A FEDERAL LOOK AT THE NEEDS FOR ENERGY-RELATED MATERIALS RESEARCH AND DEVELOPMENT

PART I: NEAR-TERM PROGRAM

APPENDIX 1: FOSSIL ENERGY PANEL REPORT

Prepared at the Request of
Committee on Materials (COMAT)
Federal Council for Science and Technology

FOREWORD

The objective of Part I of the National Plan for Energy-Related materials Research and Development is to specify materials requirements and provide guidance for government-sponsored materials work in support of the near-term national energy program. The report is based on a study by the Committtee on Materials (COMAT) of the Federal Council for Science and Technology. The working group, called the COMAT Energy Task Group, is divided into seven panels, each of which is responsible for specific technology areas. Twelve federal agencies and departments are contributing, and several of their participants have assumed panel leadership positions. The Energy Research and Development Administration is responsible for overall coordination.

This document contains supplemental information to the Fossil Energy Panel Report.

Introduction:
The specific goals in the mining of coal in the near-term include:
...Increase the supply of fossil fuels recovered from our own natural resources
...Improve the quality and quantity (yield) in coal recovery
...Improve the design of mining equipment, methods and tools.
No critical materials constraints exist in the areas of tools and equipment except those which are imposed or implied by institutional areas (MESA and OSHA). See Mining, Health and Safety. The major constraints are institutional and legal in nature. However, utilization of newer technology could help **in reaching both the near- and mid-term goals.**

The technical areas of prime importance are:

- Need for greater longevity and safer equipment for cutting, grinding, cominution, and drilling.
- Need for lighter weight, inexpensive roof supports (for Eastern mines).

Overview of Existing Work:
The identified FY 76 programs oriented toward materials technology are as follows:

- Development and evaluation of improved lubricant, wire-rope, injection dozer blade, wetting agent, coatings to replace weather foam, bolts grouted with inorganic materials, etc. $.6M - BOM in-house work.

- Development and evaluation of new seal for wet head, quiet conveyer for mining machine, pneumatic drills, flame-explosion quenching medium, polymeric support for coal mine, weathering protection coating, remotely installed temporary supports, TiB_2 bits, fiber aerosol monitor, etc. $1.4M sponsored contracts.

- See also Mining Health and Safety.

- **Private industry has R&D programs mainly focussed on developing new coal mining systems based on current materials.**

- **International agreement with Poland.**

Priority Rank: Topic

B
- Component Service Life
  Establish laboratory test methods to evaluate mining tools and equipment for erosion, cyclic fatique, impact, and fracture resistance; correlate with field and operational conditions.

C
- Coal Extraction Tools
  Evaluate, in field conditions, mining tools that have improved abrasion and corrosion resistance and are non-sparking; evaluate in field conditions the use of new lubricants and surfactants to extend useful tool life:
  evaluate sound damping techniques (see also Mining - Health and Safety).

Budgets ($, Millions)
Component Service Life -$0.3/yr to FY-82
Coal Extraction Tools -$0.1/yr to FY-82

Budget Analysis
The budget figures shown are part of the overall project of improved mining tools/equipment ongoing in BOM, and are perhaps fragmentary. A final analysis of the FY 77 plans may be possible after the COMAT "Inventory of Federal R&D in Materials".

General Discussion:

In order to double coal production in the United States by 1985 improvement of all facets of coal mining must be achieved.

Acknowledgements:
Mr. Allan Sherman, Consultant to USBM
Mr. Andrew Prokopovitsh, DoI
Mr. Tovio Johnson of BOM for information on materials programs for mining.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Component Service Life (Mining Tools & Equipment)	Nil	Nil	110	27.5
Coal Extraction Tools, Improved Lubricants and Wetting Agents	240	100	290	77.5
TOTAL	240	100	400	100

Introduction:
The goals in haulage of fossil fuels (coal) for the near-term include:
...Update and improve existing equipment to handle the expected increased flow of fuels...and
for the mid-term are,
...Design and develop improved carriers and road beds to handle longer/heavier loads
...Develop slurry pipe line technology to cost effectively move the fuels.
There are no critical materials constraints in the area of haulage; however, improvement could be made which could provide more cost/energy effective solutions.

Overview of Existing Work:
The identified FY 76 programs oriented toward materials technology are as follows:
- Improvement in haulage hardware $0.066M **Bureau of Mines Field Stations.**
- **The USA has an international agreement with Poland.**
- **The USA has an active private sector.**

Priority Rank: Topic

B
- Slurry Transfer
  Evaluate, in field conditions, components for slurry pipelines.

C
- Alternative Haulage Hardware
  Evaluate, in field conditions, performance of belts and improved (high strength) carriers.

Budgets ($, Millions)
Slurry Transfer -$0.1 /yr to FY-82
Alternative Haulage -$0.1 /yr to FY-82

Budget Analysis
A complete analysis of the budget must await the COMAT Inventory of Federal R&D in materials. A preliminary analysis, based on input data, suggests a spending level of $200,000 per year **(part of BOM's budget) to improve the haulage of coal.**

General Discussion:
Materials development and system improvements will be necessary to handle the expected increased volume of coal if the National Energy goals are to be achieved. It was also recognized that an active private sector supplies materials and components for coal haulage vehicles. This sector would benefit from newer technology in slurry pipelines but more critically needed is capital to expand its current capabilities.

Acknowledgements:
Mr. Allan Sherman, Consultant to USBM
Mr. Andrew Prokopovitsh, DoI
Mr. Tovio Johnson of BOM for information on materials programs for mining.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Improved pipe lines for slurry transfer	Nil	Nil	100	50
Improved haulage hardware (carriers, belts)	66	100	100	50
TOTAL	66	100	200	100

Introduction:
Goals for improvement in Health and Safety in coal mining for the near-term include:
...Review and update of existing laws
...Apply uniformly existing health and safety codes to insure safe working conditions
...Develop improved methods and materials in mining and miner safety.
The critical problems associated with health and safety are basically institutional; however, there are several areas in which technology impacts on the institutional (OSHA, MESA) factors.

- Sound damping and control
- Spark generation

Overview of Existing Work
The identified FY 76 programs oriented toward materials technology are as follows:

- Development and evaluation of wetting agents, coatings to replace weather foam, and bolts grouted with inorganic materials. $0.16M - BOM Lab. (internal)
- Development and evaluation of a quiet conveyer, pneumatic drills, flame-explosion quenching medium, polymeric support for coal mines, weathering protection coating, remotely installed temporary support, TiB_2 bits with reduced frictions, fire-retardant material, fiber aerosol monitor. $1.3M - BOM sponsored contracts.
- See also Mining - Tools and Equipment.
- International agreement with Poland.

Priority Rank	Topic
A	• Sound Damping and Control Evaluate materials and components used as mining tools for quality of sound damping and control (field conditions)
A	• Effect of Operating Parameters on Spark Generation Evaluate effects of operating parameters on spark generation (field test environments). (Non-sparking tools)
A	• Development/Testing of Fire Retardant Materials Evaluate and improve fire-retardant materials to be used by personnel in mining operations.
A	• Control of Vapors and Dust Develop materials (such as filters) and methods to control fumes and dust particles under typical mining operation.

Budgets ($, Millions)

Sound Damping	$ 0.50/yr to FY-82
Operating Parameters/Nonsparking Tools	$ 0.50/yr to FY-82
Fire Retardant Materials	$ 0.1/yr to FY-78
Control of Vapors and Dust	$ 0.2/yr to FY-82

Budget Analysis:
The budget for mining, health and safety in general is directed and controlled by MESA thru direct legislation. However, additional funds are supplied by the Bureau of Mines to analyze and solve mine safety problems. The budget figures presented as part of this report are based on inputs from the Bureau of Mines. A more detailed budget analysis must await the COMAT "Inventory of Federal R&D in Materials".

General Discussion:
The health and safety reports of mining must be considered along with the technical requirements to assure conformance to OSHA specifications and guidelines. Materials and components to be used for mining purpose should be evaluated for their physical, mechanical, chemical integrity with respect to both people and equipment. Testing of improved systems, procedures is needed.

Acknowledgements:
Mr. Allan Sherman, Consultant to USBM
Mr. Andrew Prokopovitsh, DoI
Mr. Tovio Johnson of BOM for information on materials programs for mining.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Sound Damping and Control	260	25	300	23
Spark Generation Control	190	18	300	23
Fire Retardant and Explosion Quenching	325	32	400	31
Control of Vapors and Dust	260	25	300	23
TOTAL	1,035	100	1,300	100

Introduction:
ERDA goals in Enhanced Oil and Gas Recovery (Ref. 1) for the near-term include:
...Develop and demonstrate in cooperation with industry recovery (secondary and tertiary) technology which will increase production flow rates and ultimate yield of oil/gas fields
...and
for the mid-term include:
...Develop in situ technology for recovery of full values from resources not economically recoverable by conventional means.
The major limitations in enhanced oil and gas recovery are institutional; however, utilization of newer technology could help in achieving both the near- and mid-term goals.
The constraints of prime importance include:

- The problems (corrosion/erosion) associated with high pressure and heated liquids and gases for injection.
- The corrosion problems associated with use of structural materials in the outer continental shelf (OCS) environment.

Overview of Existing Work
The identified problem areas are receiving attention as follows: under DOI -BuM sponsorship

- Micellar and Polymer Flooding ($0 identified as materials per se)
  Cities Service Company
  Phillips Petroleum Company
- Carbon Dioxide Injection ($0 identified as materials per se)
  University of West Virginia
- Improved Waterflood Recovery (Estimated $50K on materials)
  Improved Surfactants and emulsion (University Grants)
- Hydraulic and Chemical Fracturing ($0 identified as materials per se)
  Talley-Frac Corp.
  Petroleum Technology Corp.
- OCS Technology & Enhancement ($0 identified as materials per se)

Priority Rank	Topic
B	• Outer Continental Shelf Materials Evaluate components used for air OCS drilling; Generate data from field applications.
B	• Secondary & Tertiary Recovery Fluids Develop new fluids for secondary and tertiary recovery.
B	• Remote Sensing Techniques Develop techniques for remote sensing of component behavior (strain, wall thickness, etc.) in OCS conditions.

