to 6 last night.

Coming up on the plane we had the direct poop from Washington, via the *Washington Star*. The *Washington Star* predicts everything correctly. The *Washington Star* assured us that there would be five games in the world series, and that the Kansas City Royals would win. So after the results of last night's game, I think that maybe Kansas City might be working real hard to try to win the next four games to make the prediction of the *Washington Star* come true.

Now, as I discussed this prediction with one of my friends today, he said, "Well, anything coming out of Washington is predictable along those lines. You can put just as much faith in that as you can in anything that comes out of Washington."

The other morning I had the good fortune of attending a breakfast meeting wherein our former president Gerry Ford addressed our group, and he looks real tanned and he looks well, speaks very vigorously. He said that he has been spending a great deal of time on the golf course. He also indicated that he has been in contact with Bob Hope. He said he had wished that he hadn't so much contact with Bob Hope, because he thinks that Bob Hope does take advantage of the ex-president's abilities on the golf course.

I am reminded of it because we are in a setting here with a beautiful golf course around us. He said that Bob has made Gerry Ford a central character in trying to identify golf as a combat contact sport. He said it takes some doing, but he probably is giving Bob Hope some reason to take this position. He said, for example, Hope has told his audiences that there is only one man who has the record of simultaneously playing four golf courses at one time, and that happens to be our ex-president.

He also said that after they had played 18 holes of golf, he and Hope left the 18th green and as the ex-president has been accustomed to all of his life, the press wanted to know what his score was. Hope said, "Don't worry about the score. I'll tell you what actually happened." He said, "President Ford got a birdie, that's good; President Ford got an eagle; that's good; and President Ford also got an elk, a lion, and a moose."

But in the excellent liaison we have had with DOE, and I am speaking in behalf of VMA, we've had a problem.

The problem in the background was should we hold this particular Symposium in Morgantown or should we take it to a center that might not be so taxing on these facilities, and the decision was made to hold it here in Morgantown and you certainly have greeted us enthusiastically by your attendance. The reason, of course, is that Morgantown will allow those of you who have not seen these excellent testing facilities in the synthetic-fuel field to do so. And as I understand there will be periods Friday afternoon wherein you'll have an opportunity to tour the METC facilities.

We were very impressed with the numbers that we got in at the registration desk. We are talking about 280, 290, possibly 300. Three years ago when we had the first workshop, we had a little over 200. So there is a great interest in this field, and we are happy to do our small bit in planning and promoting this program.

I certainly want to join John in pointing out that our technical committee through the chairmanship of Donn Hammitt of Fisher Controls Company in Marshalltown, Iowa, and Dick Handschumacher of ITT Grinnell, of Providence, Rhode Island, has been wonderful in trying to give thoughts on what will be most practical as far as this Symposium is concerned. And we certainly salute the technical committee for the expertise that it has brought to the planning and promotion of this meeting.

This morning, I should like to briefly tell you about our industry and tell you how we fit into the synfuel project. I also would like to give you a very brief lecture on civics as it's played in Washington, which is entirely different from what you learned in school. And that is what is going on in Washington in this field as we see it. Finally, I want to discuss some of the problems in this field and what we can do to solve them.

As I told you originally, our technical committee, in addition to promoting seminars, also provides liaison with government, universities, and other related research agencies to improve technology and disseminate known technology in the areas of valve design, application, and maintenance. It also provides liaison from member companies to the various code and standards organizations that can significantly influence the technical aspect of the products that are manufactured by our industry.

Since the first symposium on valves for coal conversion and utilization about 3 years ago, the world political situation together with the ever-increasing cost of energy has brought into focus the dire need for a strong domestic synfuel industry. Those of you who had time to read this morning's Morgantown paper noticed a headline on the front page saying that Iran threatens to mine the Strait of Humoz, so things are getting pretty bad in that section of the world. And obviously, the focus should be, and is, how we in America can lessen our dependence upon foreign oil.

Tremendous challenges are confronting our country in efforts to facilitate programs that will greatly lessen our dependence on imported petroleum products. As an industry, we will be called upon to supply the American synfuel market with equipment not yet in the marketplace. New exotic materials will be utilized to fashion the hardware for synfuel usage. All of which makes for a most exciting and stimulating era for us to contemplate.

In 1980, this year, the United States industrial-valve industry will record annual sales of approximately $2.5 billion and employ more than 50,000 workers. As we testify on the hill, we say we can increase this by another 50,000 workers who support the valve industry. So actually we are talking about a community of 100,000 workers. Despite its large contribution to American commerce, the industry is composed primarily of small and medium-size businesses.

While there are as many as 600 companies in the United States claiming to be in the valve business, most produce either small specialty items or limited product lines for special markets. Today's valve industry has evolved into a modern, precision marketing and manufacturing organization that is sensitive to the ever-changing needs of current technologies. As long as American ingenuity continues to devise new processes that require control of gases, liquids, and suspended solids, the valve industry will continue to grow and prosper.

Although historically tied to the traditional peaks and valleys of trends in capital investment, the valve industry recently has been stimulated by the impact of energy-development programs. Energy-related industries today account for nearly 35% of total valve-industry sales. These programs explain the continued increase of the dollar value of industry shipments as projected by the VMA.

During 1978, the U.S. valve industry shipped $2 billion worth of valves throughout the world. It is estimated that about 15% of annual domestic valve production is exported. However, through licenses, subsidiaries, and affiliates, the United States-based industry supplies nearly 40% of the world's valves. Strong emerging markets include Canada, Japan, Western Europe, Latin America, and the Middle East oil-producing countries. During 1979, the industry shipped $2.2 billion of products, and although the economy this year slowed, the valve industry projects $2.5 billion of shipments—an impressive growth pattern over the past years that will extend into the foreseeable future.

The VMA was formed in 1938 and provided a coordinating role for a limited number of manufacturers through 1970. However, during the decade of the '70s, the Association expanded to the 75 member companies represented today, and the association members produce more than 75% of domestic valves.

Last night when we were discussing the registration list, somebody told us that of the companies represented here, 63 of our 75 members were represented. From a VMA standpoint, that's pretty good, to have that high of a percentage of members of our association in your very group. They also indicated that preliminary registration indicated that there were about 17 or 18 nonmember companies. That indicates to us that the industry is well represented at this seminar.

As I told you a few minutes ago, energy-related industries today account for nearly 35% of total valve-industry sales. With this in mind, the future bodes well for the valve industry. Petroleum experts tell us that a delicate balance exists between world oil production and demand. They are very nervous about what the current Iraq-Iran conflict will do in upsetting this balance. However, if nothing in the world scene aggravates the oil balance between supply and demand, the crunch years should be between 1985 and 1987.

Coal remains the centerpiece of the administration's plan to reduce the use of foreign oil. It is a big part of a synthetic-fuels program that will spend some $20 billion in Federal funds by 1984 and up to $88 billion by 1992. The investment in synthetic fuels can dwarf that of the Apollo Moon Program and the Interstate Highway System combined. So you can see the enormity of this program.

Now regarding the $20-billion category, President Jimmy Carter recently signed a bill authorizing $5 billion in Department of Energy administered financial assistance to synthetic-fuels projects and a synthetics-fuel corporation, which is now operating and which is making available Federal loan and price and purchase guarantees to projects not receiving major funding from DOE. The corporation will provide funding of about $15 billion in Federal financial incentives to synthetic-fuels plants. This $15 billion is in addition to the over $5 billion already being provided through DOE.

The United States Synthetic Fuel Corporation is now operating. As a matter of fact, it held its first board meeting last Wednesday, in Washington. The law commissions this corporation to establish a domestic industry making gases and liquid fuels from coal, heavy shale, heavy oil, shale, and other materials by providing financial incentives like loan, price, and purchase guarantees. The momentum is going forward in the synthetic-fuel development.

What are the goals in this biggest peacetime effort? There are two goals. First, to have 500,000 barrels of synthetic fuel per day by 1987. That's the first goal. The second goal is to have 2 million barrels of synthetic fuel per day by 1992. To reach this goal of 2 million barrels of synthetic fuel per day by 1992, we will have to build some 30 synfuel plants. These plants would contain, remember this, these plants would contain $2.9 billion worth of valves. Almost $3 billion worth of valves.

Now what is the breakdown? In this breakdown, one category is $1.5 billion in cast, forged, and fabricated-steel valves, 2½ inches and larger, and 2 inches and smaller. That's the first category. The second category, is $900 million in control valves. And the third category, is $500 million in safety, safety-relief, and relief valves. And that totals $2.9 billion.

Can the United States valve manufacturers supply the valves needed for this synfuel program that will take 30% of our valve-making capacity? The answer is definitely yes. The American valve-manufacturing industry has more than enough "spinning reserve" in the form of extra shifts to absorb the first "shock" of this magnitude of new business. Thus, the industry will have sufficient time to plan and accomplish physical expansion of plant and machinery to meet the demand of the latter part of this program. Of course, many problems are involved in a project of this magnitude such as scarcity of water, lack of adequate transportation and other public facilities, and construction of large industrial communities in a matter of a few years.

What about the problems of the valve industry? You know the problems that I mean that are harmful to the productivity of our business. Let me name a few. The OSHA regulations, the EPA regulations, the EEOC regulations, plus a difficulty in capital formation.

I don't have time this morning to discuss all of these aspects. However, I would like to discuss just one. And that's capital formation. In 1979, our industry had a return of 5.1% on sales and 8.8% on net worth. One of the most serious problems facing our members is that of capital formation. Currently, annual industry capital expenditures are $99 million or 4.5% of sales. Since outside sources of capital are scarce, growth must be financed internally to a large extent. One way to facilitate this type of activity is by creating a capital-cost-recovery system that is fair, simple, and competitive with domestic and international competitors.

The present system is not equitable, requiring our industry to write off the original cost of its plant and equipment on the average over a period of 12 years.

The need for effective capital-cost recovery, however, extends well beyond our industry alone. The concept of useful life and the asset-depreciation range work to inhibit investment and capital formation in our nation as a whole. A continued low level of investment in this country has resulted in sagging productivity, sluggish production, and faltering competitiveness in world markets.

VMA supports the passage of Senate Bill 2419 and House Bill 4646. They are identical, and they are called the Capital Cost Recovery Act of 1980. You probably have heard it being referred to as "10-5-3," or the Jones-Connable Act. If you have not done so, we invite you to join us. This legislation would replace existing depreciation schedules for business plant, equipment, and rolling stock, and substitute in their place a simplified system of rapid depreciation for such assets. The bill has been referred to as the "10-5-3" proposal, providing a 10-year write off for buildings, a 5-year write off for equipment, and a 3-year write off for a limited investment in cars and light trucks.

The Capital Cost Recovery Act of 1980 is designed to encourage real economic growth by stimulating investment in better, more-efficient plants and equipment. By restructuring the method of depreciation to one that places emphasis on capital recovery instead of useful life, this legislation, if enacted, will stimulate capital investment and make the United States more competitive in world markets. The bill would also permit United States' companies to catch up with the more rapid depreciation rates already permitted in many other industrial nations.

Accordingly, we of the Valve Manufacturers Association are urging Congress to act quickly, to approve the Capital Cost Recovery Act of 1980. By encouraging further investment in modern plants and equipment, it will provide major benefits to the U.S. economy and to our industry in particular. Many of our member companies and the VMW itself requested Congressmen and Senators to cosponsor this bill and to support its enactment. This effort has been very successful. At this time, the House version had 307 cosponsors. When you talk about 435 Congressmen, that's a pretty good record, isn't it? And the Senate version has 54 cosponsors. When you talk about 100 Senators, that's pretty good, too, isn't it? And they are well-balanced between Democrats and Republicans.

I urge you to immediately contact your Senators and Congressmen who are now home as you well know for reelection and are going back for a lame-duck session, and convey to them that you strongly favor an enactment of a tax cut this year, with "10-5-3" as the centerpiece.

Passage of this bill will make it possible for us to expedite modernization of our plants with the latest technology and equipment so we can better serve our country in the successful completion of this massive synthetic-fuel project.

In conclusion, it is my sincere wish that you will find this Symposium to be most constructive, stimulating, and productive. With your enthusiasm and participation, I can already project that it will be the best meeting we've ever had on this subject. Thank you very much.

Section 2

DOE's Synfuels Programs and Their Effect on the Valve Industry

Kamel S. Youssef
Acting Director
Office of Engineering and
Component Management
Major Projects Management
Office of Fossil Energy

October 15, 1980—9:00 a.m.

Abstract

As a result of efforts on the part of both the Congress and the Administration, the nation is embarking on an ambitious program to provide national energy security by developing a viable synthetic-fuels industry. An overview of this program brings into focus the scope, magnitude, and goals of this effort. The race of the government and its developing partnership with industry is discussed. Defined component-development needs with particular emphasis on the essential role of valves and their application are presented. The need for implementation of programs to identify additional requirements for devices, design verification, and life testing is included as one of the areas of increasing importance.

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Good morning ladies and gentlemen. This morning I would like to spend a few minutes to bring into perspective the role of components, especially valves, in the emerging synthetic-fuels industry.

The energy crisis influences the life of every American, everyday. With each passing month, concern about economic stability and national security increases. The price of imported oil doubled last year, and the Middle East continues to be volatile. All of us are justly worried about our present and our future.

Our problems appear to be growing, but so has our resolve to overcome them. The national solution is twofold: (1) use all our energy resources more efficiently and (2) produce more energy at home throughout our major coal-producing states. Together, the conservation and production programs, if pursued aggressively, will reduce our oil imports by 4.5 million barrels per day by 1990. That is an ambitious goal, but one that can be achieved. Out of this 4.5 million barrels per day, the displacement share of synfuels from coal, shale oil, methanol, and ethanol is 1.5-2.0 million barrels per day. This is translated into approximately 20-30 synfuel plants of the size of 100,000 barrels per day of synfuel equivalent.

It is estimated that the United States has half the free world's supply of coal—enough to provide a major portion of our energy needs for hundreds of years to come.

The President's massive, multi-dimensional coal program is well underway, and the synthetic-fuels program is growing with it. Nearly 2 years ago, our changing energy climate required a shift of emphasis to rapid commercialization of technology. Now, we no longer need to justify efforts to develop essential synthetic-fuel hardware. Our energy future rests in the hands of competitive American industry.

The U.S. Government is embarking on a massive synthetic-fuel demonstration program with plants scheduled to operate around the mid to late 1980s. However, DOE is released from the role of building the many huge commercial plants. This role is slated for the new Synthetic-Fuels Corporation, which is created to fund these commercial ventures. Our energy future does not lie with any one energy source such as coal, shale oil, enhanced recovery of oil and gas, solar, etc. DOE is presently funding approximately 20 areas of technology development and a fewer number of these are into the demonstration stage.

Government and industry must cooperate to help commercialize these technologies. Industries capable of capturing the potential of our resources will not suddenly spring up, certainly not in the time frame we believe necessary. So the federal government is taking a leading role developing broad-based technologies and removing unnecessary regulatory obstacles to construction and operation. But this must be carried out in partnership with industry, and with state and local governments.

The challenge in synfuels is to take proven knowledge and experience from many sources; combine these with our best technical and management resources; and bring into being a new industry that will serve this nation, its people, and its other industries, and enhance the stability and security of the entire world.

Catalytic refining goes back to the 1920s. It took nearly 40 years to really understand it and to bring it to its current state of development. We must compress this 40 years of work into 10 for the synthetic-fuels program. At the same time, we cannot forget that these new technologies are subject to new regulatory constraints. These processes must be safe, reliable, economical, and environmentally acceptable. No element can be neglected if the process is to succeed.

The responsibility for demonstrating the viability of this industry now rests with the Department of Energy. In addition to administrative and regulatory responsibilities, DOE also runs programs fostering nuclear and solar power, defense conservation, and, of course, fossil energy. Within the fossil-energy program, the principal areas are gas, oil, and coal.

Coal represents 90% of our current budget. This budget supports the closely interrelated activities of resource and development, process-demonstration and pilot-plant activities, and demonstration-plant programs.

The Office of Fossil Energy manages approximately $8 billion worth of major projects; currently the program is scheduled to support 10 projects involving a number of technologies. All these projects are being undertaken with the aid and cooperation of industrial partners.

Two SRC (Solvent-Refined Coal) Demonstration Plants, SRC-I and SRC-II, are scheduled to start detailed designs in the fourth quarter of 1980. Construction is scheduled for 1981. These are large plants, each with a throughput of 6,000 TPD coal. They will cost about $1.4 billion each when completed. The SRC-II Demo Plant is planned to be built in Morgantown, West Virginia, and will produce 18,000 barrels of liquids per day. In the late '80s, it could be expanded to extract 90,000 barrels per day from 30,000 tons of coal.

DOE, Gulf Oil, the Federal Republic of Germany, and the Government of Japan finished initiating a partnership in this project. We have 25% contribution from Germany, 25% from Japan, and the balance is American funded.

The SRC-I demonstration plant is planned to be built in Newman, Kentucky. DOE and International Coal Refining Company (ICRC)—which is a joint venture between Air Products and Wheelabrator Frye—and Southern Company Services, also have intentions of initiating a joint venture. Also, we have the high-Btu gas projects with Conoco and Illinois Coal Gas Gasification Group. They will continue in competition until the detail design is finished in 1981.

In addition, we have a low/medium-Btu gas project, which has recently had a selection for final design construction of a plant by Memphis Light, Gas, and Water. A planning study of a commercial plant by W.R. Grace also is funded. The scope of it is to produce methanol and high-octane unleaded gasoline. It's a possible candidate to be funded by the new Syntheti

Fuel Corporation, or W.R. Grace will continue the project through the design and construction with its own funding.

For the low-Btu utility projects, we are currently in negotiation with Combustion Engineering for conceptual design of a commercial facility and process design of a demo plant. We also have been evaluating another competitive proposal in this area.

The synthetic-fuels program has at least six major support areas. It urgently needs adequate instruments and control for successful demonstration and commercial production. Coal-charge systems and equipment, and slag, ash and product letdown and disposal valves require attention. Rotating equipment—pumps and compressors for product gases and oxygen—must be studied. Solids-handling valves are another requirement. Finally, supporting technology is essential to provide suitable metallurgy for an extremely hostile operating environment full of high temperatures and pressures.

Our technologies must stay within both cost and environmental limits. Costs depend on keeping a process under precise control, keeping the plant operating, and evolving the process to a very predictable state. Integrating a gasifier with a gas turbine compounds the problem. Gas must be prepared to reach proper combustion quality. Cleanup systems must behave properly; particulates and alkalis must be kept at safe values. Coupling all the components requires operational control to safely handle start up, transients, load following, and proper operation during emergencies. Beyond all the process and systems control is our "watch" on the environment—NO_x, SO_x, particulates, effluents, etc.

By now you are all aware that the Morgantown Energy Technology Center has been designated by the Department of Energy as the center for developing and testing components, including valves, that are essential for successful coal-conversion and coal-utilization processes. They have been pursuing this important activity for several years and have been studying a number of factors that make valves fail, including:

- Erosion and corrosion of valve bodies and trim
- Leaks
- Valve trim failure
- Valve blockage during solids flow.

The efforts also have been toward studying throttling and block valves, pressure-letdown devices, and special items such as pressure-relief and check valves. These failure mechanisms observed usually can be related to the unique characteristics of coal—its chemical and physical properties. We have seen the effects of corrosion and erosion at all levels of PDU and pilot-plant operation, both in liquefaction and gasification. The problems are seen most dramatically in letdown devices. In applications like these, the best of our design and materials capability must be matched against the process.

I have been asked many times about what is the size of the market for component and device manufacturers in light of the synfuel-industry future. The answer in the case of valve market is a very qualified one, especially in the absence of detail design of the demo and commercial plants and an item count on bills of material. The best I can offer you is a simple calculation based on our in-house estimate of $1.4 billion for the SRC-II plant.

Extrapolating this cost into the approximate 15 plants expected to meet the present target of 1.5-2.0 MB/D of synfuel, the result will be a market of approximately $2.2 billion. Please remember that this number is extremely rough and is expected to change due to crowding out in the valve market.

This very rough estimate can give you an idea about the expected size of the valve market if the projected escalation rate is around 10-15% per year.

Many of you attended the workshop on Valves for Solid-Handling Service and Coal Conversion held in November, 1977. Since then, a great deal of design information and pilot-plant experience has accumulated. Most of this information has been documented. Now those who use, design, and manufacture valves and those who develop processes actively communicate and exchange information. In this workshop, we want to continue to develop that exchange.

These groups agree that a substancial development effort is needed if we are to demonstrate that the coal-conversion processes can be safe, reliable, economical, and environmentally acceptable. Experience with pilot plants makes it quite apparent that state-of-the art valves will not meet the requirements of this continuous application. It is essential that we implement a testing program. Reliability and life evaluation are essential to process design and control. Both government and industry must assume the responsibility for these tests so that we may jointly achieve the goals that have been set for us. Valves now represent significant risk to the achievement of these goals, and we hope that all of you will take your appropriate leading roles.

The Department of Energy has set as its objective the creation of a viable industry. Our role is clearly to support this fledgling industry. We provide the planning essential to implement programs and assure that projects meet technical, schedule, cost, performance, and environmental objectives. When it is deemed necessary by the industry, the government will provide the development and support so frequently required in first-of-a-kind undertakings. This government technical role will cease after demo plants are successfully operated.

Cooperation is essential. Under the best of circumstances, proven technologies supported by abundant resources and financial capability cannot guarantee prompt construction and successful operation of major projects. However, the projects that we have mentioned have put us well on our way toward the commercialization of an industry-tested technology. In a few years we expect to find ourselves well into the transition to major on-line production of synthetic fuels.

We all know that, to meet the energy needs of the late 1980s and beyond, a viable synthetic-fuels industry must be developed rapidly. We believe in this program; we are committed to this program; and we look forward to working together with you. Our joint achievement will contribute to the technical and financial confidence needed to build a truly successful synthetic-fuel industry.

During the next two days, we will have an opportunity to focus on our needs for valves. These sessions will give all of us the chance to gain a better insight into needs of this rapidly emerging synthetic-fuels technology. We are not only hopeful, but we are sure, that the improved understanding of our needs will enhance the success of the great program. It is our earnest hope that all of you will find the deliberations of the next two days satisfying, informative, and successful.

Discussion of Paper by Kamel S. Youssef

QUESTION: What will happen to this planned objective if there is a change in presidents? Have you done any thinking along those lines?

YOUSSEF: I read the newspaper like everybody else, but my crystal ball is not better than anybody else's. This $8 billion of programs we have are authorized and most of them are appropriated for the duration of those projects. So, we have a program which is in hand right now, and any change in administration won't do anything to the existing program of demonstration and major projects of DOE.

Much of the discussion about the Synthetic-Fuel Corporation and what will happen to the acting unconfirmed chairman is up in the air; it depends on what the next administration will be and what Congress will decide. As far as our activities, we don't see it in a political way; we have a program going on right now. We have legislation in hand for the Synthetic-Fuel Corporation itself, and what kind of funding they expect to get. That industry is already born. Is the chairman of the Synthetic-Fuel Corporation to be selected or not? That is the question that is subject to political changes in administration or presidents. But as far as the program is concerned, we are on our way; we have commitments and contracts in place. The agreement I mentioned we have with the Federal Republic of Germany and the government of Japan is like a treaty. It's cast in concrete.

QUESTION: How large are the two demonstration plants that are scheduled? How many barrels per day?

YOUSSEF: Which ones do you mean?

VOICE: The SRC-I and SRC-II.

YOUSSEF: The throughput is 6,000 tons per day of coal each and the product is about 18,000 barrels per day equivalent.

QUESTION: You mentioned that the West German government and Japanese government would be participating to approximately the extent of 50% on the funding. Where will that be applied? Will they also be using that technology? Or are they just contributing money?

YOUSSEF: The answer to that question is that the negotiation was quite an intense negotiation. The two governments wanted to have in the contract that 25% of the total procurement will be spent in their respective countries.

However, that particular clause was taken completely out of the contract. Right now it's competitive bidding, and the German outfits and Japanese outfits will be bidding on the hardware, bidding on the construction, bidding on the whole phase of the contract like everybody else. So there is no guarantee in that contract or in our agreement with them that we will spend 25% of that cost in Germany or in Japan. This is the kind of money they are contributing to the project and they look for gaining that much knowledge about the process. And that's the price of gaining the knowledge.

QUESTION: There's a lot of talk about whether liquefaction or gasification will develop more quickly. Do you have any idea what proportion of DOE funding will go for liquefaction and what portion for gasification?

YOUSSEF: This question is very difficult to answer, because we have quite a few factions within the Department itself. As you know, in any liquefaction process you have to have a gasifier as a way of supplying the hydrogen needed for the process. Therefore, the development of gasification processes will work as a direct enhancement of the liquefaction technology. The country has a real need for transportation fuels and to get these liquids, you can use either the direct liquefaction or the indirect liquefaction route. In indirect liquefaction, liquids are produced in two steps. First, gasification, then reacting the produced gases into liquids (e.g., the Synthol Unit in the SASOL Plant, South Africa). However, the intermediate gasification step could prove to be a little bit more expensive, which is a debatable issue.

So presently in DOE, we are committed to four liquefaction demonstration plants, which are the SRC-I, the SRC-II, the Exxon Donor Solvent (EDS), and the H-Coal. The last two are major pilot plants. EDS is about 250 tons per day and H-Coal is about 600 tons per day. The SRC-I and SRC-II are 6,000 tons per day.

In the gasification, we have six gasification projects going on right now. The liquefaction is a little ahead of the gasification with regard to procurement and signing of contracts. The gasification is still under competition. And I am quite certain that by the coming year, calendar '81, we will have the final go/no-go decision on those high-Btu plants.

QUESTION: You indicated six support areas which I know will take a great deal of developmental money before their commercial practicability is seen and therefore there's going to be a good deal of government money. Synfuels Corporation has little or no R & D money of its own; I believe $12 million enabling legislation. Is there a long-term commitment, a long-term program within DOE to retain the sponsorship of the necessary development work?

YOUSSEF: The question is a very appropriate one, and right now we are wrestling with it. We are in the process of defining the interface between the Synthetic-Fuel Corporation and the Department of Energy. As a matter of fact, we have been getting quite a bit of questioning from OMB, and our assistant secretary is scheduled to go and discuss this matter on October 17. Evaluation of DOE/SFC interfaces on issues such as long-term planning, long-term support, technical interfaces, technology base, data dissemination, and repository of technical data are all under investigation.

The SFC future—Is it going to be another Department of Energy? Is it going to be a private entity? How is it going to be funded?

How is it going to be organized and coordinated with DOE? All these are reasonable questions which I am afraid that I can't answer today.

QUESTION: You mentioned funding SRC-I and SRC-II. Has funding for SRC-III been approved?

YOUSSEF: I don't know of SRC-III.

QUESTION: You mentioned the third plant would be coming to Morgantown, or was that SRC-II?

YOUSSEF: Yes, SRC-II.

By the way, I want to mention one other thing. Mr. Hendrickson has presented to you quantified numbers about the market size in dollars and also the prospect for the valve industry in the coming years. I independently did some calculations to find out what the size of that market will be, and believe it or not, the answers obtained were close to Mr. Hendrickson's numbers.

Just to give you an idea, we have spent about $20 million on phase zero for the SRC-II plant. This included a feasibility study, preliminary design, and pilot-plant verification runs. An essential part of phase zero was a report addressing the capital cost of the demonstration plant and the estimated cost of the product produced by a commercial plant. Therefore, the $1.4 billion estimated cost for the SRC-II plant is a reasonable number to use in our calculation of how many valves will be needed for 15 to 20 plants of a similar type. However, I should caution you that the estimated cost is based on certain assumptions such as: the inflation rate, environmental issues, number of permits required, and a reasonable schedule for construction. Therefore, the estimated cost could change with any variation of the listed assumptions. Within the $1.4 billion, the total estimated cost of piping—including piping materials, fittings, valves, expanders, shop fabrication, and field installation—is about $85 million in 1979 dollars. A good rule of thumb used in the process and chemical industries is that the valves will be approximately one-third of the estimated materials cost. This will result in a total estimated cost of valves of about $17 million.

Knowing that SRC-II demo plant is one-fifth of the total commercial plant, then the projected cost for valves in one commercial plant of the type and size of SRC-II is $85 million in 1979 dollars. Allowing for escalation on a reasonable spread on the 15 to 20 plants between now and 1992, the projected cost estimate of total valve requirements in synfuel applications is about $2.2 billion. Mr. Hendrickson was talking about $2.9 billion. I don't know what the basis of his number is, but it is close enough to show that the total volume in the valve market is going to be increased by that magnitude. Thank you very much.

Section 3

King Coal—The Sleeping Giant

Michael G. Zabetakis
Director of Research
Bituminous Coal Research, Inc.
Monroeville, Pennsylvania

October 15, 1980—8:00 p.m.

Abstract

The paper will provide an analysis of trends in the coal industry, with particular emphasis being placed on the factors that are apt to influence the industry's growth in the future.

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Good evening. It's a pleasure to be here this evening and to share a few thoughts with you regarding the role of coal in our energy future. But before I begin, let me assure you that I don't have a crystal ball. For the most part, I will attempt to analyze and, where necessary, to extend readily available information to cover situations of interest to this group.

Let's start by first looking at the principal sources of energy in the United States during the past century. As you know, wood supplied most of the energy used here in the 19th century. However, this changed around 1885 when coal became the principal energy source; coal was in turn displaced by oil near the end of World war II. These salient points are summarized in Figure 3-1. Note in particular that coal represented less than 10% of the total U.S. energy supply in 1850; by 1885 it represented just over 50%, displacing wood as the principal source of energy. By the turn of the century, coal represented over 70% of the total energy supply, wood represented 21%, natural gas and oil represented 5%, and water power represented 2.6%. The technological developments following the Civil War created

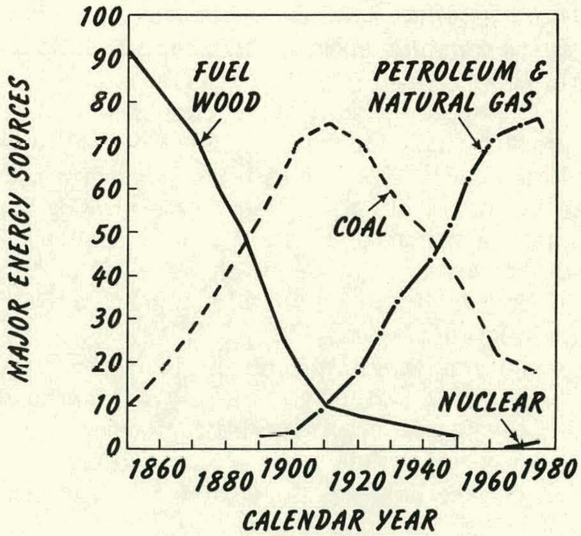

Figure 3-1. U.S. Energy Consumption Patterns expressed as percent of total energy consumption

a number of new uses for coal. What had started as a fledgling industry two generations earlier was now a major basic industry with total production approaching 300 million tons annually.

Coal production peaked shortly after World War I and then began to fall as the use of oil and natural gas increased. Between 600,000 and 700,000 men were working in the nation's mines during this period; annual production of coal ranged between 500,000 and 600,000 tons. These data are included in Figure 3-2, which shows the underground coal production and man-shifts during the period 1850-1970. Note the downward trend in total production during the period between World Wars I and II. This was followed by a rise during the second war and another drop and rise following this war. Figure 3-3 shows this in greater detail. Note that total coal production was 742 million tons in 1979 and is still rising.

Projections made as recently as 8 years ago (before the oil embargo of 1973) showed coal use rising slightly, but with the lion's share of the energy supplied by oil, gas, and nuclear energy for the balance of the 20th century. This is shown in Figure 3-4. A usually reliable source indicated the total demand for energy would grow from 68.8 quads (quadrillion Btu's) in 1970, to 191.6 quads in the year 2000, with coal supplying 20.1% of the total energy in 1970, and 13.7% (1 billion tons) at the turn of the century; the latter figures were revised 3 years later to 21.3% and 1.56 billion tons.

The projected figures for coal were revised upward again following the incident at Three Mile Island. Current estimates indicate that coal should supply at least one-third of our total energy needs by 1990 (approximately 1.5 billion tons), with as much as 17% of this amount (about 250 million tons) going into the production of synthetic fuels.

By comparison, petroleum is expected to supply 32% and natural gas 21% of our total energy needs at that time. Nuclear, solar power, and other sources are expected to supply the balance. In short, within the next 10 years, coal should once again become our dominant energy source. This, of course, assumes that the capital and other resources can be found to open the new mines needed to furnish this coal and to build the preparation plants, coal-handling systems, power plants, and synthetic-fuel facilities needed to safely transport and process this additional coal.

These latest projections are not surprising when we consider the quantities of energy that are available from recoverable domestic sources. Present estimates indicate that we have upwards of 15,000 quads of energy available in the form of coal, but less than 2,500 quads in the form of oil and gas; in other words, we have over six times as much energy in the form of coal as in the form of oil and gas. At our present and proposed usage rates, this is enough to last over 150 years. Even if the latest scenario is not realistic, barring any unforeseen technologic breakthrough, coal must ultimately become our principal energy source in the near future. However, since it cannot be used directly in many applications, it must be converted to more readily usable forms such as oil and gas.

Let's look at some of the underlying reasons for this last statement. First, domestic oil production has declined in recent years. This in spite of the fact that oil from Prudhoe Bay is flowing through the Alaskan pipeline and that an ever-increasing number of wells are being drilled each year. A similar trend is found if we look at natural-gas production. Total production of oil and gas is expected to level off at about 40 quads per year; with an anticipated energy usage rate of just under 100 quads, the balance must be made up by imported oil and coal, nuclear, hydro-power, solar, and other energy sources. Even with conservation, we will not have enough domestic liquid fuels by 1990 to take care of our transportation needs, let alone to heat our homes and operate our industrial facilities. If we are to decrease our imports, we must develop a synfuels industry. This is reflected in the new energy initiatives announced by President Carter this past year in which we are to:

- Limit our imports of petroleum to 4.5 million barrels per day by 1990.
- Limit the use of petroleum for electric power generation to 0.75 million barrels per day by 1990.
- Provide federal funds to create 2.5 million barrels per day of new domestic liquid and gaseous energy supplies by 1990.

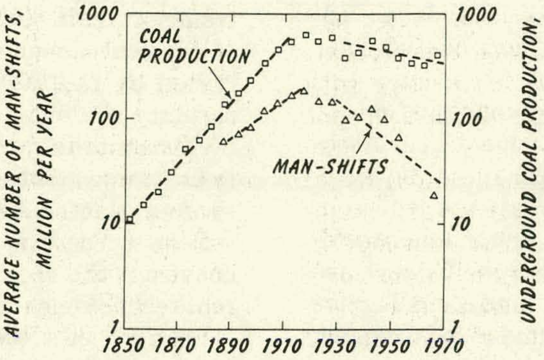

Figure 3-2. Coal Production and Employment Statistics for the Period 1850-1970

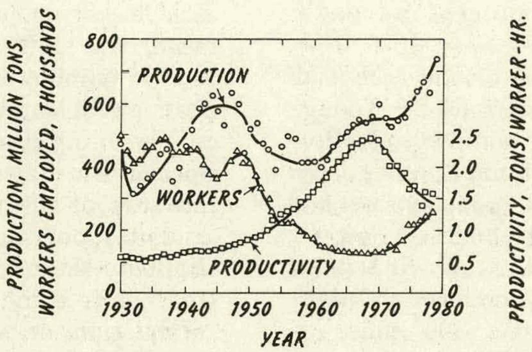

Figure 3-3. Production of Bituminous Coal, Employment Statistics, and Productivity for the Period 1930-1979

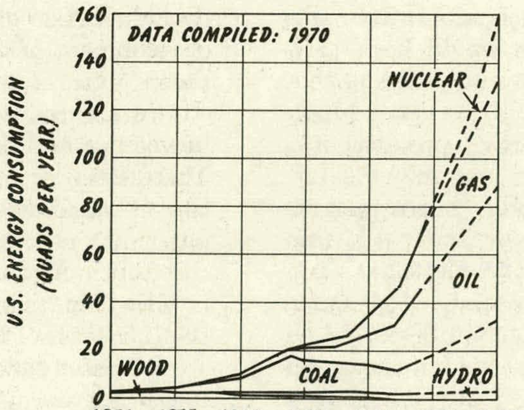

Figure 3-4. U.S. Energy Consumption Patterns

- Provide additional federal funds to advance the development and use of solar energy.
- Further encourage energy conservation.

A recent survey by the National Coal Association indicates that a total of 41 liquefaction and gasification plants are now in operation; of these, five are commercial facilities, nine are pilot plants, and the balance are process-development units and small pilot plants. Six other plants are under construction, and 42 have been proposed and are in the planning stage. Many of you will have an ample opportunity to get involved in the design and construction of these plants. As with any large undertaking, there also will be ample opportunity for innovative designs, particularly when you consider the temperature and pressure extremes encountered in today's synthetic-fuel facilities.

Now, let's look at a few of the technical problems that face the coal industry today. First, in order to essentially double production in the next 10 years, we must essentially duplicate our present coal industry; we are assured that this can be done. A recent National Coal Association study indicated that the nation's top coal producers are planning to open or expand over 300 mines to produce an additional 600 million tons of coal by 1985. Together with the industry's current capacity to produce over 900 million tons of coal, this should be enough to meet our goals—assuming the capital can be found and all the necessary applications can be completed properly and approved by the various regulatory agencies. This can be accomplished without any additional technological breakthroughs. Nevertheless, we would hope that additional funds would be invested during this period to improve our R & D posture. Much needs to be done to improve productivity, and at the same time make our mines safer. Productivity has fallen steadily in the past 10 years; it is now some 30% lower than it was in 1969. This in spite of the fact that 60% of our current production is in inherently safer surface mines, compared to 40% in 1969.

Next, we must recognize that an increased coal-production capability is just the first step in meeting our national goals. We must be able to use this coal either at the mine site or at some distant location, and we must be able to transport it in a timely fashion. While most of our coal (about three-fourths) is now transported by rail, we do not presently have the capacity to double this amount without large investments in our railroads, coal-slurry pipelines, mine-mouth generator stations, and synfuel plants. Again, large sums of money will be needed, along with the lead time to construct the necessary facilities, even if current technologies are employed.

Finally, let's briefly review the processes involved in the use of coal. By far the most efficient way to use coal is to burn it as a solid on fixed or moving grates, or to pulverize it and blow it into a combustion chamber with preheated air. These are both fairly well established procedures and require little, if any, additional research, other than that associated with pollution control. As you may recall, the shift to oil and gas after World War II eliminated many of the handling and cleanup problems associated with coal. Actually, coal handling poses no great problem in large electric-power-generating stations; the same is not true of the products of combustion. To minimize pollution, we must take pains to eliminate the undesirable impurities from the coal before combustion, remove them during combustion, or remove them from the stack gases before they are dumped into the atmosphere. Additional research must be done in each of these areas if further improvements are to be made in the use of much of our high-sulfur eastern coal.

Coal-oil mixtures are being considered as a substitute for oil. But again, we are still faced with many of the same environmental concerns. Also of interest to this group is the development of controls to handle the flow of these mixtures in retrofitted burners.

As we found during World War II, coal can be gasified and liquefied on a commercial scale. There are now over 35 years' experience with the German-developed Lurgi process. This particular process is used in the first stage of the South African Fischer-Tropsch plants. It is also being considered as the first stage of the U.S. Great Plains Gasification Plant.

As I noted earlier, some industrial synthetic-fuel units are also operational in this county. But the large commercial plants are still to be built. Nevertheless, we can safely say that control valves will be needed both in the plants and in the transmission lines that will be used to transport the synthetic fuels—both gases and liquids. Unfortunately, many of the problems experienced to date with the smaller plants—whether because of erosion, lack of precision, or dependability—are basically control-valve problems. Much work remains to be done in this area if we are to have a reliable industry.

In summary, only one fossil fuel is available in adequate supply to carry us into the 21st century—coal. All indications are that it will become our dominant source of energy within the next 10 years. However, considerable capital, equipment, and trained personnel will be needed if it is to be mined, transported, burned, and processed in a safe and environmentally acceptable manner.

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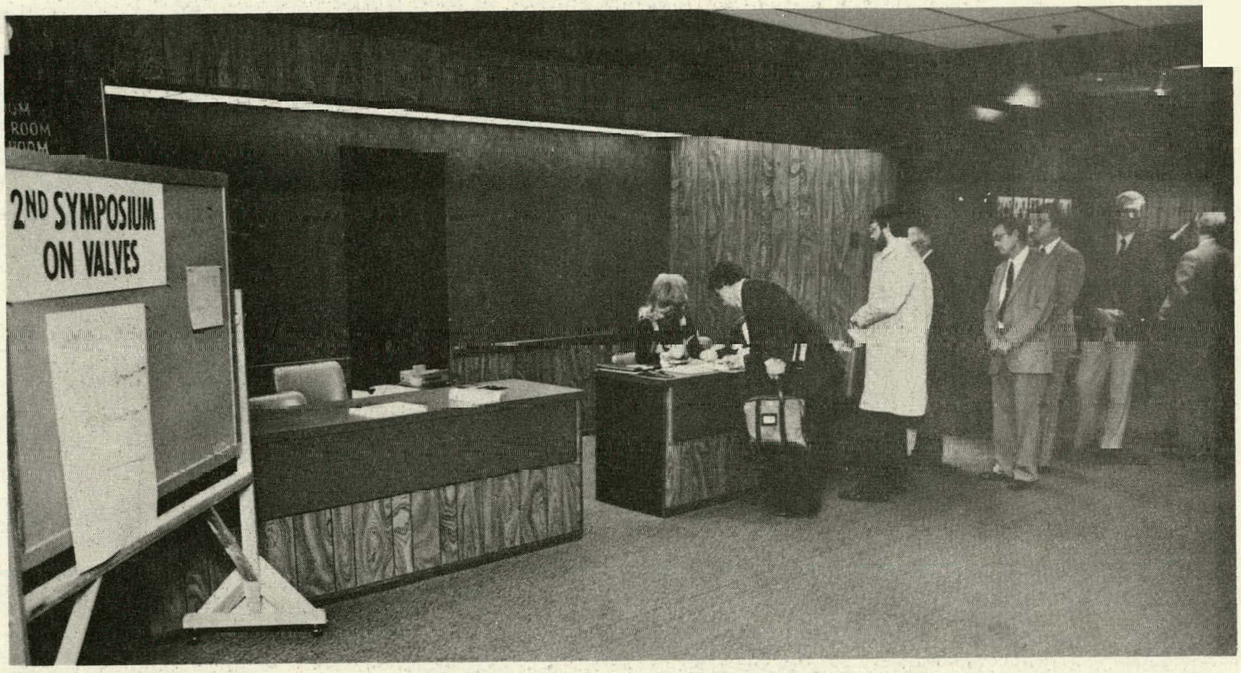
Signing Up on Tuesday Afternoon . . .



Banquet Wednesday Evening . . .

Section 4

Valve Requirements For Synfuel Plants: Today and Future

Dan W. Trapp
General Manager, Procurement
Fluor Engineers and Constructors

October 16, 1980—8:30 a.m.

Abstract

Synthetic fuels is a very interesting alternative in the production of transport fuel. Mr. Trapp will briefly discuss Fluor's capabilities in the synfuel area and Fluor's experience with the SASOL project in South Africa.

He will include some information on the coal-to-gas process as used on the SASOL project and give a summary of equipment required for a project of this type. The valve requirements will be highlighted. Mr. Trapp will also give Fluor's prediction of the valve requirements in the near future.

A short film will be shown on the coal-to-gas process and some time will be devoted to answering any questions.

★ ★ ★

I am pleased to be here with you today and have this occasion to discuss the opportunities and challenges facing the energy industries in the next several years.

In my discussion, I will cover the following: First, I am going to tell you a little bit about Fluor; next, I'll provide comments on synfuels, SASOL and how it started, SASOL-process schemes, the SASOL project, materials for valves, and the future; finally, I'll present a film titled, "Tons to Barrels," and hopefully we will have enough time for questions and answers.

First, just a little bit about Fluor Engineers and Constructors. We are in the energy business. We engineer, procure, and construct plants worldwide. We design all sorts of petrochemical, chemical, and refinery-type plants. We have engineering offices in: Irvine, California; Houston, Texas; Calgary, Canada; London, England; Manchester, England; Haarlem, The Netherlands; Dusseldorf, Germany; Johannesburg, South Africa; and Alkhobar, Saudi Arabia. In addition to being a total engineering office, these offices also have procurement offices. We also have procurement offices in Milano, Italy, and Tokyo, Japan. All of these offices are permanent offices. In addition, for particular projects worldwide, we have opened local procurement offices to handle the purchasing on a local basis. From a procurement standpoint worldwide, we have approximately 1,800 people performing this task. To give you an idea of what these 1,800 people can do, last year we purchased in excess of $1.7 billion. Fluor's permanent staff worldwide is approximately 25,000 people, not counting construction types. Now for synfuels.

Synthetic fuels is a fascinating alternative in the production of transport fuels. Basically at Fluor, when we refer to synfuels, we mean transport fuels of diesel and gaoline, primarily from two sources: coal and shale oil. In the United States, we have tremendous deposits of coal and shale, but it is solid and we must take steps to release the hydrocarbons or combine the carbon with hydrogen to create the liquids that, in the past, we felt were plentiful in the form of petroleum from the earth. Up to 35 gallons of oil can be produced from a ton of shale. More than twice that amount can be produced from a ton of coal. South Africa has taken such a step—a country rich in minerals and metals but void of petroleum.

Although several coal-conversion technologies are in one or another stage of development, only the SASOL method has been proven commercially. So today, Fluor is very fortunate in having signed an exclusive agreement with SASOL to market this technology in the United States.

The SASOL/Fluor agreement is not for just one single process but many, including a large accumulation of know-how, experience, and technology useful for planning, optimizing, designing, constructing, and operating a complete, complex facility capable of converting coal to transport fuels.

Central to this package of technology is the SASOL-licensed synthol process. This is the German Fischer-Tropsch process, which has been perfected from the original installation in SASOL I and is now the sole property of SASOL available for licensing. The selection and arrangement of other processes in the complex—from coal gasification, which, in the SASOL plants, is the Lurgi process, to final product treatment—can vary from project to project.

We mentioned that South Africa has no oil reserves, so today, coal provides 75% of the country's energy needs, the remaining coming from imported crude oil. That imported crude oil used to be provided from Iran. Today, of course, that source no longer exists and is one of the very important reasons why SASOL III became a reality so close on the heels of SASOL II.

The SASOL story began in 1947 when the South African legislature established the framework for an oil-from-coal complex and in 1950, SASOL was formed. Five years later, in 1955, oil from coal was produced for the first time in the synthesis reactor at SASOL I. By 1965, 10 years later, SASOL I had become a major producer in South Africa of petrochemical products of butadiene, styrene, ammonia, and ethylene. In 1974, the South African government announced its decision that SASOL would proceed to build another oil-from-coal complex. So, in January 1975, a SASOL team visited the U.S. to conduct talks with firms considered eligible for appointment as managing contractor. In March 1975, Fluor Engineers and Constructors was selected as the managing contractor, and planning began for a facility to produce approximately 40,000 barrels per day of synthetic-fuel products by early 1981. That project was SASOL II and synthetic-fuel products are now being produced. Already, liquid hydrocarbons have been produced from the synthol reactors and are being converted to transport fuels in the oil work-up area.

In March 1979, the decision was made to proceed with the construction of SASOL III adjacent to the SASOL II site. This decision was influenced by the cessation of oil imports from Iran, and by the benefit of using the huge construction force assembled for SASOL II. Additionally, a large percentage of engineering drawings and equipment could be duplicated. Thus, the scheduled completion for SASOL III could be accelerated from the 5 years it took for SASOL II to 3 years with completion set for 1982—when completed, approximately 90,000 barrels per day of transport fuels will be produced from SASOL II and SASOL III. These two facilities will provide more than half of South Africa's transport-fuel requirements.

SASOL II is designed for 40,000 tons per day of coal, and SASOL III for 45,000 tons per day, of which roughly 25% is used in the steam-generation facility and 75% is gasified. That 40,000 tons of coal represents a train of 800 cars, 9 miles long. The primary objective of SASOL II is for transport fuels of gasoline and diesel, but it also produces a total of 26 salable products not including 10,000 tons per day of ash.

The basic SASOL process scheme is as follows. We start by bringing coal, which is produced from two underground mines, by conveyor from a stockpile into a wet-screening building where the coal is properly sized for gasification. The fines are conveyed and burned in the steam-generation facilities. Once the coal is of proper size, it is conveyed to the gasification unit where we have 36 Lurgi gasifiers. Here, in the presence of steam and oxygen, the coal is converted to carbon monoxide, carbon dioxide, hydrogen, and methane. After gasification, the gas is processed through the gas-liquor separation unit and further cooled in the gas-cooling unit.

We mentioned that the gasification took place in the presence of steam and oxygen. The steam-generation facilities consist of six boilers, each generating 1,200,000 lbs/hr of 600-psi steam. We also generate 240 megawatts (MW) of power. Total power requirement is 600 MW. In conjunction with SASOL III, two additional boilers are being added to this area of SASOL II. This is a complete turnkey operation by Deutsche Babcock of Germany, including construction. The oxygen plant is the largest grassroots installation in the world, with six trains each producing 2,000 tons per day of oxygen. This also is a complete turnkey operation, including construction by L'Air Liquide of France. The steam-generation plant and the oxygen plant are the only units not being constructed by Fluor.

From the gas-liquor separation unit, liquids are further processed to recover ammonia and phenols in two 50% trains of the ammonia-recovery and phenosolvan units. From the gas-cooling unit, the gas is processed in two 50% trains of the rectisol unit where carbon dioxide and sulfur compounds are removed. The purified gas—which is now a mixture of carbon monoxide, hydrogen, and methane—is used to feed the synthol unit. There are seven trains in SASOL II and with the SASOL III project, we have added an eighth train.

We mentioned that the synthol unit is the one unit for which SASOL holds exclusive licensing rights. Here in the presence of an iron catalyst, which is produced in the catalyst-preparation unit, the gas is converted to liquid and gaseous hydrocarbons, oxygenated chemicals, and water. The oxygenated chemicals and water are processed in the chemical work-up area where alcohols, acetones, and keytones are produced.

The tail gas from the synthol unit is further processed to recover hydrogen and ethane and to remove CO_2. The ethane is feed for the ethylene plant. Methane from the synthol unit can be reformed to hydrogen and carbon monoxide for recycle back into the synthol unit. After that is done, the oil from the synthol unit is sent to the oil work-up area where roughly 40,000 bbls/day of transport fuels will be produced. The process units are typical refinery units.

Now that I've briefly described the SASOL process, I will mention the many resources it takes to put a project like this together. SASOL II is valued at $2.1 billion and SASOL III, at $2.7 billion. And, it takes a lot of people. The peak engineering manpower at Irvine for SASOL II was 1,400. For SASOL III, with a lot of duplication from SASOL II, the peak manpower still reached slightly over 600. Construction manpower at Secunda peaked for SASOL II at about 24,000 people and will peak for SASOL III at about 26,000 people. At present, we have 24,000 people, most of whom are on SASOL III, but still approximately 6,000 are finishing SASOL II. The expatriate supervisory staff furnished by Fluor is about 300.

I mentioned lots of resources—this means many types of equipment such as pumps, compressors, vessels, heat exchangers, etc., and valves. In a SASOL-type plant, we used approximately 80,000 valves, sizes ¼ inch to 24 inch. All types were used, including gates, globes, ball, plugs, checks, butterfly, etc., at all different temperatures and pressures. Examples include: 8,000 plugs, 3,700 control valves, 2,500 relief valves, and 3,100 ball valves.

Some of the materials used were carbon steel, stainless steel, 3¼ Ni and 1½ Cr in larger quantities, and some special low-temperature materials.

This is what we used on SASOL II and it is a good guide. However, it must be noted in the process industry today the trend is toward more severe process conditions. It is easy to say we want materials that are more corrosion resistant, lighter, stronger and able to handle higher and lower temperatures. We also need a substitute for alloys made from hard-to-get elements like chromium and cobalt.

We should recognize that a lot of other refinery-type work is going on in the world today that will compete with synfuel plants for materials. This should be taken into account in our future planning. For example, the trend now in refineries is to process the "bottom of the barrel"—here we need materials that resist high temperature in the presence of hydrogen and hydrogen sulfide. These are the same kind of materials that are used in synfuel plants. Another example is the demand for low-temperature materials—Alaskan North Slope work, the Northwest Alaskan Pipeline, LNG plants, and O_2 plants.

There is another trend you should know about that could affect synfuel plants. Plants of the future will have larger equipment and will be single-train plants. The reasons for this are both economics and the need to save space in new and existing plants caused by the difficulty of obtaining new plant sites. Larger equipment means larger valves.

Now what about the future? Each of you here probably has his own thoughts. But let me give you ours, taking into account all the many variables. By variables we mean things like:

- Available technology
- Available engineering manpower
- Available construction manpower
- Available money
- Available materials
- Available water
- Available politics

We believe that about $20 billion will be spent in the next 7 years on synfuel plants. That equates to about seven SASOL-type plants or something you may better understand, approximately 560,000 valves. In addition to this $20 billion, we see other projects in our business right now conditionally awarded or in the planning stage, worldwide, in the amount of $85 billion—making a total of $105 billion. In other words, we think the next 5-10 years will be fantastic in our business and your business. A tremendous challenge. A giant team effort.

To meet this challenge, we at Fluor are expanding many of our offices. Our Southern California Division in Irvine, California, is expanding by about 50%—adding on about 450,000 square feet. We are also aggressively hiring and training new people to meet the work load.

Needless to say, we at Fluor are very excited and enthusiastic about synfuels. I have a question—What is the valve industry as part of the team doing to meet this challenge?

Thank you for your kind attention and now for the movie "Tons to Barrels."

Figures 4-1 and 4-2 are two photographs from the movie.

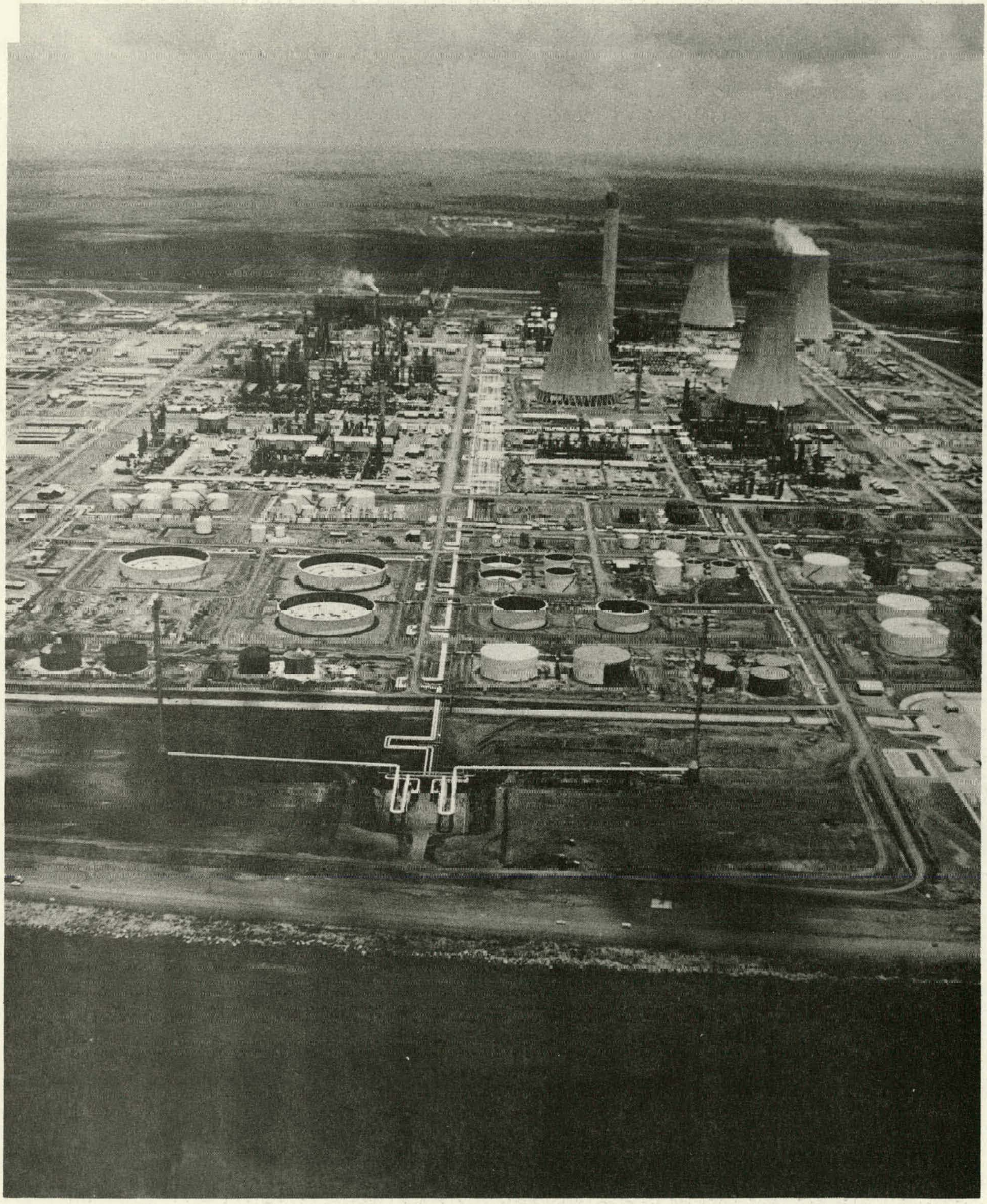


Figure 4-1. SASOL II Project: Coal-to-Synthetic-Fuel Plant Located in Secunda, South Africa

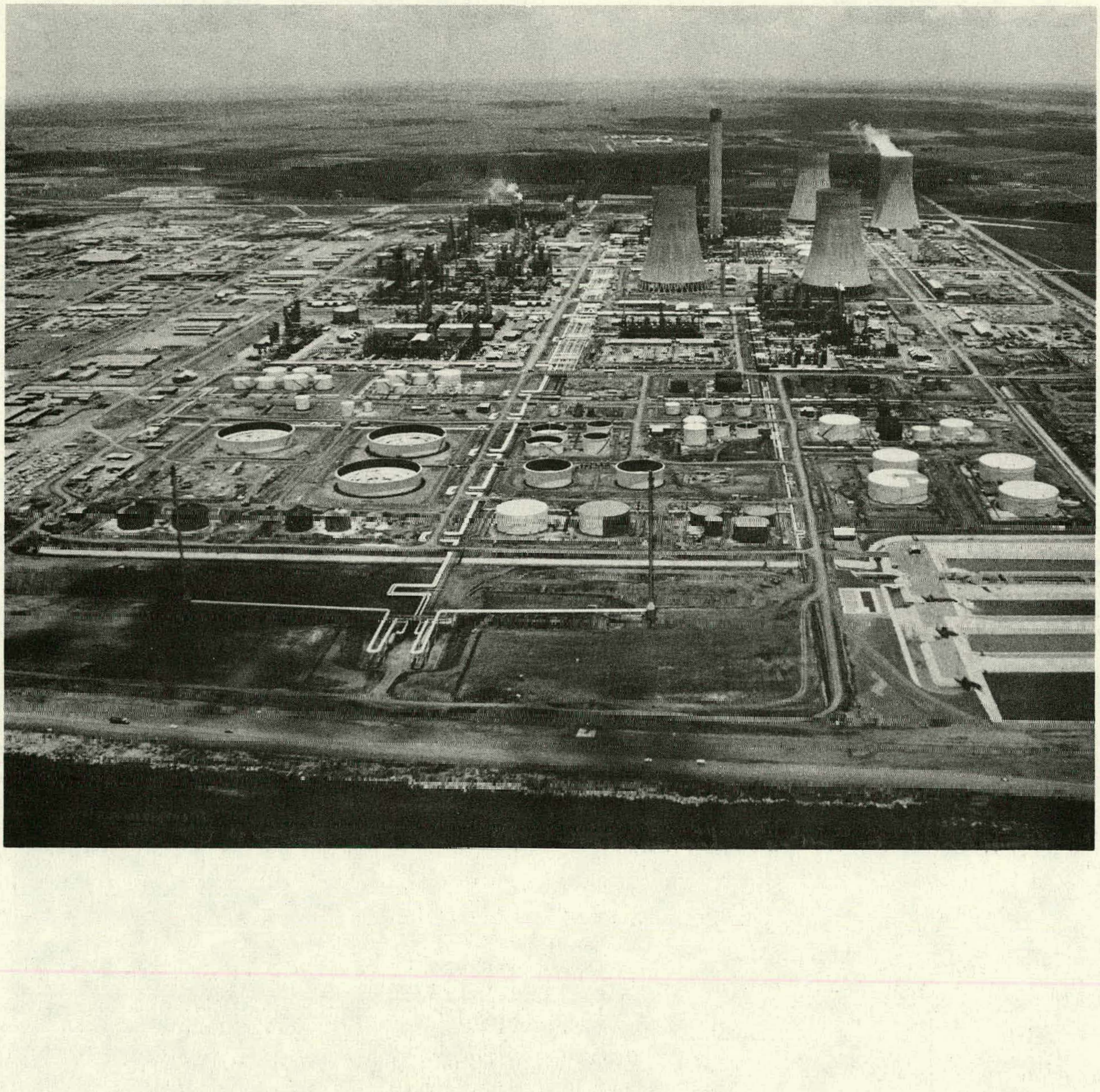


Figure 4-2. SASOL II Plant Processes Approximately 40,000 Tons of Coal Per Day into Approximately 40,000 Barrels of Oil, Which Is Transformed into 27 Different Byproduct

Discussion of Paper by Dan W. Trapp

TRAPP: The size of that plant! That stack to the water plant, is over 800 feet high. Those parabolic cooling towers are 300 feet in diameter at the base, and over 600 feet high. It's a huge one. I hope this shows you the size of the things we are talking about—big, monstrous! You've got to go out and see this to really believe it. Okay, we can go into questions. We've got a question right here. Jerry, you're bigger than everybody.

HENDRICKSON: Yesterday, I told this fine group that the synfuel program will spend some $20 billion in federal funds by 1984 and up to $88 billion in 1992. Apparently, your timetable is a little different than mine.

TRAPP: The information you have we gave you. We talked about it about a year ago. Well, things have changed and nothing has yet progressed. Nothing is started. We are doing studies you wouldn't believe.

HENDRICKSON: I'd like to keep up with you, Dan.

TRAPP: The study work we do is unbelievable, but we haven't started any construction. And of course, we are talking coal. But this oil shale is a big thing, too, and it's got to be considered in all this discussion. And I think there is a lot of plant work going on—a lot of things like that going on. But the proven technology is not here yet. And from a practical standpoint, we think it is going to be 7 years before we see spending of the $20 billion. If it takes 7 years, that's optimistic in our eyes. Very optimistic.

HENDRICKSON: What about the $88 billion in 1992, or the synthetic-fuel program?

TRAPP: I don't even want to comment because we have tremendous resources in the United States. And we can do anything. I honestly believe that if we get a couple good plants built, say in the next 7 years, we can duplicate that in a dozen places in the United States if the technology is proven. And by luplication, as we have shown you on SASOL [I and SASOL III, we had a reduced time to build a plant from 5 years to 3. So, if everybody really goes at it, and a lot of these restraints imposed on us are released, it could be done. Now, if the straits over their are mined or closed it could happen sooner.

GOODWIN: Ed Goodwin, Miter Corporation. Could you discuss some of the start-up experience with SASOL II specifically in the area of critical-valve-failure rates? That's what we're here to discuss.

TRAPP: Yes. I'm going to ask a good friend of mine to come up here, Al Swing. I don't know whether you know Al. He's the brains at Fluor on valves. He is going to help me on some of the technical questions. The question was, "Can you discuss some of the start-up problems that you have encountered in the SASOL plant with valve service?"

I'll start now and Al can add to this. I don't know how many of you are familiar with the Lurgi gasifier system. SASOL has been working for 20 years to develop a valve at the bottom to handle solids. And they perfected it, the valve, a piece of equipment, or whatever you want to call it, that really performs its function.

Unfortunately, the valves that are on the SASOL II were purchased in Japan. Not because that's where we wanted to buy them, where the technology was, but because of finance. We had to buy them in certain places. But as far as I know, we really didn't have any valve problems on starting.

SWING: First of all, I would like to correct one item here, or at least clarify one item. I was not intimately involved on the SASOL contract; I served in an overall capacity as far as the piping material engineering group is concerned. However, I'll try to answer any particular questions I can. And I do agree with you, Dan, I was not aware of any particular valve start-up problems or subsequent problems. That doesn't tell you much does it. Good engineering.

TRAPP: The question was what temperature or pressures the Lurgi gasifiers operate under? I don't know. But it has to be less than the steam, which is 600 pounds. The pressures were not in the area of what we were talking about yesterday, 2,500 psig, or anything like that. That brings up a good point. I was asked at breakfast this morning, do you have a specification you can give us for gasifiers. Yes, we can give you one for the Lurgi SASOL plant. But, there are going to be a lot of other gasification-type units and many people working on them now that are going to improve on the Lurgi. And the specifications are going to be different. It really doesn't mean much.

QUESTION: You said 85% of your business is outside the U.S.?

TRAPP: Last year, yes.

QUESTION: You bought the valves for SASOL II in Japan. How much purchasing is done in the U.S. for valves? Do you have an idea of percentage?

TRAPP: It would be a guess. I really can't tell you. We export a lot of materials out of the United States. I said that 85% of the work we are doing for plants outside the United States, but that doesn't mean we buy everything outside the United States. We buy a lot of materials from the United States. We buy a lot of things like instruments. We buy a lot of control valves and water-relief valves in the United States. And at the tail end of the job, the United States is the only place you can go and buy a valve off-the-shelf and get immediate delivery. We buy lots of valves here for export.

QUESTION: The Texas Eastern Project was mentioned earlier. Can you comment on the status of that?

TRAPP: We're not buying anything if that means anything. It's probably still in the study stage. I really don't know what the status is.

QUESTION: I am confused. If SASOL is so successful and the technology there works, why are we still studying?

TRAPP: I'd like to ask somebody that same question. We're ready. In all honesty, you look at this thing, and there are a lot of things we could do. We could take the gasification, the front-end gasification and the SASOL synthol unit, and forget the rest of the plant, and make that liquid and pipe it to an existing refinery and process it there. It would save a lot of time and a lot of money.

VOICE: One answer to the question, "Why aren't SASOL plants the 'A number 1' plant for the U.S.?" is that the energy recovery is greater for the processes under design and study in the U.S. than the SASOL plant. The SASOL plant recovery is a considerably lower number. That is the energy in and energy out. That's money, and that's the bottom line.

TRAPP: The SASOL II is producing a barrel of crude at something slightly under $30 a barrel. If we had built this starting 5 years ago, that compares a little bit less than $38 a barrel.

QUESTION: Is SASOL profitable?

TRAPP: When you can't get it, what do you do? Profitable? I'm not a finance man. I can't answer that. They've got to have it. They're charging enough to make it profitable. That's their only source; they have no competition in South Africa—yes they do. They have two refineries which have imported crude. Cal Tex has a refinery at the southern part and I believe Standard Exxon has a refinery. They import crudes—they make products. And they are paying $38 a barrel for their crude. SASOL is producing it at $30 a barrel. So they've got to be profitable.

QUESTION: Is the coal cheaper?

TRAPP: I don't know. What're they going to charge for coal? They had told us, taking everything into account, and there are many byproducts from the SASOL plant. We told you there were something like 26 other products coming out. They're even taking a gas stream out. And they're getting their food for something. A little less than $30 a barrel. So that has to take into account the cost of coal, transporting it, and all the other things.

QUESTION: You say you can produce it for $30 a barrel, and the government says we have designs that can do it for less. Would you mind telling us what those designs are and who's doing them?

TRAPP: This is an unfair question. (LAUGHTER) Just a comment on the $30 a barrel at SASOL. The cost of the land, the cost of the plant, and everything were taken into account and prorated over the life of the plant. Then the cost of the coal coming in, the cost of the maintenance, the operations all were taken into account to arrive at it. That's why it's not a very easy thing to calculate, because I don't think SASOL is paying any taxes, for instance.

QUESTION: What is the expected life of a SASOL-type plant?

TRAPP: I think our criteria from an energy standpoint and things of this nature was 7 years.

VOICE: No, it's longer than that.

TRAPP: Ten?

VOICE: Longer.

TRAPP: Okay. The bottom line, we have refineries now that have been running for 20 years. With proper maintenance, they run a long time. The financial people really set what the financial life of a plant is and calculate it on that basis. But they'll run for a long time. There are certain areas that have to be replaced that have a lot of erosion, corrosion, things of that nature.

HENDRICKSON: Dan, you indicated at breakfast today that in your opinion the synfuel program is starting. Many of us here are wondering when the whole thing is going to evolve. What you have indicated is that from everything you've seen we are going down the road right now and that things are happening. Can you comment on that?

TRAPP: We've got a lousy communication link here, you know. I didn't say that. (LAUGHTER) What I said was that the synfuel program is only part of the operation and, of course, we have to look at the overall picture. What I said was that with engineering and construction we start at the front end. You take a dog and we're right up there at the nose. We start ordering valves when we get down to the tail.

Looking at the United States and businesses that we deal with—the pressure vessel, the compressor, the pump people—they are extremely busy, extremely busy in proposals, bidding. There are a lot of orders being placed. Lots of orders being placed on a daily basis. The market is changing on a daily basis. I guess the easiest way to say it, is that we, Fluor, are anticipating that by the middle of next year, sometime in that time period, we are going to go from a buyer's market to a seller's market. Now that ought to mean something to you. Some of these shops we are dealing with right now are beginning to build up; in heat exchangers, air-cooled heat exchangers, there are a half a dozen suppliers in the United States and they are actively busy right now bidding. They are getting orders. We just got word last week that one of the suppliers we have been getting bids from has successfully filled his shop up for the next year. That's what we are beginning to see.

We are concerned that we are going to hit another period like we did in 1973. We are worried about it. And what can we do to hedge on this? If I was talking to an Exxon or an Arco or a Texaco, or something, I would say, "Boy, if you're going to build a plant or anything, do it today, because it's a good time to buy because 6 months from now, there's going to be a seller's market. Prices are going to go up and deliveries are going to go out." Is that what you meant, Jerry? And you can't just look at synfuels, because there are so many other things going on.

HENDRICKSON: Dan, if you were a valve manufacturer, what would you be doing right now?

TRAPP: I'm not a valve manufacturer, thank goodness.

HENDRICKSON: I know, but if you were.

TRAPP: I think I would get in the engineering business. (LAUGHTER) No. You know your limitations. You know your problems. I think a good place to start is to start looking for bottlenecks, and remove bottlenecks in your existing plants. What we are going to need is more production. You can do two things: look for bottlenecks and improve productivity. Spend some money. We're spending money. We're building, we're spending a lot of money on buildings just to house our engineers in anticipation. We're gambling on the economy. Just like going to Las Vegas, you're rolling the dice. I don't know. That's the best answer I can give. Improve productivity and look for bottlenecks in your plant. If you need another piece of equipment, go out and buy it, because it takes a couple of years to get some of these machines. And you've got to have some lead time there. But thank goodness I'm not in the valve business.

VOICE: I was speaking to somebody from Fluor last week and he told me that Fluor has a report that says that the valve industry by mid-1981, domestically, would be at 90% of capacity.

TRAPP: We got that from Jerry. (LAUGHTER)

QUESTION: How do the South Africans finance a plant like SASOL II or SASOL III? Is it mostly with equity or is it very much debt?

TRAPP: They dig up diamonds and gold. (LAUGHTER) With the price of gold, now, they've got a surplus of money in their budget, or in their treasury. And their taxes are very low. Very low. If they have any, in some cases.

QUESTION: Since the South Africans are basically financing their plant at 100% equity, zero debt, how would the price of a product be affected in this country where we would typically be financing the plant on a 10% or a 15% equity, 90% or 85% debt loan?

TRAPP: That's a toughie. Let me say this, that the people like Exxon, Arco, etc., are not going to build a plant unless it's an economic venture. Now what does it take to make it an economic venture? You can't have controls that say we are going to hold the price of crude down to $20 a barrel and it's going to cost $30 to produce it out in the plant. Exxon's not going to make a reasonable profit on their investment. And that's what makes the decisions on any of these plants.

Now how are they going to pay for it? Exxon's got a lot of money. I really don't know how they'll pay for it. A good example right now is in Canada. Exxon and a few others are involved in the Cold Lake project, and there are some political problems going on, on the price, what they're going to get for the price of crude. And I don't believe Exxon is going to proceed with that job until they get some assurance that they are going to make a reasonable profit on their investment. And we are talking about a $7-billion job up there.

SWING: I would like to pick up a little bit on Gary's question. As far as say a trend is concerned, we see a definite trend toward the high-performance butterfly valves. We see a greater concentration in the large-diameter valves. Dan just touched on it, but, for example, if I recall correctly, our 600-pound steam system on the SASOL contract was a 42-inch header. That's pretty big. I forget what the wall thickness was, but it's substantial. The other things that we are looking at, and looking at very seriously, at Fluor, and I think I might point them out as a matter of interest, is valve quality, looking at materials identification. There are some weak points in this particular area. And then material certification. These are some of the things that we are looking at and are concerned with at this time.

QUESTION: Do you see any significant changes in trends in automation?

SWING: We have not observed it from our standpoint.

TRAPP: I would like to add to Al's comment what we are looking for. We are also looking for good price and delivery.

QUESTION: In connection with your SASOL job, part of SASOL II was furnished from foreign vendors. Where were the negotiations and the determinations made? Are they made in Irvine, made in Japan, London?

TRAPP: Why do you ask? You got a half hour? This is really touchy. First of all, SASOL went out for worldwide financing. Having a good backup in gold and diamonds, and all of these things, is a good risk for loans.

Fluor worked diligently with the U.S. banks, asking for loans. We had it almost signed, that a U.S. bank was going to advance South Africa $500 million. This meant that we could buy here. Again SASOL wanted virtually 100% U.S.-made materials in their plant. They are sold on them, and they wanted them. Even though they knew they could go to Japan and get it for 10 or 15% less, they'd prefer to have U.S. products.

At that point, the State Department and politics got into the situation and various groups within Congress put enough pressure on the EXIM Bank that they refused the loan. Therefore, SASOL went elsewhere. They went to Germany and got all the money they wanted. They went to France and got money, and went to Japan, and got a tremendous loan at a better interest rate than EXIM Bank was offering. So we as a contractor are limited in where we can spend the money when the financing is someplace else. We'd have loved to have bought everything in the United States.

And the most distressing thing about the whole thing is the fact that, here they come along 3 years later, and put a duplicate in and we could've just gone to the U.S. and duplicated all that materials. In 5 years we'd have shipped to South Africa a billion dollars worth of equipment if we'd been able to buy it here and EXIM Bank would have given the loan.

We tried. In fact, when it came out that they refused it, I personally called maybe 100 presidents of various companies who we deal with. I call Andy Combs, everybody, for them to get in touch with their Congressmen, to try to get this thing turned around. We were unable to do it. We tried.

YOUSSEF: I don't want you to walk out of this room with some wrong information. The question was raised in the back there, "Why are we not building 10, 15 SASOL plants in this country?" And there was an answer from the gentleman over here. He said that the yield coming out of processes the Department of Energy is sponsoring is more. The yield coming out of a SASOL plant is roughly 1.7 barrels per ton of coal. The processes we are working on is 2 plus barrels of oil out of a ton of coal. So we are working with more efficient processes. That's one aspect you need to know. Or one fact you need to know. And that's not out of a paper study. This is in fact the product slate coming out of the SRC-II Pilot Plant in Fort Lewis, Washington.

The other fact you need to know is that SASOL technology cannot be applied to the Eastern coal and the Eastern deposits of coal in the United States. The reason is that the Eastern coal is a caking coal. Agglomeration will happen in those Lurgi gasifiers. When it plugs in the bottom, the whole thing can go bust. The Western coal can be accommodated in the Lurgi gasifier. However, you need a tremendous amount of steam, steam comes out of water, and you know the problem with water in the Western part of the United States.

The Department of Energy in the high-Btu gasification is using a modified version of the Lurgi gasifier, taking the bottom of that gasifier off and putting on a whole new bottom that can accommodate agglomeration and molten slag. This technology is being done in conjunction with British Gas and the German Lurgi. That's a methodical project; one of the projects we are pursuing right now.

Then you say, why don't we put 20 or 15 Lurgis in the Western part of the United States? It is possible to do that, and we don't say that we shouldn't be doing that. But the Western deposits of coal can have fines in it, from 30% to 70%. Those fines cannot be used within the Lurgi gasifier, the standard Lurgi gasifier. So far, the best run they had was about 20% fines. You mentioned that they are using about 25% down in South Africa to produce steam. So you have to find an economical way of using the remaining fines. Otherwise the whole process is not economical. I just wanted to leave a couple of facts with you, because you can walk out of here with the idea that if it is not invented here, it's no good. That's not the idea.

QUESTION: (Question inaudible.)

YOUSSEF: I don't want to open the discussion why we didn't use this technology versus why we are using that technology.

The other thing that I should mention is that in addition to the legislation enacting the Synthetic Fuel Corporation, the $20 billion Jerry spoke of, we have $5 billion right now that the Department of Energy is putting out in the street to get all sorts of studies and teams together. This is so that, once the cooperation is in motion, the work will be set out for them. I remind you of PL96126, which was a $300-million solicitation. $100 million of it was in four million-dollar pieces—25 of them, in feasibility studies. We were asking everybody to come up with any schemes and any ideas and any technologies they deem to be commercial.

The other $200 million went into cooperative agreements and one of them is the Great Plains, which is a straight Lurgi technology without modification. We are going again with a second solicitation, which is also another $200 million, and we are reviewing those bids right now. Just to give you an idea, we have about 1,000 responses to those solicitations. So the system is being pushed, we are not working in a vacuum, we are trying to get everybody to come up with the great ideas they have.

TRAPP: I just might make a short comment on that. I may go out of here with a few scars. I'm involved in procuring a lot of equipment, and one of the problems that we have in procurement is our engineers are trying to perfect the equipment to the nth degree. If you let them, they keep changing specs and we'll never get that thing on order for delivery. Are we doing too much of the study? That's my question. We should be building something now in my estimate. If they close those straits over there, we're in real trouble. Peace.

Section 5

Valve Requirements and Experience in the H-Coal Liquefaction Process

W.R. Miller
Assistant Engineering Manager
Ashland Synthetic Fuels, Inc.
Ashland, Kentucky

October 15, 1980—10:15 a.m.

Abstract

The needs and requirements for valves in the H-coal process are varied, but the largest number of valves are on-off valves, used infrequently and commonly called block valves. The block valves that are the most troublesome are those used in high-pressure, high-temperature erosive service, or the high-pressure, high-temperature slurry service. The need for reliable block valves in the H-Coal Plant (or any energy-conversion plant) is critical to its successful operation and, in particular, to our ability to isolate and remove components for maintenance and repair while the plant is in operation. Failure to produce reliable, long-lived block valves will markedly reduce operating time and grossly affect the economics of plant operations.

An additional, but no less critical area, is that of control valves, particularly pressure-control or as commonly called letdown valves. The short life of letdown valves—tens of hours, which needs to be tens of weeks in a reliable and repeatable fashion—is a limiting factor in the successful testing of the H-coal process. Valve design, trim design, and material selection are being studied and varied as dictated by the high-pressure, high-temperature, erosive, corrosive nature of fluids being tested.

A program is underway to address the highest temperature, highest pressure, and most severe location for letdown and block valves with the aim that resolution of this problem area will meet practically all block and letdown difficulties at the H-Coal Plant.

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The H-Coal Pilot Plant in Ashland, Kentucky, is a coal-liquefaction pilot plant that is designed to process up to 600 tons of coal a day and produce up to 1,800 barrels of coal-derived liquids. The pilot plant is sized to test equipment near or easily scaled to the size required by a commercial-scale process. This pilot plant is far too small for a viable commercial-production plant.

The H-coal process developed by Hydrocarbon Research, Inc., is based on the commercial H-oil process, which has operated successfully since 1963.

Coal up to 4-inch size (see Fig. 5-1) is crushed to minus ¾-inch and stored in inerted bins. The coal is further ground to a -100 mesh and dried to 2% moisture. This is done in a ball mill with a recirculated hot, inert (4% 0_2 or less) atmosphere that transports the pulverized coal to two storage bins. This recirculating dry atmosphere is vented through a baghouse. Make up is supplied through a gas-fired heater and purged with nitrogen. This dried pulverized coal is mixed with coal-derived liquids up to 40% coal slurry as dictated by test conditions. The coal is mixed in a slurry mix tank, with constant stirring, then pumped to the main charge pumps. The slurry is pumped to approximately 3,000 psig by the positive-displacement main-charge pumps. The slurry, with addition of hydrogen, is preheated in the slurry preheater. The hot slurry then continues to the reactor where, in the presence of a catalyst and with additional hydrogen, it is converted to coal liquids in an ebullated bed. This ebullated bed is accomplished by an ebullating pump that recirculates the slurry and coal liquids to maintain a bed velocity that disperses the catalyst throughout the bed. This keeps the catalyst and coal solids in a floating or ebullated condition for maximum catalyst/slurry contact. The ebullated bed and ebullating pump are unique to coal-liquefaction technology in that they: provide continuous operation, adequate residence time, and proper bed velocity with varying feed; eliminate thermal gradients; and permit the removal and addition of catalyst to maintain fresh catalyst for a constant conversion activity.

The reacted fluid containing hydrogen, coal vapors and liquids, unreacted coal, sulfur compounds, and ash leaves the top of the reactor. These reacted fluids go through two stages of pressure letdown and three degasing vessels to reduce the pressure from 3,000 psig to a nominal 50 psig. The first-stage off-gas is separated and cleaned, and the resulting gas (mainly hydrogen) is recompressed and returned to the reactor as recycled hydrogen. The fluid is then reduced from 3,000 psig to 1,200 psig through one stage of letdown, quenched, and sent into a second flash drum. The flashed vapor is separated, cleaned, and recompressed along with fresh make-up hydrogen, which is returned to the preheater.

The reacted fluids now at 1,200 psig and approximately 700 °F go through a second letdown station to be reduced to 50 psig. The flashed vapor is separated and cleaned, and the gas is returned to be burned in process heaters. The liquids separated from the flashed vapors continue to be processed through strippers and fractionation. The slurry from the 50-psig flash is processed through hydroclones. The hydroclone overhead is returned to the slurry-mix tanks for reprocessing through the reactor. The hydroclone underflow is stripped, then processed through vacuum strippers and fractionation. The solids are processed through the de-asher and/or flaker, depending on the mode of operations. This is a quick and short-form explanation of the H-coal pilot plant. Much of the plant is similar to and operated with refinery or chemical-plant equipment and techniques.

Slurry mixing, slurry pressurizing, slurry preheating, main reactors, process letdown, solids/liquids separation, and the equipment associated with these phases of the operation are the areas that require the most attention and the highest equipment-technology development. The other portions of the plant require (or so it seems at this time) less equipment development.

Valves are the universal equipment that cross all boundaries and, hopefully, keep unwanted materials from crossing boundaries. Valves are common to all systems, the lower-pressure, lowest-temperature, less-severe applications are met and being supplied by conventional valves. In these less-severe services, which are similar to any refinery or chemical plant, standard refinery valves and standard valve problems prevail.

Over 15,000 valves are used in the H-coal plant. These valves are all potential leakers in the life of the plant, and possibly are leaking right now. These valves, like all valves except welded bellows valves, potentially have two modes of leaking—seat leaking and stem leaking. Again, valves being valves all will probably leak in both modes some time in the life of the plant.

The most common type of valve throughout the plant is carbon-steel gate valves. Of the 15,000 plus valves: nearly 10,000 are gate-carbon steel, bronze, alloy, and stainless steel; close tie for second at a couple of thousand

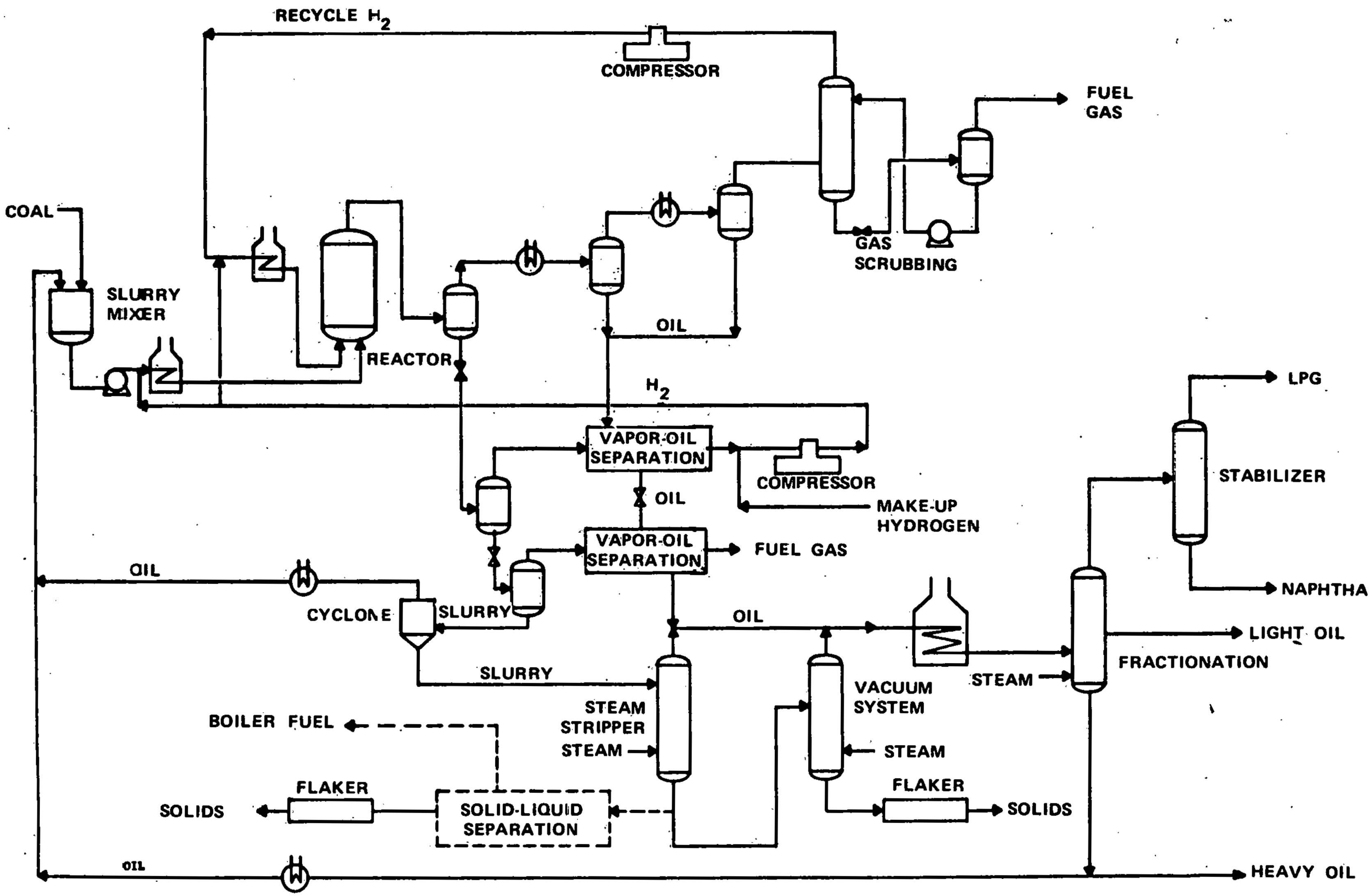


Figure 5-1. H-Coal Process

each are globe and plug valves, again carbon steel, bronze, alloy, and stainless steel; check valves in swing, ball piston lift, and disc; some special sample valves; about 600 ball valves; and approximately 30 rotating-disc letdown valves.

In a full-scale commercial plant, of the 50,000-barrels-per-day size, this number would increase to about 18,000 valves. The general distribution will be about the same. The number of valves handling the high-pressure, high-temperature slurry will increase because of the parallel-train concept being planned for most commercial applications.

Gate valves, shutoff valves, used infrequently are the most common types of valves. These are used to isolate equipment or processes for maintenance and repair during operations. One reason for a large number of valves is the need for "double-block" valves, in order to assure isolation that cannot be reliably supplied by a single-block valve.

High-temperature, high-pressure, abrasive coal/coal-liquids slurry is causing the most trouble for valve-handling and letdown service. Figure 5-2 is a schematic of the letdown location. Liquid leaves the outlet of the H-coal reactor, containing coal liquids, unconverted coal, ash, dissolved gases, and catalyst fines. This slurry at approximately 800°F and 3,000 psig first enters a degasing vessel to release any trapped gas, goes through block valves, letdown valves, more block valves, and finally into the 1,200-psig flash drum. By taking an 1,800-psi drop, the first stage of letdown has reduced the system pressure to 1,200 psig. Within the letdown valve, connecting piping, and flash drum, all the 1,200-psig volatiles have flashed to vapor. The slurry now leaves the 1,200-psig flash drum through block valves to the second-stage letdown valves, more block valves, and finally into the low-pressure flash drum which is at approximately 50 psig. This second letdown stage has taken approximately a 1,200-psi drop. These block valves and letdown valves are the area of study and test to locate valves and materials to withstand these conditions. The materials for this 6-inch piping due to the corrosive conditions is 347 stainless steel with 316 stainless steel being an acceptable alternate.

The original design had double block in only the first set of letdowns. This original installation had procured Gulf & Western (G & W) 6-inch and 10-inch ball valves for block valves and Willis choke valves for letdown. Operating experience at these conditions shows that the valves as supplied are not adequate for the process conditions.

The supplied block-valve packing (asbestos), which leaked badly at low to medium temperature, required a packing review and study that led to using a composite packed stuffing box on the block valves. This packing is a multi-ring stack with die-formed 187-I top and bottom and die-formed Grafoil solid rings in

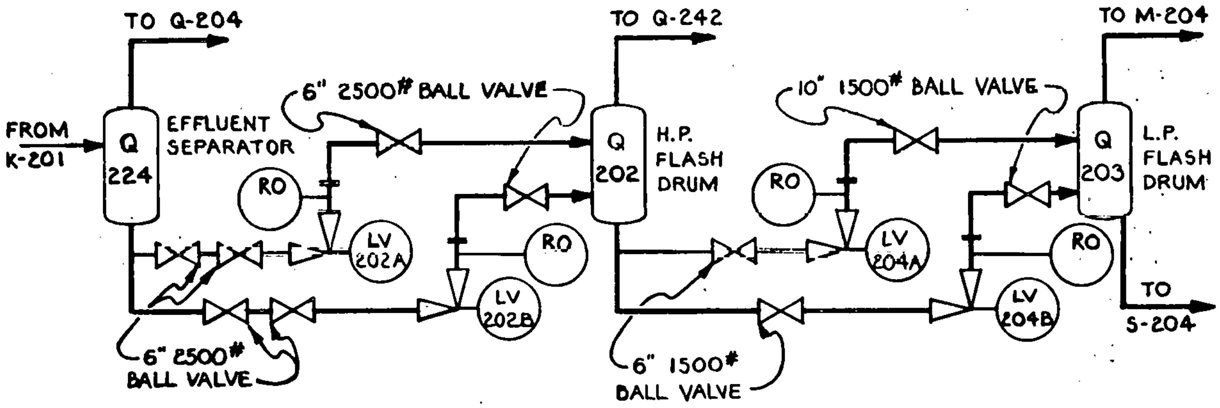


Figure 5-2. Letdown System

between. Packing, which is now operating satisfactorily, was arrived at by reviewing many installations, recommendations by packing vendors, and assistance and cooperation by G & W. The resolution of the packing problem is the first of many problems, some still unresolved, in the area of block and letdown valves.

The need for block valves in this application is to isolate the letdown valves for repairs or replacement as the life of the Willis letdown valves is only hours to a few days at the present time.

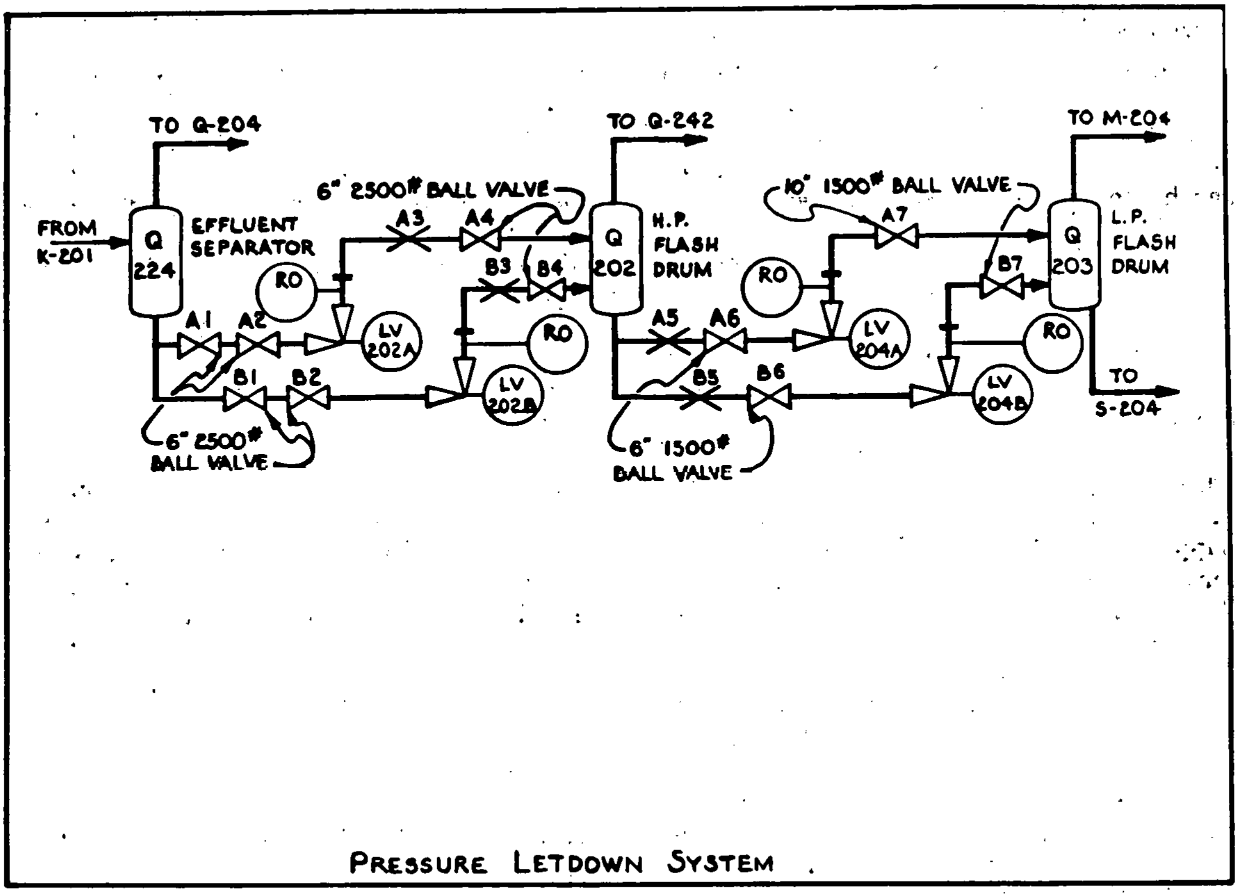
Satisfactory isolation with the current block valves is limited to a few operations, then the block valves no longer provide adequate isolation.

The G & W block valve has a spring compartment that has free communication with the process fluid. Filling of this compartment with cokeable material that will harden at ambient conditions makes disassembly nearly impossible. This compartment has a design modification that provides a sealed compartment, and we have provided a method of grease filling this compartment. The design permits greasing during operations. A study of high-temperature lubricants was undertaken to locate grease that would withstand 850°F and coal-derived liquids. G & W has been most cooperative in all redesigns, supplying parts, drawings, and consultations at all times and responded rapidly to our needs. These original valves were supplied with 316 S.S. balls, Stellite-weld overlay, and plasma-sprayed Tungsten Carbide (TC). The plasma sprayed TC flaked off, causing erosion of the balls. This TC plasma-sprayed coating has been removed from all balls, and ground and lapped-Stellite balls are currently being used. Two balls, one 10 inches and one 6 inches, with Linde "D" gun TC are now installed and will be tested during the next run. The flaking is attributed to thermal-expansion differences and also to thermal transients. In a review of hard materials and coating, a TMT-5 coating, made by Turbine Metals Technology, was located and believed to be a potential solution for some of these coatings (see Table 5-1). This coating is a diffusion-bonded coating, and preliminary testing by others and minimal exposure at our facility have shown favorable indications. One of the 10-inch balls for block valves is being coated with this TMT-5 for future testing.

Table 5-1. Comparison of Hardness Values of Various Materials on Knoop Scale

Material	Knoop (100 g)
Tool Steel	800 (Rc-63)
Chrome Oxide	1,400
Titanium Nitride	1,770
Tool Steel with TMT-5 Coating	1,800
Tungsten Carbide	1,900-2,100
MTC Dura-Cote Aluminum Oxide	2,100
431SS with TMT-5 Coating	2,100-2,200
MTC Dura-Cote Niobium Carbide	2,470
MTC Dura-Cote Zirconium Carbide	2,600
Tungsten Carbide with TMT-5 Coating	2,600-2,700
MTC Dura-Cote Silicon Carbide	2,740
MTC Dura-Cote Hafnium Carbide	2,900
Molybdenum with TMT-5 Coating	2,800-3,000
MTC Dura-Cote Titanium Carbide	3,200
MTC Dura-Cote Titanium Diboride	3,700
Boron Carbide	3,900
Tungsten Carbide with Titanium Diboride and TMT-5 Coating	4,800-5,000
Diamond	7,000

Potential valve suppliers for alternate valves were contacted for a proposal and quote on block valves for this application. Many suppliers chose not to quote; of those who quoted, three were selected to supply block valves for this letdown-isolation service. The selection was made on a technical justification, with design, material, similar application experience, and manufacturing capabilities as the main considerations. Valve manufacturers to be considered must have had the capability and manufacturing experience for up to 24-inch block valves. The findings of these tests will be inputted in the commercial-plant design. The vendors selected are: Mogas Machine Works, Kamyr, and WKM, in that order. Valves and spare internals are on



✕ = To Be Added
E = EPG - G&W
K= Kamyr
M= Mogas
W= WKM

After Modification

Position	Installed In Line	Warehouse Spares Valves	Warehouse Spares Balls
A1	E		E
A2	E	E	
A3	E	E	
A4	E		
A5	E		E
A6	E	M	M
A7	E	E	E
B1	M	M	M
B2	M		M
B3	M		
B4	K	K	2-K
B5	K	K	K
B6	W	W	2-W
B7	M		M

Figure 5-3. Ball Valves and Letdown-Valve Test

order to be installed as shown in Figure 5-3. This will provide a test program that will give us comparative data on four valve suppliers. Valves and spares have been ordered to have 100% spares, so that a complete change-out can be done in-house. Also, all locations will be changed to double blocks except the 10-inch or 50-psig blocks. All valves are ordered with the same flange-to-flange lengths so that any size class of valve will be interchangeable.

Deliveries and schedules indicate this changeover, and testing will be underway in January, 1981.

Many difficulties have been encountered with the internal design as well as material selection. Brazed or silver solder holders, or supports for TC disc and tailpieces, proved inadequate for these application. The supplied TC (commercial, almost tool grade) proved totally inadequate.

An in-house redesign of the rotary-disc support to a mechanical support, a study and procurement of other TC and alternate materials for disc material, an in-house redesign and material selections for tailpieces, new material selections for the bean, and redesigned choke sizing are all underway. The redesigns are extending Willis valve life and the program will provide some date on material life, but it is not believed that the Willis choke is the solution to the problem. This redesigned Willis valve and material study is underway until other letdown valves with higher potential for success can be obtained and tested. The data gained from materials testing will be inputted into the letdown- and block-valve program. Materials under test and to be tested are shown in Table 5-2. Long-term delivery of materials and parts have kept these programs from proceeding on a timely basis.

The long-term letdown program is the procurement of several other suppliers' letdown valves for testing at H-coal conditions. These alternate design selections were made from the experience gained at test loops, pilot plants, and PDUs in liquefaction and gasification. The alternate suppliers are: Fisher, Kieley and Mueller, Masoneilan, Cameron, Continental Disk, and an in-house "Tampa Modifications" to a Willis valve. These valves are being supplied, or are on order, but other suppliers will be considered, depending on technical merits and operating experience in similar applications.

Currently, Masoneilan and Cameron are supplying valves at no cost for testing at the H-coal plant. Valves on order are Kieley and Mueller, Masoneilan, Fisher, Continental Disk, and Tampa Mods. More information on these is provided on Table 5-3. All valves are being designed to fit in the existing piping configuration so that interchangeability will not be a problem. The Continental Disk or Paul valves is an in-line valve, whereas all others are angle valves. Deliveries are such that letdown valves should start to arrive in November 1980 and continue until June 1981.

