DOE/MC-143

PROTOTYPE LOCKHOPPER VALVE TESTING AND DEVELOPMENT PROJECT TEST PLAN

By

John F. Gardner and Thomas R. Holtz

April 1981

For the

UNITED STATES DEPARTMENT OF ENERGY
Morgantown, Energy Technology Center
Morgantown, West Virginia

TECHNICAL INFORMATION CENTER
UNITED STATES DEPARTMENT OF ENERGY

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A03
Microfiche A01

DOE/MC-143
Distribution Category UC-90h

PROTOTYPE LOCKHOPPER VALVE TESTING AND DEVELOPMENT PROJECT TEST PLAN

(Major Revision of METC/R1-79/5/R-2)

by

J. F. Gardner and T. R. Holtz

April 1981

Prepared for

United States Department of Energy
Morgantown Energy Technology Center
Morgantown, West Virginia 26505

METC Project Manager
D. R. Goff
Technology Development and Engineering Division

under

Contract DE-AB21-80MC14522

by

TRW Energy Engineering Division
Morgantown, West Virginia 26505

PROTOTYPE LOCKHOPPER VALVE TESTING
AND DEVELOPMENT PROJECT CONTACTS

Plant operators and designers desiring lockhopper valve information should contact the METC personnel listed below.

Morgantown Energy Technology Center
United States Department of Energy
P. O. Box 880
Collins Ferry Road
Morgantown, West Virginia 26505

D. R. Goff, Project Manager
Lockhopper Valve Testing and Development Projects
Phone: (FTS) 923-7125, (Commercial) (304) 599-7125

R. L. Cutright, Technical Project Officer
Prototype Lockhopper Valve Testing and
Development Contracts
Phone: (FTS) 923-7294, (Commercial) (304) 599-7294

F. D. Freeburn, Acting Chief
Component Developments Projects Branch
Phone: (FTS) 923-7746, (Commercial) (304) 599-7746

J. E. Notestein, Director
Technology Development and Engineering Division
Phone: (FTS) 923-7544, (Commercial) (304) 599-7544

L. C. Headley, Acting Chief
Process Technology and Engineering Branch
Phone: (FTS) 923-7314, (Commercial) (304) 599-7314

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

PROTOTYPE LOCKHOPPER VALVE TESTING AND

DEVELOPMENT PROJECT TEST PLAN

by

J. F. Gardner[1] and T. R. Holtz[2]

FOREWORD

This document has been prepared to summarize the overall plan for testing and evaluating prototype lockhopper valves being developed by Fairchild Industries, Inc., Stratos Division, and Consolidated Controls Corporation under contract to DOE/METC. The testing effort described herein will be used to establish the capability of these valves to meet the design criteria contained in "Lockhopper Valve and System Design Criteria and Guidelines for Coal Conversion and Utilization Applications", DOE/METC/54-138.

The design criteria was based on the requirements of the Lockhopper Valve RFP 1813, analysis of those coal conversion processes that are most promising for demonstration and pioneer commercial plants, and a desire for valve life comparable with other plant equipment.

The test plan was prepared with inputs from, and in cooperation with, Morgantown Energy Technology Center personnel and is a major revision of "Prototype Lockhopper Valve Test Plan," METC/R1-79/5/R2.

---

[1] Project Manager, Valve Testing and Development Projects
United States Department of Energy
Morgantown Energy Technology Center
Morgantown, West Virginia
(Now with Xomox, Cincinnati, Ohio)

[2] Staff Engineer, TRW Energy Engineering Division
McLean, Virginia

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PROTOTYPE LOCKHOPPER VALVE TESTING AND DEVELOPMENT PROJECT TEST PLAN

1.0 INTRODUCTION

The United States Department of Energy, Office of Fossil Energy, awarded contracts in May and June 1976 respectively to Consolidated Controls Corporation (CCC) and Fairchild Industries, Inc., Stratos Division (FSD) for the development of new lockhopper valve designs. These awards were based on the evaluation of responses to a request for proposal (RFP) by the DOE Valve Source Evaluation Board. At present, these contracts are managed by the Morgantown Energy Technology Center (METC). The implementation of these contracts is identified as the Prototype Lockhopper Valve Testing and Development project. Both contracts originally included the design and fabrication of a set of prototype and a set of pilot plant lockhopper valves that would meet the severe coal conversion and utilization service conditions and could be scaled to the size required by full commercial size coal conversion and utilization plants. Subsequently, the FSD contract has been reduced in scope to include the design and fabrication of only four prototype lockhopper valves and the design activity for pilot plant valves. The prototype lockhopper valves of both contracts are tested at METC. The pilot plant lockhopper valves that are fabricated will be acceptance tested at METC and then tested in a pilot plant to be selected later. The prototype lockhopper valve testing is defined and described in this test plan.