Budgets ($, Millions)

OCS Materials	-$0.1/yr to FY-82
Sec. & Tertiary Recovery Fluids	-$0.1/yr to FY-82
Remote Sensor Techniques	-$0.2/yr to FY-82

Budget Analysis
The dollars suggested in FY77 are to evaluate the materials and components that will be exposed to a new processing environment, e.g., secondary and tertiary fluids and sea water (OCS) environment.

General Discussion:
Materials technology is required to support th enhanced oil and gas recovery projects in view of more hostile environments associated with secondary and tertiary recovery processes such as fluid injection, hydraulic and chemical fracture and thermal inducement and off-shore drilling.

References:
Ref. 1 "Creating Energy Choices for the Future" ERDA-48, Vol. 2, July 1975.

Acknowledgements:
Dr. J. Ham, ERDA/FE
Dr. H. Finke, ERDA/FE

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Drilling Equipment Materials for OCS application	Nil	Nil	100	25
Secondary & Tertiary Recovery Fluids	Nil	Nil	100	25
Remote Sensing Techniques	Nil	Nil	200	50
TOTALS	Nil	Nil	400	100%

Introduction:
ERDA goals in Enhanced Oil and Gas Recovery for the near-term include (Ref. 1):
...Develop and demonstrate, in cooperation with industry, technology which will increase production flow rates and ultimate yields of oil/gas fields... and
for the mid-term include:
...Develop in situ technology for recovery from resources not economical by conventional means.
There are no critical materials problems in the refining area and much of the new technology may be in hand to expand the refining of petroleum. However, two constraints anticipated for the time beyond 1985 exist:

- Crude oils will become increasingly impure and acidic
- Deeper hydrotreating operations will be needed to convert larger fractions of crude oil/gas to marketable products.

Both constraints require structural materials that are stable in environments that will be increasingly aggressive with the years.

Overview of Existing Work:
No specific programs on materials per se (federally funded) for FY-76 through FY-78 are in progress.

Priority Rank: Topic
No major topics.

Budgets ($, Millions)
Not recommended. The area is adequately funded by private industry at this time.

General Discussion:
Materials technology will eventually be required to support the enhanced oil and gas recovery projects since the petroleum crudes from the enhanced recovery processes may possess quite different physical and chemical (impurity level) characteristics. Processing of these crudes and refining may require new classes of materials of construction and catalysts. However, **the subpanel did not feel that federal funds are needed at this time. However, as more data are made available, and any problems uncovered, this area may become important and require additional examination.**

References:

Ref. 1 "Creating Energy Choices for the Future" ERDA-48, Vol. 2, July 1975.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
No programs on materials could be identified				

Introduction:
ERDA goals in surface processing oil shale recovery technology (Ref. 1) for the near-and mid-term include:
...Develop technology to supply 1 to 3 Quads annually from U.S. oil shale reserves.
There are no major processing or materials problems associated with surface processing of oil shale.

Overview of Existing Work
There are no explicitly identified materials programs underway in oil shale surface processing. The budget for the total effort is:

Oil shale production Field Test and Support:

$9.35 M for FY 76

Gas Production: $3.1 M for FY 76

However, none of these monies are earmarked for materials development.

Priority Rank — Topic
No major topics.

Budget ($Million)
None recommended

Budget Analysis
Although some tens of millions of dollars are being spent on surface processing of oil shale, the subtask panel could not justify any expenditure for materials per se.

General Discussion:
There are some environmental problems associated with the disposal of spent shale after processing since the shale swells to a large volume on retorting. The possibility of utilizing the spent shale as an aggregate structural material should be explored. Further, since some of the oil shale deposits lie under recreational land use areas, surface processing, which implies prior mining, may well run into some severe environmental problems. These problems are institutional in nature and may eventually require some R&D but are better covered by the conservation or environmental sub-task panels.

References:
Ref. 1 "Creating Energy Choices for the Future" ERDA-48, Vol. 2, July 1975.

Acknowledgements:
Dr. Jerry Ham, ERDA/FE

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
No major topics are anticipated in this area. No budget recommended.				

Introduction:
ERDA goals in in situ oil shale recovery technology for the near-term (-1985) include (Ref.1):
...Develop and demonstrate in situ recovery technology to result in an annual increase of 18 million barrels of shale oil...and
for the mid-term include:
...Develop technology to supply 1 to 3 Quads annually.
The technological constraints of critical importance concerning materials are:

- Currently acceptable materials are not likely to hold up under the aggressive environments
  - brine solutions containing chloride ions
  - slurries containing quartz and alumina
  - gaseous mixtures containing high temperature hydrogen
- Data are not in existance whereby correlations can be made between laboratory tests and operational performance.

Overview of Existing Work: (In $Millions)
Field Test and Support FY 76-9.355
Gas Production (in situ) FY 76-3.1
Environmental FY-76 1.265
Supporting Research FY-76 1.265
(including oil shale, in situ coal)
The panel is unable to identify any explicit allocation for materials evaluation, materials development or failure analysis within the above mission-oriented energy development technologies such efforts are in Supporting Research (Applied).
Private industry (TOSCO, Union, Occidental) have projects but the amount of materils work is very small.

Priority Rank	Topic
A	• Hydrogen Compatibility Develop a data base describing the behavior of hardware in hydrogenous environments unique to operational in situ conditions; correlate with laboratory tests.
B	• Brine Compatibility Develop a data base describing the behavior of hardware in high pressure brine environments under operational conditions; correlate with laboratory tests.

Budgets ($ Millions)
Hydrogen Compatibility -$0.2/yr to FY-78 $0.5 79-81
Brine Compatibility -$0.05/yr to FY-77 $0.2 FY-77-80

Budget Analysis
Much of the materials R&D is covered in Supporting Research. The subtask panel decided that some funding would be required to address the specific problems in in situ processing.

General Discussion:
Corrosion/erosion problems in in situ oil shale recovery processes are critical. Severed pipelines due to corrosion may lead to costly loss of instrument packages and borehole failures. The major factors contributing to materials problems in in situ processing will be high pressure brine solutions and high velocity abrasive streams. Careful selection and evaluation of materials under simulated conditions will be an essential task for success. Wear corrosion and soil resistant coatings need to be developed. Hydrogen embrittlement is a problem due to high pressures and evaluation of materials; to combat this, materials design will be needed.

References:

Ref. 1, "Creating Energy Choices for the Future ERDA-48",Vol. 2, July 1975

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Data base on materials behavior in hydrogenous in situ environments.			150	75
Data base on materials behavior in high pressure brine environments (including abrasive slurries)			50	25
TOTAL			200	100%

Introduction:
The ERDA goal in direct utilization with atmospheric fluidized bed (Ref. 1) for the near-term includes:
...Develop and demonstrate on a commercial scale direct combustion of high sulfur coals with such beds capable of producing 1 Quad annually...
and for the mid-term includes:
...Increase options for environmentally acceptable utilization at cost and efficiencies superior to present alternatives.
The technological constraints of critical importance concerning materials are:

- Lack of test data needed for correlation of materials performance in operating plants with laboratory tests
- Lack of data on the corrosion/erosion/hydrogen embrittlement resistance of materials and coatings
- Lack of nondestructive testing techniques and equipment
- Lack of reliable techniques/materials for sorbent regeneration systems (SO_2 scrubbers).

Overview of Existing Work

The following systems work is underway or scheduled:

- 30 MW Fluidized Bed Boiler: $4.0M FY 76
  Sponsors: ERDA, Westinghouse, AMAX, Bechtel, Peabody, Public Services of Indiana
  Contractors/Site: Pope, Evans & Robbins, Foster Wheeler, Monongahela Electric Power Co.
- Industrial Applications Study: $1.0M FY 76
  Sponsors: ERDA
- Modular Integrated Utilities Systems(MIUS) $1.5M FY 76
  Sponsors: ERDA, HUD, NASA, DoD, NBS(DoC) and HEW
- Component Test and Integration Facility (CTIF): $0 FY 76
  Sponsor: ERDA (FY 77 Start Date)
- Plant Conversion: $0 FY 76
  Sponsor: ERDA (FY 77 Start Date)
- 200 MW Boiler Design: $5.0M FY 76
  Sponsors: ERDA, Westinghouse, AMAX, Bechtel, Peabody, Public Services of Indiana
  Contractors/Site: Pope, Evans & Robbins, Foster Wheeler, Monongahela Electric Power Co.

Others reported to be working in this area (Ref.2) include: British Gas Council, Argonne and Exxon.

Priority Rank	Topic
A	• Material Performance Develop test data for correlation of materials performance in operating plants with laboratory tests, and evaluate the corrosion/erosion/hydrogen embrittlement resistance of materials and coatings under field conditions.
A	• Nondestructive Inspection Develop nondestructive testing techniques and equipment, for continuous monitoring of AFB equipment under operational conditions.
B	• Sorbent Regeneration Systems Develop reliable techniques/materials for sorbent regeneration systems (e.g., SO_2 Scrubbers.).

Budget ($ Millions)
Material Performance - See Fireside Corrosion
Nondestructive Inspection -$0.5/yr to FY-82
Sorbent Regeneration -$0.25/yr to FY-79

Budget Analysis
The materials performance evaluations for the atmospheric fluidized bed concept are now carried out either in Fireside Corrosion or in Supporting Research. Federal funding for R&D in mission-oriented technologies-will require expenditures of just less than 1 million dollars per year.

General Discussion:
Coal-fired, fluid bed boilers are significantly more attractive for commercial use than conventional coal-fired boilers. They show potential for improving combustion efficiency and heat transfer rates and have demonstrated the ability to burn all types of coal in an environmentally acceptable manner. In addition, the capital cost of such systems should be somewhat less than that of conventional systems. However, major concerns exist regarding the ability of present-day material systems to provide reliable, long term operation in full-scale commercial plants due to the highly corrosive/erosive environments which are present in such boilers. One of the primary problem areas is the inability to correlate material performance in operating plants with laboratory tests, and thus respond to such concerns. Considerable work will be required in this area.