This test program on block valves, letdown valves, and suitable materials will be an ongoing program. The test data will be forthcoming as test results are completed.

These tests—which address the highest-temperature, highest-pressure, most-severe application for letdown and block valves—should lead to the resolution of this problem area, and the resolution of this problem area will meet all block and letdown difficulties at the H-coal plant, which will scale up the H-coal commercialization.

Table 5-2. Materials Used in the Willis-Letdown Valve LV-202 and 204

Material	Willis Part	Time in Service	Failure Description
VC No. 19 Tungsten Carbide 17-4 PH S.S. Holder	Rotating Disc	4 hrs	Silver solder braze joint failed.
Solid 17-4 PH S.S.	Rotating Disc	3 hrs	Massive erosion by hole on the lapped face of disc.
Solid 17-4 PH S.S. Holder	Rotating Disc	12 hrs	Massive erosion by holes on the lapped face of disc.
VC No. 19 Tungsten Carbide 17-4 PH S.S. Holder	Rotating and Stationary Discs	4½ days	Severe erosion on both lapped faces.
Kennametal K-701 17-4 S.S. Holder	Stationary Discs	8 hrs	Slight wear only. Stationary disc to be reused.
VC No. 19 Tungsten Carbide with TMT-5 Coating on a 17-4 PH S.S. Holder	Stationary Discs	8 hrs	Surface polished. Disc to be reused.
Solid Kennametal K-701	Rotating Disc	8 hrs	Locking-pin hole had a crack that ran through disc. Slight wear only.
Solid VC No. 19 Tungsten Carbide	Discharge Cone	During Heat Up	Shattered cone due to thermal shock.
17-4 SS with Stellite Overlay	Discharge Cone	5 days	Slight wear only.
VC No. 19 Tungsten-Carbide Sleeves	Discharge Sleeves	5 days	Vortex wear pattern. Part to be reused.
VC No. 19 Tungsten-Carbide Sleeves with TMT-5 Coating	Discharge Sleeves	8 hrs	No wear. Part reinstalled.
17-4 SS with Stellite Overlay	Orifice	8 hrs	Only slight wear.
17-4 SS	Orifice	1½ days	Back of orifice badly eroded to a cone shape. Part used to design new orifice.

Table 5-3. Valves to Be Tested in H-Coal Pilot Plant

Cameron Iron Works Letdown Valves

Cameron Iron Works is supplying a prototype valve for testing in the H-Coal Pilot Plant. This valve is a modified version of their high-pressure oil-letdown valve with special attention given to our operating conditions. The plunger, valve seat, and discharge cone are made of tungsten carbide. Flow is through the body, and the pressure drop is taken in one step across the valve plunger and seat. The valve is scheduled for testing in late November 1980.

Fisher Controls

The H-Coal Pilot Plant is ordering a Fisher "461," 3-inch by 4-inch angle valve for our high-pressure letdown service. This valve has a Sweep-Flo body and flows to close. The pressure drop occurs in one stage across the valve plug and seat. The plug and seat and discharge cone are made of tungsten carbide; delivery should be June 1981.

Kieley and Mueller Valve

This valve is a 3-inch by 4-inch angle valve that has a streamlined chamber which increases in volume before the flow enters the plug and seat of the valve. The flow is through the valve with the pressure drop occurring in one stage across the plug and seat. The plug, seat, and discharge cone are made of tungsten carbide. Currently, two valves are being built for a January 1981 delivery.

Paul Valve

The Paul Valve is supplied through Continental Disk Corporation. This valve has a unique in-line design and uses a free-floating solid ball of Stellite to throttle the fluid flow. The valve is operated much like a gate valve to control the flow. The solid ball, cage, valve seats, and discharge cones are made of Stellite. Currently, a valve is being built for a January 1981 delivery.

Masoneilan International, Inc.

Masoneilan is supplying two different valves for our letdown-valve service. The first valve is a prototype valve that flows to open. The seats, plunger, and plunger guide are made of tungsten carbide. The valve should be ready to test by mid-December. The second valve is a valve that flows to close and has a streamlined chamber. The valve seats, plunger, and plunger guide are made of tungsten carbide. Delivery should be January 1981. Pressure drop for each valve is taken in one stage.

Discussion of Paper by W.R. Miller

QUESTION: At this stage in the operation, does the pressure drop play much of a role in your valves?

MILLER: The answer to that, I have to say, is yes. As I pointed out, we have two letdown stations that are running with nominally the same material in them; there is some flashing of some of the hydrocarbons that are coming out of solution. The second stage is 400 psi less and it's a little cooler. The valves and trim in that application, for the 1,200-pound pressure drop, are holding up better than where we are using a similar material and design in the 1,800 pounds. So I would say yes.

I really don't know what goes into this problem; that's why you need a very detailed ogram study of all the parameters, the product that you're flowing, the temperatures, the pressures, all these variables seem very, very important and there are so many others it takes a tremendous program to correlate all this information together. We are trying to do a program to get a valve that works and as much information as we can glean in the process.

QUESTION: Who is the TMT-5 vendor?

MILLER: It's Turbine Metals Technology of Burbank, California. We deal directly with TMT.

QUESTION: In that scale you used, the hardness scale, you had an MTC overcoat on the tungsten carbide. How was that deposited?

MILLER: I don't believe we have any. I think that was just listed for hardness comparison. We do have the MTC silicon carbide on graphite, which we plan to test as a disc material on the Willis valve.

QUESTION: Is there a titanium-diboride vendor per se?

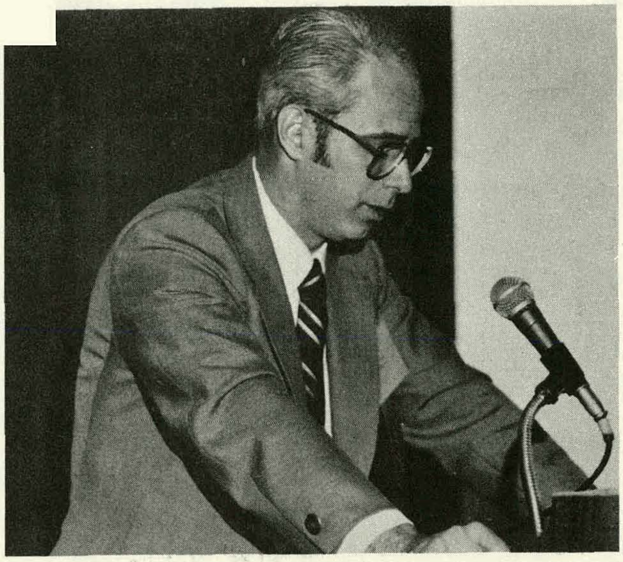
MILLER: I believe we are dealing with MTC as one of them. The other is TMT.

QUESTION: Have you given consideration to the use of any valve design other than ball valves for your block valves?

MILLER: The WKM valve is a gate valve. It's a power-seal gate valve. We have used that. We talk to anybody who will come in. We were willing to talk to other people; we wanted a full-ported valve because of the jetting action that would come out of a letdown valve. We did not want to impinge on the face of the valve, so we wanted a full-ported valve.

QUESTION: The reason I ask that is, we are currently making some 6-inch, ASA 2,500-pound, full-port valves for coal liquefaction to replace the ball valve.

MILLER: I would be more than glad to talk to you about it.



Section 6

High-Pressure Slurry-Letdown Valve Designs for Exxon Coal-Liquefaction Pilot Plant

R.J. Platt, P.E.
Exxon Research and Engineering Co.

October 15, 1980—11:00 a.m.

Abstract

This paper describes the equipment used for several critical high-pressure letdown-valve applications on the Exxon Coal-Liquefaction Pilot Plant (ECLP). These valves are used to reduce high-pressure reactor effluent slurry to low pressure. The process employed is the Exxon Donor-Solvent (EDS) process. Pilot plant throughput is 250 tons/day. The plant was designed to obtain scale-up data and perform component testing for use in a larger-size commercial EDS design.

Operations in the 250 tons/day pilot plant are part of an integrated R & D program sponsored by government and industry. The U.S. Department of Energy provides 50% of the funding through a unique government cost-sharing arrangement, the Cooperative Agreement. The remaining funding is provided by Exxon Co., U.S.A., Electric Power Research Institute, Japan Coal-Liquefaction Development Company, Phillips Petroleum Company, ARCO Coal Company, and Ruhrkohle AG. The development program status for the project was recently reported.[1]

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Introduction

Combined effects of high-pressure drop and particulate entrainment in the process have always been difficult applications for control valves primarily because of erosion, flashing, and cavitation. A substantial amount of experience for solution of either problem is available within the petroleum-refining industry when only one of the two problems is present. We have applied our engineering skill and experience to design a control valve that meets these difficult technical challenges. Before going any further with a discussion of the valve, a brief review of the EDS process is in order.

Process

The Exxon Donor-Solvent Coal-Liquefaction process produces low-sulfur liquid products from bituminous, subbituminous, and other

[1]W.R. Epperly, K.W. Plumlee, and D.T. Wade, "Exxon Donor Solvent Coal-Liquefaction Process: Development Status," presented at the American Mining Congress, International Coal Show, May 5-8, 1980, Chicago, IL.

types of coals. The Exxon Coal-Liquefaction Pilot Plant (ECLP) facilities will be capable of processing 200 ST/SD (dry basis) of either Illinois No. 6 bituminous coal (240 ST/SD as received) or a Wyoming subbituminous coal (285 ST/SD as received), converting 30-35 wt% of the coal feed to liquid hydrocarbon products and 5-10 wt% to a fuel-quality gas. An unconverted coal slurry (45-55 wt% of feed) will be solidified and disposed of in a landfill or stored for possible use as feed to test the operation of further processing facilities. The remainder of the coal (approximately 10 wt%) is converted into water, H_2S, NH_3, and carbon oxides. Hydrogen consumption is about 4 wt% of dry coal feed. Figure 6-1 is a schematic of the process. In the configuration shown, the vacuum bottoms are fed to a FLEXICOKING[1] unit to produce additional liquid products and a low-Btu fuel gas. The FLEXICOKING[1] unit is not part of ECLP.

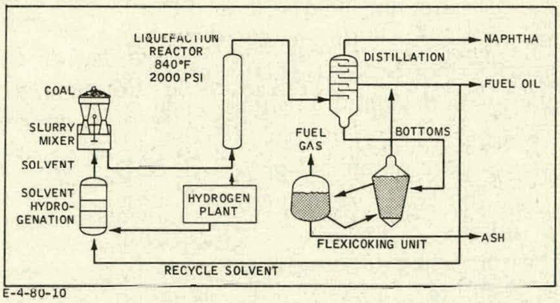

Figure 6-1. Exxon Donor-Solvent Coal-Liquefaction Process

The most important operating areas of the pilot plant as they pertain to the Exxon Donor-Solvent Process are the Coal-Preparation Section, the Slurry-Drying Section, the Liquefaction Section, the Product-Recovery Section, and the Solvent-Hydrogenation Section. Other areas of the pilot plant are similar in nature to typical support units of any petroleum refinery and include the DEA Regeneration and Fuel Gas-Treating Section, Hydrogen Compression, Safety Facilities, Waste Handling, Sour-Water-Collection Facilities, Utilities, and Tankage.

The Coal-Preparation Section receives the feed coal and crushes it to the desired coal particle size for the liquefaction reaction. The Slurry-Drying Section mixes the crushed coal with a hydrogenated recycle solvent stream to form the slurry feed to the Liquefaction Section. Mixing takes place at approximately 250°F. Any moisture that enters with the feed coal is vaporized.

In the Liquefaction Section, the crushed and dried coal is liquefied in a noncatalytic tubular reactor in the presence of molecular H_2 and the hydrogen donor solvent, which was added to the slurry drier. Reactor operating conditions are approximately 840°F and 1,920 psig.

Effluent from the liquefaction reactor is separated by distillation in the Product-Recovery Section into gas, naphtha, distillates, and a vacuum-bottoms slurry. A portion of the distillates serves as feed to the Solvent-Hydrogenation Section. In the Solvent-Hydrogenation Section, the solvent is catalytically hydrogenated before being recycled for slurrying with the feed coal. The hydrogen donor solvent is a nominal 400/700°F boiling-range material fractionated from the middle boiling range of the hydrogenated-liquid product.

Application

The Liquefaction-Reaction Section is comprised of a preheat furnace that heats a mixture of feed from the slurry drier and treat gas, the reactors, and a separator vessel. A schematic drawing of the liquefaction section is shown in Figure 6-2. A mixture of coal and solvent is pumped to a high-pressure level required for the reactors. Hydrogen-rich treat gas is mixed with the feed and both pass through the preheat furnace before entering the reactors. The reactor product then enters the separator drum where lighter material is removed in vapor form overhead, and heavier liquids exit via drum bottoms. A heavy intermediate product is sent to fractionation facilities for separation into distillates.

The high-pressure slurry-letdown-valve application, which is the subject of this paper, controls the level in the reactor separator drum. Process application data on this service are outlined below:

- Flow Rate (Normal) 25,090 lb/hr
- Design Temperature 840°F

[1]**Service mark.**

- Normal Differential Pressure — 1,845 psig
- Upstream Conditions
  - —Liquid — ~ 88 wt%
  - —Vapor — Nil
  - —Solid — 9-16 wt%
  - —Liquid/Solid Density @conditions — 50 lb/ft³
- Downstream Conditions
  - —Liquid — ~ 56 wt%
  - —Vapor — ~ 32 wt%
  - —Solid — 9-16 wt%
- Valve Body Size — 2-inch 2,500 Class ANSI

The high-pressure drop and flashing considerations along with particulate erosion make valve selection difficult. Concurrent problems with on-line alternative valves, extensive sparing of valve bodies and parts, installation methods, and the future development of more suitable trim materials have all been considered.

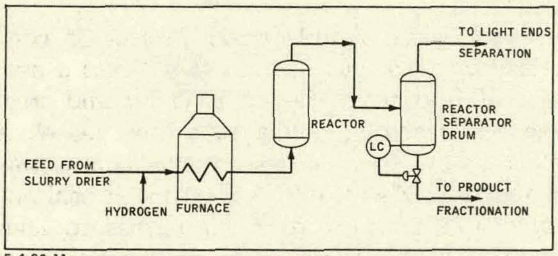

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Figure 6-2. Liquefaction Section

Letdown-Valve Equipment

Our approach to solve the problems of high-pressure drop and particulate erosion in this application was to use the best valve-body design from the standpoint of hydrodynamic considerations coupled with optimum trim materials (Figures 6-3 and 6-4). We are using the streamlined angle valve equipped with special hard trim for several reasons as outlined below:

- We have extensive successful experience with streamlined angle valves in high-pressure letdown hydrocarbon applications. Most of the applications have particulate matter present in the process.
- Our assessment of design features, such as its streamlined internal surfaces, leads us to conclude that the design is superior to 90-degree pattern-angle valves previously tried by others.
- The valve is relatively easy to scale up to meet the needs of a commercial plant design.

We expect to use both conventional (i.e., Kennametal) and special developmental materials for valve trim while maintaining the streamlined nature of the design. To reach this objective, we expect to utilize both a top-entry cage-supported seat/seat-retainer design and a bottom-entry seat/seat-retainer design. This is being done to study the seat stability of both designs. We intend to evaluate comparative performance between trim types by noting relative seat wear and potential plug face breakage.

Another aspect of letdown-valve design for erosion service is damage to downstream piping. A special downstream receiver vessel will be used with the valve to minimize this potential problem (Figure 6-5). The receiver vessel nozzle and body inside diameter allow the valve exit velocity to decrease substantially and directionally to reduce erosion. The receiver lining will be a fiber-reinforced refractory.

As a backup to cover the possibility of an unforeseen problem in the use of the streamlined angle valve, we intend to use a choke valve piped in parallel to the angle valve. Ceramic throttling-surface discs will be used along with an internal body liner for the outlet-body section. We plan to test the same trim materials in both the chokes and angle valves. A valve-receiver vessel will be used with the choke valve. One of the major problems that we see in the use of the choke valve is that it is not now available in the sizes needed for commercial plant applications.

Installation piping orientation is such that flow enters through the side-valve nozzle vertically downward. Fluid exits horizontally into the horizontal receiver vessel and then flows to interconnecting piping. Two separate assemblies are connected in parallel. No block or bypass valves are used. (See Figure 6-4.)

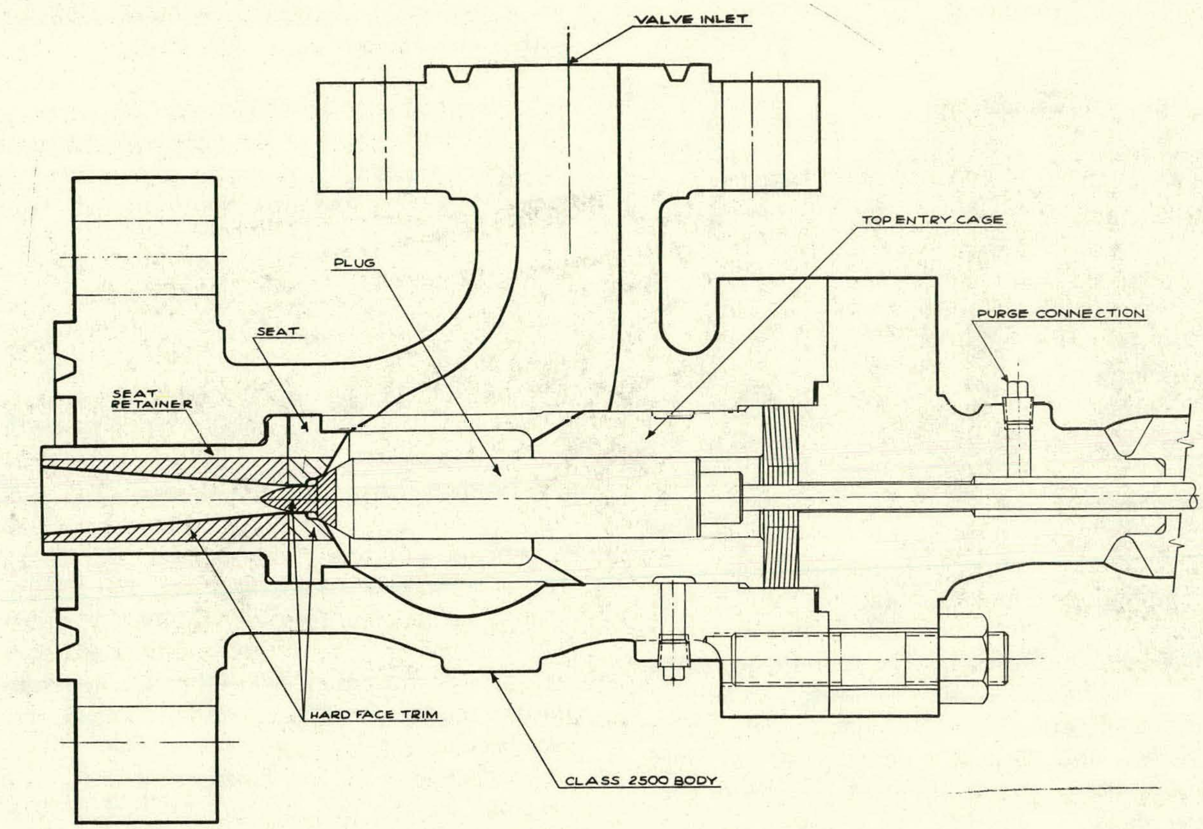


Figure 6-3. Slurry-Letdown Valve

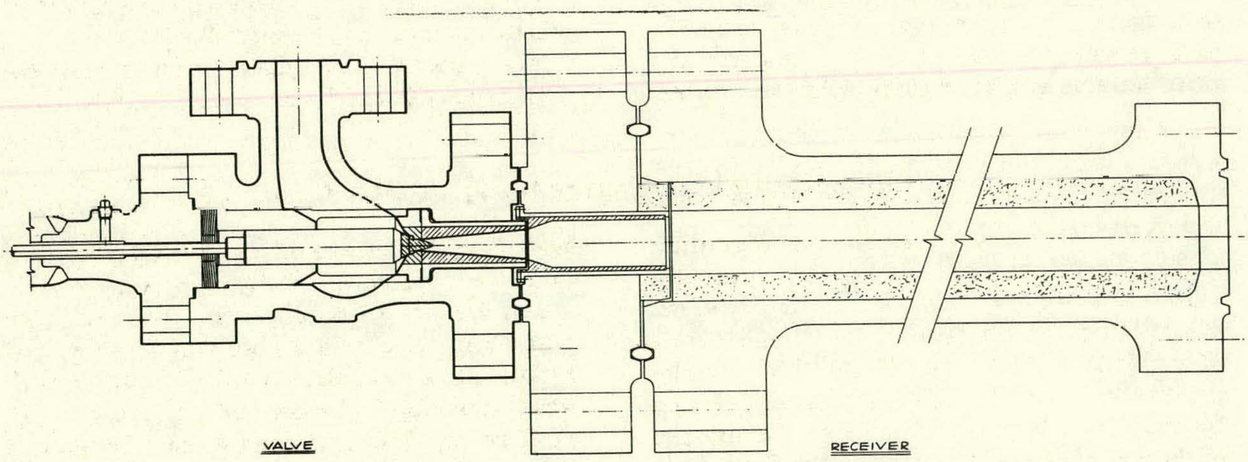


Figure 6-4. Slurry-Letdown Valve and Receiver

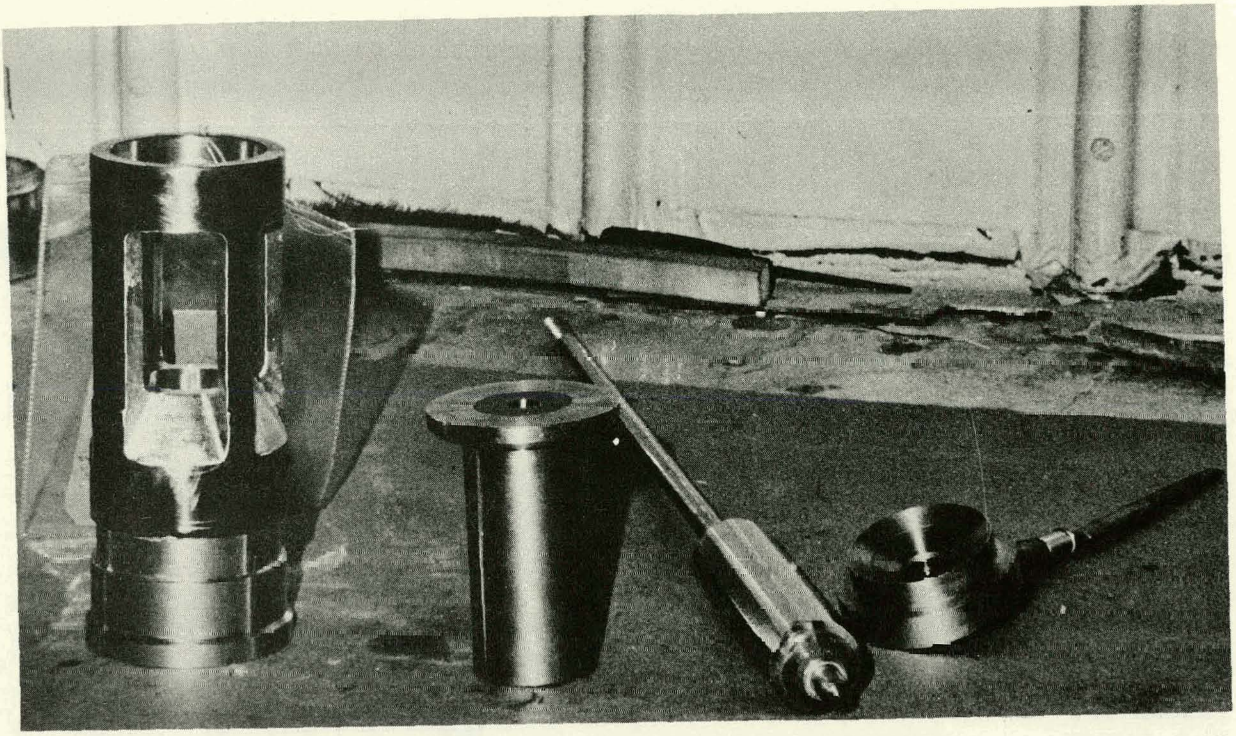


Figure 6-5. Slurry-Letdown Valve, Trim Photograph

Test Program

Valve equipment has of course been built and installed at the Exxon Coal-Liquefaction Pilot Plant. The facility is now in the start-up phase. Our program to evaluate valve performance in terms of wear factors includes routine measurement of both the valve body and trim. We plan to remove all valves from service initially on a monthly basis and do a complete mechanical disassembly to allow comprehensive measurements. As-built dimensions were obtained before the valves were installed. Depending on initial measurement results, we will continue to monitor key wear parameters or replace trim as needed. Continued checks on the trim will be made on a monthly basis or as needed to support plant operation. Our schedule will be modified to fit any specific erosion pattern seen early in testing. We plan to initially use K-701 trim in both the streamlined angle and choke valves. Other types of spare trim include K-602 and special developmental materials. These special materials include surfaces fabricated through chemical-vapor deposition and other non-standard techniques. The Kennametal trim will be our main operating valve trim.

We expect to have data on valve and trim performance in the fourth quarter of 1980.

Discussion of Paper by R.J. Platt

PLATT: The man's question was regarding flashing considerations in the high-pressure valve, I think, and he would like to know basically how much flashing we get. In terms of quantitative flashing, if you look at the total inlet rates of liquid or what appears to be liquid, at a high pressure level, the amount of flash is perhaps 10 or 20 wt% of the inlet feed. But the nature of the flashing is something that you cannot really study very well.

You can try to approximate it in advance, and design and select your valve, so it will handle these considerations. Exactly how or what's flashing and what the multi-component mixture is, I either cannot say because I don't know, or I cannot say because it's information that we derived before entering into the contract with the current set of sponsors.

PLATT: The question was is the downstream receiver vessel really necessary, based on our experience and also it is a question of the ways of bonding tungsten carbide on the internal stainless parts? The answer to the one about stainless and tungsten carbide is that all parts are shrunk fit. Regarding the question about erosion in the downstream liner, there is no noticeable erosion in the downstream liner.

QUESTION: What is your anticipated size of that particular valve in the 100-times scale up?

PLATT: I will start by saying that the present size of the orifice is ½ inch. And the characteristics of the valve are somewhere between equal percentage and parabolic. Regarding the question about how big will the final valve be, that involves our sizing procedure which we have never really divulged. I can tell you though the commercial valve, assuming we went directly to a 100-times scale, would be in the range of a 6- or 8-inch body.

QUESTION: I'm Bill West. I am with Dravo. Are you using a hydraulic or a pneumatic actuator on the valve?

PLATT: Actually we use pneumatic.

QUESTION: You said you put choke valves in series with these. Do you have any operating experience on them that you can discuss at this time?

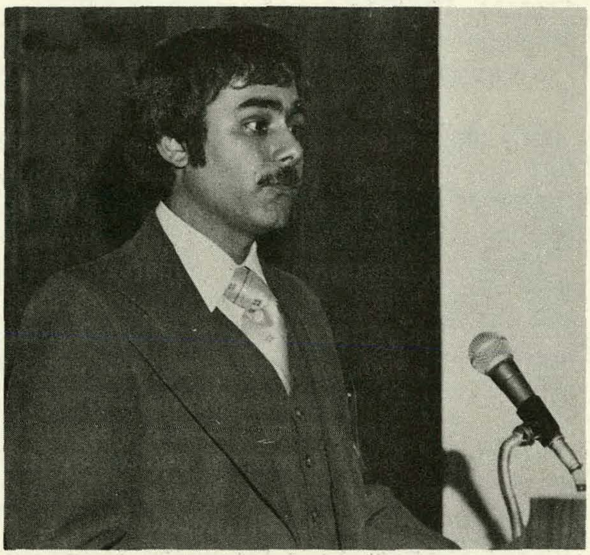
PLATT: We do not put anything in series with this valve.

VOICE: Excuse me, parallel.

PLATT: We have them in parallel. We have had such adequate performance from the normal streamline valves that we have had no need to use the choke valve.

QUESTION: How important is cavitation as compared to erosion in this application?

PLATT: It's a hard question to answer. I have already stated that we don't see any measurable erosion. We haven't had any breakage or mechanical problems, so I can only assume that we really don't have a major cavitation problem.



Section 7

Selection and Experience to Date With Block Valves for the Exxon Coal-Liquefaction Pilot Plant

Richard J. Basile
Exxon Coal-Liquefaction Pilot Plant

October 15, 1980—1:15 p.m.

Abstract

The Exxon Donor-Solvent Coal-Liquefaction Process contains many severe services for block valves because of the high pressures, temperatures, and solids concentrations present in many of the process streams. In addition, the lack of satisfactory operating experience with slurry block valves at other coal-conversion pilot plants suggested that conventional wedge-type gate valves would not provide satisfactory service life in coal slurries. To be discussed is the valve selection criteria used for choosing slurry block valves for the Exxon Coal-Liquefaction Pilot Plant and valve experience to date.

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Good afternoon. My presentation will discuss the selection, design, and performance considerations for block valves in coal-slurry service that are currently in use at the 250-ton-per-day Exxon Coal-Liquefaction Pilot Plant (ECLP). The ECLP plant utilizes the Exxon Donor-Solvent process and is being operated as part of a Research and Development program which is designed, among other things, to provide data on component performance and scale-up factors for large-scale commercial plants. Plant operations are integrated with a detailed inspection and testing program for critical components to permit an evaluation of their reliability and performance. The R & D program is funded by the Department of Energy, Exxon Company U.S.A., Electric Power Research Institute, Japan Coal-Liquefaction Development Company, Phillips Coal Company, ARCO Coal Company, Ruhrkohle A.G., and Agip S.P.A.

An overview of the EDS Program was presented on October 7 at Gaithersburg, MD.[1] In general, the lack of block-valve technology for coal liquefaction was recognized in the 1960s. The block valves used at ECLP are exposed to severe service conditions with temperatures ranging from 350 to 900°F and with pressures of up to 2,500 psig in streams containing high concentrations of solids. The lack of satisfactory operating experience with block valves in slurry service at other coal-conversion pilot plants led to a concern that

[1]Exxon Donor-Solvent Coal Liquefaction Process, Development Program Status II, 5th Annual Conference on Materials for Coal Conversion and Utilization, Oct. 7, 1980, Gaithersburg, MD, W.R. Epyerly, et al.

conventional wedge-type gate valves would not provide a satisfactory service life in high-temperature coal slurries. Therefore, criteria for selection of block valves in slurry service were developed as part of the Mechanical Engineering R & D program and design-specification effort for ECLP. In selecting different valve designs to satisfy these criteria, scale-up requirements and availability of valve designs for commercial plants were key considerations.

Prior to discussing the valve selection and design criteria, a brief review of the EDS process is desirable. Figure 7-1 is a simplified flow plan that identifies the main slurry-process streams in ECLP. Crushed coal and solvent oil are mixed together in the slurry drier and are pumped from the drier into a slurry preheater at about 300°F and 2,000 psi and with a solids concentration of approximately 46% by weight. Slurry is mixed in the slurry drier and pumped out at about 220 psi to a set of high-pressure feed pumps and is pumped through the slurry preheater at 2,000 psi. Gaseous hydrogen is added at this point. Slurry and hydrogen are heated to a maximum temperature of 850°F in the preheater.

Up until this point in the plant, the slurry has a consistency similar to that of a coal-slurry pipeline. However, downstream of the furnaces, the liquid portion of the stream becomes more viscous and the solid particles tend to set up or re-polymerize when flow is stopped. The stream is now fed through the liquefaction reactors to the reactor separator. Here, the gaseous products are carried overhead and the liquid and solids go out the bottom of the separator. The stream, at this point, is about 16% solids by weight. The pressure is then reduced to 50 psig through a level-control valve and the stream is fed into the atmospheric tower.

The stream comes out of the bottom of the separator at about 16% by weight of solids and is fed through the lever-control valve into the atmospheric tower. The lighter components are fractionated out and heavier, more viscous material and solids flow out the bottom of the tower. The stream is now about 27% solids by weight and is pumped up to a

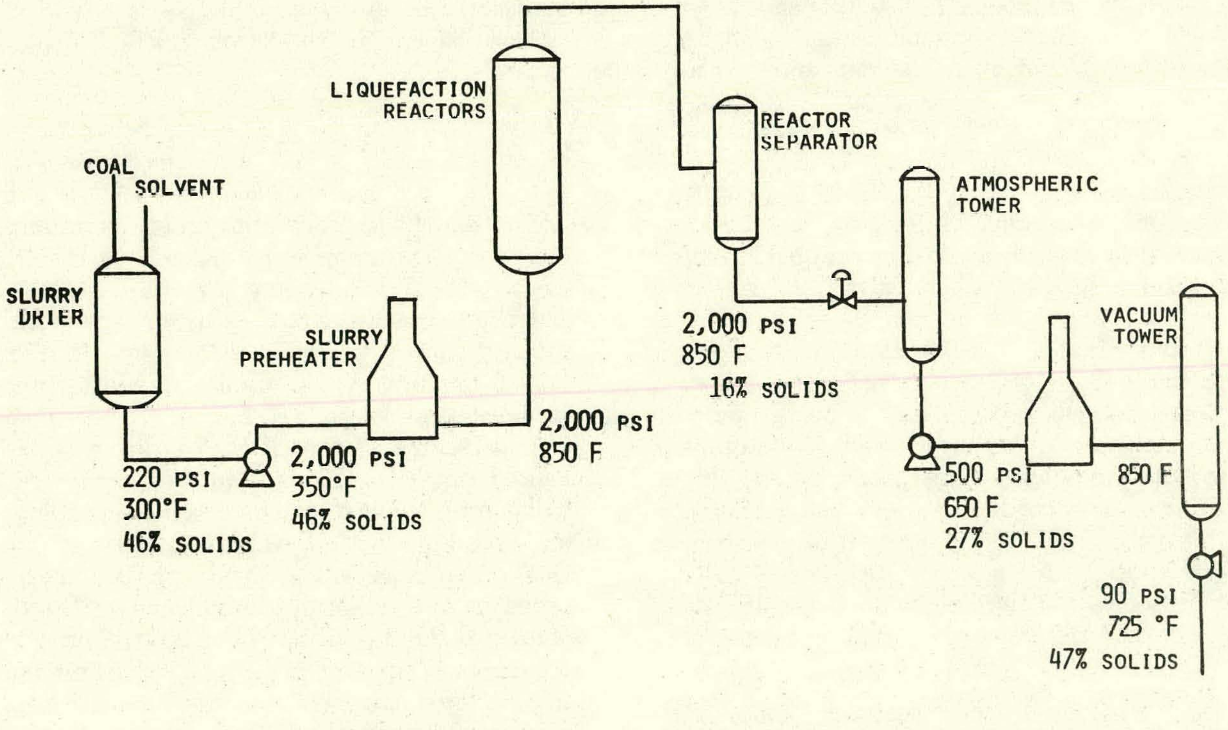

Figure 7-1. Simplified Flow Plan for Slurry Streams in the Exxon Donor-Solvent (EDS) Coal-Liquefaction Process

maximum pressure of about 500 psi and fed to the vacuum furnace. The stream exits this furnace at about 800 to 850 °F. Next it is fed into the vacuum tower where again the lighter materials are fractionated out and the heavier more viscous materials and solids are pumped out of the bottom of the tower. The stream from the vacuum tower is approximately 47% solids by weight and is pumped at a temperature of 675 to 725 °F with a maximum pressure of 90 psi.

Block valves are needed throughout these streams and their side streams to isolate pumps, control valves, sample connections, instruments, and bypass lines. In our 1-ton-per-day pilot plant, there are about 25 valves in the size range of ½ to 1 inch. In our 250-ton-per-day plant now operating in Baytown, Texas, there are about 150 valves in the size range of ¾ to 6 inches. Of these valves, about 40 are 2,500-pound-rated valves. In a commercial plant, several hundred valves would be needed in the size range of 2 to 20 inches with approximately the same percentage of high-pressure valves as the 250-ton-per-day plant.

Figure 7-2 shows the design problems associated with valves in slurry service. Valve leakage or inoperability can be caused by: (1) erosion of valve seals and internals such as valve seats, gates, plugs, or balls; (2) seat scoring and abrasion caused by sliding contact; (3) solids entrapment between seats; (4) solids buildup in the body cavity, which prevents complete motion of the gate, ball, or plug; and (5) coking or solidification of liquid material in dead spaces such as in the valve body and behind seating surfaces.

- Erosion of valve seals and internals
- Seat scoring and abrasion
- Solids entrapment between seating surfaces
- Solids buildup in body cavity
- Coking/solidification of liquid in dead spaces

Figure 7-2. Design Problems Associated with Valves in Slurry Service

Using these problems as a guide, it was determined that the most desirable design features for valves in slurry service must include the following: (1) full-port design to minimize velocity changes and erosion in the valve body; (2) a smooth, streamlined flow path; (3) seats positioned out of the flow stream to minimize solid impingement on the seats and to prevent solid entrapment between the seating surfaces; and (4) a body cavity isolated from the flow to prevent solids build-up in the body cavity.

Six commercially available valve designs were evaluated for their acceptability as block valves in slurry service. The valve types evaluated were the metal-seated ball valve, through-conduit-type gate valve, a tapered-plug valve, a soft-seated ball valve, a wedge-type gate valve, and a ram-type valve.

Figure 7-3 shows a comparison of these valves with the design features we considered desirable. A review of the information in Figure 7-3 shows that the first four valves—the through-conduit-type gate valve, metal-seated ball valve, tapered-plug valve, and soft-seated ball valve—satisfy most of the design features we consider desirable for a block valve in slurry service.

However, one concern with these valves is that the body cavity in most cases is exposed to solids while cycling. Also, in the case of the through-conduit gate valve, the gates and seats are not in contact during cycling. However, this problem can be overcome by flushing its body cavity during or after valve cycling. The soft-seated ball valve has a couple of additional drawbacks. The elastomer sealing material limits applications to less than or equal to 450 °F. Also, available elastomers are not very erosion-resistant. Based on this evaluation, it was determined that the conduit-type gate valve, metal-seated ball valve, and tapered-plug valve would have the highest probability of providing a satisfactory operating life in slurry service. All three types were specified and installed in the EDS Coal-Liquefaction Pilot Plant. The reason for installing all three types was to determine which valve type was the best for this service.

Figure 7-4 shows the through-conduit gate valve that is installed at ECLP. The standard features of this valve are: a full-port design; a smooth, streamlined flow path; seats positioned out of the flow stream; and a split-gate design that isolates the body cavity from the flow stream in both the open and closed positions. This design also minimizes the sliding contact

Valve Type	Full-Port Design	Streamlined Flow Path	Seats Out of Flow	Erosion-Resistant Seat Material	Body Cavity Not Exposed to Solids
Conduit-Type Gate Valve	X	X	X	X	X
Metal-Seated Ball Valve	X	X	X	X	X
Tapered-Plug Valve		X	X	X	X
Soft-Sealed Ball Valve T ≤ 450 °F	X	X	X		X
Wedge-Type Gate Valve	X			X	
Ram-Type Valve	X				

Figure 7-3. Comparison of Valve Designs

between the seating surfaces. As the gate travels between the open and closed positions, the gate collapses along the taper. As it moves along, the free end bottoms out on the bottom of the valve and the fixed end rises on the taper, expanding into the seats.

The modifications made to this valve for the EDS Coal-Liquefaction Pilot Plant are as follows: (1) hard-faced seating surfaces were added to minimize abrasion and (2) body-cavity flushing connections were added to minimize solids buildup in the body cavity and solids entrapment between the seating surfaces. To minimize solids buildup, flushing is considered necessary. However, this design is attractive, because the valve internals are totally isolated from the flow stream.

Figure 7-5 shows the tapered-plug valve that is installed at ECLP. The standard features of this valve are: a streamlined flow path; seating surfaces that are out of the flow stream and in constant contact; and balancing ports to equalize the pressure between the plug bore and the sealant cavities. The balancing ports minimize the potential for the tapered plug jamming by equalizing the pressure in the plug bore and in the sealant cavities. In a lubricated plug valve, the lubricant pressure in these cavities decreases with each valve cycle, and when the fluid pressure in the bore exceeds the lubricant pressure, the plug is forced into a taper-locked position. Once the valve is in a taper-locked position, the plug will not turn unless more lubricant is injected. The balancing ports minimize this problem and should, in many cases, increase the intervals necessary between the sealant injection to keep leakage to a minimum or to clear deposits from the sealant chamber. In addition, lubricated plug valves are normally limited to temperatures of 650 °F or less due to the lack of proven high-temperature sealants. Two potential concern

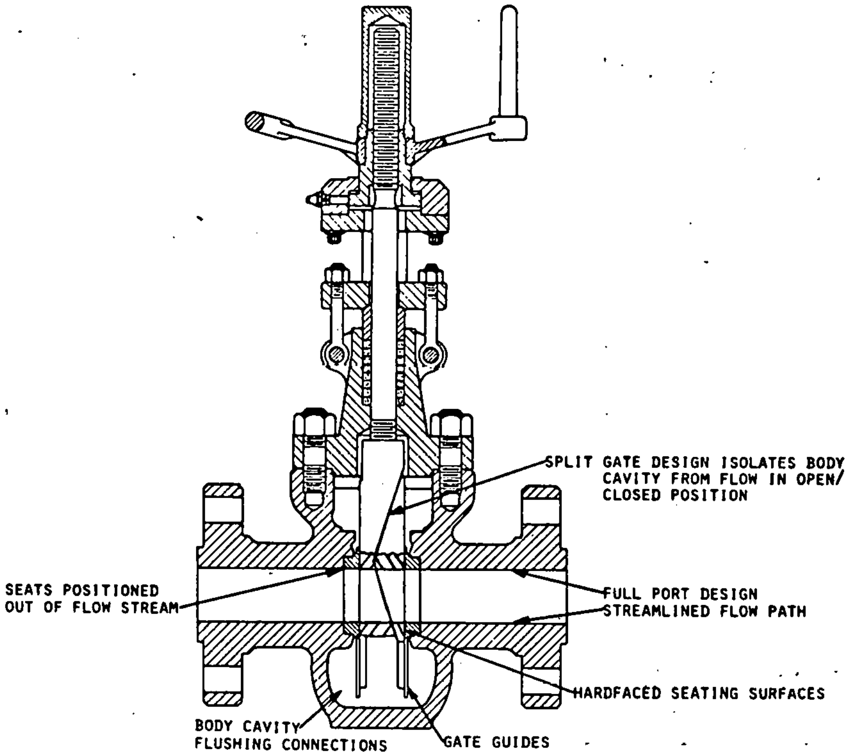

Figure 7-4. Through-Conduit Gate Valve Used at ECLP

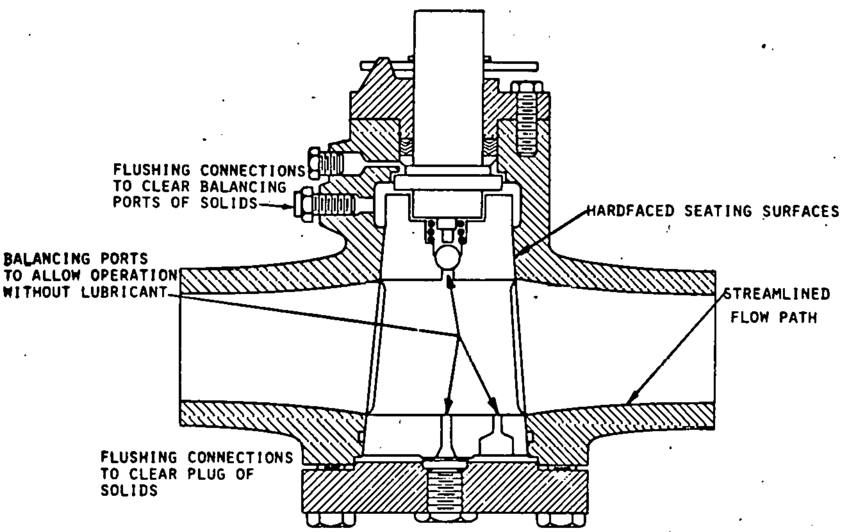

Figure 7-5. Tapered-Plug Valve Used at ECLP

with this valve design are: (1) the flow path is not full port and (2) the balancing ports may plug or coke up with solids or viscous material.

Figure 7-6 shows the trunnion-mounted ball valve that is installed at ECLP. The standard features of this valve are: a full port design; seats positioned out of the flow stream; and spring preloaded metal seats that provide for constant contact between the seating surfaces to prevent solids buildup in the body cavity and solids entrapment between the seating surfaces.

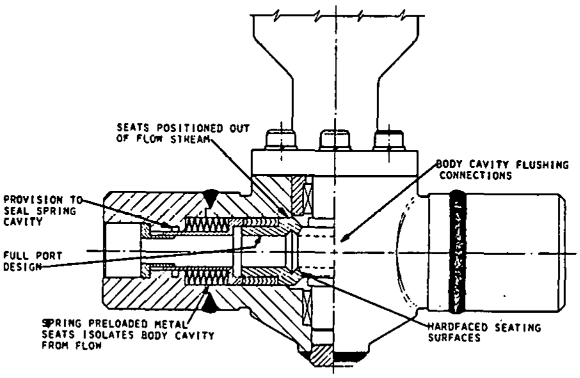

Figure 7-6. Trunnion-Mounted Ball Valve Used at ECLP

Modifications made to the standard valve include: hard-faced seating and trunnion bearing surfaces; body and spring cavity-flushing connections to allow for flushing of these cavities to prevent solids buildup; and ship-lapped joints to minimize solids migration into the spring cavity. By that we mean that we provide a spool piece behind the seat in addition to the retainer. Any migrating solids are going to have to come through two 180-degree bends to get back into the spring cavity. So it keeps all but the really small solids out of the spring cavity. In addition, spring-cavity wiper seals prevent even more solids from migrating into the spring cavity. We have machined a groove into these valves where we put in something similar to a John-Crane 187-I or Chesterton 1500 packing to provide a wiping action to additionally try and protect this area from solids.

The one main concern with this valve is the possibility of solids buildup in the spring cavity. Since the sealing force of the trunnion-mounted ball valve depends on pressure being exerted in the spring cavity, coking or solidification of solids in the spring cavity could cause the valve to leak. The use of a ship-lapped joint and spring-cavity wiper seals should help minimize this problem. The provision for flushing the spring cavity will enable solids buildup to be minimized if it does prove to be a concern.

Since coal was first fed into the Exxon Coal-Liquefaction Plant on June 24, 1980, some initial experience has been gained with the use of these valve designs. In general, experience to date with block-valve operation and maintenance has been good. In some instances, the need for flushing and use of lubricants is becoming apparent. However, due to the limited data available to date and the valve-test program being in its initial stage, it is too early to draw any firm conclusions on the performance and reliability of these valve designs. Additional data on valve cycling, leak tightness, and operability are being obtained through the test program and will be evaluated.

However, I shall briefly review the highlights of our experience to date. Isolation of our main high-pressure feed pumps, which operate at 2,000 psi and 300 °F with the tapered-plug valves, has been very satisfactory. We have also been able to isolate our atmospheric-bottom pumps, which operate at 500 psi and 600 to 700 °F with the through-conduit gate valves, with no significant problems. In addition, we have switched between our two let-down valves with the through-conduit gate valves and the trunnion-mounted ball valves successfully while circulating on oil with low solids content.

The experience gained during the first 60 days on coal did point out several operating and maintenance procedures for the through-conduit gate valve and tapered-plug valve. The need for flushing the through-conduit gate valve has been demonstrated. Three valves were not flushed during cycling, resulting in seat and gate scoring and solids buildup in the body cavity. Other valves in identical services that were flushed did not suffer any damage to the seats and gates or solids buildup in the body cavity. The need for lubrication of the tapered-plug valve with every cycle in services over 600 °F or where the material tends to set up or repolymerize has become apparent. A number of the valves have stuck in these services due to solids getting into cavities above and below the plug and setting up. The use of lubricant with every valve cycle should minimize the migration of solids to these areas.

With regard to the trunnion-mounted ball valve, we have had very limited operating experience with this valve. Therefore, we cannot comment on any particular performance or operation or maintenance problems.

In conclusion, we believe that preliminary data on the performance of these three valve designs show promising results. Further cycling of these valves during ECLP operations will enable a detailed evaluation to be made at a later date. Thank you.

Discussion of Paper by Richard J. Basile

QUESTION: Could you repeat the quantities and sizes of valves that you are using and anticipate using?

BASILE: At the present, the sizes of valves in our pilot plant range from ¾ of an inch to 6 inches. We have approximately 150 of them in slurry service, of which about 40 of them are 2,500-pound rating. In a commercial plant, we expect to have several hundred valves in the size ranges from 2 to 20 inches with the approximate percentage of high-pressure valves about the same as in our pilot plant.

QUESTION: Can you indicate a number of cycles that the three valves have gone through?

BASILE: Depending on the location in the plant, some of the valves have seen as many as 30 cycles at this point in time. Other valves have seen much less. But the maximum number of cycles we have on any one of our valves under actual coal conditions is about 30.

QUESTION: What are you using for piping and how is it holding up?

BASILE: I am not sure if I can really answer that question specifically, but we are using standard piping materials based on our own corrosion and erosion data gotten from our experience in the petrochemical industry. The materials range from carbon steel to stainless steel. We have had no significant erosion problems, except in one transfer line where the velocity was very high.

QUESTION: To follow that question, how high is high for the velocity? What have you found out for all the solid-particle entrainments? What did you use for a figure?

BASILE: I guess the answer to that question truthfully is that we really don't have a break-point figure to determine how fast you can flow through a line. It depends on the shape of a line, how many elbows and turns you have in the line, and the exact concentration of solids in the line. The velocity at the elbow where the line eroded through was about 100 feet per second.

QUESTION: How large do you expect to scale up these valves and what do you expect to be your main scale-up problems?

BASILE: I answered before that the valve sizes anticipated in the commercial plant are somewhere between 2 and 20 inches in nominal pipe-diameter valves. At this time, we really don't anticipate any major scale-up problems with the valves. The valves that we have used are all made in commercially available sizes in this range. They have successfully demonstrated experience in those sizes in services other than coal slurry.

QUESTION: What is the frequency of operation of the block valves in a commercial plant?

BASILE: The exact frequency would be very hard to pin down. It would depend really on the reliability of the equipment that is being isolated by the valves. If the pumps only last 4 or 5 months, then you figure you've got to isolate that often, but if they last for the life of the plant and never need to be repaired, the valves themselves would never be cycled. So a lot of it depends on the actual reliablity of the equipment being isolated.

QUESTION: How do you prevent solids buildup in your slide and your through-conduit gate valves?

BASILE: We have flushing connections that come into the valve body at key locations. The flushing media is approximately 50 to 100 psi greater than the process stream flowing through the valve at maximum design conditions. When the valve is cycled, the flow tends to go from the cavities into the process stream, thereby keeping solids out.

QUESTION: The chamber is pressurized during operation?

BASILE: The answer to that question is yes. Except in instances where we have found that some of our valves do leak solvent through in excess of what the process can take. In those instances, we actually shut both flush-oil valves off. The valve cavities will actually bleed down to the line pressure. But before we cycle the valves, we open up those flush-oil valves, repressurize the cavity to its useful pressure, then cycle the valve. This way we won't get any solids migration, even though we turn off the flush valves.

QUESTION: Are you using one single valve for isolation, then, or two as is used in some of these others?

BASILE: In this plant, depending on the pressure and temperature and operating conditions, we do both. For high pressure and high temperature, we double block. For low pressure and low temperature, we single block.

QUESTION: What sort of leakage criteria do you have at the shutoff condition?

BASILE: Basically, these valves were designed to meet the leakage criterion contained in API-598. That is our basic leakage criterion for construction of the valves. The criterion during actual operation is whether you feel it is safe to pull the piece of equipment downstream of it. That means basically you make certain that the amount of leakage is such that you can still break a flange and slip in a blind to isolate your pump or valve. That's basically a safety concern, and it's something that usually is left up to the plant operators and maintenance people.

QUESTION: What is your flushing medium there?

BASILE: Our flushing medium is basically the solvent oil for the process which as explained in the earlier talk is about 400 to 700 °F boiling-point range material.

Section 8

Slurry-Letdown and Isolation-Valve Performance At the Fort Lewis SRC Pilot Plant

C.D. Ackerman, D.R. Canfield,
And S.L. O'Toole
The Pittsburg & Midway Coal Mining Co.
Ft. Lewis, Washington

October 15, 1980—2:00 p.m.

Abstract

Through the six years of operating history at Fort Lewis, there has been considerable improvement in the performance of the slurry-letdown valves. The increase in trim life from 4 days to a maximum of 100 days can be attributed to a combination of: (1) change in valve type, (2) improvement in trim materials, and (3) valve sizing.

The severe valve applications of the SRC processes have not been experienced in other industries. Severe erosion and corrosion properties have caused seat leakage, and ash contained in the slurry has created sealing surface damage which makes current standard isolation and check valves unacceptable for reliable service. The experience to date will be briefly reviewed.

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Process Description

ACKERMAN: We have operated at Ft. Lewis in the last 6 years in two principal modes of operation, what we call SRC-I and SRC-II. DOE, along with other groups, is now planning to build separate large-scale SRC-I and SRC-II plants. The original goal of SRC-I was to make solid fuel with very low ash and low sulfur. With the energy problems being what they are, the goal is now shifting to make liquid and solid fuel from coal (SRC-I and SRC-II). The basis of SRC-I (Figure 8-1) is to mix the pulverized coal with a solvent that is obtained from the process, pump it up through a slurry preheater, through a reactor or dissolver and a high-pressure gas separator. The gas is purified, fresh hydrogen makeup added, and recycled. This is very straightforward and similar to all the other processes.

The high-pressure flash letdown again is similar to the other processes. The letdown scheme we have been using is two stages with a control valve at each of these locations. The separation of the ash from the solid fuel we show as a filtration process, and we tested a couple of different types. Also heated settling, or augmented settling, is now being tested in place of filtration, and these would occupy the same spot in the flow sheet. Fractionation is fairly conventional, making products as indicated and the SRC-I solid product. If you're going to burn it in a boiler, you will need to have low ash and low sulfur.

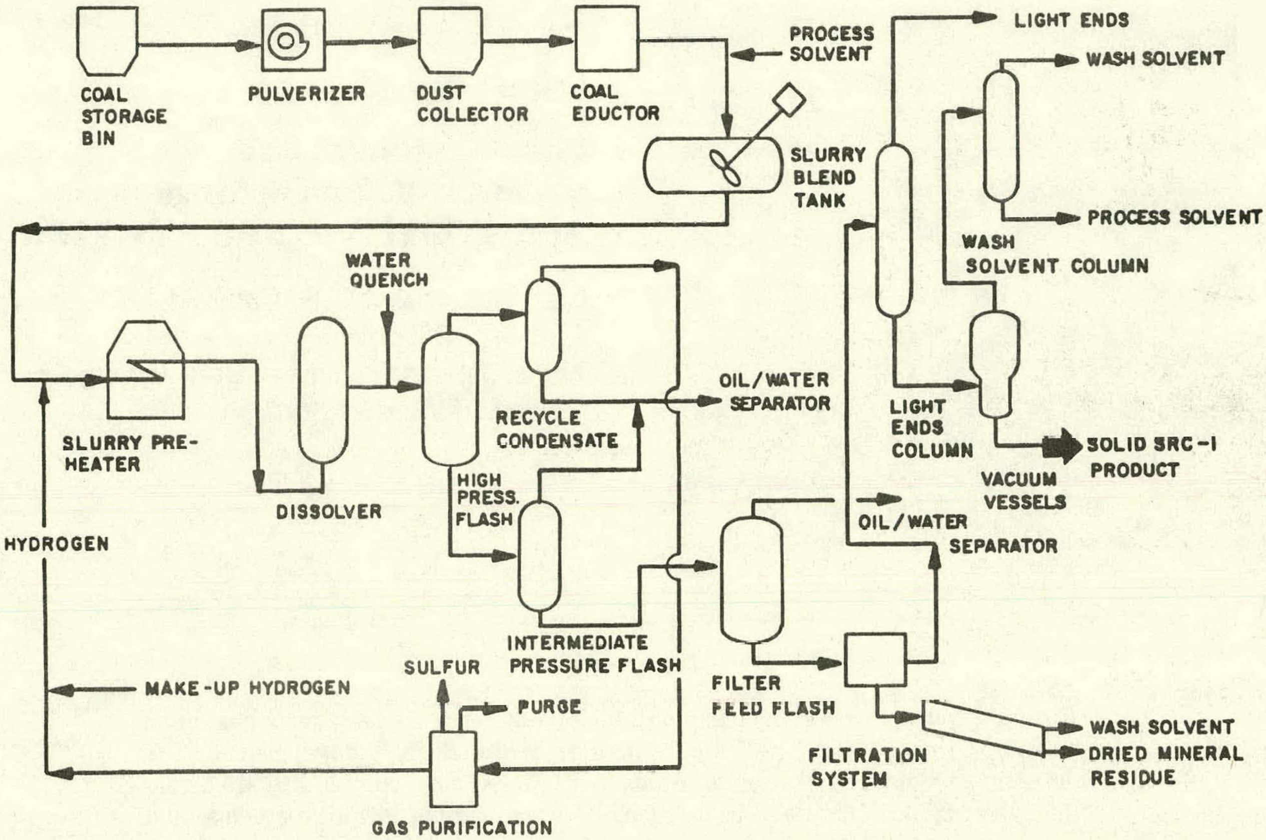


Figure 8-1. Schematic Diagram Showing Simplified Flow of the SRC-I Process

The SRC-II process (Figure 8-2) uses the same equipment as the SRC-I with some modifications to the original SRC-I pilot plant. We modified the blending so we can make a hot blend for both SRC-I and -II to achieve minimum energy losses. Essentially, the preheater and the reactor are the same. The separators also are the same, but in the SRC-II we have a recycled slurry, instead of just recycled solvent. The SRC-II separators operate at full pressure, intermediate pressure, and about 100 psig. The slurry is recycled with a simple stripping-type separation. The SRC II also has vacuum bottoms that contain essentially all the ash; therefore, no filler or separation process is required except the vacuum-flash drum, which you need any way.

Purification, gas recycling, and quench are increased because we have forced the coal to convert to the liquids. The reaction is more severe and has more heat release, so we use the gas quench to control the temperature. SRC-I may or may not use gas quench, depending on the design chosen. The byproducts are indicated and a number of off-sites are involved in each liquefaction process, which I won't go into. There will be a gasifier that was mentioned this morning. Any of the plants will need these in order to generate the hydrogen and process the by-product materials. There will be a lot of valving and other equipment required in these units. They operate with the plant, but they are not a unique part of the plant. Everybody's been talking today predominantly about the unique parts of the plant, which are in the high-pressure areas. The gasification is itself a problem that will be discussed tomorrow.

Letdown-Valve Experience

O'TOOLE: Essentially two stages of pressure letdown are in the reaction area as shown o Figure 8-3. The first stage of letdown (LCV-16(

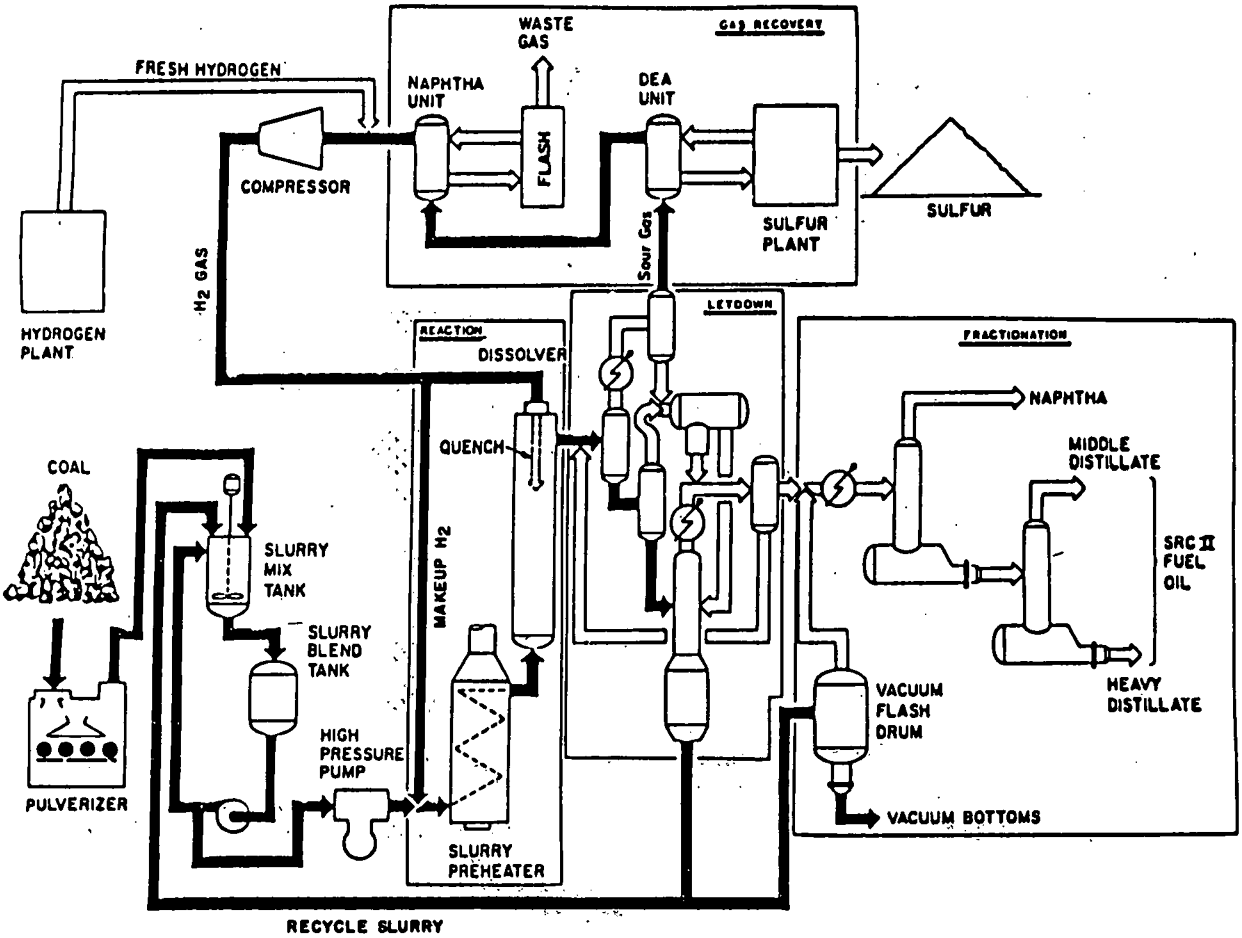


Figure 8-2. The Fort Lewis Pilot Plant in the SRC-II Mode

occurs between the high-pressure flash drum and the intermediate-pressure flash drum. The pressure drop in this service is from 600 to 1,400 psi (average 1,100 psi). The second-stage letdown (LCV-175) occurs between the intermediate-pressure flash and either the slurry-recycle stripper or the filter-feed flash vessel. The pressure drop in this service is about 400 to 900 psi with an average of 700 psi. The typical operating conditions for these valves are summarized on Table 8-1. Unless stated otherwise, all discussion will refer to the more severe service (LCV-166).

Essentially three different valves have been installed in the above letdown-valve services. Two of the valves are angle valves (1-inch Fisher DBAQ and a 1-inch Willis M1-HT) and the third is a globe valve (1-inch Fisher DBQ). The globe valve is no longer in service due to the unsatisfactory performance of both the valve body and the valve trim. After 4 days of service, both the tungsten-carbide trim and the valve body would be significantly eroded.

Two valves are in each letdown service for a total of four valves. The two valves in the first stage of letdown are a 1-inch Fisher DBAQ (LCV-166A) and a 1-inch Willis M1-HT (LCV-166B). Both valves in the second stage of letdown are 1-inch Fisher DBAQs (LCV-175A and B). The Willis valve has recently been changed to a 1-inch Fisher DBAQ with a downstream back-pressure bean.

The time between maintenance of the letdown valves in the reaction area has improved from 4 days in early plant operation to a maximum of over 100 days in the present plant operation. Even though there has been significant improvement in time between maintenance of the

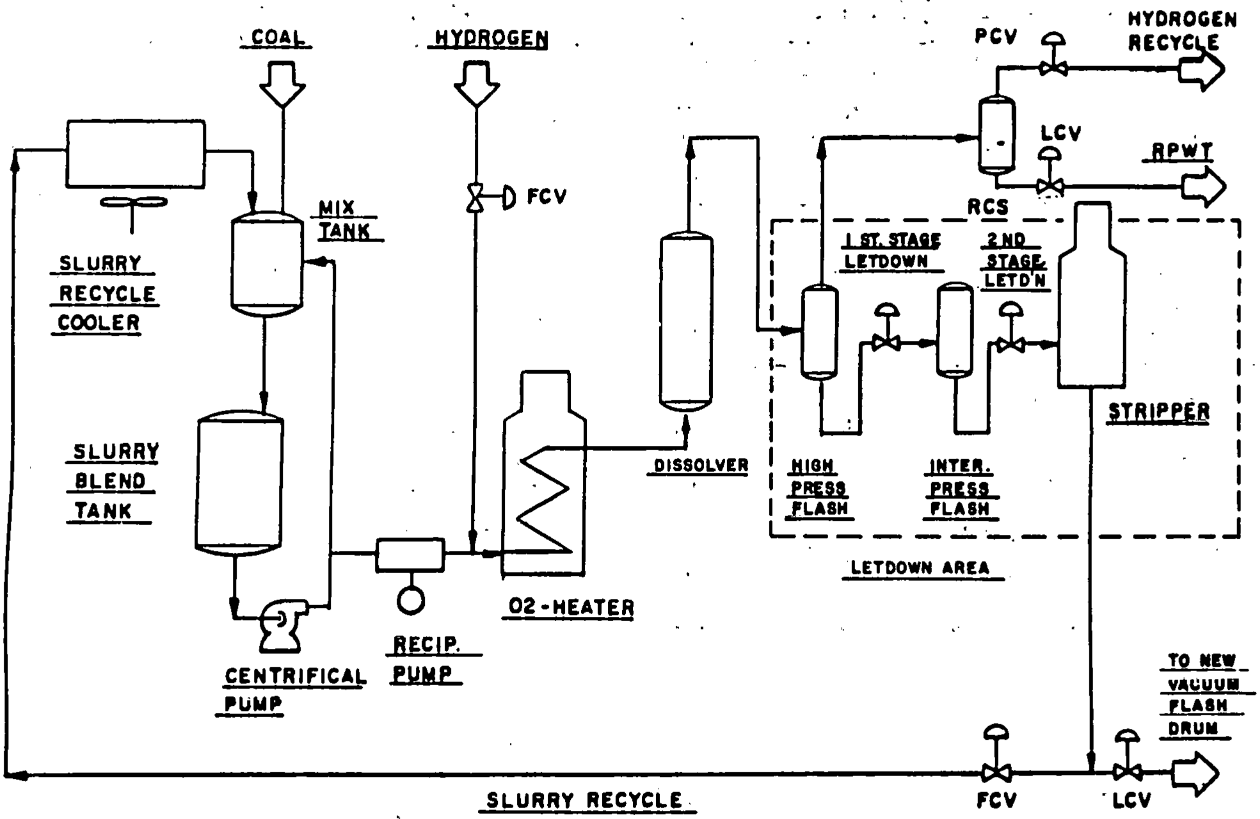


Figure 8-3. Coal Preparation and Reaction Areas, Simplified Flow Diagram

control valves, the average time between maintenance of the valves is considerably less than the maximum of 100 days. The main variables that affect valve life are:

- Valve design
- Trim materials
- Valve sizing
- Pressure drop.

The effect of the above variables along with other miscellaneous variables that affect letdown-valve life are discussed below.

Probably the most significant variable in the letdown-valve life is that of trim material. For example, the performance of tungsten carbide (Kennametal K-602) is at least 100 times better than that of Stellite. However, it is not sufficient for the trim material to be tungsten carbide, since there is considerable variation of trim life within the various grades of tungsten carbide (TC). That is, a standard grade of tungsten carbide (6% cobalt binder) has a life of approximately half of that of K-602 (less than 1½% cobalt binder).

In addition to the K-602 and standard TC, other trim materials that have been utilized are K-701, K-703, and Valenite 134. The K-701, K-703, and Valenite 134 all appear to perform about equal to the K-602. As a result of varying process conditions, it has been impossible to quantitatively evaluate the K-602, K-701, K-703, and Valenite 134. However, the recent addition of the necessary electrical equipment and computer programs to monitor the valve position (controller output), flow rate, and pressure drop, as shown in Figure 8-4, should enable the ranking of the materials. For example, a relative erosion rate can be obtained from the slope of the valve position versus time plot.

Given approximately equal operating conditions as in the case of the first stage of pressure letdown (LCV-166), the Fisher DBAQ out-

Table 8-1. Slurry-Block and Letdown Valves, Typical Operating Conditions

Location	Pressure (psi)	Δ P (psi)	Temp. (°F)	Solids* (Wt%)	Corrosives Present	Flow (gpm)
Coal Slurry (at pumps)	30-100	2,200	300-500	38-48	Traces	10-15
Dissolver Letdown:						
1st Stage	2,000	1,300	500-800	5-25	H_2O H_2S	10-15
2nd Stage	800	700	500-800	5-25	NH_3	10-15
Slurry Recycle (Vacuum Flash Feed)	75-150	60-160	300-800	5-25	Traces	5-15
Separations Streams	150	120	400-700	5-50	Traces	1-20

*Solids contain about ⅔ ash, ⅓ carbonaceous matter. Ash contains about ½ silica; median size is typically 3 microns.

performs the Willis valve (M1-HT) by at least a factor of three and probably closer to a factor of eight. For example, the DBAQ valve with K-602 TC trim will normally operate a minimum of 6 weeks even when the tip of the inner valve (Figure 8-5) is broken, whereas the trim life of the M1-HT (Figure 8-6) is only about 16 days (valve trim taken to failure) at the very best. More realistically, the DBAQ valve would probably operate 120 days with a K-602 TC trim if the tip of the inner valve would not break. (A 100-day life has been achieved; however, the trim was changed before failure.) Since approximately 40% of the pressure drop in the M1-HT is taken by a fixed orifice (bean) downstream of the valve as pictorally represented in Figure 8-6, one would expect the ratio of the trim life to be even greater than 8 to 1, if the DBAQ also had a fixed orifice downstream of the trim.

The difference in trim life between the DBAQ and the M1-HT is probably due to the difference in the impingement angle between the two valves. As shown in Figure 8-5, the slurry contacts the DBAQ trim at relative low impingement angles, whereas the impingement angle in the M1-HT (Figure 8-6) is approximately 90°. The effect on impingement angle can also be seen by a comparison of the erosion between the trim and the bean in the M1-HT. Since the pressure drops across the trim and fixed orifice are the same order of magnitude (for 42 days of operation, the ratio was approximately 20% and 80%, respectively), one would expect the wear to be similar. However, after six trim changes (approximately 112 days), the original Valenite 134 TC fixed orifice (bean) had shown very little wear. The original fixed orifice is still installed.

One advantage that the M1-HT has over the DBAQ is that the design of the trim results in less breakage. Erosion-resistant materials such as K-602, K-701, and K-703 are brittle (low-transverse rupture and impact strength) like ceramic materials. As one can see from examination of Figure 8-6, the M1-HT trim can be fabricated with the erosion-resistant trim material in compression. Since tungsten carbide and other brittle materials are strong in compression and weak in tension, this configuration has significant advantages. Conversely, from examination of Figure 8-5, the trim in the DBAQ cannot be fabricated with 100% of the TC in compression; the tip of the inner valve will always be vulnerable to tensile stresses. However, the susceptibility of the DBAQ trim to breakage will decrease as the cross-sectional area of the trim increases (larger trim). Presently, ¼-inch trim is being utilized in the DBAQ and the resultant trim breakage is reasonably high. In the past, when ½-inch (4 times the cross-sectional area) trim was being utilized, there was very little trim breakage. However, the integrated life of the ½-inch trim was shorter than that of a broken ¼-inch trim due to the fact that the ½-inch trim was oversized.

It is important that the letdown valves be sized correctly in order to achieve maximum trim life. For example, an oversized valve that is only open 10% under normal operating conditions only has an erosion allowance of 10% before the valve can no longer maintain control, whereas a correctly sized valve (assuming 50% open) has over 5 times the erosion allowance.

One method of extending trim life is by utilizing a fixed orifice downstream of the control valve. The advantages to installing a fixed orifice are:

- Less pressure differential across the trim
- Less downstream erosion (M1-HT only)
- Larger trim size (DBAQ only).

However, a common disadvantage to both the M1-HT and DBAQ is that the control characteristics of the valve are adversely affected.

The performance of the M1-HT was improved by over a factor of three when the amount of pressure drop across the fixed orifice was increased from 40% to approximately 80%. However, the control characteristic of the valve was so adversely affected, as shown in Figure 8-7, that the valve barely maintained control. As can be seen from Figure 8-7, both the flow rate and pressure drop were approximately constant during the time period of 7/20/79 to 8/2/79. However, the valve position was not constant. During this same time period, the downstream DBAQ (LCV-175A) valve, which does not have a fixed orifice, maintained approximately the same valve position. The addition of a restriction orifice adversely affects control ability and could not be applied to vessels with short residence time.

Due to the inherent characteristic of the M1-HT, a fixed orifice is necessary to prevent downstream erosion. When the valve is partially open, the discharge from the trim has a tendency to swirl and cause downstream erosion. The addition of a fixed orifice reduces the swirling effect and therefore reduces downstream erosion.

Since the residence time in the flash drums (high and intermediate) is relatively large, the overall performance of the DBAQ valves (LCV-166A, LCV-175A, and LCV-175B) could be improved by the addition of fixed orifices. The fixed orifice would improve performance by decreasing the erosion of the trim and by indirectly reducing breakage. The breakage would be reduced since a larger trim could be installed without causing the valve to be oversized.

There has been considerable improvement in the performance of the letdown valves since initial plant operation. The increases in trim life from 4 days to a maximum of 100 days can be attributed to a combination of the following:

- Change in valve type
- Improvement in trim materials
- Correct valve sizing.

Additional improvements in valve life can be gained by utilizing a fixed orifice downstream of the control valve to take part of the pressure drop. However, the use of restriction orifices can adversely affect the control characteristic of the valve. Actually any improvement in valve life that is gained by the use of restriction orifices is gained at the expense of pressure-vessel size.

Block-Valve Experience

O'TOOLE: With regard to block valves, I will discuss mostly slurry service, but will include some comments on hydrogen service and on slurry check valves. Typical operating conditions are shown in Table 8-1. Many of our higher-pressure slurry valves also contain hydrogen as dissolved gas and in three-phase flow. Thus, leakage problems are accentuated. Since our slurries contain very fine solids that can be very abrasive, even slight leaks can become catastrophic very quickly.

Most of our high-pressure hydrogen and slurry valves have been forged-angle globe type with Stellite trim. The original block valves installed in the Fort Lewis plant were Rockwell-Edward Model 6624 and are still the predominant block valve used in the plant. As listed in Table 8-2, these are in two pressure ratings and in low and high alloy as well as carbon steel. Most recurrent problems have been stem leakage in both hydrogen and slurry service and through leaks in slurry service. This latter problem usually results from

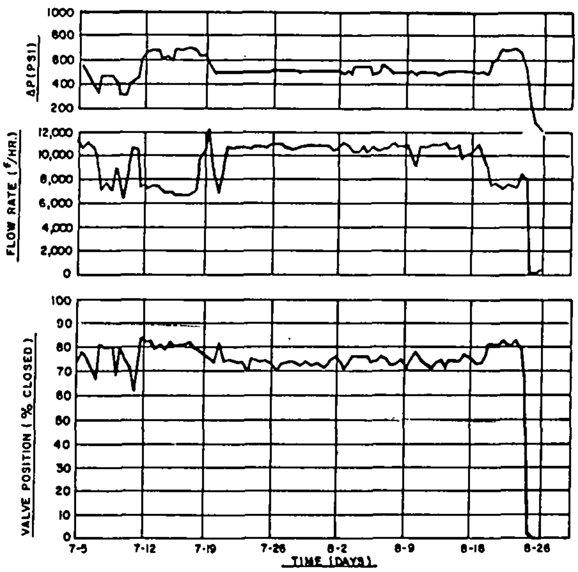


Figure 8-4. Letdown-Valve Position, Flow Rate, and Pressure Differential Versus Time, LCV-175A 1-Inch DBAQ

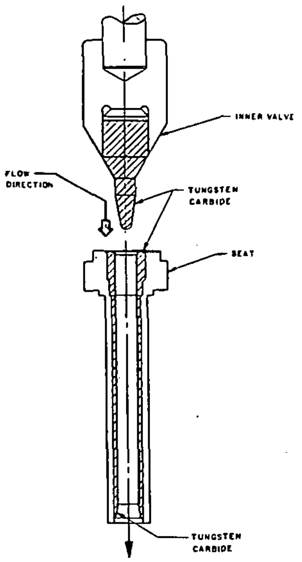


Figure 8-5. Fisher Valve Trim (LCV-166A)

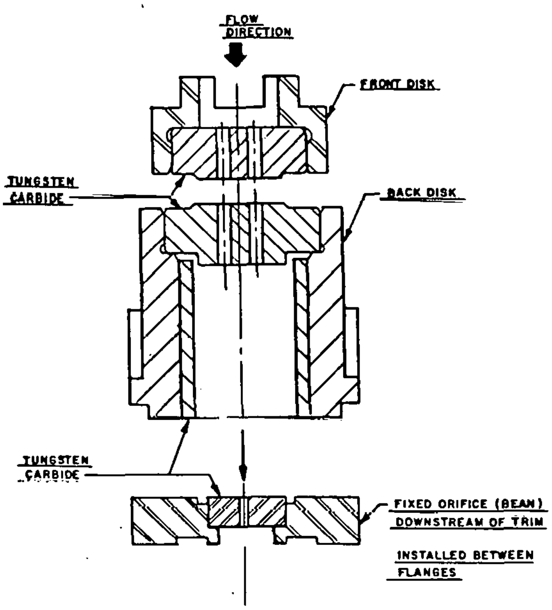


Figure 8-6. Willis Valve Trim (LCV-166B)

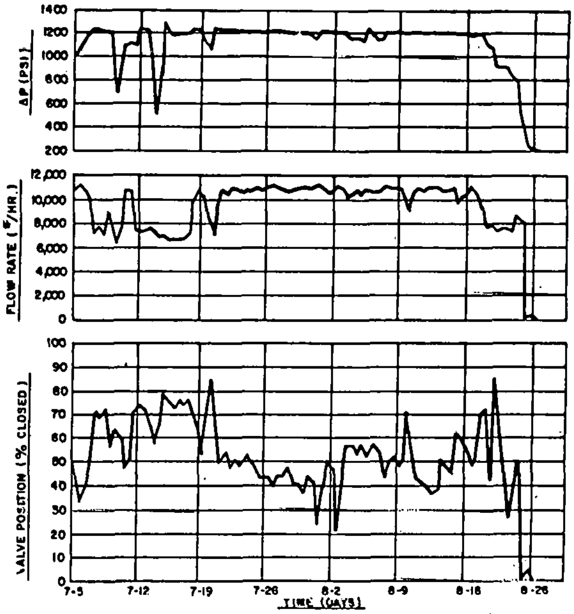


Figure 8-7. Letdown-Valve Position, Flow Rate, Pressure Differential Versus Time, LCV-166B 1-Inch Willis

reclosing on slurry. One instance of a failure of a Rockwell-Edwards globe valve involved a 2-inch valve on a line between the high-pressure flash drum and the flare line. The exact cause of the failure is not known, but was either improperly seated on a small amount of hard solid material or the seat cracked causing slurry to leak under the seat. There was approximately 1,900 psi across the valve, so once the leak started the valve body could have eroded through in a matter of hours. All valves to flare in this high-pressure service have since been changed to incorporate double-block valves between the slurry line and the flare. We are installing a high-pressure flush-oil system to permit safer removal of letdown valves. Here we use double-block and bleed valves, and flushing permits dependable operation of the blocks.

In locations with several hundred pounds' pressure drop, our experience has been that one or a few openings and reclosings on slurry

Table 8-2. Block-Valve Summary

Manufacturer	Type	Size (Inches)	Body Material	Trim Material	Service	Temp. (°F)	Press. (psi)	Solids (%)
Rockwell-Edwards	Globe Y-Pattern	1-2	347 SS	Stellite	Slurry	500-800	2,000	5-25
Rockwell-Edwards	Globe Y-Pattern	1-3	C.S.	Stellite	Slurry	300-500	2,000	38-48
Rockwell-Edwards	Globe Y-Pattern	1-2	F-22	Stellite	Slurry	300-500	2,000	38-48
Willis	Multiple Orifice M1-HT	2	347 SS	Tungsten Carbide	Slurry	500-800	2,000	5-25
Walworth	Gate	4	347 SS	S.S./Stellite Faced	Slurry	500-800	2,000	5-25
G & W, EBV*	Ball	2	347 SS	Stellite	Slurry	500-800	2,000	5-25
Rockwell-Edwards	Globe Y-Pattern	½-2	C.S.	Stellite	Hydrogen	600 400	2,200	_____
Conval Clampseal	Globe Y-Pattern	1-2	347 SS	Stellite	Hydrogen	600	2,200	_____
Autoclave Engineers	Globe	9/16	316 SS	Stainless Steel	Hydrogen & Sampling	60-800	2,200	Varies
Hex Engineering	Angle Globe	9/16	347 SS	Stellite	Hydrogen & Sampling	500-800	2,200	Varies
WKM	Ball	¼-1	_____	_____	Sampling	300-500	125	_____

*Valves no longer in service.

service leads to block-valve failure. Throttling-service use in emergency leads to serious erosion in about an hour.

Three 4-inch Walworth pressure-seal gate valves were originally installed for block and bypass service on a second dissolver. These leaked through and one bonnet leak occurred. Recent use of these valves has been with low differential pressure as block and bypass on an erosion test loop where slight through leakage is no problem.

During the plant modification to incorporate SRC-II, Gulf and Western EBV ball valves were installed upstream and downstream of the first- and second-stage letdown valves in an attempt to solve the leakage problem around the letdown valves.

The EBV ball valves did not function well in this service. Packing on all four valves failed almost immediately when exposed to normal operating temperature and pressure. Packings was replaced with Chesterton style 1500 as specified by the manufacturer. After several days of service, the packing failed on the stem of the block valve upstream of the first-stage letdown valve for no apparent reason. The failure occurred very rapidly and could have been disastrous. The ball valves were replaced at that time with Rockwell-Edwards Y-pattern globe valves, which were used originally.

The EBV ball valves were disassembled to examine and determine the cause of failure. The apparent cause of failure was the inability of the spring-loaded seats to maintain a tight seal with the ball because the seal-loading mechanism was clogged with solids. This allowed slurry to leak around the ball and expose the packing to full line pressure. The packing glands apparently were not designed to withstand this pressure. Evidence of slurry cutting grooves existed in the upstream ball seal, the ball itself, and the stem. All of these components were either solid Stellite or Stellite faced.

In further attempt to find a reliable block valve for high-pressure slurry service, rotating-disc block valves from Willis Oil Tool were procured. Two were installed on either side of the Willis high-pressure letdown valve. These block valves are still in service.

Upon hydrotesting these valves on the initial installation, the valves leaked through. The valves were returned to the factory and modified with a different internal gasket. We immediately rehydrotested the valves and they again leaked through. Our inspector discovered that the valves leaked between the tungsten-carbide seat and its stainless-steel retainer, which are bonded together with silver solder. The valves were again returned to the factory to repair the defect. The Willis valves were reinstalled and held against the 2,000-psi operating pressure.

After about 6 months of operation, we again noticed leakage through the Willis block valves. Disassembly of the valve indicated a corrosion attack on the Inconel X-750 Belleville washers. This corrosion was also found on the other three Willis block valves in service. New washers of A-286 material has solved this problem.

The relatively small orifice has caused plugging problems from migrating chunks of coke-like material. A set of discs with larger (half-moon) openings are now in service.

Hydrogen-service block valves have been a problem due to stem leakage. It is believed that an appropriate stem finish would eliminate most of this. Each stem movement causes leakage, apparently due to tearing of the packing. Seat leakage apparently has been due to scale migration from the carbon-steel system piping. Recent system changes may reduce or eliminate this scale.

Slurry-sampling valves have been used for many locations, even at the preheater and dissolver conditions. Throttling has been minimized and used only at expendable valve locations. Three valves are listed in Table 8-2 for slurry-sampling service. WKM ball valves with high-temperature seats for low-pressure sampling have worked very well up to 350 °F, 125 psig, used in sizes ¼-inch to 1-inch with 2 to 100 openings and closings. The Hex valve was fitted with an oversized air motor for tight shut off in certain sample locations. Only a small number of packing and fitting leaks have been found. A flushing procedure is used to achieve tight shut off in high-pressure sampling.

Check-valve failures have caused us enough problems to be noted here. The original angle-poppet spring-loaded valves leaked through. Double ball or one ball and one O-ring check have worked much better for preventing back flow of slurry into hydrogen lines. Even here, scale and other solids have caused back leakage. A serious failure at a feed-pump discharge led us to design and install a floating-ball check at this location. Dependability rather than absolute leak tightness was the criterion used.

Discussion of Paper by C.D. Ackerman and S.L. O'Toole

QUESTION: What causes check valve failure—particles getting in the seat?

O'TOOLE: What we feel happened was, back when the plant was designed, carbon-steel piping was installed in the hydrogen system. We got some condensation in the piping and the resulting scale migrated through the line and got into the seats, resulting in leakage. That in itself is a plant problem, but I think we have the scale problem corrected now by steam tracing the hydrogen lines. There are also cases where we may not get a tight shut off even if we didn't have that scale problem.

QUESTION: What is your top cycle life in slurry for block valve? Did I hear you say three cycles?

O'TOOLE: The cycle life of our block valves? I really don't know to tell you the truth. I don't think we've ever counted. Carl, do you have any idea of the top cycle life of the block valves?

ACKERMAN: As you mentioned earlier, typically when you shut the valve down on the slurry with the high-pressure drop, that's about the end of the valve. If you maintain high-pressure drop across it and it keeps on leaking, you are going to destroy the valve, and you shut yourself down.

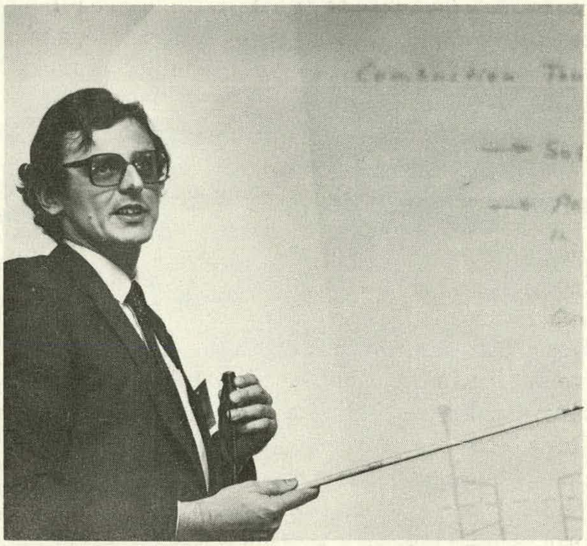
O'TOOLE: What Carl said is that it doesn't take many cycles, maybe only one, to make a globe valve leak by closing it on a dirty surface. I don't think we've given some of our valves a really fair test, because we have had to close them on dirty seats. One other comment I would like to make is that we don't at this time have a valve-testing program as such going on. Our plant is like some of the others. We built up testing of the process and process design. The block-valve program or the letdown-valve programs were kind of incidental. Within the next few months, we intend to really get involved in a detailed and documented valve-testing program.

QUESTION: On your letdown valve, downstream erosion, have you considered letting the flash into the tanks instead of into the piping?

O'TOOLE: For downstream erosion, have we considered flashing into a tank instead of into the piping? We have considered it, but we haven't had any big problems with downstream erosion. We have a 1-inch valve that discharges into a 2-inch pipe, and, with the Fisher DBAQs, we haven't had any noticeable problems.

QUESTION: What are your installation connections on your valves? Socket weld? Butt weld?

O'TOOLE: Two inch and below are socket weld, and above that are butt weld. We also have Grayloc hubs on some of the valves we may frequently remove.



Section 9

Pressurized Fluidized Beds: Process Preview and Valve Requirements

Mike Kaden, Engineering Manager
NCB (IEA-Grimethorpe) Ltd
Grimethorpe, England

October 15, 1980—3:00 p.m.

Abstract

The presentation will start with a brief description of the Grimethorpe experimental facility including the design, the objectives of the research program, and the time schedule of the project.

This will be followed by a description of the requirements for high-temperature valves, first in conjunction with the operation of the plant, and secondly with regard to the special requirements of an experimental facility like Grimethorpe.

From there it will be shown how the demands for high-temperature valves must change if a plant like Grimethorpe is developed into a commercial pressurized-fluidized-bed combustion unit. This part of the lecture will concentrate on the needs for large-sized valves and high solid loadings under pressure in applications like solids removal, coal and sorbent feeding systems, and diverter valves upstream and downstream of the gas cleaner.

The talk will also include a brief outline of the advantages and disadvantages of "pneumatic" valves compared to mechanical controlling devices.

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Good afternoon, ladies and gentlemen. I would like to thank the Department of Energy for the invitation to come here and represent the Grimethorpe Project. This is one of the conferences where we will be able to mutually benefit and I hope after I've explained the process to you, you might understand a little better what problems we have and perhaps we can together find some solutions.

I want to go a little bit into the basics of the process, especially in the light of the fact that the Grimethorpe project is a coal-combustion plant and not a liquefaction or gasification installation. We have a novel method for the combustion of coal, which is called pressurized-fluidized-bed combustion. To make sure all of you know about fluidized-bed combustion, I will start right at the beginning with some history of the project (Figure 9-1).

The Project was founded in December 1975, right at the outset of the energy crisis, when a number of nations met in Paris, France, and founded the International Energy Agency. The purpose was to deal with alternative energies such as coal and other non-oil dependent-energy sources. In 1975, three countries—the United States of America, Great Britain, and the Federal Republic of Germany—joined in a project called the pressurized-fluidized-bed combustion project in Grimethorpe. The management of this project was given to the National Coal Board, which itself founded a subsidiary, namely NCB (IEA-Grimethorpe) Ltd. In late 1975 the international agreement was signed and we started on the project with a design study during the early part of 1976. That was completed in April, 1976.

Then the main contracts were awarded for all the components. A total of 11 main equipment contracts have been placed in the period between October 1976 and March 1977. In September 1977, the construction of the plant in Grimethorpe was started. The installation is located in the middle of England in Yorkshire.

IMPLEMENTING AGREEMENT SIGNED BY THREE MEMBER COUNTRIES UNDER THE AUSPICES OF THE INTERNATIONAL ENERGY AGENCY.	..	DECEMBER, 1975
DESIGN REQUIREMENTS STUDY COMPLETED	..	APRIL, 1976
CONTRACTS LET FOR MAJOR EQUIPMENT ITEMS	..	OCTOBER, 1976 - MARCH, 1977
CONSTRUCTION STARTED	..	SEPTEMBER, 1977
COLD COMMISSIONING AND ACCEPTANCE TESTS STARTED	..	OCTOBER, 1979

Figure 9-1. Chronology of Major Events

Two years later, in October 1979, cold commissioning began. Cold commissioning is the testing of all the single components, like the feed systems, the compressors, etc., and about two weeks ago we started with the hot commissioning where we first burned coal in the combustor.

Considering the fact that Grimethorpe is an international-sponsored project, the management set-up has to be special to allow the right level of participation. All the major decisions are made by an executive committee where each country is represented by one vote. Also, major priority was given to the assurance that sufficient data were transmitted back to the sponsoring countries. Therefore, a system is used where engineers and scientists from companies in the United States, Germany and England are seconded to the project.

Referring back to the question of what fluidized-bed combustion is, it will be necessary to start with atmospheric-fluidized-bed combustion (Figure 9-2). A combustion chamber that is more or less a square box, with a perforated plate at the bottom can be seen. This "combustor" is filled with inert material such as sand or coal ash. Air starts blowing through the plate and penetrates the material. As the air flow is increased it will start fluidizing the material. The heat can be introduced. At ignition temperature, coal can be fed into the bed, which will burn and provide heat. The energy can be removed from the bed by a coil to produce steam, hot water, or whatever is needed in the process. One of the biggest advantages of fluidized-bed combustion is that the heat-transfer coefficient for tubes immersed in the bed is very high.

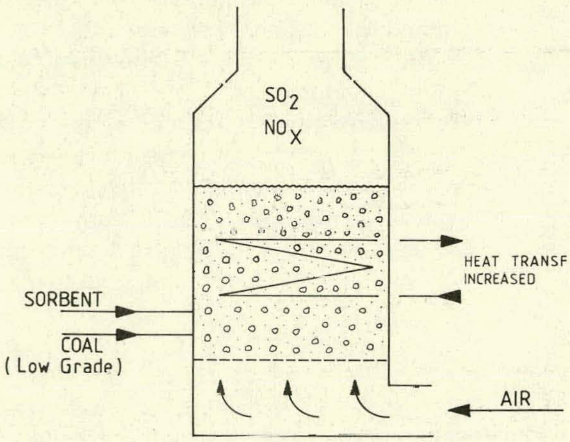


Figure 9-2. Atmospheric Fluidized-Bed Combustion

During combustion of high-sulfur coal, sulfur dioxide would be formed which is unwanted in the light of environmental pollution. To improve the performance, limestone or dolomite can be added to the bed which will absorb most of the sulfur dioxide while the coal is burned. Normally combustion at high temperatures would create nitrogen oxides, which also have an impact on the environment. However, as the fluidized bed is operated at temperatures between 800-900 °C (1420-1650 °F), a less amount of nitrogen oxides is created. To summarize the advantages, it can be said that there is a high rate of heat transfer, which makes the plant small. The emission of sulfur dioxide and nitrogen oxide can be controlled and low-grade fuel can be burned because a high combustion uniformly is reached in the bed.

To go one step further, let's look at combustion temperatures of less than 900 °C (1650 °F). It is known that the ash will not sinter in the bed. That means that the ash particles will be soft which then allows the use of an expansion gas turbine. Figure 9-3 shows the additional advantages of pressurized-fluidized-bed combustion.

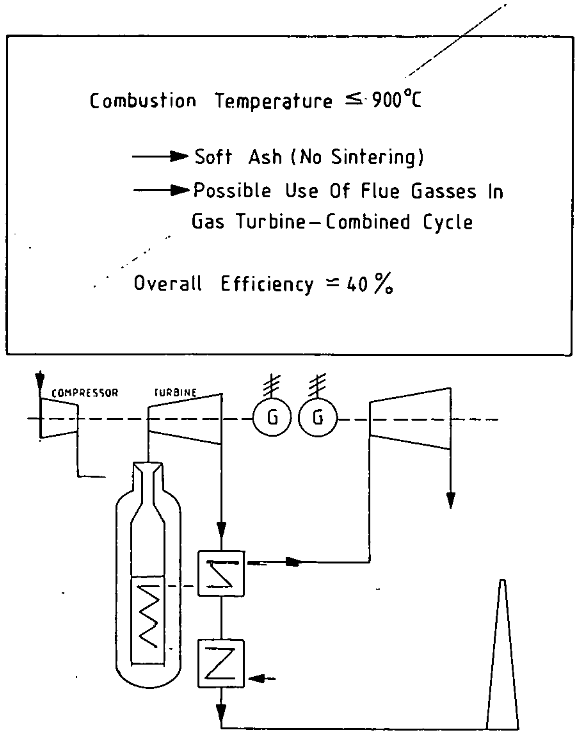


Figure 9-3. Pressurized Fluidized-Bed Combustion

With combustion temperatures lower than 900 °C (1650 °F) (i.e., no sintering), there is the potential to use the flue gases of the fluidized-bed in a gas turbine. The resulting process is shown in the schematic at the bottom of Figure 9-3. This is combined-cycle power generation. That means that a compressor provides compressed air for the combustor, which contains the fluidized bed, the exhaust gases of the combustor are going to the gas turbine, which drives the compressor as well as a generator that produces electricity. The outlet gases of the gas turbine would then be used in a waste-heat boiler to preheat the feed water. The steam coming out of the bed is fed into a steam turbine which also produces electricity.

The process, as it is shown in Figure 9-3 improves the overall cycle efficiency to something over 40%. The theoretical efficiency will be about 48%. These improvements in efficiency make it worthwhile to investigate the technology of pressurized-fluidized-bed combustion to a great extent.

The next figure, Figure 9-4, is the flow sheet, of the gas path of the Grimethorpe plant, which is of course the same as shown schematically in Figure 9-3.

A two-stage compressor with intercooler delivers up to 31 lbs/sec of air at a pressure of 12 Bar (175 psig) maximum. Figure 9-4 shows the combustion air entering the combustor in which the fluidized bed is housed. To handle the temperature and the pressure involved, the two variables are separately dealt with in the plant. That means that the cool incoming air flows down the inside of the pressure vessel and the hot fluidized bed is contained in a waterwall, cooled combustion chamber inside the vessel. Of course it is desirable to have a low level of solids in the exhaust gases when they are used in a gas turbine. Therefore, the gases flow through sets of primary and secondary cyclones, and then the hot gases enter the waste-heat boiler, generating steam for the boiler circuit. The design of the waste-heat boiler is similar to the design of the combustor. The hot gases are cooled through water and steam cooling coils and then the cold gases flow between the pressure vessel and the waterwalls in the outbed. From the waste-heat boiler the gases flow through a pressure-letdown stage and then through the stack to the atmosphere.

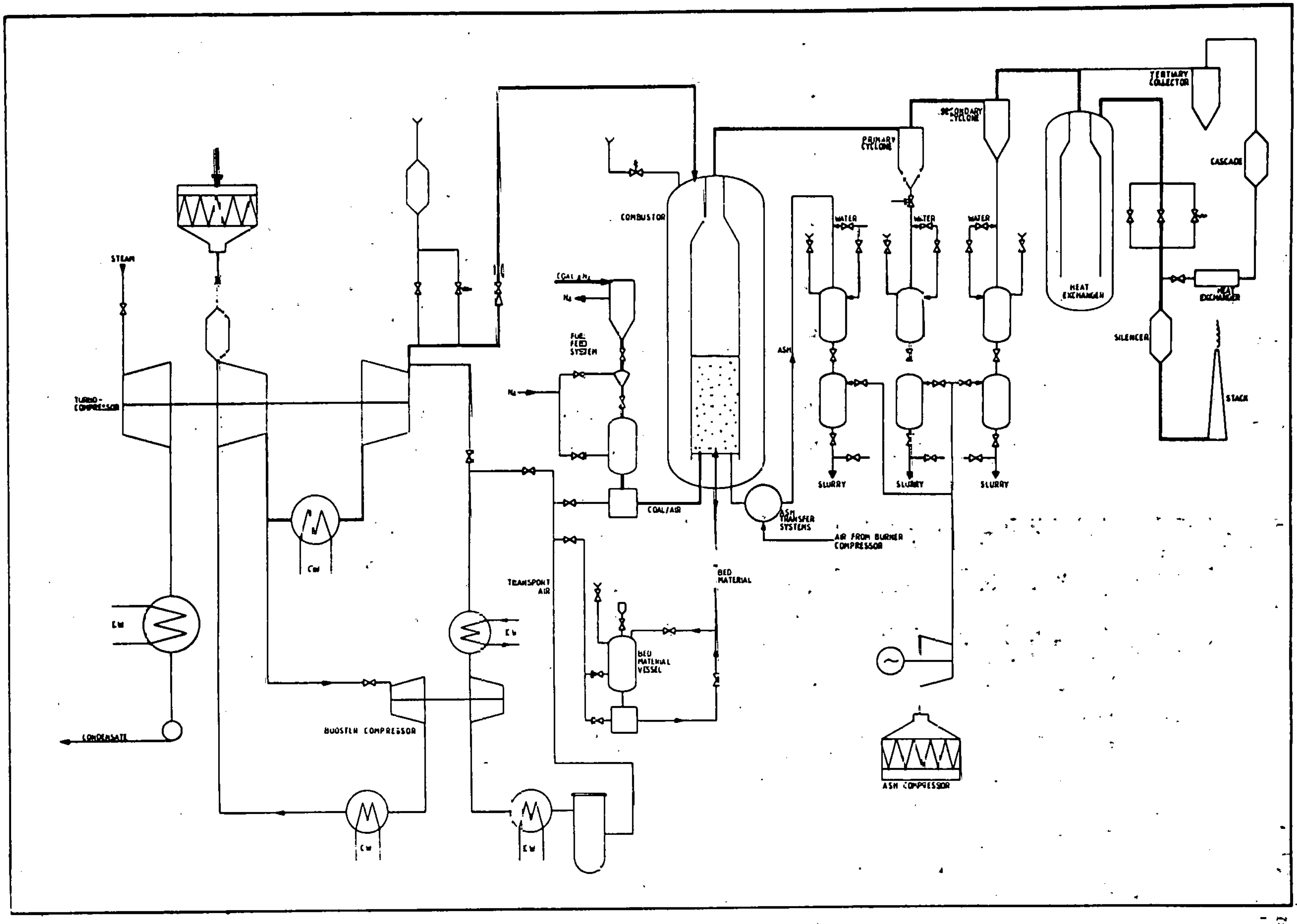


Figure 9-4. Overall Flow Diagram for Pressurized Fluidized-Bed System

The pressure-letdown stage together with the heat exchanger has the same effect as a gas turbine. The reason why there is no gas turbine at Grimethorpe is because tests will be run at different operating conditions, where if a gas turbine were used the plant would be limited to one condition and one pressure ratio.