References

Ref. 1 "Creating Energy Choices for the Future" ERDA-48, Vol. 2, July 1975
Ref. 2 "Evaluation of Coal Conversion Processes to Provide Clean Fuels." EPRI 206-0-0, 1974.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Materials Performance	See Fireside Corrosion			
Nondestructive Inspection	100	100	500	67
Sorbent Regeneration Systems	Nil		250	33
TOTAL	100	100	750	100

Introduction:
The ERDA goal in direct utilization with pressurized fluidized bed combustion (Ref. 1) for the near-term includes:
...Develop and demonstrate on a commercial scale direct combustion of high sulfur coals with such beds capable of producing 1 Quad annually ...and
for the mid-term includes:
...Increase options for environmentally acceptable utilization at cost and efficiencies superior to present alternatives.
The technological constraints of critical importance concerning materials are:

- Lack of test data needed for correlation of materials performance in operating plants with laboratory tests
- Lack of data on the corrosion/erosion/ hydrogen embrittlement resistance of materials and coatings
- Lack of nondestructive testing techniques and equipment
- Need for better definition of and the adequacy of the ASME Pressure Vessel Code.

Overview of Existing Work:
The following work is underway or scheduled:

- 20-60 MW Fluidized Bed Combined Cycle Pilot Plant: $19.0M FY 76 (Total Project)
  Sponsor: ERDA
- 1.8MW Pressurized Fluidized Bed Component Test and Integration Facility (CTIF): $1.5M FY 76 (Total Project)
  Sponsor: ERDA

Others reported to be working in this area (Ref.2) include: British Gas Council, Exxon, Fluidized Bed Combustion Company and Combustion Systems Limited.

Priority Rank	Topic
A	• Material Performance Develop test data for correlation of materials performance in operating plants with laboratory tests and evaluate the corrosion/hydrogen embrittlement resistance of materials and coatings in field conditions.
A	• Nondestructive Inspection Develop nondestructive testing techniques and equipment, for continuous monitoring of PFB equipment.
B	• ASME Pressure Vessel Code Evaluate the adequacy of the ASME Pressure Vessel Code regarding the coal-fired pressurized fluidized bed boilers.

Budgets ($, Millions)
Materials Performance - (See Fireside Corrosion)
Nondestructive Inspection - (See Fireside Corrosion)
ASME Pressure Code -$0.1/yr to FY-95

Budget Analysis
As in the case of the Atmospheric Fluidized Bed, the materials performance and inspection are better covered in either Fireside Corrosion or in Supporting Research. The unique aspect of the pressurized fluidized bed is the necessity of providing ASME Boiler Code information/data, and this is the area in which Federal monies should be spent.

General Discussion:
The advantages and concerns for the pressurized fluidized bed are similar in nature to those for the atmospheric fluidized bed. The pressurized system has the added potential for further major reductions in cost of power generation due to its use in a combined cycle system which increases the overall plant efficiency. It also has the added concern regarding the adequacy of the ASME Pressure Vessel Code under such conditions.

References:
Ref. 1 "Creating Energy Choices for the Future" ERDA-48, Vol 2, July 1975
Ref. 2 "Evaluation of Coal Conversion Processes to Provide Clean Fuels." EPRI 206-0-0, 1974.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Materials Performance (See Fireside Corrosion)				
Nondestructive Inspection (See Fireside Corrosion)				
ASME Pressure Vessel Code	Nil	Nil	100	100
TOTAL	Nil	Nil	100	100

Introduction:
The ERDA goal in direct utilization with combustion (Ref. 1) for the near-term includes:
...Develop and demonstrate on a commercial scale direct combustion of high sulfur coals with such beds capable of producing 1 Quad annually ... and
for the mid-term includes:
...Increase options for environmentally acceptable utilization at cost and efficiencies superior to present alternatives.
The technological constraints of critical importance concerning materials are:

- Lack of data needed for test correlation of materials performance in operating plants with laboratory tests
- Lack of data on high temperature/high strength materials which are compatible with the combustion environments obtained with coal-derived fuels
- Lack of data on high temperature/high strength materials which either by themselves or in conjunction with coatings can operate in coal combustion environments and can withstand attack by corrosive metal vapors and other nonconventional turbine gases.

Overview of Existing Work
The following work is underway or scheduled:

1. Design and Development of Advanced Heat Exchangers Concept
2. Improved Desulfurization in Fluid Bed Combustion
3. Regeneration of Limestone-Dolomite
4. Fluidized Bed Combustion Studies of Sulfur-Rich Coal
5. Gas Clean-Up
   Sponsor: ERDA
   Total Systems Budget is $4.1M for FY 76

Priority Rank	Topic
A	Material Performance - Develop test data for correlation of material performance in operating plants with laboratory tests. - Evaluate high temperature/high strength materials both by themselves and in conjunction with coatings to determine their compatibility with the combustion environments obtained with coal-derived fuels.

Budgets ($, Millions)
Material Performance -$1.0/yr to FY-82

Note: Additional aspects of Fireside Corrosion exist:

- Performance of turbine materials in coal-derived fuel gas combustion.
- Effects of trace impurities from coal on steam tube life.

These are covered in Subtask 4.

Budget Analysis
The budget for Fireside Corrosion basically encompasses all of the materials investigations and inspections techniques required to support the entire area of direct combustion. Based on fragmentary information the total Federal funding is approximately $1 million per year.

General Discussion:

The ability to develop new and improved coal combustion processes for reducing environmental impact and increasing power conversion efficiency will be severely limited by materials constraints. These processes will operate in more highly corrosive/erosive environments as well as higher temperatures and/or pressures than current processes. This will require a thorough understanding of available materials capabilities and the ability to correlate materials performance in operating plants with laboratory tests. Currently available turbines can operate for long times (~30,000 hours) if fuels meet rigid chemical and stereo-chemical specifications. The specifications for both the materials that make up the turbine parts and the fuels used in the units were developed after long-term tests were conducted under a range of conditions (Ref. 2). This has resulted in a situation where turbine materials are used under conditions that fully exploit their properties. A similar testing program is needed in using coal-derived fuels.

References:
Ref. 1 "Creating Energy Choices for the Future ERDA-48", Vol. 2, July 1975.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Material Performance	600	100	1,000	100
TOTALS	600	100	1,000	100

Introduction:
ERDA goals in coal gasification to low-Btu gas (Refs 1 and 2) for the near-term include:
...Develop and demonstrate second generation technology (3 Quads annually) to convert various coals to clean low-Btu gas both above ground and in situ...
...Perform laboratory study and processes development of third generation gasification processes...and
for the mid-term include:
...Develop and demonstrate advanced technologies to enable coal conversion (both gaseous and liquid) contribution to energy needs to exceed 9 Quads by the year 2000.
The technological constraints of crucial importance concerning materials are:

- Wear-resistant valve materials
- Improved ceramic reactor liners
- Corrosion/erosion of metal/ceramic components under high pressure, high temperature reactors and molten salt environments
- Regenerative solid absorbent materials (hot gas clean-up).

Overview of Existing Work
The identified problem areas are receiving attention as follows:

- Hot Gas Clean-up
  - -Screen, evaluate and develop solid absorbents for H_2S removal.
    Generate data from laboratory, bench and pilot scale studies to apply and correlate to performance in commercial units.
    Sponsor: ERDA/MERC
    Contractor: MERC
  - -Evaluation of absorbent pellet preparation techniques and absorbents and passivation techniques to combat corrosion.
    Sponsor: ERDA/FOSSIL ENERGY
    Contractor: Air Products and Chemicals
  - -Select molten salt systems and test them. Develop new chemical absorbents.
    Contractor: Battelle Northwest Labs
- Heat Pipes in Coal Gasification
  - -Evaluate sodium heat pipes for heat transfer
    Sponsor: ERDA/FOSSIL ENERGY
    Contractor: MERC
- Lock Hopper Valve Development
  - -Develop valves for lock hoppers
    Sponsor: ERDA/FOSSIL ENERGY
    Contractor: MERC

Overview of Existing Work(continued)

- Corrosion and Erosion Studies on Refractory Materials
  Sponsor: ERDA/FE
  Contractor: Combustion Engineering
  Funding: $ FY 76 -$11.4 **Total for 5 T/D PDU**
  Materials effort $0.1M
- Westinghouse Process-Sulfur Removal and absorbent regeneration
  Sponsor: ERDA/FE
  Contractor: Westinghouse
  Funding: $ FY 76 $3.8M Total for project
  Materials effort $0.1M
  Private industry may become stimulated to perform some R & D as a result of gas curtailments announced for the Eastern United States

Priority Rank	Topic
A	• Pressure Vessels -Evaluate corrosion/erosion resistance of pressure vessel materials and long-term structural stability. -Evaluate new/improved metal casing and ceramic lining materials.
A	• Pressure Feed Hardware Develop high temperature, high pressure lock hopper and pressure let-down valves.
B	• Gasifier Fabrication -Develop field fabrication, welding. -Develop inexpensive technique for ceramic lining application and maintenance.
A	• Failure Analysis Correlate plant performance and laboratory test results (see also Failure Analysis Activity in Supporting Research.)
A	• Hot Gas Clean-Up Evaluate absorbents in operational conditions.

Note that these topics are mentioned here because they fall under this fossil energy technology. They are included in Supporting Research (Applied) where research support to mission-oriented projects is carried out.

Budgets ($, Millions)

Pressure Vessels	$0.5/yr to FY-82
Pressure Feed Hardware	$0.5/yr to FY-82
Gasifier Fabrication	$0.1/yr to FY-77
Failure Analysis	-See Supporting Research
Hot Gas Clean-Up	$1.0/yr to FY-

Budget Analysis

A final analysis must await the COMAT "Inventory of Federal R&D in Materials".
A preliminary analysis, based on incomplete data, suggests that much of the R&D activities in Low-Btu Gasification is being carried out within the Supporting Research activity. The level of federal R&D within Low-Btu gasification appears to be approximately $2 million a year.

General Discussion:
No satisfactory materials system exists at the present time for coal gasification pressure vessel reactors that can ensure reliable, long term operation.
The logical approach to the materials problems is to evaluate current materials in the environments of interest, then with a firm data base develop new or improved materials as needed.

References:

Ref. 1 "Creating Energy Choices for the Future," ERDA-48, Vol 2, July 1975.

Ref. 2 "Materials Technology in the Near-Term Energy Program." National Academy of Science 1974

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Pressure Vessels	-	-	500	23.75
Feed Hardware	-	-	500	23.75
Gasifier Fabrication	-	-	100	5
Hot Gas Clean-up	-	-	1,000	47.5
TOTAL			2,100	100%

Introduction:
ERDA goals in high-Btu gas conversion (Ref.1) for the near-term include:
...Develop and demonstrate second generation technology for components and processes
...Perform laboratory studies and process development for third generation gasification process...and
The critical problems of a materials nature are:
- Service oxidation and hydrogen embrittlement in high pressure reactors and methanators
- Slag attack of reactor lining
- Lack of efficient methanator catalysts
- Lack of data on field fabrication of large gasifiers
- Lack of design/life time data on pressure feed hardware

Overview of Existing Work
The materials problems are receiving attention in ERDA-sponsored activities as follows:
- The activities in Supporting Research (Applied) such as Mechanical, and Physical Properties, Erosion, Corrosion and Wear, Failure Analysis, Quality Assurance, and Materials Development. The efforts are in program at Oak Ridge Nat'l Laboratory, Argonne Nat'l Laboratory, Nat'l Bureau of Standards, Battelle, and IITRI. Details are given in the Supporting Research (Applied) worksheet.
- Mission-oriented projects such as
  BI-GAS Project
  HYGAS Project
  SYNTHANE Project
  HYDRANE Project
  CO_2 ACCEPTOR Project
  SELF AGGLOMERATING GASIFICATION
  LIQUID PHASE METHANATION PROJECT
  These projects are jointly funded by ERDA and AGA. Mat'ls R&D is not specifically identified.

Private industry-sponsored work is underway at
M.W. Kellog Company (new gasifiers)
Babcock & Wilcox (gasifiers)
Chem Systems, Inc. (catalysts)
Harbison-Walker (refractories)
These efforts are largely systems-oriented but contain some analyses of new materials.

An international aspect exists due to the strong foreign influence in off-the-shelf gasification technology.
Lurgi (Germany) gasifiers are being evaluated for use with caking coals in Westfield, Scotland.
Koppers-Totzek (Germany) gasifiers are being evaluated with some ERDA support for use with char in Puente, Spain
Fischer-Tropsch (Germany) catalysis is under evaluation & operation in Sasolburg, Rep. So. Africa for producing fuels & petrochemicals (a fire destroyed part of the plant recently and new evaluations are in progress)

Priority Rank:	Topic
A	• Pressure Feed Hardware Develop reliable hardware for injection/ extraction of slurries from pressurized reactors.
A	• Pressurized Reactors Evaluate long-term stability of reactor materials in operational and laboratory conditions; included are gasification and methanation reactors.
A	• Failure Analysis See Supporting Research (Applied).
A	• Fabrication Assess benefits/costs of field versus shop fabrication of large gasifiers.

Budget Analysis
The high-Btu budget analysis must await the final results of the COMAT "Inventory of Federal R&D Projects". One conclusion is appropriate at this time:
- The majority of the materials R&D work in high Btu gasification is conducted in the Supporting Research (Applied) category rather than in the jointly sponsored ERDA/AGA mission.

General Discussion
No satisfactory materials system is known at the present time for coal gasification pressure reactors and high pressure methanator reactors that can insure reliable long-term operation (Ref. 1). Low Pressure (atmospheric) systems are available based on foreign technology but are inefficient (~40%). Pressurized (1000 psi) operations are needed to improve gasification kinetics and conversion efficiencies (60-80%).
Process economics studies (Ref. 3) show no economy-of-scale if standard 12-ft reactors only are available. Economics are possible if reactors could be larger (30 ft diameter) but this requires an extensive fabrication/inspection development effort on the part of American industry.

References:
Ref. 1 "Creating Energy Choices for the Future" ERDA-48, Vol. 2, July 1975
Ref. 2 "Materials Technology in the Near-Term Energy Program," National Academy of Science 1974.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
	All the recommendations concerning materials R&D are included in the various areas of Supporting Research (Applied).			
Pressure Feed Hardware	See erosion, corrosion and wear.			
Pressurized Reactors	See Mech & Phys Properties.			
Failure Analysis	See Failure Analysis.			
Fabrication	See Materials Development.			

Introduction:
ERDA goals in liquefaction (Ref. 1) for the near-term include:
...Develop and demonstrate second generation technology...
...Improve unit operations to support commercial operations...and
for the mid-term include:
...Support to commercial scale implementation...
...Develop and demonstrate third generation technology.
The critical problems constraining the development of all liquefaction technologies are of a materials nature (Ref. 1):

- Lack of techniques for separation of ash from coal liquids
- Lack of reliable components for feeding slurries to pressure vessels
- Lack of demonstrated long-term liquefaction catalysts.

Overview of Existing Work:
The identified problem areas are receiving attention as follows (Systems):

- Solid/Liquid Separation:
  H-Coal Project: $1.5M Filters, hydroclones (HRI, Inc., ERDA Sponsor)
  -SRC Project: $1M Pressurized Drum Filter evaluations in Tacoma Pilot Plant. (PAMCO-ERDA)
  -COED Project $0.1M Lab and pilot plant studies (FMC-ERDA)
  -U. Mich Project: Lab studies (EPRI-NSF)
  -Synthoil Project: $1M: Lab and PDU catalyst longevity studies
  -CRESAP TEST SITE: $1.5M: Component evaluation studies in liquefaction environment (Fluor-ERDA)

Private Industry Work
-Johns-Manville is developing new filter-aid formulations for high temperature filtration, finding TBD
-Gulf R&D is conducting materials research on catalysts

Priority Rank	Topic
A	• Solid/Liquid Separation Improve high temperature reliability of centrifuges; improve filtration rates significantly above 10 gal/ft.^{2} hr level
A	• Pressure Feed Hardware Determine operating performance in plant conditions of lock hoppers and let-down valves
A	• Catalyst Performance Determine operating performance of liquefaction catalysts under plant conditions
A	• Component Failure Analysis See Supporting Research Category

Budget ($ Million)
Solid/Liquid Separation - See Supporting Research
Pressure Feed Hardware - See Supporting Research
Catalyst Performance - See Supporting Research
Component Failure Analysis - See Supporting Research

Budget Analysis
The subtask panel identified several priority items in liquefaction, and although substantial dollars are being spent for systems construction the R&D work is being supported (on an interim basis) by Supporting Research. A more detailed analysis must await the COMAT "Inventory of Federal R&D in Materials."

General Discussion:
The materials work (metallurgy, ceramics, plastics, polymers) in most liquefaction projects has been viewed as necessary activity leading to the demonstration of each liquefaction technology (Solvent Extraction, Hydroliquefaction, Pyrolysis, Indirect). However, the materials work has not generally been the focus of activity. It has more subserviente to the determination of process parameters. More recently it has been recognized that product costs can be influenced as much by hardware reliability as by precise proven parameters, hence, additional reliability work is shown for FY 77 in the Supporting Research area.

References:
Ref. 1 "Creating Energy Choices for the Future," ERDA-48, Vol. 1, June 1975
Ref. 2 "Creating Energy Choices for the Future," ERDA-48, Vol.2, July 1975.

Acknowledgements:
J. Batchelor, ERDA-Fossil Energy, Liquefaction

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Solid/Liquid Separation	Covered in Supporting Research			
Pressure Feed Hardware				
Catalyst Performance				
Component Failure Analysis				

Introduction:
ERDA goals in MHD are for the mid-term (Ref. 1) and include:

- Develop and demonstrate a commercial-scale MHD plant
- Continue development to improve the performance reliability of commercial-scale plants.

The critical problems constraining the commercial development of open cycle MHD technology that are of a materials nature are (Ref. 1):

- High temperature corrosion/erosion of structural materials, e.g. preheaters, channel liners, combustor liners
- High cost of seed recovery techniques
- Instabilities in materials used for electrically active portions of MHD generators, e.g. electrodes and insulators
- High cost of superconducting magnets.

Overview of Existing Work:
The identified problem areas are receiving attention in programs sponsored by ERDA and DOC(NBS) in the federal government, by private industry and by international agreements.

- **DOC/National Bureas of Standards**
- **Component Development and Testing**
  $15M (FY-76) Total Budget
- **Supportive Science**
  $1.9M (FY-76) Total Budget

The amount allocated to materials R&D is ~10% of the total or about $1.2M.

- **ERDA supports work in MHD both at the Bureau of Standards and at contractor sites. Contractors include:**
  - **U. Tenn. Space Institute**
  - **M.I.T.**
  - **Montana State & U. Montana, Montana Energy & MHD Research and Development Institute.**
  - **Fluidyne Corp, Minneapolis**
  - **Argonne National Laboratory**

Private industry-sponsored work is underway at:

- **Westinghouse Corporation**
- **AVCO**
- **Reynolds Metals in Tuscaloosa, Alabama**
- **Stanford University (EPRI-sponsored)**

An international agreement between the USA and USSR provides for materials evaluations in operational units in the USSR.

Priority Rank:	Topic
A	• Electrode and Insulator System (Generator) -Develop high conductivity corrosion/erosion resistant, refractory electrodes (both cathode and anodes) that will withstand a coal combustion environment (slag, seed included). -Develop durable refractory insulator materials for MHD applications.
A	• Preheaters, Channel Liners and Combustor Liners -Develop materials that will be stable in the seed/slag/coal combustion environment as seen by the preheater, channel, or combustor, as appropriate. -Determine property data on promising materials for use in design of thermal shock resistant components (preheaters, etc.).
A	• Maintenance Systems -Develop in situ techniques for application of maintenance materials such as replenishment of combustor liners under operating conditions.
A	• Superconducting Magnet Improvements -Evaluate the performance of existing superconducting magnets in integrated MHD generators.