The next part of the paper will deal with components of the system, which might be more interesting to the valve manufacturers. Of course, one of the very sophisticated and more difficult areas to cope with is ash removal from the bed. Coal and dolomite are fed into the combustor, and it is desirable to get part of the ash out of the base of the unit. At the present, a system is installed where the ash is discharged, fluidized, and pneumatically transferred into a wet quenching system. The ash is handled as a low-temperature slurry before discharging to the water-treatment system.

One of the difficulties is to control the solids flow out of the fluidized bed. There might be the possibility that the flow cannot be stopped. So it is necessary to have some kind of shutoff device, for example, a valve. There are valves installed which, however, have not proven satisfactory.

Of course, in a commercial plant, it would be preferable to eliminate the ash-quenching system, because it is a very expensive item. It would be better to have a dry system.

The requirements would be about 850°C (1560°F) and about 12 Bar (175 psig). Of course it would also be desirable to have a dry-ash-removal system for the solids discharge from the primary cyclones which currently use the ash-quenching system as well. The solids-discharge system will be explained later in more detail.

As part of the planned research program it is necessary to have part of the ash out of the cyclones dry to enable scientific analyses to be done. Therefore, there is a branch where the hot ash is divided and sampled with a lockhopper arrangement.

Figure 9-5 shows the design conditions in terms of temperatures and pressures. The air flow is 31 kilograms a second or about 60 pounds per second. The pressure is 12 Bar (175 psig). The fluidizing velocity is about 2.5 meters per second. The bed temperature is at 850°C, which is equivalent to 1560°F. There is an overall coal-feed rate of 10 tons/hour, or about 240 tons/day.

PLANNED OPERATING CONDITIONS AT FULL LOAD

	TUBE BANK A	TUBE BANK C
AIR MASS FLOW (KG/SEC.)	31	21
PRFSSURE (BAR)	10	12
FLUIDISING VELOCITY (M/SEC.)	2.5	1.5
BED TEMPERATURE (°C.)	850	850
COAL FEED RATE (TONNE/HR.)	10	6.4
THERMAL INPUT (MW)	80	48
COAL AND DOLOMITE TOP SIZE (MM)	6.4	4.8
ESTIMATED CA/S MOL RATIO TO ACHIEVE 90% SO_2 RETENTION	2.6	1.9

Figure 9-5. Planned Operating Conditions at Full Load

Figure 9-6 shows the project time schedule. The different stages of the project are also shown. Cold commissioning, i.e., the component testing, was completed in August. The hot commissioning started in September with the use of propane burners.

During this time period, research instrumentation will be designed and installed. The research instrumentation consists of specialized equipment to measure the performance of the plant and also to extract solids and gas samples at different locations.

With the heat-transfer and corrosion probes, special knowledge will be gained about the heat transfer and the effects of temperature and the fluidized-bed environment on materials. A bypass around the pressure-letdown station passes gases through a turbine cascade to see the effect of the gases on gas-turbine blade materials.

By March of 1981 the research program will start with two tests on British coal. After that a second test period begins and runs from the middle of '81 to the middle of '82. Five different coals will be used—one from England, two from Germany, and two from the United States. This of course is a most important test for the sponsoring countries.

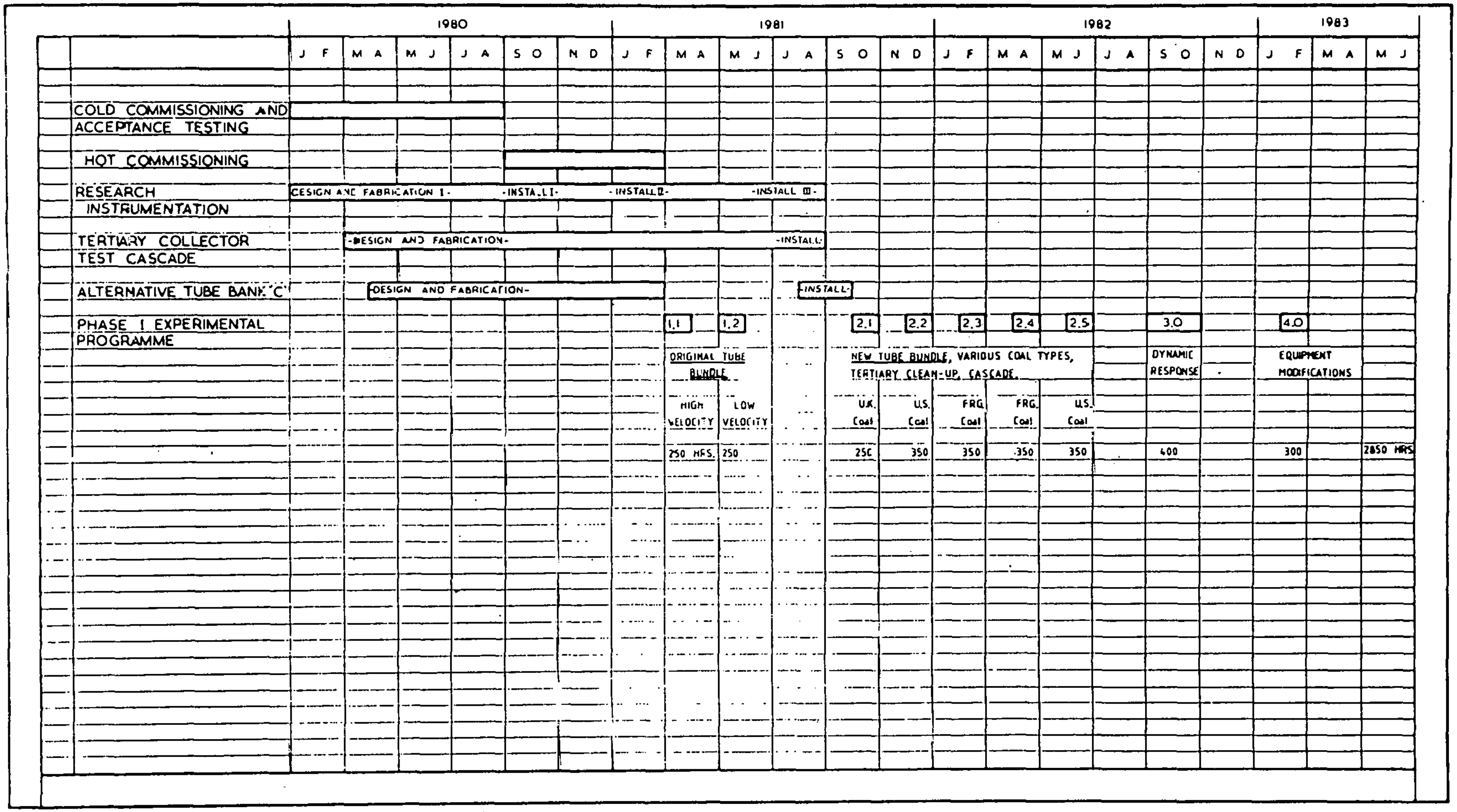


Figure 9-6. Summary Overall Schedule

Finally, a period of dynamic-response testing s planned. At the end of the currently planned program, a test will be conducted where the plant is operated under different configurations. That means changing the number of coal-feed nozzles or changing physically the layout of the bed itself.

Figure 9-7 shows the objectives of the program. Most of it has been described already. It is intended to conduct research on combustion investigations, on heat transfer, and on corrosion of materials in the pressurized-fluidized-bed unit. It is also intended to look into energy recovery, which would lead to the installation of a gas turbine at Grimethorpe.

As described above, the discharge of the primary cyclones is sampled with a system as shown in Figure 9-8, where the stream at the outlet of the cyclones is diverted and the solids are collected in a sampling vessel. These solids are at a temperature of approximately 850 °C and at that time at 10 Bar. A lockhopper arrangement is required to depressurize the solids to atmospheric pressure in a dry stage.

One of the biggest problems of pressurized-fluidized-bed technology is handling of solids at high temperatures and under pressure. This obviously is an area for development of high-temperature valves.

Another problem is very specific to Grimethorpe, and will not be found in a commercial plant. This is shown on the bottom of Figure 9-8. With this so called gas- and solids-sampling probe, samples of the solids in the combustion chamber and also samples of the gases must be extracted during operation.

Of course these applications first of all need relatively large-size block-and-bleed valves which, in an emergency, will have to withstand full operating temperatures and also must be airtight when the probe is withdrawn.

Additionally, something that is not shown on this figure is that gas samples are continuously taken. The gas temperature is in the order of 850 °C and valves are needed to cope with that kind of environment.

Taking into account the needs of a commercial installation it can be said that the size of solids-handling valves will increase but the availability of these valves as "off-the-shelf" items is very limited. The process itself needs a dry-ash-removal system, which also would require large valves for a commercial plant.

Figure 9-9 shows the ash-removal system as it is installed at Grimethorpe. On the left side it is shown what is currently installed, which is an extraction pipe in the bottom of the reactor, going through an emergency shutoff valve, into a fluidizing vessel. The ash flow from the combustor is controlled by the air supplied to the fluidizing vessel. Flow out of the fluidizing vessel goes through an orifice for maximum flow control and then by pneumatic transport into the wet-quenching vessel.

The existing system has two problem areas. One is the orifice which will suddenly block if any agglomeration of particles is taking place in the combustor. The other problem area is the bed level. The bed is the highest point in the current ash-removal system. Even with equal pressure between the two vessels, solids can still flow.

To design an alternative ash-removal system as shown on the right side of Figure 9-9, discussions have been held with engineers and specialists in the field of solids handling, and a design was selected which is commonly called a Y-box because of its physical shape. The design can be a "pneumatic valve."

This is very similar to all the other pneumatic-control valves, which also are often called L or J valves. The main advantage of the system is that there is no restricting orifice. That means that particles of up to 2 inches can get through the system.

The next step is a dry lockhopper arrangement; however, it is very difficult to find valves for that kind of application.

It is of great importance for a new process like pressurized-fluidized-bed combustion to insure that the components of the plant perform satisfactorily, especially the main components which are still not available on the market or are very expensive or special high-temperature applications.

Hopefully, the above description of the Grimethorpe facility defines the needs for specialized valves sufficiently to interest the valve manufacturers in addressing the needs of this technology and lastly I would like to thank you for your attention.

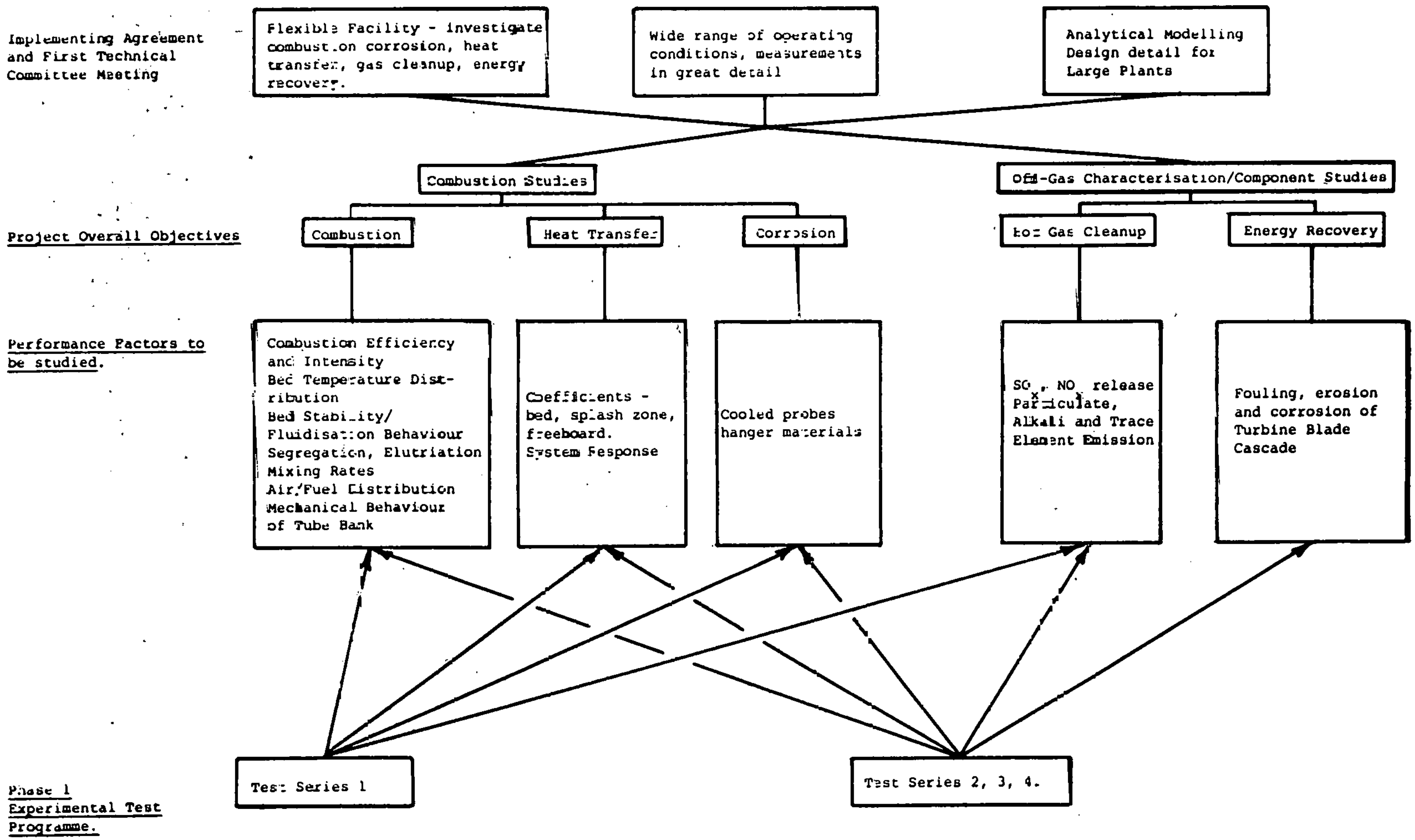
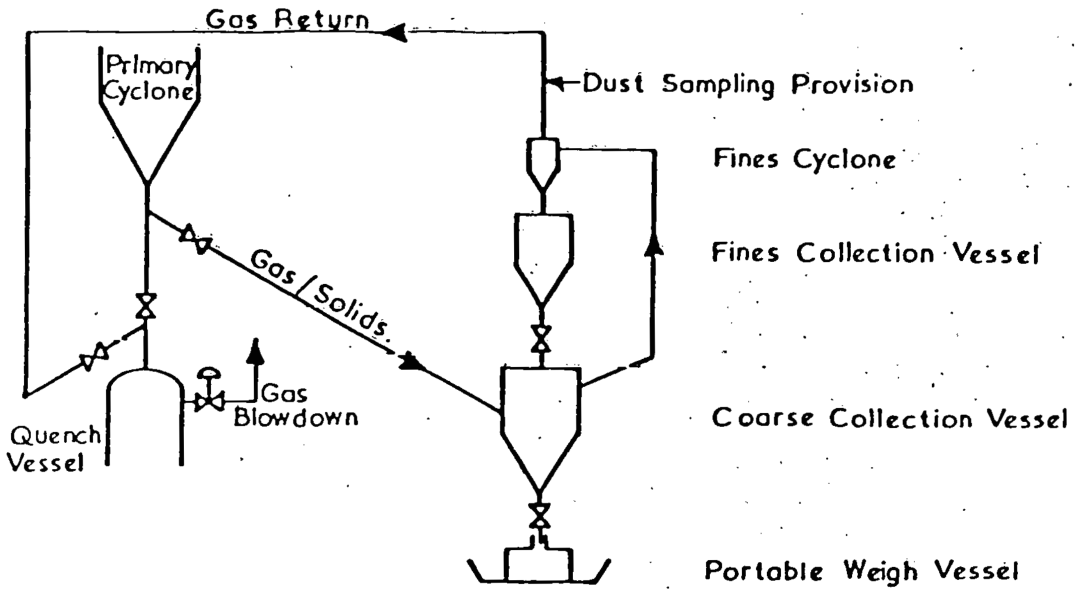
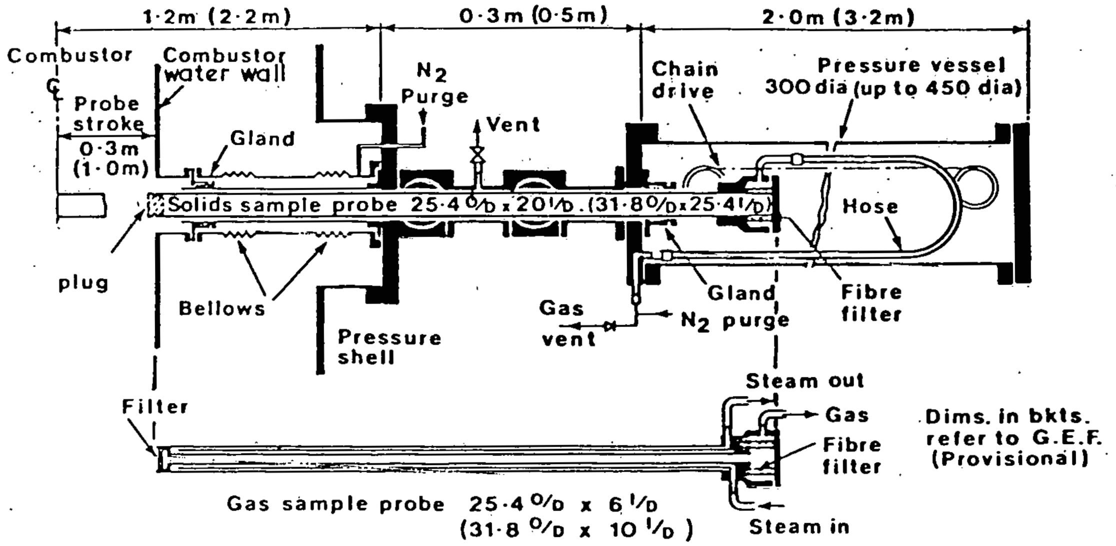


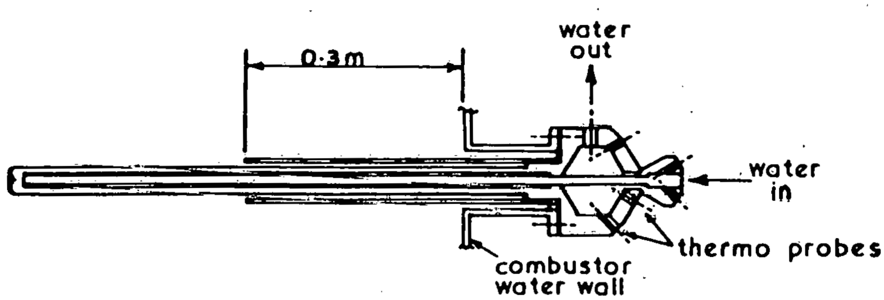
Figure 9-7. Relationship Between Project Objectives and Experimental Test Program



PRIMARY CYCLONE SOLIDS SAMPLING BASIC FLOW SCHEMATIC



PROTOTYPE IN BED SAMPLING PROBE



HEAT TRANSFER PROBES

Figure 9-8. Valve Requirements Specific to Grimethorpe

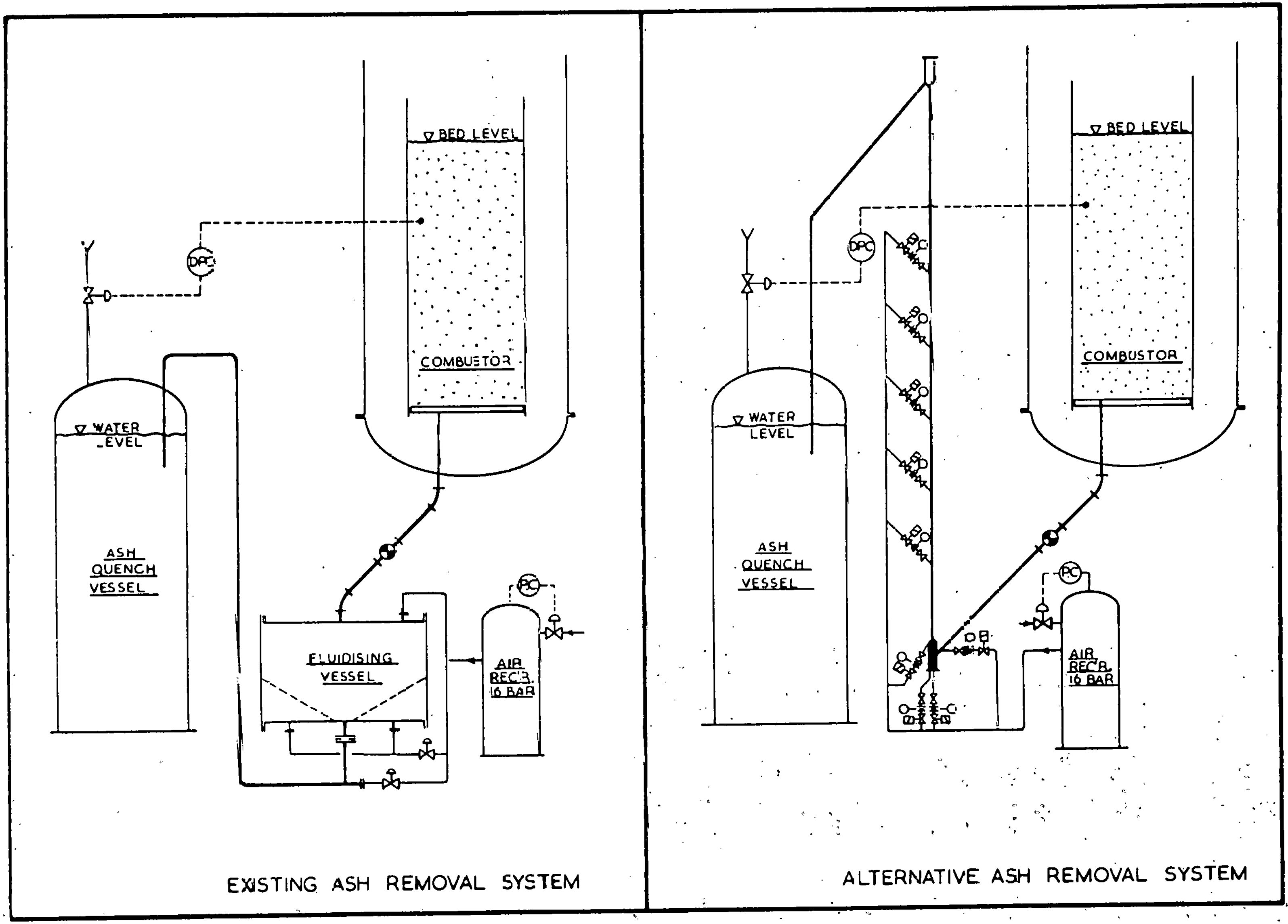


Figure 9-9. Existing and Alternate Ash-Removal Systems

Discussion of Paper by Mike Kaden

QUESTION: Judging by the cyclones and separators, I would take it that you have a lot of coal fines that blow out with the fluidizing air?

KADEN: We have only about 1% of carbon in the bed itself. When it gets fluidized, of course, we get fines blowing over. That means the particles get a certain time to combust before they are elutriated out of the bed. Therefore, the loss of carbon is low.

QUESTION: Can you elaborate a little on your reason for suggesting interest in ceramic valves?

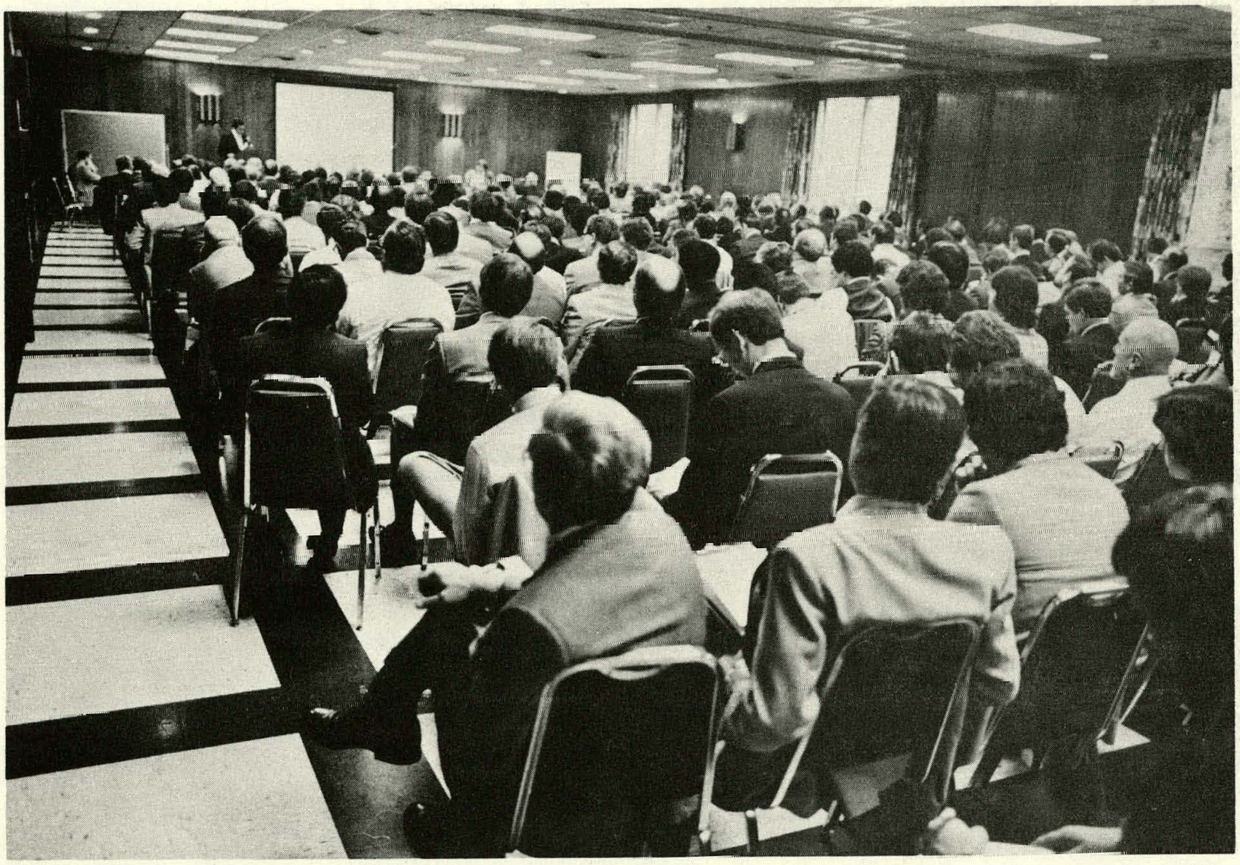
KADEN: Well, I think if you look at what I might call metallic materials, I think we have one of the rare applications where we are at relatively high temperatures, as I said about 850 °C and above, that means at least 850 °C in the design. We would like to develop designs to 950 °C to provide a safety margin. Even with the very exotic materials on this new market, you might not handle that. I came across the field of ceramics in our lining problems. We have had problems in lining our duct work and our cyclones. And it gave me great hope when I talked to ceramic people that there is a lot more than just alumina there. We found materials or we had materials quoted that were suitable for very high temperatures and very good for thermal shock as well. I think it would be worthwhile trying them out.

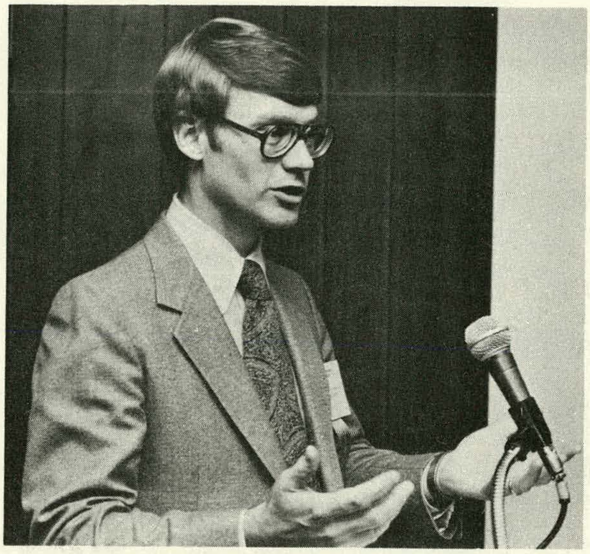
The reason I am mentioning ceramic is you don't have the limitation that comes up on the steel materials somewhere between 900 and 1,000 °C (1,650 and 1,800 °F).

QUESTION: Have you experienced any slagging problems in your refractory-lined ducts or mains?

KADEN: No. What we did so far is run the system at temperature with relatively low gas throughputs during hot commissioning. We have to prevent the ash sintering or even melting in any case, because the system wouldn't work if we did that. That is our reason for combustion temperatures of 850 °C (1,560 °F).

One of Many Full Sessions . . .





Section 10

PFB Combined-Cycle Power-Generation Valve Requirements

David K. Christensen and John Almstead

Presented by:
David K. Christensen, Manager
PFB Turbine Programs
General Electric Co.

October 15, 1980—3:45 p.m.

Abstract

A Pressurized Fluidized-Bed Combined-Cycle Plant for power generation is currently under development by the General Electric Company. A reference design has been developed, and we are now ready to proceed with the preliminary plant design followed by the design and construction of a utility demonstration plant. The goal is to be ready for commercialization by 1987 in an effort to capture a substantial portion of the 10-20 GW_C/yr coal-fired power-generation market in the 1990s.

The PFB combustion process consists of burning crushed high-sulfur coal in a fluidized bed but in the presence of dolomite (10 atmospheres, 1,750°F). The dolomite converts the SO_2 to calcium sulfate, which is discharged with the ash as a dry waste. In a combined-cycle power plant, the fluidizing air is provided by a gas-turbine compressor while the combustion products are expanded through the turbine to produce power.

The PFB piping and cleanup train contains a large volume of hot gas, which must be controlled by the gas turbine inlet stop-control valve. The success of the commercial plant depends on the development of a reliable valve which can withstand, 1,750°F, 150 psia and the erosive/corrosive atmosphere. In addition, the valve is large and must close in 2 seconds. The purpose of this paper is to focus attention on these requirements in an attempt to generate interest in developing the control/stop valve.

★ ★ ★

I would like to describe to you what General Electric has planned for the pressurized fluidized bed (PFB) in terms of power generation in the future. Also, I am interested in discussing with you what our valve requirements will be for the combined-cycle PFB power plant.

I would like to give credit to my co-author, John Almstead, who is with the Gas Turbine Division. He is a controls engineer and has selected the gas-turbine control and stop-valve sizes for this work. He will also be specifying the controls for a PFB combined-cycle power plant.

I would like to briefly discuss the cycle description and show you one of our reference designs for a PFB power plant. My major topic is the gas-turbine control valves and their requirements. Also, I would like to give you a little idea of what our schedule is in terms of building one of these plants.

The General Electric Company is developing a reference PFB combined-cycle power plant, which is representative of our eventual commercial offering. A schematic of the process is shown in Figure 10-1. The net plant output is 630 MWe at an efficiency of 40.5%. The configuration includes three MS7000 gas turbines, one 3,500 psig/1,000°F superheat/1,000°F reheat steam turbine, and three stages of cyclone for hot-particulate cleanup. An economizer has been included to recover the gas turbine exhaust heat.

The PFB combustion process consists of burning crushed high-sulfur coal in the fluidized bed in the presence of dolomite at 10 atmospheres and 1,750°F. The dolomite converts the SO_2, which is released during the combustion of the coal, to calcium sulfate. This is discharged as a dry waste. The fluidizing air is provided by the gas-turbine compressor, while the combustion products are expanded through the turbine (after cleanup) to operate both the compressor and the electrical generator.

As summarized on Figure 10-2, the advantages of the PFB combined cycle are that it can provide high efficiency and low emissions at a reasonable cost. It can also be said that it can burn any quality coal and that the dry-waste products are easy to dispose of.

The high plant efficiency (40.5%) can be attributed to the 99+% combustion efficiency and the power recovery in the gas turbine. The efficiency advantage of a PFB combined cycle increases as the gas-turbine inlet temperature is increased. However, above 1,750°F the dolomite effectiveness decreases and ash softening/agglomeration begins.

Emissions-wise, the PFB powered plant is more than acceptable. It will offer 95% sulfur removal, 0.1 to 0.2 lb/MBtu NO_x generation and 0.03 lb/MBtu (24ppm) particulates. The new source-performance standard is 90% sulfur capture, 0.6 lb/MBtu NO_x and 0.03 lb/MBtu particulates on a 4% sulfur coal.

The basic selling point is that we have a better efficiency than a pulverized-coal power

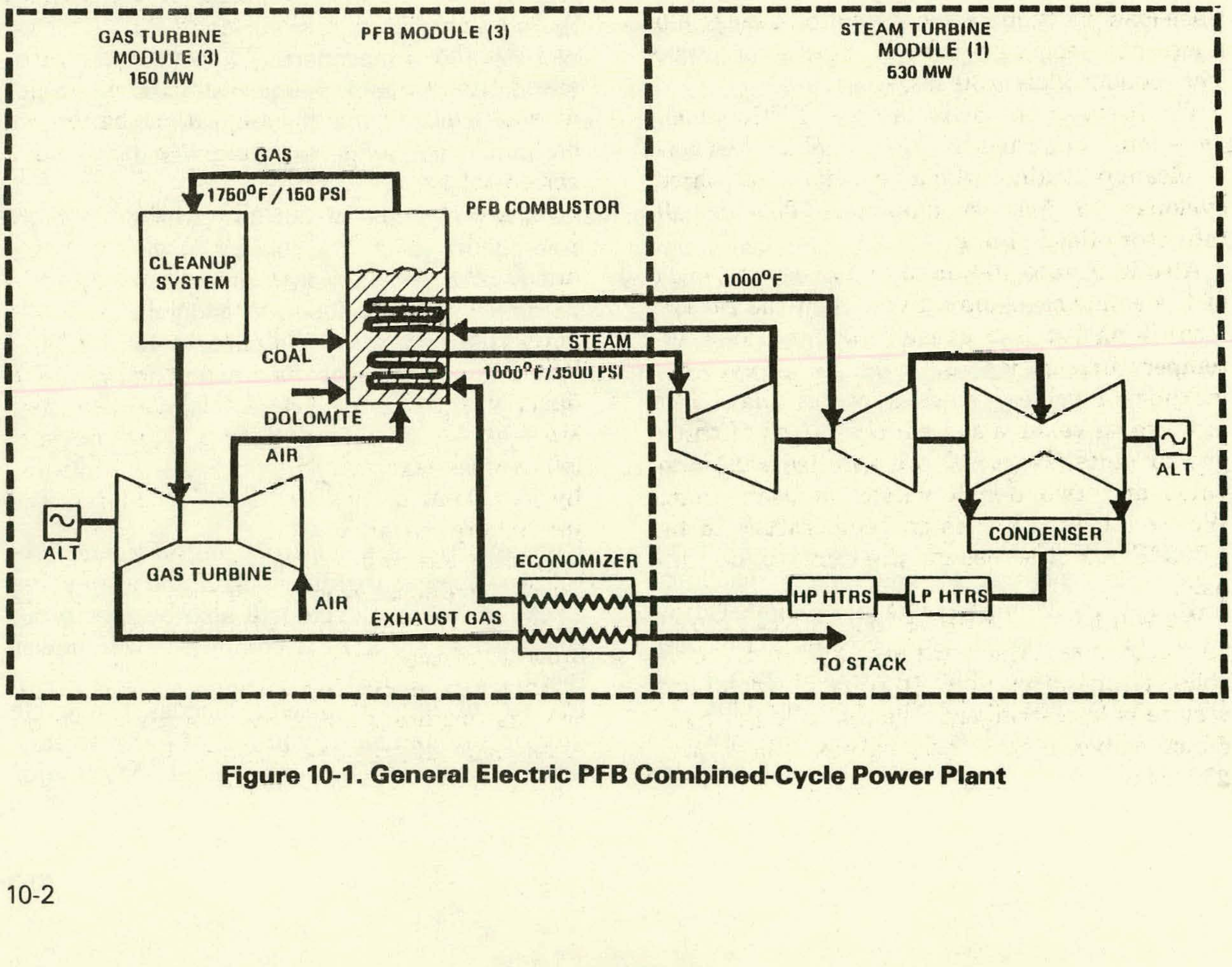


Figure 10-1. General Electric PFB Combined-Cycle Power Plant

plant with a stack-gas scrubber. Our eventual commercial plant will offer an efficiency of 40.5%. As shown on Figure 10-3, the whole plant is quite efficient over a wide range of gas-turbine inlet temperatures, anywhere from 950 °F, which is the self-sustaining limit for a gas turbine, to 1,650 °F. The efficiency for a reference power plant with a pulverized-coal combustor and a scrubber system is 35%.

The eventual General Electric PFB combined-cycle offering (1,670 °F gas-turbine inlet; 3,500 psig/1,000 °F/1,000 °F steam side) is economically competitive with the pulverized-coal-fired plant (2,400 psig/1,000 °F/1,000 °F) with wet stack-gas scrubbers, as shown on Figure 10-4. We are about 10% lower in capital cost and 10% lower on the 30-year levelized cost of electricity. We feel we should be able to sell this to a utility.

A reference PFB combined-cycle power-plant plot plan (Figure 10-5) and side elevation (Figure 10-6) are included to identify typical equipment and valving locations. The solids-handling valve requirements are approximate and reflect an eventual desire for 1,700 °F valves. The cyclone and coal-lockhopper valves will be cycled about every 1½ hours while the PFB off-take will be more frequent. Base-load plant operation is traditionally 8,000 hours per year with 8 to 10 starts per year. The economic life is 30 years.

The heart of the plant is three PFBs which have four beds in each of them. Each bed has a cleanup train, which consists of three cyclones 12 feet in diameter. This is all refractory-lined piping.

Also in Figure 10-6 is my wish list in terms of the solids-handling valves. And the reason I say wish list is because I have rather high temperatures indicated. As far as the cyclone-lockhopper valves, we think we will have 144 of these valves in a system comprised of three gas turbines. We think we will use a 12-inch valve and two 8-inch valves in each train. We would like the design temperature to be 1,700 °F and the design pressure to be 150 psia.

We will have 48 PFB offtake valves around an 8-inch size. Again we are talking 1,750 °F solids temperature and 150 psia. The dolomite service is less stringent. We are talking about 8-inch valves and 6-inch valves, 125 °F and 250 psia.

We are transporting the coal pneumatically to the bottom of each of the beds. We have quite a few 1- or 2-inch coal-transport valves. Again the conditions are 125 °F and 250 psia.

Figure 10-7 is our control-valve schematic. The present control concept utilizes a start-up combustor to start the gas turbine and bring it up to full speed. After synchronizing the generator with the grid, the PFB air-supply valve, stop valve, and control valve are opened to start, pressurize, and transfer to PFB-fired operation.

Gas-turbine trips due to loss of load will require opening the bypass valve while closing the control, stop, and PFB air-supply valves. These actions require high valve reliability, close coordination, and high response rates to prevent turbine runaway and compressor surge. The blow-off valve will be used for emergency stops. Bypass and blow-off valve leakage is undesirable due to the loss in cycle efficiency, while stop and PFB air-supply valve leakage will impede quick shutdowns.

Figure 10-8 illustrates the time frame required for the valve operation. It shows a simulation of the turbine rotor speed, operating initially at 3,600 rpm, responding to a loss of load and the tripping of the valves. It will take about 2 seconds for the pressure to come down, and during that time the rotor speeds up at about 5% a second. You can see it would not take very long at all before we had an over-speed situation. We need valve action within 2 seconds.

Figure 10-9 shows these requirements more specifically. The hot gas and the stop valve are normally in the open position, require a 2-second operating rate, and will pass 550 pounds per second of dirty gas at 1,700 °F. We have a 147-psi shut-off pressure and operating pressure. The valve has also been sized at 42 inches based on a 2-psi pressure loss across the butterfly valve. It will be fed by four 36-inch lines which will be manifolded just before the valve.

The hot-gas piping will be refractory lined to lessen heat loss. About 5 inches of lining is required. The line and valve sizes shown are inner diameters.

Another scheme that we have for controlling the gas turbine is a dual-valve system, one on either side of the gas turbine. In that case, we require two 30-inch valves. Each would be fed by two of the 36-inch lines.

The hot-gas control valve is essentially the same type of operation. We will need about the same size. The only additional requirement here is that it's a modulating type of service. It also needs a backup stop valve should this one not perform. The hot-gas blow-off valve, is also a rapid-opening valve. It can be a little bit smaller, something like 28 inches, or if we had the dual-control system, 20 inches.

Figure 10-10 shows the clean-gas valve requirements. The start-up air-supply valve along with the PFB air-supply and the bypass valve are all about the same size, and will require one 36-inch valve or two 24-inch valves. The flow is about 500 pounds per second. Here the temperature is only 600°F. Again, it has to be a low pressure-loss type of valve, and it has to be fast operating.

These valves are required for gas-turbine protection and figure quite heavily into plant availability. The valve, of course, must operate in a commercial plant. It may very well be out in the open and not inside an enclosure. We envision maintaining them yearly, which is every 8,000 hours of operation.

Figure 10-11 shows our development schedule; we are about ready to start the design of a prototype plant. We expect to be working on the preliminary design next year, which will be followed by a design and build phase. We would need prototype valves by the end of 1985. We would offer this plant for commercialization after 2 years of operation, in 1988. The commercial valve wouldn't be required until maybe 3 years downstream of this.

We do have several projects going on in the area of PFBs. We have the long-term materials test which we expect start up next year. It's a rather small rate, only a half a pound a second—a ton and a half of coal per day. The purpose of the test is to evaluate gas-turbine materials for erosion and corrosion. It will last for 14,000 hours, approximately 4 years.

Mike has already described the Grimethorpe PFB experiment. Its combustor produces about 65 pounds per second. General Electric has two experiments going on over there. One is in the area of hot-gas-cleanup cyclones. We also have a cascade that simulates the turbine blades. We are using a 12-pound-per-second slip stream.

So, in summary (Figure 10-12), what I would like to do is state one more time what I think the requirements are for the hot-gas valve. Basically, it has to be large to minimize system pressure loss. It's a high-temperature valve; high temperature is required for high cycle efficiency. Operation—it must be a fast-response valve. Also, it has a high shutoff-pressure drop. Erosion—we are talking 1,000 parts per million, 8 microns maximum-size particle. Corrosion—it is a very corrosive atmosphere. We think there will be about 5 to 10 parts per million of alkalide vapors. That is why we are developing the gas-turbine corrosion and erosion test. Finally, the reliability has to be high.

You can see we are about ready to start a plant preliminary design and I will be out looking for vendors willing to supply hot-gas valves, and block valves, too. I would like to second the request for developed valves in that area. Again, I am looking for a 42-inch valve by 1985, and a commercial valve by the late 1980s.

PFB IS A TOTALLY NEW METHOD FOR BURNING COAL

- COMBUSTION AT 1400 — 1750°F, WELL BELOW ASH FUSION TEMPERATURES
- COMBUSTION EFFICIENCY 99%
- SO_2 AND NO_x EMISSION LEVELS EQUAL OR SURPASS OIL FIRED PERFORMANCE
- CAN BURN ANY QUALITY COAL
- PRESSURIZED OPERATION REDUCES BOILER SIZE, IMPROVES HEAT RATE

SIMPLE, DIRECT COMBUSTION BOILER CYCLE AIMED AT FOSSIL BASE-LOAD MARKET

Figure 10-2. Summary of Advantages of PFB Combustion

PFB STEAM SUPPLY OFFERS COMPETITIVE PLANT EFFICIENCY

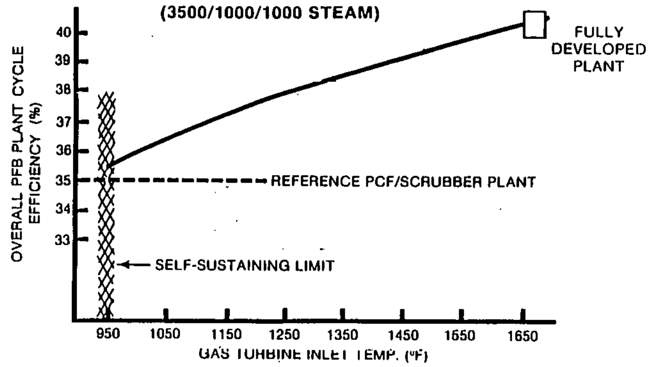


Figure 10-3. Overall PFB Plant-Cycle Efficiency Versus Gas-Turbine Inlet Temperatures

PROJECTED PFB POWER PLANT ECONOMICS

BURNS & ROE EASTERN COAL RESULTS (EPRI RP 1645-2)

(MID 1978 $)

	GENERAL ELECTRIC PFB (630 MWe)	REFERENCE PCF PLANT WET SCRUBBER (700 MWe)
EFFICIENCY (HEAT RATE)	40.7% (8467)	35.0% (9741)
TOTAL CAPITAL REQUIREMENT ($/kW)	[illegible]	734
30 YR LEVELIZED COE (MILLS/kWh)	46.2	50.3

Figure 10-4. Projected PFB Power-Plant Economics

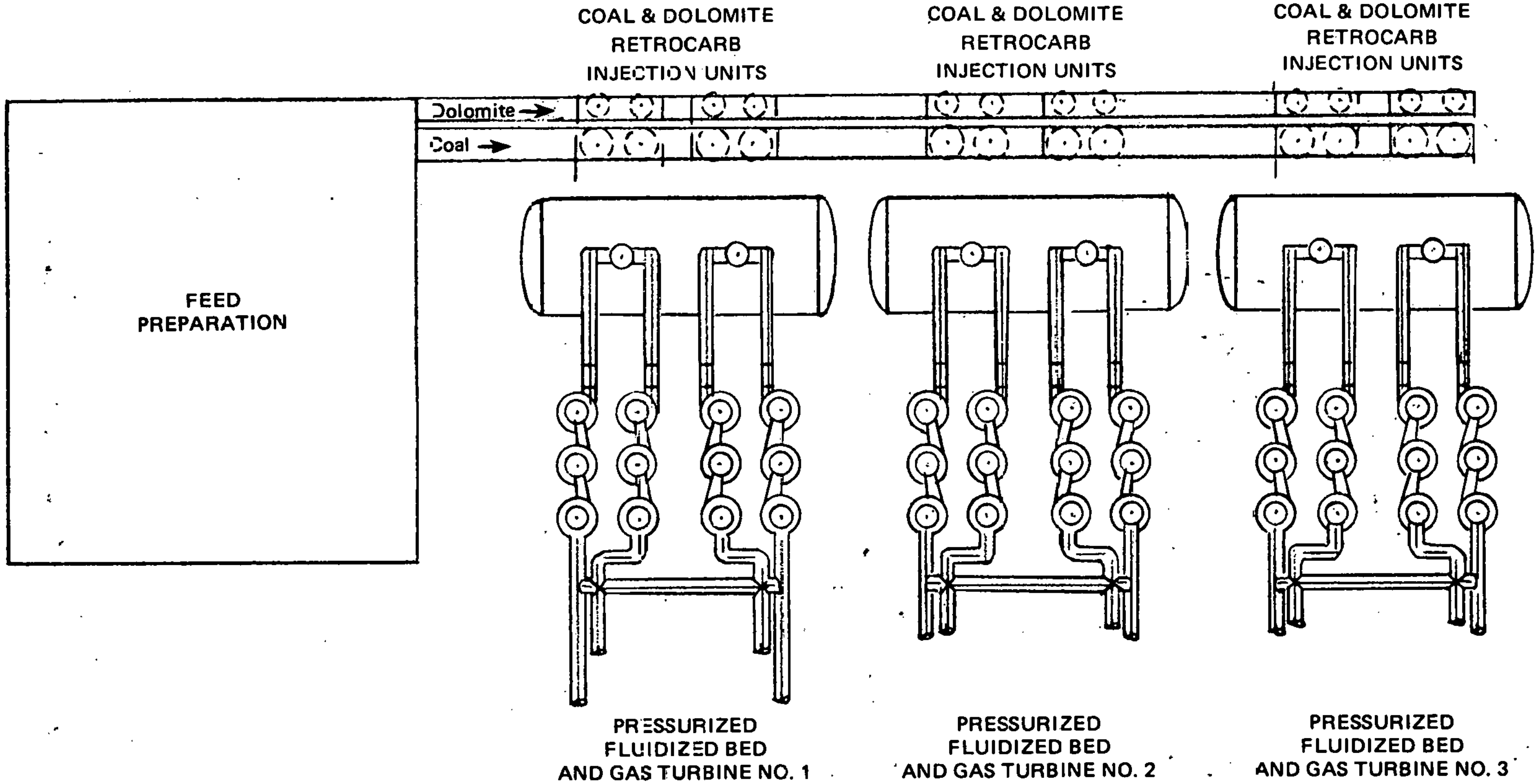
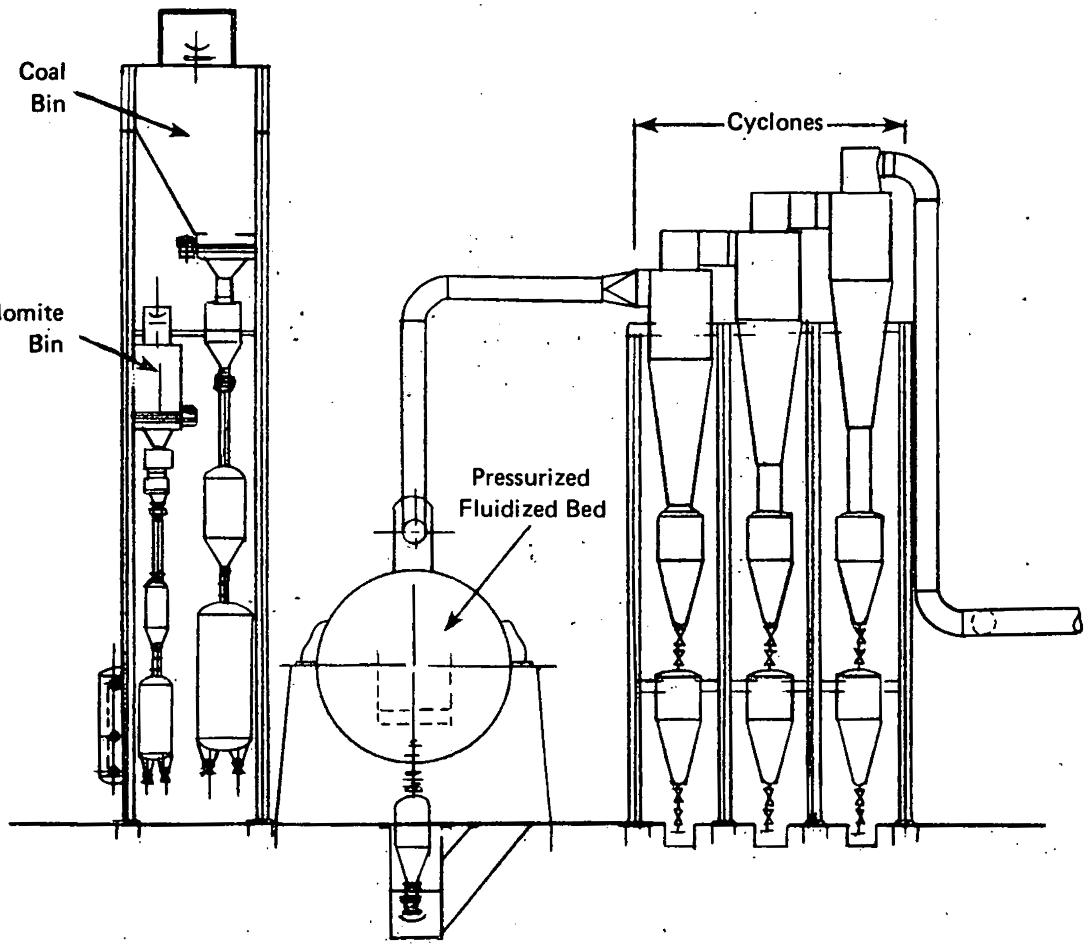


Figure 10-5. Reference PFB Combined-Cycle Power-Plant Plot Plan



SOLIDS HANDLING VALVES

	No.	Size (In.)	Temp (°F)	Pressure (psia)
Cyclone LH	144	12/8/8	1,700	150
PFB Off-Take	48	8	1,750	150
Coal/Dolomite	48	8/6	125	250
Coal Transport	192	1-2	125	250

Figure 10-6. Reference PFB Combined-Cycle Power-Plant Side Elevation

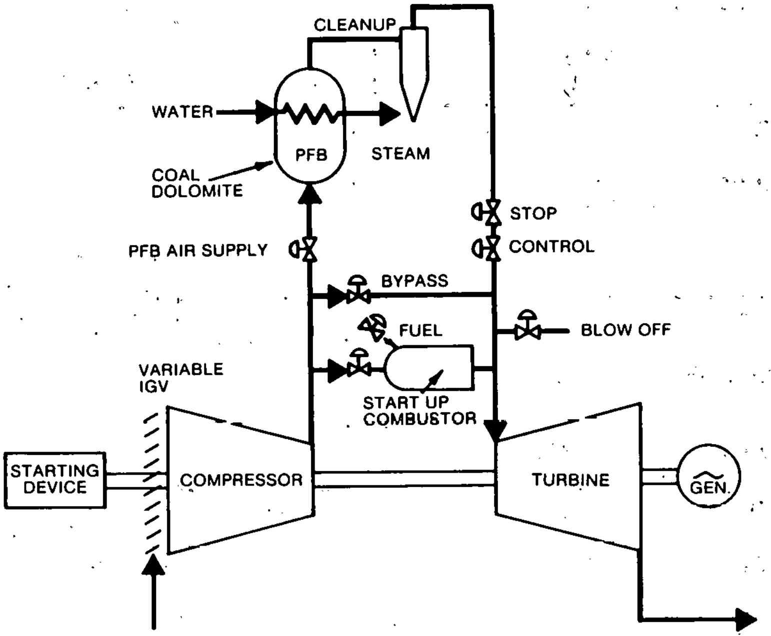


Figure 10-7. Control-Valve Schematic

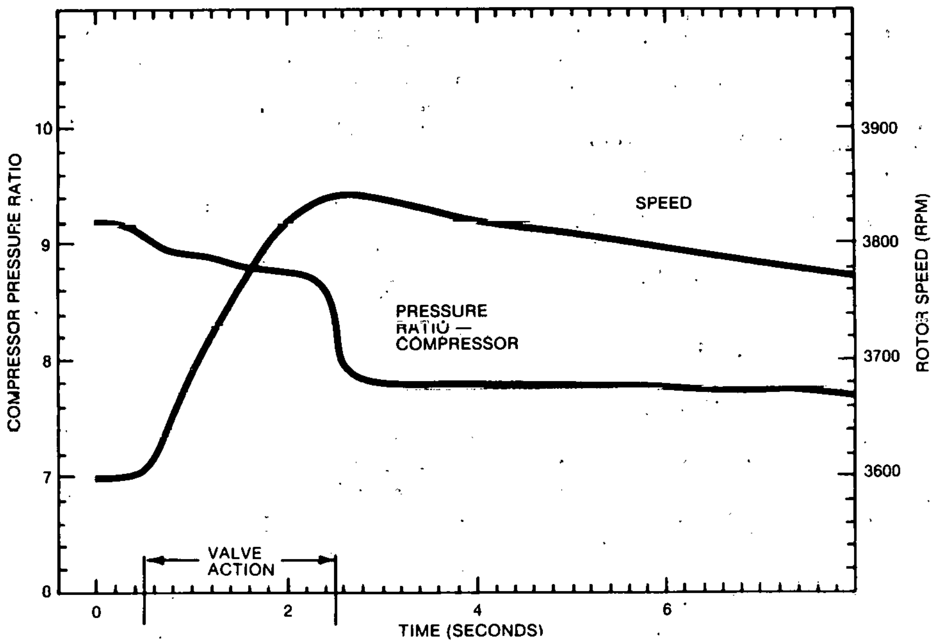


Figure 10-8. Gas-Turbine Trip Overspeed Simulation

DESIGNATION	VALVE FUNCTION	VALVE ACTUATION	DESIGN CONDITIONS	EST. LINE SIZE	EST. VALVE SIZE
HOT GAS STOP VALVE	OPEN: DURING PFB OPERATION CLOSED: TO SHUT-OFF PFB GAS FLOW	RATE COMPATIBLE WITH TURBINE PROTECTION (1 →2 SEC)	550 LBS/S 1700°F 147 PSIA SHUT-OFF AND OPERATING DIRTY GAS 2 PSI PRESS LOSS	FOUR 36" ID FEEDING ONE OR TWO VALVES	ONE 42" OR TWO 30" (ID)
HOT GAS CONTROL VALVE	OPEN: DURING PFB OPERATION MODULATING: DURING TRANSFER TO/ FROM PFB OPERATION CLOSED: DURING TURBINE START UP & SHUT DOWN	RATE COMPATIBLE WITH TRANSFER BACK UP STOP VALVE			
HOT GAS BLOW-OFF VALVE	OPEN: FOR EMERGENCY CLOSED: NORMALLY	RAPID OPENING	1700°F 147 PSIA OPERATING AND SHUT-OFF DIRTY GAS	ONE 28" OR TWO 20" (ID)	ONE 28" OR TWO 20" (ID)

Figure 10-9. Dirty-Gas Valve Requirements

DESIGNATION	VALVE FUNCTION	VALVE ACTUATION	DESIGN CONDITIONS	EST. LINE SIZE	EST. VALVE SIZE
START UP AIR SUPPLY VALVE	OPEN: DURING TURBINE START UP MODULATION: DURING TRANSFER TO/ FROM PFB OPERATION CLOSED: DURING NORMAL OPERATION	RATE COMPATIBLE WITH TRANSFER REQUIREMENTS	500 LBS/S 600 °F 147 PSIA SHUT-OFF AND OPERATING CLEAN GAS 2 PSI PRESS LOSS	ONE 42" OR TWO 30" (ID)	ONE 36" OR TWO 24" (ID)
PFB AIR SUPPLY VALVE	OPEN: DURING PFB OPERATION MODULATING: DURING TRANSFER TO/ FROM PFB OPERATION CLOSED: START UP & PFB UPSET	SUITABLE FOR PFB PROTECTION AND TRANSFER			
PFB BY-PASS VALVE	OPEN: WHEN ΔP EXCEED LIMITS MODULATING: DURING TRANSFER TO/ FROM PFB OPERATION CLOSED: START UP & NORMAL OPERATION	RATE COMPATIBLE WITH TURBINE PROTECTION DURING TRIP			

Figure 10-10. Clean-Gas Valve Requirements

SCHEDULE/OPPORTUNITIES

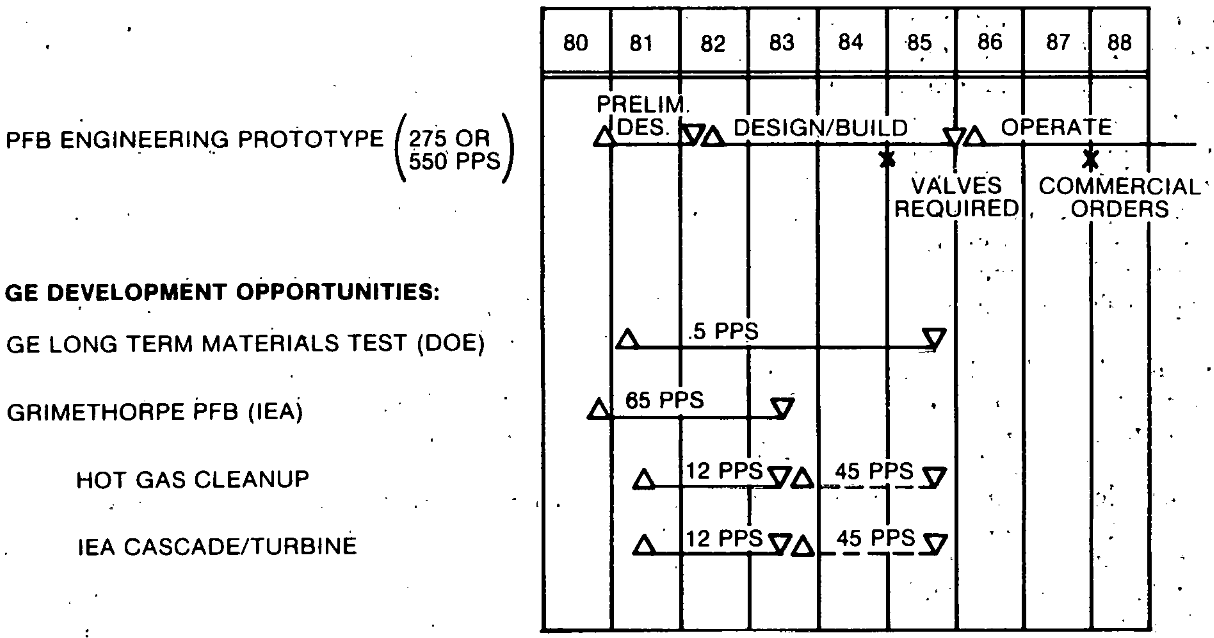


Figure 10-11. Development Schedule for GE's PFB Combined-Cycle Power Plant

HOT GAS VALVES

REQUIREMENTS SUMMARY

SIZE: LARGE TO MINIMIZE SYSTEM PRESSURE LOSS

TEMPERATURE: 1700°F

OPERATION: FAST RESPONSE, HIGH SHUT-OFF PRESSURE DROP

EROSION: DUST LOADING — 1000 PPM, 8μm MAXIMUM

CORROSION: ALKALI 5-10 PPM

RELIABILITY: HIGH

CONCLUSION

- SEARCHING FOR VENDORS INTERESTED IN SUPPLYING THE VALVES
- IF REQUIRED, SET UP A DEVELOPMENT PROGRAM TO PROVIDE:
  - 42 INCH PROTOTYPE VALVE BY 1985
  - COMMERCIAL VALVE BY LATE 1980's

Figure 10-12. Requirements Summary and Conclusion for Hot-Gas Valves

Discussion of Paper by David K. Christensen

QUESTION: These are very rough valve requirements. There are valves that have been made for temperatures in excess of 1,700 °F, like 2,500 °F, even as high as 2,900 °F. Then you put additional requirements on and I appreciate all the ramifications of it, but to a valve manufacturer, this kind of development takes a lot of time and a lot of money. One reason why we don't come up with these valves is because a lot of us are not in the position to put in the time and money. Are there any provisions for that?

CHRISTENSEN: That is partly what DOE is here for. (LAUGHTER) I haven't discussed this formally with John Gardner, but that is one area of funding. The other area that might be possible is to start small and work out something with New York State or maybe we could get a valve piggyback on one of those other tests that General Electric is involved in. It depends on what size you are going to scale from and what's available.

If you think you have something to offer, I think we would like to work this into our proposal to the DOE RFP that is due in about a month. We would like to talk over how we could do this as a joint venture. Again, there really hasn't been any money that has been identified right now to develop such a valve. Of course, we need one.

QUESTION: You had said you had a 2-second coordinate. I'm not sure what you meant by that, coordinate?

CHRISTENSEN: We would like to coordinate those three valves, the air-supply valve to the PFB, the bypass valve, and the stop and control valves. We would like to coordinate those so they all close at the same time. They all must close and open within that 2-second time frame. It's a controls problem. We could even think of mechanically linking them up, if that could be engineered in. We have thought of things like that in the past. We have some designs on the boards like that.

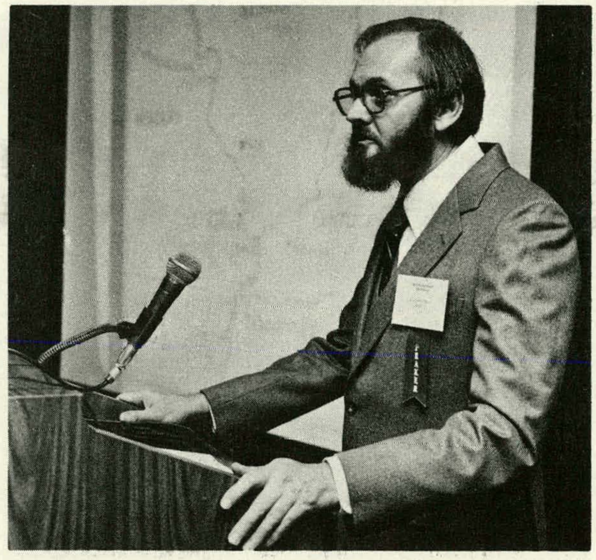
QUESTION: What would the kilowatt size be of the entire plant?

CHRISTENSEN: The kilowatt size of the eventual commercial plant is 630 megawatts.

QUESTION: Would you expect these valves to cycle very often?

CHRISTENSEN: No. Base-load operations for a gas turbine generally would consider one start per 1,000 hours, base load is 8,000 hours a year, so you are talking 8 to 10 starts a year. After about 15 years, they would probably convert this over to a mid-range-type gas-turbine installation, and there you would operate 4,000 hours a year, so you would expect maybe double the number of starts. The grand total over a 30-year span for these larger valves would be three or four hundred cycles. That's an estimate. It's not a large number, if you compare that, say, to the coal-lockhopper valves or the cyclone ash-letdown valves. They would cycle every 1½ hours. For a 30-year life span, that is hundreds of thousands of cycles. That's a very ambitious goal.

Planning Panel Discussions . . .



Section 11

Valve Requirements for the ICGG Pipeline Gas Demonstration Plant

William West
Area Engineer
Dravo Corporation

October 16, 1980—10:15 a.m.

Abstract

The ICGG Pipeline Gas Demonstration Plant consists of 20 areas, and in 10 areas it utilizes processes licensed from seven separate process licensors. Included in the presentation will be brief descriptions of the processes and related facilities from the unloading of the coal through to the delivery of the gaseous product into the pipeline and the interim storage of the byproducts, naphtha, No. 2 and 6 fuel oils, sulfur, and ammonia. Particular emphasis will be placed on the following areas wherein special valve requirements will be discussed:

- Area 202 Lockhopper valves
- Area 203 Valves for operation at high temperature and erosion are primary considerations
- Area 204 Pressure-reducing valves handling slurries at high pressure differentials and temperatures
- Area 210 Control valves functioning in high-velocity streams of high-temperature gas with entrained particulates

The depth of the subject matter may be limited in certain cases because of the Process Licensor proprietary data rights.

Estimated quantities of valves in standard and nonstandard categories will also be presented for both demonstration and commercial-scale plants.

★ ★ ★

The ICGG plant is a demo plant. The installation is designed on information from Co-Gas and, as shown on Figure 11-1, this plant will be located in Southern Illinois between St. Louis, Missouri, and Cairo, Illinois, about 20 miles from the Mississippi River.

The plant will be about one-quarter the size of a commercial-scale train—a whole-size commercial plant that has three trains. In our plant we will be processing about 2,400 tons of coal a day. Since this is a demonstration plant, our instrument density is more like that of a pilot plant, rather than that of a regular production facility.

The plant has been broken down into basically 20 areas with regard to valve requirements (Figure 11-2). Area 201 is coal unloading and handling. Basically what they do here is store about a 30-day supply of coal in such a way that we can reclaim it and get it back into the plant. Area 202 is coal preparation. Here we screen the coal, crush it down to minus 10 screen size, and run it through a lockhopper system or a special solids-handling pump system into our pressurized system. Area 203—the heart of the system—is pyrolysis and gasification. Handling Eastern bituminous coal is different from Western coals or European or African coals. We have agglomerating and caking coals. This means we can't put them directly into a gasifier without a lot of trouble.

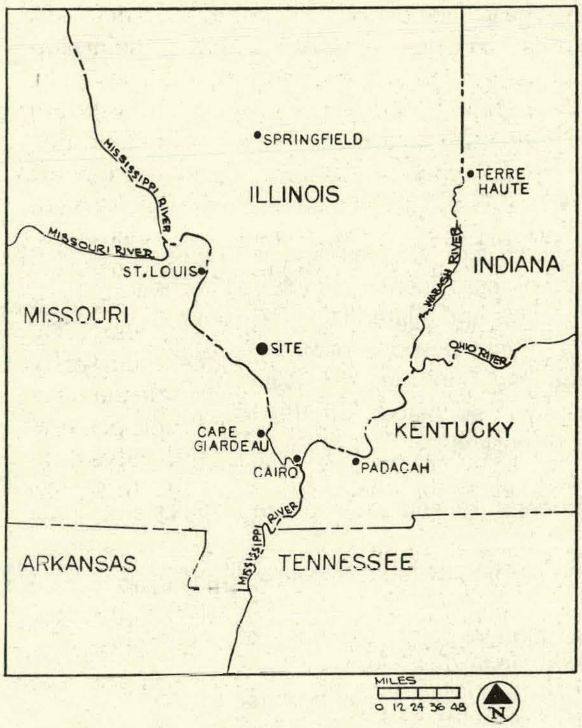


Figure 11-1. Site Location of ICGG Plant

If any of you remember hand-firing coal furnaces when you were a kid, you probably remember getting your mouth washed out with soap, like I did, for saying words that Dad used when he was fighting those big clinkers in the furnace. And that's basically the problem with the coal. What we are doing is taking the coal and running it through a multistage preparation treatment where we heat the coal by stages in a predetermined sequence that turns the coal into a char that we can then handle in the gasifiers. This is unlike the original Lurgi process. It is a continuous operation, not a batch operation. We will have a single large train of vessels rather than a whole series of smaller ones.

Area	Name
201	Coal Unloading and Handling
202	Coal Preparation
203	Pyrolysis and Gasification
204	Oil Recovery and Treatment
205	Gas Purification
206	Hydrogen Generation
207	Shift and Methanation
208	Bulk CO_2 Removal and Gas Compression
209	Gas Dehydration
210	Flue-Gas Power Recovery
211	SO_2 Removal
212	Sulfur Recovery
213	Ammonia Recovery
214	Thermal Oxidizer and Flare
215	Utilities
216	Water Supply
217	Water Treatment
218	Waste Treatment and Disposal
219	Fire-Protection System
220	Facilities

Figure 11-2. Valve Requirements of ICGG Demonstration Plant

After the pyrolysis, we then go to the gasification. In this particular process, gasification is done by injecting steam. We do not inject oxygen, because we are supplying heat from an external source.

One of the problems in handling our types of coal is fines. These fines are separated out and used as a fuel in the external combustor where the char is then heated and the heat is transferred to the gasifier. This also gives us a safety factor because if we would cut the heat input to the gasifier the temperature comes right down.

The next area is 204—oil recovery and treatment. The gas from the gasifier is recycled back through the pyrolysis area where the oils and tars are driven off of the coal. The gas is then run through a condensing section where the tars and oils are separated out and we go through a system very similar to what Mr. Miller described in detail. We treat the oil with hydrogen and then run it through a fairly standard refinery-type process. This is one of our problem areas, because: (1) we have high-pressure letdowns; (2) hydrogen treatment has to be done at high pressure, about 2,800 pounds; and (3) we have not only coal, but we have this hardened coal or char fines in our bottoms, which means that our slurry valves are having to withstand the high-pressure letdown in the presence of very hard particles. On a scale of 1 to 10, diamonds being 10, these particles are somewhere between 8.8 and 9.4.

Next step is Area 205—gas purification. We use a number of licensed processes for removing ammonia, sulfur. These are all standard refinery processes and are proven in the field over the past few years in refineries, so I won't take up your time with them now.

Area 206 is the hydrogen generation for treating our oil. Here we take substreams from the major gas stream, and use it to extract out hydrogen and then purify it for our process.

Area 207 is a high-Btu gas output. We produce a synthetic pipeline gas and have to have about 950 Btu/cubic foot. In order to do that, we have to take our regular-made gas and run it through a series of shifts and methanations to raise the Btu content to close enough to natural gas to be a substitute.

Area 208 is bulk CO_2 removal and gas compression.

Area 209 is gas dehydration, which gets the extra water vapor out.

Area 210 is another one of our areas I will be discussing today. This is a power-recovery train. We use hot gases and big valves. I'll discuss that more fully in a few minutes.

Area 211 is SO_2 removal. The coal that we are using is high-sulfur coal. That means that in this whole process, we have a lot of H_2S. In some streams, it is in lethal amounts, so tight packing requirements are necessary on our valves. We convert most of the H_2S to SO_2 through commercial sulfur-recovery plants, which are in Area 212.

We also recover anhydrous ammonia in Area 213. Area 214 is our thermal oxidizer and our flare for waste disposal. Area 215 is our utilities.

We use a lot of steam, a lot of water, and we plan to take the water from the Mississippi River and run it through our pipes about 20 miles over land and store it in a large pond for the plant. The water is for day-to-day operation and also in case of fire. Area 216 is our water supply, which is based down at the river. Area 217 is for water treatment, not only for plant water, but also for boiler feed water.

Area 218 is waste treatment and disposal. Once again, this plant has to be environmentally safe. Handling coal has produced some problems all of which we have been able to cope with. Area 219 is our fire-protection system, and Area 220 is facilities for the plant.

Now the areas that I will be covering that are of interest to everyone here today are Area 212, Area 213, Area 214, and Area 210. All these have valve problems that are peculiar to coal gasification and liquefaction and are sufficiently difficult to take up your time today. Since a lot of you are vendors and you want to know what's the bottom line, how many valves, and what kind for a plant like this, I did get some information for you. In this plant, there would be somewhere around 200 standard globe-type, carbon-steel valves; 10 to 15 stainless-steel, globe-type valves; 100 to 120 carbon-steel, butterfly valves; 30 to 40 stainless-steel, butterfly valves; 2 to 5 stainless-steel, angle-pattern-type valves; 7 to 10 carbon-steel, angle-pattern-type valves; 60 stainless-steel, ball valves; 32 carbon-steel, ball valves; and 6 to 10 bronze ball valves. All of these are fairly standard control-type valves.

Specialty items—high-temperature ball valves—would be about 30. Slide gates for high-temperature service, about 30. Refractory-lined butterflies, about 4, and high-pressure angle-letdown valves, 10 to 15.

In a full-sized plant, we could multiply all those by about 4. These are just the control valves; block valves are not included.

Sizes vary all over the map. The smallest control valve I have has a CV of 0.00028. The biggest throttling valve I have has an ID of 42 inches. It's a refractory lined valve, somewhere between 9 and 12 inches of refractory, which means it is going to weigh close to 50,000 pounds. I see some of the looks. You should have seen my structural people when I told them.

Let's take an area at a time. Area 202, that's coal preparation. The only real difficult valving problem here is lockhopper valves. These have to operate every few minutes. It can vary from as often as once an hour to maybe every 15 minutes and must be able to do this for 11 months out of the year without hanging up. We are using tarry, bituminous coal. It has a tendency to put nice tarry deposits on everything, and coal-fines pack all the cavities in the valves. We are lucky on this particular lockhopper application. We have low temperature and reasonably low pressure. We're less than 200 °F and less than 100 psig.

Right now we are considering three valves, either ball valves or plug valves, in this particular application. I do not like butterfly valves in lockhopper service; I have had no good experience with them. We are not using slide gates in this particular area because we have to seal against the back pressure. Slide gates don't do very well in this type of application.

The alternate loading method to lockhoppers is a Fuller-Kenyon pump. This has a problem on the Western coal, because Western coal has a tendency to grind up into fines in this. We are working with the pump manufacturers now to try to alleviate the problem.

The next area is the pyrolysis area. This is where we treat the coal so we can gasify it without it caking or agglomerating, i.e., forming clinkers. We do this in two to four steps by heating the coal up to predetermined temperatures. We have specially designed vessels for doing this. The vessels are a pretty good size, about 40 feet in diameter, and could be up to 100 feet tall. They vary in size, depending on the application. The number of steps and temperatures vary with each type of coal and is part of the proprietary process. As coal becomes char, the oils and the tars are driven off; these are collected to be put out as a raw product later on in the process. When we take the tars and oils out of coal, we solve the problem of gumming everything up. Unfortunately, we also make this stuff pretty hard. So we traded one problem for the other. We don't glue the valves together quite as much, but we chew them apart a little bit faster.

Most of the valves we will be using on hot-solids handling will be slide-gate-type valves. These valves will have to be handling solids temperatures in the pyrolysis area up to 1,000 °F. They will have to be able to shut off against differential pressure of over 70 pounds under emergency conditions. Also, they have to have a standard pressure drop when they are open of about 3 pounds. Fortunately, you don't have to shut those in 2 seconds. The valve sizes will vary from an ID of about 3 inches to an ID of greater than 40 inches. Nominal pipe size depends on the refractory lining, which depends on the temperature.

Some of these valves must be able to work inside the vessels. These will be a plug-type valve. The ones that we have selected are a Kellog-license design. In the gasifier, we have the same type of problem, except we have a lot higher temperature. The temperatures can go up to 1,600 or 1,700 °F for handling hot char and hot gas. So we've got the heat, we've got corrosion, and we've got a lot of erosion.

We use refractory-lined valves and special materials to handle these conditions. Most of these valves are designed similar to what is used in a coal-conveyance system. Most of these valves will be hydraulic actuated. Because of their size, they require a lot of special adaptation for their maintenance. If you have a 45,000-pound valve, you don't send two fellows up there to tear it down. If you do, I don't want to meet those guys in a dark alley.

We also have fines-handling valves. These char fines are an additional problem. These fines are down to micron sizes and migrate into everything. I swear those things could migrate upstream in a flooded river. They pack every cavity in your equipment, and are very abrasive. Also, they happen to be about 1,700 °F, a little on the warm side. Same basic valve problems as we have in the gasifier, just a little hotter. These fines are used as fuel; so, we also have to design burners that will withstand them.

Our product is gas made from our combustor, and we have two gas streams. Both of these require large hot-gas-handling valves. The valves have to be designed to handle temperatures in excess of 1,700 °F. They have to be able to withstand the erosive attack of high-velocity particles. Sizes once again are large, 40 inches and up.

The oil-recovery and processing areas once again are standard; most of the valves are fairly common refinery-type valves. The only exception is the letdown valves. Pressure in this area is around 2,800 psig. The temperatures go up as high as 800 °F, give or take a little bit. The slurry in our letdown valves can be made up of anywhere from 3 to 15% by weight of char fines and ash solids. Our pressure drop is 2,300 psi. Looking out over the audience, I can tell who sells letdown valves because they have a big sigh.

I have written down here, "This requirement is rough." The secretary said that was probably the biggest understatement of the year. We looked at a number of designs for handling this letdown application. What we need is a valve that can be easily replaced, has interchangeable parts, and, of course, can survive.

Figure 11-3 is a letdown system schematic. We've got to come down to a knock-out drum, which also acts as a surge tank, so we can minimize the amount of control we have to do with the valve. We come out with parallel systems, because the high solids content is very likely to cause flooding. Then we come down through a block valve, which will open first, and then through an angle-type pressure-letdown valve. The reason for doing this is to keep from destroying our letdown valve at low flow rates. If we have to shut the stream off, we don't want the valve to destroy itself because of the high stream velocity. When we

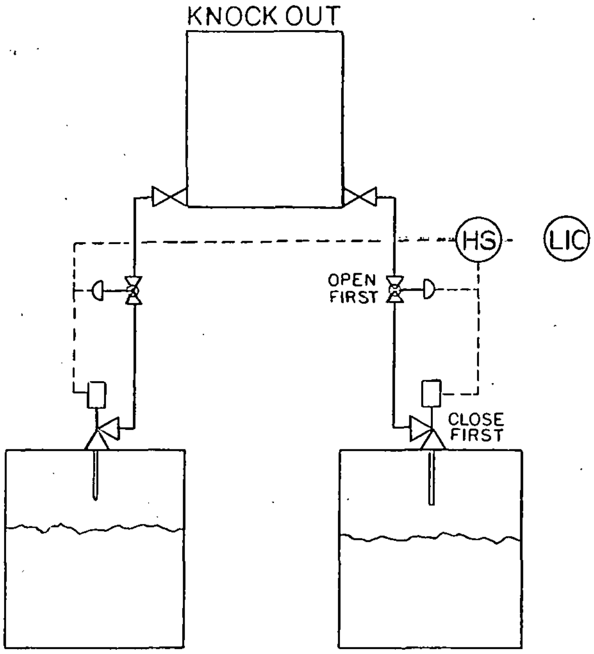


Figure 11-3. Letdown System Schematic

get down to the minimum flow, we use the isolation valve to achieve tight shut off. This hopefully will extend the life by a factor of 2 or 3.

Figure 11-4 is one of the new experimental designs that I think three different companies are working on. This is a rotatable-plug design. Our coal comes in from the top and impinges directly on the rotatable plug into a large cavity. It's large enough to allow room for the liquid to flash and then run out. The body comes in pieces that are easily replaceable. This is one of the designs.

Another design being worked on is splitting the incoming flow and impinging the flow on itself. I've been working on this problem for about 3 months, and I think I've called just about everybody in the business and said, "Hey, how're you doing and what are your problems?" I've come up with kind of a set of criteria. Number 1—if possible we try to stay either above 20% solids or below 3% solids. Unfortunately for our process, that doesn't seem to fit too well. We seem to be anchored right in the worst area, which is between 3 and 15%.

Number 2—on impinging. The worst angle of impingements for maleable material appears to be about 20 degrees. If you're impinging on soft material, you want to impinge at about 90 degrees. That seems to give the best wear. If you are using a hard surface such as carbide or ceramic, your worst angle of impingement is 90 degrees. So when you are designing the valve on hard-surface materials, try to keep your angle of impingement gradual, using large quantities of softer material, when you want to impinge directly.

The design we use is an adaptation of a design worked out by HYGAS. It was for ash letdown. It starts out with a standard Willis Choke. We throw away all the insides and start all over again. We use it as a rotating disc with a pair of holes. The first things we do is plug up one of the holes. We use only one at a time. The second thing we do is readapt their letdown bean. Instead of leaving a big cavity in the valve, where particles or slag can accumulate, we use a choke tube with the stream so that the flow clears the valve and impinges directly into an energy-absorption chamber.

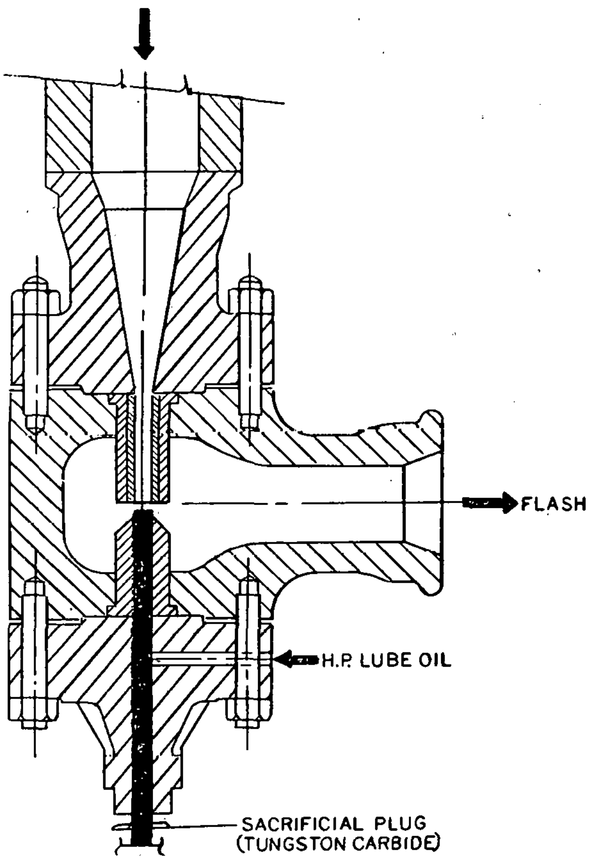


Figure 11-4. Experimental Letdown Valve for Erosion Service

All of these valves should either go into an enlarged section of pipe or into a flashing vessel, where we're impinging the liquid flow on some other liquid rather than on the piping.

The construction of the piping has to be seen to be believed in this kind of service if you get direct impingement on your metal. It also has some unusual designs; the most unusual design for this purpose is a ball-valve design by Mr. Herman Paul. It's actually a caged ball, which is free to spin so the impinging liquid doesn't have anything solid to hit on. This design is being tested at the H-Coal unit down in Kentucky next year.

We have designed piping systems so it would be easy to substitute other types of angle valves. If anybody has any suggestions on that, please call. A good criterion on designing these valves for our system—and I think it's common with most gasification systems—is that the slurries have to move at about 4 feet per second in order to not settle out. You don't want to move them much over 10 feet a second if you don't want the piping to come unglued.

An additional change made on the Willis Choke was that a thrust washer was added to the operating mechanism because of the 90-degree design; standard operation uses a lot of side thrust and extra wear. Right now, I am waiting for a reply back from a vendor who has a rotary actuator that we may be able to adapt to this style.

On our angle valves, especially on smaller sizes, the use of a hydraulic actuator helps a lot. We've got tremendous forces in the flashing liquids. Especially with small-valve designs where there's not much mass, they chatter easily. When something as hard as a ceramic or a carbide chatters, you break it up. Some people have found that using reverse-flow designs solves the problem. Other people find it doesn't work. I haven't found the common ground on why yet. That pretty well covers that particular problem.

Figure 11-5 illustrates our power-recovery area, Area 210. Power recovery was covered a little bit here by the gentlemen from GE. This is a similar adaptation. Hot gases come from our combustor. We take a lot of the heat out of the combustion gases with our coal char, and then run it into a gas oxidizer. We have to keep reducing atmosphere in our combustor, in the heat-exchange part, so we have quite a bit of CO in the gas. The gas oxidizer is somewhat similar to a CO boiler. We add some more air and some more heat, make some steam, take the gas out of there, run it through special cyclones, and clean it up to run through a turbine.

Now we come to the hairy part, because with this turbine running at full load, if something happens, we've got to be able to shut this gas flow down so that we don't accelerate the turbine. The man from GE wanted about 2 seconds' closing time on his big valves; I'm trying to be really easy on you. I only want about 3. Actually, what we've done on that is we have gone to a couple of smaller valves that we can operate in about 3 seconds, which will give us quick relief and will give our big valves time to close. We're asking for about 20-second closure on our big valves. I don't think we can close a refractory valve, of a 40-

inch size, any faster than that without destroying it. If somebody can, I would like to know.

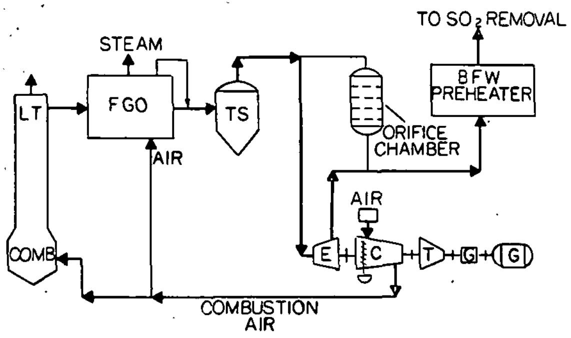


Figure 11-5. Power Recovery, Area 210

We run our gas through an expander. If something goes wrong, we valve it through an orifice chamber so we can keep back-pressure on our system. The expander drives the air compressor, which supplies the combustion air to our plant. We also have on this power-recovery unit a steam turbine and a generator that acts as a dynamic break and helps to start it up. We use the steam turbine as a source of power, and also as a come down for some of our process and plant steam.

Problems with the valves in these areas include: (1) they are large, 24 to 50 inches ID; (2) the gas is fairly clean by our standards, but dirty from the turbine person's point of view; and (3) the velocities are high, over 120 feet a second. So even though we don't have the particle count that we have in some of the other areas, we still have high erosion rates.

We're going with hydraulic operators because of our cycling requirements. Electric operators are just too slow. Required cycle times in most of the big valves are 20 seconds, full opened, full closed, and on some of the butterflies, as little as 3 seconds, or as close as we can get. We also have to have low pressure drops, under 4 psid, and we have to be able to shut against 100-psi differential under emergency conditions.

The final valve area is in the air-combustion system. Amazingly enough, this is going to be air under 400 °F, under 100 psig, the valves are going to be reasonably sized, 14 to 30 inches, and this gas is going to be clean. I don't know how we came up with that requirement in this plant; it's too easy. These designs are fairly standard heavy-pattern butterfly valves and are well within present technology. I don't think we have a real problem valve in this area. That pretty well, I think, describes our valve problems, at least the ones I've gotten involved with specifically at this plant. Thank you for your attention.

Discussion of Paper by William West

QUESTION: Can you describe the seating designs you use on those large-size refractory valves?

WEST: Each vendor I've looked at is a little different. Basically, they come in two types. These are, as I said, slide gates. The two basic designs that I've seen: one is where you come in against your gate, and your gate slides down against your seat. Your flow has a tendency to push your gate away from the seat. This has a basic advantage of having fewer cavities where you trap fines to jam up your valves. The disadvantage is it needs a heavier shaft, since you've got slide loading on your shaft. The other design is 180 degrees up. You're coming through, and your slide is pressing against the seat. Your slide is usually noble-metal coated with a refractory for erosion protection. Your seating is refractory coated, also. The pipe is usually fairly standard pipe materials. So the outside temperatures are going to be down around 350 °F. The exact way they do it, I can't really tell you.

QUESTION: Can you name the vendor?

WEST: Right now I can tell you two vendors, both of whom I've talked to. One is Zimmerman and Jenson and the other is Tapco. The vendor for the large butterfly valves, Dally, I think, is also here in the audience.

QUESTION: That rotatable-plug design, have you used it, to what success, and who's making it?

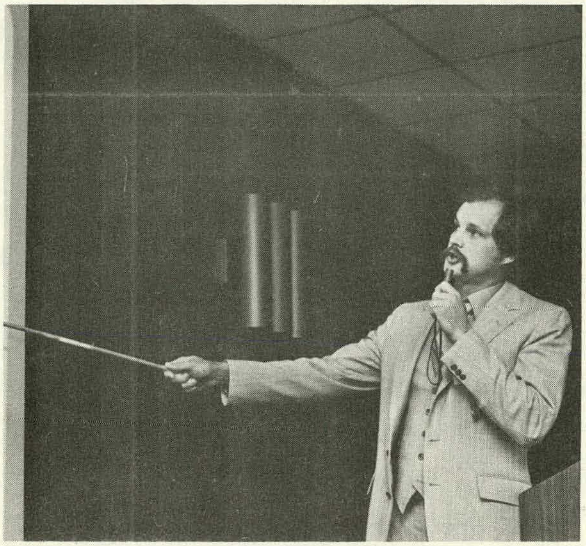
WEST: The answer is "no," "no," and "Valtek and Masoneilan."

Actually I have had several valve manufacturers come in with variations of this basic design. Both Valtek and Masoneilan are very close to the picture I had of it. This came from a valve symposium that was held on high-pressure, gas-type valves about a year ago. As far as I know, no one has actually made one yet. And when they make one I know most of the people within this business will probably want to try one, because it seems like it could be a good answer.

There is another design I didn't know about in time to be able to put a picture up. That is a design being worked on now and should be tested in the next year. That is where the flow is actually being impinged on itself, so we would be eating a lot of the drop up by working the fluid against itself rather than leaning it up against our part. The vendor on that is Pacific Valve and if you contact them, I am sure they will be glad to give you data as it becomes available.

QUESTION: What's the mass flow and the line size?

WEST: I had a little problem getting that exact flow because of the proprietary data. I can tell you that the letdown valve's between 10 and 50 gallons per minute. A good portion of this liquid will be flashed and, quite honestly, we are not really sure just what the mass flows are going to be. We are going to have to find out. We don't know yet. I'm sorry if I can't give you a straighter answer than that. Size on these valves will be 1 inch and 2 inches, in body size if that helps. The trim size would be between 3/8 and 1/2 inch.



Section 12

Westinghouse Fluidized-Bed Gasification Process And Valve Requirements

M.J. Arthurs, E.J. Chelen, and
W. Lester

Presented by:
W. Lester
Plant Operations Engineer
Synthetic Fuels Division
Westinghouse Electric

October 15, 1980—11:00 a.m.

Abstract

The Westinghouse pressurized fluidized-bed gasification process, under development since 1972, has operated in a 24 ton-per-day process development unit for more than 7,000 hours since 1975. Operation at design temperature and pressure has been achieved, using both air and oxygen, on reactive western as well as highly caking eastern coals. Reliable techniques have been developed for startup, shutdown, and full-load operation. In addition, operating data have been generated to assess the performance of components subjected to conditions expected in a pressurized fluidized-bed gasification process. In this paper, the test performance and assessment of some of the process valves are discussed.

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Introduction

Many promising developmental process concepts are never shown to be feasible simply because of the inability to startup and operate test units successfully so that process data can be developed. In the development of process technology utilizing reduced-scale equipment, such as the Westinghouse process development unit (PDU) shown in Figure 12-1, an equally important and parallel effort must be considered to gain the full benefits of the development effort. Included in this effort is the modification of designs and installation techniques for off-the-shelf hardware, including valves. Since 1975, in 7,000 hours of hot operation, a substantial data base has been achieved for scaling the process and related hardware to commercial size. Figure 12-2 illustrates the PDU as four separate systems and the process valves associated with these systems. In Table 12-1, a brief summary is given of the valves employed in the PDU for the past 5 years.

Description of Process

The Westinghouse single-stage gasifier shown in Figure 12-3 utilizes direct feed of coal, and in its four primary zones, combustion, gasification, ash agglomeration and ash/char separation take place. Operation of the PDU shows the Westinghouse gasification process to be technically sound, readily operable, and adaptable to the production of both low- and medium-Btu fuel gas with air and oxygen, respectively. The feasibility of the Westinghouse single-stage gasifier has been amply demonstrated with feedstocks, including highly caking Pittsburgh coal; mildly caking, highly volatile Indiana #7 and Western Kentucky #9 coals; and highly reactive, sub-bituminous B, Montana Rosebud, Texas lignite, and Wyoming sub-bituminous C coals.

Air and oxygen tests in the PDU continue to gather additional process design and operability data for future commercial plants. Operability data obtained during these tests include service and performance data on various materials and components used in the construction of the plant. Plant components such as valves were subjected to a variety of erosive/corrosive environments, and in many instances material failures occurred, preventing sustained test runs. Based on the operating experience obtained from the PDU and other similar operating units, selection of new materials of construction for off-the-shelf components and design changes to increase the reliability of the unit resulted in longer test durations that otherwise could have been difficult to achieve.

Areas of increased reliability include the coal storage and feed system; recycle-gas, quench, and waste-water-handling systems; gasification-fines collection system; and ash-handling system. These areas are shown in Figure 12-4.

Coal Storage and Feed System

In an effort to obtain uninterrupted coal feed to the gasifier, a number of revisions were made in the transport lines, the results of which are more than satisfactory.

Kamyr and Hills McCanna block and bleed valves, shown in Figure 12-5, were installed to isolate the pneumatic conveying feedlines and associated lockhopper system from the rest of the process. Severe erosion in the valve bodies can occur if, during the initial installation, the alignment is not performed properly or if the valves are positioned in a partially open or closed position.

Also, the outside body of a valve can be machined so that it matches the inside diameter of the flanges between which it is sandwiched. If no protruding edges or corners are left in the main pneumatic stream, the chances of valve erosion are reduced significantly.

As a preventative measure, carbon-dioxide purges are used to sweep erosive material away from the balls and seats to prevent internal scoring of the valves.

Figure 12-6 illustrates a 4-inch Kamyr ball valve. These valves have been in service in the coal-handling lockhopper system since 1975. Transporting coal through 4-inch ball valves between the lockhoppers is not difficult since both hoppers are equalized in pressure before a transfer is made. Even if a valve did leak, a problem would not occur. However, purges are used to help wipe solids away and to protect the packing so that no coal dust escapes into the atmosphere. This present configuration is directly scaleable for commercialization.

Finally, the vent valves on the lockhoppers are protected with a filter that is capable of removing 98% of particulates 0.7 micron and larger and 100% of particulates 1.8 microns and larger. To date, no major operational problems have been encountered with this design and installation.

Recycle-Gas System

The recycle-gas system handles approximately 12,000 pounds/hour of product gas from the Westinghouse gasifier. Particles in the size of 80 mesh pass through strainers before entering a 10-micron filter housing.

One of the valves in the recycle-gas system is PV-171, a 1-inch Camflex valve with a carbon-steel body and a Type 316 stainless-steel plug and seat. Illustrated in Figure 12-7, this valve operates in a dirty-gas environment that contains coal fines less than 10 microns in size. The gas is composed of carbon monoxide, carbon dioxide, hydrogen, and methane. Problems occur when coal fines migrate into the upper and lower bushings, preventing the valve from operating. In present preventative measures, the valve is removed and cleaned approximately every 500 hours of hot operation.

Another 1-inch Camflex valve, FV-60, is used to control gas flow for coal transport. This valve is shown in Figure 12-8. After cycling for over 5,000 hours of hot operation, no problems have been experienced with thi valve.

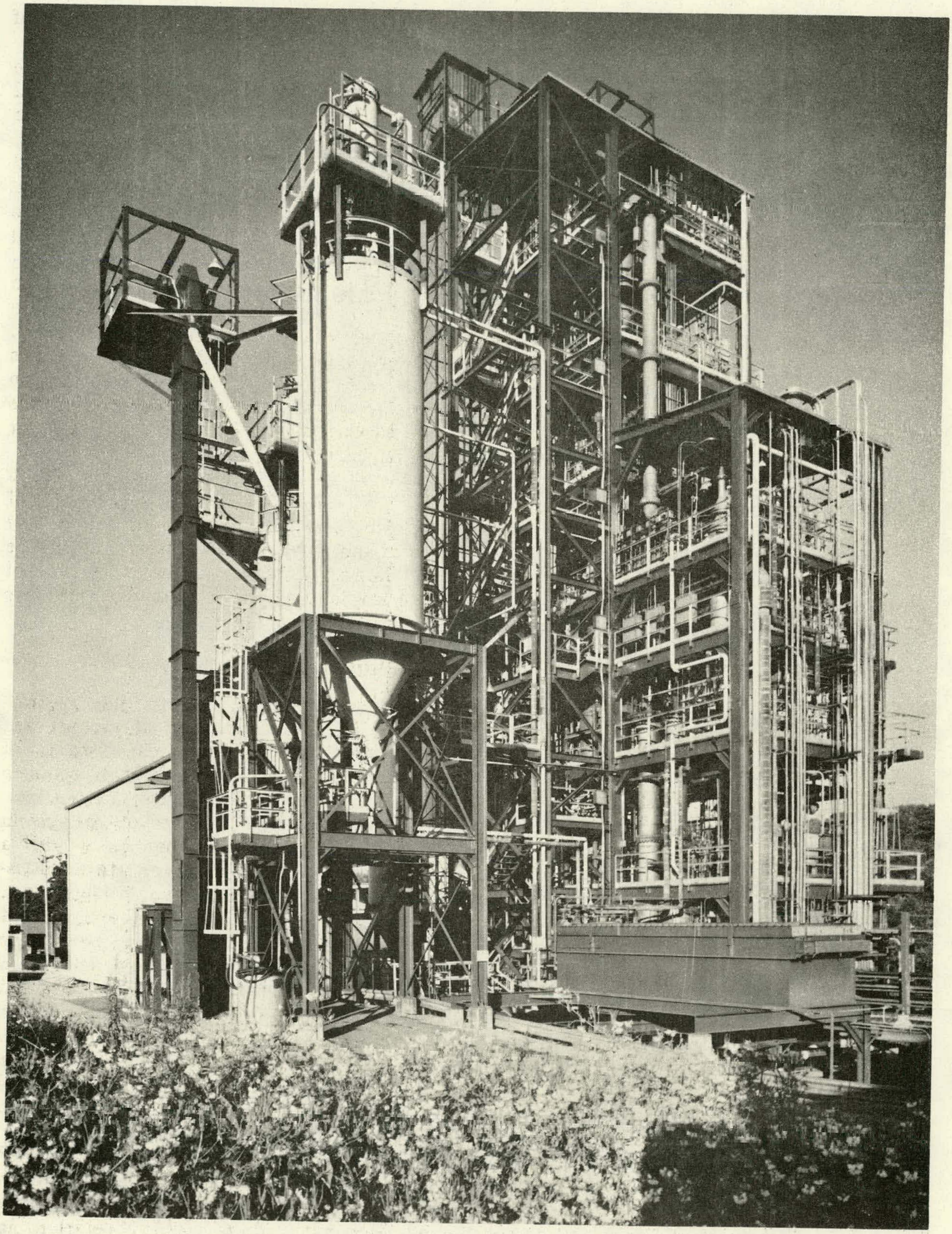


Figure 12-1. Westinghouse Process Development Unit (PDU)

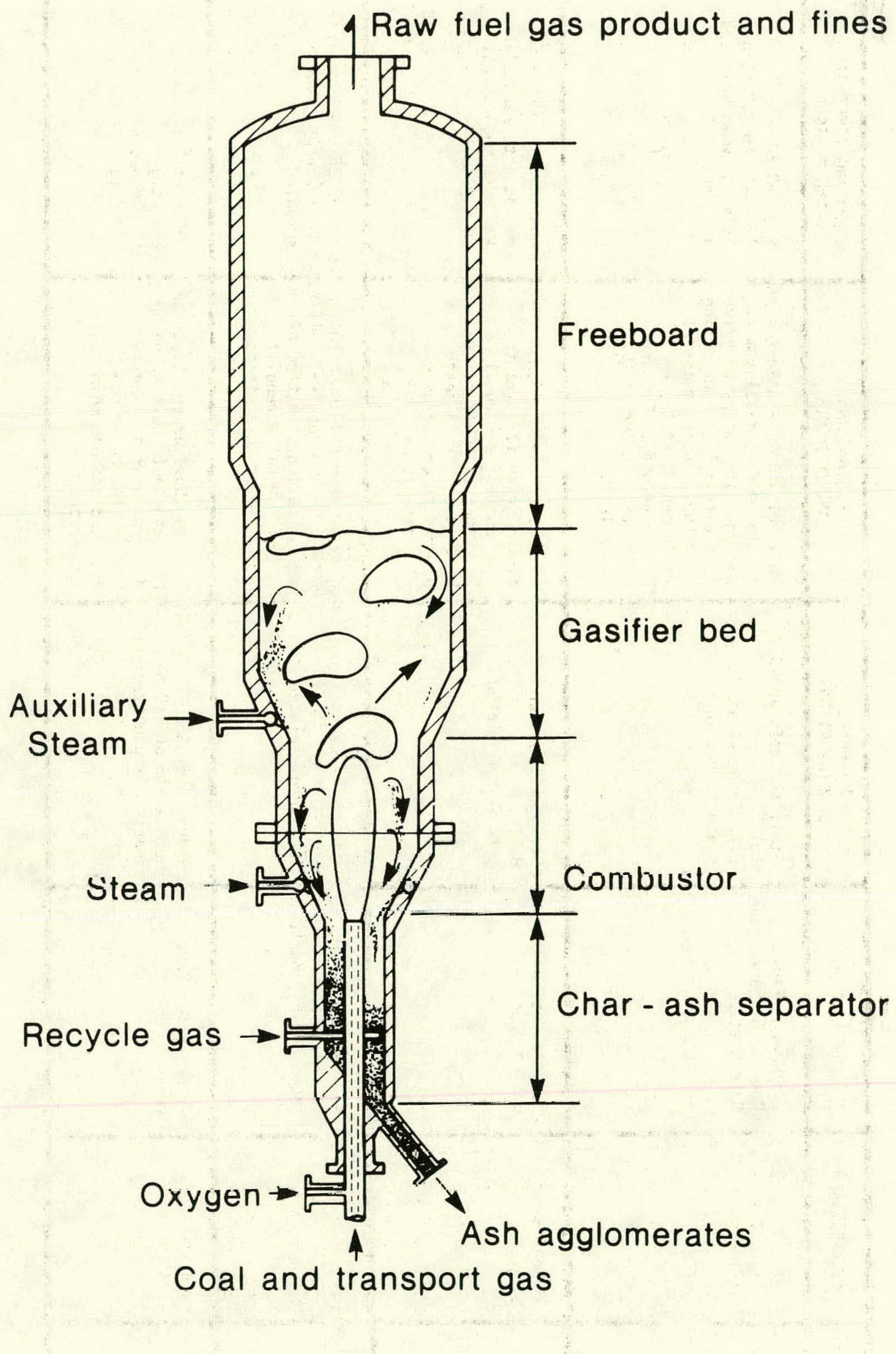


Figure 12-2. Functional Schematic of the Westinghouse Gasifier

Table 12-1. PDU Valve Characterization

TYPE	MANUFACTURER	APPLICATION	MATERIAL SPECIFICATIONS	RELIABILITY AND COMMENTS	OPERATING TEMPERATURE AND PRESSURE
1" Ball Modified Wafer	Kamyr	Feedlines. Fines Recycle Gas and Coal, Coke Breeze	Stellite Seats and SS Ball Hard Chrome-Plated Graphite Packing	Very reliable. Problems with erosion due to misalignment during installation or valve left partially closed during HV setup, causing material impingment directly on ball and valve body. Gas and water tight prior to installation.	600-1000°F 130 psig to 230 psig Valve ΔP when actuated is 0 psi
1" Ball Wafer	Kamyr	Recycle Gas, Heater Outlet Block	Stellite Seats and SS Ball Hard Chrome-Plated	Reliable. Heat cycling causes graphoil shims to compress and eventually breakdown. Should be re-built after three tests. No erosion or corrosion problems.	600-1000°F 130 psig to 230 psig Valve ΔP when actuated is 0 psi
1" Ball Screwed Ends	Kamyr	Water System Dump Valves. Approx. 20% Fines and H_2O Mixture	Stellite Seats and SS Ball Hard Chrome-Plated	Very severe service. Problems with erosion due to fines concentration at bottom of vessel. Usually rebuilt after two or three tests.	130-320°F at 230 psig ΔP is 230 psig when actuated
1" Ball Screwed Ends	Hills McCanna	Water System Dump Valves	Body - 316 SS Ball - 316 or 410 SS Seats - Carbon Steel or Stellite	Same as above except that the ball and seats have to be discarded during rebuild whereas the Kamyr can be relapped and new shims installed.	350°F at 130 psig to 230 psig ΔP when actuated is 230 psig

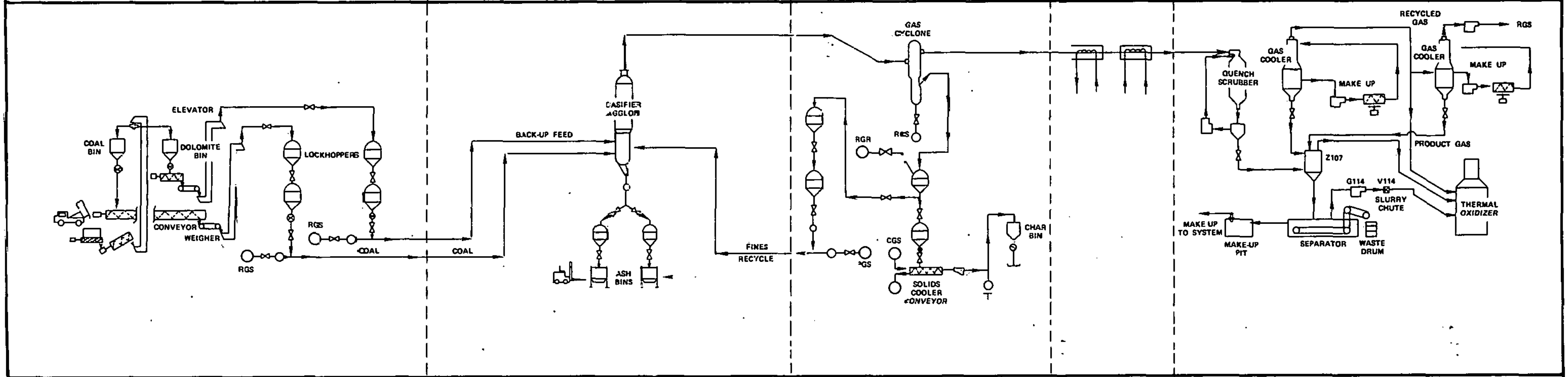
Table 12-1. PDU Valve Characterization (Continued)

TYPE	MANUFACTURER	APPLICATION	MATERIAL SPECIFICATIONS	RELIABILITY AND COMMENTS	OPERATING TEMPERATURE AND PRESSURE
3" and 4" Ball Flanged	Kamyr	Lock Hopper Let-Down, C-115 Ash Discharge	Stellite Seats and SS Ball Hard Chrome-Plated Teflon Packing	Occasional problems with erosion. Valve failures (sak thru) are usually caused by valve opening and closing against material, and this scratches or scores the ball. Have not been rebuilt in four years and are leak tight.	Ambient Temperature 130 psig to 245 psig ΔP when actuated is 0 psi
1" Ball	Fisher	Valve in Solid Slurry Line to Thermal Oxidizer		At last inspection the valve showed signs of wear. The seats were lapped and reinstalled.	225°F and 90 psi to 120 psi
4" Gate	Powell, Stockholm	Recycle Gas Filter Block	Stellite Seats and Chromium Stainless Disc (Gate)	Problems with corrosion on disc causing pitting and fines buildup in bottom of valve not letting gate seat completely and causing leak through.	300 psig at 100°F
1" Ball Screwed Ends	Hills McCanna	Water System Tricocks	Body - Carbon Steel Ball - 316 SS Seats - Reinforced Teflon	Erosion due to high fines concentration in water.	350°F at 130 psig to 230 psig

Table 12-1. PDU Valve Characterization (Concluded)

TYPE	MANUFACTURER	APPLICATION	MATERIAL SPECIFICATIONS	RELIABILITY AND COMMENTS	OPERATING TEMPERATURE AND PRESSURE
1", 1-1/2" and 3" Camflex, (Sliding Plug and Port)	Masonelian	Water System, Recycle Gas Control, Steam	Carbon Steel Body 316 SS Plug and Seat	Erosion and corrosion problems occasionally. Usually very reliable. Problems are usually with PV-21 and PV-171. PV-171 - Corrosion and fines buildup in valve causes it to stick and operate erratically. PV-21 - Erosion of valve plug, port and body. Due to high fines concentration in recycle gas and high velocities. Improper pipe design and valve size.	150-280°F at 60 psig
4" Pinch Valve	Flexible Valve Corporation	Recycle Gas Filter Block	Carbon Steel Casing Hypalon Body	Problems with Hypalon body cracking and leaking.	Ambient Temperature to 100°F, 100 psi to 200 psi

	COAL STORAGE & FEED	GASIFICATION	PARTICULATE REMOVAL	HEAT RECOVERY	GAS CONDITIONING



	COAL STORAGE & FEED	GASIFICATION	PARTICULATE REMOVAL	HEAT RECOVERY	GAS CONDITIONING
TYPICAL COMPONENTS	BINS ELEVATORS LOCK HOPPERS CONVEYORS SCREENS STAR WHEEL FEEDERS BALL VALVES FEED LINES EDUCTORS HEATER WEIGHT RECORDERS BELTS & LOAD CELLS FLOW CONTROL VALVES EXPANSION JOINTS FLEXIBLE PRESSURE LINES INERTING SYSTEMS	REACTOR VESSEL REFRACTORY HIGH TEMPERATURE VALVES THERMOCOUPLES PRESSURE TRANSMITTERS PRESSURE TAPS SAMPLING POTS SOLIDS FEED TUBE ASSEMBLY AIR / STEAM TUBE ASSEMBLY STAR WHEEL FEEDERS EXPANSION JOINTS SAFETY VALVES & RUPTURE DISCS VESSEL HI - TEMP PROTECTION NUCLEAR LEVEL MONITOR	CYCLONES FLOW CONTROL VALVES PRESSURE CONTROL VALVES PRESSURE TRANSMITTERS THERMOCOUPLES SAMPLE POTS SOLIDS TRANSFER EQUIPMENT BAGHOUSE REFRACTORY STAR WHEEL FEEDERS TEMPERATURE PROTECTION	HEAT EXCHANGERS PIPING FLOW CONTROL VALVES PRESSURE CONTROL VALVE PRESSURE TRANSMITTERS THERMOCOUPLES	COOLING TOWER VESSEL QUENCH SCRUBBER VESSELS LEVEL GAGES DUMP VALVES SOLIDS SEPARATOR CIRCULATING PUMPS WASTE LIQUID PUMPS SAMPLING POTS STRAINERS PACKING ISOLATION VALVES HEAT EXCHANGERS

Figure 12-3. Westinghouse Process Development Unit (PDU) Schematic

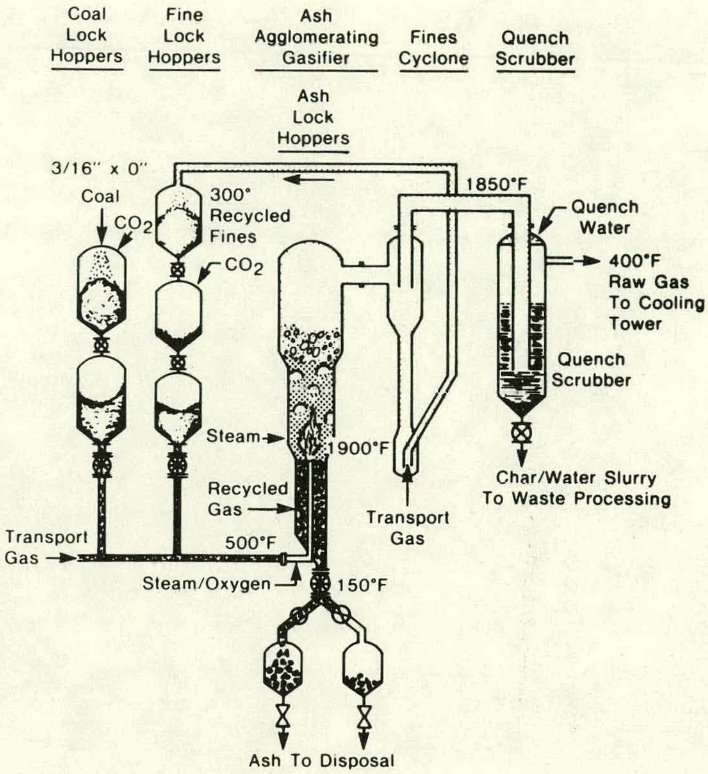


Figure 12-4. Westinghouse Process Development Unit (PDU) Components

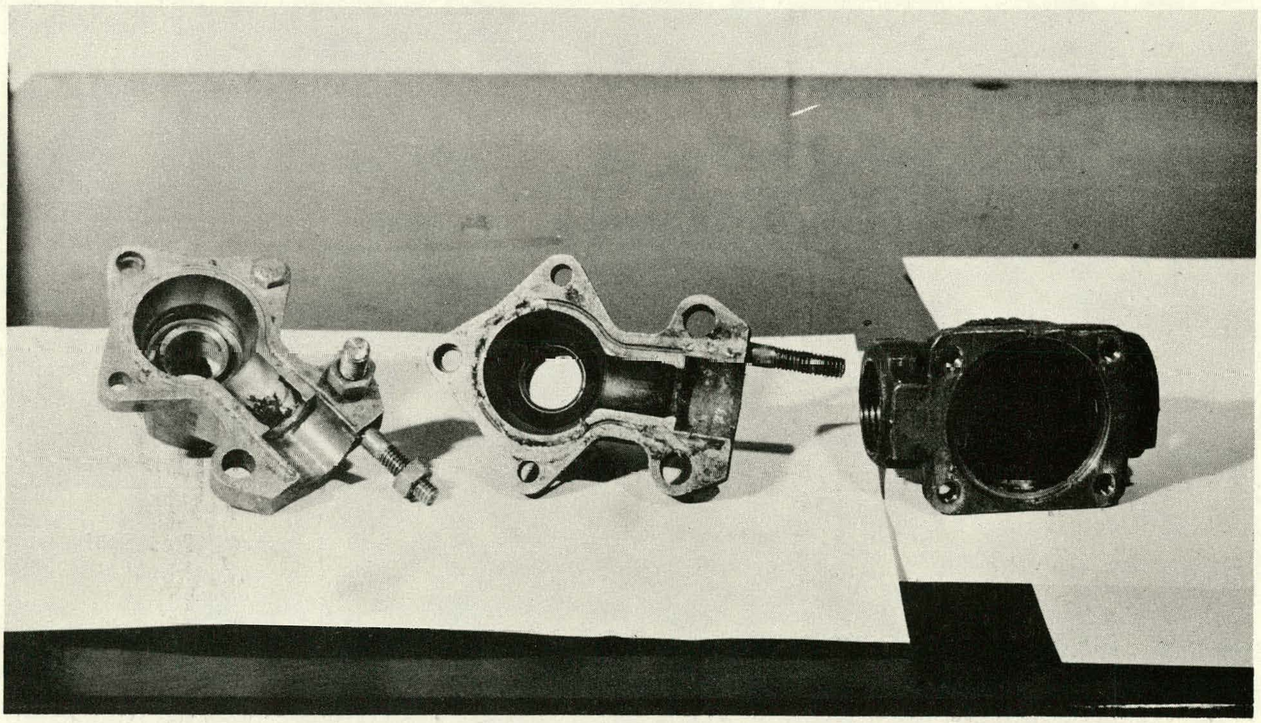


Figure 12-5. Kamyr and Hills McCanna 1-Inch Block and Bleed Valves

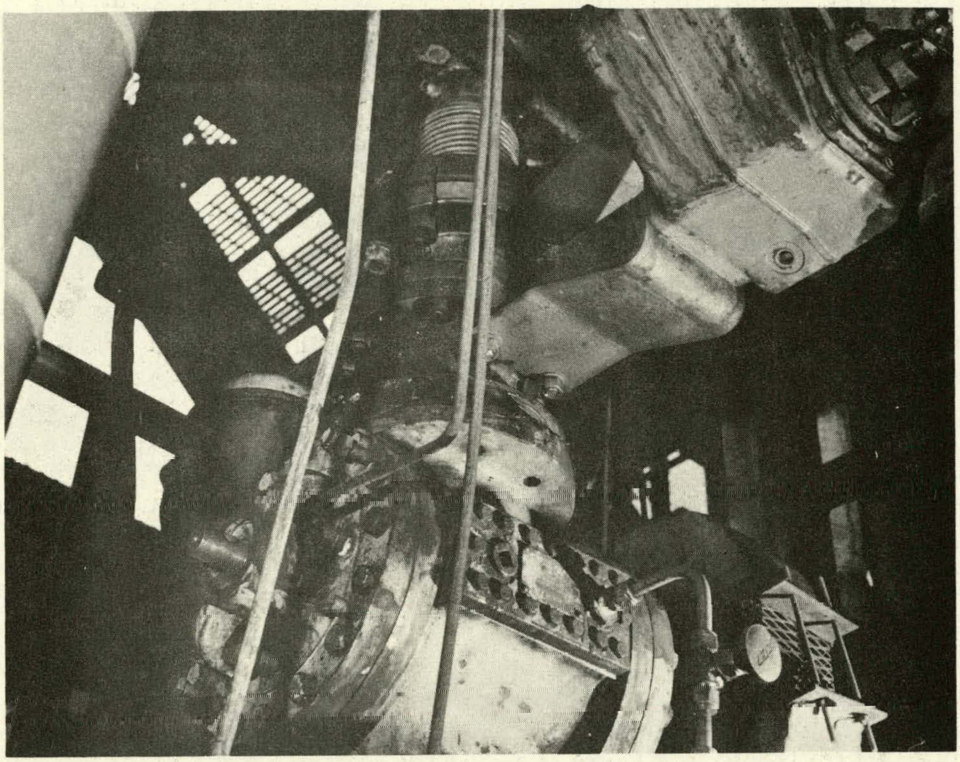


Figure 12-6. Kamyr 4-Inch Valve (C-103A Lockhopper)

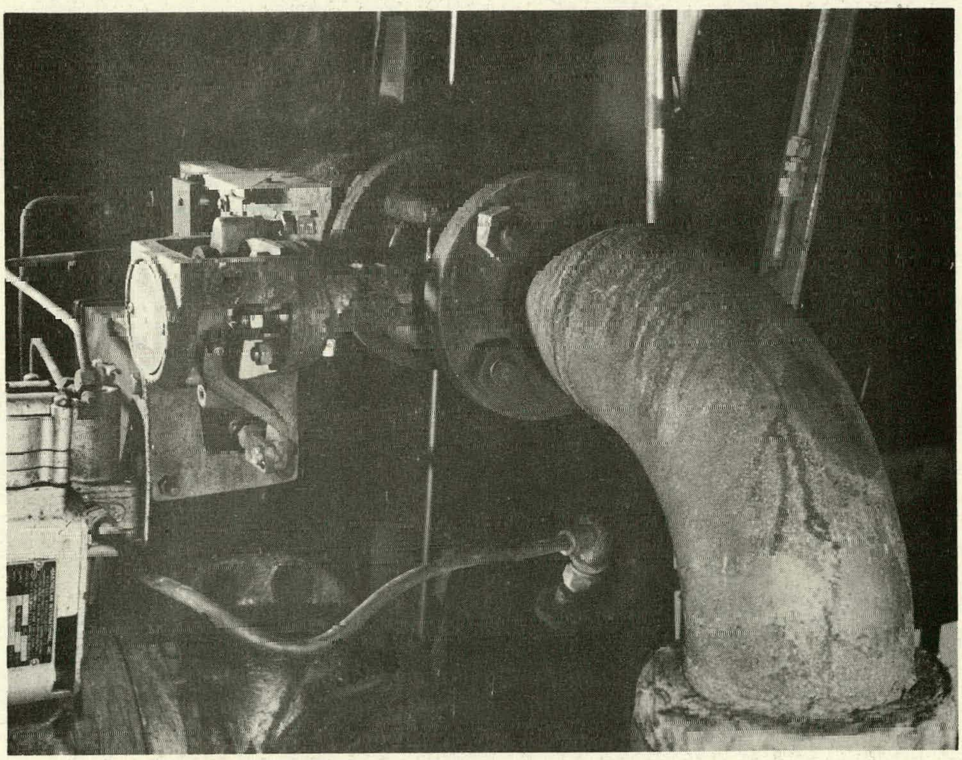


Figure 12-7. Masoneilan 1-Inch Camflex Valve (PV-171 Recycle-Gas System)

At the inlet to the filter bank on the suction side of the recycle-gas compressor, the gate valves, shown in Figure 12-9, were severely eroded. These valves isolate the filter banks that remove solids from the gas stream to protect the PDU reciprocating recycle-gas compressor. To change the filter cartridges, the valves must seal from atmospheric pressure against 250 psig.

Coal fines migrate between the wedge and seat, which contributes to the main problem and prevents the valves from providing a positive shutoff until the filter elements are changed. Stockholm valves were installed in the PDU, and although erosion time was still somewhat of a problem, the rebuild time was once every 400 hours instead of every 100 hours of hot operation. Approximately two months ago, a Flexible Valve Corporation pinch valve, shown in Figure 12-10, was installed in the recycle gas piping system. After logging over 300 hours of PDU run time, the bladder on the flexible valve cracked and the valves were replaced with the original Stockholm valves.

Quench and Waste-Water System

The purpose of this subsystem is to cool, or quench, the hot-gas stream (1,600-1,900°F) depending on the mode of operation and to scrub and remove fines from the gas stream. The waste slurry is dispelled from the coned bottom of the fines settler, C-112, and the contact coolers, C-113 and C-122. The frequency with which dumps are made and the dump duration are set by a timer. These dump cycles are determined by the rate of solids accumulation in the vessel bottoms and the difficulty with which they can be dispelled. Each vessel is equipped with two pneumatically operated 1-inch ball valves.

Figure 12-11 shows a 1-inch Hills McCanna seal and a 1-inch Kamyr valve. These valves are installed in parallel with individual blocks to permit removal and replacement while operating at system pressure.

The slurry-letdown valves are 1-inch Kamyr ball valves with Stellite seats and chrome plating on the ball. When actuated, the valve $\triangle$P is 230 psig. At the PDU, these slurry-letdown valves open and close every 2 minutes. The valve stays in the open position for 2 to 5 seconds. As many as 30,000 cycles are experienced on some of the valves and 12,000 to 15,000 cycles is a good average value. To remove excess surface particulates out of the quench vessels, 1-inch Hills McCanna seals and Hills McCanna flow-blowdown valves are used. The valves are manually opened and closed once per hour and the service rebuild time varies from 200 to 1,000 hours. Coal/char fines with an average particle size of 24 microns are expelled through these valves with a $\triangle$P of 230 psig when actuated. Gas composition is 20% carbon dioxide, 30% hydrogen, 45% carbon monoxide and 5% methane. Body corrosion and seat breakdown are the main problems that plague this type of design.

Another valve in the quench and waste-water system is a stainless-steel Fisher Porter No. 657-BF valve, as shown in Figure 12-12. This valve is used to control a solids-slurry feed to the thermal oxidizer for burnoff. After 5,000 hours of operation, the valve showed some signs of wear. However, the seats were lapped and the valve was placed back in service.

A 3-inch Masoneilan Camflex valve with a carbon-steel body and a Type 316 stainless-steel seat and plug is used to control the system's back pressure at the PDU. After 4,000 hours of hot operation, the valve was removed from the system for maintenance, since coal fines migrated and packed around the guide bushing on the main shaft, freezing the valve in the open position. The valve was cleaned, rebuilt, and placed back in service.

Gasification Fines-Collection System

Pressure control is needed downstream from the dipleg of the cyclone. Collected fines from the cyclone are transferred through this valve into a storage lockhopper. After 1,000 hours of operation, fines eroded a hole through the body of a 1½-inch Masoneilan globe valve. A 1½-inch Masoneilan Camflex valve, shown in Figure 12-13, was then installed. The seat and plug are replaced as a result of erosion every 500 hours of operation.

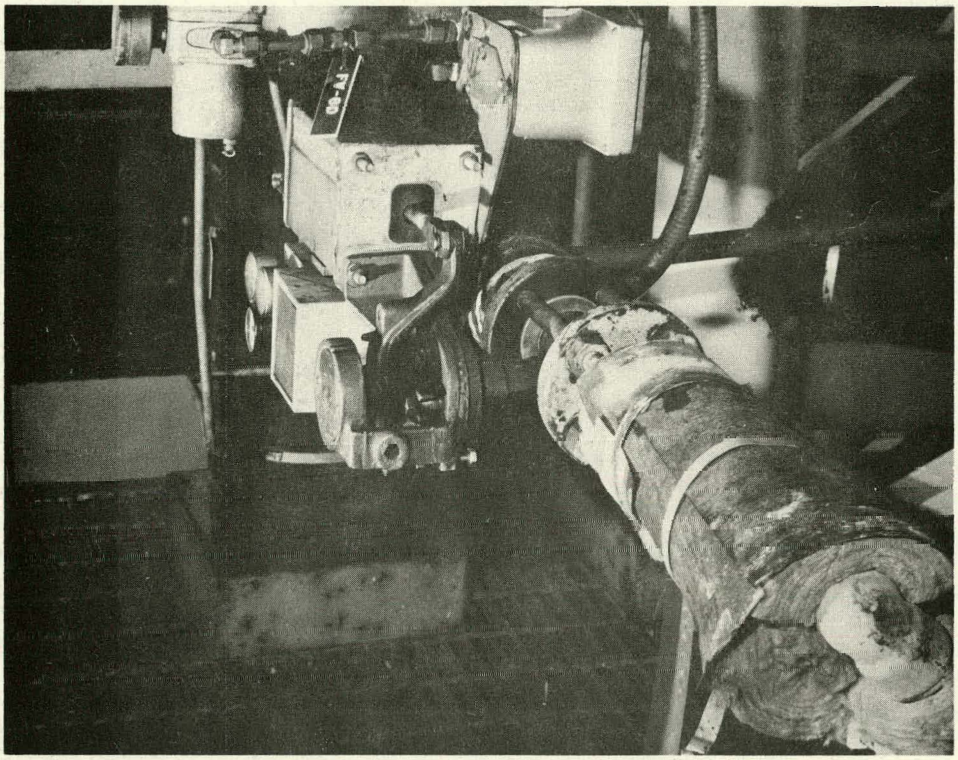


Figure 12-8. Masoneilan 1-Inch Camflex Valve (FV-60)

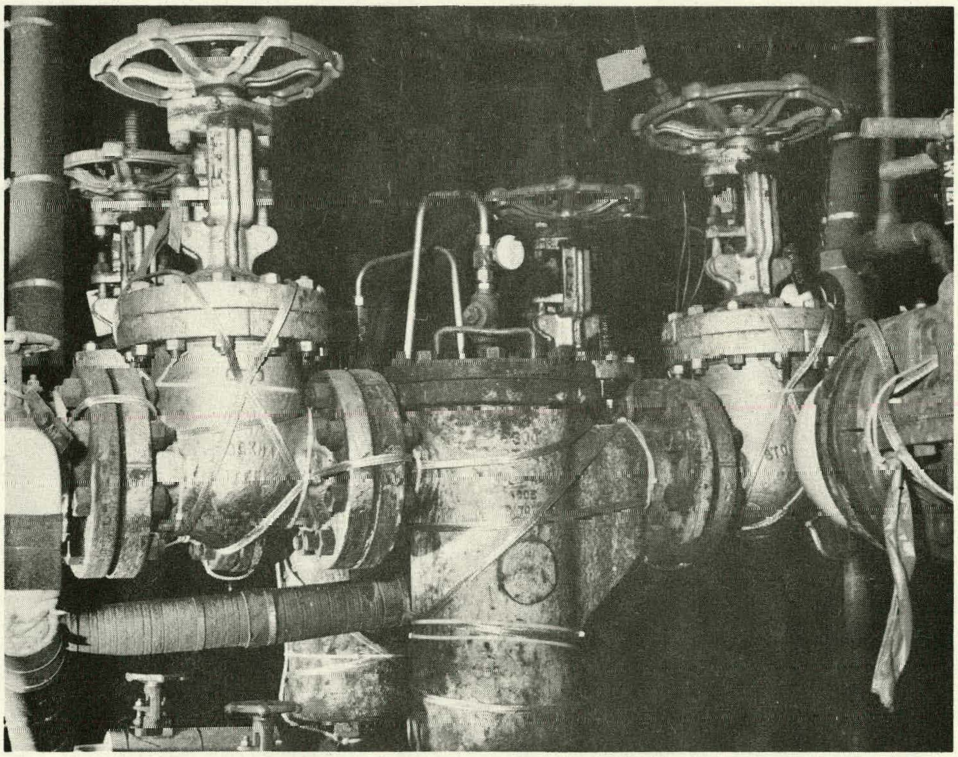


Figure 12-9. Stockholm 4-Inch Valve (Recycle-Gas System)

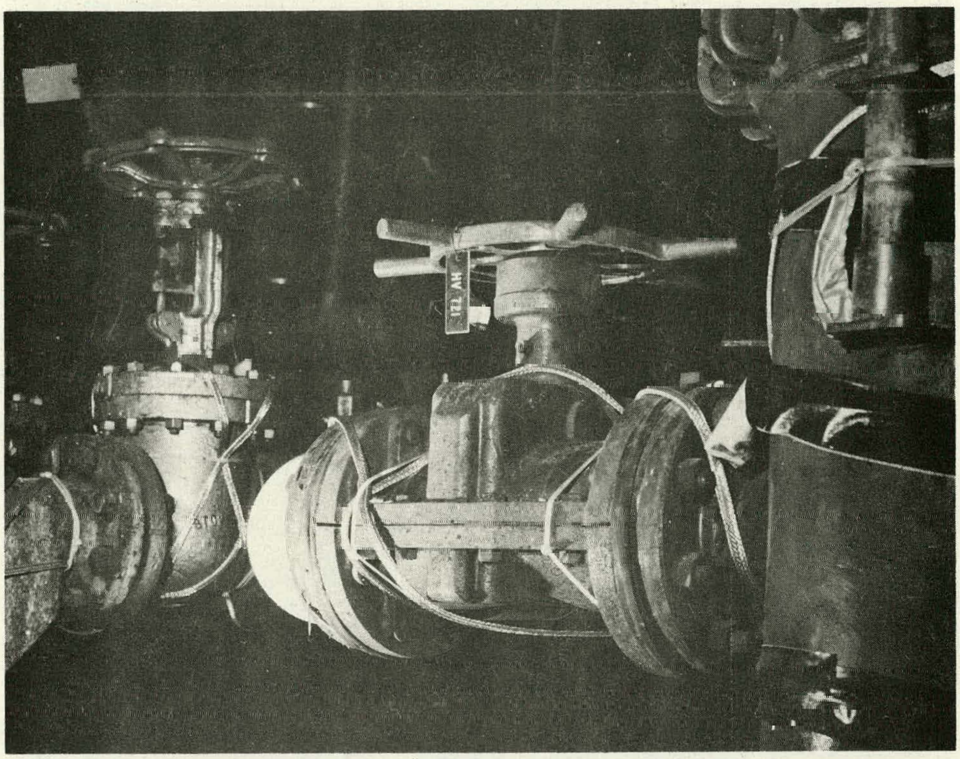


Figure 12-10. 4-Inch Pinch Valve (Recycle-Gas System)

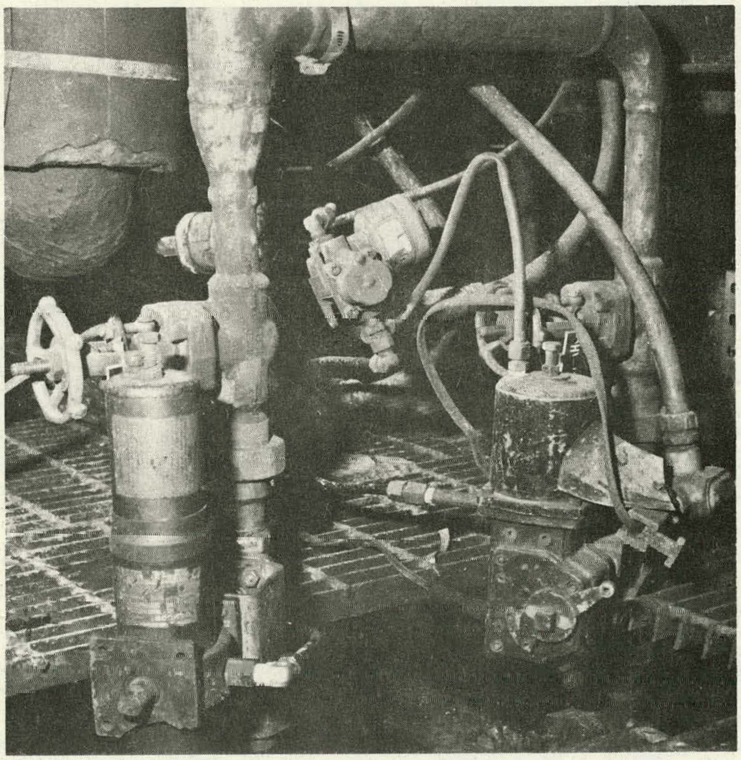


Figure 12-11. Kamyr and Hills McCanna 1-Inch Valves (Quench and Waste-Water Systems)

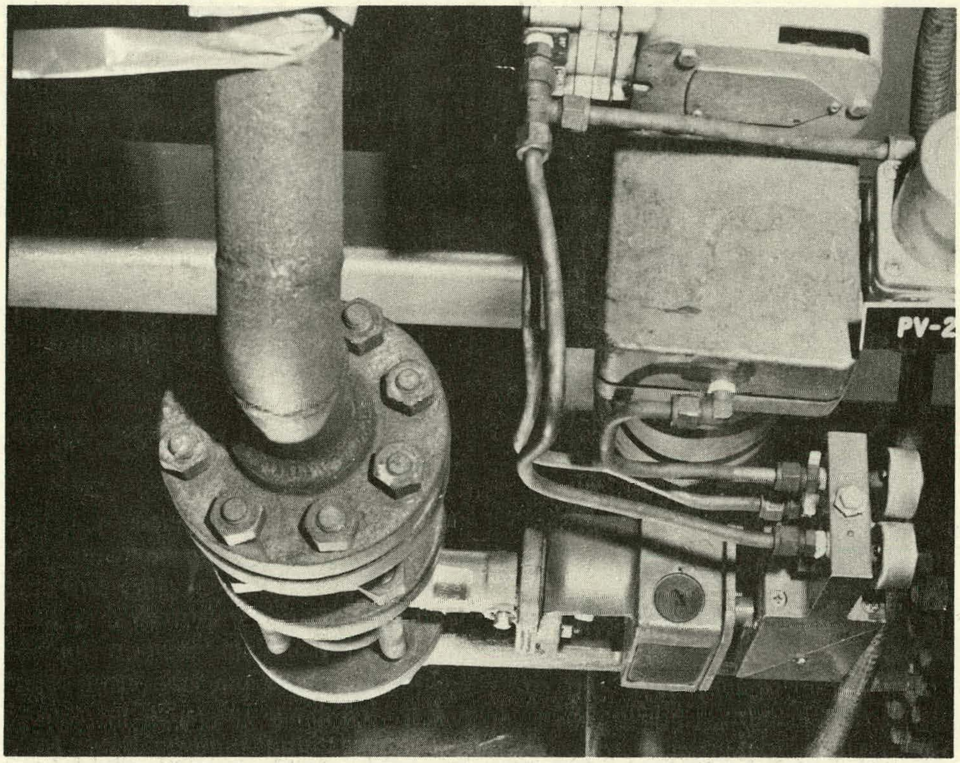


Figure 12-12. Fisher Porter 1½-Inch Valve (Thermal Oxidizer)

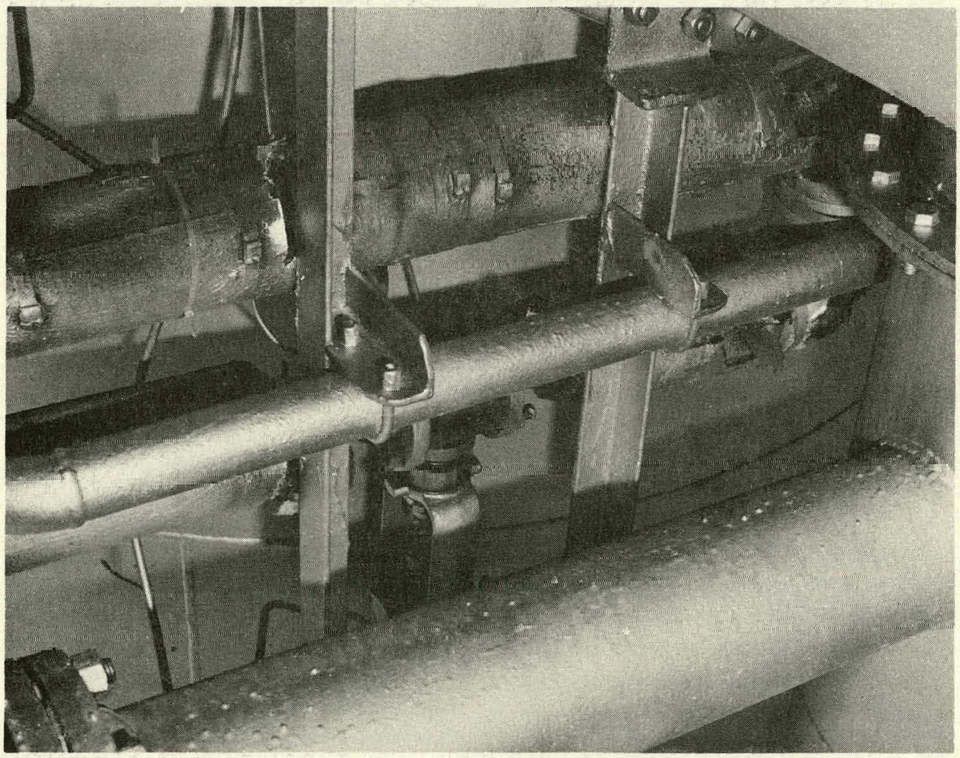


Figure 12-13. Masoneilan 1½-Inch Camflex Valve (PV-21)

Ash-Handling System

For ash disposal, a 4-inch Kamyr ball valve with Stellite seats and hard chrome plating on the ball is employed. The valve, shown in Figure 12-14, alternately opens for 1 hour and closes for 1 hour. The service time average of approximately 1,000 hours is a result of the buildup of material behind the seat, which causes actuating problems.

Figure 12-15 shows the wear experienced on the Type 316 stainless-steel plug and seat of a 1½-inch Masoneilan Camflex valve.

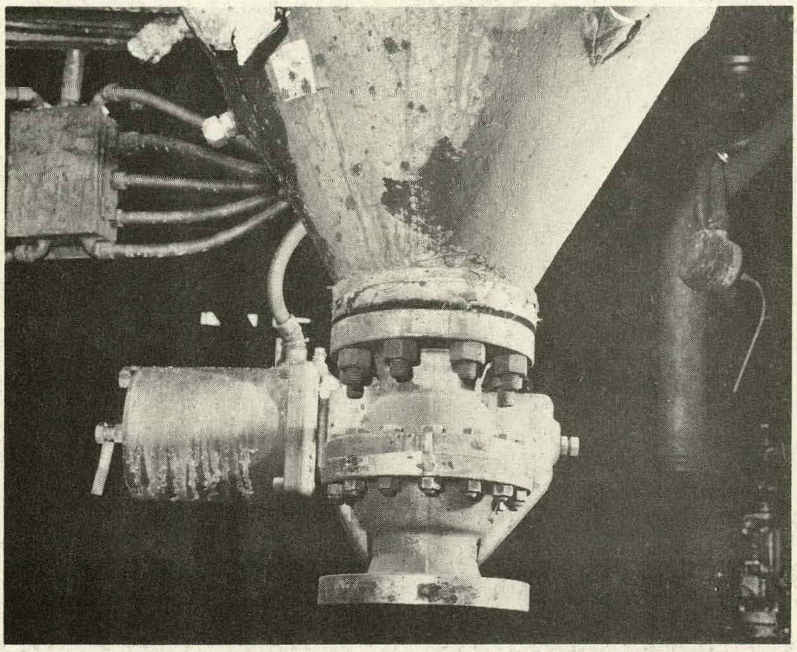


Figure 12-14. Kamyr 4-Inch Ball Valve (Ash-Handling System)

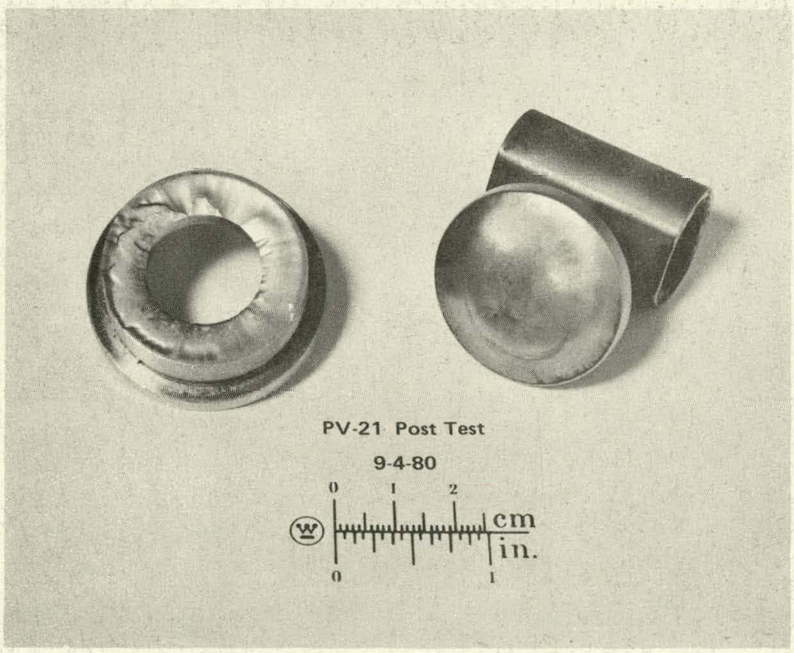


Figure 12-15. Plug and Seat of 1½-Inch Camflex Valve

Discussion of Paper by Warren Lester

QUESTION: You mentioned gate valves with filters. You didn't say how often you had to open up the filters.

LESTER: The filters are changed once a shift.

QUESTION: Do you have to pre-treat your coal?

LESTER: Yes, we buy run-of-the mine coal, and have just installed a Williams crusher-dryer. We grind the coal to minus 6 mesh and no more than 10% under 100 mesh. We dry it to less than 5% moisture.

QUESTION: What happens to the sizes of these valves as you go into commercial operation?

LESTER: The valves are going to get larger. We have a group of engineers working on the commercialization of the plant. The size of the valves will depend on what capacity we go to.

LESTER: The question was, "Are we going to use a waste-heat boiler before we go to the turbine?" We haven't got that far yet. We are still developing the gasifier itself.

QUESTION: How many Btu's per cubic foot of gas do you get?

LESTER: We get about 150 Btu's per cubic foot on our low-Btu gas and when we're oxygen blown, it goes up to about 280 Btu's per cubic foot.

QUESTION: What energy efficiency do you expect from your system?

LESTER: We project mid to upper 40s.

QUESTION: Earlier in your talk you mentioned a Camflex valve in recycle-gas compressor service. That was a small valve and it was eroded. Was that valve a kick-back valve around the compressor or what service was it actually in?

LESTER: It's a pressure-control valve across the recycle-gas compressor.

Section 13

BI-GAS Gasification Process And Valve Requirements

Frank Plut
Instrumentation Supervisor
Stearns-Roger, Inc.

October 15, 1980—4:30 p.m.

Abstract

Control-valve operating experiences by type and process application relating to coal gasification at BI-GAS and CO_2 Acceptor facilities are discussed. The paper also will cover lockhopper service, high-pressure letdown service, low-pressure service, and high-temperature service with possible solutions to problem areas in valves by type and design-application considerations.

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Many valve problems occur and in all probability most have been discussed by the industry at previous symposia and meetings, but please bear with me if you have heard them before. I will discuss the problems I have encountered in the actual process of coal gasification.

Valve problems in coal-gasification processes are somewhat different from those in other chemical processes. The greatest difference comes from the fact that the process is required to handle solids in addition to gases and liquids. These solids can, and do, cause considerable damage by erosion. They would be considered to be dirt or foreign material in any other type of process. A good, reliable, solids-handling pressure regulator is worth its weight in gold if somebody could make one. If a very minute leak occurs across a valve in the process of handling entrained coal or char, the solids will pass rapidly through the originally small opening and continue to erode the opening to an increasingly larger hole. This effect also seems to occur when a control valve operates at a nearly closed position. The erosion observed has also occurred in cases of low-pressure drop across the valve on the order of 15-psi differential pressure. Particular cases have occurred with char flow through valves that had Stellite-faced trims. The pattern of erosion is somewhat peculiar, appearing as a deep, smooth gouge on ball valves. I have never experimented with plastic or resilient-trim material, which may be a solution to our erosion problems.

If any manufacturer or research group has done testing or experimenting in this area, I would appreciate more information about the results. I realize that soft trim material would probably find more applications in lower pressure and temperatures than in higher pressure and temperatures. In this same vein, has any manufacturer or research group attempted to solve the problem associated with cavitation erosion in control valves? If not, this may be an area of investigation that would prove helpful and profitable. The way I envision the problems associated with the handling of coal in the gasification industry is very similar to problems that must be encountered in sandblasting for removing rust or corrosion.

I have encountered many experiences with various types of valves used in coal gasification. I will, no doubt, have to mention various manufacturers' names. Some representatives I'm sure are present. Please do not be offended if I should say something derogatory about your product or consider it an endorsement if I say something good.

The first category that I would like to briefly comment upon is the type known as a knife-edged valve (Figure 13-1). This is the type that has a flat plate with a hole traversing the cross section of the pipe. In this type valve, a rectangular housing is required to accommodate the extension beyond the cross section of the pipe, either when the gate is removed or the hole is inserted to permit flow. The accommodating area that the knife-edged gate has to traverse is subject to pluggage problems from solids. This is a dead-end volume and is a very good place for solids to collect. When the solids do collect in one end or the other end of this cross section, the knife just fails to penetrate all of the solids. To keep the solids out of the section where a knife travels, a very good seal for the solids is required; however, the seal must permit the knife edge to go through. We have been unsuccessful in our attempt to purge the area the gate traverses. It is my opinion that a valve of this type would find very little application in solids handling.

The next type of valves I would like to comment on are ball valves, which are used extensively in all chemical industrial plants (Figure 13-2). I like the concept of ball valves; however, voids are designed into the top-entry-type ball valve that tend to collect solids. If these voids collect solid materials, any time the ball moves or rotates, it has a tendency to pull the solids in between the ball and the seat. If the seats are in close contact or tight contact with the ball, the solids tend to scratch the surface of the ball and/or seat. Eventually, the valve starts to leak and enlarge due to erosion problems. One possible solution to the top-entry ball-valve problem collecting solids would be to fill the void between the ball and the body with some sort of soft plastic material. I have attempted using General Electric's RTV (Room Temperature Vulcanizing) compounds to fill the void with soft material that will not harden and prevent the ball from rotating. This type of material, again, can only be used in low-temperature applications up to 350-450°F, since the plastic is not suitable for the high temperature.

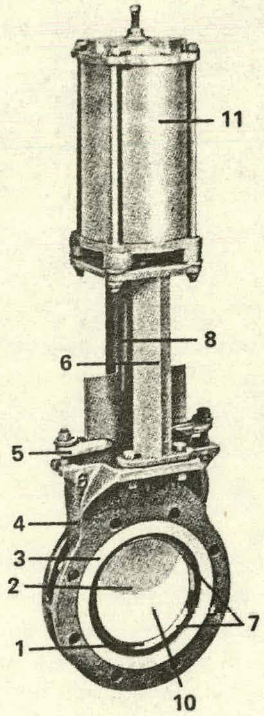


Figure 13-1. DeZURIK Series L Gate Valves

The other type of ball valve is the type that has the body split in half; when the valve is assembled, the ball and seats are enclosed within the split body (Figure 13-3). In this type of valve, very small voids are present where solids accumulate. This valve presents a problem with respect to the valve ball binding between the two halves of the valve body. If the two halves are tightened together with the ball enclosed too tightly between the seats, the ball is prevented from rotating because of the lack of sufficient clearance between the body, seats, and ball. At least one manufacturer has attempted to correct the valve clearances, or lack of clearan

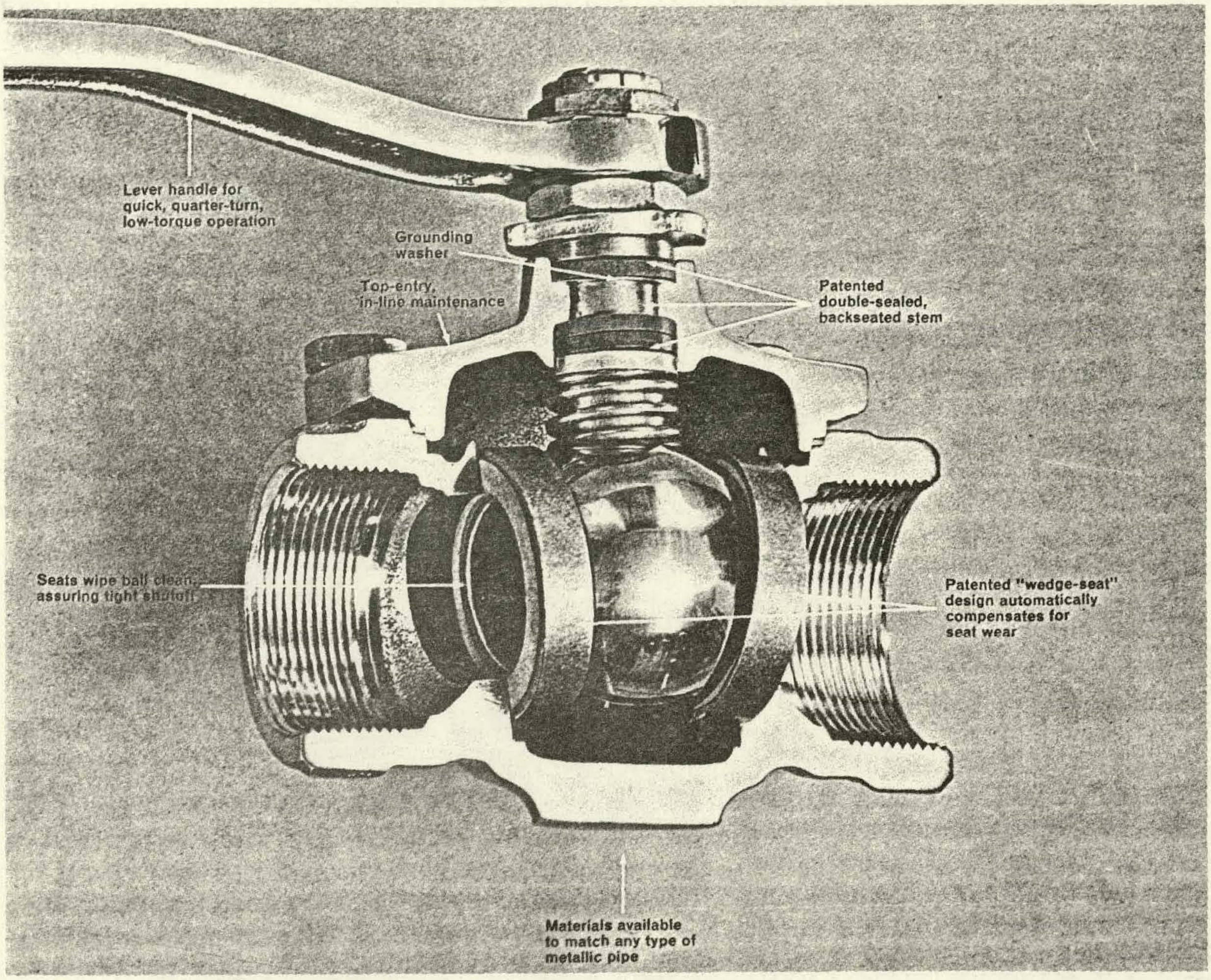


Figure 13-2. Common Ball Valve

ces, by installing a Bellville washer behind the seats to maintain tension between the ball and the seats. The drawback to using these washers is due to the fact the washer doesn't always seal, allowing leakage around the back of the seat.

Fisher Controls Co. makes a modification of a ball valve, which they call a Vee-Ball (Figure 13-4). This valve has solved the disadvantages of the ball valves. I have had very good service from these valves in char service.

Fisher has removed about two-thirds of the spherical ball itself and utilizes the other third to close on the seal ring. The remainder of the ball has a vee-notch machined into the partial sphere. As the ball is rotated from the seal ring, an increased opening of the vee permits a gradual increasing flow rate. In addition, the rotating stem does not extend through the center of the flow path to restrict the flow. The Vee-Ball has two types of seals. One is a solid seat ring that requires a certain amount of clearance between the valve and the seat, but it is not very well suited to tight shut off. In fact, the ball can only be brought within a certain clearance of the seat. The Vee-Ball is suitable for services that do not require tight shut offs. Another type of seal is a flexible steel ring that actually contacts the steel ball. This type of seal has better shut-off capabilities, but is not absolutely leak tight. A certain amount of leakage exists around this flexible knife-edged seal. The Fisher Vee-Ball has nearly eliminated all the voids associated with other ball valves.

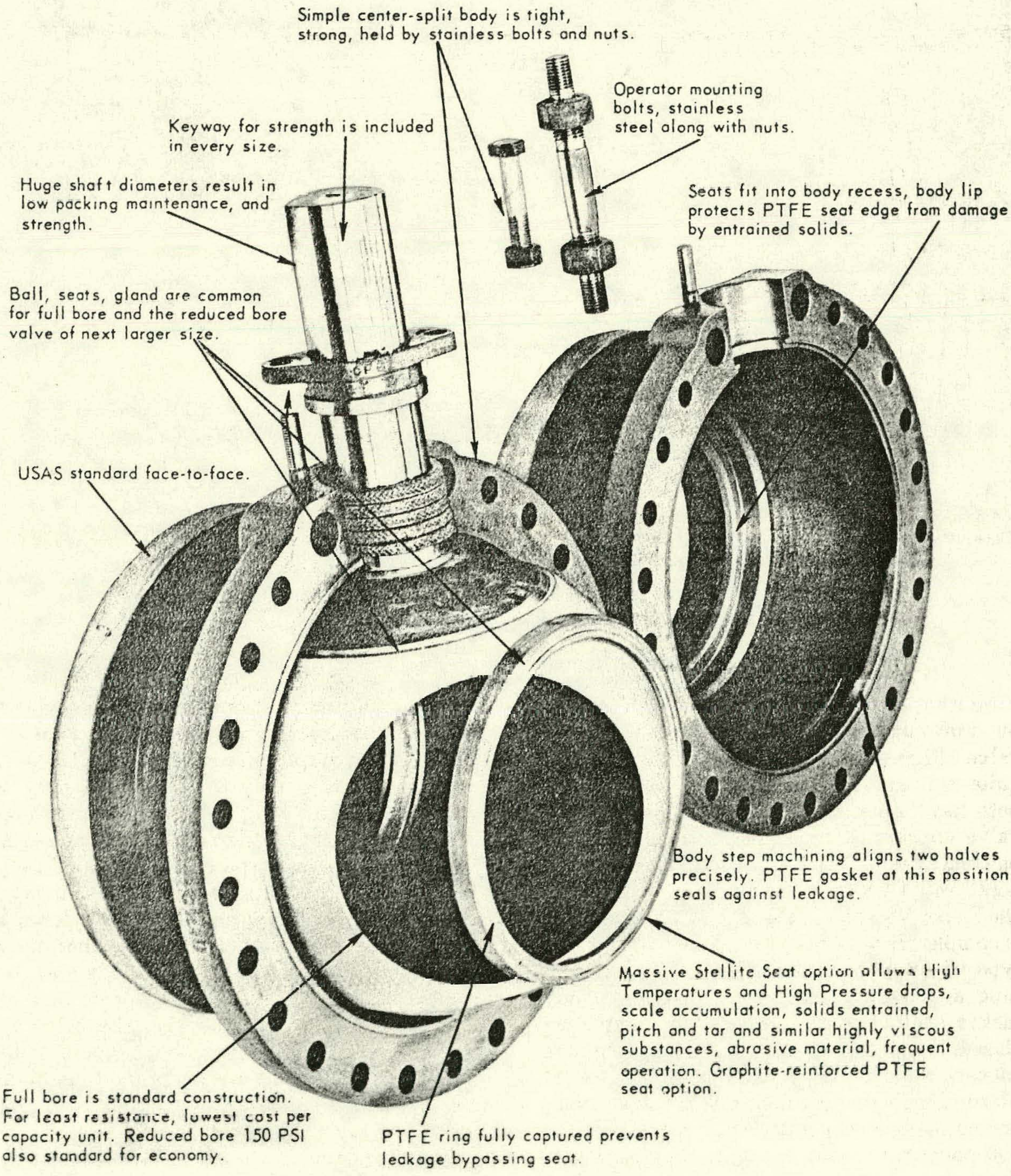


Figure 13-3. Split-Body Ball Valve

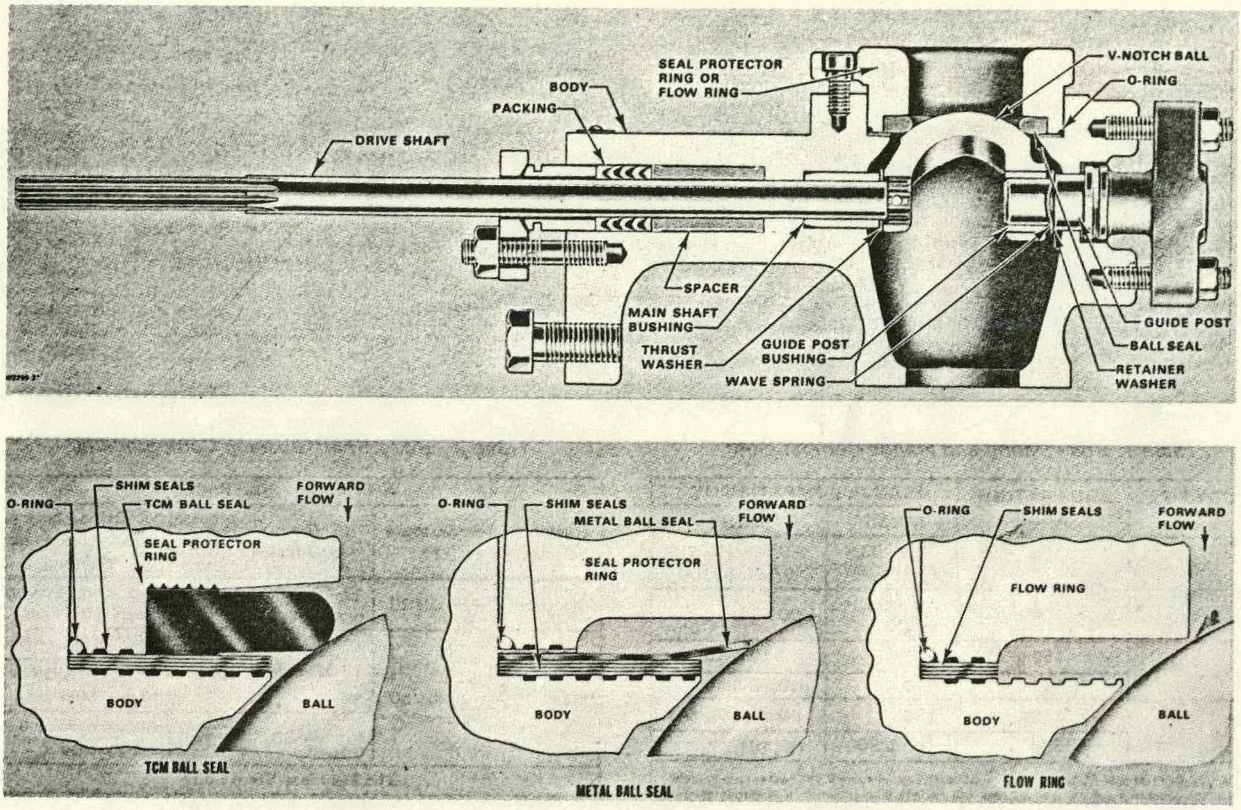


Figure 13-4. Fisher Control Company's Vee-Ball

Another type of valve is manufactured by Masoneilan and is called a Cam-Flex valve (Figure 13-5). The Cam-Flex valve is quite similar to the Fisher Vee-Ball in that both have a disc that rotates on a shaft. This valve appears to be a good alternative for a ball valve or a Vee-Ball valve at lower temperatures. They have the similar advantage to the Fisher Vee-Ball in that the disc, when open, is completely out of the flow stream. With this type of valve, the disadvantage of the ball rubbing against the seat is eliminated. It only makes contact when the valve is completely closed, whereas the ball valve is in complete contact with its seal ring when it rotates. If Masoneilan could be convinced to make a high-pressure, high-temperature valve, greater than 600 pounds, it could find great application in the coal-gasification area.

The next valve I would like to talk about is a plug valve (Figure 13-6). This type of valve has a couple of configurations: in one, a plug is tapered and in the other, a plug is cylindrical. These plug valves annoy me to no end, particularly, if they are of the four-way switching type and tapered. The tapered plug has very small clearance between the body and the rotating plug. If a minute piece of foreign material, in our case being coal or char, gets between the plug and the valve body and the clearances aren't enough to take care of that small piece of foreign material, the valve invariably hangs up. If the valve happens to be stainless steel, which is very prone to galling, the problem just grows and grows to the point where the valve fails to rotate.

My suggestion is that wherever a four-way plug valve is needed, don't use a tapered plug,

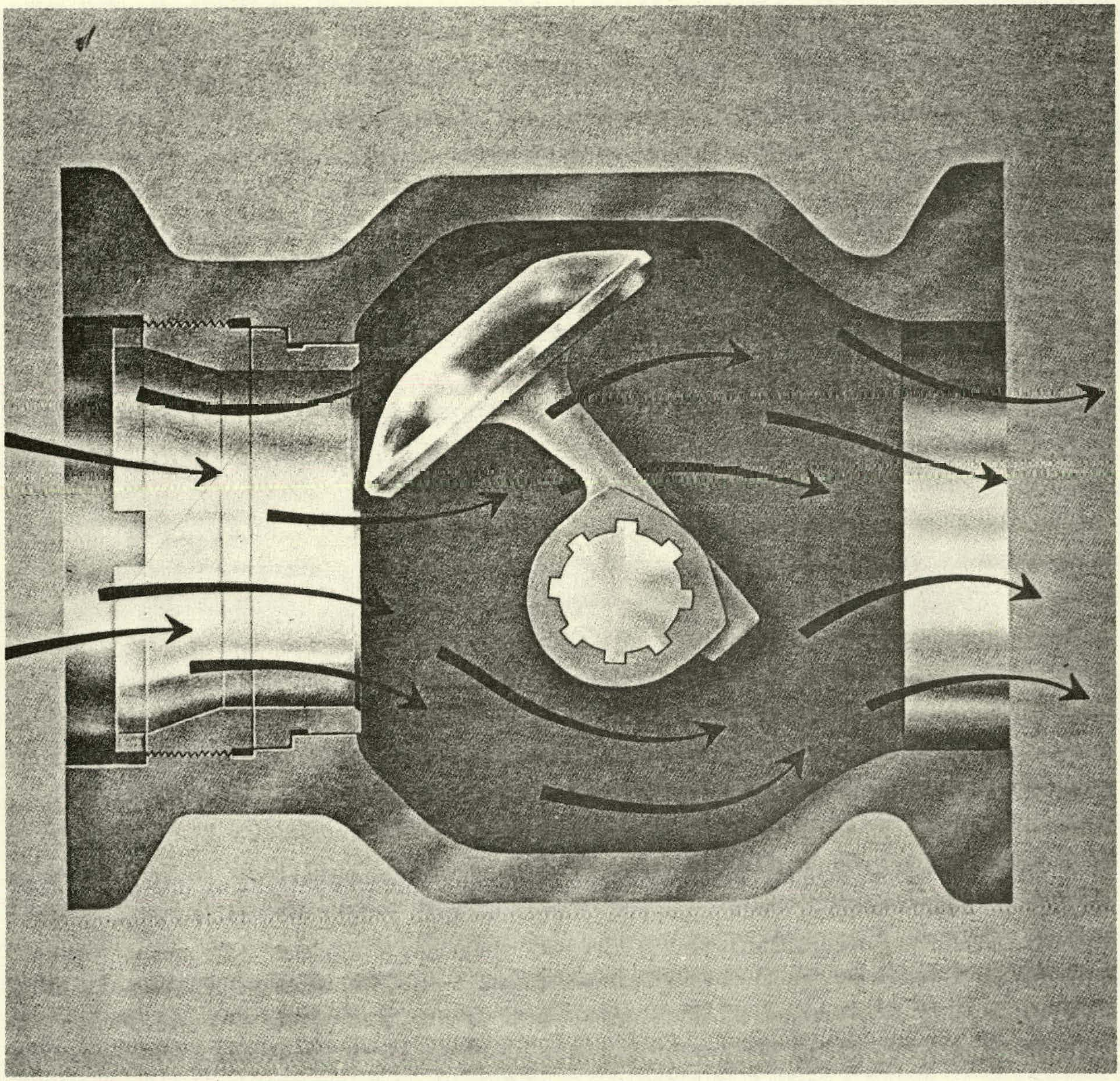


Figure 13-5. Masoneilan's Cam-Flex Valve

because as the tapered plug is inserted farther into the body, the tighter it becomes within the body. Unless it has a travel limit, the plug can become jammed into the body to the point it will not rotate.

At the BI-GAS facility, we have an automatic lubricator on our tapered-plug valves in the lockhopper system. We have a number of plug valves on this system that are operated by a timer. Each time these valves go through a cycle they are lubricated. The lubrication is applied to the bottom of the plug valve and tends to raise the tapered plug out of its body; at the same time, the lubricant is forced between the body and the plug. This arrangement is very satisfactory as long as th

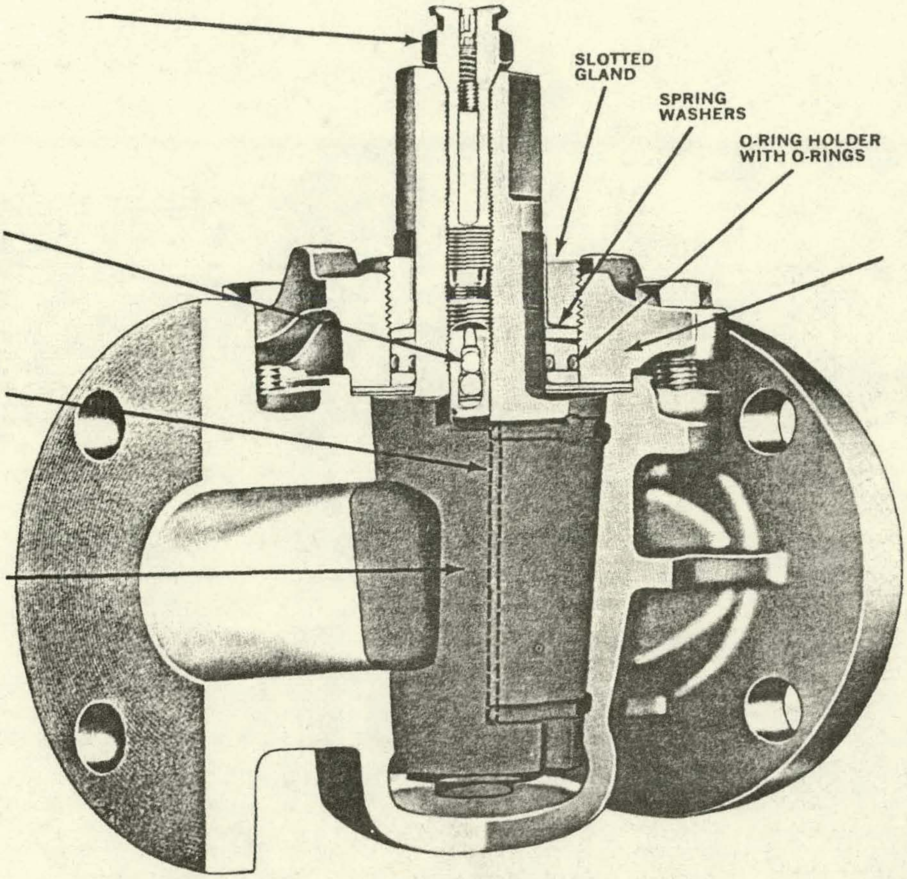


Figure 13-6. Plug Valve

lubricators continue to work.

My personal preference is to avoid use of four-way plug valves. For some reason, I have had many problems with them. I also prefer two three-way solenoid valves in lieu of one four-way.

I have experienced problems with several manufacturers' valves where the actuator has enough strength to actually twist the stem when the valve binds (Figure 13-7). There have been occasions where a splined connection between the actuator and the valve ball has been twisted to the point where the splined connection had to be screwed off in order to get them apart. They made their own threads. This indicates the stem isn't stout enough, the actuator is too large, or the valve itself is being used at too high a temperature. When this situation occurs, it can be a bad situation because there is no visible means of telling when the valve is closed, completely closed, or completely open, or if you've traveled too far. You can't see whether it is closed or opened. It might be a safety problem, as far as the plant is concerned.

Another type of valve is the Willis Oil Tool rotating-disc-type valve (Figure 13-8). To open this valve, one of the discs is in line with the hole in the rotating disc. When we first started using the Willis valves, we used them in a service as a high-pressure drop valve, that is, 750 pounds to atmosphere. The rotating discs were prone to erosion. In attempting to solve this problem, we tried two valves in series to drop

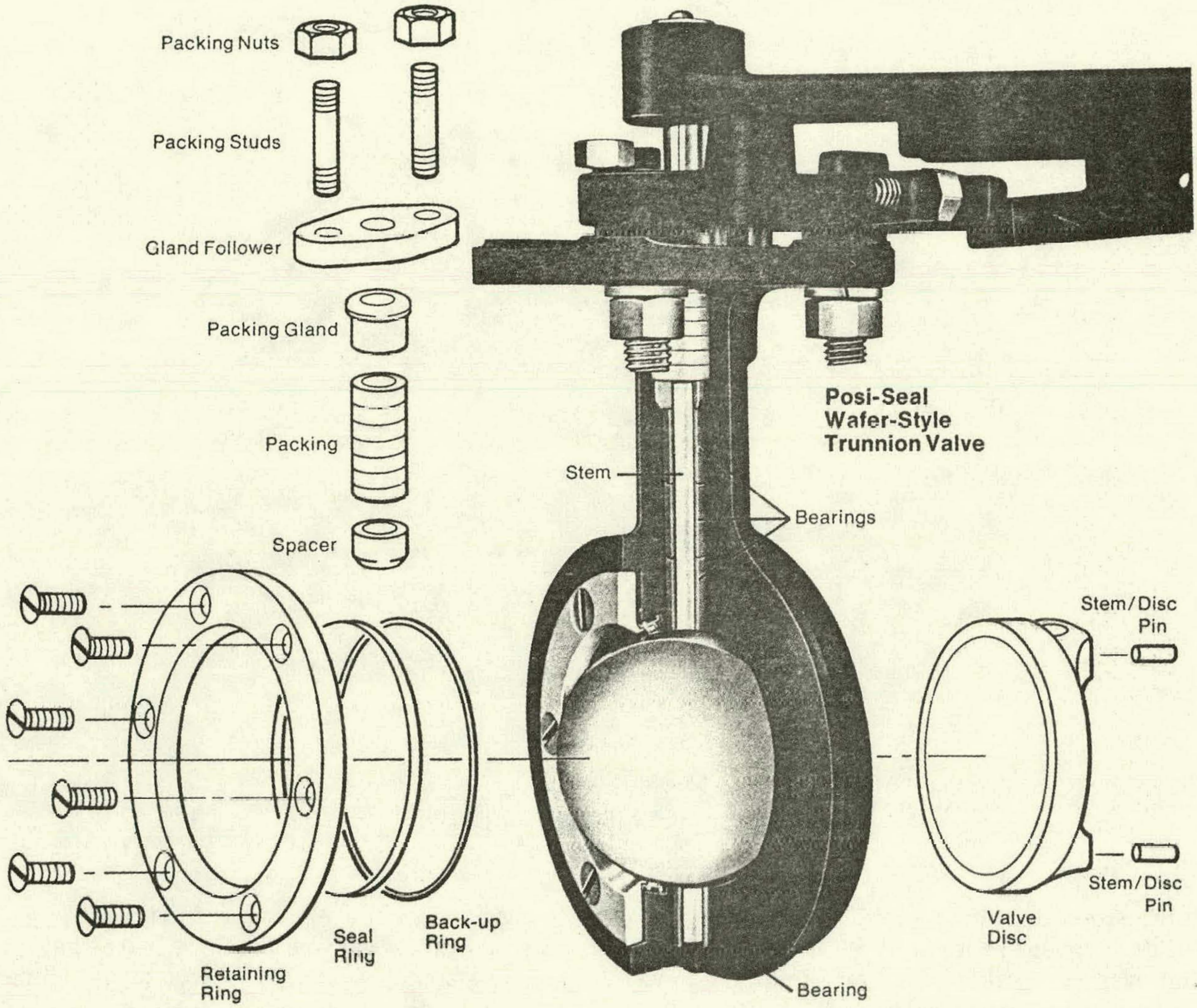


Figure 13-7. Posi-Seal Wafer-Style Trunnion Valve

the 750 pounds. The two valves were controlled by one controller and operated simultaneously. This proved to be a fairly satisfactory solution, but we had to use two valves instead of one valve. However, this seems to have solved our erosion problems on high-pressure letdown valves. The Willis valve has a minor binding problem whenever the valve is in the completely closed or open position. The binding is caused by the acute angle required by the actuator to apply force to the rotating shaft. The first movement that occurs is a lateral movement of the shaft within the body. The lateral movement causes friction between the shaft and body, and the friction has to be overcome before the shaft can rotate. This problem should be considered worthwhile of investigation and solution.

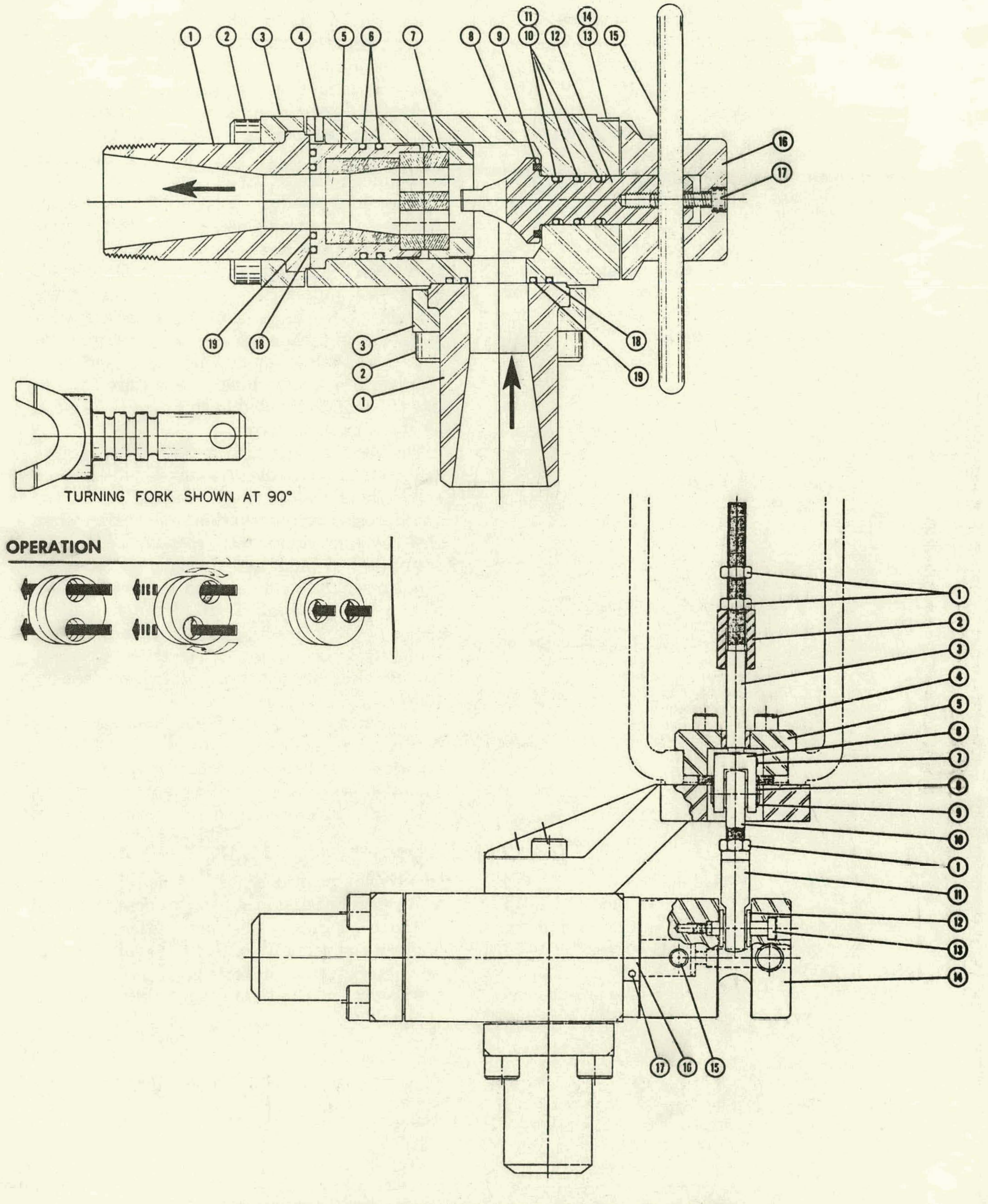


Figure 13-8. Willis Oil-and-Tool Rotating-Disc-Type Valve

One idea I would like to pass on to the Willis Oil and Tool Company is to elongate one of the apertures in their discs in an attempt to have a more linear opening area with possibly better resistance to erosion.

Another valve I would like to mention is manufactured by Yarway (Figure 13-9). It is designed to be a high-pressure letdown valve with multiple discs as the control for regulating the pressure drop across the valve. The multiple discs are designed in such a way that each disc, or flute, takes an equal amount of the total pressure drop. This action distributes the energy across several steps rather than one or two steps.

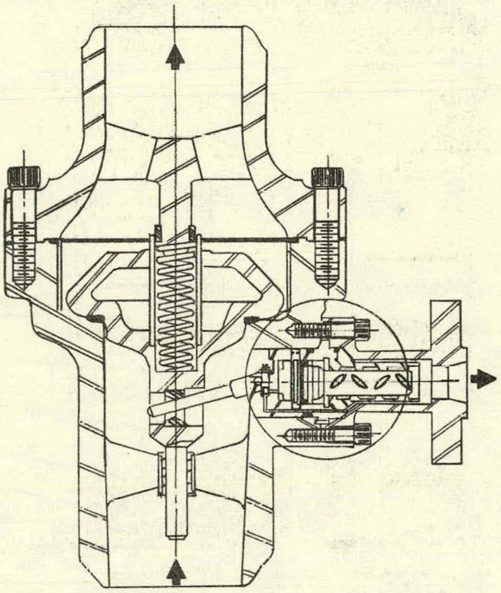


Figure 13-9. Yarway's High-Pressure Letdown Valve with Multiple Discs

I haven't applied these in a slurry-letdown application, but it would be interesting to try it. They work well on recycle valves for high-pressure boiler feedwater. We had two of these valves in service on a high-pressure boiler feedwater system dropping 2,300 pounds. They were in continuous service for about 5 years before they required rebuilding, but they did their job with very little wear.

Another valve that gives very good service and reliability in low-pressure and temperature slurry applications is a sleeve or boot-type valve (Figures 13-10 and 13-11). Fluid flows through an elastic tube, which forms a part of the fluid conduit. Two actuators are attached to opposite sides of the elastic tube, which pinch the elastic tube in order to close the valve. The elastic tube apparently doesn't suffer as much permanent damage from erosion as we have come to associate with metal-seating material. I highly recommend this type valve for low-pressure and low-temperature applications. One feature I would like to see incorporated in this type of valve is a valve-travel indicator.

The familiar butterfly-type valves (Figure 13-12) have some disadvantages in slurry or solids handling. First, the butterfly and the shaft present an obstruction to flow even when the valve is completely opened, which can result in line pluggage. Second, we have the problem of the voids around the shaft collecting solids material. Third, I am frequently requested by operating personnel to make the butterfly travel a full 90 degrees, which is usually a feature not incorporated with the actuator.

One comment I would like to make regarding control valves has to do with the valve positioner on pneumatic-actuator valves. Some manufacturers use a spring connection between the valve stem and the positioner as a feedback to tell the positioner when it has reached its proper opening. This spring on most valve positioners is a rather fragile item and protrudes and is subject to being bumped or knocked off. It also can suffer from the elements, causing freezing on the valve spring, thus sending a false signal back to the positioner and positioning the valve other than it should be.

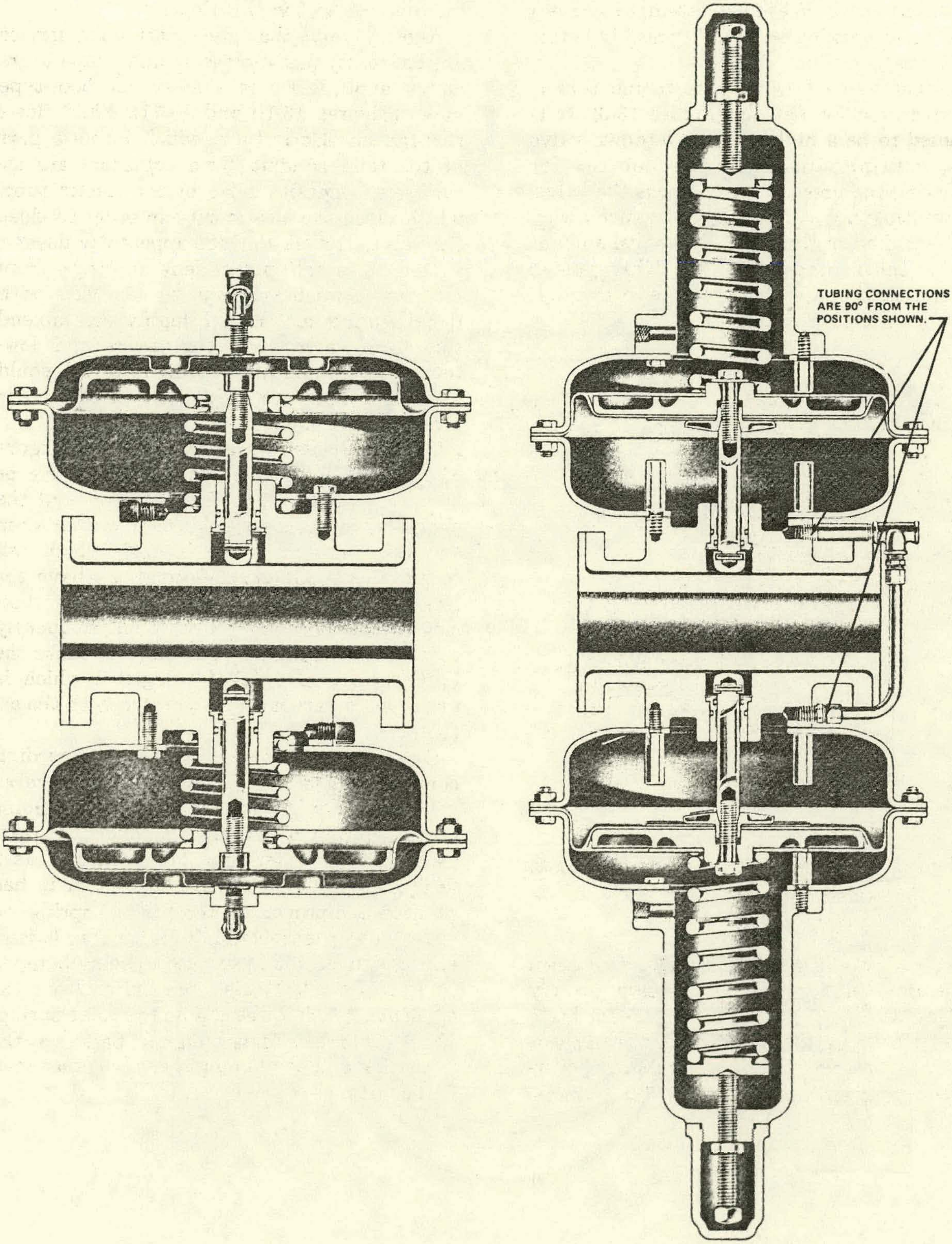


Figure 13-10. Sleeve (Boot) Valve

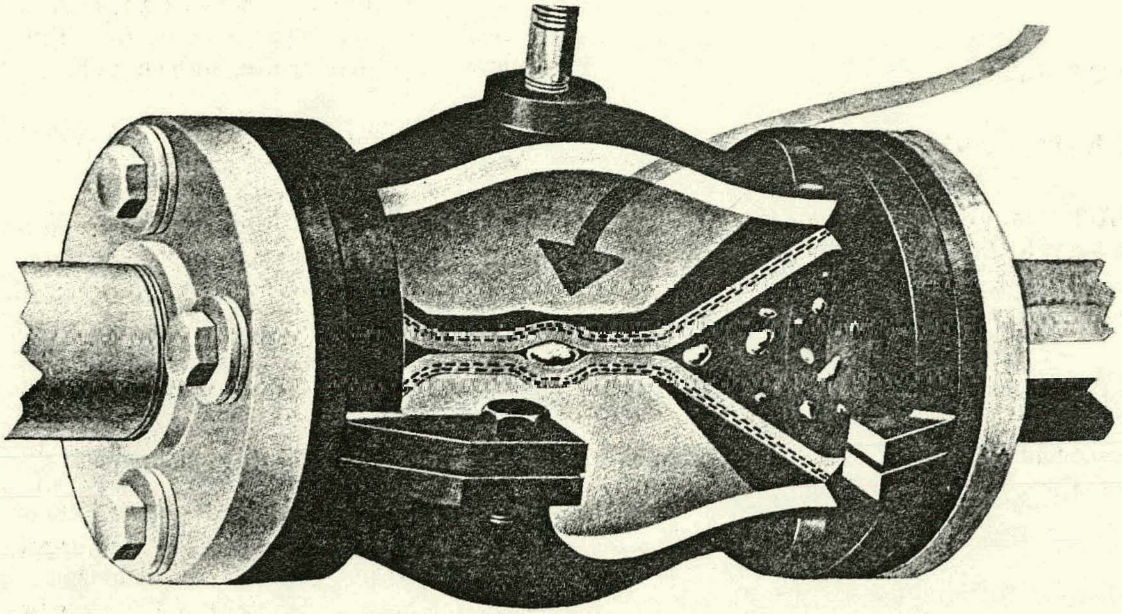


Figure 13-11. Sleeve (Boot) Valve

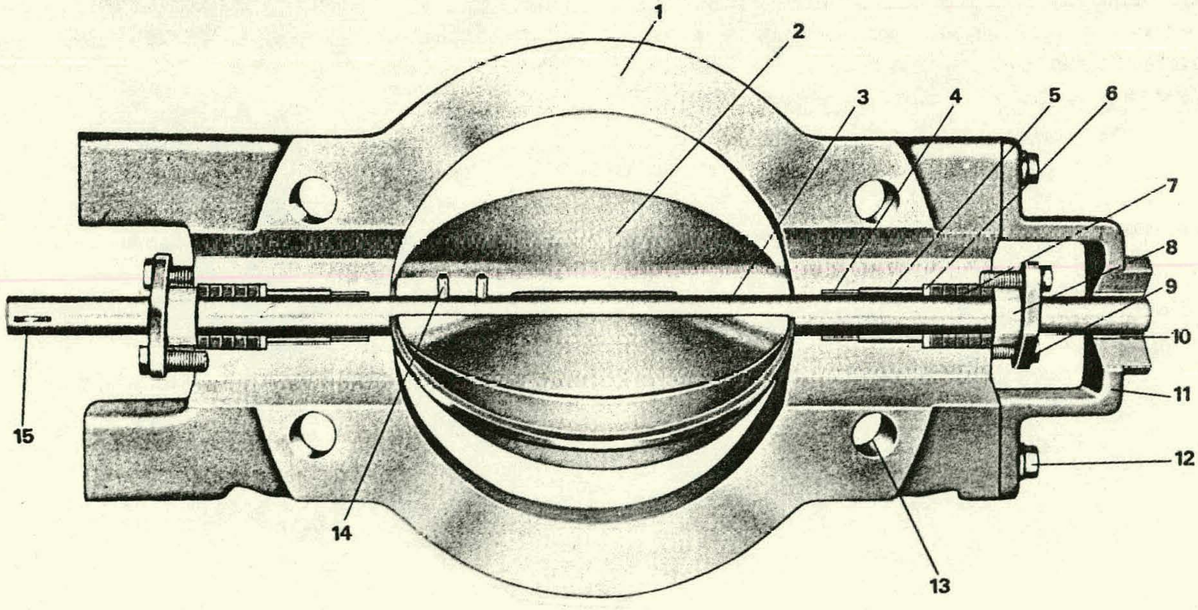


Figure 13-12. Butterfly-Type Valve

Discussion of Paper by Frank Plut

QUESTION: With the elastic tube valve, or whatever you called it, what elastic did you use?

PLUT: Rubber.

QUESTION: What kind of rubber?

PLUT: Plain old rubber. As far as I know, plain old rubber.

QUESTION: How well did it survive?

PLUT: Very well. I was trying to think. We just pulled one into the shop about a month ago that had been in service for 5 years. That's on-and-off service. But it showed very little signs of erosion.

QUESTION: What was the pressure drop?

PLUT: 60 pounds; 35% coal.

QUESTION: On the liquefaction, the people who have spoken before you, most of the valve applications have been with higher pressures and higher temperatures on the valve. Does that mean that on the coal gasification, there are more applications for valves to have lower temperatures and lower pressures? I assume these valves that you showed had coal slurry.

PLUT: No, the low-pressure and low-temperature valves are run-of-the-mill valves. The exotic things that these guys are talking about are just hard to come by. High temperature, high pressure, high shut off.

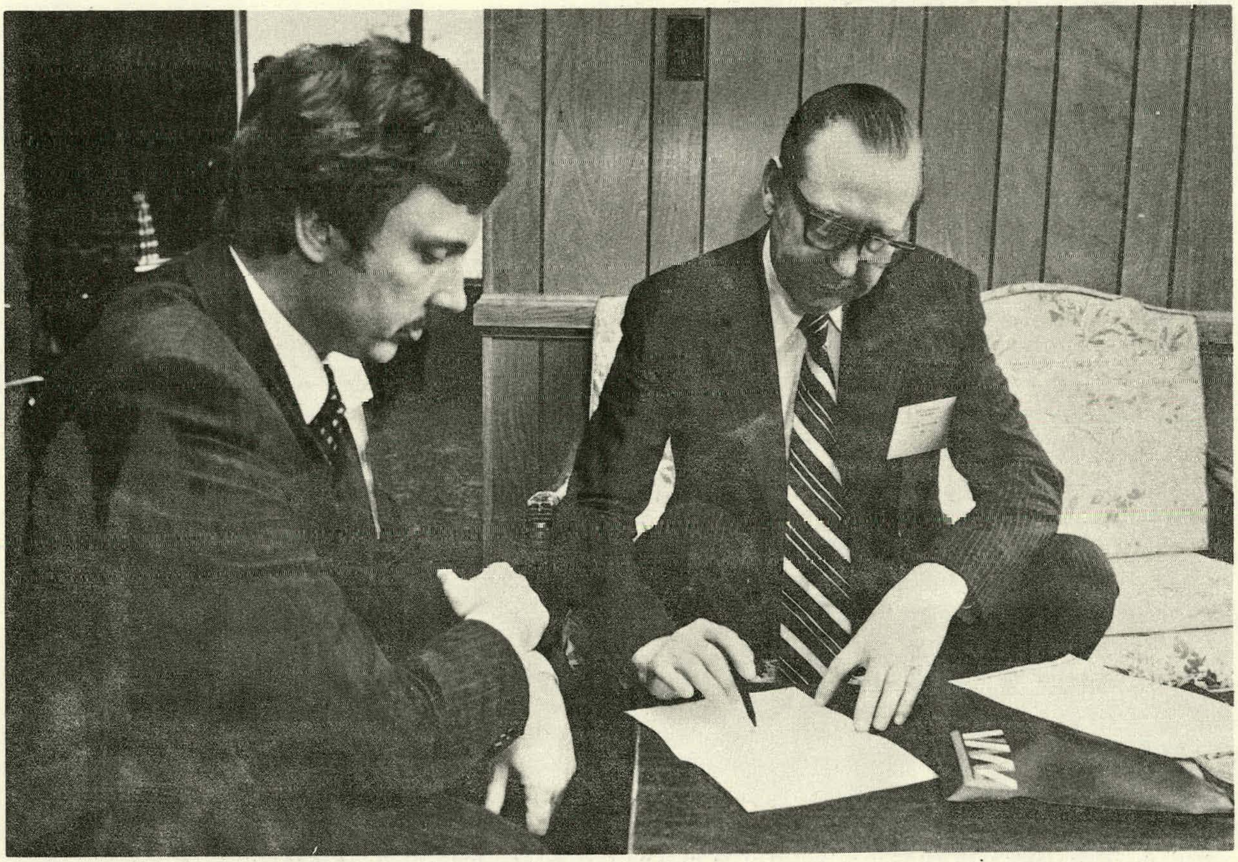
QUESTION: What services can these valves and the butterfly valve give?

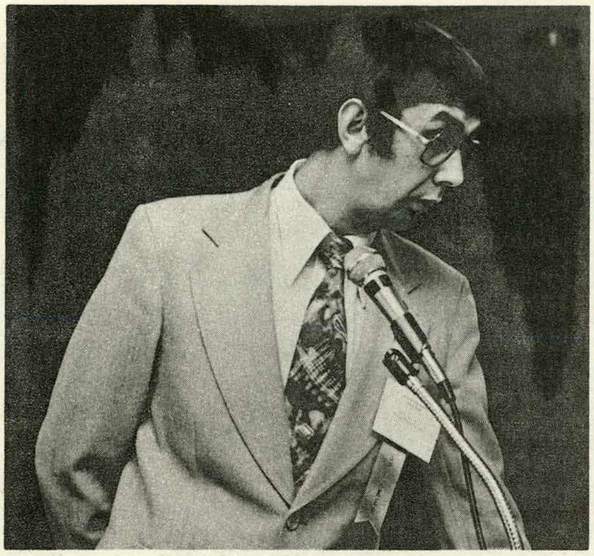
PLUT: I've seen valves in service, a butterfly valve in service, up to 1,800 degrees. They tended to, well they weren't tight shut off—no butterfly valve is—but they tend to be eroded, damaged, plugged with solids, and even burned off the shaft.

GARDNER: Thank you, Frank. Just so there isn't a misconception on the gasification processes, the question was asked does this mean that gasification involves lower-pressure or lower-temperature applications that are not found in liquefaction work. I think the best answer to say is that one is process-dependent. You do find applications that require temperature ranges from near atmospheric all the way to 1,600 or 1,700 °F. The pressures can get up from ambient to 1,000 psig.

Some of the speakers tomorrow will address the second-generation gasification processes where you will see much higher temperatures or much higher pressures, depending on the process itself.

Last-Minute Planning . . .





Section 14

Materials for Erosive Valve Applications

Authors: I.G. Wright, D.K. Shetty, J.H. Peterson and A.H. Clauer

Presented by:
I.G. Wright, Associate Section Manager
Corrosion Section
Battelle Columbus Laboratories

October 16, 1980—1:15 p.m.

Abstract

The erosion-corrosion behavior of a range of commercially-available and advanced cermet and ceramic materials in hot erosive slurry service and in a laboratory simulator is reported. In both types of conditions, low-binder WC-CoCr cermets were found to perform consistently well. Further laboratory screening tests indicated that some ceramics, notably SiC as a coating or in some massive forms, could offer erosion-corrosion resistance superior to that of WC-CoCr. The reproducibility of performance of the ceramics from batch to batch, or between sources, however, was very variable. Some of the factors affecting the erosion-corrosion behavior of these materials, and some of the considerations necessary in their selection and application in practical valves, are discussed further.

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The results I will present today came mainly from a 3-year program supported by EPRI, which was intended to provide materials for the letdown-valve problems being experienced at Wilsonville. Currently, the DOE-supported program that we are working on continues work that we did for EPRI, but expands it in a more general way such that we are now looking at the problems associated with the other pilot plants or the PDUs, such as H-Coal.

What we are talking about is material for trim for valves that handle slurries containing solids like those shown in Figures 14-1 and 14-2. Solid particles are taken out of process streams from Wilsonville, and as ca[illegible] they are quite small, but are fairly sharp. They range from skeletal fossil-type materials to all sorts of agglomerated pieces.

One part of the work that we have been doing recently has been to try to find out what we really have to contend with in terms of particulate. Really, the most abrasive part of the solids is the sort of material that tends to break on passage through a valve and give you sharp corners which then do the damage. The irregular sharp particles in Figure 14-1 relate more to unprocessed coal agglomerations of fine particles which split apart but apparently don't do too much damage.

Figure 14-3 is another picture of solids from slurry from H-Coal, and again you can see agglomerated pieces and also sharp looking pieces. There don't seem to be many skeletal pieces in Figure 14-3. It is the same magnification as Figure 14-1.