Budgets ($, Million/Year)

Electrodes, Insulators	$0.750
Preheaters, Channel Liners	$0.210
Maintenance Systems	$0.245
Superconducting Magnets	$0.050

Budget Analysis
A final analysis must await the results of the COMAT "Inventory of Federal R&D in Materials".

A preliminary analysis, based on fragmentary data, suggests that the federal government is spending not quite $1 million per year in the materials component of all the MHD work.

General Discussion:
This technology has high promise because it can use dirty fuels (coal with ash, sulfur) and has good potential for high efficiency (~ 60% vs. 35% for current fossil plants). However, the development of MHD technology is constrained primarily by the performance of the materials.

For MHD electrodes and insulators, properties ranges can already be identified (Ref. 2) in terms of electrical conductivity and dielectric strength.

This COMAT activity defined R&D topics of an applied or developmental nature. It is recommended that basic **research also be sponsored in the following areas to support** the development effort:

- Phase Diagrams (2000°C Regime) MgO, Al_2O_3, SiO_2, ZrO_2, CaO, Cr_2O_3 with alkali oxides
- Basic thermodynamic studies in 2000°C temperature regime
- Reaction kinetics in the 2000°C temperature regime at ~10^{-6} Torr oxygen pressure and ~1 amp/cm^2 electric current

These activities must be started in the near-term in order to ensure achievement of MHD goals for long-term (year 2000) energy production.

References:
Ref. 1 "Creating Energy Choices for the Future", ERDA-48, Vol. 2, July 1975

Ref. 2 Bowen, H.K., "Ceramics in MHD and Other Coal-Fired Systems" in "Critical Needs and Opportunities in Fundamental Ceramics Research", ERDA-9, January 1975

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Development of Electrode and Insulator System Materials (Electrical Generator Materials)	500	56	750	60
Development of Preheater, Channel Liner, and Combustor Liner Materials	120	13	210	17
Development of Maintenance Systems (in situ replenishment of liner materials under operational conditions)	240	27	245	19
Superconducting Magnet Improvements	30	4	50	4
TOTAL	890	100	1,255	100

Introduction:
The basic ERDA goals in MHD as stated in Ref. 1 are:
...Develop and demonstrate a commercial scale plant
...Continue development to improve the performance and reliability of commercial plants
The critical problems constraining the development of closed cycle MHD technology are of a materials nature:

- Development of higher temperature materials in both combustor and heat exchangers to achieve the 1800°K required to achieve 50% efficiency
- Development of electrically active materials resistant to corrosion/erosion by the alkali metal gas stream
- Design/development of improved superconducting magnets
- Development of higher heat transfer, refractory (increased thermal conductivity) materials

Overview of Existing Work:
The identified problem areas are receiving attention as follows:

- Closed cycle Plasma $0.7M (76) Systems Studies
- The major contractor in closed cycle is the General Electric Company (Valley Forge Space Center)

Priority Rank	Topic
A	• Materials Development Develop materials for electrodes, preheaters, heat exchangers, and magnets needed for 1800°K regime by understanding response of current materials.

The subtask panel felt the closed cycle MHD technique was a high risk approach requiring significant breakthroughs in materials technology. It could have impact in the long range picture. The budget data offered below reflect the need for basic understandings of materials behavior in MHD conditions rather than a near-term identification of an off-the-shelf material.

Budgets ($, Millions)
Materials Development -$0.15/yr to FY-80
-$0.2/yr FY-80 to FY-95
-$1.0/yr beyond FY-95

Budget Analysis
Since MHD closed cycle is a high risk area for energy, the subtask panel put a low overall priority on this technology. However, within the field itself, a need for basic materials understanding exists; thus a small materials effort of approximately $200,000 per year is suggested.

General Discussion:
The national MHD program stresses the fact that the development of durable materials systems for MHD is one of the most important issues facing MHD power generation. Since combined MHD cycles promise efficiencies of up to 65%, an intense effort to study MHD materials problems and develop durable materials should be undertaken. The critical areas are the electrode system, channel materials, heat exchangers and combustor materials. It appears that closed cycle MHD will not provide a significant portion of energy requirements until after the year 2000.

References:
Ref. 1 "Creating Energy Choices for the Future" ERDA-48 Vol. 2, July 1975

Acknowledgements:
C. S. Cook, G.E. - Valley Forge

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Materials Development	69	100	160	100
TOTAL	69	100	160	100

Introduction:
The successful development of most fossil energy processes will depend on the ability of materials to withstand adverse operating conditions. In addition, gas process efficiencies, e.g., for gas and steam turbines, can be significantly increased by going to higher operating temperatures. To achieve these objectives, the materials technology base must be expanded. The primary goals in **Supporting Research (Applied)** on mechanical and physical properties are to evaluate materials performance in operating plants and to correlate with laboratory materials performance on properties such as:

- Tensile
- Creep/stress rupture
- Fatigue
- Notch sensitivity
- Density
- Electrical resistivity
- Thermal conductivity
- Thermal expansion

Overview of Existing Work:
The following work is underway as scheduled:

- Metallic Cladding Effects on Fracture Toughness: $0.3 FY 76
  Sponsor: ERDA
  Contractor: ORNL
- Technical Assessment of Coal Conversion Pressure & Piping Materials: $0.3 FY 76
  Sponsor: ERDA
- Effects of Gas Pressure & Comp. on Stability of Monolithic Refractories: $0.2 FY 76
  Sponsor: ERDA
- Thermal Condition of Multicomponent Refractory Lined Process Vessel Walls: $0.4 FY 76
  Sponsor: ERDA

Priority Rank:	Topic
A	• Materials Performance-Mechanical Properties Evaluate materials performance in operating plants and correlate with laboratory materials performance on mechanical properties such as tensile, creep/stress rupture, fatigue (e.g., slow cycle, high cycle, thermal fatigue, fracture toughness, notch sensitivity and crack growth.
A	• Materials Performance-Physical Properties Evaluate materials performance in operating plants and correlate with laboratory materials performance on physical properties such as density, electrical resistivity, thermal conductivity and thermal expansion.

Budget ($ Million)
Mechanical Properties - $1.15/yr to FY 80
Physical Properties - $0.50/yr to FY 80

Budget Analysis
The suggested budget contains significant funding for activities that form the data base for correlations between plant performance and small-scale laboratory tests. Such data are lacking for coal conversion plants and for fluidized bed combustors but are critically needed.

General Discussion:
The properties of currently available materials limit essentially all energy technologies. Therefore, in order to attain the nation's energy goals, it is essential that the materials technology base be rapidly accelerated so as to understand the determinants of the limiting properties and to identify approaches for overcoming present limitations.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Mat'ls Performance - Mech. Prop.				
Cladding Effects on Fracture	800	80	450	27
Monolithic Refractories	200	20	200	13
Correlate with Laboratory	nil	—	500	30
Mat'ls Performance - Phys. Prop.	nil	—	500	30
TOTAL	1,000		1,650	

Introduction:
The successful development of most fossil energy processes will depend on the ability of materials to withstand adverse operating conditions. In addition process efficiencies, e.g., for gas and steam turbines, can be significantly increased by going to higher operating temperatures. To achieve these objectives, the materials technology must be expanded. The primary goal in Supporting Research (Applied) on corrosion, erosion and wear is to evaluate materials performance in performing plants and to correlate with laboratory performance the effects of:

- Corrosion
- Stress corrosion
- Erosion
- Wear
- Hydrogen embrittlement

Overview of Existing Work:
The following work is underway as scheduled:

- Materials for the Gasification of Coal: $0.8M FY 76
  Sponsor: ERDA
  Contractor: IITRI
- Inspection Techniques for Wear & Process-Resistant Coatings: $0.1M FY 76
  Sponsor: ERDA
  Contractor: ORNL
- Compatibility of High Temperature Alloys in Gasification
  Environments: $0.15 FY 76
  Sponsor: ERDA
  Contractor: Metals Property Council & Other Contractors
- Evaluation of Materials for Application to Conversion Systems on Coal
  Sponsor: ERDA
  A. Open Cycle Turbines $0.3M FY 76
     Contractor: G.E.
  B. Electric Power Plant Systems $0.3M FY 76
  C. Boilers $0.3M FY 76

Priority Rank: Topic

A • Materials Performance
Evaluate materials performance in operating plants and correlate with laboratory performance the effects of:
-Corrosion (e.g., oxidation, hot and chemical corrosion)
-Stress corrosion
-Erosion
-Wear
-Hydrogen embrittlement

Budget ($ Million)
Materials Performance -$2.4/yr to FY 82

Budget Analysis

This budget represents the single most important set of activities in the materials area, namely, acquiring performance data on state-of-the-art materials in operational coal conversion and utilization plants.