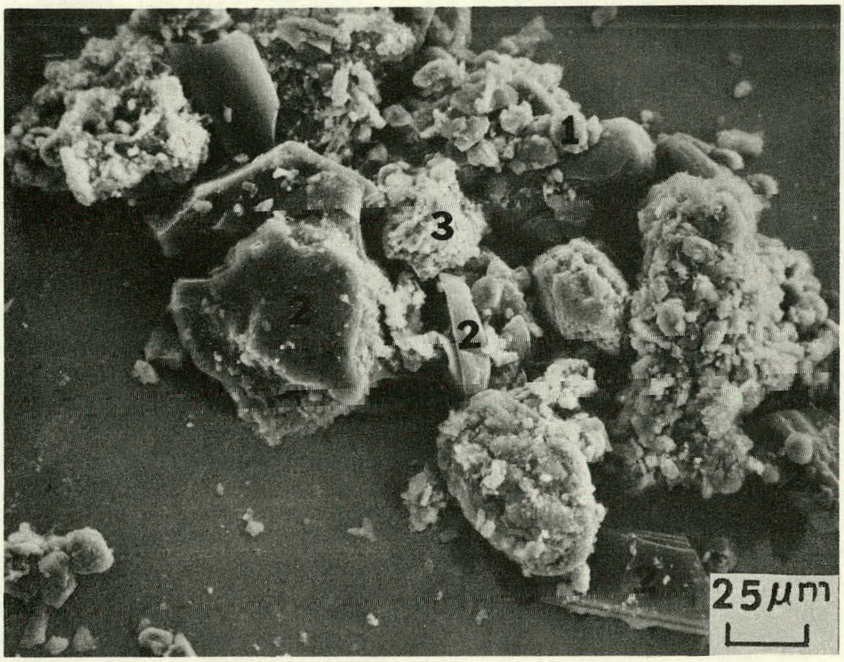


Figure 14-1. Solids From SRC-I Product Stream (Monterey, Illinois No. 6 Coal)

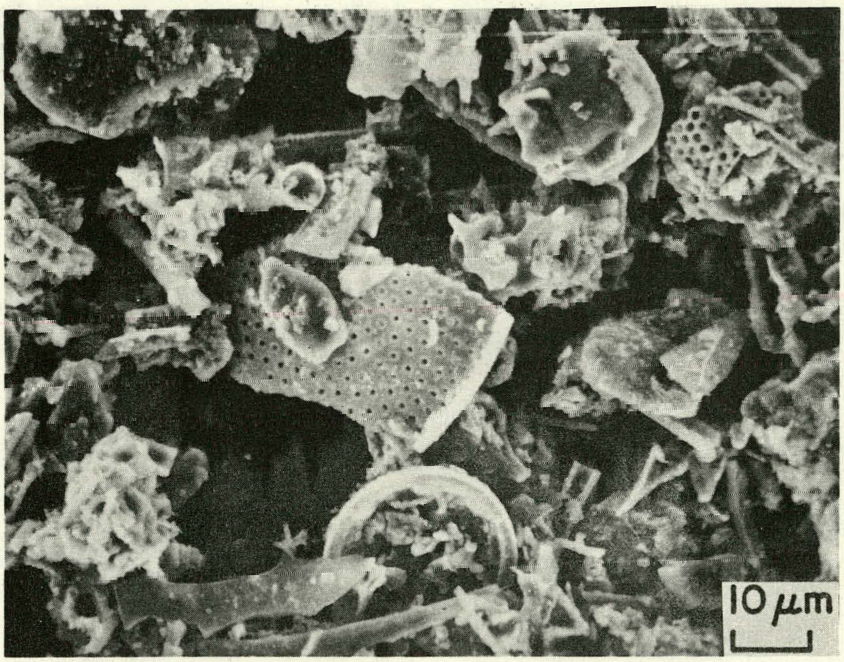


Figure 14-2. Solids from Filter Cake of SRC-I (Ash Plus Diatomaceous Earth)

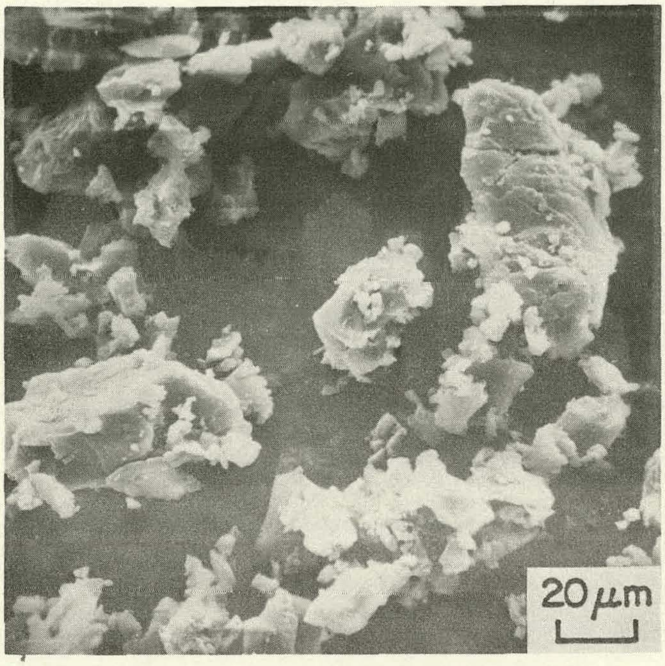
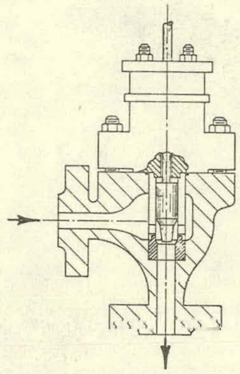


Figure 14-3. Pulverized Coal Particles

Facility	Trim Material	Nominal Wear Life[1] (Days)	Trim Fabricator
Consol	13 percent cobalt/tungsten carbide	15-18	Carbide Components Co.
H-Coal	K701	14	Kennametal/local machine shop
PAMCO	GEM 550 or low-cobalt WC	36	GEM Oil Tool Co. or McCain Metals Co.
SRC-I	GEM 550	120	GEM Oil Tool Co.
Synthoil	K701	42-84	Kennametal
Anonymous Industrial	Cobalt binder/tungsten carbide	21-35	Kennametal

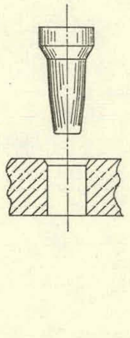
[1]Life times received were converted to equivalent days. Values are for the first stage of letdown, if more than one stage is used.

Figure 14-4. Trim Practice Among Liquefaction Facilities

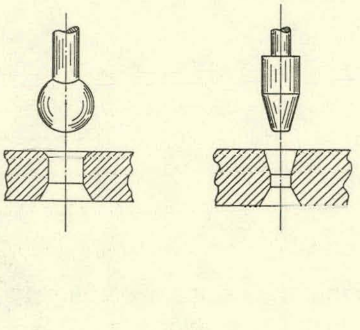


This valve design provides a change in direction of flow in the low-velocity section and a direct exit for the flow after exiting from the orifice. The trim can be removed without breaking a line connection.

Figure 14-5. Sketch of Angle Valve

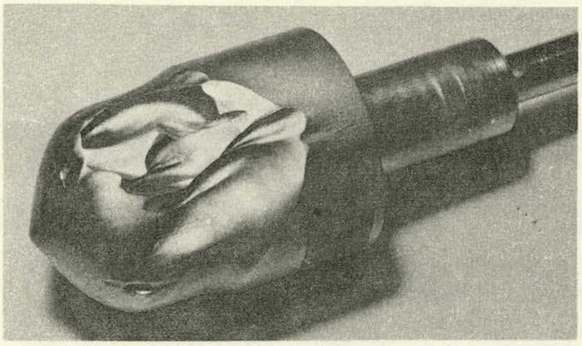


(a) Plug and Seat Trim Set



(b) Ball and Tapered-Stem Check Valve Trim Sets

Figure 14-6. Designs of Valve Trim



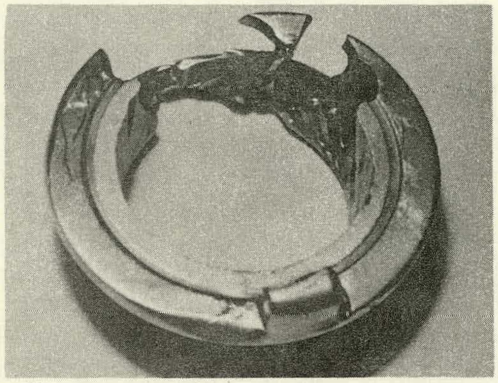
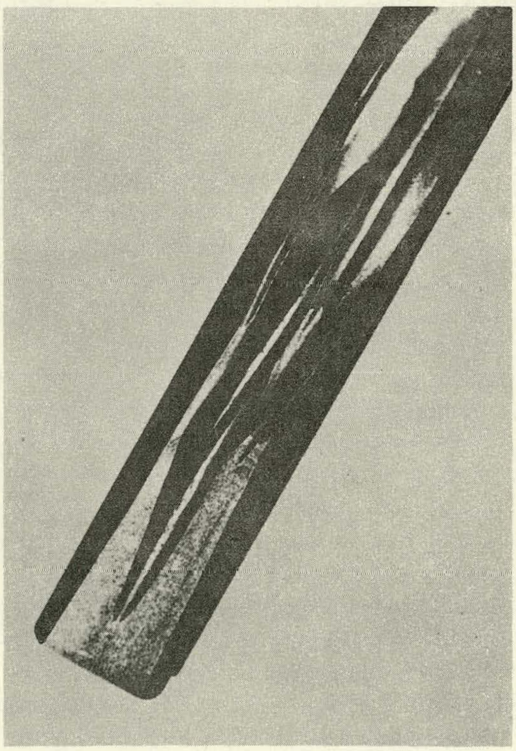


Figure 14-7. Erosion Damage to Stainless-Steel Plug and Seat After Service in a Slurry-Recirculation Valve



Valve 14-8. Valve Stem from H-Coal PDU Showing Wear from Nominal 2 Weeks of Operation

What I would like to do is to give you a little bit of background on the work, on the procedure, of the programs that we have looked at, and then get into the information that we have generated on the materials. Initially, we surveyed the trim practice in the coal-liquefaction plants to try and determine what materials were being used, what sort of conditions the materials were being exposed to, and what problems they were having. We looked at the various PDUs that were then in operation (Figure 14-4) which were CONSOL, H-Coal, PAMCO, SRC-I, and Synthoil. An anonymous industrial process also was investigated. It turned out that after many trials and tribulations with the usual sort of hardened metallic valve trim, most of the processes have graduated to using cermet, cemented tungsten-carbide-type materials.

Even though most of them have graduated to using these more expensive materials, the experience in terms of life of the valves was extremely variable, varying from 14 days at worst, at the time we did the survey, up to something like 84 days, with the Synthoil plant. In most cases, the plants were using typical bonnet valves of the sort of design shown in Figure 14-5, which permitted easy replacement of the plugs and seats.

One feature of these valves, which is conducive itself to producing erosion conditions when you have high velocities, is the turning motion forced upon the slurry, which tends to concentrate somewhere on the side of the seat even before the slurry enters the rapid-letdown stage.

The types of trim that were being used ranged from the plug-and-seat type trim (Figure 14-6a) where the plug usually has a tapered flat side to produce throttling, so that, with the trim withdrawn partially from the seat, throttling will occur in the tapered region of the plug. When the plug is fully inserted, a stop off or blocking can be achieved. The other extreme was the ball or tapered-stem kind, which is a reverse-flow trim where the flow is coming upwards in Figure 14-6b and unseating the plug. In the case of the tapered plug, throttling was achieved by simply oscillating the plug in and out of the seat.

Some of the horrors that we came across in the survey are shown in Figure 14-7, which are from a stainless-steel recirculation valve that handled coal-oil slurry. The stainless-steel plug and seat were in service for only a few weeks. You can see the plug is extensively eroded, whereas the seat is completely eroded through, and at this point, the slurry passed through the seat and made a hole in the valve body—the valve was then considered to be useless.

Figure 14-8 is a stem from H-Coal. This is a stem made of cemented tungsten carbide, probably Kennametal's K701 type carbide. You can see these are quite small stems, the tapered flat on the stem is extensively grooved by erosion. The flow in this case would come into the stem and down the flat from the top of Figure 14-8. The erosion done is quite obvious; the surface is sufficiently eroded that it can no longer perform any of its duties.

Another stem with a tapered flat design is the one shown in Figure 14-9 from the Wilsonville SRC facility. The original tapered flat, with erosion damage on it quite evident. The grooving at the top of the stem apparently comes from damage from slurry entering the valve before it turns around the stem and goes

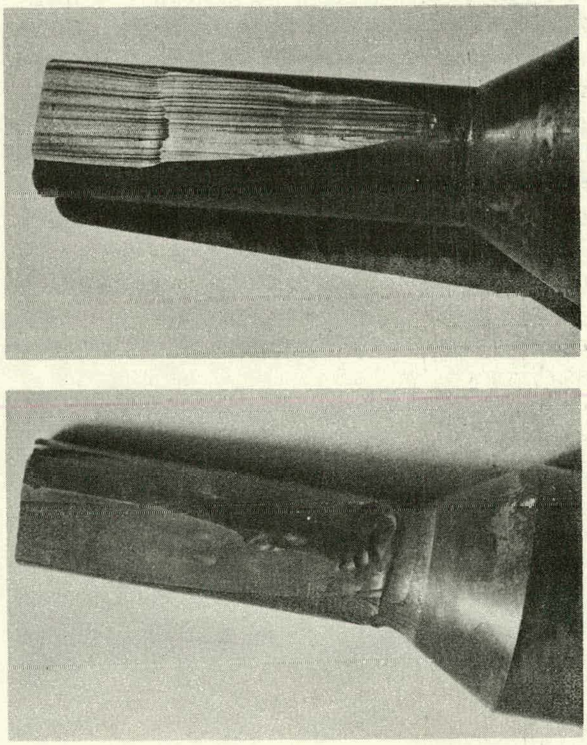


Figure 14-9. Erosion Damage to GEM 550 Plug Trim from SRC-I

out through the opening. The same sort of damage, which I think they call worming, is shown on the opposite side to the flat and it appears that although this damage is quite severe, the damage that caused the valve to be withdrawn was damage to the flat, which prevented either proper throttling or proper seating.

Figure 14-10 is a picture of a seat that had been modified to resist erosion by having a cemented tungsten-carbide insert brazed into it, but had failed by pinholing because the slurry had attacked a defect in the braze and eaten away the casing. The slurry then bypassed the cemented tungsten-carbide liner and completely failed the system. Other sorts of damage were related to mechanical handling of these relatively brittle cemented tungsten-carbide materials. While these cemented tungsten carbides have gained a fair amount of exposure and use in valves, there are still problems from handling that need to be taken care of. It comes down to a matter of the education of the engineers involved in handling special materials like this.

The way that these cemented tungsten carbides fail in erosion is that when the slurry flows over the surface, it takes away the metal that is used to bind the cemented tungsten-carbide grains together. K701 (Figure 14-11), which is a favorite material among some of the plants, comprises tungsten carbide cemented together with 13% of a cobalt-chromium-based metal. This 13% coats the grains and sticks them together. If you look at the failed surfaces in the scanning-electron microscope (Figure 14-11b), you can see how small the grains are. You can also see that erosion of the binder leaves the tungsten-carbide grains sticking out of the surface. The next lot of slurry that comes across the surface can rip some of these grains out and continue the degradation.

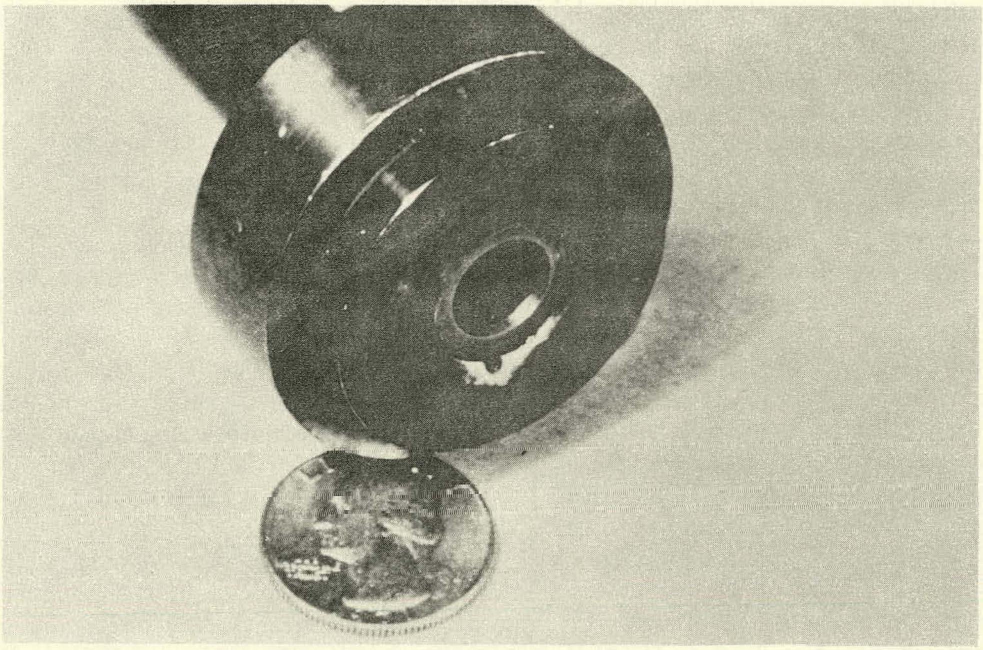
The micrograph of Figure 14-10a is a cross section showing that indeed there is very little porosity in this material so off-specification material or excess porosity is not a factor in this case. Compare this with the 701 cemented tungsten carbide taken out of H-Coal. While this piece has more porosity than the one from the SRC plant (Figure 14-12), the degradation mechanism is the same: removal of binder followed by ripping out of carbide particles rather than degradation specifically associated with the porosity.

The use by most of the plants of various grades of tungsten carbides led us to perform a laboratory screening of available tungsten carbide to determine if there was any rhyme or reason why given grades performed better than others. Figure 14-13 is a plot of erosion depth in a standardized erosion test as a function of carbide type. The various carbide types we looked at were the cobalt-chromium-bound carbides, the straight cobalt-bound carbides, and the nickel-bound carbides. The prices of these materials increase as you go from the nickel binders to the cobalt-chromium, which can be a driving force for trying to use the lower-cost carbides.

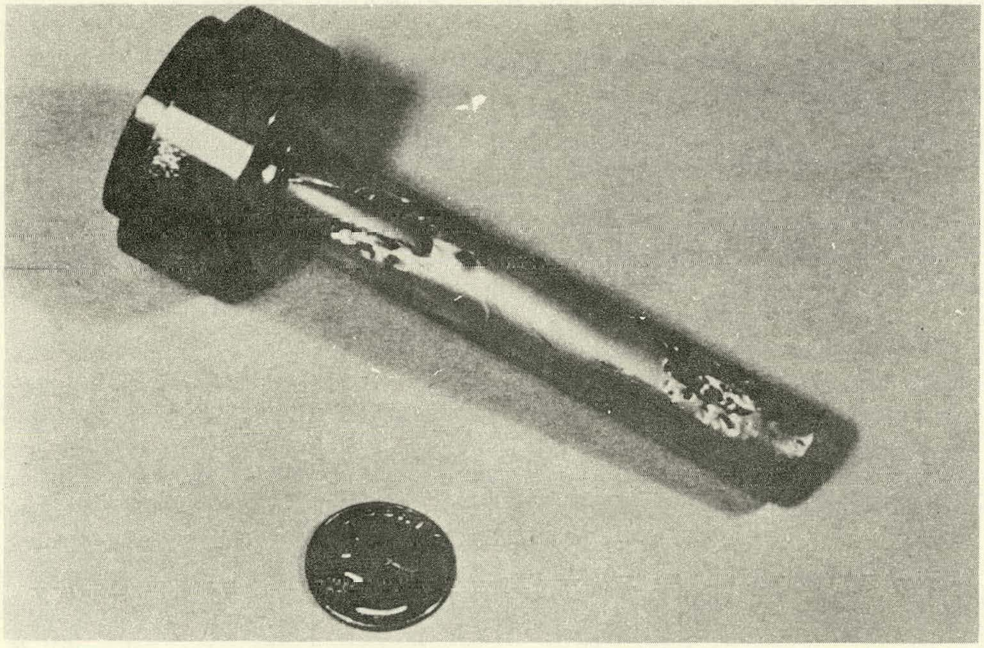
The major findings were that the resistance to erosion of the carbides increased with decreasing binder content. As the binder content decreased from 20% through 13% to 7%, we observed increasing erosion resistance in our laboratory test.

As a means of trying to confirm this trend, we produced two simple cobalt-bound materials in our lab with supposedly 2% binder, one of which did demonstrate potential for this sort of approach. The other specimen showed a very large amount of erosion, mainly due to our not knowing how to decrease the porosity properly in all samples. The major finding then is that the erosion resistance increases as you decrease the binder content. The problem is that as you decrease the binder content, the toughness of these materials is decreased, so you have a dichotomy there. If you are going to use the most erosion-resistant material, special attention must be given to handling.

The Battelle-Columbus laboratory rig (Figure 14-14) comprises a loop that circulates slurry—the slurry being made of the product from one of the pilot plants redissolved into oil until it is a mixture that represents as closely as possible the slurry seen by the letdown valves in practice. What the loop does is pump the slurry through a check valve into a pressure vessel, and from the pressure vessel the slurry is forced by gas overpressure (we use hydrogen) through a heater and then through a nozzle that accelerates the slurry onto a specimen. From here the slurry is then collected, cooled, and sent back around the loop. The actual erosion

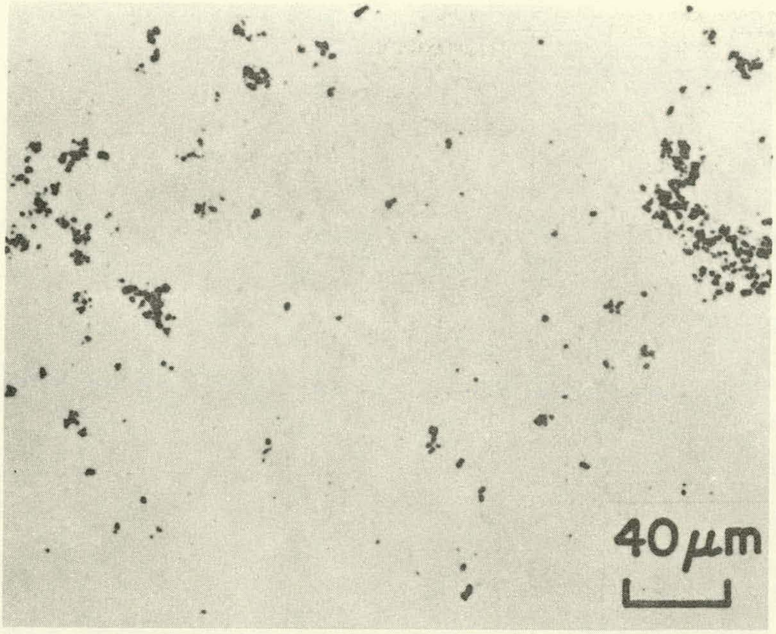


(a) SRC Valve-Seat Assembly Showing Leak Along Braze Interface



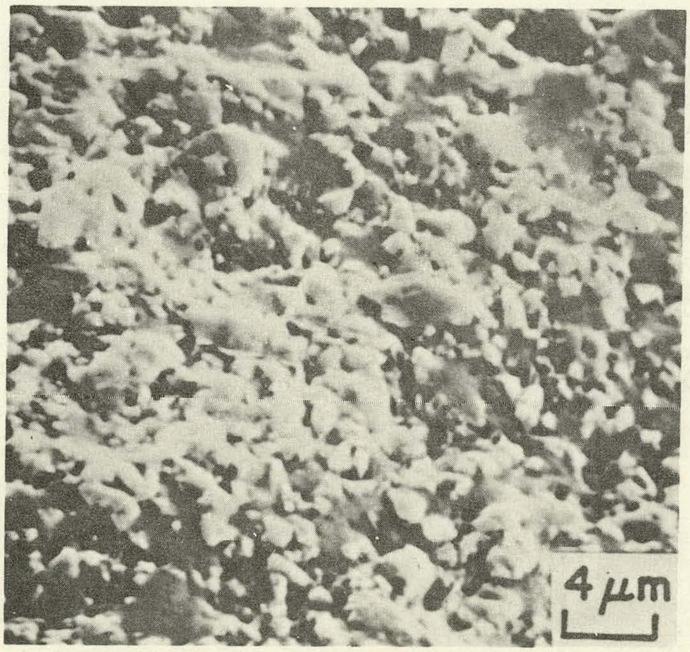
(b) Back Side of SRC Valve-Seat Assembly Showing Erosion from Leak

Figure 14-10. SRC Valve-Seat Assembly



250X

(a) Photomicrograph of H-Coal Stem (K701 Cemented Carbide)



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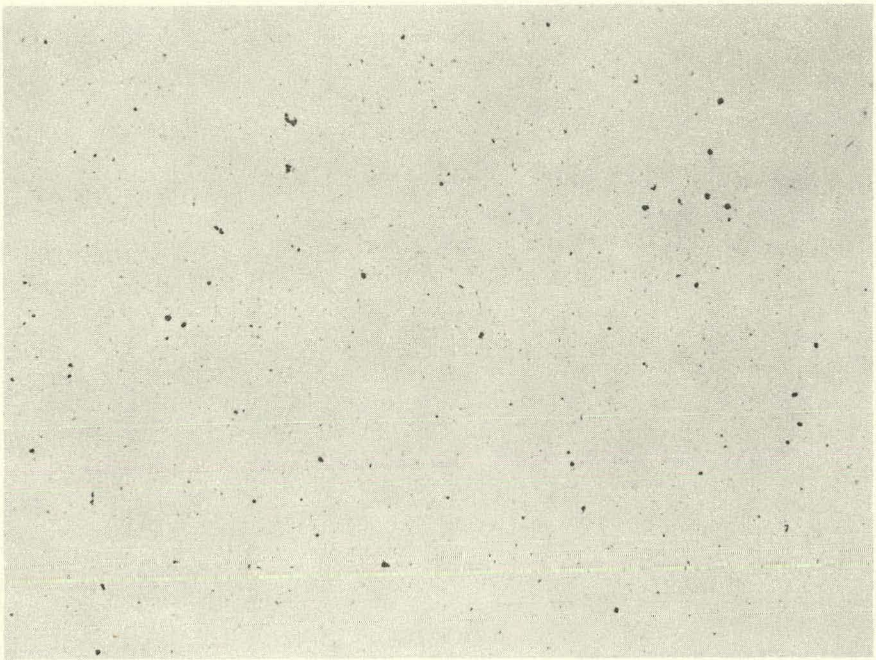
(b) Eroded Surface of H-Coal Stem Observed by Scanning-Electron Microscope

Figure 14-11. H-Coal Valve Stem (K701 Cemented Carbide). The softer binder material is eroded away, leaving the hard carbide particles extending from the surface.



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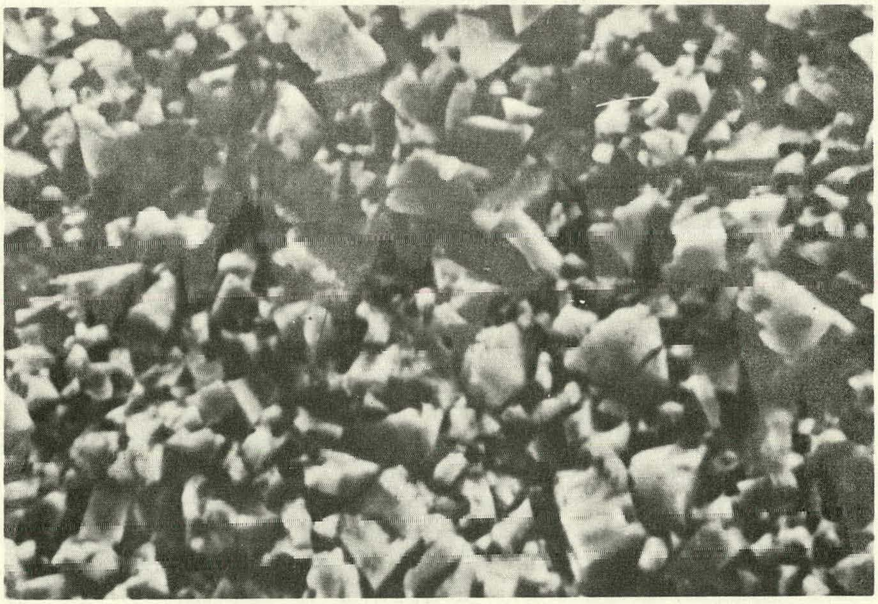
(a) Photomicrograph of SRC Valve Stem (GEM 550) Showing Pore Structure



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(b) SEM of Eroded Surface of SRC Valve Stem Showing Typical Removal of Binder Material From Around the Hard Carbide Particles

Figure 14-12. SRC Stem

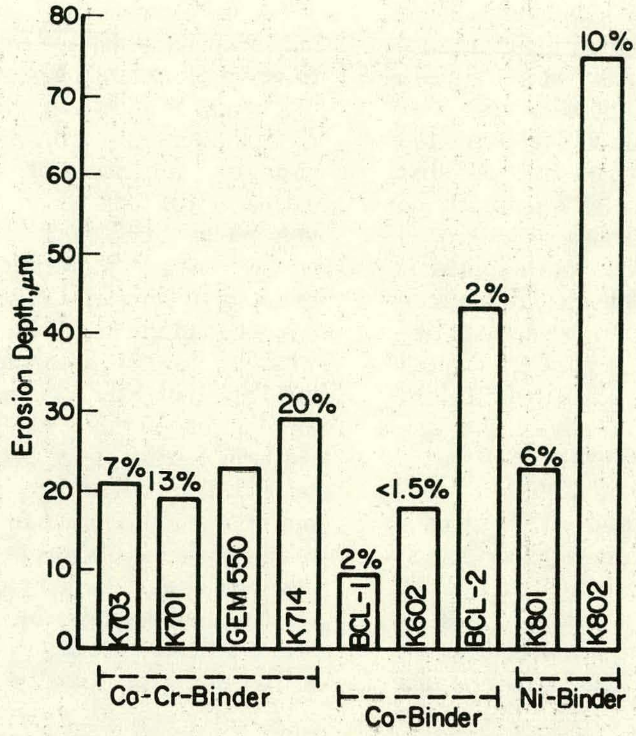


Figure 14-13. Erosion Results for Cemented WC, Coal Ash-Anthracine Oil Slurry 300°F, 2000 to 75 psi (367 Ft/Sec), 45°

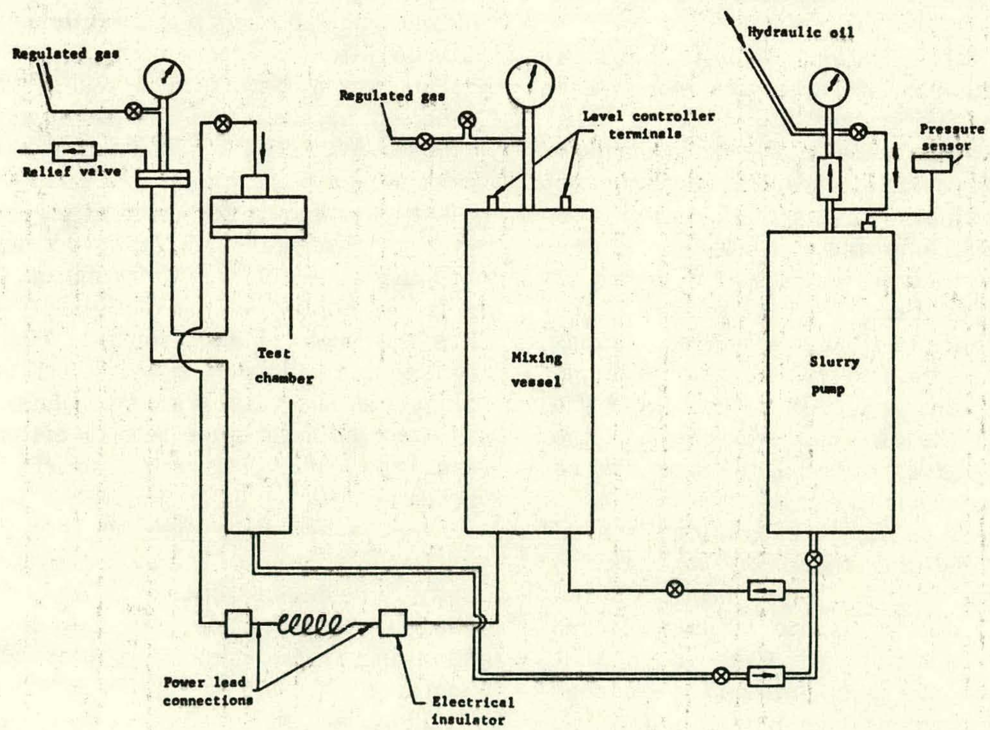


Figure 14-14. Schematic of Coal-Derived Slurry Erosive Wear Test System

rig is shown in Figure 14-15. The business end of this rig is shown schematically in Figure 14-16. The heated slurry comes through a mesh screen to take out any agglomerations that may occur, and then the flow is columnated through a carbide orifice. The fine jet that emerges is impinged upon a simple specimen held at a fixed angle beneath the jet.

The sort of specimen that was evolved is shown in Figure 14-17. The specimen itself is simply a cylinder, but can be almost any shape. The diameter of this cylinder is about a quarter of an inch and it is held in the fixture at a given angle throughout the test. The rig is used at temperatures up to about 650°F. We use a slurry, then, that is close to the real thing, overpressured with hydrogen, and heated to the actual process temperatures.

The problem with the rig in not simulating the letdown valve particularly well is that we don't dissolve hydrogen to the extent that it's dissolved in the plant, so that the assistance given to the slurry velocity, when the hydrogen flashes off, doesn't actually occur in this rig. By controlling the pressure drop across the orifice to simulate the pressure drop seen in the plant, however, the slurry velocity is made to match the mass flow through the real valve.

The specimen end after erosion is shown in Figure 14-18. In this case, the slurry has impinged on the surface and drilled a hole; you also can see some of the worn surface. The most expedient and realistic way we have found for evaluating this sort of erosion is to make a surface profile traverse across the damage and to take the maximum depth of penetration as being representative of the material. Figure 14-19 shows the traces across erosion craters for different angles of impingement. These are longitudinal traces and the arrow shows the direction of the flow of the slurry. For a given material, the shape of the hole changes with angle.

We've tried to look at a comparison of volumes of material eroded, but while this is probably scientifically more accurate, and more meaningful, it is too tedious and expensive. In addition, we have found that volume gives the same order of correlation between materials as does maximum depth so we use maximum depth.

The information that we have been generating recently, which we feel will be of most use to valve designers and people who apply these materials, is shown in Figure 14-20. This is a plot of maximum erosion depth as a function of angle of impingement on cemented tungsten-carbide K701. The response of erosion to angle is actually fairly close to the classical way in which brittle materials are supposed to respond to erosion. Erosion increases with increasing angle, until, at 90 degrees, there is what appears to be a maximum erosion rate for this material. Figure 14-21 is a plot of similar data for KZ701. The Z stands for the material having been hot-isostatically pressed (HIP). The advantage is that the HIPed material should have full density and much more reproducible properties. In fact, there does not appear to be much difference between the angular response of this material and the standard K701 grade.

The effect of velocity on erosion is shown on Figure 14-22 for a given angle of 50 degrees; as can be seen, the velocity dependence is extremely powerful. These data indicate that erosion of these materials is proportional to velocity raised to the power 3.6, which means that if you can reduce the velocity, by any means, you can exert a large influence on the erosion rate.

This power here is not really what one expected, because from classical erosion work, a power more like 2 (erosion proportional to velocity squared) is more usual. In fact, we find 3.6 or thereabouts for most of the materials we have looked at in this class of cermets.

Using some of this information, Wilsonville has applied K703 (Figure 14-23), which has the lowest binder content, 7%, that is commonly available. Using K703 for both the plugs and the seats, Wilsonville has obtained lives for at least three sets of materials, on the order of 3,000 hours, which is quite acceptable.

In an attempt to discover if any of the available advanced ceramic materials were more erosion-resistant than the cemented tungsten carbides, we performed a series of screening tests, some results of which are shown in Figure 14-24. K701 was used as a standard and there weren't many materials that even matched its performance. The hot-pressed silicon carbides that we tested were not very resistant. Boron carbide showed good potential though, as did some reaction-sintered silicon carbide, and silicon-carbide coatings formed by chemical-vapor deposition. In fact, the best material under these conditions of a 20-degree angle, 466 feet per second, was a consolidated diamond product. While expensive, the diamond has proved a practical proposition if available in large sizes. A significant result of these tests was that the standard K701 has very good erosion resistance.

Figure 14-25 shows further screening data under slightly different conditions, at a different angle, 45 degrees, where most of these materials erode faster. Again, K701 looked good compared to almost all the other materials that are shown, with the exception of fine-grained, hot-pressed boron carbide and hot-pressed titanium carbide. The CUD coatings were not tested at this angle.

We have recently generated the same sort of curves that were generated for the cemented tungsten carbides, and, in fact, the angular response of erosion of sintered boron carbide (Figure 14-26) is fairly similar to that of cemented tungsten carbide, which is a surprise. The velocity dependence for boron carbide is shown in Figure 14-27, and in this case, the erosion was proportional to the velocity raised to the power of 2.4, which is less than for the cermets but is still a powerful effect.

Problems that can lead to trouble when considering the use of ceramics as opposed to cermets (the cemented tungsten carbides) are illustrated in Figure 14-28, which compares the erosion behavior of different samples of alumina ranging from hot-pressed, through sintered to sapphire, to hot-isostatically pressed. The erosion rates vary all over the place. Attempts to determine the reasons for such variations have not provided any simple answers. Similarly, for silicon-carbide types (Figure 14-29), two versions of hot-pressed silicon carbide behave quite differently and there is an even more marked difference between reaction-sintered silicon carbide. In contrast, most CVD silicon carbide coatings seem to be reproducibly good. The difference between reaction-sintered silicon carbide actually illustrated the difference between two lots having different ranges of particle size from the same manufacturer.

The way in which a surface erodes might also be important in determining how the material is applied in service. Figure 14-30 shows profiles across the erosion tracks on three materials. The standard K701 surface is shown at the bottom of Figure 14-30. It erodes to give a relatively uniform channel and the maximum depth of erosion that we measured would be a meaningful parameter here. Similarly, boron carbide (the top profile on Figure 14-30) erodes uniformly. However, the reaction-sintered silicon carbide (middle profile) eroded in a very irregular manner, and the erosion depth that we would measure would be down one of the penetrations. Erosion of this material tends to remove the free silicon from between the silicon carbide particles in the surface to give very fine narrow channels such that, even if this material is eroding at a nominally slow rate, the channels would cause the valve to leak even in the fully-closed position. In contrast, a uniform eroding material like boron carbide would still be able to form a seal, even though it eroded at a faster rate.

A preliminary attempt was made to demonstrate that some of these ceramics could perform in the plants themselves, and Figure 14-31 shows an attempt to replace the K701, K703 plugs with ceramic plugs in the Wilsonville facility. A ceramic shape was designed that could be fixtured to produce a plug that could replace the standard K701-type plug, with a minimum of changes to the valves.

The problem with these ceramic materials is that they are extremely brittle, and careful attention should be paid to the detailed design of the part. If necessary, the design of the actuator and the stem should be modified to take into account the limitations of the ceramic materials. In this case, simply cycling the valve within the tolerances given in the valve, and the movement during assembly of the valve, has been sufficient to cause fracture of these materials where the section change occurs on the stem.

To summarize, in choosing materials for erosion resistance (Figure 14-32), we need to consider the erosion resistance, but also the handleability and the unfamiliarity of the materials. The engineers involved are used to

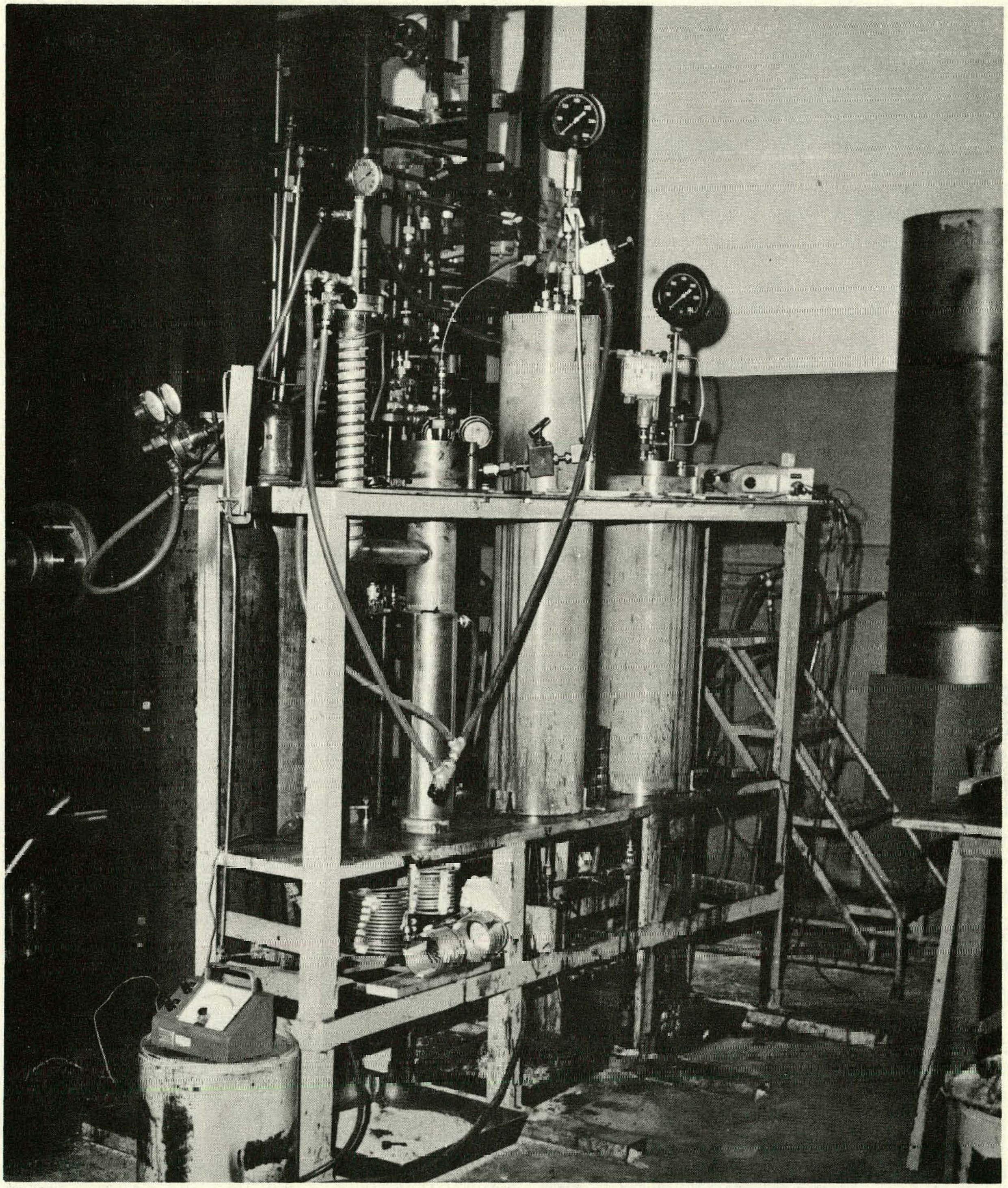


Figure 14-15. Overall View of BCL Slurry-Erosion Test Rig

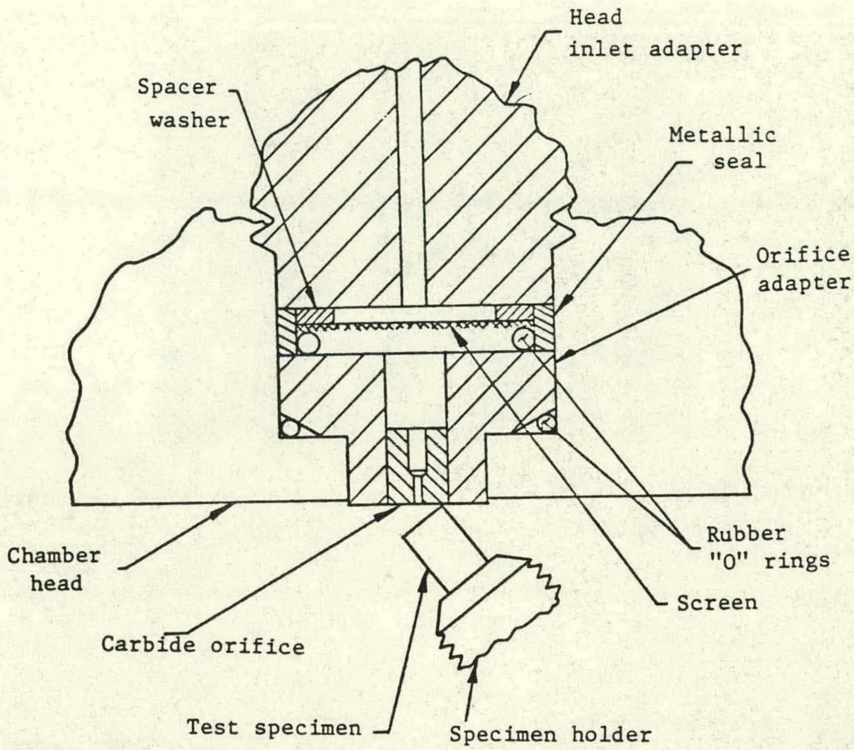


Figure 14-16. Schematic of Orifice and Specimen Arrangement

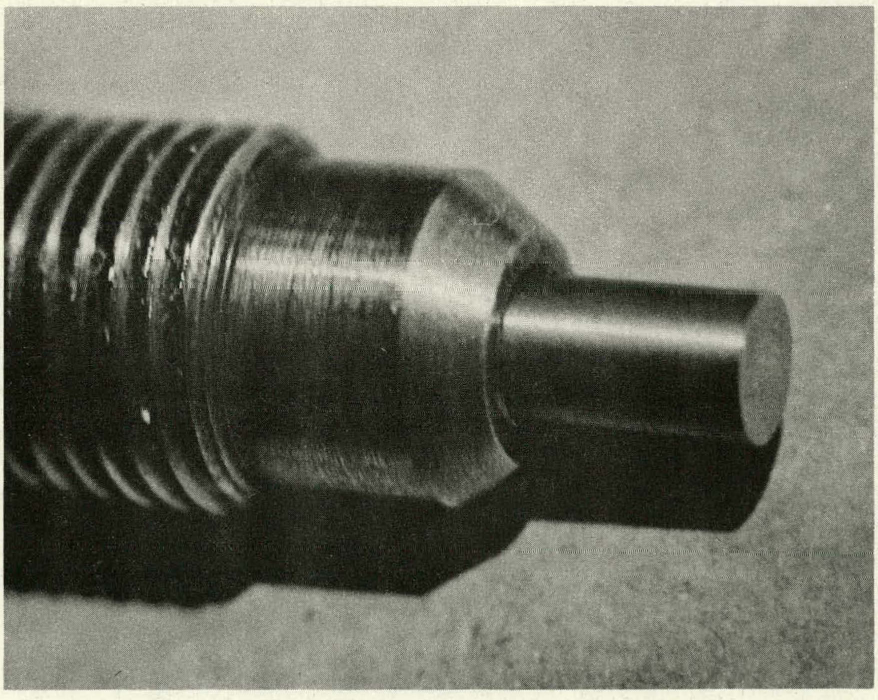


Figure 14-17. View of Test Specimen in Holder

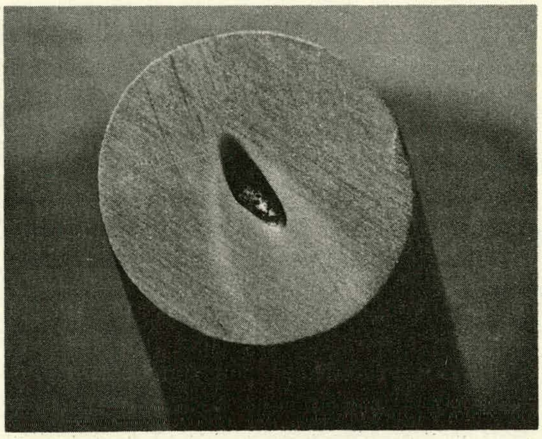


Figure 14-18. Typical Erosion Crater in Cast Stainless-Steel Test Specimen from BCL Erosion Rig

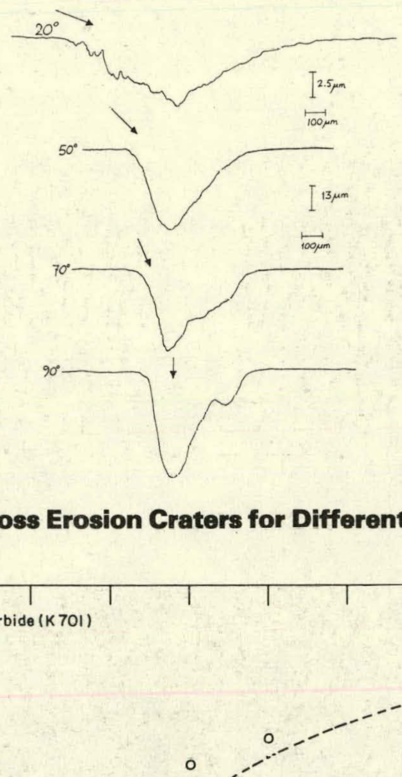


Figure 14-19. Traces Across Erosion Craters for Different Angles of Impingement

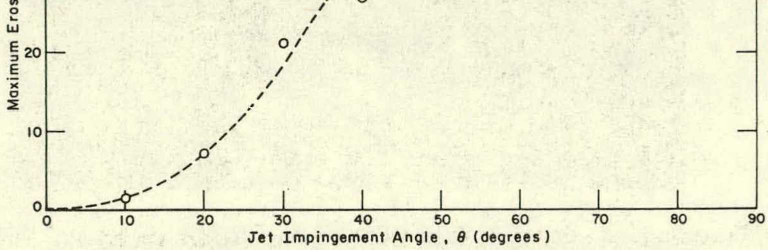


Figure 14-20. Cemented Carbide (K701) Impingement Angle Versus Maximum Erosion Depth

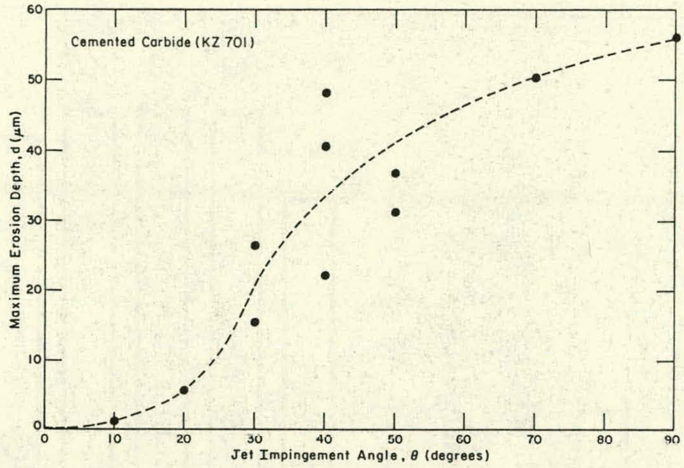


Figure 14-21. Cemented Carbide (KZ 701) Impingement Angle Versus Maximum Erosion Depth

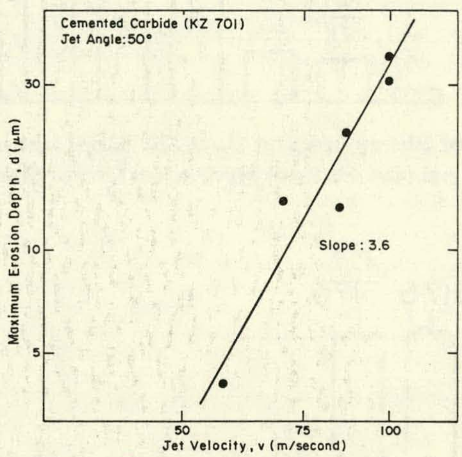


Figure 14-22. Cemented Carbide (KZ 701) Jet Velocity Versus Maximum Erosion Depth

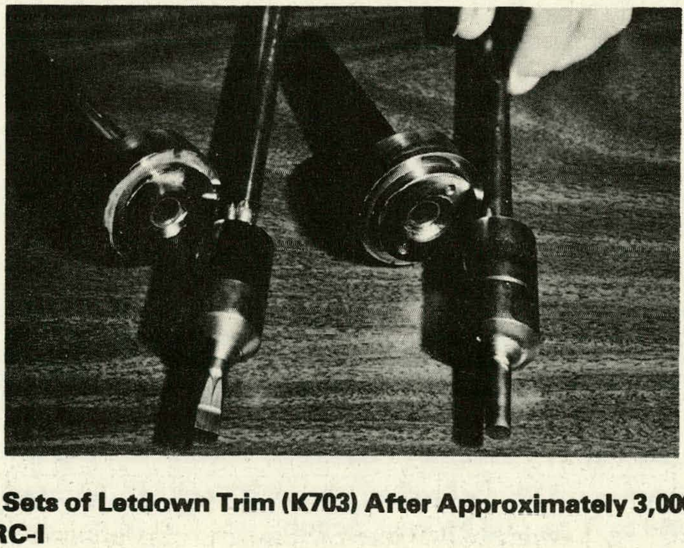


Figure 14-23. Two Sets of Letdown Trim (K703) After Approximately 3,000-Hr Service Each In SRC-I

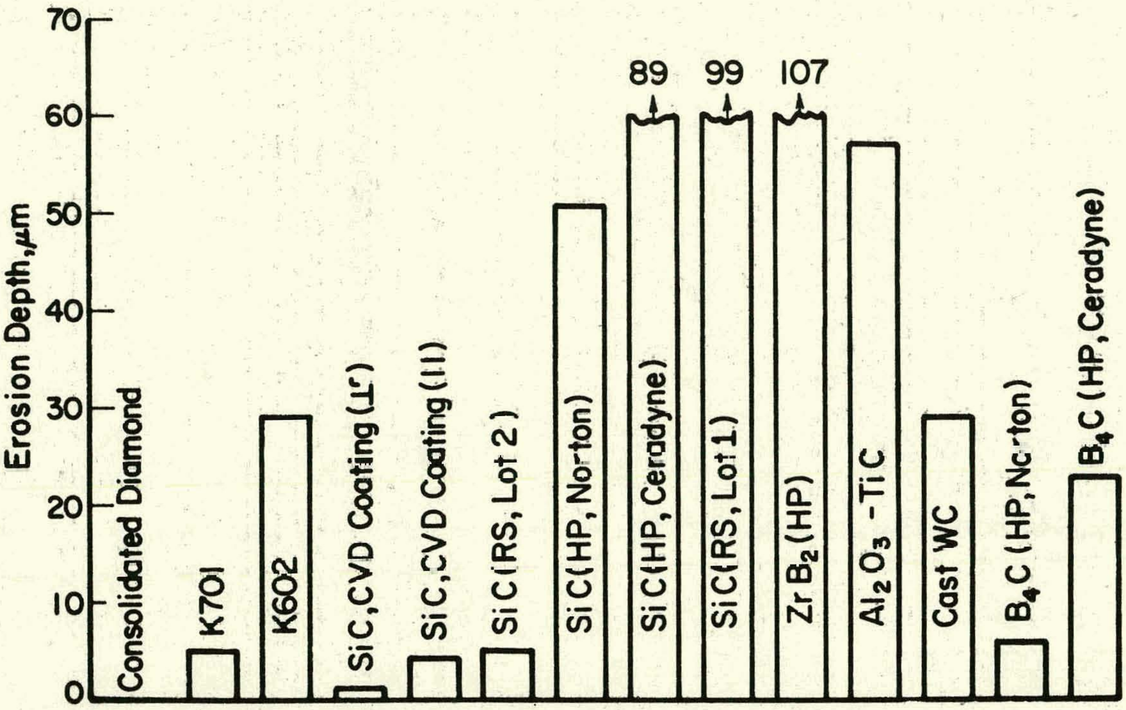


Figure 14-24. Summary of Slurry Erosion Data, 20° Coal Ash-Anthracine Slurry, 650°F, 2000 to 100 psi (466 Ft/Sec) Hydrogen Driver Gas

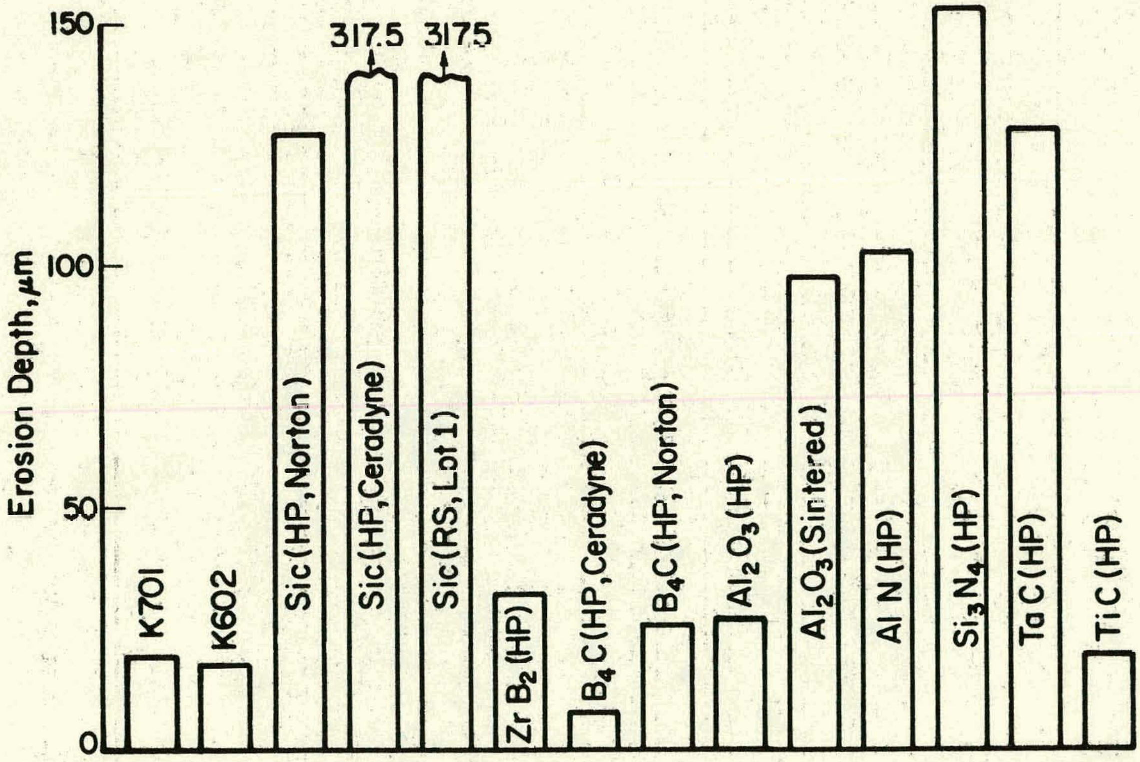


Figure 14-25. Summary of Slurry Erosion Data, 45° Coal Ash-Anthracine Slurry, 300°F, 2,000 to 75 psi (367 Ft/Sec), Argon

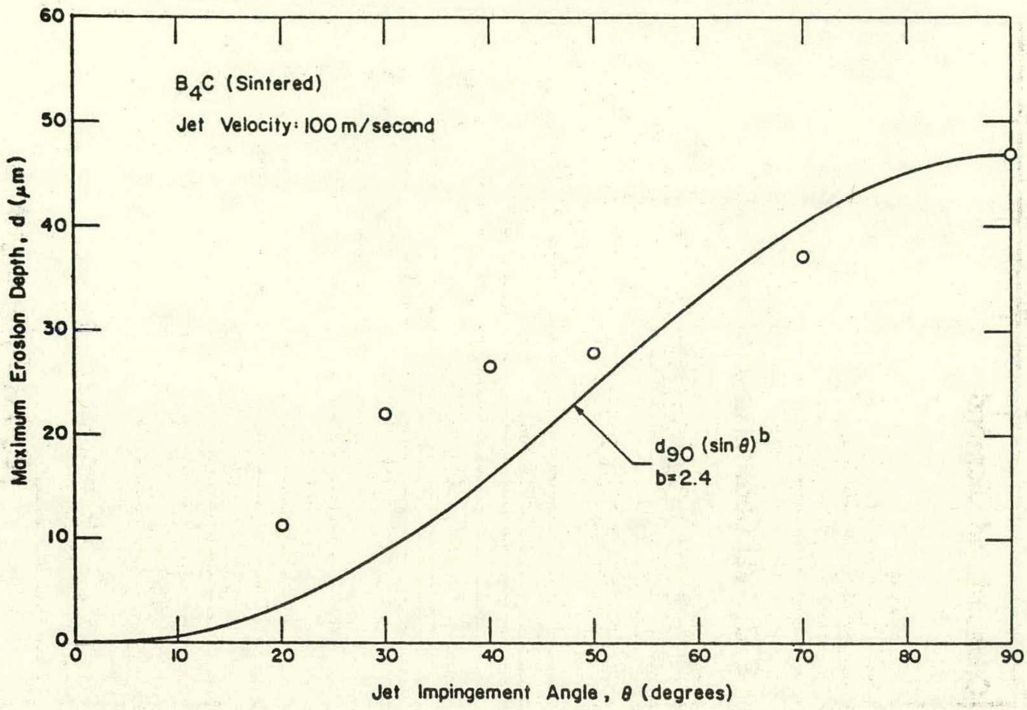


Figure 14-26. The Effect of the Slurry Jet Impingement Angle on the Erosion Rates in Sintered B_4C (Norton Norbide)

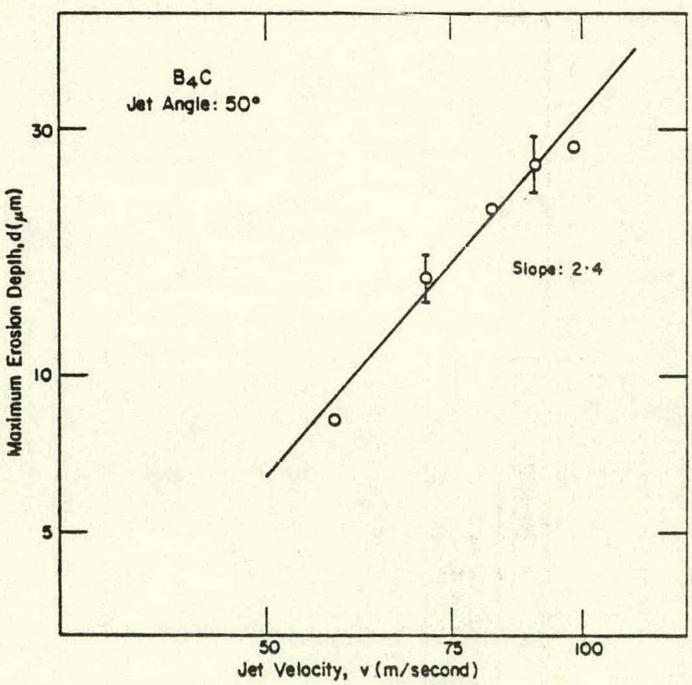


Figure 14-27. Maximum Crater Depths as a Function of the Coal Slurry Jet Velocity for a Boron Carbide at a 50° Jet Impingement Angle

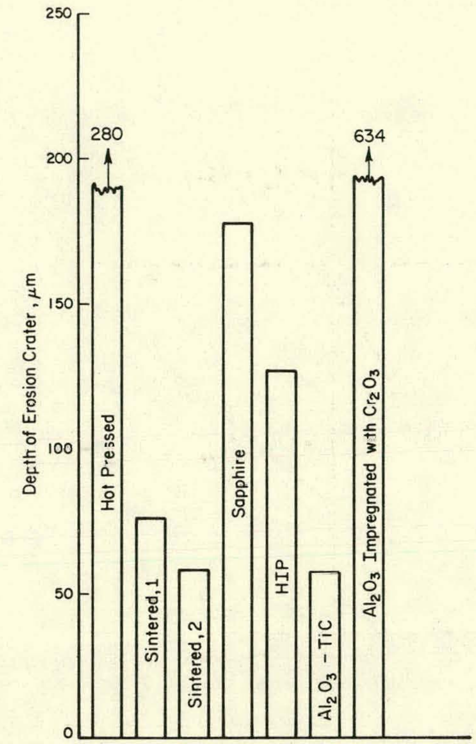


Figure 14-28. Summary of Slurry Erosion of Al_2O_3, Coal Ash/Anthracine, 20°

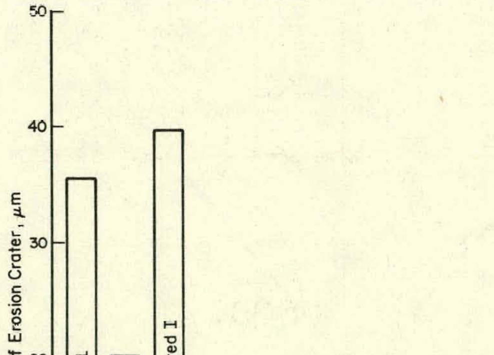


Figure 14-29. Summary of Slurry Erosion of SiC, Coal Ash/Anthracine, 20°

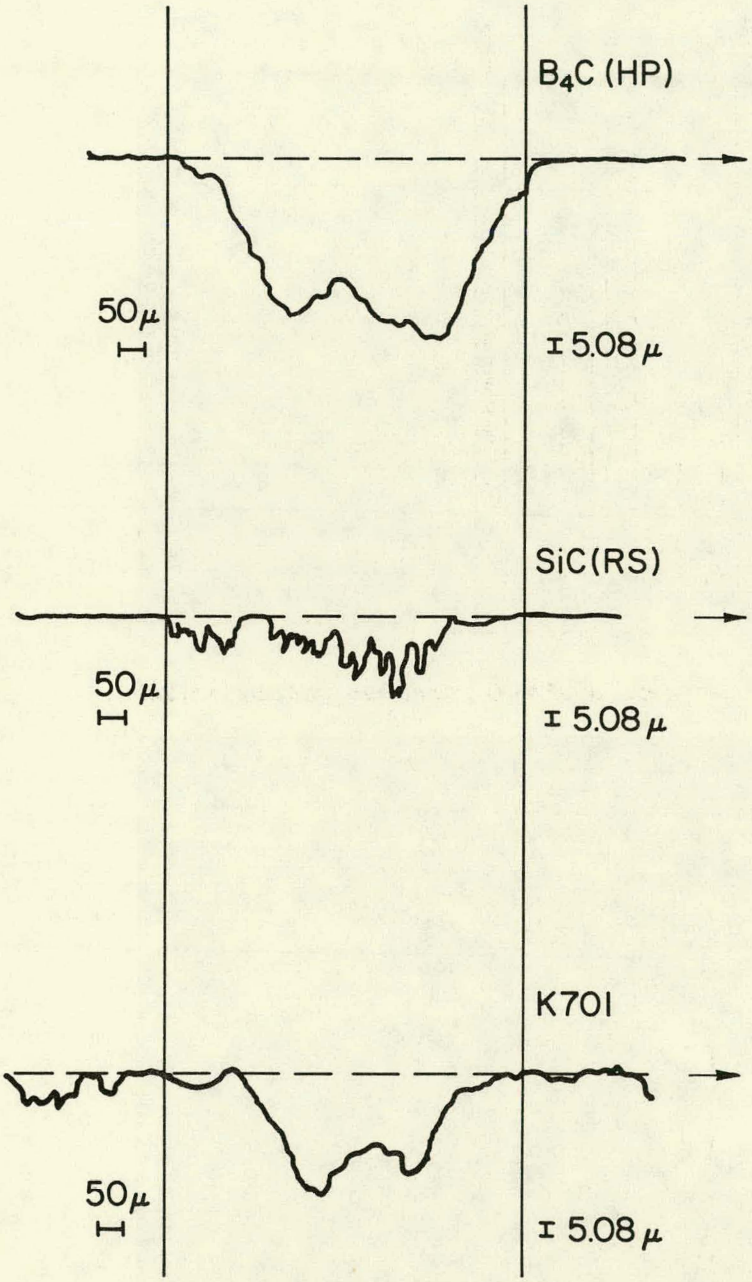
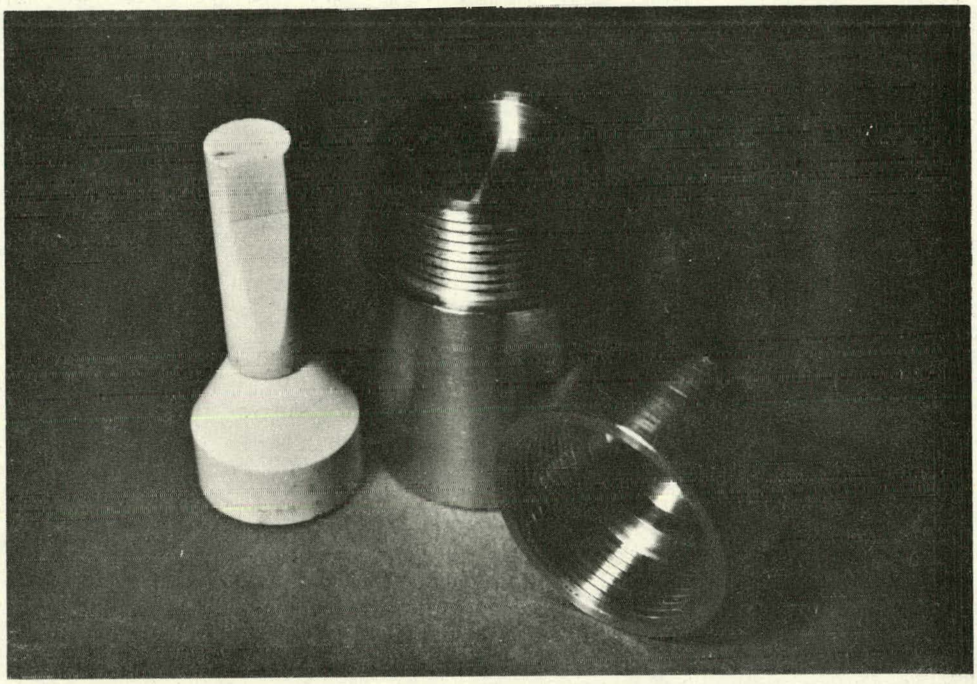


Figure 14-30. Comparison of Erosion Crater Traces



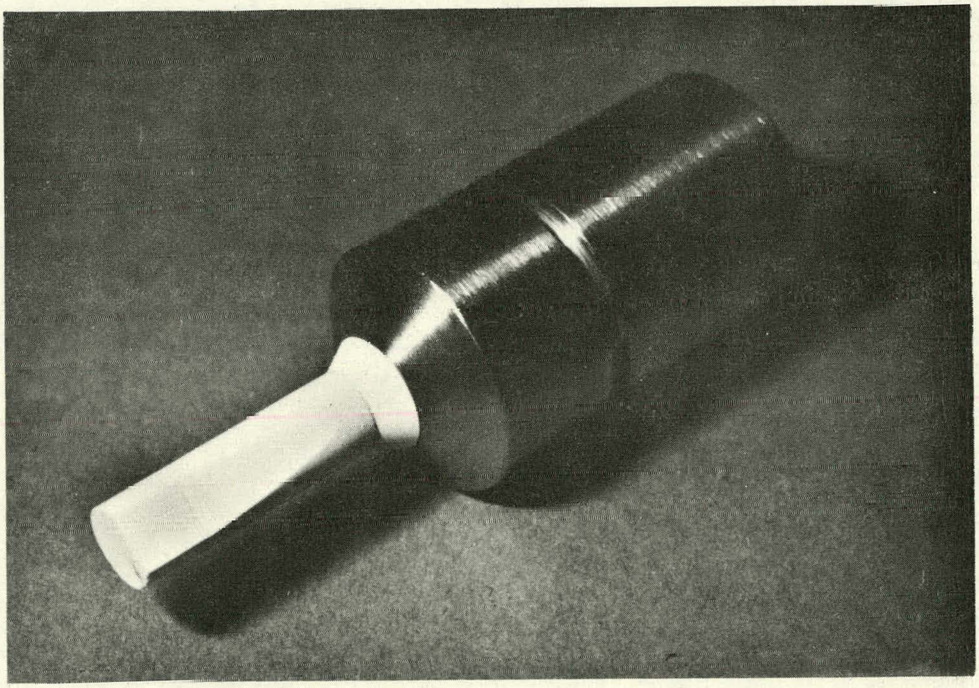


Figure 14-31. Fabrication of Ceramic Test Plugs for SRC-I

handling materials that can be hit with a hammer. Ceramics and some cermets cannot even be dropped. Consideraton must also be given to changing the design of the valve to allow for some of the shortcomings. Additionally, although materials might be developed that have extremely good erosion resistance like CVD silicon carbide, we also need to take the cost and availability into account. It may well be preferable to have a material that erodes at a known finite rate than to have one that erodes extremely slowly but is not a stock item.

Conclusions

- Need to Consider — erosion resistance
  handleability
  applicability
  cost
- Simple Laboratory Erosion Test Useful
- Cemented WC Materials Possess Good Combination of Properties
- Ceramics — many forms, not-standardized
  significant differences in generic types
  SiC has good potential
- A Given Test Result Should Not Be Used To Typify Expected Behavior of a Generic Type Of Material

Figure 14-32. Choosing Materials for Erosion Resistance

Simple laboratory erosion testing is useful and quite essential in trying to screen materials and to show differences between different grades and different batches.

For the severe letdown applications, cemented tungsten carbides are indeed extremely good materials. Of the ceramics, many forms are available but most are not standardized. Reportedly erosion-resistant ceramics such as reaction-sintered silicon carbide are in practice very valuable, so that some sort of qualification test is required for each batch. There are significant differences between generic types of material; however, silicon carbide in some reaction-sintered and CVD forms looks to have extremely good potential.

Figure 14-33 shows the needs for both the new materials and for the materials in general that have potential for use in valves. We need information that tells something about erosion rate as a function of angle and velocity, at least, in order to determine which types of materials to select, how to apply them, and where to apply them. We need a standardized low-hazard laboratory test, which we are trying to address in our current program. We need a correlation of the ranking that's obtained in a laboratory with actual testing service, but this might be one of those things that we chase and never attain.

In order to progress to improved materials, we need a better understanding of materials behavior; the screening work must be supplemented with an understanding of how these materials fail in erosion. If we know how the materials degrade, then we can perhaps tell the manufacturer something about how or what they should do to manufacture a better material. And, finally, the mechanism of technology transfer, which is the aim of this meeting, is an extremely neglected area that must be improved.

NEEDS

- EROSION RATE VS. MATERIAL/ANGLE/VELOCITY DATA TO ASSIST MATERIALS SELECTION/VALVE DESIGN.
- STANDARDIZED, LOW HAZARD LABORATORY TEST
- CORRELATION OF RANKING, IF NOT RATE, OF LABORATORY TEST WITH ACTUAL SERVICE
- BETTER UNDERSTANDING OF MATERIALS BEHAVIOR
- TECHNOLOGY TRANSFER

Figure 14-33. Future Directions

Discussion of Paper by I.G. Wright

QUESTION: Does surface finish seem to have anything to do with erosion?

WRIGHT: Our experience is that it does appear to have an influence on erosion in all conditions except the most severe. Unfortunately, most of our work has been at extremely severe conditions.

QUESTION: What material did you use for the orifice?

WRIGHT: That was a machining grade of cemented tungsten carbide that was not the best choice for erosion resistance. The orifice is measured after each test, and has been found to wear extremely slowly, probably because the slurry stream is collimated by the time it reaches the exit of the orifice, and impinges the orifice at a very low angle.

QUESTION: How long a straight section of plugs do you have before it enters the orifice?

WRIGHT: Not long enough according to hydrodynamic calculations.

QUESTION: Do you attempt to correlate temperature?

WRIGHT: No. The work we have done has only been under conditions designed to simulate the plant conditions themselves.

QUESTION: Do you do any test work with Stellite?

WRIGHT: Yes, we have done some work on metallics under less-severe conditions to provide information for pump designs. Metallics under these conditions, 360 to 460 feet per second, just don't last at all, and are penetrated in a few minutes. Stellite 6 does not appear to resist erosion in this test any better than the cast stainless steels, for instance. Again, we've only looked at it under a very limited number of conditions.

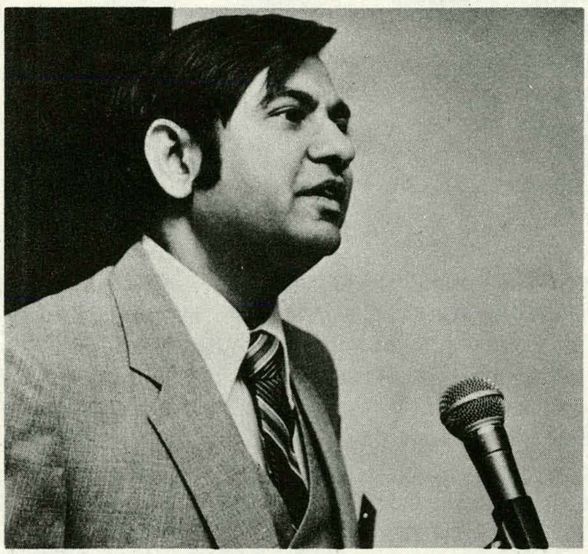
QUESTION: Have you done any work on the refractories for large valves?

WRIGHT: No. The program is directed solely at the letdown valves and so the conditions, the severe conditions, used are from that source.

QUESTION: Do you have any data that might indicate whether the exponents of velocity are a function of the impingement angle?

WRIGHT: No. It was an arbitrary choice to pick 50 degrees. These measurements are obviously needed at some stage. But we haven't made them yet.

A Lively Discussion During Break . . .



Section 15

Wear Mitigation In Valves For Coal-Conversion Systems

Kirit J. Bhansali, Metallurgist
National Bureau of Standards

October 17, 1980 — 10:15 a.m.

Abstract

Valves used in coal-conversion systems are often subjected to extremely hostile conditions. In most cases, valves are required to handle fluids containing solid coal particles or other harsh products derived from coal at either high temperature or high pressure or both. Past experience in the pilot-size plants has indicated that useful life of valves has been severely affected by the materials used. Erosion/corrosion of valve bodies and trim, galling, and seizing or breakage of the moving parts are examples of the type of problems encountered. Materials-design criterion for controlling wear are discussed. An overview of the state-of-the-art laboratory wear tests is presented and some of the results are discussed.

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Introduction

Wear of materials is a subject that has not received a widespread attention of scientific investigators in the past. As a result, many classifications of wear exist and the terms used are often ill-defined and descriptive as shown in Figure 15-1. This list is by no means all inclusive of various terms used today. There must be one to three different tests pertaining to each of these terms. Hence, it could be extremely confusing for a person to select a test pertinent to his application. Furthermore, very few of the tests are standardized which is one reason why the National Bureau of Standards is getting involved in this field. In this paper, a simplified approach to classification of wear systems will be presented. A number of laboratory tests believed to be relevant to valve manufacturers will be described. Finally, results of some of the valve tests will be presented.

WEAR

Adhesive	Seizing	Oxidative
Abrasive	Galling	Metallic
Erosive	Rubbing	Impact
Corrosive	Scratching	Fatigue
	Scoring	Fracture
Mild	Scathing	Cavitation
Severe	Gouging	Impingement
	Sliding	Surface Fatigue

Figure 15-1. Classifications and Terms Describing Wear of Materials

A simplified classification of wear systems is presented by many investigators as follows: adhesive, abrasive, erosive, corrosive, surface fatigue, and combinations of the preceding.

Adhesive wear usually occurs during metal-to-metal contact when surface asperities interact to form a wear particle during sliding. Wear due to the cutting action of hard particles under load is termed abrasive wear. The cutting action resulting from the kinetic energy of the particles suspended in a gaseous or liquid medium is termed erosive wear. When the wearing surface is chemically attacked, corrosive wear results. Surface fatigue is usually accompanied by the formation of a pit due to the growth of a surface crack owing to repeated cyclic stresses. Another term called "galling" is used to describe a form of a surface damage that occurs during sliding metallic contact accompanied by material transfer from one point to the other. In this case, the amount of material lost as measured by weight loss may be negligible or nil. However, the particular component would be rendered useless due to galling and hence it is a very important form of wear for valve application.

Valves have a basic function of controlling or isolating flow of fluid from one part to the other. In order to achieve this, there is a seal of some kind which should not leak. The best valve is the one that leaks the least. In order to achieve tight seals at very high stresses and/or at elevated temperatures, the seating surfaces are often made out of metals. Thus, there is metal-to-metal contact. If the metallic materials used are prone to galling, material transfer will occur during the first few actuations. The transferred material will prevent a tight seal, resulting in valve leakage. If this leakage continues and a sufficient pressure differential is present, a very high velocity jet can result and erosion would become a major problem (this damage is quite often called wire drawing).

In addition to the specific type of wear resistance, hardness, formability, impact resistance, and of course cost are also important factors. When all these factors are considered, it gets a little complicated to select an alloy. The rest of the discussion will be limited to presenting what one has to look for in an alloy in terms of abrasion resistance, galling resistance, metal-to-metal wear resistance, hot hardness, corrosion resistance, and impact resistance. Typical laboratory wear test and results will be described.

Wear Tests and Results

Figure 15-2 shows a schematic of a metal-to-metal wear tester. This particular test, called LFW-1 test, is more frequently used by lubrication engineers to evaluate lubricants. Of course, in lubricated wear situations, metal itself plays a minor role. Most people tend to ignore the role of metals in lubricated wear, but the kind of alloys used become important when lubricants fail. In this particular test, the block is made out of the material to be tested, and typically the ring is carbonized 4620 steel, with a hardness of Rc 65-66. The ring is typically rotated at 80 rpm for 2,000 revolutions and the amount of material worn or wear rate of the alloys is calculated from the weight-loss measurements.

In this particular test, cobalt-based alloys appear to be worse than nickel-based alloys. This particular test has very poor applicability to most valve manufacturers, because this particular test ignores the typical service, where a valve is actuated and reseated, and is not used for a long time and is reactuated. Such off-and-on type service is not taken into consideration here. Due to the nature of the test, a lot of frictional heat is generated during the test which changes the interface and relevant applicability of this test for valves.

Figure 15-3 shows a test used for measuring galling resistance. In this particular test, a pin and a block are made out of the alloy couple that one wants to evaluate. Using a test machine, a normal load is applied and the pin is turned one revolution. The wear scar is then observed for galling surface damage. If there is no damage, the load is increased until such damage is observed or the yield strength is exceeded. If the material does not show any galling damage up to the yield strength of the material, then it is called galling resistant; this limit is chosen because one would very rarely be expected to use a material very close to its yield strength.

On the other hand, if very heavy surface damage is observed, the applied load is lowered until the surface damage is not seen. The minimum stress at which galling is observed

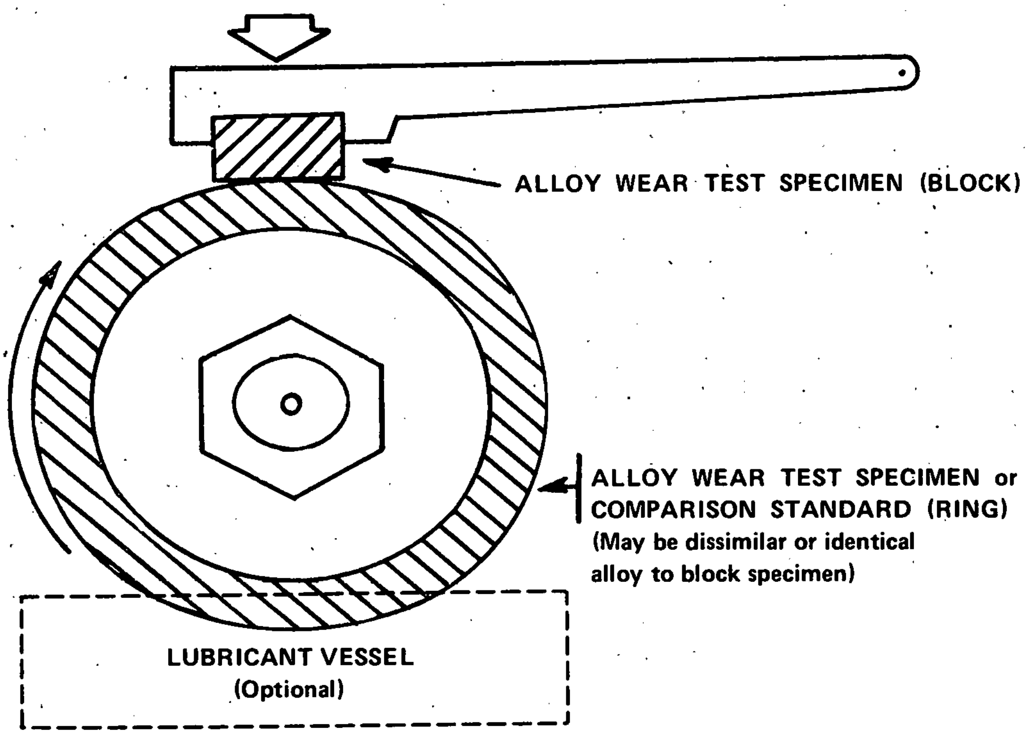


Figure 15-2. Adhesive Wear Test Unit (Metal to Metal)

is called the threshold-galling stress. Figure 15-4 shows some typical results. These tests were conducted at Cabot Corporation when I was working for them on a program for replacement of cobalt-based alloys.

It can be seen that the cobalt-based alloys do not gall. Nickel-based alloys, on the other hand, gall at very low stresses. Some of these nickel-based alloys even have higher hardnesses than some of the cobalt-based alloys. Hardness, thus, does not correlate well with galling resistance. Iron-based austentic stainless steels are quite well known for their poor galling resistance.

Figure 15-5 shows an abrasive wear test. In this particular test, a rubber-lined steel wheel is rotated at 200 rpm, and AFS 50-79 rounded silica test sand is fed through a hopper at 110-120 grams per minute. The sample fits in the test unit and typically a 30-pound load is applied. This particular test is also called a low-stress scratching test or dry-sand rubber-wheel abrasion test. The reason it is called low stress is because the sand supposedly does not crack during the process. The rubber, presumably, absorbs the force to the point that it does not let the stress in the sand particles exceed the crushing strength of the sand. This particular test correlates well with many applications where abrasion is a major problem. Recently, a standard has been written for this particular test by ASTM Committee G-2 on erosion and wear. As one would expect, a correlation exists between abrasion resistance and hardness of the material. However, it is not a linear correlation. The path taken to achieve the hardness is also very important.

Figure 15-6 shows abrasive-wear resistance versus hardness for a group of alloys. It shows abrasion resistance of cobalt- and iron-based alloys with different amounts carbides. As can be seen, a linear relationship is observed for cast cobalt-based alloys and a different line is obtained for cast iron-based alloys. This is very important because to a lot of people hardness and wear resistance are synonymous. From Figure 15-6 it is evident that cobalt-based alloys would provide similar abrasion resistance at much lower hardness than the iron-based alloys. In addition to hardness, how this hardness is achieved is also very important. For example, finer carbides in an alloy would result in higher hardness but would not provide as good an abrasion resistance. To summarize, when the relative amounts of carbide to matrix in an alloy are increased, the abrasion resistance is increased.

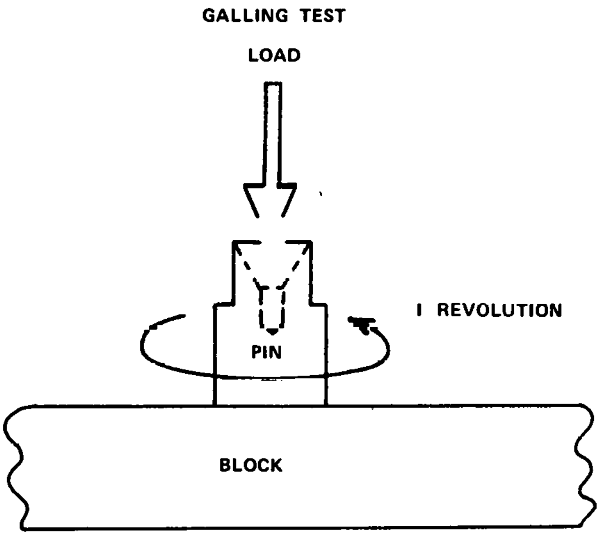


Figure 15-3. Schematic of Galling Test

Typically, one wants to compile the type of data such as shown in Figure 15-7, which provides hot hardness, adhesive wear, abrasive wear and galling resistance, impact resistance, weldability and corrosion resistance for some widely used commercial hardfacing alloys. For hot-hardness, a high amount of solid solution strengthening as provided by Co-Cr-W alloys is desired. This is where cobalt-based alloys exhibit their superiority to iron-based alloys, because most iron-based alloys will start softening around 1000 °F. As can be seen that at 1400 °F, metals that are highly alloyed with tungsten or molybdenum have much higher hardnesses than those without tungsten or molybdenum; e.g., Alloys 6, 12 and 1 compared to Haynes Alloy 40.

As can also be seen as carbide content is increased abrasive wear resistance is increased but impact resistance is lowered. The carbides act as internal notches or crack initiators and hence the impact resistance is decreased. For corrosion resistance, iron-based alloys are not preferred; in general, high amounts of chromium and molybdenum or tungsten are desired.

Based on these tests and some basic metallurgical considerations, Cabot Corporation tried to come up with an alloy that would match the wide range of properties of cobalt-based alloys. A nickel-based alloy, Haynes Alloy N-6, is considered to be equivalent to Haynes Stellite Alloy 6. This experimental alloy matches very closely to Alloy 6 in hot hardness, corrosion, impact abrasion resistance, and adhesive wear resistance but it does not match in the galling resistance. This alloy along with Nitronic-60 and Haynes Stellite Alloy 6 were evaluated in a leak test for gate valves. Figure 15-8 provides some of the data on composition of these alloys. As can be seen, Nitronic-60, which is an austenitic stainless steel, contains virtually no carbides. The structure is basically austenite. Microstructurally Haynes Alloy No. 6 is identical to Haynes Stellite Alloy 6.

Figure 15-9 shows the leak rate versus the number of cycles for a 1-inch gate valve. The valves were seated with 180 inch-pounds of torque and leak was tested with 100-psig nitrogen. A valve made out of Haynes Stellite Alloy 6 started out at a very high leak rate, and it decreased to virtually zero leak rate. Alloy Nitronic-60, on the other hand, had zero leak rate from the beginning whereas Haynes Alloy N-6 remained at a very high leak rate, even after 10,000 cycles.

Figure 15-10 shows the condition of the valve made out of Haynes Stellite Alloy 6 after the test. There is very little surface damage or galling or scoring. A small amount of surface damage is observed in one area but it is negligible. The valve in Figure 15-11 is made out of Haynes Alloy N-6, the nickel-

COBALT-BASE	
HAYNES STELLITE Alloy No. 6	>72
HAYNES STELLITE Alloy No. 12	>72
HAYNES STELLITE Alloy No. 1	>72
TRIBALOY Alloy T-400	>72
TRIBALOY Alloy T-800	>72
NICKEL-BASE	
HAYNES Alloy No. 711	27
TRIBALOY Alloy T-700	27
HAYNES Alloy No. 40	24
HAYNES Alloy No. 41	9
N-1	9
FE-BASE	
304	18
316	18

Figure 15-4. Threshold Galling Stress (KSI), Self-Mated Alloy

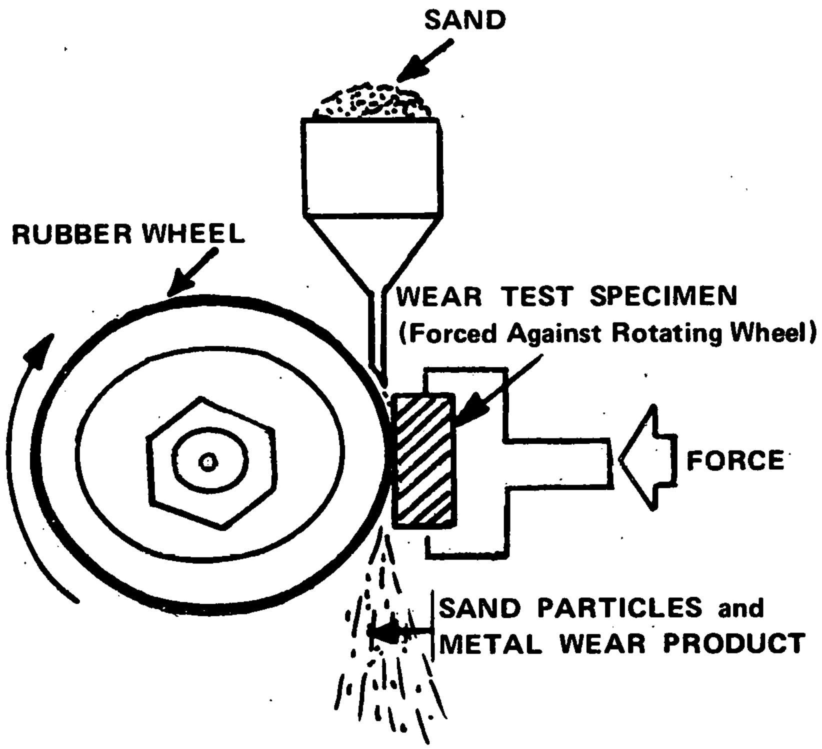


Figure 15-5. Abrasive Wear Test Unit (Dry Sand)

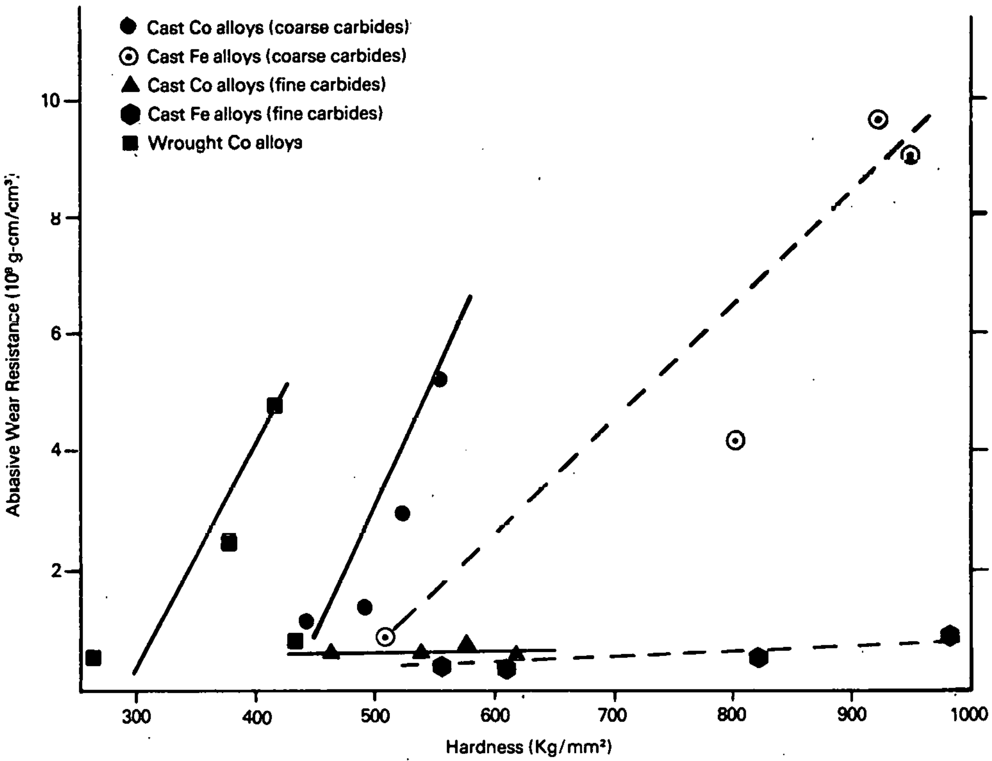


Figure 15-6. Abrasive-Wear Resistance Versus Hardness for a Group of Alloys

	COMMERCIAL ALLOYS						NEW ALLOYS					
	21	6	1	40	T-400	T-800	711	716	721	N-1	N-6	T-700
THRESHOLD GALLING STRESS (ksi)												
1020 Steel	18	36	18	18	36	>72	36	36		13	36	18
316 Stainless Steel	18	18	18	18	18	45	36	18		13	18	18
HASTELLOY alloy C-276	18	9	18	9	36	27	18	18		13	36	9
HAYNES STELLITE alloy No. 6	>72	>72	>72	18	>72	>72	36	>72		>72	>72	>72
IMPACT STRENGTH (FT-LBS)												
Unnotched Charpy	>18	17	4	2	3	1	2	11	16	2	10	1
MAXIMUM CRACK FREE TIG DEPOSIT WITH NO PREHEAT (inches)	1	0.5	0.2	–	–	–	0.1	0.3	0.3	–	–	–
OXYACETYLENE WELDABILITY*	2	10	9	7	3	2	8	9	–	7	4	2
CORROSION RESISTANCE												
30% Boiling Acetic Acid	E	E	G	U	E	E	E	E	E	E	E	E
65% Nitric Acid 66°C	–	U	U	U			U	U	E	G	S	S
5% Sulfuric Acid 66°C	E	E	E	U			U	U	E	U	E	E
50% Phosphoric Acid 66°C	E	E	E	U			U	U	E	–	–	E

*HAYNES STELLITE alloy No. 6 = 10

E–Excellent <5 mpy
G–5 to 20 mpy
S–20 to 50 mpy
U– >50 mpy

Figure 15-7. Various Characteristics of Hardfacing Alloys

	COMMERCIAL ALLOYS						NEW ALLOYS					
	HAYNES STELLITE alloy			HAYNES alloy	TRIBALOY alloy							
	No. 21	No. 6	No. 1	No. 40	T-400	T-800	711	716	721	N-1	N-6	T-700
BASE	Co	Co	Co	Ni	Co	Co	Ni+Fe+Co	Ni+Fe+Co	Ni	Ni	Ni	Ni
ALLOY TYPE	Carbides	Carbides	Carbides	Borides	Laves Phase	Laves Phase	Carbides	Carbides	Carbides	Borides	Carbides	Laves Phase
ALLOYING ELEMENTS	Cr, Mo	Cr, W	Cr, W	Cr, Si	Cr, Mo, Si	Cr, Mo, Si	Cr, Mo, W	Cr, Mo, W	Cr, Mo, W	Cr, Si	Cr, Mo, W	Cr, Mo,W
HARDNESS R_c	20	42	54	57	55	58	41	32	30	42	38	48
HOT HARDNESS (DPH)												
800°F	150	300	510	555	604	659	380	295	220	365	365	500
1000°F	145	275	465	440	499	622	335	285	215	310	345	485
1200°F	135	260	390	250	400	490	300	240	220	185	310	400
1400°F	115	185	230	115	249	308	215	190	160	100	190	280
ABRASIVE WEAR VOLUME (mm^3)												
OA	–	29	8	12	–	–	26	23	–	12	12	–
TIG	70	66	46	11	66	24	26	63	70	17	50	43
ADHESIVE WEAR VOLUME (mm^3)												
LOAD 90 lbs	2.5	1.1	0.6	0.1	0.75	1.03	0.1	0.1	0.23	0.23	0.1	0.07
150 lbs	5.2	2.6	0.6	0.2	1.27	1.75	0.2	0.2	0.47	0.61	0.2	0.09
210 lbs	10.3	9.5	0.7	0.2	1.64	2.2	0.3	0.4	0.5	0.62	0.2	0.20
300 lbs	14.5	18.8	0.8	0.3	1.73	2.2	0.4	0.6	1.5	0.81	0.4	0.28

Figure 15-7. Various Characteristics of Hardfacing Alloys (Continued)

	ALLOY 6	NITRONIC 60	N-6
Co	Bal	—	—
Ni	—	—	Bal
Fe	—	Bal	—
Cr	28	8.5	29
C	1.1	0.1	1.1
Si	1.0	4	1.0
Mn	1	8	1
W	4	—	4 (W-1 Mo)
N	—	0.12	—
Structure,	Carbides in Austenitic Matrix	Austenitic Matrix	Carbides in Austenitic Matrix

Figure 15-8. Composition of Alloy 6, Nitronic 60, and N-6 Alloys

based alloy. Massive plastic deformation on the surface called "galling" is observed. Figure 15-12 is a picture of the valve made out of Nitronic-60. Here, the extent of surface damage is greater than that in Haynes Stellite Alloy 6, but the damage is not deep enough to increase the leak rate. All of these details can be seen more clearly at corresponding higher magnification pictures. Self-mated threshold galling stress reported in ARMCO publications for Nitronic-60 is approximately 50 KSI. As can be seen, the results from the galling test correlate fairly well with the leak test on gate valves.

Summary

It would be advantageous for both the valve manufacturers and user to understand the applications. The type of service should be anticipated prior to selecting an alloy. It is highly recommended that metallurgical evaluation of the worn component be performed to determine the most predominant wear mode to assist in subsequent material selection. Galling rather than adhesive wear is a major concern for valves. Cobalt-based alloys are found to be one of the most suited group of alloys to resist galling. A high fraction of carbides in alloy microstructure are desirable for abrasion resistance whereas the converse is true for impact resistance. Wear resistance should not be equated with high hardness.

Haynes, Haynes Stellite are registered trademarks of Cabot Corporation.
Nitronic is a registered trademark of ARMCO Corporation.
Colmnoy is a registered trademark of Wall Colmnoy Corporation.

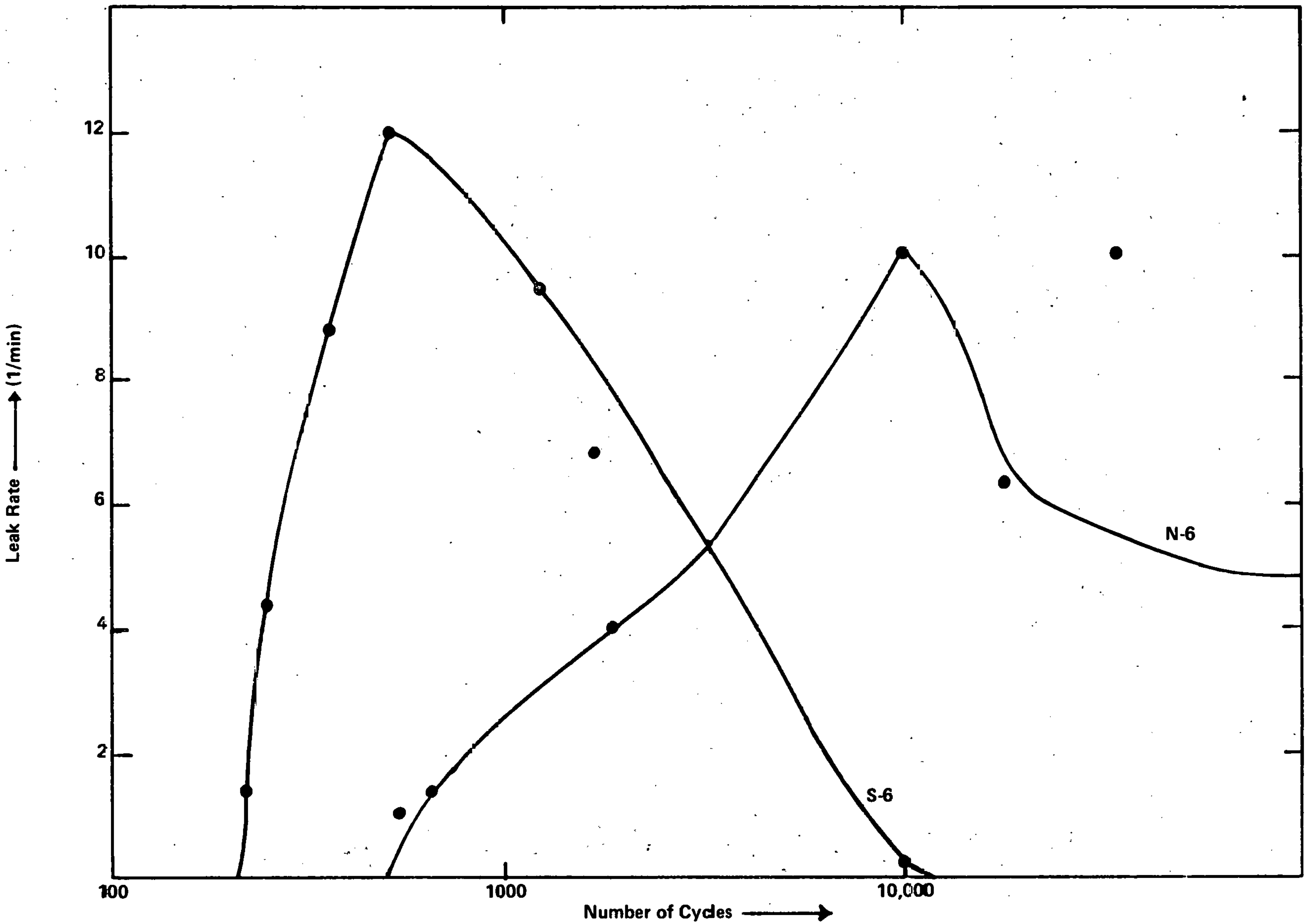


Figure 15-9. Leak Rate Versus Number of Cycles for 1-Inch Gate Valve

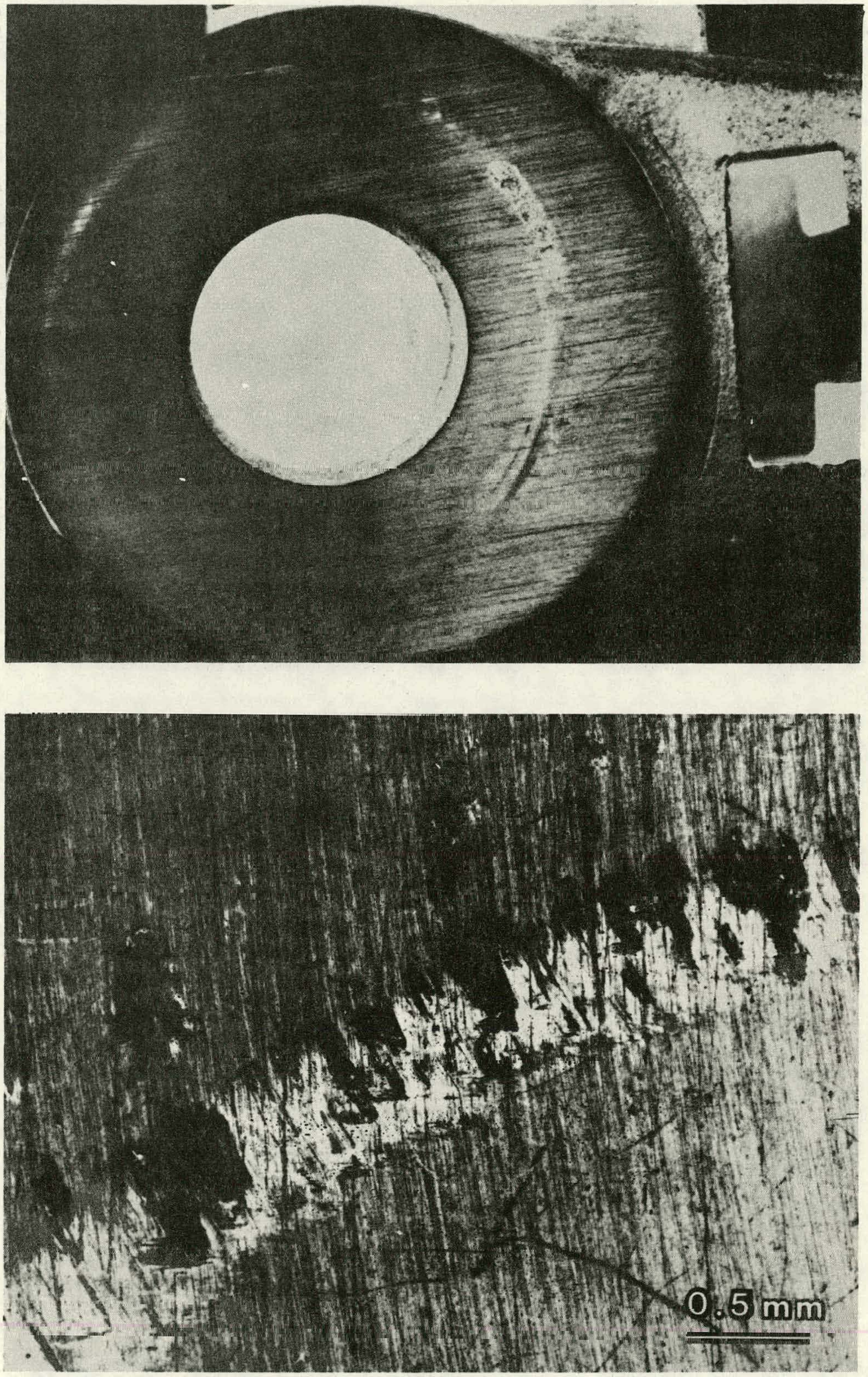


Figure 15-10. Condition of Haynes Stellite Alloy-6 Valve After Test

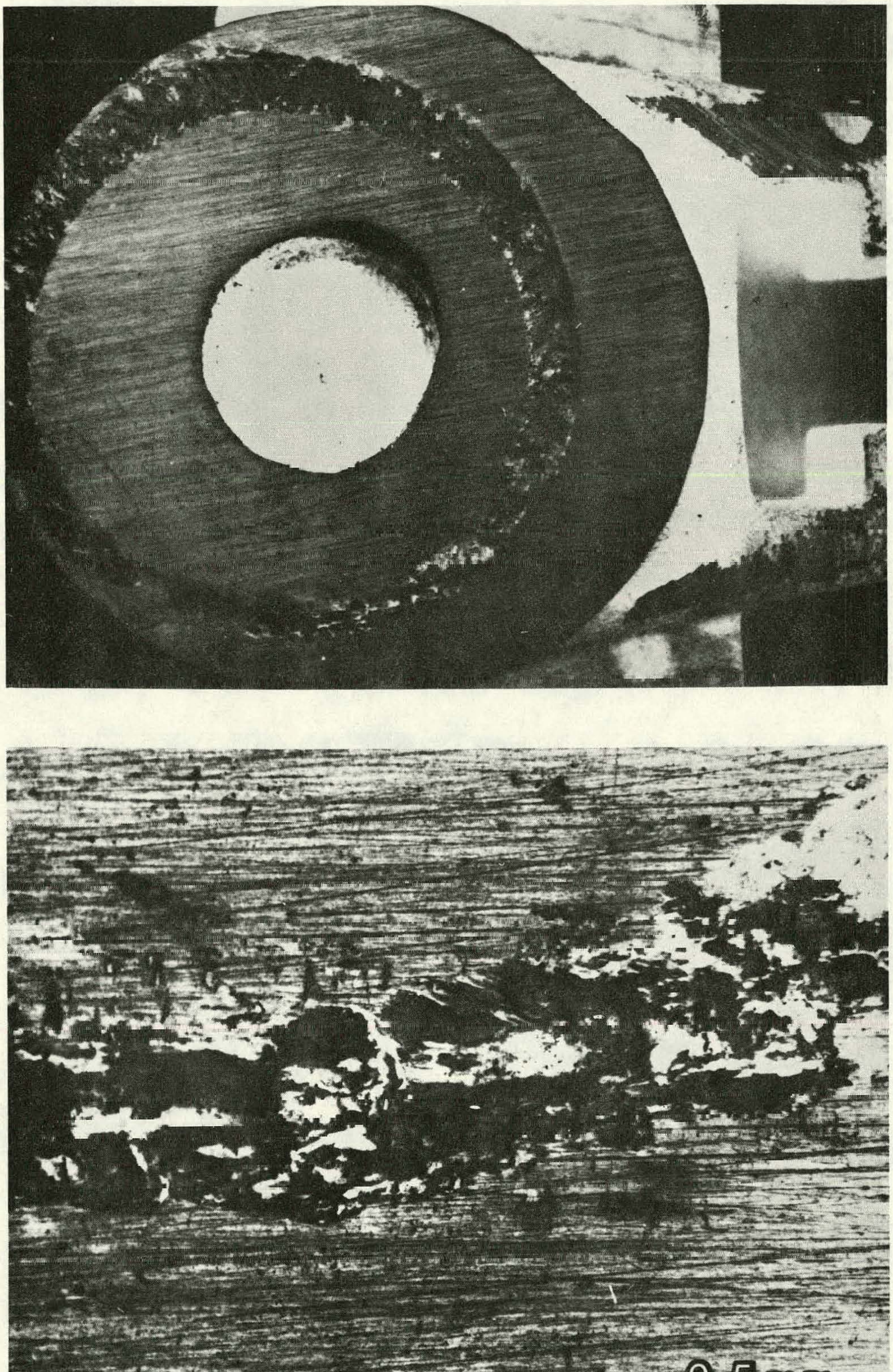


Figure 15-11. Condition of Nickel-Based Haynes-Alloy N-6 Valve After Test

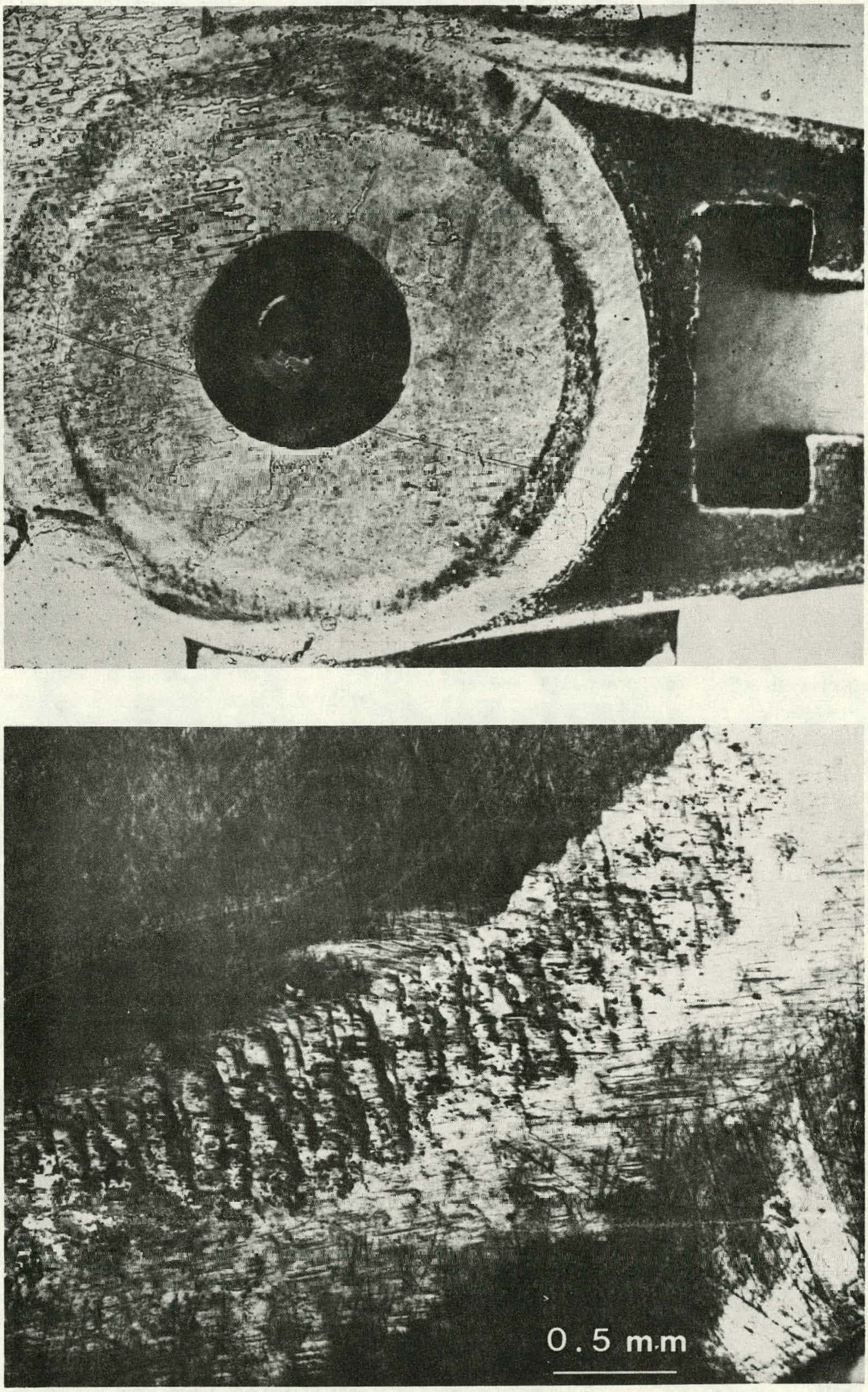


Figure 15-12. Condition of Nitronic-60 Valve After Test

Discussion of Paper by Kirit J. Bhansali

QUESTION: Have you investigated the effect of surface finish on gall resistance of these or any other alloys?

BHANSALI: The answer is yes. What we found was the surface finish has a marked influence on galling resistance of the alloys that do gall. In other words, threshold-galling resistance was increased with increasing surface roughness in the alloys that do gall. However, surface finish has no influence on the alloys that do not gall. So I think you have to decide for yourself whether surface finish is doing any good.

VOICE: On these leak rates where you were talking about the N6 and the Stellite and the Nitronic, I didn't get which was your order of preference as far as resistance to leak rate is concerned, how the results ranked.

BHANSALI: Well, based on the leak-rate data, I would have to say Nitronic 60 is better than Haynes Stellite Alloy 6. It is better than Haynes Alloy N6, a nickel-based alloy. I would like to just point out one additional factor, and that is Nitronic 60 has virtually no carbides. So, if there is any abrasion present, the surface would get scratched. Remember, these tests were done in pure nitrogen, and if the slightest amount of abrasion is present, Nitronic 60 can get scratched far more easily than Stellite 6.

QUESTION: You may reverse the order then with abrasives?

BHANSALI: I would say between Nitronic 60 and Stellite 6, yes.

ACKERMAN: Would you expect that the oxidation, sulfidation, or other surface films would have a marked effect on the relative ranking?

BHANSALI: I am not really clear on what we are ranking for . . .

ACKERMAN: Does it have any effect, ever, on wear resistance or abrasion resistance?

BHANSALI: It depends on what you are talking about wear resistance. When we talk about wear resistance, you have already decided that the mode of failure is controlled by wear. So that means sulfidation resistance of the alloy or material that you are using has already met the environmental-resistance criteria. You see, if the environmental resistance is not present, it is going to deteriorate or degrade due to environmental-corrosion problems and it is not going to have enough time to wear out.

ACKERMAN: Let me put it another way. We have seen some indication that something like a sulfide film can increase erosion resistance and these should always be considered as part of the story. So, the laboratory testing is just a beginning.

BHANSALI: Well, laboratory tests are at the beginning or at the end. Unfortunately, they come out at the end rather than in the beginning. But I agree with you, laboratory tests are a beginning.

What you are saying is very true, and the best test for any particular service is the service itself, the field test. However, one does not have the money to build a test every time you have a new service, not a single valve manufacturer, or materials supplier, or any particular laboratory. So, what you have to do is you have to understand each factor, isolate it from other factors and then take an educated guess as to which alloys you would put in the field test.

QUESTION: In those gate-valve tests, what were the seat materials?

BHANSALI: The seat materials were the same. They were self-mated.

FORBES: Why does differential hardness of the seat material improve the galling resistance?

BHANSALI: I wasn't aware it does.

FORBES: This seems to be standard procedure, in particular by the stainless-steel valve manufacturers. The trim is the same material, but with a differential hardness. The stainless-steel valve normally offers a bad galling problem. The way they have gotten over that is to have the same stainless-steel material on the trim but with a differential hardness. It has always been a little obscure how this is accomplished. You were not aware that they did this?

BHANSALI: I, in effect, was saying that I wasn't aware that they improve the galling resistance. I am aware of the practice. I have not found a satisfactory explanation, why it is done, and that is the reason why I said that.

I can only conjecture that maybe one surface, whatever they do, tends to change with hardness. They are modifying the surface by some means. If it is done through case hardening or surface treatment like carburizing or nitriding or some such thing, then you are altering the surface layer, and you no longer have a surface layer that is going to undergo a massive plastic deformation. So that may be the reason. If one were to take stainless steel and change the hardness by work hardening on the surface, you would not see any changes.

QUESTION: I would like to ask if you know if the N6 is the equivalent of the new 5-A trim that is coming out?

BHANSALI: I will have to plead ignorance on terms of the 5-A trim, because I am not really clear on these terms. If you care to explain to me what the 5-A trim is, I might be able to answer your question.

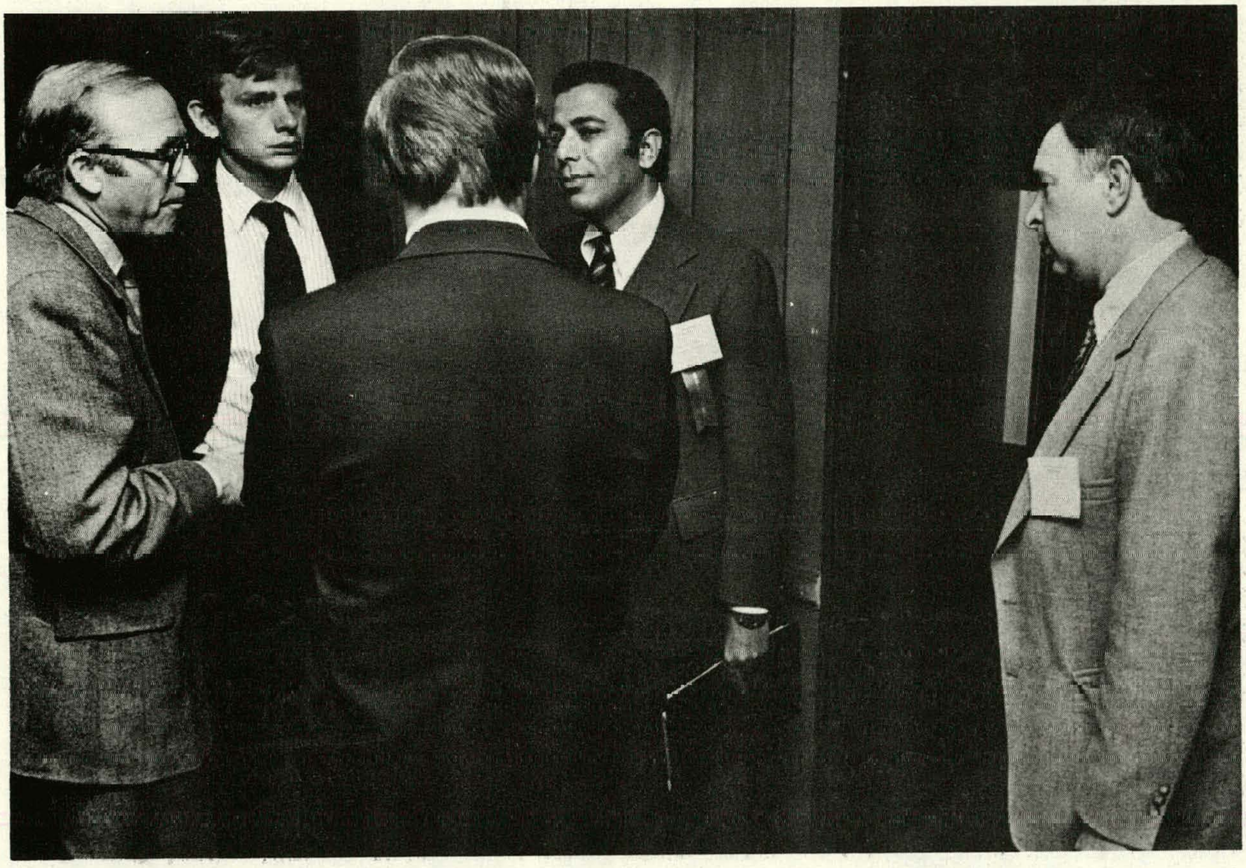
VOICE: It is a nickel-chromium trim and it is a substitute supposedly for the Stellite 6.

BHANSALI: Okay. I think I can take a guess at it. The alloy you are talking about is maybe an alloy called Colmnoy alloy. It is a nickel-chrome-boron alloy.

VOICE: What is the difference between CoCr A and CoCr B?

BHANSALI: They both are cobalt, chromium and tungsten alloys. There is just a difference in the carbon content.

"Buttonholing" a Speaker . . .



Section 16

Erosion Testing Of Potential Valve Materials For Coal-Gasification Systems

by J.S. Hansen,[2]
J.E. Kelley,[2] and F.W. Wood[3]

Abstract

In support of its objective to conserve mineral resources by minimizing premature failure of materials, the Bureau of Mines conducted a cooperative study with the U.S. Department of Energy on the erosion and abrasion resistance of hard materials for valves in coal-conversion systems. This report describes a newly developed erosion-testing apparatus and presents data on the erosion resistance of over 200 materials.

Erosion resistance of most metals was comparatively low. In contrast, ceramics and cermets such as B_4C, WC, SiC, Si_3N_4, and TiB_2, when fabricated to minimize porosity, displayed greater than five times the erosion resistance of metals. Coatings such as boron diffused into Mo and WC, chemical-vapor-deposited TiCN, and electrodeposited TiB_2 were highly erosion resistant if applied in thicknesses ranging from 60 to 75 μm. Erosion resistance of cemented carbides was inversely related to metal binder content.

★ ★ ★

Introduction

Beginning in 1945, the Bureau of Mines constructed a series of pilot plants to demonstrate various coal gasification technologies *(12)*.[4] Presently, a stirred-bed, producer-gas facility (Morgas) is in operation at Morgantown, W.Va. *(10)*, and a synthetic natural-gas facility (Synthane) is in operation at Bruceton, Pa. *(7)*. Other coal-gasification investigations are underway throughout the world *(2)*.

A general problem that has developed in coal gasification is the short wear life of

[1]Due to illness, John Kelley was unable to prepare a paper for the Symposium. This paper is one of his recent publications. It is included to provide information on the programs underway at the Albany Metallurgy Research Center.

[2]Metallurgist, Albany Metallurgy Research Center, Bureau of Mines, Albany, Oreg.

[3]Supervisory research physicist, Albany Metallurgy Research Center, Bureau of Mines, Albany, Oreg. (now with the Naval Air Rework Facility, Materials Engineering Division, Naval Air Station, Jacksonville, Fla.).

[4]Italic numbers in parentheses refer to items in the list of references preceding the appendixes.

valves used to transfer solids as dry bulk, slurries, or gas-borne particulates. The valves are exposed to harsh conditions: temperatures and pressures are high; gases are reactive; the coal, coal dust, char, and ash are abrasive; and condensed tars cause gritty materials to stick on wear-prone surfaces. Materials that are currently available in off-the-shelf valves have proven inadequate to the conditions. An objective of the Bureau of Mines is to conserve mineral resources by minimizing material wear losses. This study, conducted in cooperation with the U.S. Department of Energy, supports that objective.

The careful selection of available wear-resistant materials and the development of improved materials offer partial solutions to wear problems. In this regard, the Bureau of Mines conducted an investigation which included both laboratory screening of candidate materials and service testing of the more promising materials as valve parts in the Morgas gasifier. The laboratory tests in one particular wear mode, erosion, are the subject of this report. Results of other wear tests conducted in the investigation will be reported separately.

Erosion, according to an ASTM definition,[5] is the progressive loss of original material from a solid surface owing to mechanical interaction between that surface and a fluid, a multi-component fluid, or impinging liquid or solid particles. The 316 stainless-steel butterfly valve liner shown in Figure 16-1 is an example of solid particle erosion in a coal gasifier. The valve, which was used to regulate gasifier pressure, was located in a product gas line of the Morgas pilot plant and eroded through in less than 40 hours of operation. Another example, an eroded ball valve which was used to seal a lockhopper at 300 psig against atmospheric pressure, is shown in Figures 16-2 and 16-3. The erosion was caused after a small leak developed (possibly from an abrasive wear scar) and was steadily increased in size by high-velocity ash-laden gases. This type of failure is common and is known as the "wire-drawing effect."

[5]Proposed by Committee G-2 for inclusion in a revision of American Society for Testing and Materials standard G40-73.

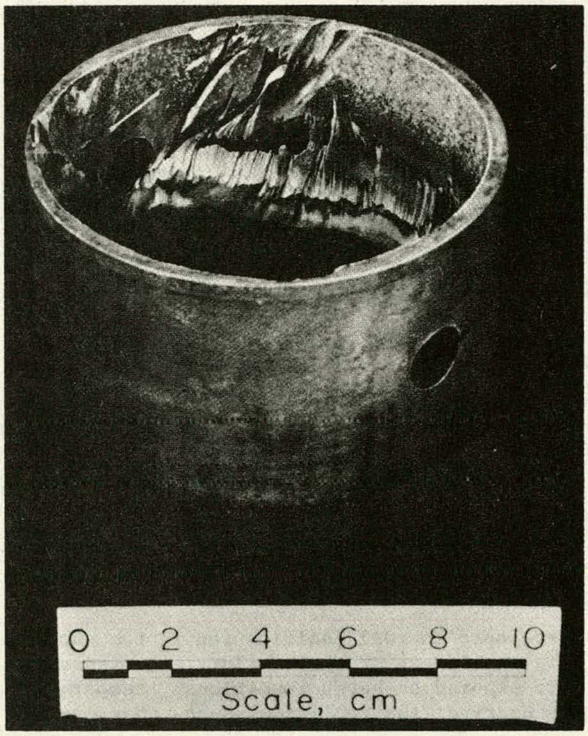


Figure 16-1. Erosion Damage to a 316 SS Butterfly Valve Liner Caused by Hot, Dirty Product Gas from the Morgas Gasifier

Although previous researchers have done substantial work, erosion problems in gasifier valves and elsewhere remain formidable. The complex nature of the problem is such that a change in any one of several variables affecting erosion renders a material satisfactory in one application but unsuitable in another. (The variables are defined in Appendix A.) Researchers have developed several relationships to equate the variables to physical properties *(1, 6, 8-9, 11, 16-17)*. However, design engineers, needing materials-selection guidance, have found the equations to be of little practical significance in that they apply only to narrow classes of materials, difficult-to-measure properties are involved, all variables are not accounted for in any one equation, and special tests are required for the determination of constants. Furthermore, useful published erosion data are lacking, and standard erosion tests are nonexistent.

In this study, no attempt was made to determine the causes of erosion or to improve upon

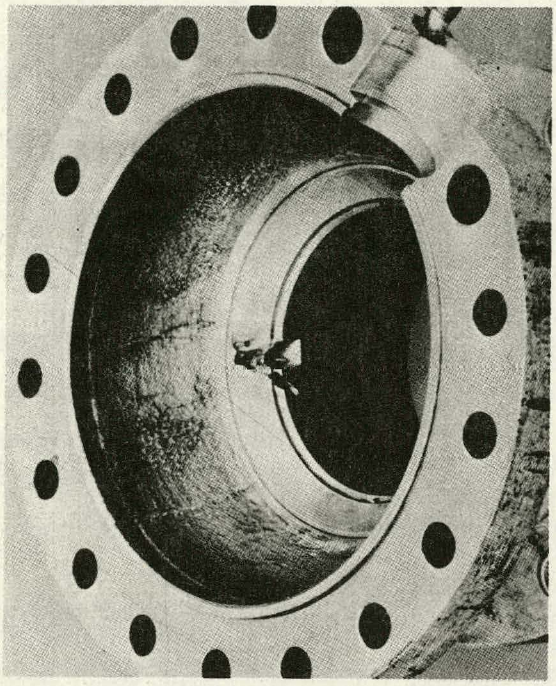


Figure 16-2. Erosion Damage to a Lockhopper Ball Valve Seat Caused by a High-Velocity Stream Through a Leak

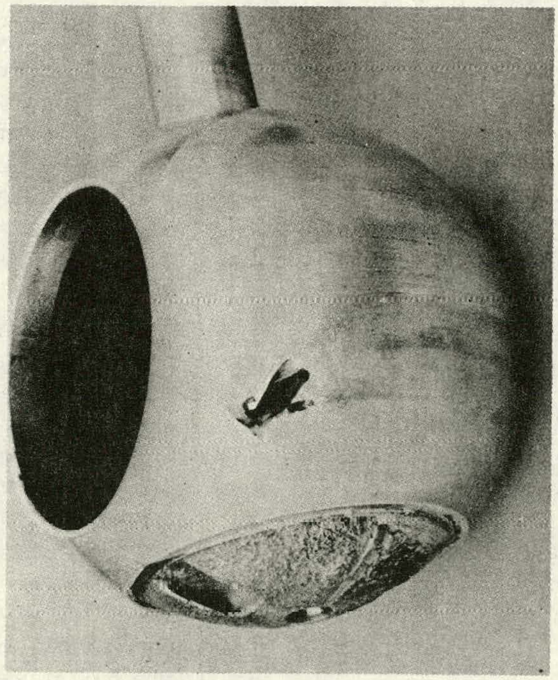


Figure 16-3. Erosion Damage to the Mating Ball of the Equipment Shown in Figure 16-2

established erosion models. Instead, an empirical erosion data bank has been developed.

Test Equipment

Room-temperature erosion tests were performed by using a sandblast-type tester. The tester incorporated an S.S. White Model H Airbrasive[6] unit to mix alumina particles with a gas stream and to control the particle flow rate and velocity. The mixing was accomplished within the Airbrasive unit by a pressurized particle container mounted on a vibrator. An orifice in the container bottom controlled the flow of particles into the gas stream. The particle flux was a function of the voltage applied to the vibrator, and the velocity was a function of the gas stream pressure. All particle velocities were measured on a two-disc device described by Ruff *(13)*.

The particle delivery nozzle was specially designed to minimize nozzle wear and to withstand high temperatures. It consisted of a molybdenum shank about 4 cm (1.4 in) long and a 1.3-cm (0.5-in) sapphire tip 0.058 cm (0.023 in) in inside diameter, which was glued into one of the shank ends. During elevated-temperature operation, the glue evaporated, but the tip remained secure because of tip and shank thermal-expansion differences.

Elevated-temperature tests were done in one of two high-temperature systems. The first system (Figure 16-4) consisted of the Airbrasive unit, a sealed Kanthal resistance furnace, a specimen stage, a shutter to control the abrasive blast duration, and the same particle-delivery nozzle that was used in room-temperature tests. A thermocouple was placed behind the specimen, and the test-temperature profile was recorded. A tube to flow a simulated coal-gasifier atmosphere without abrasive or to evacuate the furnace was situated next to the specimen. A reference specimen that experienced all test conditions except the particle blast was attached to the opposite side of the specimen stage. Its purpose was to determine the degree of corrosion loss.

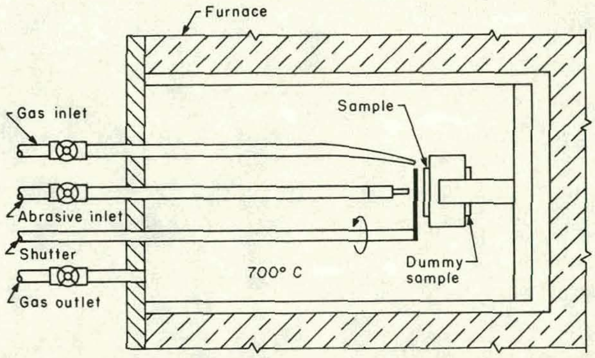


Figure 16-4. The One-Specimen, High-Temperature Erosion Test System

Because the one-specimen system was inadequate for the large number of materials that were to be screened, a larger apparatus capable of accommodating multiple specimens was constructed. Details are shown in Figures 16-5 and 16-6. Essentially all internal equipment from the first system was duplicated in the second system, except that a multifaceted turret was used to secure 12 specimens for testing in one heating, and an infrared pyrometer was used to monitor the temperature of the impingement area. The erosion losses of reference materials, tested in both systems, were comparable.

Procedure

Two test procedures were used, one for room-temperature tests and the other for elevated-temperature tests. Both procedures utilized specimens that were nominally 1.3 by 1.3 by 0.2 cm (0.5 by 0.5 by 0.063 in). Specimens were cleaned and weighed before testing. In room-temperature tests, specimens were positioned 0.952 cm (0.375 in) beneath the nozzle tip. The angle of incidence was adjusted to either 90° or 20°, and a hand-operated shutter was passed between the nozzle tip and the specimen surface. Subsequently, the particle blast was started and allowed to reach a steady state, after which the shutter was removed. The particle blast was stopped after

[6] **Specific brand names are used for identification and description only and do not imply endorsement by the Bureau of Mines.**

3 minutes, and the specimens were recleaned and reweighed.

Parameters were identical for high-temperature tests. Heating was normally done under a partial vacuum, but in some instances in which specimens were readily oxidized, heating was done under a small flow of nitrogen. When the desired test temperature was reached, a stream of nitrogen or other gas was directed to the specimen surface at a rate equal to that which flowed through the particle nozzle during a test. Specimen temperatures dropped initially but rapidly returned to normal. At steady state, a shutter was positioned between the nozzle and specimen, and the particle blast was started. As soon as the particle blast was constant, the shutter was manually removed to begin the test. The impingement area temperature rapidly dropped an average of 63 °C (145 °F) in tests begun at 700 °C (1,292 °F), remained at about 637 °C (1,179 °F) for the duration of the 3-minute test, and returned to 700 °C upon the automatic test termination. Another specimen was indexed under the nozzle in the 2-minute period that elapsed prior to the next test. The procedure was repeated for the remaining specimens, and at the conclusion, the furnace contents were cooled under nitrogen. The tested specimens were recleaned, reweighed, and checked for excessive oxidation, cracking, and spalling.

A control and computation procedure was developed to organize both the room-temperature and high-temperature weight-loss data and to reduce an error that resulted from particle flux variations caused by the Airbrasive unit vibratory feeder. In the procedure, three Haynes Stellite Alloy 6B wrought standards from a single source were run at equal intervals with each set of nine specimens. The erosion tester was adjusted to keep the volume loss of the standards within 10% of a value established from preliminary tests. The standard volume loss was 0.00146 cm^3 at room temperature and 0.00178 cm^3 at 700 °C, both at a 90° impingement angle, and 0.00219 cm^3 at room temperature and a 20° impingement angle. A series of tests showed that when the Stellite 6B erosion losses deviated from these values, the erosion loss of the specimens deviated a proportional amount; that is, the ratio of the specimen volume loss to the Stellite 6B erosion loss remained constant over a range of particle fluxes. Therefore, this ratio was chosen as the means by which all materials were ranked and is referred to hereafter as the Relative Erosion Factor (REF).

Test Precision

The reference specimens that were run with each elevated-temperature test in the first erosion tester had weight losses due to oxidation or corrosion of less than 1.5% of total weight in most cases. Some exceptions were Beta III Ti, which gained 15%; 316 SS, which gained 4.2%; and some of the SiC and WC materials, which also gained several percent. Because the weight changes due to oxidation were generally low, reference specimens were not run in the improved erosion tester.

The erosion factor values referred to in the "Results" section of the report are the mean of five tests. One standard deviation of a set of five tests was typically within 10% of the mean. Variations were higher in some of the most erosion-resistant materials, such as K-714 with 30.24% or Noroc-33 with 21.5% because weighing precision closely approached the total weight loss of these specimens. Additional error was caused by the change in impingement angle with time that resulted when the geometry in portions of the developing erosion pit was altered as the test proceeded. This error was greatest in specimens that lost large volumes.

Results and Discussion

A large number of materials were subjected to the same test conditions. The relative erosion factors, chemical compositions, and manufacturing methods are listed in Appendix B. For further clarity, a representative portion of the information is graphically presented in Figures 16-7 through 16-12, according to material type.

As shown in Figure 16-7, most metals and metallic alloys, except tungsten and molybdenum, had nearly the same room-temperature REF values with a 90° impingement. At best, only a 30% improvement over Stellite 6B was evident. From Figure 16-8, all metallic alloys, except tungsten and molybdenum, again had similar erosion resistances at a

20° impingement, but in addition all had lower REF values.

Many alloys eroded more at 700°C than at room temperature, but a few eroded less. No explanation for the mixed high-temperature behavior was apparent, although others have noted similar results. Young *(19)*, using 5-μm particles and a 52-m/sec particle velocity, found erosion penetration was markedly less at 500°C than at 25°C in tests on several stainless steels and high-Ni-Cr alloys. However, with a 50-μm particle size, erosion penetration was slightly more at 500°C (932°F) than at 25°C (77°F) on most of the same materials. Young postulated that the chromium in the materials rapidly formed an adherent, self-healing, and protective oxide barrier that had an erosion resistance greater than that of the underlying metal. Presumably, the barrier was more protective against bombardment by the 5-μm particles than against the 50-μm particles because the larger particles were capable of causing more damage at an equal velocity. Smeltzer *(17)* found a related behavior in 2024 Al, Ti-6A1-4V, and 17-7 PH stainless steel. Because the erosion was greater at high impingement angles than at lower angles, Smeltzer also surmised that a ceramic film was protecting the substrate material underneath.

In contrast with metallic materials, numerous cermets and ceramics, as illustrated in Figures 16-9 and 16-10, had REF values that were over twice that of Stellite 6B at both room and elevated temperatures. Notable among these were a series of mixed ceramics that were prepared by pressing and sintering; several commercially available hot-pressed ceramics such as boron carbide (B_4C), silicon carbide (SiC), silicon nitride (Si_3N_4), cubic boron nitride (CBN), and synthetic diamond; and several tungsten carbides (WC).

Several ceramic coatings also had outstanding REF values. Data for coatings are listed in Appendix B, Tables B-4 through B-6. (Unlike single-composition materials, an REF value could not be accurately computed for all coated samples or samples with a protective layer. Instead, one of three conditions was noted—the sample was easily penetrated, penetration was retarded over a similar unprotected sample, or the sample was not penetrated.)

The outstanding coating materials included electrodeposited TiB_2, chemical vapor deposited (CVD) SiC, and boron diffused into Mo and Wc. Diffused boron improved the erosion resistance of WC and Mo at room temperature and a 90° impingement by more than 80%; at a 20° impingement, the improvement was more than fivefold. Electrodeposited TiB_2 was also exceptional and completely resisted erosion even after the test duration was extended to 10 minutes.

The thermal expansion of many coatings did not match that of the substrates. The result was that the coatings cracked in one or two heating and cooling cycles. The cracks exposed substrate material that was easily eroded, and the coatings were undermined. The TiB_2 and diffused boron coatings were noteworthy exceptions. Additionally, several coatings were inadequate when thin but were entirely protective when the thickness was increased to 50 to 70 μm (2 to 3 mils).

No easily measured physical or mechanical property was found that could be used as a universal indicator of erosion resistance for either ceramic or metallic materials. There were, however, generalized correlations between erosion and binder content in carbides and porosity in pressed materials. In plotting the binder contents of various carbides against relative wear as shown in Figure 16-13, a general trend was evident. With a decrease in binder content, erosion resistance was increased. The relationship suggested that the less-resistant binder was eroded preferentially to the carbide phase. This mechanism was more apparent in several tests (not shown) on refractories in which the cement binders were eroded but the hard ceramic particles were not eroded.

The effect of porosity was demonstrated by several alumina ceramics. Lucalox, which is essentially 100% theoretically dense, was more than 1.5 times more erosion resistant than 95- to 98-percent dense sintered aluminas. At an extreme, Lucalox had more than 10 times the erosion resistance of 99P, a porous alumina that was less than 70% of theoretical density. Similarly, hot-pressed Si_3N_4 had more than 10 times the erosion resistance of reaction-bonded (and less dense) Si_3N_4.

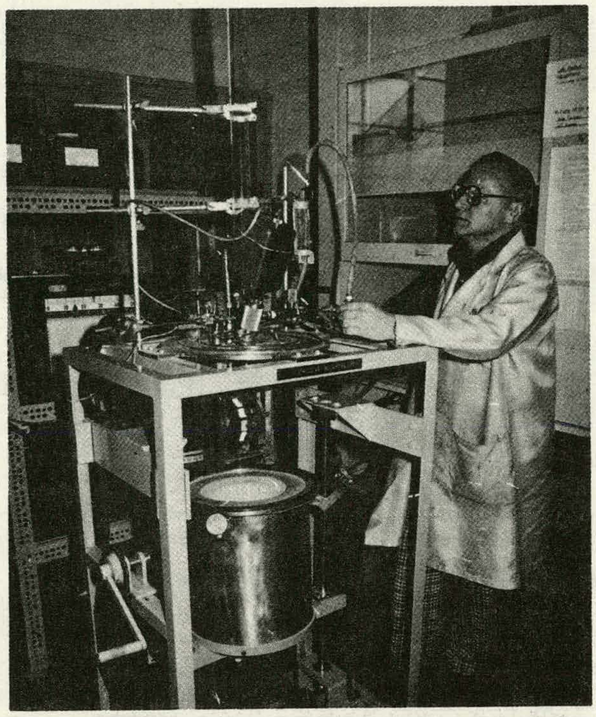


Figure 16-5. The Multispecimen, High-Temperature Erosion Test System

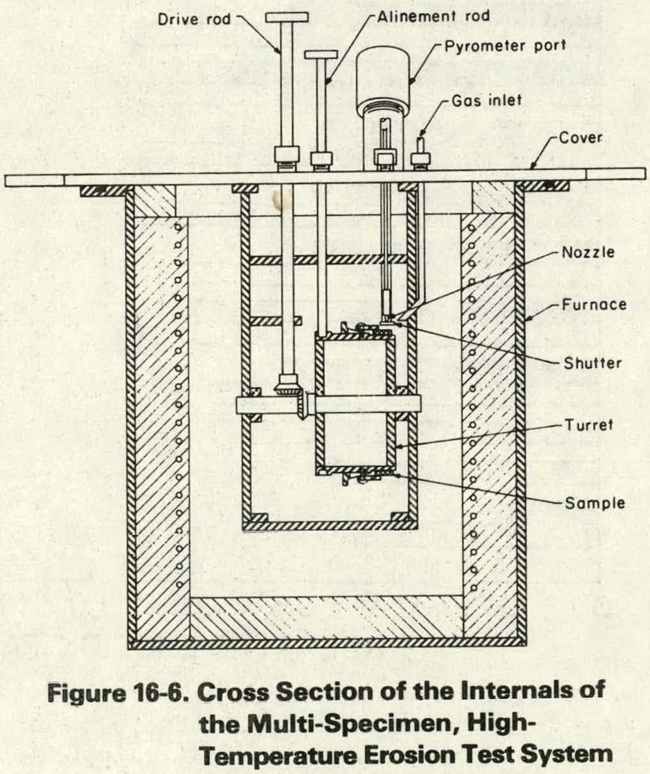


Figure 16-6. Cross Section of the Internals of the Multi-Specimen, High-Temperature Erosion Test System Showing the 12-Faceted Turret With Specimens Affixed for 90° Impingement

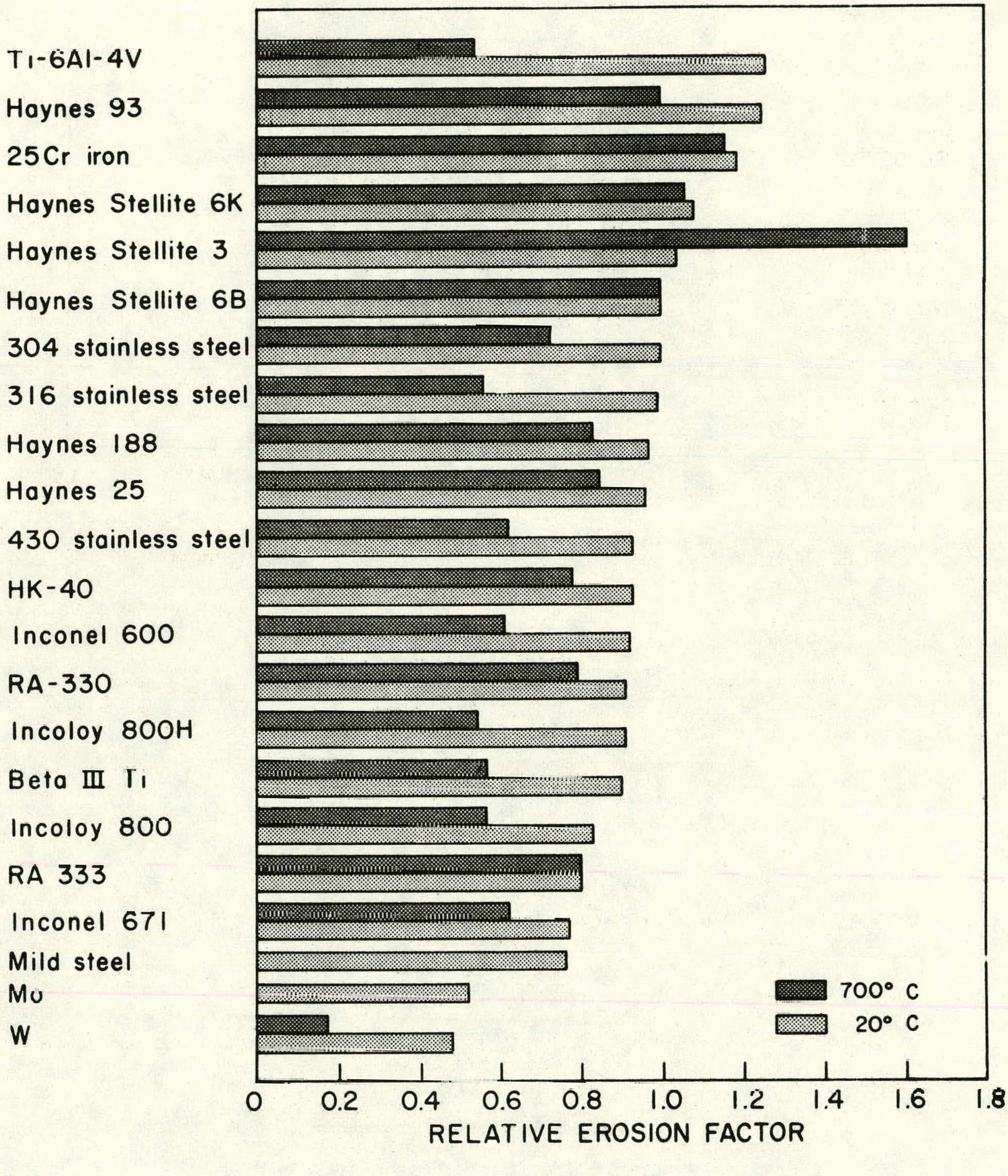


Figure 16-7. REFs of Commercially Available Metals (90° Impingement)

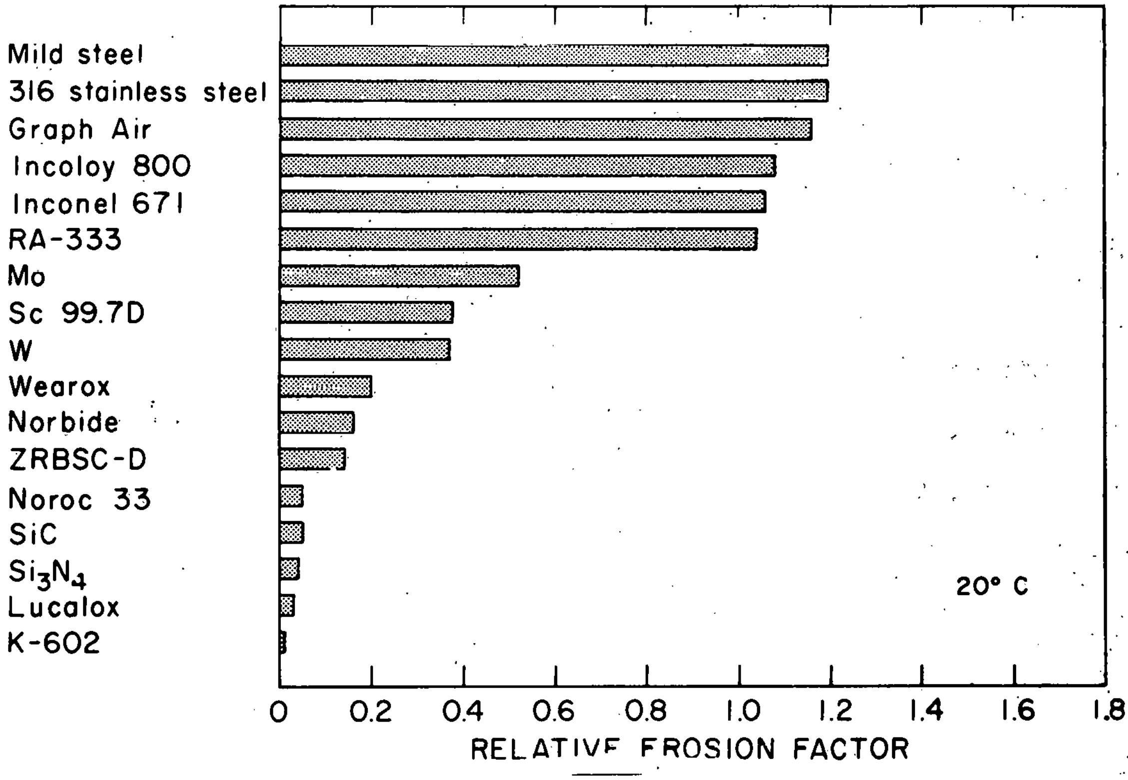


Figure 16-8. REFs of Several Metals and Ceramics (20° Impingement)

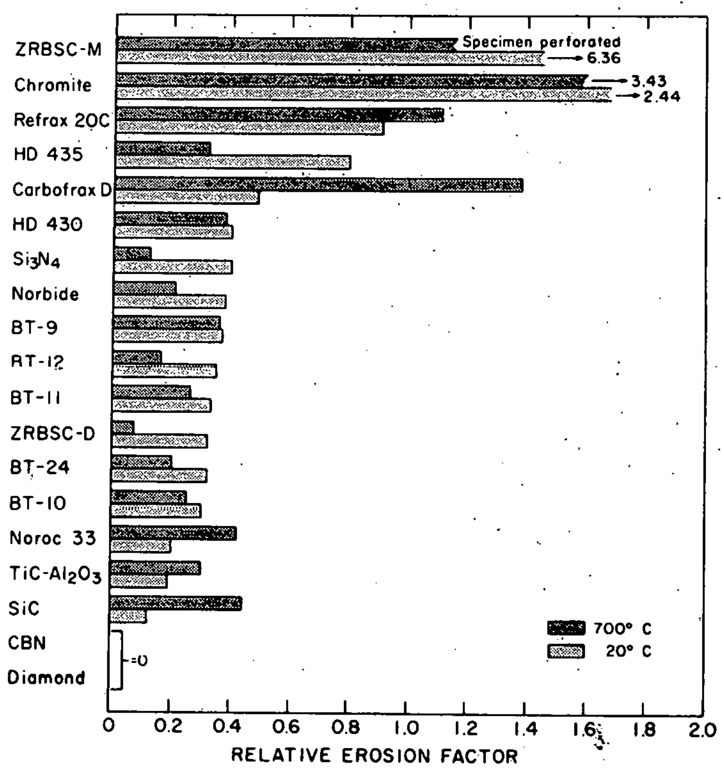


Figure 16-9. REFs of Commercially Available Ceramics (90° Impingement)

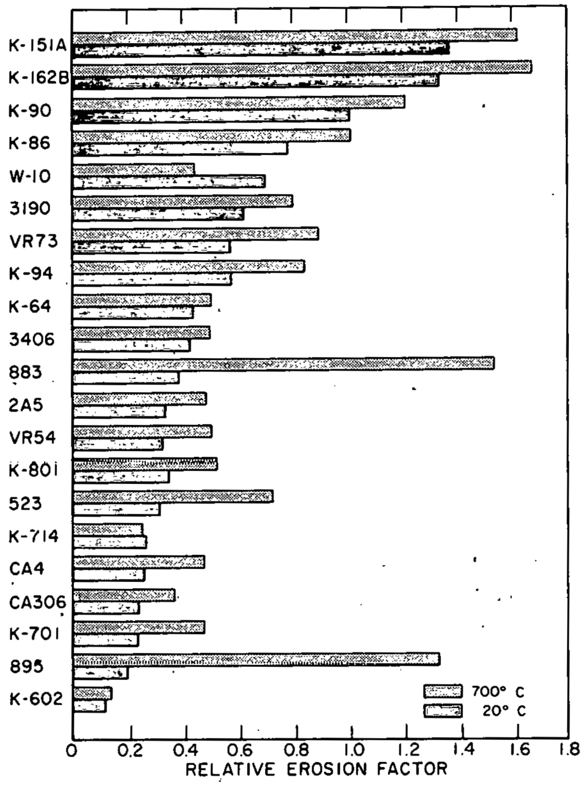


Figure 16-10. REFs of Commercially Available Cemented Carbides (90° Impingement)

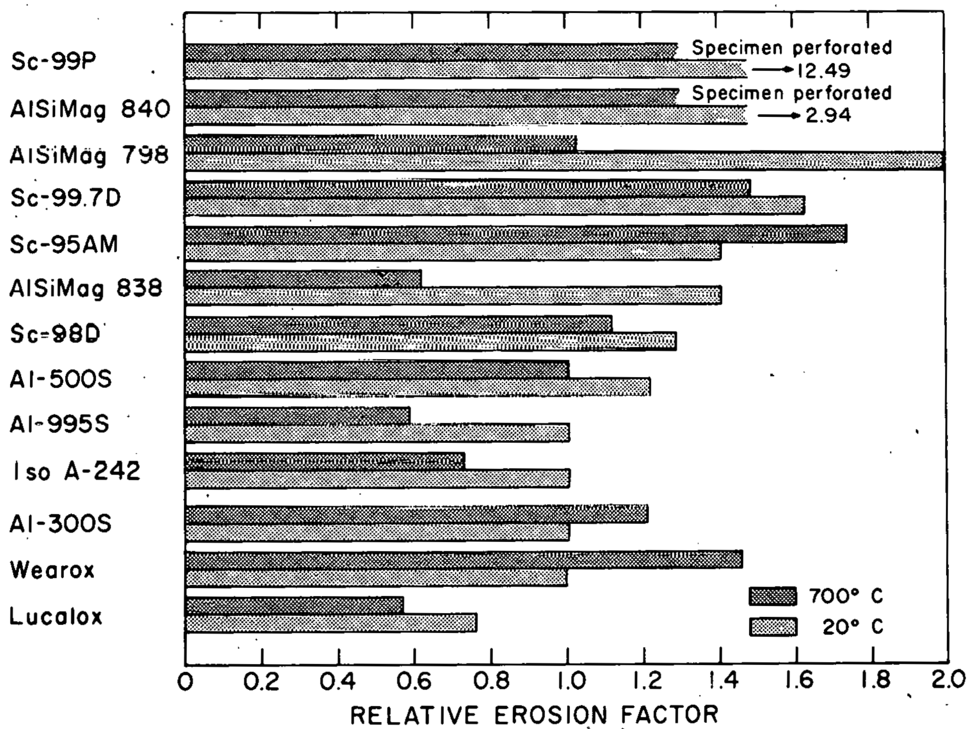


Figure 16-11. REFs of Commercially Available Sintered Alumina Ceramics (90° Impingement

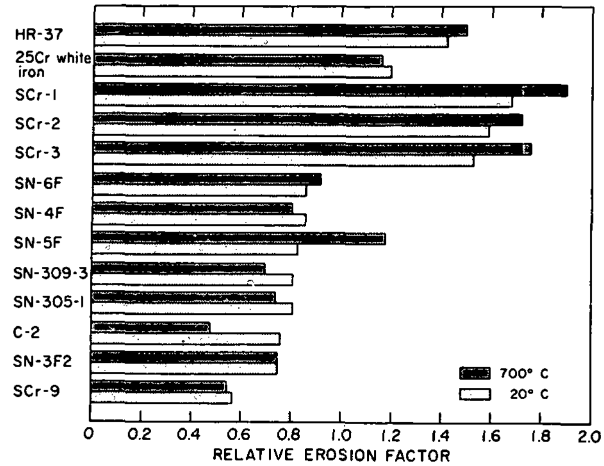


Figure 16-12. REFs of Oregon Graduate Center Carbonitrides and Cast Alloys (90° Impingement)

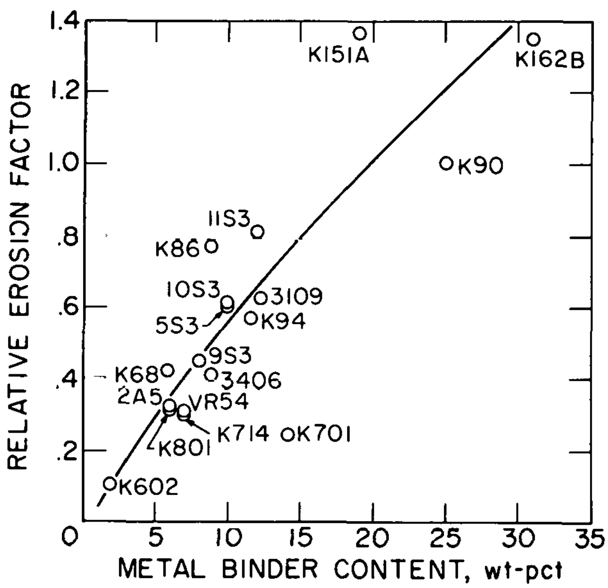


Figure 16-13. Relative Wear Resistance of Cemented Carbides as a Function Of Metal Binder Content

Conclusions

A data bank of erosion information on various materials has been prepared that can serve as a guide for the selection and application of erosion-resistant materials for coal-gasifier valves. However, the variability of service conditions in any coal-gasifier plant precluded general recommendations. Test procedures and equipment used in this investigation were designed to approximately simulate the erosion exposure of many valves. In addition to the erosion data presented, such additional factors as the possibility of corrosion, oxidation, and thermal expansion incompatibility must be considered.

Metallic alloys, other than tungsten and molybdenum, were shown to be at most no more than 30% more erosion resistant than Stellite 6B, which was used as a standard. Unfortunately, evidence from coal-gasifier valve erosion failure indicates that even a two-fold increase in erosion resistance over Stellite 6B is not adequate.

Certain ceramics and cermets were shown to be highly erosion resistant. Materials that had more than a fivefold increase in erosion resistance over metallic alloys included tungsten carbides with low binder contents, SiC, B_4C, Si_3N_4, and several other ceramics. All were fabricated to nearly theoretical density. Several adherent ceramic coatings or surface treatments were shown to have erosion resistance equal to that of solid ceramics. These classes of materials should develop the greatest acceptance as gasifier valve materials.

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Appendix A—Review of Erosion Variables

Knowledge of the variables affecting erosion is necessary to predict the severity of material loss when the conditions of a set of data do not precisely duplicate an actual field situation. Variables are described below.

1. Impingement angle—Erosion varies in a complex manner with impingement angle, the angle at which a particle strikes a surface. The relationship is illustrated in Figure A-1 *(6)*.[1] For ductile materials, the angle of maximum erosion is about 20°, although in a study by Smeltzer *(17)* using 5 μm alumina abrasive at 152 m/sec (500 ft/sec), the maximum occurred between 30° and 37.5° depending upon the target material. In a determination by Head *(8)* using rounded glass beads, the maximum occurred at 45°.

For brittle, ceramiclike materials, the angle of maximum erosion is 90°, but Sheldon *(15)* found that under certain conditions, the erosion rate-impingement angle relationship for a brittle material will approximate that of a ductile material. Sheldon changed the brittle erosion rate-impingement angle relationship when he reduced the size of the bombarding particles. He produced maxima at increasingly lower angles until finally, with 1,000-mesh particles, brittle behavior became indistinguishable from ductile behavior.

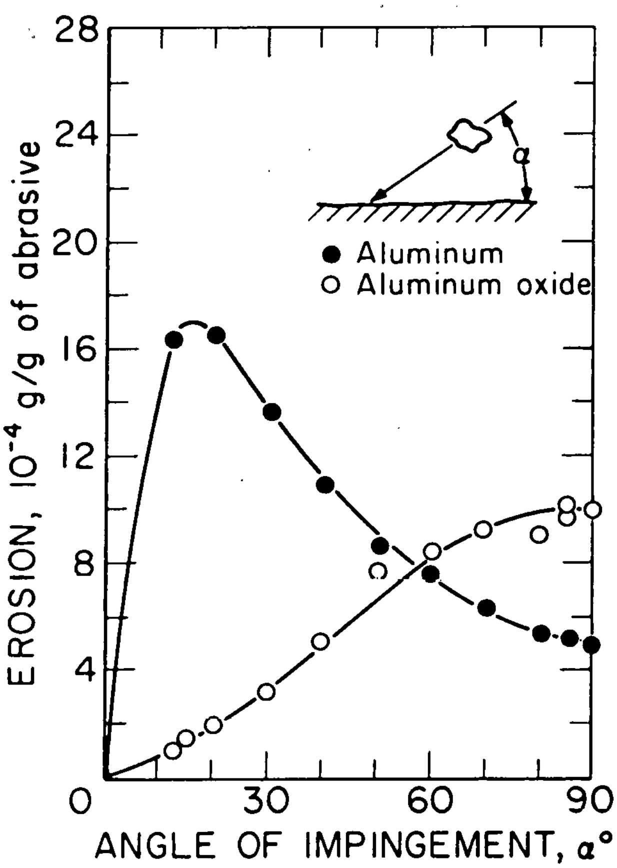


Figure A-1. Weight removed by erosion as a function of angle of impingement for 1100-0 aluminum and high-density aluminum oxide *(6)*. Both materials were eroded by 100 μm SiC particles at 152 m/sec.

The correct labeling of a material as either ductile or brittle is necessary. A hardened steel, for instance, that is normally thought to behave in a brittle manner in terms of impact resistance may behave in a ductile manner in terms of erosion. Additionally, data given for only one angle may give a false impression of the total erosion resistance of a material.

2. Particle velocity—Through its motion, a particle has a quantity of kinetic energy that is available to do damage to a material upon impact. Both the kinetic energy and the damage increase with an increase in particle velocity. The damage is equatable to a power function exponent of the velocity which is within a range of 2.1 to 2.4 for ductile materials *(6)*. For brittle materials the power function exponent may be as high as 4.4 *(14)*.

3. Particle flux—In general, an increase in the quantity of abrasive impinging upon a surface produces a proportional increase in erosion. At high concentrations, erosion efficiency decreases, presumably because the particles expend their energy in hitting each other rather than in removing material from a surface. At low concentrations, Wood *(18)*, Smeltzer *(17)*, and Young *(19)* all reported greater erosion efficiency per particle.

[1]Italic numbers in parentheses refer to items in the list of references preceding the appendixes.

4. Particle size—Within limits, erosion is directly related to particle size. However, there is disagreement as to where the maxima develop with increasing particle size. Finnie *(5)*, for example, found that size had no effect above 100 μm, while Head *(8)* found that the erosion of carbides increased with particle size up to 300 μm, and thereafter decreased up to 900 μm. Sheldon *(16)* noted no size effect on aluminum for 51-, 125-, and 250-μm particles, but for smaller particles, he reported decreased erosion.

5. Particle shape—Sharp particles produce greater erosion in ductile materials than do rounded particles.

6. Particle hardness—Particle hardness will not influence the erosion of ductile materials provided the eroding particles are harder than the material undergoing erosion.

7. Time—Time has a linear effect on erosion rates unless the actual impingement angle is sufficiently altered by the developing crater, in which case erosion may increase or decrease accordingly.

8. Temperature—The effect of temperature is not well know. A partial explanation of the effect is included within the test.

9. Material factors—There are no reliable material properties that universally correlate with erosion resistance. For certain pure materials, Finnie *(6)* found that erosion is proportional to Vickers hardness, but the same researchers also found that erosion is constant for different hardnesses of the same steel. Similarly, Smeltzer *(17)* noted that differing heat treatments on 2024 aluminum, 17-7 PH stainless steel, 410 stainless steel, and Ti-6A1-4V alloys had no effect. Finnie *(4)* suggested flow stress as a universal indicator of ductile erosion resistance, but his equations require the use of difficult-to-measure micro flow stress values that are considerably greater than the easily measured macro flow stress values obtainable from a tensile test. In addition, melting point and elastic modulus have been shown to have a rough correlation with erosion *(8, 17)*.

Appendix B—Erosion Test Data

TABLE B-1. - Room-temperature erosion test results--90° impingement, 27-μm Al_2O_3 particles, 5-g/min particle flow, 170-m/sec particle velocity, 3-min test duration, N_2 atmosphere

Test material	Fabrication method[1]	Composition	Source[1]	Relative erosion factor[2]
SC-99P	ps	99+ Al_2O_3	Krohn	12.49
ZRBSC-M	hp	ZrB_2-SiC-graphite	N	6.36
CbC	c	Not applicable	Unknown	3.56
HfC	c	Not applicable	Unknown	3.49
5527	hp	$45MgAl_2O_4$-55MgO	NBS	3.39
AlSiMag 840	ps	Modified Al_2O_3	3M	2.94
4310	hp	$97MgAl_2O_4$-3MgO	NBS	2.56
TaC	c	Not applicable	Unknown	2.48
4879	hp	$91MgAl_2O_4$-9MgO	NBS	2.44
Chromite	ps	Unknown	UCAR	2.44
AD-995	ps	$99.5Al_2O_3$	Coors	2.25
AlSiMag 798	ps	$85Al_2O_3$	3M	2.00
$MgAl_2O_4$	hp	Not applicable	NBS	1.84
SCr-1	ps	85.5(Ti,Cr)CN-14.5Ni	OGC	1.67
SC-99.7D	ps	$99.7Al_2O_3$	Krohn	1.63
SCr-2	ps	85.8(Ti,Cr)CN-14.2Ni	OGC	1.58
SCr-3	ps	86(Ti,Cr)CN-14Ni	OGC	1.52
SC-95AM	ps	$94Al_2O_3$	Krohn	1.41
AlSiMag 838	ps	$99.5Al_2O_3$	3M	1.41
HR-37	c	5Cr-1Ti-14W-8V-3.9C-13Mn-bal Fe	OGC	1.41
K151A	ps	19Ni binder	K	1.37
K162B	ps	25Ni + 6Mo binder	K	1.35
SC-98D	ps	$98Al_2O_3$	Krohn	1.29
Ti-6Al-4V	c	Not applicable	Unknown	1.26
Haynes 93	c	17Cr-16Mo-6.3Co-3C-bal Fe	Stel	1.25
Al-500S	ps	$94Al_2O_3$	Wesgo	1.22
Graph-Air	w	1.4C-1.9Mn-1.2Si-1.9Ni-1.5Mo-bal Fe	TRB	1.19
25Cr iron	c	25Cr-2Ni-2Mn-0.5Si-3.5C-bal Fe	OGC	1.19
AZ-27Cr	ps	TiC in D_2 die steel	OGC	1.14
AZ-31HF	ps	TiC in H-13 die steel	OGC	1.14
FeTiC-23	ps	TiC-(Fe,Ni,Cr,Mo)C	OGC	1.14
FeTiC-29HS10	ps	TiC in M-10 die steel	OGC	1.12
AZ-20-1	ps	TiC-(Fe,Ni,Cr,Mo)C	OGC	1.11
AZ-30HS42	ps	TiC in M-42 steel	OGC	1.10
Stellite 6K	w	30Cr-4.5W-1.5Mo-1.7Cr-bal Co	Stel	1.08
Al-995S	ps	$99.5Al_2O_3$	Wesgo	1.08
Iso A-242	ps	Al_2O_3	Green	1.07
Al-300S	ps	$97.6Al_2O_3$	Wesgo	1.04
Stellite 3	c	31Cr-12.5W-2.4C-bal Co	Stel	1.04
K90	ps	25 binder	K	1.01
Stellite 6B	w	30Cr-4.5W-1.5Mo-1.2C-bal Co	Stel	1.00
304 SS	w	17Cr-9Ni-2Mn-1Si-bal Fe	Unknown	1.00
Wearox	ps	$99.5Al_2O_3$	Wesgo	1.00
316 SS	w	17Cr-12Ni-2Mn-1Si-2.5Mo-bal Fe	Unknown	.99
Haynes 188	w	22Cr-14.5W-22Ni-0.15C-bal Co	Stel	.97
Haynes 25	w	20Cr-15W-10Ni-1.5Mn-0.15C-bal Co	Stel	.96
430 SS	w	17Cr-1Mn-1Si-0.1C-bal Fe	Unknown	.93
MoTiCN	ps	Not applicable	TWCA	.93
HK-40	c	26Cr-20Ni-0.4C-bal Fe	Unknown	.93
Inconel 600	w	76Ni-15.5Cr-8Fe	HA	.92
RA 330	w	19Cr-35Ni-1.5Mn-1.3Si-bal Fe	RA	.91
Refrax 20C	ps	$SiC-Si_3N_4$ bond	Carbor	.91
[illegible]oloy 800H	w	32.5Ni-21Cr-0.07C-46Fe	HA	.91
[illegible]a III Ti	w	11.5Mo-6Zr-4.5Sn-bal Ti	Unknown	.90
[illegible]-6F	ps	85(Ti,Mo)CN-12Ni-3Mo	OGC	.85

See footnotes at end of table.

TABLE B-1. - Room-temperature erosion test results--90° impingement, 27-μm Al_2O_3 particles, 5-g/min particle flow, 170-m/sec particle velocity, 3-min test duration, N_2 atmosphere--Continued

Test material	Fabrication method[1]	Composition	Source[1]	Relative erosion factor[2]
SN-4F	ps	84(Ti,Mo)CN-13Ni-3Mo	OGC	0.85
Incoloy 800	w	32.5Ni-46Fe-21Cr	HA	.83
SN-5F	ps	85(Ti,Mo)CN-12Ni-3Mo	OGC	.82
11S-3	ps	85(Ti,Mo)CN-12Ni-3Mo	OGC	.82
SN-305-1	ps	94(Ti,Mo)CN-5Ni-1Mo	OGC	.80
SN-309-3	ps	89(Ti,Mo)CN-9Ni-2Mo	OGC	.80
HD 435	NAp	Recrystallized SiC	N	.80
RA-333	w	25Cr-1.5Mn-1.3Si-3Co-3Mo-3W-18Fe-bal Ni	RA	.80
MoTiCN	c	Not applicable	TWCA	.80
K86	ps	8.8 binder	K	.78
Inconel 671	w	50Ni-48Cr-0.4Ti	HA	.77
Lucalox	NAp	Densified Al_2O_3	GE	.76
Mild steel	w	0.15C-bal Fe	Unknown	.76
C-2	ps	97(Ti,Mo)CN-2Ni-0.5Mo	OGC	.75
SN-3F2	ps	84(Ti,Mo)CN-13Ni-3Mo	OGC	.74
FeWC-33	ps	Not applicable	OGC	.73
W-10	ps	90W-10(Ni,Cu,Fe)	K	.70
3109	ps	12.2 binder	K	.62
10S-3	ps	90(W,Cr)C-10Ni	OGC	.62
5S-3	ps	90WC-5Co-5Ni	OGC	.61
K94	ps	11.5 binder	K	.57
VR73	ps	71WC-12TiC-10TaC,CbC-6.5Co binder	F	.57
SCr-9	ps	84(Ti,Cr,Mo)CN-3Mo-13Ni	OGC	.56
Mo	w	Not applicable	Unknown	.52
Carbofrax D	ps	SiC-ceramic bond	Carbor	.49
W	w	Not applicable	GE	.48
9S-3	ps	92(W,Cr)C-8Ni	OGC	.46
K68	ps	5.8 binder	K	.43
3406	ps	7.8 binder	K	.42
HD 430	NAp	Recrystallized SiC	N	.40
Si_3N_4	hp	Not applicable	N	.40
Norbide	hp	B_4C	N	.38
883	ps	WC-6Co binder	Carb	.38
BT-9	ps	2MgO-25TiB$_2$-3.5WC-bal Al_2O_3	OGC	.37
BT-12	ps	1.5MgO-49TiB$_2$-3.5WC-bal Al_2O_3	OGC	.35
2A5	ps	WC-6Co binder	F	.33
BT-11	ps	1.7MgO-38TiB$_2$-3.5WC-bal Al_2O_3	OGC	.33
ZRBSC-D	hp	ZrB_2-SiC	N	.32
VR54	ps	WC-7Co binder	F	.32
BT-24	ps	2MgO-30TiB$_2$-3.5WC-bal Al_2O_3	OGC	.32
K801	ps	6Ni binder	K	.32
523	ps	WC-TiC coating	Carb	.31
BT-10	ps	2MgO-30TiB$_2$-3.5WC-bal Al_2O_3	OGC	.30
K714	ps	6Co + 1Cr binder	K	.26
K701	ps	10.2Co + 4Cr binder	K	.25
CA 4	ps	WC-6Co binder	Carmet	.25
CA 306	ps	WC-6Co binder	Carmet	.23
Noroc-33	hp	Si_3N_4-SiC	N	.20
TiC-Al_2O_3	ps	Not applicable	B and W	.19
895	ps	WC-6Co binder	Carb	.19
SiC	hp	Not applicable	N	.12
K602	ps	<1.5 binder	K	.11
SiC	NAp	98 pct dense	GE	.05
CBN	NAp	Not applicable	GE	0
GE diamond	NAp	Not applicable	GE	0

[1]Abbreviations are explained in table B-7.

[2]REF (relative erosion factor) = $\frac{\text{vol. loss material}}{\text{vol. loss Stellite 6B}}$.

TABLE B-2. - Room-temperature erosion test results--20° impingement, 27-μm Al_2O_3 particles, 5-g/min particle flow, 170-m/sec particle velocity, 3-min test duration, N_2 atmosphere

Test material	Fabrication method[1]	Composition	Source[1]	Relative erosion factor[2]
SC-99P......	ps	99+ Al_2O_3..........................	Krohn	16.42
Ti-6Al-4V...	w	Not applicable......................	Unknown	1.56
Mild steel..	w	0.15C-bal Fe........................	Unknown	1.19
316 SS......	w	17Cr-12Ni-2Mn-1Si-2.5Mo-bal Fe......	Unknown	1.19
Graph-Air...	w	1.4C-1.9Mn-1.2Si-1.9Ni-1.5Mo-bal Fe.	TRB	1.16
Incoloy 800.	w	32.5Ni-46Fe-21Cr....................	HA	1.08
Incoloy 800H	w	32.5Ni-21Cr-0.07C-46Fe..............	HA	1.08
Inconel 671.	w	50Ni-48Cr-0.4Ti.....................	HA	1.06
HK-40.......	c	26Cr-20Ni-0.4C-bal Fe...............	Unknown	1.04
RA 330......	w	19Cr-35Ni-1.5Mn-1.3Si-bal Fe........	RA	1.04
RA 333......	w	25Cr-1.5Mn-1.3Si-3Co-3Mo-18Fe-bal Ni	RA	1.04
Stellite 6B.	w	30Cr-4.5W-1.5Mo-1.2C-bal Co.........	Stel	1.00
AlSiMag 840.	ps	Modified Al_2O_3..................	3M	.86
AlSiMag 798.	ps	85Al_2O_3.........................	3M	.64
Mo..........	w	Not applicable......................	Unknown	.52
W-10........	ps	90W-10(Ni,Cu,Fe)....................	K	.48
SC-99.7D....	ps	99.7Al_2O_3.......................	Krohn	.39
W...........	w	Not applicable......................	GE	.37
SC-98D......	ps	98Al_2O_3.........................	Krohn	.30
SC-95AM.....	ps	94Al_2O_3.........................	Krohn	.29
Refrax 20C..	ps	SiC-Si_3N_4 bond..................	Carbor	.27
AlSiMag 614.	ps	96Al_2O_3.........................	3M	.26
AlSiMag 838.	ps	99.5Al_2O_3.......................	3M	.25
Al-995S.....	ps	99.5Al_2O_3.......................	Wesgo	.22
Wearox......	ps	99.5Al_2O_3.......................	Wesgo	.20
Norbide.....	hp	B_4C..............................	N	.16
ZRBSC-D.....	hp	ZrB_2-SiC.........................	N	.14
Al-500S.....	ps	94Al_2O_3.........................	Wesgo	.11
Al-300S.....	ps	97.6Al_2O_3.......................	Wesgo	.09
Noroc 33....	hp	Si_3N_4-SiC.......................	N	.05
BT-11.......	ps	1.7MgO-38TiB -3.5WC-bal Al_2O_3.......	OGC	.05
Carbofrax D.	ps	SiC-ceramic bond....................	Carbor	.05
SiC.........	hp	Not applicable......................	N	.05
Si_3N_4.......	hp	Not applicable......................	N	.04
Lucalox.....	NAp	Densified Al_2O_3.................	GE	.03
K701........	ps	10.2Co + 4Cr binder.................	K	.02
K714........	ps	6Co + 1Cr binder....................	K	.01
K602........	ps	<1.5 binder.........................	K	.01

[1]Abbreviations are explained in table B-7.

[2]REF (relative erosion factor) = $\frac{\text{vol. loss material}}{\text{vol. loss Stellite 6B}}$.

TABLE B-3. - 700° C erosion test results--90° impingement, 27-μm Al_2O_3 particles, 5-g/min particle flow, 170-m/sec particle velocity, 3-min test duration, N_2 atmosphere

Test material	Fabrication method[1]	Composition	Source[1]	Relative erosion factor[2]
ZRBSC-M	hp	ZrB_2-SiC-graphite	N	High
AlSiMag 840	ps	Modified Al_2O_3	3M	High
SC-99P	ps	99+ Al_2O_3	Krohn	High
Chromite	ps	Not applicable	UCAR	3.43
5527	hp	$45MgAl_2O_4$-55MgO	NBS	2.84
4879	hp	$91MgAl_2O_4$-9MgO	NBS	2.77
4310	hp	$97MgAl_2O_4$-3MgO	NBS	2.76
$MgAl_2O_4$	hp	Not applicable	NBS	2.56
SCr-1	ps	85.5(Ti,Cr)CN-14.5Ni	OGC	1.89
SCr-3	ps	86(Ti,Cr)CN-14Ni	OGC	1.75
SC-95AM	ps	$94Al_2O_3$	Krohn	1.74
SCr-2	ps	85.8(Ti,Cr)CN-14.2Ni	OGC	1.71
K162B	ps	25Ni + 6Mo binder	K	1.67
K151A	ps	19Ni binder	K	1.62
Stellite 3	c	31Cr-12.5W-2.4C-bal Co	Stel	1.61
883	ps	WC-6Co binder	Carb	1.53
SC-99.7D	ps	$99.7Al_2O_3$	Krohn	1.49
HR-37	c	5Cr-1Ti-14W-8V-3.9C-13Mn-bal Fe	OGC	1.49
Wearox	ps	$99.5Al_2O_3$	Wesgo	1.46
Carbofrax D	ps	SiC-ceramic bond	Carbor	1.38
895	ps	WC-6Co binder	Carb	1.32
Mo	w	Not applicable	Unknown	1.32
K90	ps	25 binder	K	1.21
Al-300S	ps	$97.6Al_2O_3$	Wesgo	1.21
SN-5F	ps	85(Ti,Mo)CN-12Ni-3Mo	OGC	1.17
25 Cr iron	c	25Cr-2Ni-2Mn-0.5Si-3.5C-bal Fe	OGC	1.16
AlSiMag 798	ps	$85Al_2O_3$	3M	1.15
Refrax 20C	ps	SiC-Si_3N_4 bond	Carbor	1.15
SC-98D	ps	$98Al_2O_3$	Krohn	1.12
Stellite 6K	w	30Cr-4.5W-1.5Mo-1.7C-bal Co	Stel	1.06
Al-500S	ps	$94Al_2O_3$	Wesgo	1.04
K86	ps	8.8Co binder	K	1.03
Stellite 6B	w	30Cr-4.5W-1.5Mo-1.2C-bal Co	Stel	1.00
Haynes 93	c	17Cr-16Mo-6.3Co-3C-bal Fe	Stel	1.00
11S-3	ps	88(W,Cr)C-10Ni	OGC	.99
TiCN	ps	Not applicable	TWCA	.98
10S-3	ps	90(W,Cr)C-10Ni	OGC	.92
SN-6F	ps	85(Ti,Mo)CN-12Ni-3Mo	OGC	.91
VR73	ps	71WC-12TiC-10TaC-CbC-6.5Co	F	.89
AlSiMag 614	ps	$96Al_2O_3$	3M	.87
5S-3	ps	90WC-5Co-5Ni	OGC	.87
9S-3	ps	92(W,Cr)C-8Ni	OGC	.86
Haynes 25	w	20Cr-15W-10Ni-0.15C-bal Co	Stel	.85
K94	ps	11.5 binder	K	.84
Haynes 188	w	22Cr-14.5W-22Ni-0.15C-bal Co	Stel	.83
RA-333	w	25Cr-1.5Mn-1.3Si-3Co-3Mo-3W-18Fe-bal Ni	RA	.80
SN-4F	ps	84(Ti,Mo)CN-13Ni-3Mo	OGC	.80
3109	ps	12.2 binder	K	.80
RA-330	w	19Cr-35Ni-1.5Mn-1.3Si-bal Fe	RA	.79

See footnotes at end of table.

TABLE B-3. - 700° C erosion test results--90° impingement, 27-μm Al_2O_3 particles, 5-g/min particle flow, 170-m/sec particle velocity, 3-min test duration, N_2 atmosphere--Continued

Test material	Fabrication method[1]	Composition	Source[1]	Relative erosion factor[2]
HK-40	c	26Cr-20Ni-0.4C-bal Fe	Unknown	0.78
SN-3F2	w	83(Ti,Mo)CN-13Ni-3Mo	OGC	.74
304 SS	w	17Cr-9Ni-2Mn-1Si-bal Fe	Unknown	.73
Iso A-242	ps	Not applicable	Green	.73
SN-305-1	ps	94(Ti,Mo)CN-5Ni-1Mo	OGC	.73
523	ps	WC-TiC coating	Carb	.72
SN-309-3	ps	89(Ti,Mo)CN-9Ni-2Mo	OGC	.69
AlSiMag 838	ps	99.5Al_2O_3	3M	.62
Inconel 671	w	50Ni-48Cr-0.4Ti	HA	.62
430 SS	w	17Cr-1Mn-1Si-0.1C-bal Fe	Unknown	.62
Inconel 600	w	76Ni-15.5Cr-8Fe	HA	.61
Al-995S	ps	99.5Al_2O_3	Wesgo	.59
Lucalox	NAp	Densified Al_2O_3	GE	.57
Beta III Ti	w	11.5Mo-6Zr-4.5Sn-bal Ti	Unknown	.57
Incoloy 800	w	32.5Ni-21Cr-46Fe	HA	.57
316 SS	w	17Cr-12Ni-2Mn-1Si-2.5Mo-bal Fe	Unknown	.56
Ti-6Al-4V	w	Not applicable	Unknown	.54
Incoloy 800H	w	32.5Ni-21Cr-0.07C-46Fe	HA	.54
SCr-9	ps	84(Ti,Cr,Mo)CN-3Mo-13Ni	OGC	.54
K68	ps	5.8 binder	K	.50
VR-54	ps	WC-7Co binder	F	.50
3406	ps	7.8 binder	K	.49
2A5	ps	WC-6Co binder	F	.48
K701	ps	10.2Co + 4Cr binder	K	.47
CA 4	ps	WC-6Co binder	Carmet	.47
C-2	ps	97(Ti,Mo)CN-2Ni-0.5Mo	OGC	.47
K801	ps	6Ni binder	K	.46
SiC	hp	Not applicable	N	.44
W-10	ps	90W-10(Ni,Cu,Fe)	K	.44
Noroc 33	hp	Si_3N_4-SiC	N	.42
HD 430	NAp	Recrystallized SiC	N	.38
CA 306	ps	WC-6Co binder	Carmet	.36
BT-9	ps	2MgO-25TiB_2-3.5WC-bal Al_2O_3	OGC	.36
HD 435	NAp	Recrystallized SiC	N	.32
TiC-Al_2O_3	ps	Not applicable	B and W	.30
BT-11	ps	1.7MgO-38TiB_2-3.5WC-bal Al_2O_3	OGC	.26
K714	ps	6Co + 1Cr binder	K	.25
BT-10	ps	2MgO-30TiB_2-3.5WC-bal Al_2O_3	OGC	.25
Norbide	hp	B_4C	N	.21
BT-24	ps	2MgO-30TiB_2-3.5WC-bal Al_2O_3	OGC	.20
W	w	Not applicable	GE	.17
BT-12	ps	1.5MgO-49TiB_2-3.5WC-bal Al_2O_3	OGC	.16
K602	ps	<1.5 binder	K	.13
Si_3N_4	hp	Not applicable	N	.12
ZRBSC-D	NAp	ZrB_2-SiC	N	.07
SiC	NAp	98 pct dense	GE	.02
Diamond	NAp	Not applicable	GE	0
CBN	NAp	Not applicable	GE	0

[1] Abbreviations are explained in table B-7.

[2] EF (relative erosion factor) = $\frac{\text{vol. loss material}}{\text{vol. loss Stellite 6B}}$.

TABLE B-4. - Room-temperature erosion test results on coated materials--90° impingement, 27-μm Al_2O_3 particles, 5-g/min particle flow, 170-m/sec particle velocity, 3-min test duration, N_2 atmosphere

Test material	Fabrication method[1]	Composition	Source[1]	Relative erosion factor[2]
TiC	CVD	TiC on unknown substrate	Unknown	([3])
Al_2O_3	CVD	Al_2O_3 on unknown substrate	Unknown	([3])
TiCN	CVD	TiCN on unknown substrate	Unknown	([3])
TiN	CVD	TiN on unknown substrate	Unknown	([3])
TiCN	CVD	TiCN on Ti-6Al-4V	Unknown	([4])
TiCN	CVD	TiCN on Inconel 718	Unknown	([4])
TiCN	CVD	TiCN on WC	Unknown	([4])
Borofuse Stellite 31	pc	B on 25Cr-10.5Ni-2Fe-7.5W-0.5C-bal Co	Stel-MDC	1.40
Ni-Cr-B-Cu	Plasma	0.5C-4Si-16Cr-4B-4Fe-2.4Cu-2.4Mo-2.4W-bal Ni	CWS	1.32
Borofuse Stellite 6	pc	B on 28Cr-4W-1C-bal Co	Stel-MDC	1.29
Cr_2O_3	Plasma	Cr_2O_3-5SiO_2-3TiO_2	CWS	1.23
WC	Plasma	35(WC+8Ni)-11Cr-2.5B-2.5Fe-2.5Si-0.5C-bal Ni	CWS	1.11
Borofuse Stellite 3	pc	B on 31Cr-12.5W-2.4C-bal Co	Stel-MDC	.92
W	CVD	Pure coating	RMRC	.53
Borofuse MT-104	pc	B on 0.5Ti-0.08Zr-0.03C-bal Mo	Syl-MDC	.30
Borofuse PM moly	pc	B on Mo	CM-MDC	.25
SiC	CVD	SiC on C converted to SiC	Unknown	.06
SiC	CVD	Pure coating	Unknown	.05
Borofuse WC	pc	B on WC	MDC	.02
TiB_2	e	TiB_2 on Ni	CPMRC	0
18B-11	e	TiB_2 on 310 SS	UT	0
19A-13	e	TiB_2 on 310 SS	UT	0

[1]Abbreviations are explained in table B-7.

[2]REF (relative erosion factor) = $\frac{\text{vol. loss material}}{\text{vol. loss Stellite 6B}}$.

[3]Ready penetration--coating too thin.

[4]Retarded penetration--coating 0.002 in thick.

TABLE B-5. - Room-temperature erosion test results on coated materials--20° impingement, 27-μm Al_2O_3 particles, 5-g/min particle flow, 170-m/sec particle velocity, 3-min test duration, N_2 atmosphere

Test material	Fabrication method[1]	Composition	Source[1]	Relative erosion factor[2]
TiC	CVD	TiC on unknown substrate	Unknown	([3])
Al_2O_3	CVD	Al_2O_3 on unknown substrate	Unknown	([3])
TiCN	CVD	TiCN on unknown substrate	Unknown	([3])
TiN	CVD	TiN on unknown substrate	Unknown	([3])
TiCN	CVD	TiCN on Ti-6Al-4V	Unknown	0
TiCN	CVD	TiCN on Inconel 718	Unknown	0
TiCN	CVD	TiCN on WC	Unknown	([4])
Ni-Cr-B-Cu	Plasma	0.5C-4Si-16Cr-4B-4Fe-2.4Cu-2.4Mo-2.4W-bal Ni	CWS	0.98
WC	Plasma	35(WC+8Ni)-11Cr-2.5B-2.5Fe-2.5Si-0.5C-bal Ni	CWS	.72
Cr_2O_3	Plasma	Cr_2O_3-$5SiO_2$-$3TiO_2$	CWS	.61
Borofuse Stellite 6	pc	B on 28Cr-4W-1C-bal Co	Stel-MDC	.45
Borofuse Stellite 31	pc	B on 25Cr-10.5Ni-2Fe-7.5W-0.5C-bal Co	Stel-MDC	.40
Borofuse Stellite 3	pc	B on 31Cr-12.5W-2.4C-bal Co	Stel-MDC	.37
SiC	CVD	Pure coating	Unknown	.20
SiC	CVD	SiC on C converted to SiC	Unknown	.13
Borofuse PM moly	pc	B on Mo	CM-MDC	.09
Borofuse MT-104	pc	B on 0.5Ti-0.08Zr-0.03C-bal Mo	Syl-MDC	.03
Borofuse WC	pc	B on WC	MDC	.01
TiB_2	e	TiB_2 on Ni	CPMRC	0
18B-11	e	TiB_2 on 310 SS	UT	0
19A-13	e	TiB_2 on 310 SS	UT	0

[1]Abbreviations are explained in table B-7.

[2]REF (relative erosion factor) = $\frac{\text{vol. loss material}}{\text{vol. loss Stellite 6B}}$.

[3]Ready penetration--coating too thin.

[4]Retarded penetration--coating 0.002 in thick.

TABLE B-6. - 700° C erosion test results on coated materials--90° impingement, 27-μm Al_2O_3 particles, 5-g/min particle flow, 170-m/sec particle velocity, 3-min test duration, N_2 atmosphere

Test material	Fabrication method[1]	Composition	Source[1]	Relative erosion factor[2]
TiC	CVD	TiC on unknown substrate	Unknown	([3])
Al_2O_3	CVD	Al_2O_3 on unknown substrate	Unknown	([3])
TiCN	CVD	TiCN on unknown substrate	Unknown	([3])
TiN	CVD	TiN on unknown substrate	Unknown	([3])
Ni-Cr-B-Cu	Plasma	0.5C-4Si-16Cr-4B-4Fe-2.4Cu-2.4Mo-2.4W-bal Ni	CWS	2.79
WC	Plasma	35(WC-8Ni)-11Cr-2.5B-2.5F-2.5Si-0.5C-bal Ni	CWS	2.06
Borofuse Stellite 6	pc	B on 28Cr-4W-1C-bal Co	Stel-MDC	1.40
Borofuse Stellite 31	pc	B on 25Cr-10.5Ni-2Fe-7.5W-0.5C-bal Co	Stel-MDC	1.37
Borofuse Stellite 3	pc	B on 31Cr-12.5W-2.4C-bal Co	Stel-MDC	.83
Borofuse WC	pc	B on WC	MDC	.72
Borofuse PM moly	pc	B on Mo	CM-MDC	.28
W	CVD	Pure coating	RMRC	.25
Borofuse MT-104	pc	B on 0.5Ti-0.08Zr-0.03Cr-bal Mo	Syl-MDC	.19
SiC	CVD	Pure coating	Unknown	0
SiC	CVD	SiC on C converted to SiC	Unknown	0
TiB_2	ϵ	TiB_2 on Ni	CPMRC	0
18B-11	ϵ	TiB_2 on 310 SS	UT	0
19A-13	ϵ	TiB_2 on 310 SS	UT	0

[1]Abbreviations are explained in table B-7.

[2]REF (relative erosion factor) = $\frac{\text{vol. loss material}}{\text{vol. loss Stellite 6B}}$.

[3]Ready penetration--coating too thin.

TABLE B-7. - Abbreviations used in tables B-1 through B-6

3M..........	American Lava Corp., Subsidiary of Minnesota Mining & Manufacturing Co.
B and W.....	Babcox and Wilcox.
Carb........	Carboloy Systems Dept., General Electric Co.
Carbor......	Carborundum Co.
Carmet......	Carmet Co., Allegheny Ludlum Steel Corp.
c...........	Cast.
CVD.........	Chemical vapor deposited.
CM..........	Climax Molybdenum Co.
CPMRC.......	College Park Metallurgy Research Center (now Avondale Metallurgy Research Center), Bureau of Mines.
Coors.......	Coors, USA.
CWS.........	CWS Corp.
e...........	Electrodeposited.
F...........	Fansteel, Inc.
GE..........	General Electric Co.
Green.......	A. P. Green
hp..........	Hot pressed.
HA..........	Huntington Alloy Products Div., International Nickel Co.
K...........	Kennametal, Inc.
Krohn.......	Krohn Ceramics Corp.
MDC.........	Materials Development Corp.
NBS.........	National Bureau of Standards.
N...........	Norton Co.
NAp.........	Not applicable.
OGC.........	Oregon Graduate Center.
pc..........	Pack cementation.
ps..........	Pressed and sintered.
RMRC........	Rolla Metallurgy Research Center, Bureau of Mines.
RA..........	Rolled Alloys Corp.
Stel........	Stellite Div., Cabot Corp.
Syl.........	Sylvania Electric Products Inc.
TWCA........	Teledyne Wah Chang.
TRB.........	Timken Roller Bearing Co.
UT..........	United Technologies Corp.
UCAR........	Union Carbide Corp.
Wesgo.......	Western Gold and Platinum Co.
w...........	Wrought.

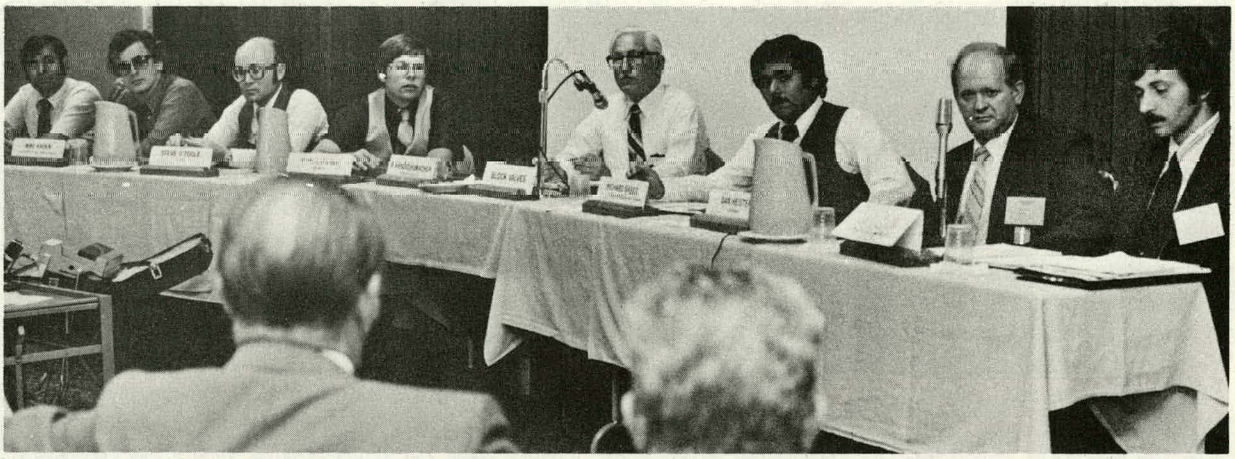
Even the Speakers Found Time to Share Ideas . . .

Section 17

Panel Discussion on Block Valves

Chaired by Richard Handschumacher

October 16, 1980—2:15 p.m.



BLOCK-VALVE PANELISTS—Left to right: Kirit J. Bhansali, Mike Kaden, Steve O'Toole, John Gardner, Richard Handschumacher, Richard Basile, Dan Heister, and Gary Qualls.

GARDNER: This should be a very informal panel discussion today. Feel free to speak up at any time. The group is small enough, I think, if everybody stays close to the front we won't have to shout, nor will we really need the microphones. If we have trouble hearing what you have said we will ask you to repeat. Anytime you can't hear, speak up; let us know.

Mr. Dick Handschumacher from ITT Grinnell will serve as the moderator for this panel discussion. I would like to introduce the rest of the panel members. On my extreme left is Mr. Gary Qualls who is currently involved with the block-valve program at the H-Coal Pilot Plant in Catlettsburg, Kentucky. Next to him is Mr. Dan Heister, involved with the three quarter ton per hour hydrogasification unit that Rockwell International has.

Next to him is Rich Basile from Exxon, whom you've already heard. To my extreme right is Kirit Bhansali, who is currently with the National Bureau of Standards in the area of wear of materials. Next to him is Mr. Mike Kaden, IEA. Right to my right is Mr. Steve O'Toole, with us from PAMCO. And I think everybody knows that I am John Gardner from METC here in Morgantown. I will turn over the podium to Dick.

HANDSCHUMACHER: Thank you, John. This is truly a shirt-sleeve kind of session now, and I am most anxious for people to understand questions and understand what may be a factor in posing a question. If you could give your name and the company you are involved with, I think it will help people either to contact you later on if they want to get into more specific questions or will provide the audience with an understanding of where the question may be from.

One of the things I think would be helpful is to have Dan Heister give us a little bit of information about the Rockwell effort. We have heard all different approaches and systems and you've heard from some of the people at the podium here, but you haven't heard from Dan. Dan, would you just give us a very brief rundown on the Rockwell system?

HEISTER: Energy Systems Group, a division of Rockwell, is involved with developing a high-Btu coal-gasification system. The process incorporates a short residence time reactor. The reaction takes place within a reactor system that uses technology gained from rocket-engine development. An injector is used to mix pulverized coal, heated hydrogen, and gaseous oxygen in the reactor. The term "flash hydropyrolysis" is used to describe the gasification process.

By controlling the pressure of the reactants within the reactor, the product can be either all gas or a combination of gas and light oils (BTX), such as benzene having a commercial value for the chemical industry. The range of reactor pressure is 1,000 to 1,500 psi. The total plant will have the capability to process coal from lump form into the usable product for flowing to the reactor injector. It is necessary for the coal to be pulverized to 70% through 200 mesh and be dried to a moisture content of approximately 2 to 3%. From here, the coal is stored in a silo and upon demand is loaded into a lockhopper system for transfer to the coal main-feeder vessel, which is kept at constant pressure. The mode of transfer to the main feeder and to the reactor injector is by dense phase flow. There is just a small amount of hydrogen gas within the stream of coal.

The 1,850 to 2,000°F product-gas and char stream is cooled in a series of heat exchangers downstream of the reactor. We refer to the first heat exchanger as a recuperator and the second as a char cooler. The recuperator is a hydrogen-cooled device, and the char cooler is a water-cooled heat exchanger. The temperature of the gas and char is reduced to 600°F, which allows for use of conventional stainless-steel materials with specialized coatings.

From here the product stream is piped through a series of cyclone separators with solid collectors mounted below. These units are used to separate the product gas from the char particles with the majority of the solids being deposited in the char lockhopper after passing through an axial flow cyclone. The collected solids are then lockhoppered out to a charge surge hopper. The temperature is then cooled to approximately 120 to 150°F by a device we refer to as a slurrifier. The gas flowing from the cyclones is further cooled to approximately 120°F and demisted. Letdown valves reduce the pressure from the 1,000- to 1,500-psig operating pressure to 4-8 psig prior to being put through the chemical scrubber to remove the sulfur products. Ultimately the gas goes to the product-gas combustor.

HANDSCHUMACHER: Thank you, Dan. I think that will give you a chance to pose some questions that may be specific to that type of process. Now to get the most out of this panel discussion, we received a number of questions and I have found a group of them fell into one kind of category, and that was the category of what valves are used in different systems and what are the requirements of those valves? I would like to pose this general question, if anybody is not clear on what the size range, what the pressure range, what the temperature range, the fluid, the quantities, the trends or even the definition of terms are, ask now.