General Discussion
The activities in this area represent evaluations of state-of-the-art materials in coal conversion environments. These data do not exist. The nearest similar regime of operation is the high temperature turbine. That operational environment is much simpler because the fuels meet rigid specifications. Testing is needed to determine materials behavior in the variety of environments to be expected in coal conversion.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Materials Performance Topics				
Materials for the Gasification of Coal	800	48	1000	42
Inspection Techniques for Wear and Process-Resistant Coatings	100	6	250	11
Compatibility of High Temperature Alloy in Gasification Environments	150	10	225	9
Evaluation of Materials for Application to Conversion Systems on Coal				
A. Open Cycle Turbines	300	18	450	19
B. Electric Power Plant Systems				
C. Boilers	300	18	450	19
TOTAL	1,650	100	2,375	100

Introduction:
The successful development of most fossil energy processes will depend on the ability of materials to withstand adverse operating conditions. In addition process efficiencies, e.g., for gas and steam turbines, can be significantly increased by going to higher operating temperatures. To achieve these objectives, the materials technology base must be expanded. The primary goals in Supporting Research (Applied) on materials development include developing:

- High temperature, high strength materials
- Wear resistant materials
- Materials to combat corrosion/erosion/wear
- Materials resistant to hydrogen embrittlement
- Improved filter aid materials for separation of ash from coal-derived fuels
- Fire-retardant fabrics

Overview of Existing Work:
The following work is underway as scheduled:

- Materials Research for Coal Gasification Processes: $0.7M FY 76
  Sponsor: ERDA
  Contractor: Argonne
- Materials for Coal Conversion-Synthane Plant: $1.8M FY 76
  Sponsor: ERDA
  Contractor: BOM
- Feasibility Study on Prestressed Concrete Pressure Vessels: $0.1M FY 76
  Sponsor: ERDA
  Contractor: ORNL

Overview of Existing Work (continued)

- Substitution for Critical Alloying Elements: $0.5 FY 76
  Sponsor: ERDA
  Contractor: LSMC-INCO
- Lock Hopper Valve Development: $0.2M FY 76
  Sponsor: ERDA

Priority Rank:	Topic
A	• Structural Materials -Develop new high temperature, high strength materials -Develop improved wear resistant materials -Develop materials with improved corrosion/erosion/wear resistance -Develop materials resistant to hydrogen embrittlement
A	• Filter-Aid Materials -Develop improved filter aid materials for separation of ash from coal-derived liquids
A	• Fabrics -Develop fire-retardant fabrics
B	• Catalysts -Develop sulfur-tolerant hydrogenation catalysts

Budget ($ Million)
Structural Materials - $2.1/yr to FY 80
Filter-Aid Materials -$1.0/yr to FY 80
Fabrics -$0.1/yr to FY 78
Catalysts -$1.0/yr to FY 80

Budget Analysis

The budget follows that of the Materials and Components Group in Fossil Energy Research except that this budget contains supplemental work in filter and materials (for coal liquefaction) and fire-retardant fabrics (for coal conversion). The latter is responsive to safety issues already in effect in mining and soon to be felt in coal conversion technology.

General Discussion:
The properties of currently available materials limit essentially all energy technologies. Therefore, in order to attain the nation's energy goals, it is essential that the materials technology base be rapidly accelerated so as to understand the determinants of the limiting properties and to identify approaches for overcoming present limitations.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Structural Materials				
Materials Research for Coal Gasification Processes	700	22	1,050	25
Materials for Coal Conversion - Synthane Plant	1,800	55	2,000	49
Feasibility Study on Prestressed Concrete Pressure Vessels	100	3	50	1
Substitution for Critical Alloying Elements	500	15	500	12
Lock-Hopper Valve Development	150	5	200	5
Structural Materials Development	nil		100	2
Filter-Aid Materials	nil		100	2
Fire-Retardant Fabrics	nil		100	2
Sulfur-Tolerant Hydrogenation Catalysts	nil		100	2
TOTAL	3,250	100	4,200	100

Introduction:
The successful development of most fossil energy processes will depend on the ability of materials to withstand adverse operating conditions. In addition process efficiencies, e.g., for gas and steam turbines, can be significantly increased by going to higher operating temperatures. To achieve these objectives, the materials technology base must be expanded. The primary goals in Supporting Research (Applied) on materials failure analysis include:

- Establishing ongoing and continuing programs to collect and identify failure modes and mechanisms in existing hardware used in current coal conversions and coal utilization devices.
- Providing an operational data base for an integrated plant reliability/maintainability assessment.

Overview of Existing Work
The following work is underway as scheduled:

- Materials and Components-Oriented Newsletter: $0.1M FY 76
  Sponsor: ERDA
  Contractor: Battelle
- Valves Compatible with Gasifier Plant Conditions: $2.0M FY-76
  Sponsor: ERDA

Priority Rank	Topic
A	Failure Criteria Establish ongoing and continuing programs to collect data and identify failure modes and mechanisms in existing hardware used in current coal utilization devices.
A	Data Base Provide an operational data base for an integrated plant reliability/maintainability assessment.

Budget ($ Million)

Failure Criteria	$4.5/yr to FY-85
Data Base	$3.1/yr to FY-95

Budget Analysis

This budget provides for the failure analysis reporting system instituted at ERDA for new coal technology plants and for the valve compatibility work needed for high pressure gasifiers. This effort is crucial because it forms the basis and direction for any material improvement program.

General Discussion:
Failure analysis and reporting techniques were proven effective in the space program and, for an unmanned mission, their cost was a mere ~0.1% of the total project cost. Failure analysis reporting forms the basis for assessing the reliability of an integrated commercial scale coal conversion plant or an advanced combustion utility plant. Existing data are virtually non-existent but are critically needed for two reasons:

- The availability factor of existing fossil energy plants is far too low (~60%) and must be improved (Ref. 1.)
- The longest continuous run in a coal conversion plant is ~400 hours. This is far shorter than ~25,000 hours in a typical refinery. Conversion plant reliability must be improved.

References:

Ref. 1 "A Report of Improving the Productivity of Electric Powerplants" Prepared by FEA Interagency Task Force on Powerplant Availability, March 1975.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Failure Criteria Topics				
Materials & Components-Oriented (Newsletter)	100	5	150	2
Valves Compatible with Gasifier Plant Conditions	2,000	95	3,000	39
Collect and Identify Failure Modes and Mechanisms in Existing Hardware	nil		3,000	39
Establish Failure Criteria	nil		500	7
Data Base				
Provide Operational Data Base for Integrated Plant Relaibility/Maintainability Assessment	nil		1,000	13
TOTAL	2,100	100	7,650	100

Introduction:
The successful development of most fossil energy processes will depend on the ability of materials to withstand adverse operating conditions. In addition, process efficiencies, e.g., for gas and steam turbines, can be significantly increased by going to higher operating temperatures. To achieve these objectives, the materials technology base must be expanded. The primary goals in Supporting Research (Applied) on materials quality assurance include:

- Development of test procedures correlatable to fossil energy plant operations.
- Development of in situ continuous monitoring nondestructive inspection techniques.

Overview of Existing Work:
The following work is scheduled:

- Filters & Cleaners: $ 0.4M FY 76
  Sponsor: ERDA

Priority Rank	Topic
A	Test Procedures Develop test procedures that can be performed in a laboratory and that correlate to fossil energy plant operations.
A	Nondestructive Inspection Develop in situ continuous monitoring nondestructive testing equipment techniques.

Budget ($ Million)
Test Procedures 0.5/yr to FY-79
1.0/yr beyond FY-79
Nondestructive Inspection 0.50/yr to FY-85

Budget Analysis

The budget is for development of laboratory test procedures needed for quality assurance in coal conversion plants. Such procedures, agreeable to buyers and sellers of coal conversion hardware, do not currently exist.

General Discussion:
A vast body of test procedures already exist for characterizing coal, minerals, and alloys. However, they do not satisfy new needs. For example, no existing standard tests exist for determination of toxic trace elements (Sb, Te, Cr, Pb, Se, etc.) in coal. Their fates are important and must be known in order to prepare environmental impact statements (Ref 1).

An extensive series of tests are needed to correlate laboratory tests with operational plant performance. This correlative procedure requires a consensus of industry experts and, in turn, requires an extensive body of background data.

References:

Ref 1. L. Lorenzi, "Environmental Considerations in Coal Conversion Processes". Paper presented at Symposium on Coal Gasification, Liquefacton, and Utilization: Best Prospects for Commercialization, U. Pittsburgh, Pittsburgh, Pa., August 1975.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Develop Laboratory Test Procedure which can be correlated to Plant Operations	400	100	500	50
Develop NDI Equipment/Techniques	nil		500	50
TOTAL	400	100	1,000	100

Introduction:
Primary metals production consumes about 8 percent of the total energy production. Demands on all materials supplies for improved energy conversion will cause the increased use of lower grade ore increasing the overall energy costs per unit of product (Ref. 1). Goals (near-and mid-term) for improvement in extractive metallurgy include:
...Develop more energy efficient processing methods...
...Develop commercial scale improvements in alternate mining methods such as in situ leaching and ocean mining.
There are no critical materials related problems per se; however, since extraction of raw materials from lower quality ores will require increasing quantities of energy the economics and mechanics of new methods of extraction should be examined.

Overview of Existing Work:
BOM's work, mostly conducted in-house, focuses on extraction of the 12 critical materials required to insure an adequate supply to meet energy needs from domestic ores, lean ores and non-conventional resources such as sea nodules and lake brines.

	FY 76 ($ million)
Extraction of critical materials (BOM)	$7.83

Priority Rank	Topic
A	• Beneficiation of Taconite using coal as fuel
B	• Extraction of metals and minerals from coal ash, spent shale and other sources for recovery of materials that are scarce, imported as needed for energy production.

Budget ($ Millions)

Beneficiation of Taconite.....$3.0 M/yr to FY 80

Extraction of scarce materials.....$11.0 M/yr to FY 80

General Discussion:
The extraction and refining of raw materials is the basis for any of the energy plants which will be built to meet the National Energy Goals. A detailed discussion of Raw Materials Processing will be found in Appendix B.

References:

Ref. 1 Materials Technology in the Near-Term Energy Program, National Academy of Sciences, 1974.

Acknowledgements:

Allan Sherman, Consultant to USBM
Andrew Prokopovitsh, DOI

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Beneficiation				
Beneficiation of Taconite using coal	1,540	20.2	3,000	22.0
Extraction Topics				
Extraction of Ni and Co from sea nodules and laterites	800	10.5	1,500	11.0
Extraction of Cu and Mn from sea nodules	1,190	15.6	3,400	24.9
Extraction of Al and Al_2O_3 from clays, dawsonite, etc.	3,200	41.9	3,700	27.1
Extraction of V from dolomite shale	100	1.3	250	1.8
Extraction of Cr, W, Ti and Cb from chromite, searles lake brines, ilmenite and carbanotite respectively	800	10.5	1,800	13.2
Extraction of CaF_2 from fluosilicic acid	---		---	
TOTAL	7,630	100	13,650	100

Introduction:
The near-term goals in refining include:
...Improve current technology to insure that sufficient ore may be processed to provide useable raw materials to build the equipment needed to meet the National energy goals... and for the mid-term include:
...Develop and demonstrate new methods of refining which allow higher utilization of the ores in a cost/energy effective manner
...Support commercial scale implementation.
The critical problems constraining refining are highly institutional but inprovement in yield and/or quality are possible from improvement in processing materials.