If you have any questions—admittedly, as these men were putting on their presentations, there were slides going up rapidly—and I would like to get those questions cleared away early. Is there anyone who wants a summary from any one of these gentlemen on the requirements of their system in terms of valves? Good, everybody knows the pressures and temperatures; I am sure the marketing people in each of your organizations will be pleased to hear that.

MILLS: My name is Les Mills and I'm with SOHIO, and I would like to know why they use ball valves for block valves.

HANDSCHUMACHER: The question is why do they use ball valves for block valves. How about it, Rich, do you want to start?

BASILE: Well, when we started our program, we recognized that gate valves, regular wedge-type gate valves, in this type of service might be difficult to shut after you have flowed solids through them for a period of time. The solids collect between the seats of the gate at the bottom of the valve or in the bonnet, and a purging flow may not clear them out sufficiently to shut the wedge gate.

At this point, we basically made a survey and drew up a list of requirements that we thought would be necessary for a valve in this service, such as the seats isolated from the flow stream, the body cavities isolated from the flow stream in both the open and closed conditions, and so on. Ball valves, plug valves, and conduit-type gate valves all filled these criteria. Because no one had a lot of experience with any one of these valves in this type service, we decided to test all three to determine which one would work the best. I don't know if that specifically answers your question. If you have experience in this field, I would appreciate hearing it, as to why you wouldn't choose a ball valve as a block valve.

MILLS: The only time your body cavities aren't exposed to the material is when they are opened or closed. But when you are going into those two positions, you expose the body cavity to the slurry or the fines or whatever else you are pushing through the valve. So you still need a flushing system in there as you would in a gate valve.

BASILE: Yes, but the only time the valve is exposed, as you said, is when you are cycling the valve. If your seats stay in contact with the ball, as in a trunnion design or as in some floating-ball designs, then you minimize the chance of getting solids between your seating surfaces. If the solids tend to present a problem in the body cavity such as solidifying on the ball and causing subsequent scoring on the resulting cycles, it's much easier to flush out the cavity of a ball valve than to try to clean out a gate-valve cavity when the gate is wide open.

MILLS: One of the problems that occurs with the ball valve is freezing of the stem of the trunnion, top and bottom. They sometimes freeze solid. We've had instances with very corrosive material where the rust that forms there is almost a talcum-powder consistency. It squeezes those valves so they are inoperable. Now the solution to that problem was to put an injection system in.

HANDSCHUMACHER: I wonder if there is a ball-valve manufacturer who would like to maybe comment on that?

MILLER: I am not a manufacturer. Bill Miller, from Ashland. Even if you would fill up the compartment of the ball valve with a solid, the ball is still free to move. It's not a compartment in which it obstructs the normal operation of that valve. Secondly, any powders or any corrosive products that would be present on the surface of a ball valve would certainly also be there on the surface of almost any other valve that you have. So if you have that problem in a ball valve, you have it with the slide surfaces in a gate valve and/or any other moving surfaces. The same corrosive atmospheres are working on the same kinds of materials.

HANDSCHUMACHER: Can you give your name and company?

HARPER: Cliff Harper with Consolidated Controls. Now that you have had a limited amount of experience on all three types of valves, would you go back and pick the same valves again for the same services they are now in, or would you standardize on one type of valve?

BASILE: At this time I don't think we have enough experience with any one of the valves to say that we would pick it over any other for usage throughout the whole plant. We have put a minimal number of cycles on our valves to date, and the results show that they all perform adequately provided certain conditions exist. However, we don't have enough data to say that one valve performs best under all conditions. Perhaps we will after we finish running the plant, which is in 2½ years. That's our goal, basically—to determine which valve operates best over a long period of time. We haven't had enough operating experience yet to say which one we would pick.

HANDSCHUMACHER: Gary.

QUALLS: Well to date, the only experience we have had has been with the ball valve, and it has been satisfactory to this point—we do anticipate using it. In the near future, we have two other ball valves we are going to put in and test. But again, we still have not had the experience to decide at this time which valve would be best.

BACKSTROM: I'm Oscar Backstrom from Zimmerman and Jansen. I'm wondering if you have given consideration to using a valve that is basically a full-port, clear-way, pipeline-type valve with purges in the upper bonnet and lower bonnet so you are actually moving the valve with a positive pressure on both sides of it. Can you picture the valve I am talking about?

BASILE: Yes, I can picture the valve you are talking about. We basically use that type of valve; our through-conduit gate valve that I presented in yesterday's show is a pipeline-type valve. It's a full-bore through-conduit valve. There's no change in diameter throughout the whole valve. The valve, through its unique design seal, isolates the body cavities in both the open and closed positions. We do flush that valve when we go from the open and closed positions to prevent solids buildup. So the type of valve you are describing is used in our plant.

BACKSTROM: How do you evaluate that in comparison with a ball valve in the same service?

BASILE: You mean in terms of how they perform so far or how we are going to evaluate them over the life of the project?

BACKSTROM: Well, either way.

BASILE: Basically, over the life of the project, we have decided on a specific number of cycles that we are going to put on our valves under actual process conditions. And then after a certain number of cycles we are going to measure leakage that we have gotten through these valves and if we have severe leakage through the valves, we are going to disassemble them and determine why we had the leak. After we've cycled the valves and collected our leakage data, we'll make a detailed evaluation based on our service conditions, and determine which valve has operated the best for which category, or if they've all operated satisfactorily. From that we will make a decision as to which types of valves should be specified for what service conditions in a commercial plant.

HANDSCHUMACHER: John, do you want to comment?

GARDNER: I would like to go back to the gentleman from SOHIO's question on why did we select ball valves, or why we are evaluating ball valves. I would like to say that back 5 or 6 years ago, when many of the gasification pilot plants were getting started and going out on competitive specifications-bidding procedures, we were unable to secure bids from any other type of valve manufacturer for the services encountered in these gasification processes, such as the lockhopper-valve service. I can't speak from experience on the applications that Rich has, but I do know that in the lockhopper-valve services where we are putting the valves to many, many cycles of operation in a given day—in the range of about 100 cycles per day—even though we are seeing fines buildup in the cavity between the ball and the body wall, that has not been detrimental to the functioning of the valve, nor has it impeded the seal capability of that valve, as long as it maintains the proper loading between the seat and ball surface itself. We've seen some ball-valve designs go to excess, 15,000 cycles now with almost no maintenance at all.

MILLS: I appreciate that, because we use the same type of valve in that type of service. If not, we haven't got a gasification plant. I'm thinking about platform units, for example, which are a lot like this. I was thinking more of the block valves that you use to isolate equipment such as pumps. Those are larger valves. For small valves, it's ideal.

GARDNER: Well, if you call a 12- or a 16-inch valve small.

MILLS: Yes, they are small. They're not as bad as the other ones though, like those slurry pumps.

HANDSCHUMACHER: How about PAMCO?

O'TOOLE: We have been using globe valves, basically because of the size of our plant.

In looking at ball valves, one consideration is that it's a quarter of a turn between opening and closing of the valve, whereas a gate valve has a number of turns in order to operate it. Another, which Rich addressed in the flushing of this body cavity with the gate valve, is that the ball valve does not require nearly as much flush while you are operating the valve, because you have a lot smaller cavity. From the process standpoint, when you flush into the system, you are in effect diluting your product. From economics and the process standpoint, that could be significant and especially in a small plant like we have. I don't know what effect it would have in a larger plant. Maybe it wouldn't be that significant. From our standpoint it would be.

HANDSCHUMACHER: Do we have any comment from any ball-valve manufacturer or people who think that there may be another type of valve that would be suitable for that kind of service?

ROBBINS: Mr. Vern Robbins, Hills-McCanna. We have many of our ball valves on lockhopper-type services. Where you have fines and solids that could possibly cause a problem, the user can put another block valve ahead of our valve. That will shut off some of the solids, then our valve will close with no fines; no flow through it. That will lower some of the problem Les is talking about. Now I know that yesterday several of the speakers indicated that where they had let-down pressures to worry about, that is exactly what they were doing. They were using a double-block system. And that is what we find works best for our valves.

HANDSCHUMACHER: Okay, are there any other questions? Gentleman back there.

SWING: Al Swing; I'm with Fluor. I would like to know whether any of the panelists have had any experience with a teflon-sleeve plug valve provided they are below 450 °F?

GARDNER: Yes, I have. We currently use a TFE sleeve-plug valve in our gasification pilot plant at Morgantown. The process there is a stirred fixed-bed gasifier. It goes through a primary solid separation followed by a quench of the product gas. From after that quench, all the way downstream, TFE plug valves are used as block valves for isolation and also process blocking.

SWING: You do have solids?

GARDNER: Yes, there are still some solids left. I can't quote you the exact percentage.

SWING: How has it been working out?

GARDNER: No problem whatsoever with those valves to date. And they have been in service now in excess of 2 years.

SWING: Thank you.

HANDSCHUMACHER: Kirit would you want to add anything to that from your experience?

BHANSALI: No. The only thing I could think of is that the teflon has a tendency to creep at low temperatures. What would happen is that if it remains under high stress it will deform even though it is not used and you may lose your tolerances. There is another material, if any other valve manufacturer is interested in nonmetallic polymer materials, high-molecular-weight polyethylene. It offers the same advantages as teflons, but it has a very low creep rate. I am glad to hear that it is working out for John.

VOICE: What was the material?

BHANSALI: High-molecular-weight polyethylene.

HANDSCHUMACHER: Any other question related to the presentations that were heard during the last couple of days? I think it's important, and one of the objectives of this whole symposium was to give people who are interested in block valves and in throttle valves the opportunity to come here and get an idea of the size range, pressures, temperatures, approximate quantities, and the like. We have had a number of our management people say that we are not going to be interested until we can find something that's a little bit more concrete. And one of our objectives from 3 years ago was to come here and say that we want you people to be able to go back to your companies and say here is the market size, here is the opportunity, and we feel that the presentations that were made up to this point have tried to address those points very well. So if we go home now, will we have all the answers? Gentleman here.

MARION: My name is Ken Marion, and I am with MARPAC Controls. Mr. Basile indicated that 40 valves out of 100 you had in your power plant were class 2500. What is the pressure class and size range of the remaining valves?

BASILE: The remaining valves in our plant run anywhere from 150-pound to 1,500-pound valves.

MARION: Equal percentages?

BASILE: Well, I really don't have a breakdown of percentages in that class range. I just basically, for my talk, broke out the high-pressure-range class valves to give you an idea of the percentage of high-pressure-class valves. I don't really know the percentage of 600-, 300-, 150-pound valves in the plant.

FLEMING: Jonathan Fleming, Foster-Miller. I have a comment on your comment on polyethylene, not with valves, but with seals and polyethylene and liquid environments—we have observed swelling.

BHANSALI: It depends on what liquid you are talking about.

FLEMING: Water.

HANDSCHUMACHER: Liquid, I guess you are talking about certain temperatures?

FLEMING: Ambient temperatures and ambient pressure.

BHANSALI: That's something that I didn't know. I haven't heard of that at all.

HANDSCHUMACHER: How many other people have experienced this swelling effect of polyethylene?

SCHOENWEIS: My name is Fred Schoenweis, Rockwell International. We manufacture polyethylene valves and we have experienced no problems with swelling of polyethylene. Our tests were 1,000 plus hours in water at different temperatures and pressures.

HANDSCHUMACHER: I guess this is one of the occasions where you watch your suppliers. Set some pretty good specs. Question over here.

PAULSON: Wendell Paulson of Zimpro. I think one of the problems is that he is referring to just standard polyethylene. What we are using in some of our vulcro seats is the ultra-high molecular weight, and there is a difference. I have another question for Dan from Rockwell. What type of valves are you using on your block service?

HEISTER: For our blocking valves upstream of our letdown systems and also our slurry, we are actually using the plug-type valves; quarter turn with the balance poppit and provisions for the lubrication in case we should get a lockup.

HANDSCHUMACHER: The gentleman here.

ROZALSKY: Herb Rozalsky, Shell. The last speaker talked about the need for a standardized low-hazard type of erosion test. I was wondering if the Bureau of Standards was going to do anything about it to help in that regard?

BHANSALI: The Bureau of Standards is participating in a committee, ASTM committee for G-2, which is currently in the process of standardizing an erosion test for impingement erosion. This particular test does not take into account liquid—it is a gaseous impingement erosion test. And, yes, the Bureau is taking part in that. Taking a lead and setting up a standard. If anybody is interested in or participating in this program, I would be more than happy to give you the name of the chairman of the committee of ASTM G-2. Right now they are running a round-robin test About five to six materials manufacturers as well as end users like Kodak and Union

Carbide are taking part in this round-robin program. As you may have gathered from the previous speaker, ductile and brittle materials have different erosion behavior, and so right now they are working on ductile material, 10 20 steel, to produce a standard for that particular test. Does that answer your question?

ROZALSKY: Yes.

HANDSCHUMACHER: Gentleman in the back.

GROSS: Art Gross, Kast Metals. We are a foundry and I noticed most of the discussion was on valve internals. With the high temperatures you talk about, do you see any trouble with the pressure rating of the material itself? How about valve materials of the future?

HANDSCHUMACHER: How about if we ask Mike Kaden to give us a little background from England.

KADEN: Perhaps I can start a little bit earlier down the road, because I really would like to enforce a point that John made, which we came across 15 years ago. Not me personally, because I was not in the field. I don't know if people are aware of the pressurized fluidized-bed research center in Netherhead at Curl. They did research on new solids applications for 15 years and they did it under pressure as well for about 10 years. I am talking about 1,600°F and 250 psi. Coming back to that question, just briefly about the application, they are using a lot of valves that are actually machined. That means they are not cast bodies. The body is turned out of a stainless-steel 310 or 304.

I want to go back to that point about ball valves and other valves because, funny enough, after 15 years of experience, Curl is using only ball valves. They have tried everything they can get in the market to use in their lockhopper arrangements, speaking of gate valves, block valves, or whatever. They didn't work as good as ball valves. So we are going exactly the same route now. I really want to ask manufacturers if they could come up and say to me they have a gate valve or any different construction from a ball valve which they believe will stand these kinds of conditions. The only people we find are ball-valve manufacturers, and there are only a few who will say, "We will do it," and they always can prove that they have done it and that they are going to do it again.

HANDSCHUMACHER: Well, to answer that gentleman's question back there. As I understand the question, we have been talking about trim to a great extent. I think the gentleman from the foundry was interested in the problems that may be encountered in cast-pressure containment vessels. Is that correct?

GROSS: Yes, that's right. Some materials become brittle and other materials, like 340, 347, are very difficult to cast. I was wondering if you have to get the trim down; if, with long-term service, you might not have other difficulties with the materials.

HANDSCHUMACHER: How about Gary. Do you have any comments on the pressure-containment parts and the use of castings?

QUALLS: You are specifically talking about valve bodies?

GROSS: Yes.

QUALLS: Well if the trim doesn't hold up, the body won't hold up either. We did have some experience with body erosion; once we lost the trim, in one particular valve.

HANDSCHUMACHER: John, maybe you've had some experience here that...

GARDNER: I am trying to think of the longest duration I have had valve bodies installed in some of the gasification systems. I guess there were a couple of valves installed before I joined with the current technology center in Morgantown. I think that overall those valves, those bodies, have now been in line 8 to 10 years in an intermittent service condition. It would probably total out at maybe 3½ years of continuous service in this particular project. With body materials as low as A-216 grade WCB, we have seen very few troubles on very-low-temperature application. Most of our typical valves are built with 316 stainless bodies, most of that being a cast form. To date, we have not seen a problem with corrosion.

There is a significant amount of work being performed for DOE and the Materials Property Council at EPRI and if anyone is interested, Mr. Vern Hill is the person to contact. I think they have done a lot of long-term high-temperature corrosion testing relating to coal gasification. I can't address the liquefaction side, but I do know that in the gasification area, the data are available on a long-term nature about corrosion and high temperature in environments of coal gasification.

PAPPAIOANOU: John, Vern Hill is not at EPRI anymore; he's at ITT.

HANDSCHUMACHER: Steve.

O'TOOLE: At the Ft. Lewis pilot plant, we have some Walworth 4-inch gate valves in our high-pressure, high-temperature service that are cast 347 stainless; I believe that it's 347. And we have had no problems to date. We also have cast bodies on Rockwell-Everett globe valves and have had no problems that I know of.

HANDSCHUMACHER: I'm inclined to think that another factor that would come into the pressure-containment vessel is the design on the discharge side. And I am inclined to think that valve manufacturers that have been in the industry for a while have a little bit of experience in this area and either they have avoided the erosive effect in the body, or maybe they pass it downstream to the pipe, but on a block valve I don't think you have as much of a problem as with throttling valves.

VOICE: Are those fluid temperatures we are talking about, or were those actual valve-pressure temperatures? You are talking about 1,700, 1,750°F . . .

GARDNER: I think the practice right now, at least in gasification, is specifying media temperature and not a valve-body temperature. I think that's pretty universal right now, from my experience.

HANDSCHUMACHER: Rich?

BASILE: Our process doesn't really have any valves in that temperature range. Our highest temperature is 900°F. We've drawn on our refinery experience where we have processes in that temperature range, and the valves last for many years. So we don't really see any significant problems within the body material of the valves in our process.

HANDSCHUMACHER: I think, as John has suggested, maybe Kerry Gunn would have some comments on that. Is Kerry out in the audience?

GARDNER: When you specified the valves for the catalytic-gasification process, that specification was on media temperature, correct?

GUNN: Yes, it was.

GARDNER: And there have not been really any significant body effects there in 2, 2½ years.

GUNN: Yes, that's true. However, I believe we specified 1,400°F media temperature, which is roughly 100°F above what we expected, and we know they are not going to get that hot even though we do heat the valves. In the 2 years' service, we've never had any troubles at all.

HANDSCHUMACHER: Okay. This gentleman here.

HARPER: Cliff Harper, from Consolidated Controls. I would like to hear the collective experience of the panel with regard to the cause of the failures they have. Is it temperature? Is it pressure? Or is it just the fact that you've got solids? Is there some threshold you get above so much pressure and you get problems? Anything like this?

HANDSCHUMACHER: How about Dan? Do you have any feel from Rockwell's standpoint?

HEISTER: I don't think I can address that properly. To date, we've just run the ¾-ton scale with limited duration of 20 to 40 minutes. We are building the ¾-ton plant, which is going to demonstrate a 30-day run continuously. I don't think I would have an answer to that. I would like to pass it out to somebody else.

HANDSCHUMACHER: Rich.

BASILE: Well, in answer to your question, we've had good experience with our valves. What I would feel, just to offer an opinion, would be that probably the most severe requirement for the valves in coal liquefaction is the solids content. Most of your failures would result from the solids. Because in general, in the petrochemical industry, you have had valves run at high temperatures for quite a number of years, and they have been able to effectively use them over a number of years. So I would feel that solids content is probably the main ingredient that causes failure, and not the temperature.

HANDSCHUMACHER: John, would you want to give a comment?

GARDNER: In running the test program for the lockhopper valves, I really doubt if I can separate at this point between temperature and solids in the severe-service gasification environment. I think it is an interaction of the two, as I have seen it to date. Pressure has not tended to be a limiting factor for us.

HANDSCHUMACHER: How about Steve? Have any comments?

O'TOOLE: Well, basically, in the slurry service, which is the most severe, we've got the erosion problem that is accentuated by the differential pressure, and you've also got the corrosion problem that increases generally with temperature, so I don't know how you could really say one is the most significant. I think when you get a high pressure drop across the valves, you are going to increase your chances of erosion and when you get high temperatures you are going to increase the chance of corrosion. You generally get a combination of both.

HANDSCHUMACHER: Mike, what's the experience in England?

KADEN: Well, if we look at the process of pressurized fluidized-bed combustion, we have a relatively low pressure. Also, we have very soft solids, so the erosion is a secondary problem. I think the main problem is the temperature where we are really at the limits of the materials, and we get material failure just because of the high temperature. I think that's our biggest problem on that process.

HANDSCHUMACHER: Was there another? This gentleman.

GAPPISCH: My name is Max Gappisch from Argus Company. What are the expected differential pressures under which the valves have to operate? Is it right to say that most valves can operate without differential pressure?

HANDSCHUMACHER: I think, really, from what I have heard within the last couple of days, there are a lot of different answers to that, but let's sort of run a poll and find out. Mike, you want to give a comment again?

KADEN: Well, in our case it's up to 150 psi. We do isolate against the process pressure when we go to atmosphere.

HANDSCHUMACHER: Steve?

O'TOOLE: In our process, we can have differentials up to about 2,000 psi, because we've got bypasses around our safeties from the slurry line to our flare system. We have to have those blocking capabilities and that is from almost full operating pressure down to ambient.

HANDSCHUMACHER: John, as you are running at the Morgantown facility . . .

GARDNER: We are into support really of gasification, and we see that going from near atmospheric to a top end of around 1,500 psig. More commonly, I think, we are in a 600- to 1,000-psig range, as opposed to that 1,500 pounds. We see a few processes in the 1,500-psig range.

HANDSCHUMACHER: Rich?

BASILE: Well, in our process, the valves have to be capable of shutting off against the line pressure for that particular section or particular piece of equipment in the plant. In our plant, that runs anywhere from approximately 350 psig to roughly 2,500 psig. The temperatures vary roughly from 350°F to 900°F. We expect our block valves to operate against the design pressure of the system. We have to be able to open and close against that pressure.

HANDSCHUMACHER: Dan, how about your experience?

HEISTER: The plug valves are going to have to be able to shut off against system pressure. We will actually be rotating them, from a closed to an open position with full line pressure across them.

HANDSCHUMACHER: Gary? Want to pass the mike down?

QUALLS: In our case, it would be the same with Rich and Dan. We would like maybe not to have to close against the full line pressure, but that possibility is there and that is what we really need.

HANDSCHUMACHER: Does that answer your question?

GAPPISCH: But I am wondering about the 20-inch ball valves that were discussed yesterday. Could you operate these valves and could you open these valves with differential pressure of about 1,000 psi? I don't think it's possible to do that.

BASILE: I think that particular question ought to be addressed to the vendors or the makers of ball valves, personally, because I don't have any experience with nor do I think anybody up here has any experience with ball valves of that size and those pressures. Maybe some manufacturers of ball valves would like to answer the question.

HANDSCHUMACHER: Do we have a ball-valve manufacturer that would like to answer the question? The gentleman back there.

PATTON: Al Patton, Gulf & Western Manufacturers. We also make a steam-isolation valve that is a nuclear-seat and shutoff valve. They are the 24-inch and 20-inch size. The operation of those valves has nine times required the tops at like 1,100 psi. So, I think it is possible at those pressures for the larger valves.

SWING: Al Swing. Northwest Pipeline has 48-inch ball valves, not at elevated temperatures, but nevertheless we are talking about 1,260 pounds.

HANDSCHUMACHER: Yes, I think I can say that we have done some work on nuclear valves, shut off at a differential pressure that . . . but they haven't been under these circumstances. They may be a variation. This gentleman over here.

HATTER: Bill Hatter, Gulf Research. You mentioned you had pressures of 2,000 pounds and 900 degrees. What kind of valves were you using for shutoff service? A ball, or gate, or . . .?

BASILE: In that service, we are using both the through-conduit gate valve and a ball valve. I'm not sure if we have any plug valves in that service or not.

VOICE: You mean like a WKM valve?

BASILE: Yes.

FORBES: Jack Forbes, Scientific Design Company. In all these discussions, I don't think I've heard much reference made to fly-ash service. We are working on a contract for Allis Chalmers, on a gasification project. We will have fly ash up to about 800 degrees. What does the panel think is the optimum material to be used in that type of service?

HANDSCHUMACHER: John, have we done any work on fly ash here?

GARDNER: I think Allis Chalmers calls it fly ash. In our system we call it a char. It's the fine particulate matter separated from the main gas stream of that kiln-gas process. My experience to date at 800 degrees, I would be looking at a chrome-nickel-boron surface on a ball against maybe a Stellite seat. We could be looking at some of the carbide D-gun coatings also. Various seating materials . . . Stellite 6 is not bad.

FORBES: You say ball valve?

GARDNER: Yes.

FORBES: This is a real new service for us; since we have been in the petrochemical business, we tried to borrow from the experience of our conventional power plants. I came across three alternatives; one is what is called chrome-hardened iron, which I think is what you are referring to, a product made by Alan Shamerhoff. Another is one Corning claimed they used successfully, an epoxy-reinforced fiberglass. This is the choice we face without having any major experience. It became a question just which way we go.

GARDNER: There is considerable open-literature information available on the subject of materials for abrasive-wear surfaces. John Kelly, who unfortunately is not going to be with us due to a health problem, would have made a presentation on the very topic. Kirit Bhansali has considerable experience, and I would like to turn it over to him.

BHANSALI: The question of fly ash: the previous speaker, Ian Wright, has done a good amount of work on the project for EPRI, at up to 1,600°F and very high velocities of ash. A considerable amount of work is published, as John said. But, basically if you want to think in terms of more or less how do you specify an alloy or if you want to ask some intelligent questions of a supplier, then I can give you a rule of thumb. "The erosion behavior depends on the angle and whether the material is ductile or brittle." For low angles, 0 to 20 degrees, you want a very brittle material that resists a cutting-type action. So if you go with carbon steel or hardened steel or something like that, the only problem is that it would work well at room temperature, but when you increase the temperature, it tends to soften.

So, essentially what John was talking about is a Stellite-type alloy. It contains carbides that resist this cutting-type action in a cemented matrix. To answer your question then, a high-carbide-containing alloy is what you want to go after, like Stellite 1, 1016, or tungsten-carbide D-gun coated, but then when you go to thin coatings like titanium dichloride, which are only a few mils thick, a problem occurs when the substrate starts to soften. So you want a substrate that's going to hold up also. That's where the Stellite-type alloys give you an advantage. Does that answer your question?

FORBES: Yes.

HANDSCHUMACHER: Okay, referring to those people who were willing to write down their questions, I thought I might go through and pose some of them to the panel. We don't have names on them but I think I would like to have the reaction of members of the panel as to their experience in answering some of these questions.

The first one is: Does it appear that standard safety-relief valves will be sufficient for most applications, or will special designs need to be developed for plugging of the nozzle? Have any of you had experience with the safety-relief-valve end of the business? Gary? Anything from Rockwell?

HEISTER: No. I have not encountered that as yet.

HANDSCHUMACHER: Rich, any problems?

BASILE: Well, in terms of safety-relief valves, one of the main problems in slurry service is keeping the inlet from plugging, and the way we have adopted to do it is to keep a slight purge underneath the safety valves in order to keep the lines clean and, therefore, free of solids and plugging problems.

The other main problem with safety-relief valves in slurry service is once they have lifted, they generally destroy the capability of sealing off tight again. And so, at this point, our philosophy is if we have a safety valve that lifts in slurry service, we remove it and have it reconditioned and replaced. Now, an application of better materials to the seats and to the plugs of safety valves other than what we have would probably increase their life possibly. Or maybe a different design. But we are just using standard relief valves with hard-faced seats.

HANDSCHUMACHER: John, have you done any work . . .

GARDNER: I have a limited amount of experience. I've got to second Rich's points, you know. Once a valve lifts, our situation is such that we typically put at least two valves on the system with a block valve underneath. We also use a rupture disc under the safety valve to protect the safety valve itself. Once the rupture disc pops and the safety valve lifts, we isolate that valve, take it apart, clean it, rebuild it, and then reset it. It's troublesome, but it's workable with standard products.

HANDSCHUMACHER: Steve? Any comment?

O'TOOLE: Our experience is basically the same as Rich's. We do not purge the seats of the safety valve, but each time that we lift it we have to remove it from service and rework it before we place the valve back in service. I really don't know what the intention is on the demonstration-size plant, whether they will go with other materials or the rupture-disc situation like John mentioned or the purge.

HANDSCHUMACHER: Mike?

KADEN: I think we are somehow fortunate with our process. We can put our safety valves on what we might call the clean side. That means at the air inlet before the reactor or at the air outlet after the gas cleanup. So we don't have the erosion problem in safety valves. We have a lockhopper arrangement where we isolate the pressure vessel and it still might be at high temperature. We pipe the safety valve away from it, to get it away from the high-temperature environment. At the same time it gives us a pressure-temperature benefit; it prevents the safety valve from lifting with every pressure surge we get. We haven't had experience with these safety valves for the lockhopper arrangement yet, but we expect that we would have to change seats at every lift.

HANDSCHUMACHER: I just might add a little bit. At breakfast this morning, we were talking to Dan Trapp. He said his greatest concern about safety valves is the ability for the industry to supply the number that would be required. I thought that was an interesting observation. There's been a lot of attention given to some of these other valves. His concern was that maybe safety valves were getting a little short chipped.

Okay. Another question. What are the preferred types of end connections for high-temperature and pressure slurry-block valves? Greylock, ring joint, raised face, lens rings, etc. Anybody want to comment on that? Is there a preferred end connection? What are we using? Rich, do you want to start off?

BASILE: Well, I guess the answer to that question, if you had a reliable valve, the preferred end connection for any valve at high-pressure, high-temperature service would be a weld end. Weld the valve and then you have no problem with leakage of the flange. That would be the direction we would go in if we had reliable valves in high-pressure service. We would weld them all in. If there were places where you needed to break flange connections, we at present use a standard API ring which we have had great success with in our refineries and we basically see no reason to change at this time.

HANDSCHUMACHER: Dan?

HEISTER: Well, in our design we've looked throughout the various testimonials, read various papers, and with the high failure rates, we looked for the system that would come apart the quickest and go back together the quickest, and that would be the Greylock. It gets a little more expensive, but I think it's worthwhile.

HANDSCHUMACHER: Gary, what's your experience?

QUALLS: That's what was in our design, too. The Greylock in the high-pressure and high-temperature slurry. Why they have chosen this over that, I don't know. They do easily disassemble and reassemble. As far as any problems, I'm not aware of any.

HANDSCHUMACHER: John, what have we been using here?

GARDNER: Well we've used raised face rings and Greylock. The break tends to be whether it's something we need to get out of line quickly; there we would lean toward the Greylock.

HANDSCHUMACHER: Steve, any preferences?

O'TOOLE: We prefer to weld the valves in line also, where there's not going to be much of a need to ever have to remove the valve. Some places, like control valves, where we periodically take them out, we use a Greylock or a standard ring-joint flange. The predominant end connection is the Greylock in the removable valves.

HANDSCHUMACHER: Mike?

KADEN: Well we don't have a slurry application, but we want to get our valves out of service as quick as possible, so we don't weld them in. However, we don't use Greylock couplings because if I understand it right they cannot bear very high moments. We will have tremendous thermal expansion of our gas duct work; we will have quite high moments on these valves. So, we use standard raised flanges.

HANDSCHUMACHER: Another part of that question was, what operating experience is there on the different types of end connections? Really, what we are finding in the comments range pretty much from the high pressures to the low pressures and from the high temperatures all the way through. I would expect that as you get down to the lower pressures and temperatures, you would be going to the more conventional flanges. Is that about a right analysis? (AFFIRMATIVE NODDING OF THE HEADS)

Okay, another question. Is there any reason to believe the scale-up factor would drastically affect block-valve performance in slurry service? How about if we start down at this end. Steve?

O'TOOLE: I think this might be another one of the questions that could be directed to the valve manufacturers. I really don't have enough experience in valve design to answer that.

HANDSCHUMACHER: Is there someone from the audience who would like to offer some experience they have had with the scale-up factor.

BACKSTROM: We make primarily gate valves. This gentleman was just talking about a 24-inch ball valve. I'm not really familiar with the torque requirements, but you have much less area exposed to the pressure when you go to turn it. But if you take a 24-inch gate valve, and 2,000 psid, and multiply that out, unless I am wrong, that is about 400 tons on that disc. Now you might have one awful time trying to move that. So you may, on large scale ups, have no alternative. If you're staying with these very high pressures and you are not going to equalize pressure, you may have to go with a ball valve or some type of valve that you can move. Any other gate-valve people in here want to comment on that?

HANDSCHUMACHER: Any comments from the audience on the scale-up factor? The gentleman here.

BENSINGER: I'm Floyd Bensinger from Anchor/Darling. We make gate valves also, and we see no problem of scaling up for actuators.

BACKSTROM: With a 2,000-differential process?

BENSINGER: Yes, we supply maintenance-flusher valves also. We are up to 1,200 psi.

BACKSTROM: 24-inch valves?

BENSINGER: The main streams are 24-, 28-inch valves.

BACKSTROM: We're not talking about equalizer pressure. That's differential.

HANDSCHUMACHER: One question has been imposed here, John, and I think, raises a good question. What would be the minimum-size valve that would scale up to a 24 inch? Does anyone on the board or in the panel have a . . .

GARDNER: It's better addressed to the manufacturers. What size would the manufacturers want data on in order to scale through say, 24 inch? This is a question that was asked at the last symposium. Not really a good answer at that time.

HANDSCHUMACHER: Does anyone have an answer to that?

GARDNER: A lot of valve manufacturers. Still apparently no opinion.

VOICE: Half of the size anticipated.

HANDSCHUMACHER: There was a question over here.

BOWMAN: Jeff Bowman, Fabri-Valve. I was just curious as to whether it was possible to put a bypass valve around the larger valve. It would open first to balance the pressure, and then open your ball valve or your gate valve, instead of opening the ball valve or the gate valve at 2,000 psid.

HANDSCHUMACHER: Has that been considered in any of the systems? Is that a feasible approach? Rich?

BASILE: The only thing I could say about that is if you put a small bypass line around the block valve, and you keep that bypass line shut, you are going to plug that line solid when you open up that bypass valve. You are not going to get any pressure across it anyway. The line is going to be plugged solid because there is no flow and so the solids are just going to pack in. I don't think it buys you anything in terms of slurry service.

HANDSCHUMACHER: Gentleman, here.

VAN KESSEL: Van Kessel, Shell. I have to meet the first operator who is willing to open a valve size 10 inch, or 14 inch, or 20 inch against a 1,000-psi differential pressure. He would probably be fired. The way to do it is to design a process such that you never meet that requirement. And that's what is done in practice.

BASILE: Well, I guess the only question I would ask is can you conceivably do that? In every process design, can you lower the pressure before you have to open your valve, without detrimentally affecting the process?

HANDSCHUMACHER: Would you want to define what you mean by differential pressure?

VAN KESSEL: Yes, well, if you have a differential pressure over a block valve, you'll never open it, or you will do it very slowly. But with the larger sizes, that's asking for trouble, and in operational practice it would be impossible, I would say. So that's why in large systems you would apply bypass valves for independent pressurizing lines to a downstream system.

HANDSCHUMACHER: Sounds like I have a nod over here from Mike.

KADEN: We have a very low pressure in our system, as I said about 150 psi, but we do exactly what this gentleman was saying. We pressurize with nitrogen. Also, because we have carbon in the solids we have to pressurize with inert gas. I would have thought that as we use a clean gas to do that, the slurry people would use a clean liquid to avoid blockage. We wouldn't use our flue gases to do that because our solids would settle down in these lines as well.

HANDSCHUMACHER: What you are suggesting is that it may be possible to put a fluid in the bypass line that will not clog, and then have that available for . . .

KADEN: Well, I'm also astonished that you get through with a design where you say you can work with 2,000 psi, because already we have done a safety review on ours before going into operation, and I know that there would be no way we would be permitted to operate if we would open valves at even 150 psi with solids at 1,500 °F.

BACKSTROM: I know only a little bit about gasification, but supposing you have a gasifier. You've got a block valve on top and you want to have the whole system isolated. You come off the bypass line, get your gas up to some type of purity or something like that. Now, you wouldn't open that large valve up there against that full differential. Even if it is a 48-inch valve, and only 150 pounds. What I think you would do is back nitrogen into your system for safety reasons, and build that on up, then you would operate your block valve under a minimal differential. I think you have to do that for safety reason. Four hundred tons is an awful lot to pull a gate valve through.

HANDSCHUMACHER: Dan, what's your feeling on the basis of experience here?

HEISTER: I don't know that I really have enough operations experience with the overall plant to address it. I know that our standard practice is that we do have to purge all of our downstream lines before we start putting our syngas into the downstream process. I wonder if we're not having trouble with semantics, definition of differential pressure.

BACKSTROM: You can close on a flowing stream. Now your problem occurs when you're down about to cut it off. That's not the differential pressure we're talking about. No, I'm talking about when a valve is closed. I've got 2,000 pounds on this side, and practically nothing on this side. So I have all this pressure against this. I think the ball valve will react considerably differently, but we are talking about maybe trying gate valves for block-and-bleed service, and I think when you get into the large-scale plants and you get into the size we are talking about, and the differential pressures we are talking about, I don't think you are going to do it gentlemen.

HANDSCHUMACHER: What this may be is a caution in terms of system design as you scale up. You may have to give some kind of consideration to equalizing that pressure before you open those valves.

BACKSTROM: Right. Clean your media is one way of doing it if you have to.

HANDSCHUMACHER: All right, would anyone else like to comment on that question of scale up? It's an important factor if we talk about going from power-plant operation up to the demo and the full scale. Gentleman here.

FORBES: Jack Forbes, Scientific Design Company. I think there is a little confusion here. I would interpret the term operator as used, meaning an actuator. I don't think the gentleman from—Darling is it?—is talking about a human being coming up there and opening that valve; we're talking about an actuator. Isn't that right?

BENSINGER: Right.

FORBES: So it isn't a question of whether a man, rather a plant operator, is going up and opening the valve; it's inconceivable of that size.

HANDSCHUMACHER: Is that a better definition for Shell?

KESSEL: Well, in our company, we have buttons you push. The operator pushes a button and the valve will do the job.

HANDSCHUMACHER: We solved two problems; we identified the operator as the guy who pushes the button, and the actuator as the thing that opens the valve. That helps the semantics. What experiences are there on check valves for high-temperature pressure-slurry service? Mike, how about starting down at your end. Any experience?

KADEN: No, nothing at all.

HANDSCHUMACHER: Steve?

O'TOOLE: Well, we've had some experiences with check valves not holding in the slurry service. But the problem with check valves is that you don't know if they are bad until you need them. We had one instance where we were injecting hydrogen into our slurry line and we lost our hydrogen pressure, so it tended to back the slurry into the hydrogen system when the check valves didn't hold. Before we could get anything closed, we had quite a bit of slurry backed up into the hydrogen line, and we had a big job to clean it up. I don't really know what there is to do about the situation; whether it is a materials problem or just find something to replace the check valve. The question was asked out here, what kind were they? They were an autoplate ball-type check.

HANDSCHUMACHER: Rich, any comments on check valves?

BASILE: Well, as part of the valve-test program at ECLPP, we have included check valves as part of our program to determine if the types of valves we have selected are adequate for our service, and we will be evaluating the wear tolerance and their ability to shut during the length of our project. At this point in time, due to the limited operating experience we have, I really have no comment as to whether the designs we have chosen are satisfactory.

HANDSCHUMACHER: Dan?

HEISTER: Well, the only place we are endeavoring to use a check valve is on clean purges going into dirty systems. I think that they have been tried several times in some dirty systems, and they ultimately fail by virtue of leaking after a few hours of operation. And not continuous operation; 20-minute intervals.

HANDSCHUMACHER: The next question. Hard facing and hard surfaces seem to be a major concern in the manufacture of valves. What properties does the designer consider most important for designing or specifying a hard-surface type valve? Kirit, maybe you want to comment on this. This is your area.

BHANSALI: Well, I could only address it from a materials' standpoint. I understand the valve manufacturers' needs, but I think the question was really posed to valve manufacturers, if they have any specific input.

Anyway, first let me give you the few concepts I have developed, and maybe the valve manufacturers could elaborate on that. Typically, hard facing is only used for economic reasons. If one could make a valve of solid Stellite it would be too expensive. So, when you go from that to using weld overlay, of course, that's an economic reason. But even though it started out as such, it has gone beyond economic considerations, because, especially with coal-gasification service, the materials that you are looking for are for greater and greater abrasion resistance, erosion resistance, and corrosion resistance, all these resistances.

When you start to combine all these things, Mother Nature says that you can't have everything for nothing. You are going to sacrifice something. And that something is impact resistance, or your ability to handle the materials, which gets very, very poor. So the hard facing, or any coating for that matter, gives you an added advantage that you can have a soft core, which is tough, which gives you impact resistance, but then you can put on a coating that resists your abrasion, and you can have your cake and eat it too, as long as you have applied the coating very carefully.

So, in this process then, you have added one more factor, or one more variable, and that is the processability. That is a new word that I am coining, but essentially, when you start to put down weld overlay, you want good weldability, good pourability, and so forth. So that adds some more restraints on the hard-facing material. So essentially what you pay for in a hard-facing material is a good combination of abrasion resistance, corrosion resistance, impact resistance, if possible, and galling resistance . . .

HANDSCHUMACHER: It would be helpful to have a valve manufacturer comment on what properties they look for in hard-facing materials. Or is that all secret?

BACKSTROM: This gentleman summed it up pretty well. There is one thing though that you do have to be careful of. And we use colmonoy, Stellites, and so on. There are some applications, for example, where colmonoys hold up beautifully. But take that same thing and put it into another application, and it will take it out very quickly. In some cases, Stellite is much better even though it's a little softer, so your process compatibility, you might say, is also very important. The other items he said are correct.

BHANSALI: I would like to make one more comment about the question that was asked earlier about what is the failure mode. Looking at the materials point of view, what has happened is some of the earlier coal-gasification units were designed sort of state-of-the-art design. Most architects and engineers who supply the designs for these things, when they come across a corrosion problem, they specify stainless steel.

There are some materials other than stainless steels that resist corrosion; so if stainless steel fails in corrosion, that doesn't mean that's the end of their work.

There are publications put out by the Bureau of Standards that give you a rundown on failures in the coal-gasification-type environment. If you look at those publications, you will see that the largest number of failures are attributed to high-temperature corrosion. But you look at the other side, and say, well, what were these failures on? What were the materials? And some of them were carbon steel and some were stainless steel, and these problems have been overcome as people go to nickel-based alloys or cobalt-based alloys, which are better able to withstand elevated temperature and corrosion, producing sulfur-type environments.

HANDSCHUMACHER: Any other manufacturer? The gentleman back there.

MOGAS: Louis Mogas with Mogas Incorporated. On the question about plating—a metallurgist would be a lot better qualified to answer that question than I am—if you do have a soft material, an economical material, and are going to cover it with a hard plating, it can be thought of as putting a hard plating over a balloon. It's not going to do you any good to put a very thin plating on a very soft material. What you are looking for is compatibility, for such things as thermal expansion. You don't want to have a base material that has a much greater expansion rate than the coating you are putting on top of it. Very quickly you are going to get cracks. Sometimes you have plating that has gotten a bad name in the industry and it's not always the plating that's at fault. Many times it's the base material that has had a reaction.

One of the other difficult things is that so many valve manufacturers are sending materials to platers, which has now become standard for a ball valve. But it's not for this particular market. You have to be very careful that what you ask for is what you get back. If you ask for 5 mils, you have to be very careful that it wasn't put in with the balls that are going to get 3 mils of plating. So one of the things that I think is required is attention to be sure that the base material is prepared properly and selected properly and that the two materials are compatible.

HANDSCHUMACHER: I think from a valve manufacturer's standpoint, the application of hard facing, whether it's for this industry or whether it's for the car industry, I don't think is that much different. I think that some of the comments that have been made are very appropriate. I think the thickness of the hard-facing material as it comes under indentation by any materials that are trapped can be a factor. The dilution effect of the hard-facing material as it's being applied, all these factors, I don't think they are any different in this industry or the application of this industry than they would be to the power industry. I don't know whether any one would feel differently about that or not.

BHANSALI: The only difference would be this is a more aggressive application. Fine tuning needs to be done more carefully for this particular application. In other industries, the process will be much cleaner and you may not get as many contaminants due to the ash or slurries. Also, with the high-sulfur coal, the amount of sulfur dioxide present tends to increase the corrosiveness of the environment. The power industry can tolerate X amount of contaminates and not sacrifice significant erosion resistance. In our case, the reduction in erosion/corrosion resistance caused by a slightly out-of-spec alloy may be critical.

HANDSCHUMACHER: Good, that's a good point. Gentleman in the back.

VAN HORNE: I'm Dale Van Horne, from RPC Valve. I would like to preface my question by saying that I have nothing against Stellite. It is my understanding that there are other manufacturers of hard facing. Do you have a listing of the ones besides Stellite that anybody on the panel would accept? If you specified Stellite, is that what you want, Stellite 6 or 2? I am kind of curious about that.

HANDSCHUMACHER: I think that's a very appropriate question. Frequently it is being used as a generic term now, in contrast to . . .

BHANSALI: Being an ex-Cabot person, let me assure you that nobody would be at Cabot Corporation if that term was used properly, and not generically. The list of manufacturers is not at all necessary. You could look at the American Building Society Handbook, and that gives alloys by the generic names; Stellite is cobalt chromium tungsten A, B, and C. However, in a situation like this discussion, the problem is one of communication. You tell people Stellite and they understand it faster than if you tell them cobalt chromium tungsten. If a day comes when everybody can understand what is meant by somebody who says cobalt chromium tungsten, I think that would be the day we metallurgists would have achieved success explaining to everybody what materials really mean.

VAN HORNE: You know, it's great for this discussion, but we are manufacturing valves, and we would like to have our valves used in these applications, as well as anybody else. Say we do use Stellite . . .

BHANSALI: Well, there's a very simple answer to that and that is when you look at the specification, whoever supplies the specification, ask them.

HANDSCHUMACHER: Are any of the system designers specifying Stellite per se, or are you really talking about hard facing?

QUALLS: I don't think we really specified Stellite as such. I think as we went out to try to come up with alternate valves, I am pretty sure we did not specify a particular hard-surface material, such as Stellite. We went after what really was on the market that we could use. I think that is how we approached it. We didn't specify any set material.

HANDSCHUMACHER: What would be in the Rockwell specifications?

HEISTER: Well, many of them we just put down that the vendor is to determine. That was in our blocking valves and our lockhopper valves, but in some of the letdown valves we did specify Stellite and called out the number and did not say equivalent. I think part of the reason is the spec sheets don't allow you that much room. (LAUGHTER)

HANDSCHUMACHER: Dick, how about your experiences? What are your specifications?

BASILE: In our specifications sometimes we do make a generic use of Stellite 6. In general when we talk about getting Stellite 6 trim, we are referring to API 600 trim number 5, which would allow you to use, I think, generic equivalents. I think when you talk to people, and you say Stellite 6, they understand that you want hard facing and that you want a certain grade of hard facing. I just think it's used commonly, and I don't know if that's right or not. When we ask for it, we are asking basically for API 600 trim number 5, which does allow you to use a generic equivalent.

HANDSCHUMACHER: Steve, how about your experience?

O'TOOLE: We also generally specified Stellite just from a generic standpoint. And on some of our valves, we just call for hard facing. That's in the lower-pressure valves. I think we would be open to consider other manufacturers.

HANDSCHUMACHER: Mike, how about the English?

KADEN: Well, I must admit, we don't even specify materials for the valves. We normally specify for a certain service, and we leave it to the manufacturer to advise us what we can do. However, we wouldn't buy a valve on these grounds. When the manufacturer comes back we would go to our specialist from Morgantown, or a materials specialist from England, and look at what the manufacturer can give us. Then, through discussions, we will find the end material together. We would never say that we would restrict ourselves to something like Stellite if the manufacturer comes out with something equal or perhaps even better.

HANDSCHUMACHER: Thank you. Let us move on to another type of question. In the questions that we have posed to the panel, a number have talked about funding for test valves. I would like to read one of the questions submitted that may relate to some of the smaller valve manufacturers. The question was, "To encourage maximum innovation, especially from smaller companies, or high-technology-research companies, not now making valves, it seems desirable to stimulate valve development through government support through research efforts. Will the government support new concepts through R & D contracts or will this support be limited to testing of hardware developed under private financing?" John, would you want to answer it?

GARDNER: I want to say right up front, this is a personal opinion and not to be reflected as the position of the U.S government. After that disclaimer, I would say that at this point in time, there is currently only one government-funded valve-test program existing, and that is for lockhopper valves. I am going to address that particular project, and any other application, I think, would have to come on a case-by-case basis, based on the merit of the proposal itself.

In the lockhopper-valve program, we are doing it both ways. I have a definite personal preference to act as a tester of designs and not a funder of industrial R & D, pure R & D contracts. I have no opposition whatsoever to cooperative-style agreements. I think the basis for my position is that we are out to develop commercial hardware, and industrial R & D contracts leave us with a design and nobody to take it into the commercial sector, short of going out on something like a program-opportunity notice, and trying to sell it fully developed back to a manufacturer. That's pretty difficult to do.

You lose know-how, or else you have to go back and pay the guy that did the R & D to act as a consultant to the manufacturer. It becomes very sticky and very time consuming. I don't see it as a very efficient method to develop hardware, especially in a very short time frame.

HANDSCHUMACHER: Are there any other questions concerning government funding? John, I did hear a couple of comments as people were going through the facilities. People noticed that certain of the tests had been put on hold, and they heard that you just weren't able to proceed with them. Would you want to comment on what is necessary to get those tests back on the road again?

GARDNER: One is called funding. (LAUGHTER) You cannot run tests for nothing; it costs dollars for the people. The funding levels have been fairly small. You just cannot go forth and conduct tests and not pay your people. They tend to like to get their pay checks. That's been the biggest problem.

HANDSCHUMACHER: I think that question is an important one to bring up in a group like this. I guess one of the questions in my mind is, is there anything that the VMA or this group can do to help stimulate a renewal of this testing effort, or help in the funding effort?

GARDNER: Well, my question is back to the manufacturers. Do the manufacturers really want this type of testing or would you prefer to go to someone like Exxon, putting your valves in an actual processing condition? I think that's a question in itself to be addressed to the manufacturers.

HANDSCHUMACHER: That question is a good one. It's posed to the whole group. Does anyone want to comment on it?

VOICE: What was the question?

GARDNER: Does the government really have the need to function as a tester of hardware to go into gasification, coal-liquefaction processes?

VOICE: No.

GARDNER: I've heard one answer.

PLATT: Don Platt, Contromatics. I think we've got the cart before the horse. You're asking a question, do we need a test facility such as Morgantown when we need something to test in it? I want to know where the funding is coming from that will allow the valve industry to develop the valves that you are obviously in great need of. I don't believe the valve industry is going to put it up itself.

HANDSCHUMACHER: Anybody want to comment on that type of answer.

VOICE: Yes, I think the valve industry is ready. I think it's just a matter of a little more communications from us. A little more understanding of what you need. I think the valve industry is going to respond. I don't think just my company, but everybody's company.

HANDSCHUMACHER: John?

GARDNER: What we want to point out at this symposium is what the market potential is. You have been given an idea of what kind of valve quantities are involved per plant, process, etc. Many of those valves in the large quantities are pretty standard applications, which the large manufacturers are going to go after as quickly as they can.

I think one thing valve manufacturers tend to forget is that in each plant, there exists somewhere between 100 and 1,000 of these specialty valves. That without them, you are not going to sell your maybe 10,000 standard valves, because the process area is never going to come about. It's not going to be feasible to operate.

I think I would like to comment that in the past 3 years I have seen valve manufacturers willing to take their R & D, both dollars and man-hours, and put them up front to give us some valves that are very acceptable for some of the coal-conversion-process applications. I think that what I have found, in a lot of cases, is that valve manufacturers really need more data on the applications, where do they exist and what are we going to be facing in the future. When I say that these manufacturers are ready to come up and do the work, I've seen that happen, and not only at the smaller manufacturers who are traditionally more mobile and easier to move in a given direction. I have also seen it happen in very large-scale valve-manufacturing concerns. So I think valve manufacturers are ready.

I think it's a point that each company has to make a decision. Is it going to be a viable market or not? Is it one that we are going to chase or not? Maybe in your case, you are not ready to chase. I don't think the government has a place to expend large sums of dollars to try to develop, well to more or less fund, your R & D. What do we really get out of it? Most times, the government R & D says if we fully fund it, we want your patent rights, manufacturing rights, and license rights. I don't think that we should have them, because we can't do anything with them after we have them and, on the other hand, should we really give you money for nothing? It's always going to be a point of contention.

I don't know whether anyone will correctly answer your questions, and I recognize concern, but I think that you are going to have to look at it. Are you willing to chase that kind of market? Do you see it as a significant potential in the future?

HANDSCHUMACHER: Gentleman here.

HARPER: Cliff Harper from Consolidated Controls, again. John, your point is very well taken. Imagine a capitalist working in the government. I think that's wonderful. (LAUGHTER) John and I have talked about this before and I have to agree with a lot of what he says. I would like to urge you not to shut down your test program. Not just yet. If I go to Dick Basile, or Gary Qualls, or any of these people, say I have got a new hydrogen-metric, quadruple ball-valve, never been tested, and maybe a good one, would you test it in your plant? They will show me to the door. They would have to get it in a specialized test facility to do something with it, and there really is no other facility like it. To expect a plant to do it is expecting a lot unless you've just got a minor variation from a proven product.

HANDSCHUMACHER: Gentleman over here.

RICHARDSON: John Richardson, Dresser Industries. I would like to comment on both of the last questions. First, the valve manufacturers' attitude toward the development of valves for the industry, I certainly can say that Dresser Industries is very interested in pursuing the requirements of this industry and are willing to spend some money on it. I can also say that I very much appreciate the open frank discussions in this symposium. Hopefully they will come out loud and clear in the proceedings and will provide some guidance that heretofore has not been available. I know many of us have spent a great many hours looking for the kind of information that has come forth here. With respect to John's test program, I certainly would like to see that continued, and for the same reasons that were just expressed, although there are some of the pilot plants that have special loops that permit testing. I don't think there's anything that's available that will allow the step-by-step shakedown that is necessary to really make something of a new concept available to a pilot-plant test. Thank you.

HANDSCHUMACHER: Any other comments on funding? Questions on funding? Let's move to another area.

BHANSALI: I'd like to make one comment t the government, on the question of the government funding and the role of the government. I am sort of new to the government business, so I am going to take a different approach. My personal opinion about the role government can play is that as long as the government provides a facility and stimulates the research and development for the promotion of the individual business, I think the government has a role to play. It's just that government also should know and realize what is involved. The test facility such as Morgantown is very valuable. We did the same thing in the space program.

However, the government regulations get to the point that they become a hindrance to the development, and I think there is a time that the government should back out. I don't think the coal gasification has reached that point, yet.

HANDSCHUMACHER: Okay. Let's move on to another generic type of question that has come up in a number of conversations. That relates to the quality aspect of the valves that these manufacturers are providing to these users. I would like to have some questions posed by users to the valve manufacturers, as to how they are seeing the quality of the valves that are being supplied for these services. Gary would you want to start on a comment? What kind of quality are you seeing in terms of valves?

QUALLS: I am at a disadvantage to answer that question, because I really haven't been at H-coal long enough to be involved with that system. I don't think it would really be fair for me to make a judgment on what I've seen.

HANDSCHUMACHER: Dan, do you have any early comments?

HEISTER: In our specifications we call out a lot of quality points as far as leak tightness and the demonstration of operation under temperature conditions, not necessarily with the abrasive materials. I think it's up to the user to call out what he wants and try to make the manufacturer adhere to it, so we can get a quality product. You cannot rely strictly on the manufacturer to give you quality.

HANDSCHUMACHER: Rich, what are you looking for?

BASILE: What we are looking for is like everybody else. The user is looking for a quality product. I would like to second Dan's philosophy. Basically, we put a lot of requirements in our specifications for the vendors to meet, and we also follow up on the requirements with very thorough inspections of the product at very specific points during construction and manufacture to guarantee that we get the quality we want. I think that has a lot to do with the quality we do get on our valves.

However, I can't comment on the assumption that if you just go out and order a valve from Company X, what kind of quality you would receive. Basically, we don't really do that a whole lot. Especially in terms of special equipment.

HANDSCHUMACHER: John, I know you have had some experience.

GARDNER: Probably in working with about 50 valve manufacturers over the past 5 or 6 years, we've seen various levels of quality come in. It's gone from totally disgusting to absolutely superb. I think it's based on the nature of the management within each organization. We, too, write in, and we have for the past 4 years, written our own quality control into the spec most of the time. We probably cannot follow up as much as Exxon, just due to a lack of staff, but I think when it tends to be followed up you get a better product overall. I know that a pet one for me is the installation and maintenance manuals that are supplied with hardware. I think that those definitely need a lot of improvement on the part of the manufacturers.

HANDSCHUMACHER: Steve, what's your experience been? What are you expecting of the supplier?

O'TOOLE: We've had good service from the valve manufacturers. We have received some products that wouldn't be quite up to what we would expect. I think in the beginning when our plant started up 7 years ago, we were still learning and we probably didn't spec a lot of valves right. Over the period of time we have had to change some specifications.

I think predominantly, the problems we have run into are things like damaged seats and seating. In the past few years we have gotten more involved in testing a valve before we put it in service, especially if it's in critical service. I think that overall we have good service from the valve manufacturers.

HANDSCHUMACHER: Mike, what's your experience?

KADEN: We are at a little bit of a disadvantage here. We can't really inspect the valves that we buy mostly in America. We rely on just waiting and when it arrives look inside. Fortunately, so far, and perhaps that's due to the recommendations we got from John Gardner, we have been very happy in what we have received from the manufacturers. What has been installed in our plant, in terms of manufacturer quality, was very good.

HANDSCHUMACHER: Quality is usually adherence to specification. I think in the development of the specification, there is a concern by some valve manufacturers as to how far they will go. I think that some of us felt in the nuclear effort, we almost went overboard. Maybe in other cases, we didn't go far enough. I'm interested in whether you want to see the quality requirements or the quality-assurance requirements approaching a nuclear style or is there some more economical way to assure that the facilities are going to be safe and be able to operate? I don't know whether anybody up here wants to comment on that or not.

MILLS: I think there's an overkill, already. I've looked at some valves that have been in a refinery service for 50 years. You cut them apart and they are full of holes. They have voids, they are hollow. We set up X-ray specs that bother me. For example, they didn't start X-raying valves until they had weld ends. They X-rayed the weld ends, because when you welded it to a piece of piping, you X-rayed that weld and when you saw how bad the valve was, you got scared. The other thing that disturbs me is when we specify X-ray quality valves, the foundry gates them different. So they must know something. They put the gates on different, the rises on different, and give us a higher-quality valve. And they charge you for that. I say why don't they practice and give us a good valve all the time?

I also want to comment on ball valves a little bit. I want people to know that I've got nothing against them. I was at the start up of a plant that had an 8-inch class 300 gate valve. I couldn't open it, and had to get a 6-foot-5 guy with a wrench to open the damn thing. I came back from that operating experience saying, there's got to be something better than a gate valve.

So in our last spec in a rather general way, I wrote in, "We want to encourage use of quarter-turn valves." We want the contractor to make selective judicial and innovative use of quarter-turn valves. They didn't do a damn thing.

Every time I looked at an API, I suggested where they might use one of these quarter-turn valves. More than that, at your meeting in California where Fred Callahan belittled the oil industry for taking so long to develop 607, which is fire test for ball valves, I told them, we've got a swell test for fire testing ball valves, but we never told anybody what we wanted in the way of a ball valve.

There's no ANSI spec on ball valves. There's no API spec on ball valves, so I say to you people, when you specify a ball valve, what spec do you refer to? Because if you take your brochures and plot temperature pressure rating, holy cow. It's like throwing a paint brush on a graph. That's the kind of temperature-pressure range you people tell us your valves are good for. It bothers me a little bit, fellows. What specification? The British have one. They have a ball-valve spec. At a recent ANSI meeting when the question was raised, when do you think you will publish a ball-valve spec, one answer was 5 years, and the other answer was never. (LAUGHTER)

HANDSCHUMACHER: I think the ball-valve requirements will be published as part of B-16.34.

MILLS: Well that's nice. We got API-16, 6, which Fred Callahan refers to as 6 dogs.

HANDSCHUMACHER: Coming back to the question of quality, are any other manufacturers feeling concerned that they are not clear on what the volume requirements may be for this industry? It's an emerging one; it's one that I think it is pretty important to get understood early in the game. Are there any other comments?

AL SWING: One of the fallacies that I think a person can get into is to write a specification. At our company, we write extensive specifications covering valves, for example. The fallacy, though, is to write an extensive spec and expect that it is going to settle the problem; you are going to get a perfect item. Unless you are doing some degree of monitoring of that quality, you can run into various problems.

STAETH: Terry Staeth, Hills-McCanna. I'm concerned about the level of documentation these people might be looking for. In other words, the number of procedural approvals that would be required prior to manufacturing and so forth.

You mentioned the nuclear industry. Okay, I think processing nuclear valves is taking anywhere from 1 to 2 years. It can get hung up tremendously in the procedural cycle. With critical delivery requirements for a plant like this, you'd have to weigh the quality and level of documentation with delivery requirements. I'm just wondering what level of documentation in terms of casting-certification procedures, procedural approval, and drawing approval they feel they'll need to insure the quality plant they are looking for.

HANDSCHUMACHER: Would any users want to comment on that?

HARPER: I am not a user, but a manufacturer again. You can follow the MC specs right down to the letter, or the MSS specs or the API specs, and nowhere in there does it say the valve has to work. (LAUGHTER)

It tells you thicknesses and materials and things like this. I would think as a user of a valve or if I were interested in things like that, I would write into my specification it must operate under these conditions and if I were really interested, I would say, you do a test on it to show this.

It's going to cost me to do this, I know, but you do a test to show that it will seal with steam at 600 degrees and so many psi. That's an expensive way to do it, but no valve manufacturer that I know of does something like that, because it would make the valve cost two ninety-eight instead of one ninety-eight and they wouldn't sell them. But if you want it, it can be had at a price, and that is the way to get it.

HANDSCHUMACHER: John, would you want to comment?

GARDNER: Well, the current specifications that I have used for most of our severe-service valves do include a test procedure, and I won't buy a valve short of having that test actually conducted. We will not go with less than 100% tested. We have manufacturers doing it and it does cost us, but it is not significant compared to the price of the valve itself.

HANDSCHUMACHER: I think to say that no manufacturers do that may be a little oversimplification. I think what we . . .

HARPER: That is temperature and pressure and further specs with the medium; that's what I mean. Everybody gives you a test with water.

HANDSCHUMACHER: Obviously, in order to do that, you have to build a plant similar to what you are applying it to.

HARPER: You have to have a test facility or go to one. But a lot of people use a test with water or a hydrostatic test, which is by the way in the specs. But a hydrostatic test with water doesn't prove that it will work with steam or something like this.

HANDSCHUMACHER: Mike, would you like to comment?

KADEN: I think that is really what all the standards refer to. We ask for documentation in reference to safety. We don't want to get that body to blow out, or that steam coming up out of the valve when you pressurize it. We ask for documentation in terms of the X-rays of the body of the valves and so forth and so on. I don't think we can really put ourselves as a process designer in the position of wanting to tell the manufacturer what he should do in his designs and his manufacturing accuracy and his quality control and how he should document it and we are going to check it. That would elongate the process a lot. To protect us in the first step against the manufacturer who doesn't do a good job, we have a guarantee. So if he just manufactures wrongly by default, he doesn't look after it carefully, he has to put it right.

The other thing that is a lot stronger is if we have a specification and we pay a hell of a lot of money for a valve and it doesn't work, doesn't do what the manufacturer said, it's the last time he was on our list. I think manufacturers do know that. That is a lot more than if we have a certificate, a drawing or an approved drawing where we can't say we are really experts in their field anyway.

HANDSCHUMACHER: All right. I have one other area of question that has come up. We have been talking a lot about the dirty side of all these plants. There's been a question concerning the interface between the clean side of the system and the dirty side of the system and interfaces, and the contamination of the clean portion of the system. Is this expected or is this something that you are planning to cope with? Is this a problem at all or is this something that you haven't encountered. Steve, how about it?

O'TOOLE: Well, I don't know if I can exactly answer that question. It is a problem, and I think I mentioned before about our check-valve problem. What that is is an interface between a clean system and a dirty system.

HANDSCHUMACHER: John, are you encountering any of that in your tests?

GARDNER: I just think it is going to be on a case-by-case basis. I don't see how you can answer that question generically.

HANDSCHUMACHER: Any other comments?

HEISTER: I don't know if this is applicable. We had a choice in our lockhopper system to either go ahead and vent the lockhoppers down with the issuance of dirty gas through the letdown valves, or try to develop some filter system between the lockhopper itself and the letdown valves. We're going ahead and using a sintered-metal filter. We'll build a cake on it and then pulse it to get rid of the cake. We're trying to eliminate problems in that area, and go as clean as we can.

HANDSCHUMACHER: I notice that we have just about run out of time. There are many questions that may be in the minds of you participants out there. Some of them we haven't had a chance to get to. Some of them are very specific questions. I encourage you to pose those questions to the members of the panel, perhaps send a copy of that question to John. We will try to get some kind of response back to you.

I think that the response of this panel meeting has been excellent. I am encouraged by the attention that has been given. It gives me an indication that there has been a lot of interest; there's been a lot of good communication. I think that as we look back over what has happened in the last 3 years, we as manufacturers and users are ready to cope with this new industry. I am anxious to see what is going to happen the next time we have a meeting like this.

I would like to call this meeting adjourned.

Section 18

Panel Discussion On Throttle Valves

Chaired by Donn Hammitt

October 16, 1980—2:15 p.m.

THROTTLE-VALVE PANELISTS—Left to right: Ian G. Wright, David K. Christensen, F. Don Freeburn, Neil Bond, Donn Hammitt (Chairman), Frank Plut, Robert J. Platt, Carl Ackerman, and William O. West.

HAMMITT: Ladies and gentlemen, I am Donn Hammitt. I am going to moderate this session on throttling valves for coal-conversion processes. Welcome to the group.

I think you have met all of the members of the panel except three. I will introduce those three to you now. Neil Bond, to my right, is with Ashland Synthetic Fuels. He is a 1975 graduate of the University of Missouri at Rolla. He worked 4½ years at Dow Chemical in the Magnesium Department. Since May of this year, he has been involved with the H-Coal Pilot Plant primarily working on valve and other component problems.

Second from my left, Carl Ackerman is a graduate of the University of Illinois in chemical engineering. For the past 30 years, he has been with Gulf. The last 7½ years, he has been at Fort Lewis.

Don Freeburn was introduced briefly last night; his credentials are rather impressive. He is a graduate of the University of Pittsburgh. He spent 14 years with NASA and the Johnson Spacecraft Center and has been with DOE for the past 2 years. In that position he is chief of the Component-Development Project Branch for the Morgantown Energy Technology Center.

What we are going to have today is sometimes called a colloquy. Webster says a colloquy is a structured conversation. We are going to try to make it easy on structure and pretty long on conversation. We are going to expect you to help us in that. I will give you an outline of the way that I see things unfolding right now. They may or may not unfold in that direction. How we go will depend on you.

The questions that you are interested in are the ones that we want to pursue. Anyone here is fair game. I think that any question is fair game. If a question is not answered because someone doesn't know or perhaps might tread on a proprietary toe, naturally that would block off that line of questioning. But, we will go as far as we can.

The outline that I put together here is tentative. First of all, to keep the marketing people awake, I would like to get into what the general throttling market is. And then, from there, into severe-service or critical valves. We will spend some time on actuators, accessories, the buying practices, involvement of the valve companies with METC, and finally I would like to ask the panelists to get the crystal ball out and tell us what is going to happen five years from now. That should give us a fairly full afternoon.

At this time, I would like to start with Bill West and have each of the panelists give a few words on how they are involved in this process, what programs they are working on, give us a word on each and where they are, what the status is and where they expect to be 6 months to a year from now.

And so, Bill, we will start out with you and we will just go right down the line.

WEST: I am with Dravo. As most of you know, we are presently designing a demonstration plant. Its capacity and coal usage will be about 2,400 tons a day. It will be built in Illinois. We are doing the final justification to go for approval sometime next year.

If it is approved next year, then it should be coming up out of the ground shortly thereafter. Delivery on this will be about 4 years after that. The big valves have about a 48-month delivery. Where we will be 6 months from now, we will be waiting for the government to tell us whether we can go ahead or not.

ACKERMAN: I am Carl Ackerman. I am involved in the Fort Lewis Pilot Plant in various ways. My title is Supervisor of Process Development, which means almost anything you want. The place we are now at in Fort Lewis is testing more and more on equipment and of course still continuing to demonstrate pieces of the process. We will be testing a preheater design and other components for both SRC-I and SRC-II for the next 2 or 3 years. At least, that is proposed for our next budget renewal.

I can't speak for the demo plant very much, but it has been described already. It is in between stage zero and stage one of design; namely, they are going into "hard design" on it. That will depend on money to proceed with the "detailed design" of hardware and so on; approval should be received in the near future.

Six months from now, we at Fort Lewis expect to be still getting more data, both on equipment—mostly on equipment—but also on process development and improvements. The demo design should be under way; that is, the hard final design.

PLATT: My role within Exxon is the instrument or control-valve coordinator for our government program, which is the Exxon Coal-Liquefaction Plant (ECLP), a 250-ton-per-day Pilot Plant.

Basically, we have just started up our plant. The objective is to prove out all of the equipment in the plant so we can build a commercial plant in the future. We have several partners; the government has 50% and a lot of other oil companies and interested parties share the rest. We have been fairly successful with our valves so far. We haven't had any real problems. Certainly nothing that caused down time of the plant.

We have somewhere between 40 and 60 hours of operation to date. The reason the performance factors are so much below 100% is that we have had trouble with other equipment such as pumps and heat exchangers.

In the near future, we expect to continue to run the plant for about 28 months. That is the current plan. We are going to run various types of coal and there are plans to modify the process slightly to test another option. I think you asked questions on the number of valves and things like that.

HAMMITT: We will catch it later on. Where you are going to be 6 months to a year from now?

PLATT: We are going to be well into this first run of coal, which is Illinois No. 6, and hopefully at that point we will have the equipment able to run for a projected 2-year life.

PLUT: My name is Frank Plut and I work for Stearns-Roger. Our work consists of trying to operate the Bituminous Coal Research Bi-Gas Plant. My job is to repair all these valves that design engineers select or vendors sell us. I also get involved in a lot of instrumentation. We have about 400 control loops which all use a valve. Presently, we do not have a test program going for valves per se. We try to leave that up to some sort of a research group or test facility.

Six months from now, we may end up being a test facility, because our program is rapidly losing interest in the higher ups in DOE, or so I hear. They are thinking in terms of making the Bi-Gas Plant a test facility.

BOND: I am Neil Bond. I work with the H-Coal Pilot Plant. Currently, we are in a phase-three operation. We are trying to run Illinois No. 6 coal. We are having a little trouble running to date. We have run 7 days. That is our longest run.

Currently, we are working with the Willis valve, and it is nothing but trouble. We are currently buying, or receiving from companies for testing, valves from Cameron, Fisher, WKM, Masoneilan, and Continental Disk for the poppet valve, as it is referred to.

In phase four of the plan, we hope to get more into testing equipment. We are going to be testing valves and comparing them to each other and hopefully to some kind of power-recovery system. All this is needed to be done for a commercial scale-up, which is the next step after this pilot plant has been proved out.

FREEBURN: I am Don Freeburn from Morgantown, DOE. I am chief of the Components Project Development Branch. As many of you know, DOE was started in 1977, originating in ERDA. There have been quite a lot of changes in the organization since that time.

One of the changes that has happened in the last year and a half is what is called decentralization. A number of the field organizations, which were originally called research centers, have now been termed technology centers and have been given lead areas of responsibility for support in the technology areas.

Our center here at Morgantown has about four basic areas, one being gasification, the second being combustion, which is really the fluidized-bed area, and gas cleanup being the third. We do have some oil and gas duties left here at the center and then my area of components, which is basically a support to all of the other areas.

Right now, it is primarily support to gasification, not so much combustion. It is a small branch; I only have two other people besides myself. You know John Gardner. He is on the engineering side of the fence and really is working both sides, project and engineering.

So, actually, I have four people. Our responsibility in components again is not only supposed to address valves, but other things like compressors, pumps, heat exchangers, instrumentation, etc., and it is a very big area. And, as we mentioned, I only have 2 years right now in this particular field. Many of you probably have less than that, too, so you can appreciate that.

John and I have been working the last 2 years in conjunction with headquarters trying to come up with a program plan for throttling valves. We had one particular scenario that we have been pitching, but in the last couple months, headquarters, under the chairmanship of Kamel Youssef, has come up with an internal DOE support-type oversight committee. It is called the Materials and Components Oversight Group. The prime purpose is the fact that the DOE has the demo plants and the major pilot plants in front of them with real problems in both materials and components that have to be addressed.

At the last meeting of this panel, we had four specific areas that we think are going to be problem areas. One being block valves; another one being letdown valves.

Both John Gardner and I are chairman/cochairmen of these panels. Like I said, we have been working the last 2 years trying to define a program. We have been talking to most of the pilot-plant operators and, also, to the designers of the demonstration plants. We still feel, after this meeting, that we probably need some additional input from the valve people (i.e., those who may have valves for the applications that were shown in the last 2 days).

Where do we hope to be in 6 months? I hope that we can—primarily out of this subcommittee on letdown valves—define a program that states exactly what elements are still needed for development of these valves, whether it be test analysis, whether it be using the pilot plants, or even using the demo plants for further testing in the development of these valves. Thank you.

CHRISTENSEN: My name is Dave Christensen, and I am with the General Electric Company. I am in the Energy Systems Programs Department, which is in the business of bringing new processes to the power-generation market.

My particular section is involved in the PFB, pressurized-fluidized bed, and we now feel that this process has come far enough that we have to start trying to commercialize it so that it will be ready for power generation at about the time the supporting technologies are ready.

As far as the power plant is concerned, we expect to be in a second-study phase for about a year and that will be following by, hopefully, "design" and "building" phases for a PFB product-type plant.

We are also involved in supporting technologies for the PFB. One area, for which I am the program manager, is a long-term materials test that is partially funded by GE and partially by DOE. There we are developing and proving out gas-turbine protection for the nozzles and buckets. It is a 4-year, long-term materials test.

We also have tests going on in the area of hot-gas cleanup. Some of my coworkers are working on things like cyclones and electrostatically-augmented, granular-bed filters. We hope that we can do this; the valve manufacturers can supply some valves, and we will have a plant ready for demonstration and sale in the near future.

WRIGHT: I am Ian Wright from Batelle-Columbus. We have been working in the area of erosion-corrosion for the past 5 years and characterization of materials for letdown valves and slurries for the past 4 years.

The work originally was looking at the letdown valves and conditions for the small Process Demonstration Units (PDUs). The current work is supported by DOE and is no longer just the screening work that we did to try and develop data that might be of use to designers.

In 6 months, assuming that our contract continues, we hope to be into the area of developing data over a broader range, increasing our data base to take care of the conditions in the pilot plants which are in some cases considerably different from those in the PDUs, and also developing the data base to include other valve systems and pumps.

Hopefully, also we shall have an involvement in trying to generate a better understanding of the reasons why these materials fail, so that we can give some direction to improvement of materials.

HAMMITT: Thank you. Well, we are here to talk about throttling valves. We have heard quite a bit of talk about throttling valves in the last day and a half.

What I would like to do now is to talk about throttling valves in general for these various processes. I am wondering if the people who are involved with the various pilot plants can tell me about how many throttling valves they are going to see on an average commercial coal-liquefaction or gasification plant? How many throttling valves, the sizes, the ratings, how many are taking high-pressure drops, what are the materials and if we look at the plain throttling valves, could we have a breakdown by style of valve: butterflies, balls, high-performance butterflies, globes, etc.? Who wants to start? Neil?

BOND: Okay. I will start off. Basically, we have 30 to 40 letdown valves in our pilot plant. It is still a question of how many we will need in the way of commercial-size plants. Obviously, it depends on how many reactors and so forth we will have.

But the ones that we are concerned with are the high pressure. They are the ones giving us the most problems. The drop is 3,000 psig down to 1,200 psig and 1,200 psig down to 70 psig.

The other letdown valves have not been giving us any problem, but there is basically very little pressure drop involved with those valves. So, really, we are addressing the most visible problem, which is our higher-pressure-letdown valves.

HAMMITT: How many other throttling valves in a typical commercial plant?

BOND: About 30, 40 right now. In ours, I don't know.

HAMMITT: Other than the letdown valves?

BOND: That is it.

HAMMITT: Those are the only throttle valves you have?

BOND: Right, right now, currently.

HAMMITT: Okay. Bob, do you want to try?

PLATT: I think before I give you any numbers, there is something that has to be considered and that is my process which is the Exxon Donor-Solvent process. So, the numbers I give are only for the Exxon Donor-Solvent process.

In the current pilot plant, there are perhaps 17 or 20 valves that have a status that I consider critical such that they would impede the commercialization of the process if any of them fail. The main valves of interest are the 2,000-pound letdown valves. They are the ones that I was indicating were working without too much difficulty.

As far as the whole plant is concerned, there are probably 150 control valves. In terms of commercialization, it very much depends on the train size or how many trains are utilized.

If we just go ahead and build a commercial plant that is 100 times bigger than what we have now, then I wouldn't anticipate more than 200 or 220 control valves in the whole plant. But if we stop short of the 100 and build multiple trains, the number of valves will just simply multiply by that number.

The rest of the question was, what type of valves would these be? The 20 or 25 critical ones in the group of 120 to 150 control valves would most likely be streamline-angle valves. The other valves in the plant are lower differential pressure and the same relatively high slurry loading, such as recirculating valves in the slurry drier.

These could be other types of valves such as eccentric-rotary valves (i.e., the Cam-Flex or modified-Kamyr valves).

The issue will be one of what differential pressure is really available. If one has a solution like a streamline-angle valve, it is fine if you have enough driving force. But I don't foresee using streamline-angle valves throughout the plant.

HAMMITT: Carl?

ACKERMAN: Well, the answer is I don't know how many valves are going to be used; I am not that intimately involved with the details of the demo-plant design, which is just getting underway. The P and I.D.'s that I have seen have mostly just been simplified P and I.D.'s that don't show control valves.

I know that awhile back, the thinking was there would be about 12 slurry letdown valves. This was split in three pieces. Splitting the pressure drop in three pieces is just the converse of the Exxon thinking. Fort Lewis currently has two stages of letdown.

The number of other valves in the slurry service would be a larger number. I can't even guess at the number, but it would be a larger number than that in the slurry service throughout the plant for fractionization feed, level control, recycle, etc. There would be a number of other valves with low-pressure drop.

How many valves would be in the whole plant? Oh, boy, a $1.4 billion plant would have a lot of valves is all I can say. It is a very complex plant, so it has everything from large steam-generation equipment to very large gasification equipment to ammonia-recovery trains, H_2S sulfur-recovery trains, and all the other auxiliaries that would go with the plant. These would take a lot of valves. I can't even make a wild guess at the number of control valves.

WEST: We are in the design stages on a demo plant, one-quarter-size full commercial. Approximate figures are: ball-type control valves, 150; standard-pattern globe-control valves, about 300; refractory-lined slide gates, 30; high-pressure angle letdown valves, 10 to 15, depending on the way we end up designing it; and about 15 high-pressure, letdown, specialty valves such as a drag valve.

These globe valves would be basically used on utility, steam, air, water, transport gas. Sizes will range from 2 to 8 inches, pressure drops of less than 150 pounds. Ball valves would be in the 2- to 6-inch class. They will be taking a little higher pressure drop, about 200 pounds. The slide gates are all specials. They range in sizes from as small as 3- or 4-inch I.D.'s to over 40-inch I.D.'s. Quite honestly, we haven't come up with exact sizes on them. Angle letdown valves, there will be 4 severe-service cases and 10 or 11 minor cases.

Now, these valves would be in a single train of a commercial unit, so that if you wanted to go for a commercial unit which, according to present plans, would consist of three trains, you have to multiply those by three. And that should get you within plus or minus 10 to 15% for the valve requirement for our type of plant.

HAMMITT: Thanks, Bill.

PLUT: As I said, we have about 400 loops on our plant, but that is probably more than a commercial plant would have. They range in size from 4 inches on down to ¾ inch, with, of course, various size trims in them.

We have 14 high-pressure letdowns, most of these being of the Willis construction. We have, I would say, five globe-type valves. We would have about 10 butterfly valves, which are of the 4-inch size. I would say we would have about 75 of the collapsible, elastic-tube, conduit-type valves that I described in my talk.

But as I say, we have 400 control loops, most of them having control valves. A commercial plant surely wouldn't have half that many.

HAMMITT: How about scale? Do you have any idea what size they would be on the commercial plant?

PLUT: I would say on scale up, our largest size—even for commercial size—wouldn't be over 20 inches in diameter.

HAMMITT: Butterfly?

PLUT: I don't know. I would imagine that size would have to be a butterfly.

HAMMITT: Does anyone have any questions that they would like to pursue on this particular matter before we leave the general-service valves?

ACKERMAN: One more thing; I should point out that there is one large demo plant that is not represented here and that is the SRC-I or ICRC or Air Products Group, and so you have to take sort of what I said and double it, which I didn't say anything, so that is not much help.

HAMMITT: Do any of you who are not involved in the coal-gasification or coal-liquefaction plants want to make a comment? Don, do you have any further comments?

FREEBURN: No.

HAMMITT: This is supposed to keep the marketing people happy, I hope. One of the questions I had along the line of general-service valves; are we going to see any tougher specs for atmospheric leakage on these general-service valves that we normally see on the refinery or power plant or something along this line? In other words, is the standard packing for control valves adequate or are we going to have to see bellow seals? Somebody want to answer that?

PLATT: I don't think you are going to see much bellow seals. As far as packing goes, most of the materials involved put you squarely into Grafoil. There haven't really been that many problems, at least not that I am aware of, with packing and leaks in packing. Most of the time, the difficulty is just poor maintenance in terms of putting too many land rings in and things like that. I really don't see any leakage-type problems. I think what we have is pretty adequate.

ACKERMAN: I would generally agree. We have run about 6 years on coal and have generally very good service out of Grafoil packing, with the appropriate cooling fins. So there are no significant problems—any more than you would find in a refinery.

If you have erosive material getting into the packing, you have another problem. You have a deeper problem in your valve that you had better solve. Holding hydrogen is old hat and I think that it is well-established technology.

HAMMITT: Bill, do you want to mention anything on that? You mentioned the hydrogen sulfide?

WEST: From my point of view and having worked around a pilot plant for years, I found that the standard packing most of our material has run us into is Grafoil. In the plant I was working at, we were fairly conscious of keeping the packing pretty tight.

In the particular plant I am working on, the gas will be containing in excess of 2,000 parts per million of hydrogen sulfide. That much makes it downright dangerous. So, Safety has been raising questions, you know, what can we do about it?

From a practical point of view, other than having detectors around, I don't think there is a whole lot we can do about it. It is really up to the plant personnel and the local safety man to set up the proper maintenance. If your packing is maintained, you won't have any problems with standard units. That is my experience. If it is not maintained, somebody is going to get knocked down.

HAMMITT: Okay. Thank you much, Bill. Anyone else want to add anything to this?

PLUT: I would. To add to his comments about H_2S leakage, we also have a threat of CO leakage, and it too is a poisonous gas. Of course, we have atmospheric monitors around to tell us if we have a leak, whether it be from packing or anything else. As long as the plant is outdoors, not enclosed, the packing doesn't present much of a problem.

PLATT: I would like to make a comment about standard refineries. It is well-known that gas plants run at 98% H_2S on the feed line. Most refineries gave up bellow seals and other mechanisms of that type a long time ago.

What they have done is simply have strict safety procedures where you cannot enter the area without breathing apparatus and so forth. They have routinely put out the new form of solid-state H_2S detectors which alarm. You just keep all the people out of the area and that is the normal routine way of handling leaks.

You can't really depend on doing super maintenance in a refinery all the time. So what you do is keep everybody well.

BOND: Along with the Grafoil we use on our valves, we also try to make provisions for high-temperature grease. Many people like to use oil—but we use a Lock-tite, high-nickel, high-temperature grease. It seems to work out real well. When we take apart a Willis, we still have this grease. It is not powdered or anything. It is still in grease form. It is very messy, but it works.

HAMMITT: Thanks, Neil. Anything else on the standard throttling valves? I would like to start talking about tough valves in particular, and what I would like to do is get into some of the questions that we might have on tough valves. As I said, the audience is encouraged to ask questions at any time.

Some of the things I want to talk about are materials, valve shutoff, port sizes for the various types of bodies, split ends—three by fours and that sort of thing, packings, steam jackets, and cycle.

Let's start with Mr. Wright. If you had to make a recommendation today, what would you recommend for valve-trim materials, not just in the critical-wearing areas, but throughout the valve?

WRIGHT: Let's start off with the critical-wear areas. Obviously, the best experience is with the K-703 in the Wilsonville plant. The good performance of the K-703 has come about not only from the use of a material that has good erosion resistance, but from considering its mechanical properties, too. The material is in the valve to suit the trim and also from some consideration of the flow—trying to mitigate the flow characteristics of the slurry, too.

It is a combination in choosing your material—mechanical design and design of your flow system. It is a systems approach. The material property of hardness is much maligned as a criterion for resistance to erosion, and does not have a tremendous basis in theory. However, for less-critical applications, hardness still holds some power as a selector for materials.

So, material hardness in conjunction with attempting to have as uniform and as fine a microstructure as possible seems to be a way to go for obtaining good erosion life in less-critical applications where you can use a metallic, for instance.

In these less-critical applications, it is not just a matter of having the best erosion-resistant material; you have to take into account the mechanical properties, and actually apply it in an engineering sense as well.

HAMMITT: Thanks, Ian. I think it is only fair for anyone who has operating experience that differs with him to feel free to fire at Ian. Frank.

PLUT: Ian, did you ever attempt to use soft material as opposed to hard material for erosion-type service of flexible elastic?

WRIGHT: Yes, but bear in mind that most of our work has been involved with very severe conditions. We initially tried everyone's favorite materials, so we tried diamond and also neoprene rubber.

In our severe-letdown conditions, neoprene rubber was useless. I think that if the conditions were sufficiently severe, you can fully compress an elastic material and keep it compressed. Then all you are doing is compressing it and cutting it once it is compressed.

If you have conditions where the rate of arrival, if you like, of the erodent is well spaced so that the material can recover, yes, I think the elastic materials may have some use. In fact, they wear very well at the lower velocities and possibly larger particle-size conditions.

ACKERMAN: Specifically, I can say in our plant, I don't know how many different valves we tried. Of all the different valves we tried and all the different services—including filtration, filter cake, letdown, and so on—there have only been one or two spots in our whole plant where we could put a soft-seated valve or a squeeze-tube-type valve in.

Almost anyplace in our plant, the solvent and/or the conditions just chew up Enviton. Enviton is resilient, but it won't stand the solvent. It just swells up and at 400 or 500°F, it will last for a day or two or three. Filter-cake letdown from a filter was the only place we found that Enviton would stand up and that was a high-maintenance job.

PLATT: We have the same problem with resilient materials, like Enviton C. The solvent causes them to swell. I think it is the same story across the board with everyone's process because of the aromatic content.

I have another comment regarding the extensive testing that Ian has done. I must say that what he presented this afternoon was a very thorough investigation of a good screening study of what doesn't work.

HAMMITT: Question over here. For questions from the audience I would like to have everyone state their name, company they are from, and then the question.

WILKIE: Galen Wilkie with Fisher Controls. Of the liquefaction processes, do you foresee the stabilized grades of stainless steel such as 347, 321, being a requirement on commercialization as it has been on your pilot plants, or might standard 316 be acceptable?

HAMMITT: Who wants to start?

BOND: Definitely 347 if we can get it.

PLATT: I would be tempted to say that the valves are chrome 5, the more critical ones. We have had experience in the past with some very large high-pressure, furnace-outlet valves where we have used 316 and have employed hard internal coatings. Unfortunately, or fortunately, the coatings came off and the stainless help up. So I am not awfully sure that 316 may not work on the commercial plant in the larger sizes, especially if the design is aerodynamically or hydrodynamically correct.

ACKERMAN: One of our concerns about the stainless materials, especially stainless piping, is the reaction conditions at the inlet and outlet. We have concern about chloride stress-corrosion cracking and we have seen some.

So 316 and even 347 has to be used judiciously, and 5 chrome might be a better choice if you can use it and get away with it. It is probably safer for stress-corrosion cracking. I don't like to agree with you, but I have to.

HAMMITT: Bob, do you want to comment on that?

PLATT: I think the only thing to add is that chrome 5 is very hard to cast and I don't think Galen would want to sell that.

WEST: Number one, my plant is a little different in that I have both nonsolvent liquid and gas. I am afraid I find the question is really impossible to answer. We just have to look at each valve, because there are quite a few where we can use 316. For most of our valves, we are talking about 310 stainless or 5 chrome. Because of the chemical content of coal, you just can't take a chance with anything else or you end up in trouble.

HAMMITT: Anyone have any comment?

PLUT: We recently had a nasty experience with stress-corrosion cracking. And from now on, we are going to look very carefully for corrosion and stress corrosion; this would include valves also.

Our problem specifically was with piping. We had an expensive job to replace all that piping. So it would be something to consider in the selection of a valve. Of course, it always depends on where you are using it. Generally speaking, you could get away with 316 in almost any area.

HAMMITT: Dave, do you want to speak to that?

CHRISTENSEN: Myself, I am not a valve expert, but in the process of building our long-term materials test, I have been discussing materials with my materials men. Basically, when we have to build something that is relatively unstressed and high temperature (i.e., 1,700°F hot gas), we talk 310 or 316 stainless; 304 just doesn't have a high enough chrome content. When we are talking about a service that has some stress to it, high-pressure piping, we talk about lined pipes.

When we talk about gas-turbine materials, we start talking about FeCrAlY and CoCrAlY, which is a combination that seems to have made out. FeCrAlY is an iron-based material; it is 24% chrome, 4% aluminum, and 1% Yttrium, which my metallurgist calls fairy dust. It doesn't necessarily benefit valves, but that is what we use in the hot-gas areas.

HAMMITT: Does anyone else want to pursue that materials' question any further on this?

VOICE: We have an extensive valve-testing program at present in West Virginia, and one of the things we found was that coatings did help in improving the valve life. I wanted to find out if any of the panelists had any experience in coatings and, if so, what type of experience they have had. Do you think it is promising?

BOND: To date, we are using TMT-5; it is a proprietary coating. We are not really sure what it is. We used the same valves except for the tungsten-carbide piece. The K-701 started to show wear after 8 hours. With TMT-5, it had more hours of coal on it, but it was just polished.

VOICE: We also use the TMT-5. It is a titanium-diboride type of coating.

BOND: They didn't tell us that. We have titanium diboride and TMT-5. So I am not sure that that is titanium diboride. They have had trouble putting that on first and TMT-5 after it. TMT-5 is really easy to coat.

HAMMITT: Would anyone else like to answer that question? Experience on coatings?

PLATT: I think the only thing I would like to say is we plan to try some, but it may not be for quite awhile. We do have a lot of experience on coatings, but in the past we have not been very successful. That is why we didn't really use them on the critical valves in the ECLP plant.

GOODWIN: Ed Goodwin, Mitre Corporation. I would like to address a question to Bob Platt. Uniquely, among the presenters, he is relatively satisfied with what he has got. And I was wondering if he has decided why he is so satisfied? If he is able to identify why his valve performance is substantially better than the other panelists?

PLATT: The basis of the design and the selection of the critical high-pressure letdown valve was to take advantage of what I considered to be very good hydrodynamic characteristics of that design.

When I selected the design for use in ECLP, I did not consider the materials, frankly, because I felt that whatever happened, assuming I put in the valve the best possible material available at the time, and I would have the best mechanical design.

So, to answer your question, I feel that the relative success has been due to the style of the valve and the fact that, inherently, it does not put undue stress on the K-701 trim.

Clearly, we have many examples of failed K-701 trim. Maybe not all K-701, but K-701 has been failing left and right in various other designs. There is no difference between my K-

701 and others. The difference has to be in the style of the valve and how well the style is matched to the application.

I think that is really the only thing I can say about relative success. As I said before though, my materials' people are busy arranging to make titanium-diboride, chemical-vapor coatings, which they would like to try. After we get enough experience so that what we have is suitable for commercial purposes, we will go in and experiment.

BOND: I have to agree with Bob on that. Streamline design is a good design. Willis is a material tester. We are trying to get somebody else's valve in very quickly.

RANDICH: Erik Randich. I have a question for a couple of people on the panel. You mentioned with your TMT-5 coatings you have had 8 hours' experience with it. I know Bob has had a maximum of 50 days.

PLATT: Somewhere between 50 and 60 days, but we don't have any—hardly any—wear on the pieces, so it is not completely certain.

RANDICH: I think that Ian might address this point, whether the failure occurs at a steady rate from time zero on to 3,000 hours. It seems to me the longer life-time valves to date are the SRC valves. So how do you feel about being a little premature in your judgment of these materials especially with an 8-hour test program?

WRIGHT: We have looked at titanium diboride in a couple of places. The forms we have looked at haven't looked to be one of the more promising materials.

The reasons why stem from the fact that erosion is a very localized form of failure, so that if you get a localized discontinuity in the surface, then you very quickly change the angle of attack and probably the velocity of attack and the erosion. The titanium diboride we had was a hot-pressed material and had solid porosity at the particle boundaries. It failed by erosion at the boundaries, resulting in particles falling out.

This business of when does erosion attack occur? If the material is erosion resistant, inherently erosion resistant, then erosion occurs at the point where the uniformness of material uncovers some discontinuity, some change in structure or some grain boundary or porosity or so on.

I can see that if you have an erosion-resistant material, then you might find steady erosion rates for a long time. If it is a uniform material without different phases, yes, it might erode steadily and uniformly for a long time.

If, however, there is a different phase in there, if there is porosity or structures from prior processes, once these become uncovered, then the thing will fail locally and probably quite quickly.

HAMMITT: Carl, do you have a comment?

ACKERMAN: On our valves at least, which are down-flow microform Fisher trim, the wear rate seems to be proportional to time, in millimeters or microinches per day or whatever you want to call it.

Are we satisfied with our valves? No, we are still trying to find longer-life valves. Why don't our valves last? Our valves don't last as long as those in use at the Wilsonville pilot plant. We are going to be trying the same shape trim they do; that is, with a flat on one side of a cylinder to see if that gets us a longer life. At least it is our plan to try that shape.

One of the key things I think on our short life, namely, 100 days' maximum life on a system and then it is worn down to a nub, I think it is based on the fact that our valves are greatly oversized. So they are starting out at, say, 20% open instead of 80% open. That was chosen because we need to pass particles, so we compromise on size and take a beating on wear.

If we put in the right size valve, which would be about a 1/8-inch or 5/32-inch hole, I would expect we can probably double it or quadruple it or multiply it by 10. I don't know. We have more than doubled our valve life by going down in size; from ½-inch to ¼-inch. We don't have the intestinal fortitude to try a smaller valve except on the Willis valve, which we tried and which did plug up frequently.

HAMMITT: Does that answer some of your questions? Who is next?

BOND: The longest we got out of tungsten carbide, which was a cheap grade, was 4½ days. So quite obviously, the Willis valve, when it starts eroding, keeps eroding until you can't hold level.

It was encouraging after 8 hours on the TMT-5 to see only slight wear on a disc. We are not saying it is successful. We are saying it shows good, and we will be starting to run this next week and hopefully we will have better data. But once the Willis valve starts going, it is gone. I mean, 4½ days is what you can expect on tungsten carbide, cheap grade.

PLATT: I just wanted to add that we plan to try to determine how the erosion or how the wear that occurs does occur. We are making measurements on corrosion and what little wear I have on a routine basis, every 3 or 4 weeks, depending on circumstances.

The one scenario that we had considered was that we may get a little bit of wear initially in the first 10 or 15 days of service and then have reduced wear. But this is something that we intend to keep up surveillance on to try to get some more information.

HAMMITT: Another question back there?

VOICE: West Virginia University. I would like to ask the panel their opinion about the validity of comparative performance of a valve in, say, the different processes of your plant, with the performance of another valve in the ECLP plant when you ran at the rate of 250 tons of coal per day.

WEST: One of the problems in this business is not only just the different plants and different processes, but running on different kinds of coal. I guess a couple of us here have worked in plants long enough to actually have run 1- or 2-month runs and compare what happens when you are using coal from different parts of the country.

Now, on the ash letdown systems at Hi-Gas—back when we were doing this—the only choice we had was the Willis choke. I have to agree with them. We started out by getting like a half a shift out of a choke, and then we learned how to handle them and how to modify ıem and we finally ended up with what faintly sembled the Willis choke. That is what we ended up with and we could get 45 days out of it with a $200 repair.

The difference though is that just by changing coal, you could have doubled your valve lifetime. So, I guess what I am saying is that it is difficult to compare experiences in different plants, because I know in the same plant using different feed stock you would get widely varying results.

HAMMITT: Bob.

PLATT: This past Tuesday, I heard some things about the Wilsonville experience that may help to at least give you some more information on your question. Their material size—they are grinding the coal; it is very fine and it is much finer than the EDS coal. So it is not only true that you should hesitate to make comparisons because of throughput, but also because of the nature of the coal, the size of the coal, forgetting about the origin of the coal. So, I think you are right. It is difficult to make comparisons.

HAMMITT: Here is another question.

VOICE: I would like to make a comment and then ask a question. My comment is that I had come across a report by TRW that said that using tougher material is not really going to solve all the problems in valve design and more effort should be spent on redesigning the entire valve. I think Mr. Platt's experience kind of shows that redesign is the solution, rather than just looking at tougher materials.

My question is: Why are the manufacturers or anyone on this panel so reluctant to look at new designs and spend some money or efforts in new design other than just looking for tougher and tougher materials? And if it is a question of money, who is the one who is going to support that kind of research?

HAMMITT: Since I am the only manufacturer on the panel, I think perhaps I should address that. I don't think manufacturers are reluctant to look at new designs. I think they are looking at new designs. I think they have spent quite a sum of money looking at new designs. The manufacturers are gun shy of putting an awful lot of money into processes that aren't going to show commercialization.

That is one of the questions that is going to be sorted out.

They are also very shy about putting a lot of money into development work that really has no counterpart with real field installation. Unless we can find a place to get our valve tested, it is worthless for us to put an awful lot of development into a new design.

Everybody has ideas. But getting the thing made with these expensive materials and getting it tested is something entirely different. This is something we are looking for the industry and DOE to give us guidance on.

FREEBURN: I am going to make a little diversion. I can mention I am chairman of the committee within DOE to address letdown valves, since we again do have all the demonstration projects and a number of them have letdown-valve areas.

Of course, everybody says if Exxon has their thing working, why can't we use theirs. I wish the answer would be as easy as that. But you have already heard a couple of the complications such as what type of coal you are using, the particle size, do you recycle some of the ash?

In fact, you are talking about flashing also, what pressure levels you are coming from, how much vapor you really are flashing off, what type of vapors?

You are also talking—I have heard it already today—I looked at Exxon myself and said, "Now, why is theirs working and the other ones seemingly having problems right now?"

First of all, you come up with a system approach to the total area, not just the valve itself. You have got to consider the inlet as well as the outlet stream flow, too. You don't want to cause any process to take place in front of the valve nor do you want to put more problems on the valve. You can alleviate them downstream somewhat.

It also may be the temperature, also the turn-down requirements, which have not been mentioned yet either. Where do you want to actually control this process at? You are talking about the trim itself, how much do you want the trim to be exposed, etc.

A big question is scaling up. How much can you extrapolate from one size to another in a test program? Can we actually use Fort Lewis, which is a smaller scale even than EDS and H-coal for testing of certain valve designs which we haven't seen yet or modifications of designs we have already seen? So, scale up is one big concern to us.

Another area of course is the trim itself. What kind of quality control do you actually have? What kind of assurance do you have that the trim parts in there are indeed to the specifications you have? What nondestructive testing methods will determine this?

Also, what about a requirement on shutoff? Some people say, well, you should also use that valve for shutoff. We tend to think that is imposing a penalty on a design that already has very stringent requirements. I think it is more reasonable to address shutoff with a block valve.

Another area, too, is just exactly how is your plant going to be designed as far as maintenance and service? Can you actually accept a 30-day life on a valve? Can you get into an area that is high pressure? Are there parallel flow streams? Can people actually get in there on a 30-day basis and change out, or do you have to accept maybe a 60-day or maybe a whole year's operation because you can't get into that area.

These are all considerations, like I said, for the whole area. You just can't go down to just the trim material and justify the valve. It is a whole system-type design consideration. What else? I think I covered most of those, but I just wanted to relay that type of information on for you to start thinking a little bit more too—down more paths. Thank you.

HAMMITT: Thank you, Don. Question right here.

SLUSSER: Joe Slusser, Air Products. I would like to follow up on that scale-up question. How comfortable is the panel, especially you, Donn, since you are a manufacturer, in taking a design that is working at, say, Exxon and scaling it up from 2 inches to 10 inches such as we would need in a demonstration plant. How confident are you that you maintain acceptable lifetime?

HAMMITT: Bob, what port size is a 2-inch valve?

PLATT: The orifice size is ½-inch.