Overview of Existing Work:
Refining activities are included in extraction programs sponsored by USBM and largely conducted at the research stations.
Extensive R&D activity is sponsored by the major mining companies viz, Alcoa Aluminum, Kennicott Copper Company, U.S. Steel, Jones & Laughlin Steel, Johnson-Matthey, St. Joseph Lead .

Priority Rank	Topic
C	Research on more energy effective methods/processes of metal refining
C	Develop improved structural and process materials for use with refining techniques

(Other priority topics covered in Raw Materials Processing Development)

Budget Analysis
This area appears to be an extension of Raw Materials Processing (Ore treatment) and budgets could not be easily extracted from the overall subject matter.

General Discussion:
Refining methods are needed that do not require natural gas but can operate with lower quality energy.
Process modifications are needed that make better use of waste heat.
In the steel industry, improved methods are needed to produce metallurgical grade coke. Anthrecite and other coal supplies are in short supply.

Acknowledgements:

Allan Sherman, Consultant to USBM
Andrew Prokovopitsh, DOI

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Programs on Refining are part of work on extraction.				

Introduction:
Although the fabrication of raw materials is not an ERDA goal per se, the subject has been mentioned in almost all of the coal conversion studies as being a major technology area which must be pursued if ERDA is to reach its near- and mid-term goals.
The major constraints, which are institutional in nature, that impact ERDA goals are:

- Domestic capacity to fabricate large thick sections needed in pressure vessels is severely limited.
- Proven technology does not exist to field fabricate and inspect thick-walled pressure vessels of the sizes and weights envisioned to produce economically competitive coal-derived products.

Overview of Existing Work:
This area is covered by Subtask Panel V on Conservation.
Some topics such as Pressure Vessel fabrication are covered in the area of Materials Development under Supporting Research (Applied).

Budget ($ Million)

Activities are covered by subtask panel on conservation of energy.

Budget Analysis
Since this activity should be covered by another COMAT subtask panel, no budget figures are supplied by subtask panel #1. The total for this area should be available in subtask V after the COMAT inventory has been completed.

General Discussion:
The most important activity is developing process modification, in the vast existing metallurgical private industry, aimed either at saving energy or utilizing waste heat more effectively.
The detailed R&D topic that support this general objective are discussed in Subtask V.

Acknowledgements:

Allan Sherman, Consultant to USBM
Andrew Prokopovitsh, DOI

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
No Budget Recommended				

Introduction:
The recycling of materials, i.e., the establishment of secondary materials, will be required if near-term national energy goals are to be achieved. The major constraints seen at this time which impact the goals are:

- Lack of high quality steel scrap to be used in large section pressure vessels
- Lack of technology needed to recover the alloying elements used in almost all steel manufacturing
- Lack of an efficient method to recover and reclaim non-magnetic materials from commercial and domestic waste (aluminum, copper alloys, stainless steels)

Overview of Existing Work:
EPA has an active effort in recovery of materials from municipal refuse (Ref. 1). Additional topics covered in other areas are relevent to recycling methods.
Improvement in Separation - See Liquefaction
Filters - See Liquefaction
Major industries recycle and have for years:

- Engine blocks...automotive manufactures
- Aluminum cans...Aluminum companies
- Steel scrap...All steel companies
- Titanium scrap...Turbine component suppliers
- Copper...Electrical suppliers

Budgets ($, Millions)
All topics in this activity are covered in Subpanel V, Conservation and Recovery of Materials and Energy.

Budget Analysis
This areas is covered by COMAT Subtask Panel V.

General Discussion:
The implementation of the national energy program implies a drain on specialty materials. These requirements as well as the general requirements of non-energy industry will require additional sources of materials to meet the demand. Improved recycling can provide a part of this source as well as lead to an overall economy of both resources and energy.

References:

Ref. 1. H. Alter and E. Horowitz "Resource Recovery and Utilization", ASTM Special Publication STP-592, 1975.

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Budget data are in COMAT Subtask Panel V - Conservation				

Introduction:
The entire field of scarce materials must be evaluated with respect to:

- Essentiality for the energy program
- Extent of reliance on imports and optimal uses of the resources now in hand

The near-term goals (Ref. 1) include:
...Conservation of scarce materials
...Prioritization of energy use to insure supplies of scarce materials...and
The mid-term goals include:
...Development of new alloy systems
...Substitution involving extensive redesign of present alloy systems.
There are no critical materials problems constraining the development of substitutes for scarce materials; however, the mid-term goals require early attention since there will be a long time lag in these areas of development.

Overview of Existing Work:
Most of the work in this area is currently being done by BOM with in-house funding. Topics include reduction of Cr content in stainless steels, developing coatings and claddings, developing substitute ceramics for superalloys, developing Ti and Mg alloys, etc.
DOD has active programs analyzing the effects of materials embargos on national security (Ref.1)

	FY 76 ($Millions)
BOM work on substitution	$2.39
Substitution of critical alloying elements	$0.50

Sponsor: ERDA
Contractor: LSMC-INCO

The automotive industry is actively exploring substitutes for chromium in decorative uses.

Priority Rank	Topic
A	• Supply Analysis Perform a materials demand/supply study to forecast material supplies consistent with production capabilities and competing demands.
B	• Coatings Development Develop surface coatings that decrease demand for chromium.
B	• Materials Development Development of alloy systems/ceramics which will reduce the need for critical alloying elements.

Budgets ($, Millions)
Supply Analysis - $0.20/yr to FY 79
Coatings Development - $0.505/yr to FY 79
Materials Development - $4.7/yr to FY 79
(Totals)

Budget Analysis
The budget figures presented are based on preliminary input from the Bureau of Mines and show spending plans of almost $5.5 million per year. Although the payoff for this work is not near-term the research and development must be started now to ensure that required materials (freed by substitutions) are available for the mid- and long-term. A final budget analysis must await the COMAT Inventory.

General Discussion:
Scarce materials (e.g., Co, Ni, Cr, Mn, Pt, etc.) will be required in substantial amounts as alloy additives, catalysts, coating, etc. in the construction of large plants if ERDA energy goals are to be met. Even the more abundant materials will be needed in vast tonnage quantities due to the greatly increased demand for construction and process materials that will be created. While research on substitution of scarce materials should be intense, every effort should be made to improve refining processes not only for conservation, but also to ensure the quality of the resulting product.

This task, while not of immediate critical importance except in the scarce materials area, is in keeping with national goals to effect an overall increase in energy and resource utilization.

References:

Ref. 1. Proceedings of the Department of Defense Materials Shortage Workshop, MCIC SR-75-01, January 14-16, 1975.

Acknowledgements:

Allan Sherman, Consultant to USBM
Andrew Prokopovitsh, DOI

Near-Term (FY 76 - FY 77) Budget Data

Item	Approximate FY 76 Budget ($-Thousands)	% of Total Budget	Suggested FY 77 Budget ($-Thousands)	% of Total Budget
Supply Analysis	100	4	150	3
Coatings Development	600	25	1,500	27
Mat'ls Development				
• Substitutes for Scarce Materials	500	21	---	---
• Ceramic Substitutes for Superalloys	290	12	1,000	18
• Lower Cost Ti and Mg Alloys	230	9	830	15
• Alloys with Reduced Critical Elements	720	30	2,000	36
TOTAL	2,440	100	5,480	100

COMAT

APPENDIX B

(Supplemental Input From U.S. Bureau of Mines)

RAW MATERIAL PROCESSING (ORE PROCESSING)

INTRODUCTION

The proposed energy program requires substantial tonnage of structural materials superimposed on the increasing demand already projected for American industry. These material demands are concentrated within the steel industry and, within that sector, materials able to tolerate high stresses and temperature in severely corrosive and erosive environments are already in short supply. These specialty steels require large amounts of chromium, a commodity that is wholly imported in the United States. For example, a single coal gasification plant producing 250 million cubic feet of gas per day would require 24,000 tons of steel and another 2,400 tons of special alloys containing chromium. If 30 such plants are required by 1985, some 720,000 tons of steel and 72,000 tons of special alloys, including stainless steel, will be required. Other materials essential to steel making include manganese, also wholly imported, and fluorspar, vital to both steel and aluminum production and over 80 percent imported.

A special report entitled, "Critical Imported Materials" by the Council on International Economic Policy, dated December 1974, identified the following 18 minerals and metals as being critical because of U. S. import dependence, their impact in world trade as industrial raw materials, or in the case of phosphate, their importance in providing an adequate and continuous supply of food at reasonable prices:

Aluminum	Cobalt
Chromium	Mercury
Platinum	Tungsten
Iron Ore	Lead
Manganese	Columbium
Zinc	Vanadium
Tin	Fluorspar
Titanium	Copper
Nickel	Phosphate

Of these 18 minerals and metals, 12 are critical to fossil energy utilization. The exceptions are platinum, zinc, tin, mercury, lead and phosphate. Titanium is included because it could substitute for stainless steel in applications where resistance to aqueous corrosion is important, if its cost can be reduced by further research.

Overview of Existing Work

Except for chromium, assuming cobalt can be extracted from sea nodules, the United States is blessed with abundant mineral resources for the remaining 10 materials critical to fossil energy. Consequently, the primary concern is not with the adequacy of supply, but rather with improving the technology to convert the raw rocks, soils, and fluids of the earth into processed materials. The Bureau of Mines has been performing research in extractive metallurgy for each of these critical materials and much of it is being done in cooperation with industry. This research is outlined below in the order of importance to fossil energy together with specific recommendations that are required to achieve the near-term energy goals.

Iron Ore

Domestic reserves of iron ore, mostly in the form of magnetic taconite, amount to 9 billion tons, equivalent to a 20- to 25-year supply at present rates of consumption. Domestic resources containing non-magnetic iron oxides are estimated at 100 billion tons. The main problem for the steel industry is not with iron ore supplies, but with the use of natural gas for induration (fire hardening) of the pellets required for steel making. About 44 billion cu.ft. of gas is used annually.

By 1980 the estimated annual usage is expected to be 65 billion cu.ft. Several years ago, the Bureau of Mines initiated research to study the use of bituminous and subbituminous coals for direct firing of a grate-kiln pellet induration system having a capacity of 800 pounds of pellets per hour. Satisfactory operating conditions have been found for many coals although one bituminous coal caused a ringing problem on the pellets attributed to ash formation at the firing temperature. This research should be continued and greatly expanded to include all coals and to scale-up the activity.

Manganese

The United States has substantial deposits of low-grade manganese located in Maine, Arizona, Minnesota, and Arkansas, but commercial exploitation has been uneconomical because of the low price of imported manganese and the refractory nature of the domestic deposits. However, further research is warranted in light of the demand for manganese steel for energy conversion systems.

The sea bed deposits of manganiferous nodules represent a vast new source of manganese. Several processes have been proposed for treating these nodules, but recovery has centered on copper, nickel, and cobalt. The Bureau of Mines has developed processes on a laboratory scale for extracting metals, including manganese from the calcareous deposits of the Blake Plateau in the Atlantic Ocean and from the siliceous deposits in the deep Pacific. These processes, as well as industrial processes, must be demonstrated aboard ship with land-based supporting research. An expanded program in ocean mining together with mineral processing and sea water corrosion testing of structural materials is recommended.

Chromium

A strict program of conservation and recycling is probably the most practical way to reduce the dependence upon chromium imports. Nevertheless, there are some domestic chromite deposits in Montana, as well as a small percentage in the laterites of northern California, for which extraction techniques should be developed to take care of emergencies. The Bureau of Mines has begun research to extract chromium from these deposits, and this research should be accelerated.

Fluorspar

Both the aluminum and the iron and steel industries depend heavily upon a continuing supply of fluorspar, a mineral (CaF_2) that is 84 percent imported despite the fact that we discard more fluorine than we use in processing domestic phosphate rock for fertilizer. Also, the discarded fluosilicic acid creates a pollution problem. Therefore, research is recommended to convert this waste acid into useful fluorspar. The Bureau of Mines has developed the technology for converting crude fluorspar,

and is currently developing more simplified techniques. This research should be continued and scaled-up to the pilot plant stage as quickly as possible.

Nickel

The United States imports about 73 percent of its nickel, and the deficit of payment is expected to approach $1 billion by the year 2000. The added demand by energy conversion plants will increase this deficit still further unless domestic production increases. Aside from the Pacific and Atlantic sea nodules (1.0 and 0.6 percent nickel respectively), the United States has about 7 billion tons of low-grade nickel-copper sulfide resources averaging about 0.2 percent Ni, principally as gabbro in the Minnesota area. In addition, substantial deposits of nickeliferous laterites (0.7 percent Ni) have been identified near the California-Oregon border. Promising schemes exist for extracting nickel and other metals from these deposits, but research needs to be accelerated to the pilot plant stage.

Cobalt

The sea nodules of the Pacific and Atlantic Oceans contain 0.1 and 0.3 percent cobalt, respectively. When ocean mining becomes a reality, these sea beds will become a rich source of cobalt, but current research on extracting metals from sea nodules is in the laboratory bench-scale stage. Until ocean mining becomes a reality, research to extract cobalt from nickeliferous laterites of California and Oregon 0.3 percent cobalt should be accelerated to the pilot plant stage. Also, 5,000 tons of cobalt might be recovered annually from the Missouri lead ores with research in hydrometallurgical techniques.

Aluminum and Alumina

The United States imports 90 percent of the raw material (bauxite) needed to make 34 percent of the world's aluminum. Yet there are abundant domestic resources of aluminum-bearing minerals such as clay, shale, anorthosite, alunite, and dawsonite that could be utilized to make the nation less dependent upon imports. The Bureau of Mines, in conjunction with eight aluminum producing companies, is operating mini-plants to

determine the most economical way to extract alumina from these resources. This effort should be expanded as quickly as possible to the pilot plant and then to the demonstration plant stages to establish cost data.

Columbium and Vanadium

These metals are moderately critical to fossil energy utilization. They are discussed together here because they are both important alloying elements for steel, but the dependence upon columbium, which is wholly imported, could be substantially reduced by more extensive use of vanadium as a carbide stabilizer. Approximately 40 percent of the vanadium used is obtained from imported ore, and the Nevada dolomite shales, containing 0.2 to 1 percent vanadium, represent a vast new supply. Technologies have been developed for extracting vanadium from these shales, but a commercial process does not exist. In view of the fact that currently used domestic deposits such as the Colorado Plateau uranium ores, Arkansas vanadium ores, and Idaho ferrophosphorous ores, are expected to be depleted before the year 2000, a commercial process for extracting vanadium from shale deposits should be developed. For columbium, some low-grade domestic deposits exist in carbonatites at Iron Hill and Gem Park, Colorado; Rocky Boy, Montana; Magnet Cove and Potash Sulfur Springs, Arkansas; in euxenite placer deposits at Bear Valley, Idaho and in the bauxite deposits of Arkansas. Initiation of a low-level research program to extract columbium from these deposits is recommended.

Tungsten

On a tonnage basis, tungsten is not a major commodity, but it is an important alloying element in some steels and superalloys, and it is an essential ingredient in the carbide tools vital to the mining industry. The United States imports about 50 percent of its tungsten ore, and this is expected to increase to 75 percent in a few years. There are tungsten mines in California, Colorado, and North Carolina, but a significant new source could be the Searles Lake brines of California. Half of the U. S. tungsten supply could come from these brines, and more could come from the mines if a process could be developed to handle mixed ores, especially

those containing both scheelite and wolframite. The Bureau of Mines is working on the Searles Lake brines. This, and additional research on mixed ores, should be expanded.

Copper

The United States is currently self-sufficient in copper and is not vulnerable to cartel-like action by foreign producers. However, our high-grade resources are essentially exhausted and the industry now relies on treatment of low-grade ores. Therefore, copper processing technology needs continuing research to insure an adequate supply.

Renewed interest has developed in the native copper deposits of Michigan's Upper Peninsula. This ore is costly to mine and transport to surface facilities for treatment. In situ, ammonium carbonate leaching techniques, together with the development of recovery techniques, such as ion exchange, is a fruitful area for research.

Hydrometallurgical processing as an alternative to smelting remains a fertile field of research. The Bureau of Mines has proposed several schemes for recovering copper from sulfide concentrate by hydrometallurgical techniques designed to eliminate the environmental problems associated with sulfur dioxide emissions from conventional smelting operations. Among the industrial schemes being considered or tested are the Cymet, Clear, and Arbiter processes.

Industrial and government research should be unified under a joint corporate-federal program to arrive at a earlier solution for the near-term energy program, 1985. For existing smelters, research on the double-alkali and the Bureau of Mines Citrate Processes should be accelerated in order to obtain a solution to sulfur dioxide emission problems.

A vast new source of copper exists in sea bed nodules, 0.5 percent for the Pacific Ocean Nodules and 0.1 percent for the nodules on the Blake Plateau, in the Atlantic Ocean. Efforts to obtain these nodules and to recover their metal contents should be greatly accelerated.

Titanium

Titanium metal is made from rutile, but resources of this mineral are fast becoming depleted. The United States has abundant deposits of ilminite, an iron-titanium mineral, and technology exists for extracting titanium from it, but not without pollution caused by ferric chloride formation. The Bureau of Mines is developing a pollution-free process, and this research should be scaled up to the pilot plant stage. Research should be accelerated on extracting titanium from other potential sources such as low grade sands, consolidated rock-type ore, and titaniferrous magnetite. Low-cost casting techniques should be developed for less than aircraft-quality titanium valves and tees so that titanium can be substituted for stainless steels.

APPENDIX C

R&D Topics

(Supplemental Input From U.S. Bureau of Standards)

The previous lists of R&D topics in materials have largely been expressed in terms of mission-oriented program objectives, e.g., development of corrosion-resistant liners for slagging coal gasifiers.

The following list contains topics that consolidate R&D activities needed to solve materials problems in several technologies at once. For example, corrosion by coal slag is a major problem in gasification, in MHD, and in direct coal combustion. This area of corrosion need not be studied separately three times if it is consolidated into a single R&D activity.

Strength & Durability of Materials

1) Determination of corrosion rates of metals and ceramics up to and above 2000°C as a function of composition, density, and alkali-containing environments; lifetime tests, post-test analyses using X-ray, SEM, ESCA, etc.

2) Effect of hydrogen embrittlement of materials as a function of composition, temperature, partial or total pressure of hydrogen and oxygen.

3) Mechanical Properties Determination of Metals. Tensile and yield strengths, fatigue limit (several frequencies), creep strength, and stress rupture as a function of composition, grain size, temperature and environment.

4) Mechanical Properties Determinations of Non-Metals (ceramics). Tensile and yield strengths, creep strength, and crack propagation properties as a function of composition, density, porosity, grain size, temperature and environment.

5) Determination of wear resistance. Effects of sliding and rolling friction in both intermittent or continuous situations.

Development of Non-Destructive Evaluation Methods

6) Development of acoustic methods.

7) Development of radiographic techniques.

8) Development of other methods (electric, magnetic, optical, etc.)

Development of Hydrogen Production

9) Hydrogen production by chemical decomposition of water 300 - 1000°C.

Catalyst Development/Evaluation

10) Development of catalysts for methanation, shift reaction, coal-steam reaction, liquefaction, etc., and the effect of poisoning and sintering.

11) Improvement of catalysts for hydrodesulfurization.

Development of Stronger Materials

12) Cermets-Determine strength and durability as a function of composition, temperature, and effects of diffusion.

13) Composites-Determine strength and durability as a function of composition, temperature, and effects of diffusion.

14) Determination of the phase diagrams of MgO, Al_2O_3, SiO_2, ZrO_2, CaO, Fe_xO_y and Cr_2O_3 in all combinations.

Effects of higher temperatures to 2000°C and above on:

15) Thermal Conductivity

16) Diffusion

17) Thermal Expansion

18) Electrical Conductivity

19) Adhesion

Extraction

20) Development and improvement of extraction techniques including magnetic separation of Fe, V, Ni, Co, Ca, Al, Cr, W, Ti and Nb.