HAMMITT: From ½-inch to 1-inch is oughly 4-to-1 capacity.

SLUSSER: I am talking more like a 2-inch-diameter port.

HAMMITT: Two-inch-diameter port. In that case, you are talking roughly 8 to 1. I would be fairly confident.

SLUSSER: Where is the break point?

HAMMITT: The question came up during the break. I don't know how the rest of the manufacturers feel. From my own experience, I would feel fairly confident in going up two nominal sizes or down two nominal sizes without expecting any particular deviation of results. But if I went much beyond that, I would have my eyes open and I would be looking for something to happen. I think that goes through the industry. API, for example, on their specs for fire-safe valves, allow you up or down two nominal sizes.

SLUSSER: What do you mean by nominal size?

HAMMITT: If I had a 2-inch valve, I would be allowed to go down to a 1-inch size or up to a 4-inch size.

RERECICH: Frank Rerecich, Marotta Scientific Controls. It is a general-type question. As a neophyte in this sort of business, I would like to have a general specification, if I could, from someone who can explain specifically what they are after, not that they want something to last to 1,700; what do they want to last to 1,700? Do they want a quarter-inch valve with a 1,500-pound rating? Do they want a 2-inch valve with a 600-pound rating? Pressure drop, temperature, service? If I wanted to size the valve, I would want to know the density, so information of this sort would be appreciated.

FREEBURN: Again, I guess I addressed some of that in my last comment. I think you could come up with some criterion that is going to be general. For many of the conditions I ~entioned, I am not too sure how you are ›ing to specify that. I think some of the actual operators and designers should be into that end right now.

ACKERMAN: You want about a three-page set of specifications on every single valve. I don't think it is practical to give you that this afternoon. You would have to write to each of these various demo-plant firms or engineering firms or whoever is doing the detailed engineering and ask to get on their bidding lists.

WEST: I have got a little edge because I was talking with him during the break. I think he may have a valid point. All of us, especially here at the table, are fairly familiar with each other's problems. Most of us are good phone buddies. I think what he means is when we are talking about a letdown valve, if we can say, all right, it is a 2-inch valve and it is a thousand-pound drop or it is a ½-inch valve and whatever. It might make more sense to some of these people out here who really don't know the details because we are giving really fairly broad terms up here.

I know this morning I talked about 1,700 °F valves. He said well, there are all sizes. It doesn't give a man much to try to work on if he isn't familiar with the problem. I think from my point, if I am talking about a specific problem, I can say, okay, I was working with a 1-inch valve or 2-inch valve and give a little more general conditions, it might be a lot more help to the people out in the audience.

HAMMITT: Thanks, Bill, for the elaboration. Did I see a question back there?

MILLER: One of the comments that Donn discussed earlier I would like to make a comment on. That is shutoff specification. I would like to ask the panel, are you requiring these throttling valves to show some degree of shutoff? If so, what is it?

HAMMITT: Bill, do you want to start off?

WEST: Originally, we did require shutoff in the Willis, but we found out we got a lot more life out of it if we didn't. Willis choke can give you good life if you tailor it to the specific problems. Neil is struggling with the same problems I did about 6 years ago and it was a real shame. We could have saved him some effort if the information had been available.

It is available, but it is like going into a library and not knowing what the card system is. And if you don't know who to call, you are really kind of out in left field.

He calls Willis and Willis says they are using them over there and they are doing fine. Yes, they were, after somebody changed the thing, it looks a lot different. I think this type of communication with the manufacturers is what is needed. I know this week, the Willis man came up and asked me specifically what we did to change the valve because he didn't have the faintest idea

HAMMITT: We have found that problem also. Carl?

ACKERMAN: The operators have been aware of this and occasionally try for shutoff, but they know darn well they can't do it. The instrument men who set up our valves and trims set our letdown valves specifically to not shut. They are 2% open when they approach as close as they are going to get to closed and that is the way it ought to be.

HAMMITT: Thank you. Bob?

PLATT: I don't think I would ever allow a control valve—especially in this service—to come anywhere close to shutoff. We would not require it to shutoff.

PLUT: I believe, generally speaking, the designers buy every valve with absolute tight shutoff; control valves, that is. I agree with the previous two, that it is not necessary to have absolute tight shutoff. What I am looking for in a valve is that it doesn't leak internally. That would be my number-one concern. The control valve is not supposed to shutoff completely in all cases. You have block valves that do this. The control valve is designed to control, but every spec I have ever seen has absolute tight shutoff against maximum pressure. That is part of the data or specifications.

My second desire as far as a control valve is concerned is reliability. The thing just sits there and operates month after month after month. The next criterion I would like to have in the valve is ease of in-line maintenance. Maybe that is because I am associated with the maintenance mostly. But tight shutoff comes way down near the bottom of the list.

HAMMITT: Thanks, Frank. I would like to clarify the point. I know that probably the majority of the control valves purchased have some degree of shutoff required from B-16.10 Class IV on up; perhaps Class II on up. But the question I am really concerned about, and you fellows are addressing very well, is how about these valves that we are talking about here? In your opinion, is it overly penalizing the valve to require it to give a degree of shutoff in addition to its relatively tough throttling application?

BOND: In our plant, I would hope in the future that we would never make our letdown valves a shutoff valve. I agree it is a block valve's duty to do that. Our valves are really level-control valves. We have a fixed pressure upstream and downstream and we try to maintain that. It is only because of our block-valve problems that we occasionally try to use the Willis as a shutoff valve.

HAMMITT: Dave, how about you?

CHRISTENSEN: The valve that I worry about most is my high-temperature valve. It is 1,700°F. It is 30 to 42 inches in diameter. In fact there are two valves: there is a block valve and a control valve. We have looked at the simulation of the gas turbine where we are trying to stop a large volume of gas back in the PFB. I don't think we have to require full shutoff. We can make the gas turbine come to a halt with 3% leakage, whatever that translates into opening on a butterfly. You can see I am not a valve expert. But I think that could be worked out with time and it is part of the valve manufacturer's duty to tell us what we can do and then how this thing needs actuating. I am sure we will have a trade off in the end.

HAMMITT: You are saying you use both a control valve and a stop valve to get the shutoff you need.

CHRISTENSEN: The stop valve would b~ really an on-off valve and that might be a littl tighter in shutoff, being that we reall;

wouldn't ask that thing to modulate and it could be a different type of valve.

I would ask that we would have tight shutoff valves on our air side, the 600 °F side, where we have the bypass and air supply to the PFB. In that particular case, we would hurt our cycle efficiency should that valve leak.

If it leaked 1% that would be 1% of efficiency overboard for no reason at all. But there, it is a clean gas, it is air, it is only 600 °F. It is still a 36-inch valve, but . . .

VOICE: Before we leave this subject, I got the impression listening to the block-valve people that most of the designs that they are looking toward as far as block valves are concerned work great as long as you turn them from the open position to the closed position at a zero-velocity point and flow.

And how close to zero velocity? Does anybody know how much you have to choke down the flow with the letdown valve before you can throw the block valve shut?

PLATT: Obviously the objective is to not have to take the control valve out. So, there is no need to move the block valves. Depending on the characteristics of the valve, if you can assume for a moment that you have an equal-percentage characteristic or something close to that, you don't really have to go awfully close to the seat in terms of millimeters or tenths of an inch, thousandths of an inch, before you get a considerable throttling.

I think the way to look at this issue of what does a block valve have to take, is simply that the control valve can be pinched down to take the pressure effectively off the block valve. But the block valve clearly has got to be able to take some of the pressure, perhaps 20 or 30 or 40% of the nominal, regular, control-valve pressure drop.

BOND: This is going to be a horror story. I think the block valve has got to shutoff at any pressure. Because if you have a pipe leak—I am talking about a catastrophe now—you have got to be able to isolate that plant as quickly as possible, minimize catastrophe. I am asking that valve to close one time in that case.

PLATT: I think one point to add is you are talking about an emergency block valve. We have to make a distinction here between block valves and what we would typically call emergency block valves, which have to operate for safety reasons. You do a lot of things to make sure these valves operate, like you fire protect them and you insulate the cabling if they run on electric operators, and do all sorts of other things to make sure they work. Clearly, those always have to work. I think the question was really addressed to the garden-variety, run-of-the-mill valve that needs to work when your exchanger is plugging and you want to take it out of service.

HAMMITT: Question in the back of the room.

VOICE: I would like to address the answer to that. I think again, a block valve or an isolation valve has to be able to close under full parameters of the plant, full conditions, that is what it is there for. In case a piece of equipment that you are blocking or isolating fails, you have got to be able to take it out of service.

Neil said it might be a one-time affair and after the situation is resolved, you may even replace the block valve. But it has got to close under full load and full conditions in order to fulfill the job it was asked to do, which is a block valve or an isolation valve.

Again, I don't think control valves have to close to provide a tight shutoff. That is why we are asking what we are asking from the block valves.

HAMMITT: I would guess from the answers we have been getting that most of you people are thinking in terms of an automatically operated shutdown valve in service with the control valve. You are setting up your control schemes, so that you get that; is that a correct assumption?

ACKERMAN: That might be in the control scheme, but you would rather have a cheaper valve than an automatic valve. Where you have a risky enough situation, you might have to do that, but you only put that in where you have to.

PLATT: Typically—not typically in all cases—if there was an emergency shutdown system or a protective system, we would always act to put in a separate valve for a separate function. We would not ask a control valve to do it. In fact, a new Exxon basic principle on protective systems has been written specifically with this as a condition.

McCABE: Jack McCabe, MTI. Are there any processes represented by the panelists where throttle valves will not be allowed to be removed unless the process is down?

ACKERMAN: We had that at the Fort Lewis plant when we had single block valves and they didn't hold, so we didn't take any control valves out until we got double blocks and bleeds in.

Now we are going to double blocks and bleeds and a flush to get even more reliability and less chewing up of the block valves. So, we are trending toward boots and belts and suspenders and overshoes and everything else to try to overcome the weaknesses of the block valves.

If you can shut a block valve, one block valve, that is enough. It is no more dangerous, let's say, than any other high-pressure, high-temperature stream that is sitting there staring at you. But, it has the quality of erosion, so the block-valve dependability is, I would say, pushed by that. A little bit of leak is too much leak if you are going to depend on that for an hour or two or whatever it takes to change out your control valve.

BOND: Our problem is the same. Many times we have shut the plant down on coal runs, because we could not isolate the valve and take it out and put new trim in it. If we had good block valves right now, even though we don't like the Willis valve, we could run.

McCABE: You are misunderstanding me. Is there a regulation that is going to say you must close the plant down before the throttle valve is removed?

BOND: Only if the block valves fail.

McCABE: How many of your processes are considered carcinogenic, cancer causing?

ACKERMAN: The process is not carcinogenic. But the stuff inside the pipe is carcinogenic.

McCABE: Does that fact prevent you from performing maintenance while the plant is running?

ACKERMAN: All you do is wear gloves and protective clothing. If you get it on you, wash it off. What do you do after you smoke a cigarette? You go wash your hands. It is the same stuff.

HAMMITT: The question you had about a regulation, I think it was Daniel Webster who said neither life, limb, nor property is safe as long as the legislature is in session. You might keep that in mind.

PLATT: The only comment I had to what Carl said is that it is true; the whole plant is carcinogenic. It is also true that you have got to wear protective clothing and you have got to monitor who goes in and out of the plant. You have got to force them all to take the safety precautions by all sorts of diffuse means.

HAMMITT: Thank you. I though I saw a question in the back of the room.

VOICE: I have one for Bob Platt—rather three, actually. What methodology did you use in sizing your letdown valve? What kind of scaling laws would you use to scale it up to a commercial size, and then what is your operating point and the controlability required of your throttling valve?

PLATT: The first point about sizing is that my sizing procedure was developed before the advent of the DOE contract. It is a long-established system that is a result of studies done over many years with high-pressure mixtures of hydrocarbons. The company has decided that that is critical information and it is not going to be released to the government or to anybody else. Again, it predates the Department of Energy agreements. So, I have no choice; I can't answer that question. What we promised—or what Exxon promised to deliver to the Department of Energy and all the other sponsors—in terms of valve application is what all the sizes are, what all the materials are, what the experience is, and the conditions they operate under.

The second point about scaling falls into the same category. There is only one thing that I can say and that is it would be a mistake, in my personal opinion, to take the valve that exists and make it bigger and preserve the relative geometrics and preserve the clearances of all of the parts.

As for the operating point, I can tell you what that is. The operating point is on level control; the valve is holding level in the disengaging drum. I have it on a continuous or every-4-second scan with a data-logging system to monitor the position. The position of the valve varies somewhat, but it is always in the 20% of lift to 28% of lift position. It varies significantly depending on the flow rate, but that is where it operates most of the time.

HAMMITT: Incidentally, the control scheme that Bob described, I think, is a critical factor in the success of the valve. I also give the geometry a lot of credit. Any other questions along this line?

VOICE: From some of the data that Ian Wright showed us this morning, with respect to the velocity, this would indicate that if you can keep the velocity down as low as possible, that you should get better erosion life.

It seems to me that one way to do this is to go to multiple letdown stages . . .

PLATT: I don't dispute the point that lower velocities reduce erosion. But I don't think that we could put enough stages in the letdown valve for the pressure we are dealing with here to achieve a reduction that is going to be very meaningful in the velocity.

What I am getting at is I don't really see a big difference between applications at 1,200 or 1,300 pounds and applications at 2,800 pounds under these conditions. Mainly because when we have vaporization in the valve-seat area, which we almost always do, the velocities have gone to sonic. A sonic velocity is a function of the temperature and the molecular weight.

It doesn't matter, in my view, an awful lot once you have gone into sonic velocity how much pressure you have taken. It is nice to say use a multicomponent, multistep valve, and a lot of people have tried this. But it is difficult to do, difficult to achieve in terms of construction.

A good example of the difficulty to achieve his is Consolidated Control's design of a spiral letdown valve where they are trying to take pressure on a long sinuous path. The situation is that in theory it seems like a nice idea, but when you try to make the stages multiple and when you try to make the path long, you get into problems of accumulation of particles and other difficulties. That is why I chose not to use that approach.

ACKERMAN: I agree with what he says. I am saying it another way, that the design of the valve is probably more important than how many stages. Based on intuition and what Ian shows, the key thing is don't impinge the particles on the surface—or try to minimize the impingement. Wearing the particles out against themselves doesn't hurt you because they are going to go downstream, but impinging the particles against a wall is the wrong thing to do.

The shape and design of the valve is the key and the material helps; that is, getting harder and harder materials can help, but you are fighting the problem. So the best thing to do is to minimize how complex a valve is and try to simplify the flow pattern and get the stuff to not hit the wall, but stay away from the wall. The Exxon design is to minimize the turbulents around the trim.

HAMMITT: I would like to add a comment to that, if I could. Theoretically, if you could hold your differential pressure over one stage down to a fairly low level, you would not get sonic velocity. However, if you are going to go from 3,000 psig down to ambient, you are going to have to have an awful lot of stages in order to not reach sonic velocities.

I don't think the jury is back on this entirely, but I do think that it is much more important to keep the high velocities away from the surface, that is the wear surface, than it is to go to staged trims.

ACKERMAN: I can say that an 80-psi pressure drop wears out steel like mad.

HAMMITT: That is the point. You have always got to take that last drop and somewhere along the line the velocity is going to get high even if you are talking about 20 or 30 stages.

VOICE: One other comment on that. You wouldn't gain much from multistage letdown unless you would disengage between each stage, because as soon as you start taking the pressure off this product, you have got to flash. And so you have gone to a three-phase configuration rather than two-phase.

Unless you disengage between each stage, you are not going to gain as much in all these stages as you might think because you have gone to a gaseous situation. So again, if you have 10 stages and need 10 disengaging vessels, that becomes pretty much of a nightmare on control and cost.

HAMMITT: Comment over here.

DAHL: I would like to comment—I am Tom Dahl from Oak Ridge National Lab.

In regard to that, DOE is funding a novel approach to this pressure letdown that we are doing. Mr. Pete Carlson and the Oak Ridge Lab are working on it and instead of a valve; it is more like a packed bed. It uses spheres for an SRC-II application. It is going to start off about 8 inches in diameter and expand to around 20 inches. It is going to take around 10 to 15 feet, but it is going to keep lower velocities and it will have a choking effect with the flashing, which will also give you a turndown capability.

HAMMITT: Is that similar to the Hitco device of a decade or so ago?

DAHL: Yes, it is. After we proposed this for slurry and high-temperature applications, we ran across Hitco's. It is commercially available and working, but it is for low-temperature and fairly low-pressure applications.

HAMMITT: There is never a new idea in the world; it is just an idea whose time has come. Did I see another question?

HUZENLAUB: Ron Huzenlaub of Tabco International. Primarily what the panel has been saying is that most of the valves that have been discussed are the smaller sizes. I would like to know from the panel members, do they see a service where the larger, say, 18-inch and above valves, will be in service?

WEST: The larger sliding plug in our demo plant would be roughly 24-inch I.D. We also would have one more in the 12- to 18-inch class. As far as I know, those are the only two sliding plugs.

HUZENLAUB: Slide or plug?

WEST: Those are the two internal valves. The slide valves will be throttling valves and they are large, as you well know. Up to 40 inches in our plant. In a full-size plant, it would be up to 50 inches. They will have to throttle. No, they wouldn't have to shut off tight.

ACKERMAN: I can't think of any application that big even on the raw slurry feed at low pressure. The control valves, if there were any, would not be that big. The piping might be that big, but your control valve would be smaller.

HAMMITT: I think what we are seeing is the dichotomy between the gasification and liquefaction . . .

PLATT: We don't have any slide valves, at least not in throttling service, but everybody knows that most of the cat plants and everything else have used pretty large slide valves.

PLUT: We don't use any slide valves in our present plant. And as I mentioned in my talk, I try to avoid them if I can.

BOND: We don't use slide valves either.

HAMMITT: Dave?

CHRISTENSEN: No.

HAMMITT: We are about out of time. I guess that I would like to ask the panel what is it that we, as valve manufacturers, could do to make your life easier? What would you like to have us do? And why don't we start with you, Frank? Now is your chance.

PLUT: We talk a lot about pressure-letdown valves, and they have created problems. But there are a lot of situations where the question is, why do I have to let this pressure down? Why do we build it up so that we have to let it back down?

So, thinking along these lines we build pressure up high enough so that when we open a valve we can get enough flow through it. I say control the speed of the pump to get the necessary flow regardless of the pressure. You can do likewise with compressors. Just speed your compressor up enough to get the necessary flow, and you won't have to fiddle around with valves. Just control the speed to get the flow that you need for the particular process. Pressure isn't everything in the world. Actually, valve-controlled flow is not necessarily pressure. Any time you open a valve, you are controlling flow. The pressure just happens to be there.

PLATT: I think what I would like to see from valve manufacturers is cooperation in terms of willingness to get involved with special designs. Admittedly, I don't think I would ever ask anybody to do anything for nothing. I do want them though to have at least a cooperative attitude in being willing to consider the possibility of working on some special designs, realizing that they will of necessity be expensive.

I think that is probably what I would want mostly, not just in the area of coal liquefaction, but in all the special areas that seem to be growing, all pseudo-synthetic fuels such as recovery of tar sands and recovery of heavy, very heavy, crudes.

I think the other thing I would like to see from valve manufacturers is a revitalization of the old concept of a letdown machine. Nobody except a man who works for Kiely & Mueller has ever published an article on a device that recovers horsepower. Clearly in a commercial plant, the letdown valve is going to be a big machine, for it is going to be dropping one heck of a lot of horsepower.

Now, going back to what Frank just said in terms of shaving the horsepower off the pump and not pushing the pressure too far, the other way to look at that is maybe you ought to try to get some of it on the way back. One could say that this is in the area of pumps and compressors and what have you, but I don't see it that way. I see it as a kind of a valve-alive area.

ACKERMAN: Anybody who wants to study up on that, read the German literature. The Germans had power recovery during World War II in their coal-liquefaction plants, so that is your starting point.

I agree wholeheartedly with what you just said. The interest is building, but up to recently, it has been sometimes very hard to get an interest out of manufacturers building a valve or even answering sometimes. So, I think cooperation is a key word and I would like to repeat it.

WEST: From my point of view, my favorite peeve was when I was in the field. I would call up for a standard quote on off-the-shelf trim and be told it was going to arrive about 12 weeks from when my plant is shut down.

Actually, in my present position in design, I have few problems with the valve people. Most of them have been quite helpful in coming up with new designs as long as I could show them there was a market—that it would be a profitable thing for them to do.

I know, for myself, I have been at fault at times; I wanted a design from the guy and I can't show him where it is profitable and I get mad because he won't make it. But I guess he really can't do that.

I would like to maybe point out to the group that in our particular process, we are using a letdown-machine system for power recovery, both on stream, using the usual letdowns and recovering horsepower, and on expansion turbine for recovering horsepower from the flue-gas oxidizer.

HAMMITT: Are you saying you are the competition?

WEST: No, I am just pointing out that it is being done. Also, this wouldn't be apparent because the actual design is not open to the public, but most of our flow system in this gasification plant is arranged to be done without valving.

I mean, it is designed in such a way and arranged in such a way that we don't have to use valving. That is one of the reasons why the plant is theoretically at least coming up with a better than 60% return. I don't know if I answered the question or not.

HAMMITT: Yes, you did.

BOND: I would think in the future, that we, as synfuel people, ought to work together with the valve manufacturers to try to work toward testing programs on these coal-type applications, to develop good C_V's for valves and/or power-recovery equipment that we may have in the future. I think the manufacturers I have talked to so far have been very cooperative except for, obviously, the problem we have been having with Willis. We have had very little cooperation getting trim. We have made most of our parts ourselves which is unfortunate.

I think cooperation from the coal industry or synfuel industry with the valve manufacturers will help solve this problem in the near future.

HAMMITT: Donn, what can we do as manufacturers to make your life easier?

FREEBURN: I think you have pretty much helped by co-sponsoring this type of conference the past two times.

As you know, I can't emphasize too much that we have responsibilities for these plants and major projects, as well as the industrial partners. We see the need. One reason for this meeting on critical valves is that we do not see them coming along as fast as they should be.

Otherwise, we would be just holding a social meeting. Again, we see a reluctance on a number of the manufacturers to go into the speciality-valve field, and I think we understand why, because of the market and everything else like that. But we wish they would venture a little bit more into the R & D side.

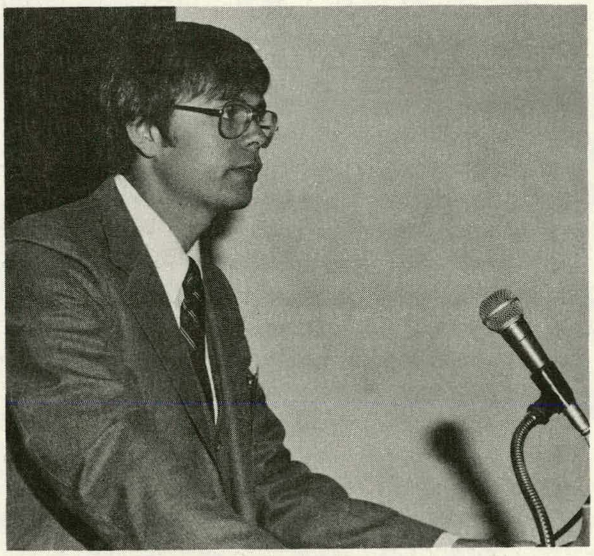
HAMMITT: Dave.

CHRISTENSEN: You might say that I am in the vendor-selection mode. What I mean by that is that I am looking for a vendor to work with me to first tell me what he can do now, tell me what his experience is, so I can relate to what has to be done in the future. I would like a vendor to come to me and help me, i.e., tell me what has to be done and how we can set about doing this and how we set up a program to do this. Basically, it is information gathering and developing from there.

HAMMITT: We are asking you to help us.

WRIGHT: I think, in order to make better valves or to make valves work better, what we need to know is in detail what the condition of the valve is. We need, I think, to characterize the conditions of the valve which are a function of process—processing conditions and variation of coals. I think we get this characterization largely from cooperation between the people in the plant and the valve manufacturers.

HAMMITT: Thank you. That concludes the panel presentation on behalf of the VMA and DOE. I would like to thank the panel members for their attention. I would like to thank you for your attention and good questions. We have covered perhaps half the material that we could have covered today. Again, thank you very much.



Section 19

Critical Valve Specifications and METC Valve-Testing Projects

John F. Gardner, Project Manager
Valve Testing and Development Projects
U.S. Department of Energy
Morgantown Energy Technology Center
Morgantown, WV

October 17, 1980—8:30 a.m.

Abstract

There is a wide diversity of processes for converting coal to energy and/or synthetic fuels. Each of these has its own set of mechanical details and range of process conditions. The demands placed on valves, however, are not as varied as it might appear. These demands have been summarized in a set of specifications for critical-service valves.

These "Critical Valve Specifications" and their development will be discussed. In addition, the METC projects and facilities for valve testing will be reviewed.

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Today, I am going to talk to you only on the severe-service valve applications relating to coal conversion. I think that the manufacturers know very well the standard applications. Manufacturers are quite interested in selling large quantities of valves for these standard applications. I would like to reiterate a point that I made yesterday in the Block Valve panel discussions—"If someone does not develop the required severe-service valves for coal conversion, then commercialization of this new industry will not become a reality. Without commercialization, you will never sell the 10,000 or 15,000 standard valves required for each plant." I think that this important point is something that I would like all of you to take home with you.

What I am going to do is try to review the severe-service valve requirements for coal conversion. The eight areas shown on Figure 19-1 are the ones I feel deserve attention. With the lockhopper valves, discussed in depth in 1977, we have made great strides toward solving the problems associated with them. I will go into each one of these sub-areas of lockhopper valves in depth.

In this program, you have heard a lot about the slurry-letdown valves. That is probably the most critical application, at this point, relating to the direct coal-liquefaction processes and one that most certainly deserves your attention.

I think Rich Basile has done an excellent job of describing the slurry block-valve program at Exxon and some of the considerations to be taken into account when designing and specifying block valves for this service.

The next application, hot dirty-gas control valves, was discussed by Mike Kaden from IEA, Dave Christensen from GE, and Bill West from Dravo.

CRITICAL VALVING FOR
COAL CONVERSION PROCESSES

DESCRIPTION	SERVICE	SEAL REQ'D
1. LOCKHOPPER VALVES a) Coal Feed b) Hot, Dry Solids Removal c) Slag/Slurry Removal d) Tar/Cleanup Area Removal	ON/OFF	YES
2. SLURRY LETDOWN	THROTTLING	NO
3. SLURRY BLOCK	ON/OFF	YES
4. HOT, DIRTY GAS CONTROL	THROTTLING	NO
5. SOLIDS CIRCULATION/FLOW CONTROL	THROTTLING	NO
6. SOLIDS PURGE/VENT VALVES	ON/OFF	YES
7. DIRTY GAS VENT VALVES	THROTTLING	NO
8. PRESSURE RELIEF VALVES	SAFETY	YES

Figure 19-1. Critical Valving for Coal-Conversion Processes

The area of hot-solids circulation flow-control valves deserves some attention. We have a credible amount of expertise in this country associated with hydrocarbon catalytic cracking ("cat-cracker") and valves for these processes. However, some of the gasification and pressurized fluid-bed-combustion routines will require an advancement in this state of the art in a range of 300 to 400°F on an operating-temperature basis and also an increase in the pressure capabilities over current "cat-cracker" valve technology.

I am not going to dwell on purge and vent valves a great deal. I personally feel that they really are just specialized applications of some of the five that we have just talked about.

Pressure-relief valves have not been addressed in as much depth as they probably should. We have found ways to live with the existing pressure-relief-valve situation in coal-conversion applications using existing, state-of-the-art hardware. These current methods of coping with relief valves utilize either multiple-relief valves such that maintenance can be performed without process interruption, isolation devices such as rupture discs in front of the relief valves, or purge connections to keep the safety-device system free of solids.

In the lockhopper-valve area, you have heard many people talk about various processes, each with its own unique requirements. What I would like to do is put in a tabular format for you the range of specifications that you will be seeing in the next 3 to 5 years.

The characteristics for feed-side lockhopper valves are shown on Figure 19-2. Pressure requirements range greatly from as low as 10 psig, all the way to 1,500 psig. More typically, most processes are going to be in the 200- to 1,000-psig range. Very few gasification processes are operating above 1,000 psig. There are a few, but they are somewhat limited in quantity at this time.

At the time of operation of the lockhopper valve you will see approximately a 1- to 15-psig differential pressure existing across the closure element. Temperature ranges for feed-side lockhopper valves in the range of ambient to 850°F will be encountered, more typically, 200 to 600°F.

The valves are going to be handling solids, coals, and limestones in media size ranges from 2-inch to minus 100 mesh. Typically, solids in the 1-inch through minus 50 mesh size are most commonly required.

The nominal valve bore size range will be 2 through 24 inches for lockhopper valves. I think that the trend in plant design is going to be to utilize dual feed trains of somewhat smaller size, as opposed to one train feeding into the gasification reactor. Typically, you are going to be seeing 4- to 12-inch valves in pilot plants and 8- to 16-inch lockhopper valves in demonstration and early commercial plants.

The valve leakage rate requirements shown on Figure 19-2 have evolved from the test programs at Morgantown. When a valve comes into the test program or into a process application, METC requires a maximum leakage of one standard cubic foot per hour per inch of nominal pipe size for the new valve as delivered. This is typically tested with a gaseous medium, either air or nitrogen, at both a 100-psi differential pressure and at the full-line differential pressure required by the particular application.

CHARACTERISTICS OF LOCKHOPPER VALVES

COAL FEED LOCKHOPPER SERVICE

PRESSURE RANGE:	10 TO 1500 PSIG
TYPICAL:	200-1000 PSIG
ΔP AT OPERATIONS:	LESS THAN 15 PSIG
TEMPERATURE RANGE:	AMBIENT TO 850° F
TYPICAL:	200-600° F
MEDIAS HANDLED:	COAL AND/OR LIMESTONE
MEDIA SIZE RANGE:	2" TO -100 MESH
TYPICAL:	1" TO 50 MESH
VALVE SIZE RANGE:	2 - 24 INCH BORE
TYPICAL:	4 - 12 INCH, PILOT PLANT 8 - 16 INCH, DEMO PLANT
SEAL REQUIREMENTS:	1 SCFH/IN. NPS NEW 3 SCFM/IN. NPS MAX.IN-SERVICE
DESIRED LIFE:	25,000 CYCLES W/O INTERNAL REFURBISHMENT
APPLICABLE PROCESSES:	LURGI, CO-GAS, & MANY OTHERS

Figure 19-2. Characteristics of Lockhopper Valves

After usage, we would like to see the valve leakage rate not exceed 3 standard cubic feet per minute per inch of nominal pipe size. That is a high leakage rate in some people's opinion. But, if we look back to 1975, criteria were written that proposed up to 10 standard cubic feet per minute per inch of valve bore as an acceptable valve leakage rate. The factor which is going to really influence this is the overall cost of compressing gas in the process itself.

In terms of desired life, the goal for lockhopper valves has been set at approximately 25,000 cycles, without internal refurbishment. This represents about 1 year of plant operation in a typical application relating to gasification or pressurized fluid-bed combustion.

An area that currently needs special attention is lockhopper service for the removal of hot, dry solids. Its requirements are shown on Figure 19-3. For the feed side, the METC test project has developed some very successful lockhopper valves. On the hot, dry ash-removal side, we have seen improvement in valve life and reliability, but we have not attained life and reliability goals that we would like to have from this particular type of valve.

HOT, DRY SOLIDS REMOVAL LOCKHOPPER SERVICE

PRESSURE RANGE:	10 TO 1500 PSIG
TYPICAL:	200-1000 PSIG
ΔP AT OPERATION:	LESS THAN 15 PSIG
MEDIA TEMPERATURE RANGE:	600-1800° F
TYPICAL:	600-1400 GASIFICATION 1000-1750 PFBC
MEDIAS HANDLED:	CHAR, ASH
MEDIA SIZE RANGE:	1 INCH TO -100 MESH
VALVE SIZE RANGE: SEAL REQUIREMENTS: DESIRED LIFE:	} SAME AS COAL-FEED LOCKHOPPER VALVES
APPLICABLE PROCESSES:	LURGI, PFBC, WESTINGHOUSE

Figure 19-3. Hot, Dry Solids-Removal Lockhopper Service

The pressure requirements are the same as those on the feed side. The temperature range for dry, ash lockhopper valves is important: 600 to 1,800 °F. More typically, media temperatures are in a 600 to 1,400 °F range in gasification. Pressurized fluid beds would give you 1,000 to 1,750 °F. These are all media temperatures, not valve-body temperatures. The media to be handled will be chars and ashes in the size ranges as shown on Figure 19-3.

The other required type of lockhopper valve, slurry removal, is found most prevalently with the entrained-type gasifier. It is also used in the CONOCO demonstration project, which is being developed based on second-generation Lurgi technology. However, Lurgi will furnish their patented lock system for this application. This type of lockhopper valve is also required in the Texaco gasification process and the Bi-Gas process, which DOE has been working on. Their characteristics are shown on

Figure 19-4. The media temperature range is 450 to 1,000°F, more prevalently, 450 to 650°F. The required valve size range is 4- to 24-inches nominal bore size, but many of the valves required in early stages of coal conversion are going to be about 8- to 10-inches nominal size.

SLAG/SLURRY REMOVAL LOCKHOPPER VALVES

PRESSURE RANGE:	10 TO 1500 PSIG
Δ P AT OPERATION:	LESS THAN 15 PSIG
MEDIA TEMPERATURE RANGE:	450-1000° F
MEDIAS HANDLED:	WATER QUENCHED OR SLURRIED CHAR, ASH, OR SLAG
VALVE SIZE RANGE:	4 INCH TO 24 INCH
SEAL REQUIREMENTS:	SAME AS COAL FEED LOCKHOPPER VALVES
DESIRED LIFE:	SAME AS COAL FEED LOCKHOPPER VALVES

TYPICAL SPECIFICATIONS:
8 INCH BORE, 600-1000 PSIG, 450-650° F HANDLING WATER QUENCHED SLAG

APPLICABLE PROCESSES: TEXACO, BI-GAS, SLAGGING LURGI

Figure 19-4. Slag/Slurry-Removal Lockhopper Valves

Let us now review the slurry-letdown valves. Their characteristics are listed on Figure 19-5. You have heard over the past few days that the processes have inlet pressures to the valve in the range of 600 to 3,000 psig. The low end of these pressure requirements will be found in gasification (i.e., the slurry-letdown valves at the bottom of the reactor).

In direct coal liquefaction, pressure requirements are in a range of 2,000 to 3,000 psig. Figure 19-5 shows the SRC-II and H-Coal process conditions. You will find pressure drops across the valve from 500 to 2,000 psig, depending on whether the plant designer decides to go with a single stage or a dual stage or even three stages of pressure letdown in the process slurry stream.

CHARACTERISTICS OF SLURRY LETDOWN VALVES

INLET PRESSURE RANGE:	600-3000 PSIG SRC II-2000 PSIG H-COAL/H-OIL - 2800 PSIG
ΔP ACROSS VALVE:	500 TO 2000 PSIG SRC II ≈ 1200 PSIG
INLET TEMPERATURE: TYPICALLY:	750-950° F 800±50° F

MEDIA: TYPICALLY A HYDROCARBON BASED SOLVENT WITH 15-40% BY WEIGHT COAL, CHAR, OR ASH. DISSOLVED GASES POSSIBLE.

PARTICULATE SIZE RANGE:	1/8 INCH TO -200 MESH
INLET LINE SIZE: TYPICAL:	1-12 INCH 1-4 INCH PILOT 3-12 INCH DEMO/COMMERCIAL
DESIRED:	INITIALLY, MINIMUM OF 5000 HOURS BETWEEN MAINTENANCE OVERHAULS. COMMERCIALLY, MINIMUM OF 10,000 HOURS BETWEEN MAINTENANCE OVERHAULS, WHICH CORRESPONDS TO 1 YEAR OF LPLANT OPERATION ON-LINE.
APPLICABLE PROCESSES:	SRC I, SRC II, H-COAL, H-OIL, EXXON DONOR SOLVENT.

Figure 19-5. Characteristics of Slurry-Letdown Valves

The process-stream temperatures are very closely clustered. Most of them are 800°F, plus or minus about 50°F. The media range is shown on Figure 19-5. Inlet piping 1 to 12 inches in size will be used. I think that you have heard similar numbers in the Exxon and H-Coal presentations.

The desired life for slurry-letdown valves, shown on Figure 19-5, is a Morgantown-established criterion. There may be different viewpoints among the plant operators, but we feel 5,000 hours of valve life is reasonable in the near term. For the future, we would like to have a year of plant operation between letdown-valve overhauls or about 10,000 hours of life.

The slurry-block valves have been discussed in great detail and are summarized on Figure 19-6. Slurry valves for block service are r quired for process pressures of 150 to 3,000 psig, at temperature ranges of from 150 to 500°F on the feed side, and 750 to 900°F in the reactor areas. With regard to the size of the valves, I have heard some people talking about 20- and some 24-inch valves; but, I think that 3- to 16-inch valves will cover the majority of these applications. I think we do have to note that there is a possibility of a need for some of the larger valve sizes in full-scale commercial plants. Figure 19-6 shows the seal requirements and desired life criteria that we are currently using for slurry block valves.

CHARACTERISTICS OF SLURRY BLOCK VALVES

PRESSURE RANGE:	150-3000 PSIG
TEMPERATURE RANGE: TYPICALLY:	150-500° F & 750-900° F 800±50° F 350±50° F
MEDIA:	TYPICALLY A HYDROCARBON BASED SOLVENT WITH 15-40% BY WEIGHT COAL, CHAR OR ASH. DISOLVED GASES POSSIBLE.
PARTICULATE SIZE RANGE:	1/8 INCH TO -200 MESH
VALVE SIZE RANGE: TYPICAL:	1 INCH TO 16 INCH 1 TO 6 INCH PILOT 3 TO 16 INCH, DEMO/COMMERCIAL
SEAL REQUIREMENTS:	DESIRED TO HAVE MSS TYPE SEAL CAPABILITY DUE TO THE INDUSTRIAL SAFETY/HYGIENE CONSIDERATION INVOLVED WITH THE PLANT.
DESIRED LIFE:	INITIALLY, 5 YEARS OF ON STREAM LIFE WITH SEAL INTEGRITY INTACT. COMMERCIALLY, LIFE OF PLANT WITH SEAL INTEGRITY INTACT.
APPLICABLE PROCESSES:	BI-GAS, H-COAL, EXXON DONOR SOLVENT, SRC I, SRC II

Figure 19-6. Characteristics of Slurry-Block Valves

The hot dirty-gas control valves (HDGCVs) are required for pressurized fluidized-bed processes and some of the gasification processes. Their characteristics are summarized on Figure 19-7. Without these valves, we are not going to have integrated combined-cycle power plants based on coal gasification or pressurized fluid-bed-combustion technology. The pressure ranges seen by the valve designer will be up to 500 psig, with inlet temperatures of 1,000 to 1,750°F. The top-end temperature is going to be a problem and will require development work and an extension of the current state-of-the-art capabilities existing in the valve manufacturing industry.

CHARACTERISTICS OF HOT, DIRTY GAS CONTROL VALVES

INLET PRESSURE:	50-500 PSIG
MEDIA TEMPERATURE:	1000-1750° F
Δ P ACROSS VALVE:	NOMINAL 5-50 PSIG
MEDIA:	SYN-FUEL GAS WITH 0.1 TO 2 GRAINS/SCF OF CHAR SOLIDS.
PARTICULATE SIZE RANGE:	5-50 MICRON
VALVE SIZE RANGE:	4 TO 40 INCH
DESIRED LIFE:	INITIALLY, 10,000 HOURS MINIMUM BETWEEN MAINTENANCE OVERHAULS. COMMERCIALLY, 50,000 HOURS MINIMUM BETWEEN MAINTENANCE OVERHAULS.
APPLICABLE PROCESSES:	PFBC COMBINED CYCLE, LOW BTU GASIFICATION COMBINED CYCLE, CO-GAS.

Figure 19-7. Characteristics of Hot, Dirty-Gas Control Valves

The differential pressure across the HDGCV is nominally in the range shown on Figure 19-7. Typically, it is in the low end of this range, or around 5 psi. The media, particulate size, and the valve sizes, are shown on Figure 19-7, also. I think that this information corresponds well with what you have heard from our other speakers. Again, the life of the valve shown is a criterion taken from METC project-planning documents.

The hot solids-circulation/flow-control valve is summarized on Figure 19-8. It has a good technology basis from the "cat-cracker" area. What we have to do is extend that to the higher temperature range required by coal-conversion applications. We must also increase the pressure capability of these valves. We see this as being primarily an area for materials-development and materials-testing activities.

CHARACTERISTICS OF SOLIDS CIRCULATION/ FLOW CONTROL VALVES

PRESSURE RANGE:	50-250 PSIG
ΔP ACROSS VALVE:	2-10 PSIG
MEDIA TEMPERATURE:	1000-1700° F
MEDIA:	CHAR
MEDIA SIZE RANGE:	8 TO 100 MESH
VALVE SIZE RANGE:	3-60 INCH
DESIRED LIFE:	INITIALLY, 10,000 HOURS MINIMUM BETWEEN MAIN-TENANCE OVERHAULS.
	COMMERCIALLY, 50,000 HOURS MINIMUM BETWEEN MAIN-TENANCE OVERHAULS.
APPLICABLE PROCESSES:	CO-GAS, BI-GAS, TEXACO, HRI FLUID BED

Figure 19-8. Characteristics of Solids-Circulation/Flow-Control Valves

The dirty-gas vent and the purge valves are summarized on Figure 19-9. These are generally much smaller valves, but very critical to the successful operation of the plant. We have had some applications on hot-char lock-hoppers, where the venting valves are a very difficult application. The current valve life in this service may be less than 6 months.

We have done several things in an attempt to clean up the process stream using mini-cyclones ahead of the vent valves, etc. This helps, but every time you start adding cleanup devices, you need more and more valves. So, it is an area where improvements can be made.

CHARACTERISTICS OF DIRTY GAS VENT AND SOLIDS PURGE/VENT VALVES

PRESSURE RANGE:	50-1200 PSIG
ΔP ACROSS VALVE:	ON/OFF UP TO 1200 PSIG THROTTLING UP TO 500 PSIG
TEMPERATURE RANGE:	160-1500° F
MEDIA:	GAS WITH ENTRAINED SOLIDS (CHAR/ASH). VARIABLE LOADINGS OF SOLIDS DEPENDENT ON EXACT APPLICATION.
VALVE RANGE:	1 TO 12 INCH
DESIRED LIFE:	10,000 HOURS MINIMUM BETWEE MAINTENANCE OVERHAULS
TYPICAL APPLICATIONS:	VENTING OF LOCKHOPPERS

Figure 19-9. Characteristics of Dirty-Gas Vent And Solids-Purge/Vent Valves

In the symposium, we have tried to give you a picture of the size and valve requirements of coal conversion (Figure 19-10). I don't know anybody who can rub their crystal ball and give you an exact, bona fide number of plants to be built. Many studies have been done and many reports are available through the open literature to help you assess how many plants, the size of those plants, the mix of those plants, the labor requirements for those plants, and where those plants will be sited in terms of U.S. activity. All I have tried to do is identify plants that are associated with DOE involvement. In the high-Btu gasification programs, DOE has the CONOCO Slagging Lurgi Project and COGAS; or, as you have heard it, the ICGG Project, from the Illinois Coal-Gasification Group. In the medium-Btu area, DOE has the Memphis Light, Gas, and Water Project (U-gas process) based on technology developed at IGT and th-

W.R. Grace Project, which utilizes the Texaco gasification process.

DOE has multiple advanced pilot plants existing in this country: Combustion Engineering, Bi-Gas, Hy-Gas, Westinghouse Agglomerating Ash, Rockwell Hydrogasifier, and Exxon Catalytic Gasification, many of which you have heard about at the symposium.

COAL CONVERSION
?? HOW BIG

- DOE INVOLVEMENT
  - GASIFICATION
    - — CONOCO SLAGGING LURGI } HIGH BTU
    - — CO GAS
    - — MEMPHIS L. G. W/U-GAS } MEDIUM BTU
    - — WR GRACE
    - — COMBUSTION ENGINEERING } ADVANCED PILOT PLANTS
    - — BI-GAS
    - — HY-GAS
    - — WESTINGHOUSE AGGLOMERATING ASH
    - — ROCKWELL HYDROGASIFICATION
    - — MANY, MANY LOW-BTU/INDUSTRIAL APPLICATIONS W/SOA TECHNOLOGY
  - LIQUEFACTION
    - — SRC I DEMO
    - — SRC II DEMO
    - — H-COAL MAXI-PILOT PLANT
    - — EXXON DONOR SOLVENT MAXI-PILOT PLANT
    - — FT. LEWIS PILOT PLANT
    - — WILSONVILLE PILOT PLANT
  - PFBC
    - — CURTIS-WRIGHT
    - — GRIMETHORPE

Figure 19-10. Coal Conversion—How Big?

Many, many technologies are available commercially for small-scale industrial use for low-Btu synfuel generation. DOE has many of those currently operating in the country. A couple that come to mind very quickly are the Land of Lakes Project and the Glen Gary ick Works project where a low-Btu fuel gas generated.

Maybe the unique thing about gasification is that commercial plants do not always mean huge. It means fitting your customer. You are going to be seeing not only these huge demonstration commercial plants, but you are also going to be seeing small plants; all designed to meet the needs of the customer or user. All of those plants need valves. Some of them need very critical valves. Gasification has to fit its customer's requirements.

In the liquefaction area, we have the SRC-I and SRC-II demo plants. You have heard Kamel Youssef describe to you these plants. You have heard about the H-Coal large-scale pilot plant in Catlettsburg, Kentucky, from Bill Miller. You have heard quite a bit about the Exxon Donor-Solvent large-scale pilot plant at Baytown, Texas. You have heard from the Fort Lewis facility, an SRC pilot plant. We didn't have a representative speaking from the Wilsonville SRC pilot plant, which is a 6-ton per day unit located in Wilsonville, Alabama.

In the pressurized fluid-bed-combustion area, you have heard from the Grimethorpe IEA project and in the U.S., about research being conducted by Curtiss Wright and General Electric.

I would like to swing from summarizing what you have heard to giving you a very quick run-through on the valve projects that are active in Morgantown, and the work we are thinking of doing in the future.

At this time, METC is doing lockhopper-valve testing (Figure 19-11). All of our test facilities are designed to test lockhopper valves and lockhopper valves only at this point. I will try to take you through the test facilities and the test projects very quickly.

Figure 19-12 is an aerial view of the Morgantown Energy Technology Center itself. If you take your tour today, you will be walking through these facilities. All of the valve-testing work is being performed in the areas marked.

The Morgantown Energy Technology Center has operated under the Office of Coal Research of the U.S. Bureau of Mines, Energy Research and Development Administration, and now the Department of Energy. Last Fall, METC celebrated its 25th anniversary.

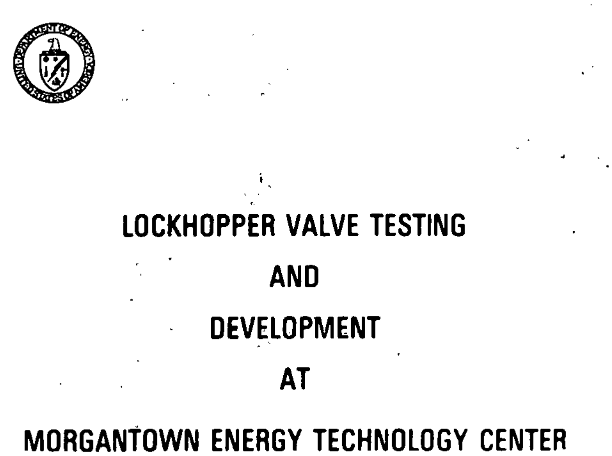

Figure 19-11. METC Lockhopper-Valve Testing and Development

The Morgantown Energy Technology Center has been identified as DOE's lead technology center in the area of component development for coal conversion and utilization. Don Freeburn is responsible for heading the Components Branch at the Center. Figure 19-13 shows how we at the Center see components being developed for coal conversion. We feel that there must be a strong cooperative effort among the manufacturing industry, the government, and the users of the equipment.

To date, we have felt that the best way to stimulate this cooperative effort has been through the provision of adequate test facilities to be used by all, which quite frankly are extremely costly for an individual manufacturer to try to develop. The test facilities were developed to be very realistic in terms of actual service conditions, so that we can acquire test data, more or less tailored to your needs, not to our needs. Our (DOE's) needs are to have commercially available hardware to allow successful demonstration of coal-conversion processes. Testing is being done for you, the manufacturer. If we are not providing the kind of test data that you need, we need input from you so that we can alter these test programs, so that we can acquire test data that is meaningful to you.

The projects try to be very active in terms of feeding back data from the test facilities to the manufacturers involved. I think we have done a reasonably good job here. We try to transfer our experience and problems in the operation of valves and other components in the pilot plants back to you, the manufacturer, and one way of doing that is conducting symposia such as this.

We try to actively publish information through vehicles such as the DOE Components & Materials Newsletter, the various trade journals, and through active participation in other conferences, such as AIChE. The University of Wisconsin also has a summer seminar on valve technology in which we actively participate.

The transfer of materials developments and technology to manufacturers, operators, and to the private sector is done through workshops and conferences. Last week in Gaithersburg, Maryland, a conference was held on materials work sponsored by DOE in support of coal conversion. This conference is held every October and is sponsored by Sandy Dapkunas of DOE Headquarters and the National Bureau of Standards.

The objectives of the Lockhopper Valve Test Program (Figure 19-14) are to develop long-life valves for solids handling in coal conversion. The state-of-the-art (SOA) lockhopper valve project has been very active over the past 3 years. A total of 30 test articles are currently involved or have been involved in the project. I will go into more detail on the status of how many valves have been tested in each of the test units a little later.

The other project is aimed at the development of a new breed of lockhopper valves through funded research and development (Figure 19-15). The Prototype Lockhopper Valve project was started at a headquarters level prior to 1976. Two contracts were awarded and, to date, one testable article has been delivered to the test facility. Initiation of testing on it is scheduled to begin within the next 30 days.

In the State-Of-The-Art Testing Project (Figure 19-16), we are trying to evaluate the capability of existing valves to meet the requirements of coal-conversion lockhopper

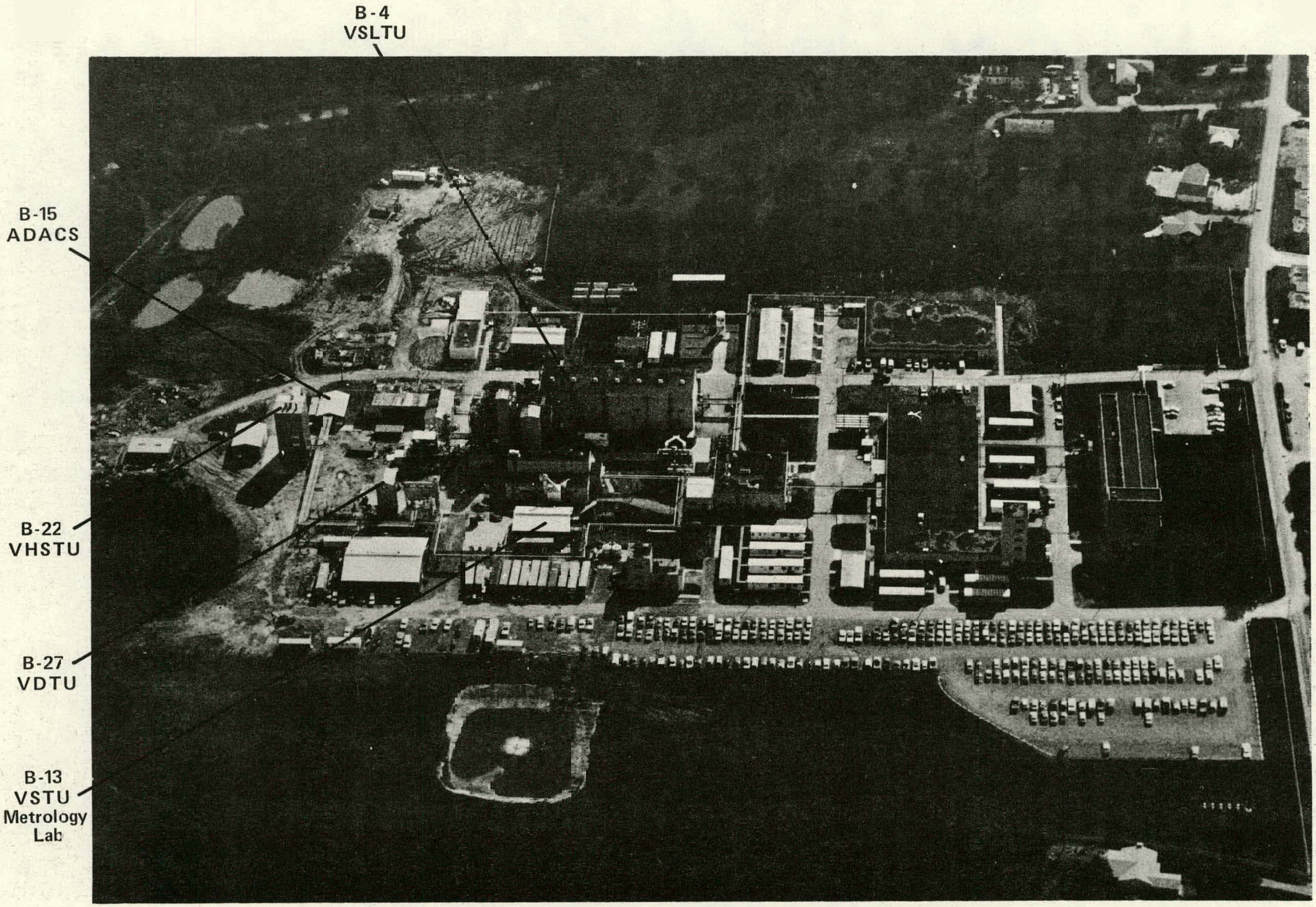

Figure 19-12. Aerial View of Morgantown Energy Technology Center

applications. When we say existing valves, we mean existing valve designs available from valve manufacturers. They may be modifications or they may be prototypes to you, the manufacturer. In the project, information is generated on valve life and failure modes. This information is used by both valve manufacturers and plant operators. I think many manufacturers have benefitted through the design-improvement data generated by the SOA Lockhopper Valve-Testing Project.

The final objective of the project is proof-of-concept testing. It is important to prove that the modified valves will work in an actual application in the plant, not only in our simulated tests. This type of testing has not started yet.

Figure 19-17 shows typical lockhopper applications. I think everybody is quite familiar with the feed-side applications and with the way a lockhopper works.

The test program for lockhopper valves in Morgantown is set up as shown on Figure 19-18. I will go through each one of these steps.

The first step is inspection and acceptance testing. I have already presented the through-seat leakage criteria that is used in the program. An external-leakage criterion of not to exceed 0.1 standard cubic foot per minute has been set. We also have established valve response-time criteria. Valves must cycle from full close to full open or full open to full close in not more than 30 seconds for each direction of travel. Inspection also includes verification against our contract documents or the cooperative agreements that all items furnished are complete and accurate. Additional acceptance tests called for within the contract are verified by retesting at METC after delivery.

Static testing is used to obtain baseline information on a valve design. What we are looking for is "How do the independent parameters of pressure and temperature affect a valve in its performance?" These tests are conducted with clean gas. The valve is not subjected to any solids flow at this point. First, the effects of pressure on the valve design performance are evaluated, then the effects of temperature. This particular test has a duration of about 500 cycles of the valve.

Figure 19-19 is a schematic of the static test system. There are multiple leak-detection systems. Currently in use are four different methods to measure valve leakage rates, both internal and external. Figure 19-20 is a picture of the static test facility itself.

After static testing, the test valve goes for metrology inspection. We are very interested in the ability to maintain these valves at remote field locations. As such, we will go through a complete teardown of the valve and then perform a detailed inspection procedure in terms of dimensional, photographic, and surface finish analysis on critical components internal to the valve (i.e., in a ball valve, the balls, the seat, stems, and other internal parts subject to wear). In addition to determining maintainability, we are establishing a baseline of initial configuration and condition from which the rate of wear a given valve experiences as it goes through the test program can be determined. Figure 19-21 shows the three-dimensional coordinate-measuring machine used in the program as part of our dimensional inspection procedures. Following inspection, we will rebuild the valve. Figure 19-22 is a picture of our workshop facilities.

Following reassembly, the test valve goes into the re-establishment of baseline test. We want to make sure we haven't degraded the performance of that test valve through disassembly and inspection. This test is again a clean-gas test and we allow a deviation of not greater than 10% from the baseline data that was taken under the static test conditions as a success criteria.

Dynamic testing is a simulation of lockhopper-service conditions with solids at the pressure levels typically found in a coal-gasification environment, but within the allowable working pressure of the particular valve design. The pressure-temperature curves found in ANSI B16.34 are used as guidelines to develop the test conditions in terms of allowable pressure/temperature combinations.

Figure 19-23 is a schematic of the dynamic test system. The system is nothing more than a lockhopper test train with a solid recirculation system. Size distribution of the solids media is maintained through sampling and the addition or subtraction of media, as required. The test has a duration of about 8,000 cycles. We have correlated test data from this unit with actual on-line applications through three different valve types and valve designs. It was found that this unit very accurately

METC APPROACH TO COMPONENT/VALVE DEVELOPMENT FOR COAL CONVERSION AND UTILIZATION PROCESSES

- DEVELOP A STRONG COOPERATIVE EFFORT BETWEEN INDUSTRY MANUFACTURERS, THE TEST/DEVELOPMENT PROJECT, AND THE COAL CONVERSION PILOT/DEMO PROJECT TEAM.
- PROVIDE ADEQUATE TEST FACILITIES WITH REALISTIC SERVICE CONDITIONS TO ACQUIRE MEANINGFUL TEST DATA FOR MANUFACTURER IMPROVEMENTS OF DESIGN, NEW DESIGNS, AND VERIFICATION OF ALL DESIGN CONCEPTS.
- FEED BACK OF DATA FROM THE TEST FACILITIES, SPECIFICALLY ACQUIRED TO FILL THE NEEDS OF THE MANUFACTURER TO IMPLEMENT DESIGN MODIFICATIONS OR NEW VALVE DESIGNS.
- RAPID TRANSFER OF EXPERIENCE AND PROBLEMS WITH OPERATION OF VALVES IN PILOT PLANTS AND EARLY DEMO PLANTS.
- TRANSFER OF MATERIALS DEVELOPMENT AND TESTING TECHNOLOGY TO INDUSTRY MANUFACTURERS, PLANT OPERATORS, AND PRIVATE SECTOR.
- PERIODIC CONFERENCES/WORKSHOPS TO BRING TOGETHER INDUSTRY, PLANT DESIGNERS AND OPERATORS, AND TESTING GROUP: i.e., MORGANTOWN VALVE WORKSHOPS, November, 1977 and October, 1980.

Figure 19-13. METC Approach to Component/Valve Development For Coal-Conversion and Utilization Processes

LOCKHOPPER VALVE TESTING AND DEVELOPMENT PROGRAM

OBJECTIVES

DEVELOP RELIABLE LONG LIFE VALVES FOR SOLIDS HANDLING IN COAL CONVERSION AND UTILIZATION PROCESSES

1. DETERMINE CAPABILITIES OF CURRENT (STATE-OF-THE-ART) VALVES TO MEET PROCESS REQUIREMENTS.
2. DEVELOPMENT OF A NEW (PROTOTYPE) CLASS OF VALVES AND DETERMINATION OF CAPABILITIES.

Figure 19-14. Lockhopper Valve-Testing and Development Program

PROTOTYPE LOCKHOPPER VALVE TESTING AND DEVELOPMENT PROJECT

OBJECTIVES

1. EVALUATE CAPABILITY OF CONTRACTOR-DEVELOPED PROTOTYPE VALVE DESIGNS UNDER SIMULATED SERVICE CONDITIONS.
2. COMPARE PROTOTYPE VALVE PERFORMANCE WITH SOA DESIGNS.
3. PROVIDE DATA FOR DESIGN IMPROVEMENTS CONCERNING:
   A. LEAKAGE RATE
   B. WEAR
   C. RELIABILITY AND MAINTENANCE
   D. FAILURE MODE INFORMATION
4. VERIFY DESIGN IMPROVEMENTS THROUGH SIMULATED SERVICE; PILOT OR DEMONSTRATION PLANTS.

Figure 19-15. Prototype Lockhopper Valve-Testing and Development Project

STATE-OF-THE-ART (SOA) LOCKHOPPER VALVE TESTING AND DEVELOPMENT PROJECT

OBJECTIVES

1. EVALUATE THE CAPABILITIES OF EXISTING VALVES TO MEET VARIOUS SOLIDS LOCKHOPPER APPLICATIONS.
2. GENERATE VALVE LIFE CYCLE AND FAILURE MODE INFORMATION TO AID IN ESTABLISHMENT OF REPAIR AND MAINTENANCE REQUIREMENTS.
3. GENERATE DATA FOR VALVE DESIGN IMPROVEMENTS BASED ON EXPERIMENTAL TESTING.
4. PROVE VALVE DESIGNS THROUGH PILOT AND DEMONSTRATION PLANT APPLICATIONS.

Figure 19-16. SOA Lockhopper Valve-Testing and Development Project

TYPICAL VALVE APPLICATIONS IN COAL CONVERSION PROCESSES

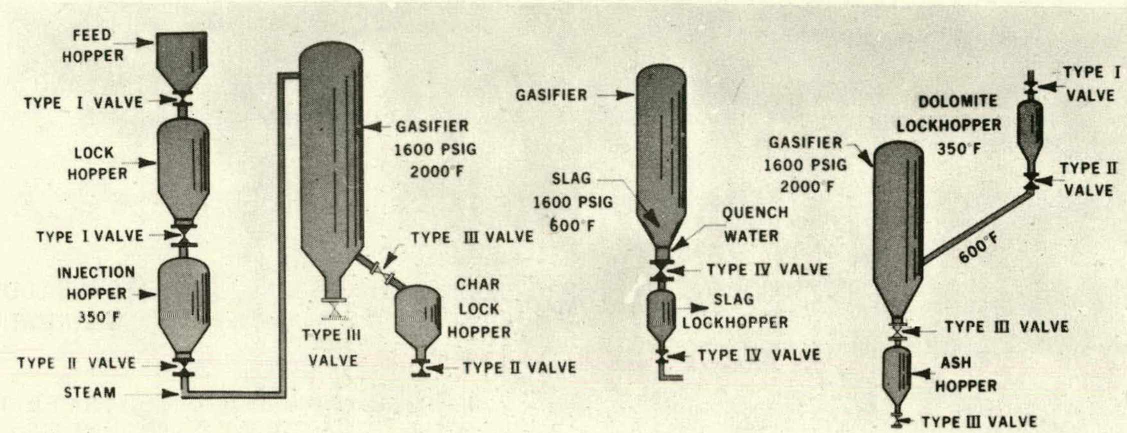

Figure 19-17. Typical Valve Applications in Coal-Conversion Processes

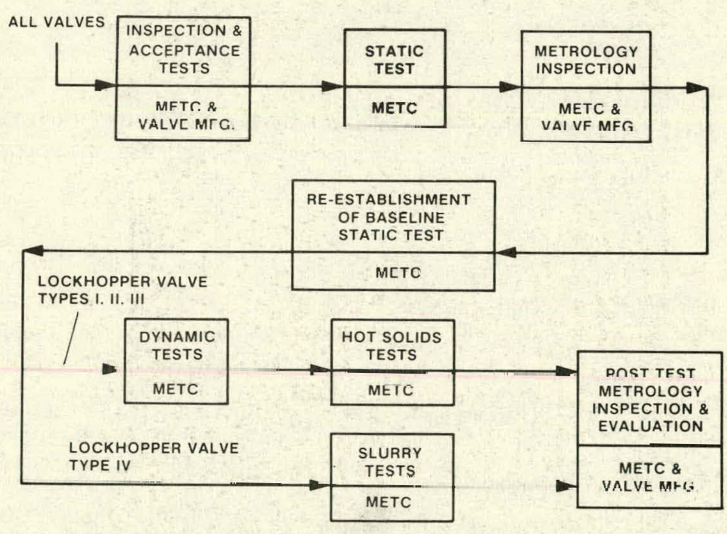

Figure 19-18. Lockhopper Valve-Testing and Development Program Test Sequence

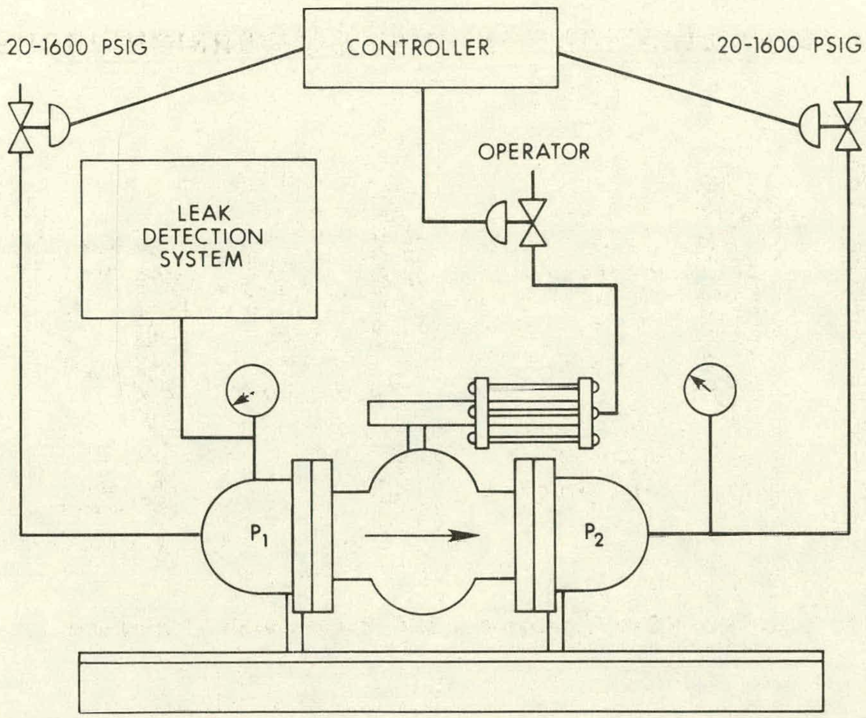

Figure 19-19. Valve Static Test Unit (VSTU) Installation

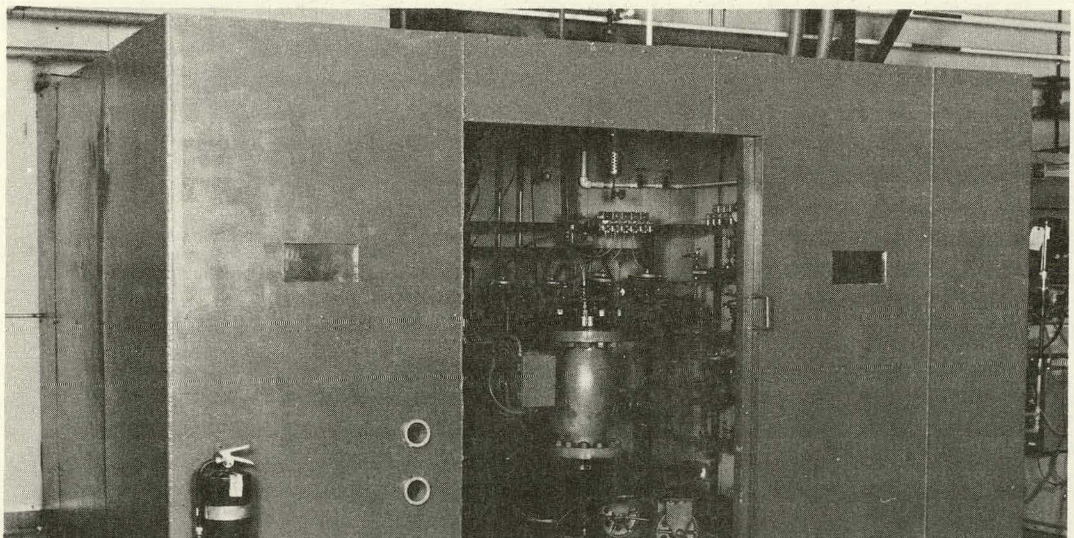

Figure 19-20. METC's Valve Static Test Facility

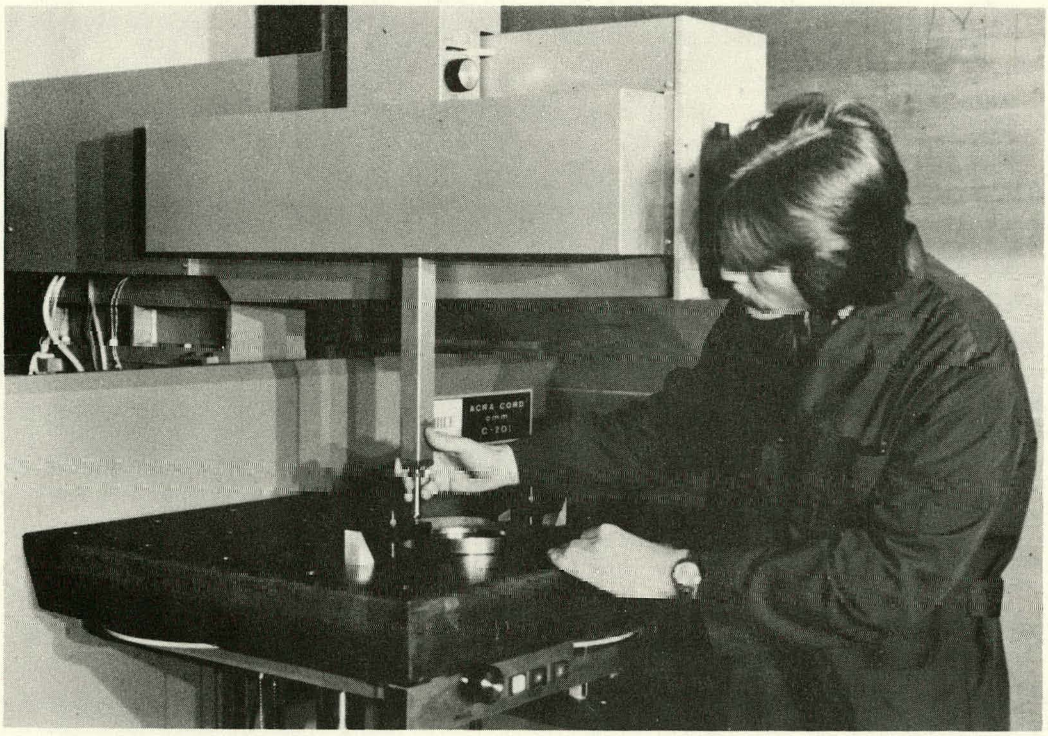

Figure 19-21. METC's Three-Dimensional Coordinate-Measuring Machine

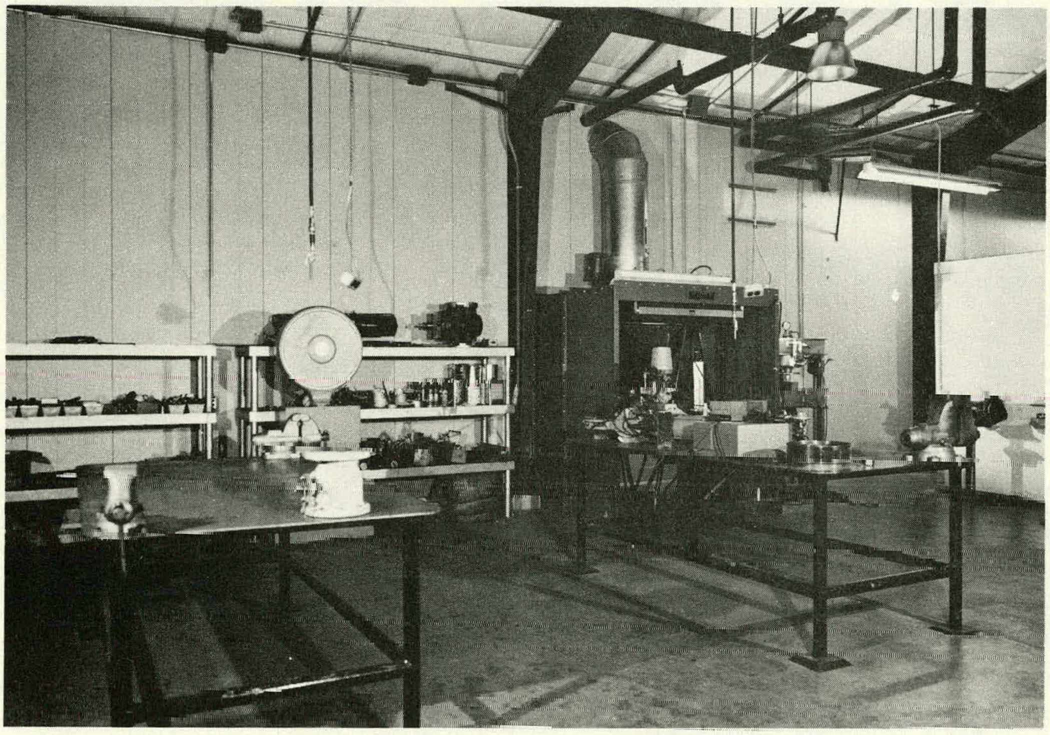

Figure 19-22. METC's Workshop Facility

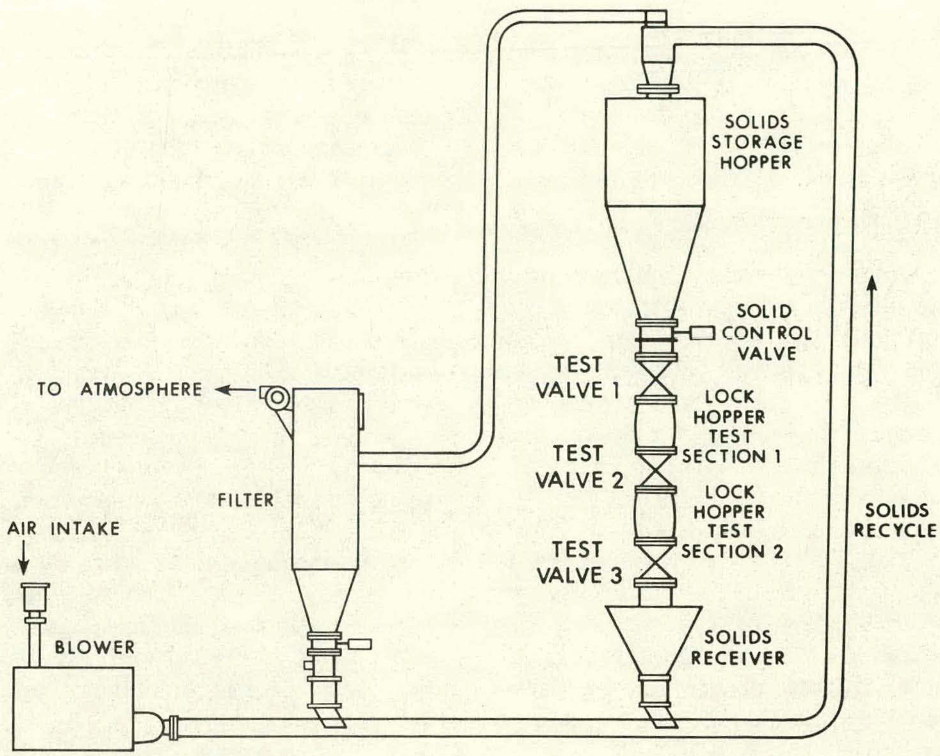

Figure 19-23. Valve Dynamic Test Unit (VDTU) Installation

HOT SOLIDS TESTING OF PROTOTYPE VALVES

TEST CONDITIONS:
- Material (Solids): -8 Mesh
- Limestone up to 600° F
- Alumina or Silicon Carbide @ 2000°F

HEAT RATE:
- Not to Exceed 100°F per hour

VALVE FLANGE INTERFACE TEMPERATURE:
- Not to Exceed 850°F

REQUIRED DATA:
- Valve Body Temperature
- Test Chamber & Flange Temperatures
- Test Material Temperature Inlet
- Chamber Pressure
- Leak Rate (Pressure vs. Time)
- Test Material Temperature Outlet
- Pressurizing Gas Temperature
- Valve Operating Force
- Valve Response Time
- Maintenance Requirements
- Wear Rates

Figure 19-24. Hot-Solids Test Program

simulates the type of wear that one would find in feed-side applications of a coal-conversion process.

The next step in testing is intended for valves to be applied to hot, dry, solids-removal lockhopper service, the hot-solids testing facility. Here the effects of pressure, temperature, and solids are combined into one test. Figure 19-24 gives a quick rundown of the test program that would be run in the hot-solids test unit. The heat rates shown are a design limitation of our prototype lockhopper valve-test project only. They do not apply to the state-of-the-art lockhopper valve-test project.

Figure 19-25 shows the outside of the hot-solids test facility. It is a very difficult facility to photograph from the inside. Figure 19-26 shows the heart of the facility: the fluid-bed solids heater that generates hot-solids media for the test program at temperatures between 300 and 2,000 °F. The capability with this particular test unit allows tests to be performed to 2,000 psig at temperatures to 2,000 °F.

Valves intended to go on slagging lockhopper application go through our slurry test program. On Figure 19-27, you can see where the paths diverge. Slurry testing is conducted with the unit shown on Figure 19-28. Again, this is slurry testing for lockhopper valves only. It does not have a continuous-flow capability; it is a batch-style test facility with capability to allow tests at pressures up to 2,000 psig.

All the tests are followed by post-test metrology inspections and evaluations. Key items in these inspections are summarized on Figure 19-29. Cause-of-failure inspections occur whenever the need exists.

At the conclusion of a complete round of tests, there will be a public report issued for each valve tested. Currently, two of those reports are at the printer. One already has been disseminated. Another five are ready or nearly ready to go to the printer at this time.

Figure 19-30 is a picture of the inside of our central data-acquisition and control facility. The use of automated facilities for data logging minimizes the manpower requirements and increases the accuracy of data obtained.

While conducting the project, we are constantly trying to correlate between simulated testing and the real world. METC is fortunate to have its own gasifier on-site at Morgantown. Figure 19-31 is a picture of our stirred fixed-bed gasification system in operation. The project has also done some correlation with the Bi-Gas pilot plant, an entrained-style gasifier, in Homer City, PA, right now.

I would like to give you a real quick summary of where we stand in the project in terms of valves tested. As I said before, 30 test articles have been or are in the program. Of these, 26 have gone through static tests, and 24 have had metrology inspections. Twelve of 30 have been successful in static testing and have gone on to dynamic testing. Of those 12, we found three to be highly successful in feed-side applications. Those designs came to us through Everlasting Valve Company, Kamyr Valves, and Rockwell International.

Another three valves achieved moderate success and offer potential. We have made recommendations to those three manufacturers which we feel will lead to a highly successful design. To date, we have deleted 11 test articles from the project. Primarily this was because in the initial stages a constraint was placed upon the project by DOE headquarters that tests would be performed on a representative valve in every valve family. As such, many designs are in the project to fulfill that requirement, and are not suitable for lockhopper-valve applications.

The state of the art has changed since 1976 or 1977. At that time, we felt that the state of the art consisted of about 500 cycles in lockhopper service at not more than 500 psig per lockhopper stage operating at temperatures of about 600 °F. Today, I am quite pleased that the state of the art has progressed to 15,000 cycles of valve life at up to 1,000 psig per stage, and at temperatures up to 1,000 °F. We have operating systems working quite well on our gasifier at Morgantown at 1,000 °F.

Numerous publications are available concerning the program and some of the planned programs, relating to valves, which we would hope to implement in the very near future. One of the areas we are looking at is additional testing in the area of slurry-letdown and

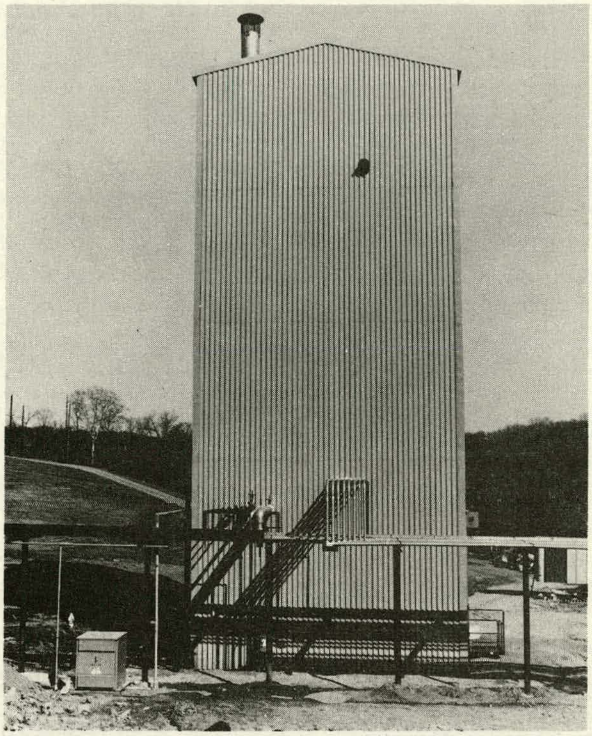

Figure 19-25. METC's Valve Hot-Solids Test Facility

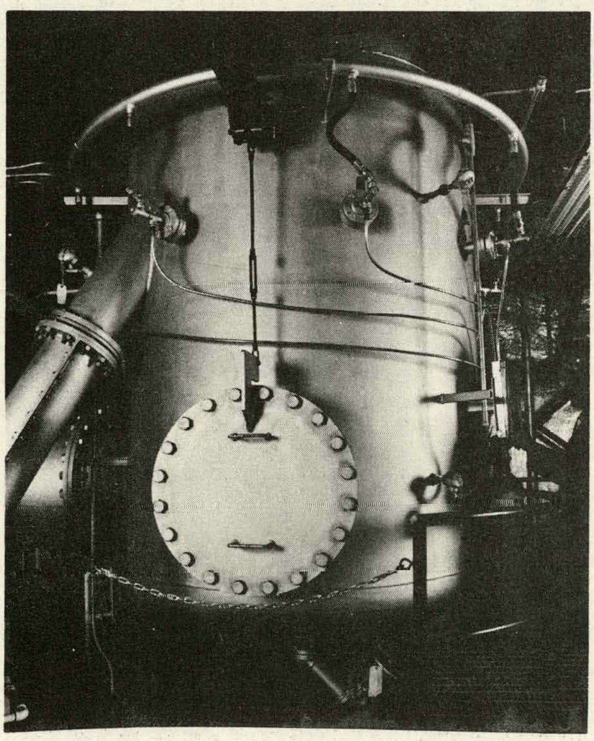

Figure 19-26. Fluidized-Bed Solids Heater in Valve Hot-Solids Test Facility

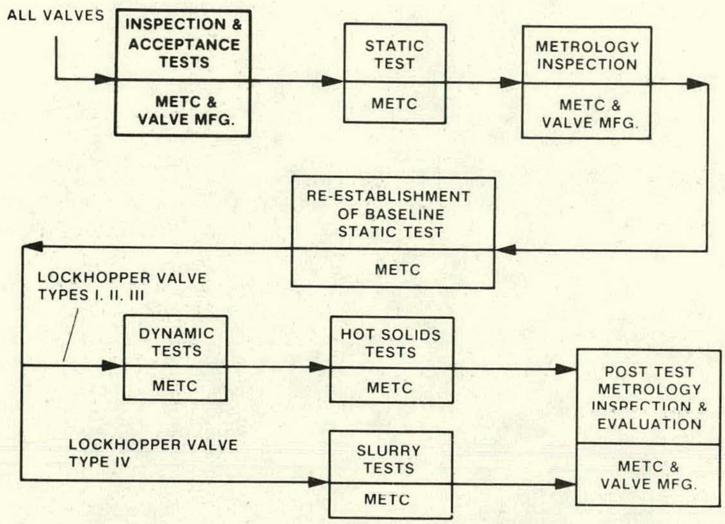

Figure 19-27. Lockhopper Valve-Testing and Development Program Test Sequence

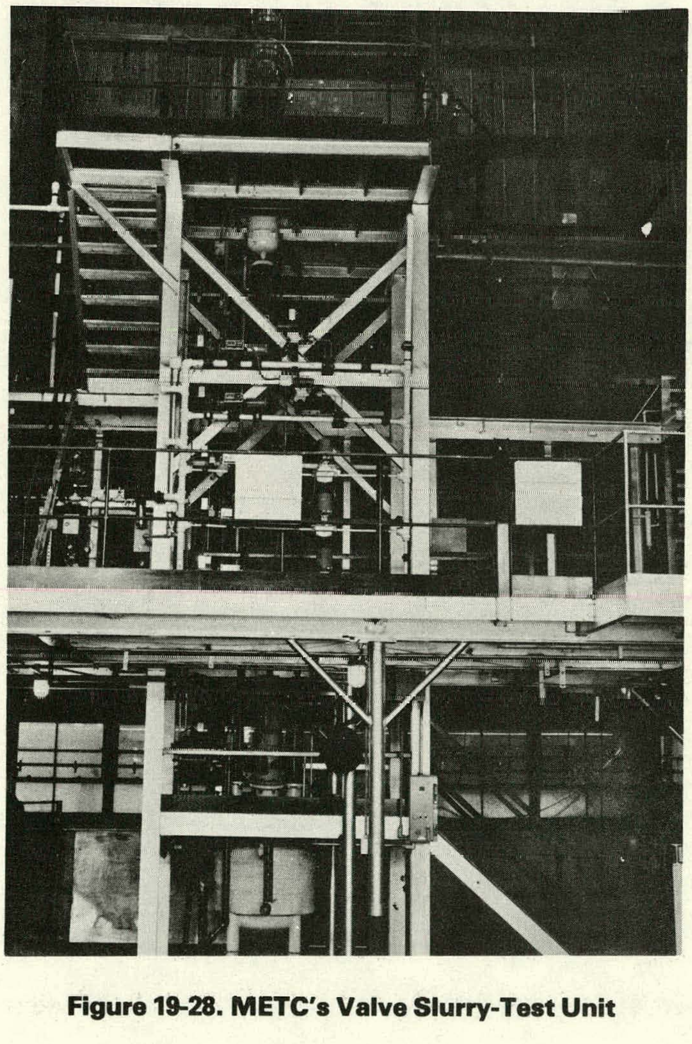

Figure 19-28. METC's Valve Slurry-Test Unit

INSPECTIONS & MEASUREMENTS
(SOA)

DISASSEMBLE. INSPECT AND MEASURE KEY DIMENSIONS BEFORE TESTS.

REPEAT MEASUREMENTS AFTER TESTS AND INSPECT FOR:

- WEAR
- EROSION
- CORROSION
- SURFACE DETERIORATION
- SPALLING, CRACKING OR OTHER DEGRADATION
- DUST CONTAMINATION OF SEALED AREAS
- GENERAL CONDITION

Figure 19-29. Key Items of METC Post-Test Metrology Inspections and Evaluations

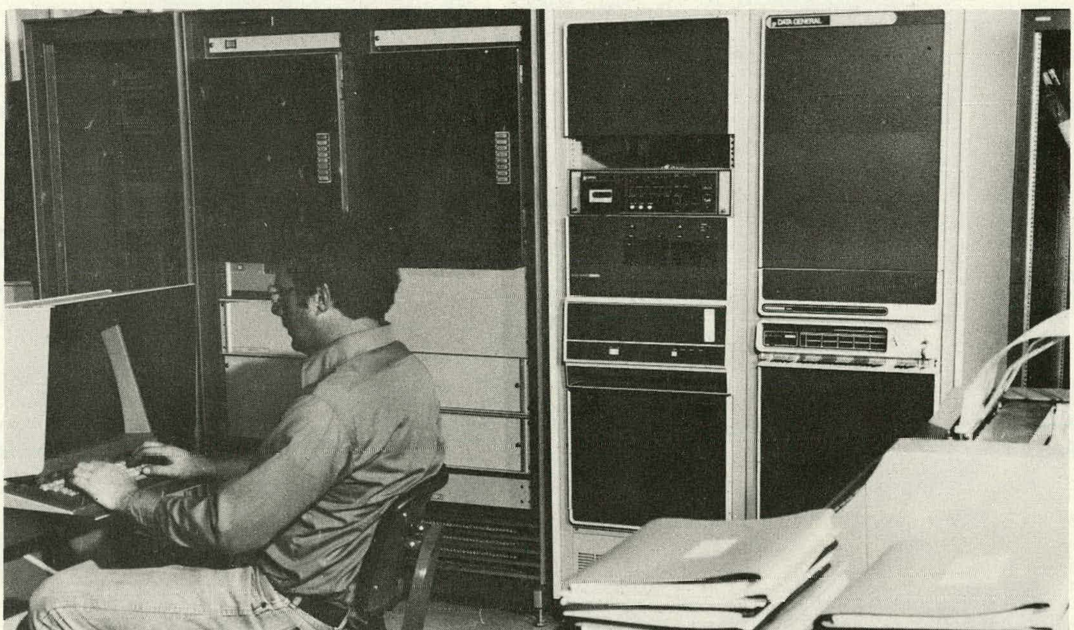

Figure 19-30. Automated Data-Acquision and Control System

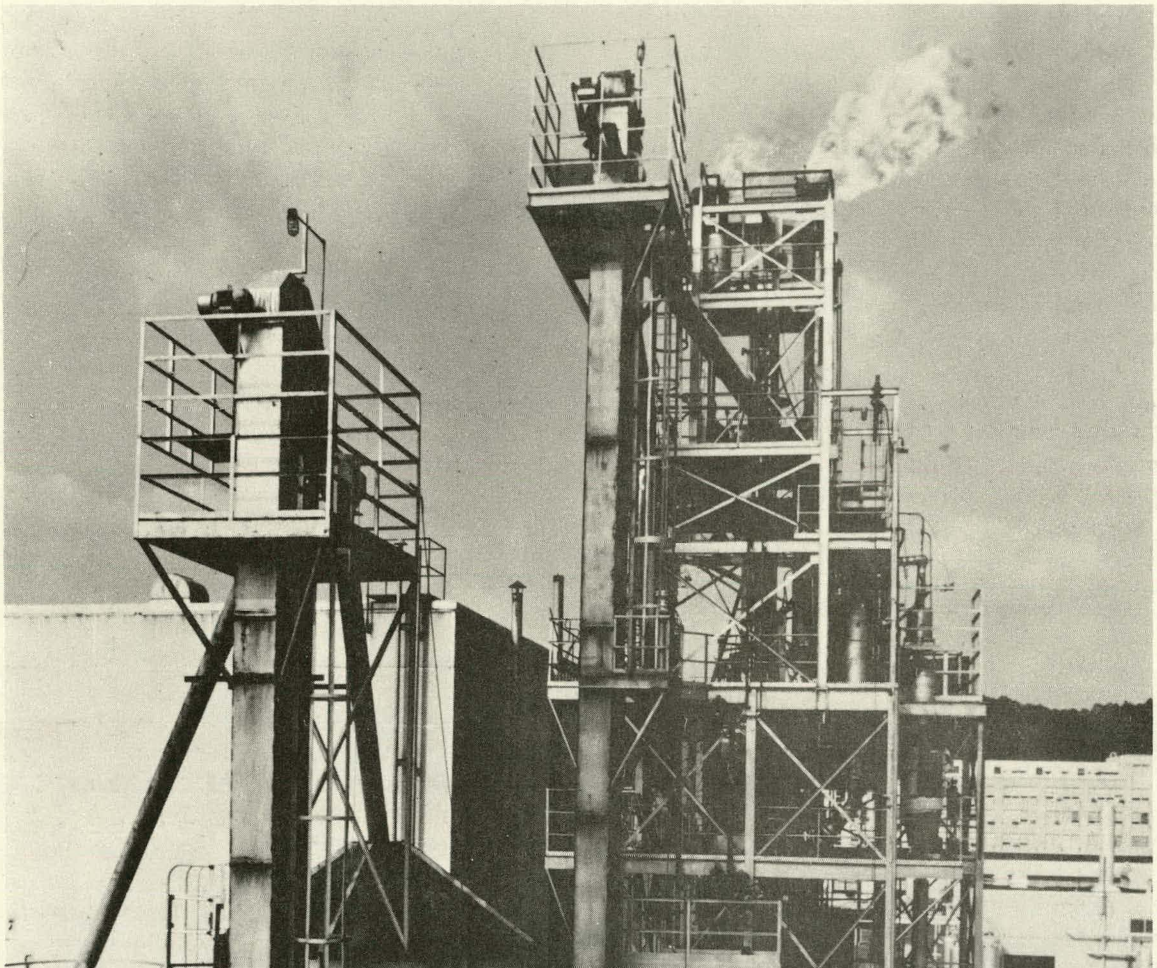

Figure 19-31. METC's Stirred Fixed-Bed Gasification System

slurry-block valves. A program plan has been laid out. Funding to date has been a problem. METC hopes that this does become an operable program.

We also feel that some work must be done on three-phase flow. Accurate correlation equations for the correct sizing of valves with three-phase flow do not exist in the public literature.

We would also like to see some work done with the hot dirty-gas control valves and some of the other areas I mentioned to you. I might add that recently a new office has been formed at the DOE headquarters level. Components projects can now be initiated by coming down from the top, as opposed to the way we worked in the past from the bottom up, to make sure that we haven't overlooked a component, material, or piece of equipment relating to the coal-conversion demonstration plant. Kamel Youssef heads the office of engineering support and he has formed the Materials and Components Oversight Group. The intent of that group is to review, in detail, the processes and their needs for equipment, components, and materials, and to assure that the correct research, development, and test programs are implemented such that an adequate technology data base exists to insure the successful operation of the coal-conversion demonstration plants.

That pretty well wraps up what I would like to say here this morning. I will field questions from the audience at this time.

Discussion of Paper by John F. Gardner

QUESTION: What did you say were the seal requirements for block valves?

GARDNER: We are looking very closely at a specification that would allow leakage rates 10 times that of MSS-7261.

As I said before, that is a Morgantown criterion and not one that some of the industrial partners to the demonstration plants would necessarily agree with. I know Exxon has their own, and I am sure that some of the others have their opinions.

QUESTION: Other than lockhoppers for introducing coal into processes, is anybody looking at any other ways to introduce the coal in a continuous manner?

GARDNER: Yes, there are multiple programs going on for alternate continuous dry-coal feed devices, both with DOE funding and also with private-sector funding. There is a gentleman here, his name is Bob Gall, who works at the Morgantown Energy Technology Center who is heading up those program areas. You can ask Bob for more information.

HAMMITT: John, would you describe for us how we as valve manufacturers can get involved in these cooperative valve-test agreements?

GARDNER: DOE is interested in developing commercially successful hardware. This can be done only by working with the industry. The way that we are operating the state-of-the-art project is through what we call cooperative agreements. These agreements are such that DOE will perform testing for you with no charge; and we expect you, as an industry supplier and manufacturer, to provide the test article at no charge. This arrangement has worked very well with several manufacturers, and we would continue to see the state-of-the-art lockhopper-valve project as well as other component projects working along those lines.

If Morgantown were to operate a slurry-letdown valve-test program, for instance, we would also see it providing basically a test service at no charge, with the manufacturer providing his hardware to us at no charge.

We would not close the door on somebody coming in with a proposal for an R & D activity. Every proposal we receive of this type will be looked at based on the merit of the proposal. We are looking at how that proposal is going to get us to commercial hardware. That is a point that I would like to make that I really didn't make yesterday—and that is the fact that we are not closing the door on R & D. We are willing to go to an R & D agency to get a design that would work. But what we are looking at is how can we take that design and commercialize it if we get it from someone that is not a manufacturer and doesn't have manufacturing capabilities? Are we going to obtain a commercially available product that can be bought and put into a plant?

HAMMITT: One other question. What is the probability of getting a hot-slurry test loop with slurry-letdown valves and where would it be?

GARDNER: I don't think I can give you the right answer. I can make a projection and this is it. I would think there is going to be testing of slurry-letdown and slurry-block valves.

I would project it is probably going to be at one of the three pilot plants that we have in the country—like Fort Lewis, EDS, or H-Coal—where we could get data that could then be rapidly disseminated. I don't want to say when because of too many outside influences.

QUESTION: My problem is a little bit different. I move around to a lot of different companies. How do I go about getting where I am on the information-receiving list?

GARDNER: You mail a memo in some form to me saying would you please include my name on your report-distribution list. It should be mailed to my attention or to the attention of Don Freeburn at the Center.

GARDNER (in answer to a question): The government is not in business to sell service, and that is why we like to work in a cooperative nature. We are putting up our limited resources, manpower, utilities, and equipment. We are most interested in working with those people who are willing to more or less match us on a resource basis in order to develop commercial-scale equipment required for the coal-conversion industry.

Section 20

Closing Remarks

John F. Gardner, Project Manager
Valve Testing and Development Projects
U.S. Department of Energy
Morgantown Energy Technology Center
and
Donn Hammitt, Manager
Control Valve Research and Engineering
Fisher Controls Company

October 17, 1980—11:00 a.m.

GARDNER: Now the time has come to wrap up this, the Second Symposium on Valves for Coal Conversion and Utilization. I would like to thank again the VMA, especially Jerry Hendrickson and Carl Novak, and the VMA Technical Committee for their assistance in setting up the program, especially Donn Hammitt and Dick Handschumacher, for their active participation here as panel-discussion leaders.

Also, I would like to recognize Bill Knecht with Anchor-Darling, who also was very active during the Technical Committee work leading to this program.

I would like to thank my coordination-support team from TRW, especially Dave Maxfield and Gordon Sine, and my coworker at the Morgantown Energy Technology Center, Don Freeburn.

Most importantly, I would like to thank all our speakers and their employers for allowing them to be with us and to share their experience and knowledge on the subject of valves and coal conversion.

We would appreciate your comments and criticism on this program, and ask that you fill out the critique form supplied. We also would like to have your thoughts as to whether a program like this should be repeated in the future, and if so, when?

In the program we have tried to give you an overview of the valve needs associated with coal conversion and a feeling for the market potential existing within this new and emerging industry. We tried to share with you our experiences in trying to operate the pilot plants existing here in this country and across the ocean. We tried to give you a brief review of applicable materials information for severe-service valves.

We, the Program Committee, feel that the program has been very successful. It has been successful because of you, the audience. We thank you for your attendance, your participation, and your enthusiasm. Now, before you leave, I would like to offer you a challenge. The challenge is that I would like to see 90% of our severe-service valve requirements for coal conversion solved within the next 2 years. We have present, in this room, an audience of both parties responsible and necessary to carry out this challenge. Those parties being you the valve manufacturers and the valve users. I would hope that you would give serious thought to the point that I made before about how we must address the severe-service valves. Without successfully solving these severe-service valve problems, coal conversion will very likely never become a commercially reliable and acceptable industry in this country.

To the valve users, I would like to say, I hope that you would get with your valve manufacturers, would work with them closely in guiding them toward your needs in the future relating to coal conversion and to try to feed back data to your manufacturers, not only to their representatives, but also directly back to their engineering staff, so that the latest improvements in valve design can be incorporated.

Without cooperation between these two important groups, coal conversion, as I have said, cannot become commercially viable and healthy. Without cooperation, we are going to find that coal conversion has to take the necessary evolutionary development process and may require 40 years to successfully develop.

Gentlemen, thank you for being here. It has been a pleasure and I hope that you have gained some valuable insight into the new emerging industry of coal conversion. Thank you.

HAMMITT: My remarks will be brief. First of all, I would like to second all the thanks John put up and I would particularly like to thank John. I think that John has done an excellent job of chairing this symposium and I think he deserves a hand.

It has been a pleasure for the VMA Technical Committee to cooperate with John in putting this program on. I would also like to make a few remarks about the panel sessions. From the feedback I had, I thought both of the panel sessions went very well. I was pleased with the participation. In my own case, I know we covered about half of the material that we intended to cover because of the enthusiastic participation from the audience. I hope that we can do this again.

I also second John's remarks about the need for feedback from you concerning future symposia of this sort and particularly the time element. If we were to be very optimistic and say that we would have it 3 years from now, 99% of the problems would be solved and there would be no need for it. Perhaps a year and a half, two years, two and a half years from now might be better timing.

The final remark that I would like to make is not on behalf of the valve manufacturers or of any of the participants here. It is a remark that I would like to challenge you with. I would urge each of you to go home and find that creature running around your congressional district or state called a candidate for federal office. He is perhaps your elected representative. Explain to him the importance of this test program. Explain to him the need for adequate funding for the program. Explain to him the importance of this program to the future of the energy industry in this country. Ask him to support the work that we are attempting to do here. We desperately need that hot test if we are going to answer these questions in a timely and organized fashion. John says 90%. I will settle for no less than 99%.

Other than that, I wish you good speed. I hope you go back and solve these problems that we have looked at. I know your appetite has been whetted by this very enticing picture of the valve-business area, but we've got to solve the problems in order to get there.

Thank you very much.

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