The purpose of this test plan is to define the objectives, tests, methods, measurements, and data requirements for the evaluation of prototype lockhopper valves. The plan was used initially as a basis for test equipment design and for coordination of activities among the government and contractor organizations involved in the Prototype Lockhopper Valve Testing and Development project. As the valve designs and test system designs have progressed, the test plan has been revised to reflect the changes. In its present form, the test plan is the basis for detailed test objectives, procedures, instrumentation, and data analysis requirements.

1.1 OBJECTIVES

The overall objective of the Prototype Lockhopper Valve Testing and Development project is to evaluate the ability of the contractor-developed prototype lockhopper valve designs to operate with high reliability, long life, and low maintenance under severe operating conditions, which include the high temperature, high pressure, and solid materials exposure found in coal conversion and utilization lockhopper applications. Specifically, the detailed objectives are to:

- Evaluate the capability of contractor-developed prototype lock-hopper valve designs under simulated service conditions
- Compare prototype lockhopper valve performance with state-of-the-art design lockhopper valve performance
- Provide data for design improvements concerning
  - Leakage rates
  - Wear
  - Reliability and maintenance
  - Failure mode identification
  - Purge requirements
- Verify design improvements through operation in pilot or demonstration plants.

2.0 BACKGROUND

At the time the METC Prototype Lockhopper Valve Testing and Development project was initiated, the commercially available valves being used were not capable of reliably handling the pressures, temperatures, and solid materials associated with feeding dry coal and limestones and removing dry and wet residues (ash/slag/char) produced by many coal conversion processes. The early pilot plants tried a wide variety of valve types. The online times experienced were in the order of hours or days. The Department of Energy, through the Morgantown Energy Technology Center, initiated the Lockhopper Valve Development Program to assist industry and the government in resolving this problem. The two major efforts that evolved are the Prototype Lockhopper Valve Testing and Development and the State-of-the-Art Lockhopper Valve Testing and Development projects.

METC is DOE's lead technology center in component and valve development for coal conversion and utilization processes. The METC approach in implementing this responsibility is to:

- Develop a strong cooperative effort between industry manufacturers, the test/development project, and the coal conversion pilot/pioneer commercial project teams
- Provide adequate test facilities with realistic service conditions to acquire meaningful test data to support manufacturer's improvements in design, new designs, and verification of all design concepts
- Feedback data from the test facilities, specifically acquired to fill the needs of the manufacturer, to implement design modifications or new valve designs
- Rapidly transfer information on experience and problems with operation of valves in pilot plants and pioneer commercial plants
- Transfer materials development and testing technology to industry manufacturers, plant operators, and the private sector
- Sponsor periodic conferences/workshops to bring together industry, plant designers and operators, and testing groups, i.e., Morgantown Valve Workshops (November 1977 and October 1980).

To date, the most effective way to stimulate this cooperative effort has been through making adequate test facilities available to all members of the government/industry team. Suitable test facilities would ordinarily be prohibitively expensive for an individual manufacturer to develop. The METC valve test facilities have been designed to realistically simulate actual lockhopper service conditions. Test conditions and data acquisition can to a great extent be tailored to the valve manufacturers' needs. These test facilities therefore satisfy the valve manufacturer's need by providing a method for obtaining design verification and improvement data. They also assist in satisfying the DOE need to have commercially available process hardware, in this case lockhopper valves, that allows for successful demonstration of coal conversion processes.

The state of the art has changed since the State-of-the-Art Lockhopper Valve Testing and Development project was initiated in the 1976-77 time frame. At that time, the accepted opinion was that a valve in lockhopper service had the capability of approximately 500 cycles at no more than 500 psig per stage operating at temperatures up to 600^{o}F. Valves have now progressed to the capability on the order of a 15,000-cycle life at pressures of 1,000 psig per stage and temperatures up to 1,000^{o}F. Systems showing this level of capability have been verified in operation on the METC gasifier and at other DOE-sponsored pilot plants.

The goals of the state-of-the-art project are to demonstrate lockhopper service capability with coal, limestone, slag, char, and ash to 25,000 cycles without internal refurbishment at pressures of 1,200 psig per stage and media temperatures up to 1,600^{o}F. The goals of the prototype project are to extend lockhopper service capability with coal, limestone, slag, char, and ash to 30,000 cycles without internal refurbishment at pressures up to 1,600 psig per stage and media temperatures up to 2,000^{o}F.

Valves are being developed for four types of lockhopper service. Figure 2-1 shows the typical lockhopper valve applications and indicates where each of the four valve types may be used. The applications are further described below.

- <u>Type I Valves</u> — These are usually located at the inlet to a loading lockhopper or an injection hopper. They permit the flow of coal or other similar solid media from the feed hoppers to the

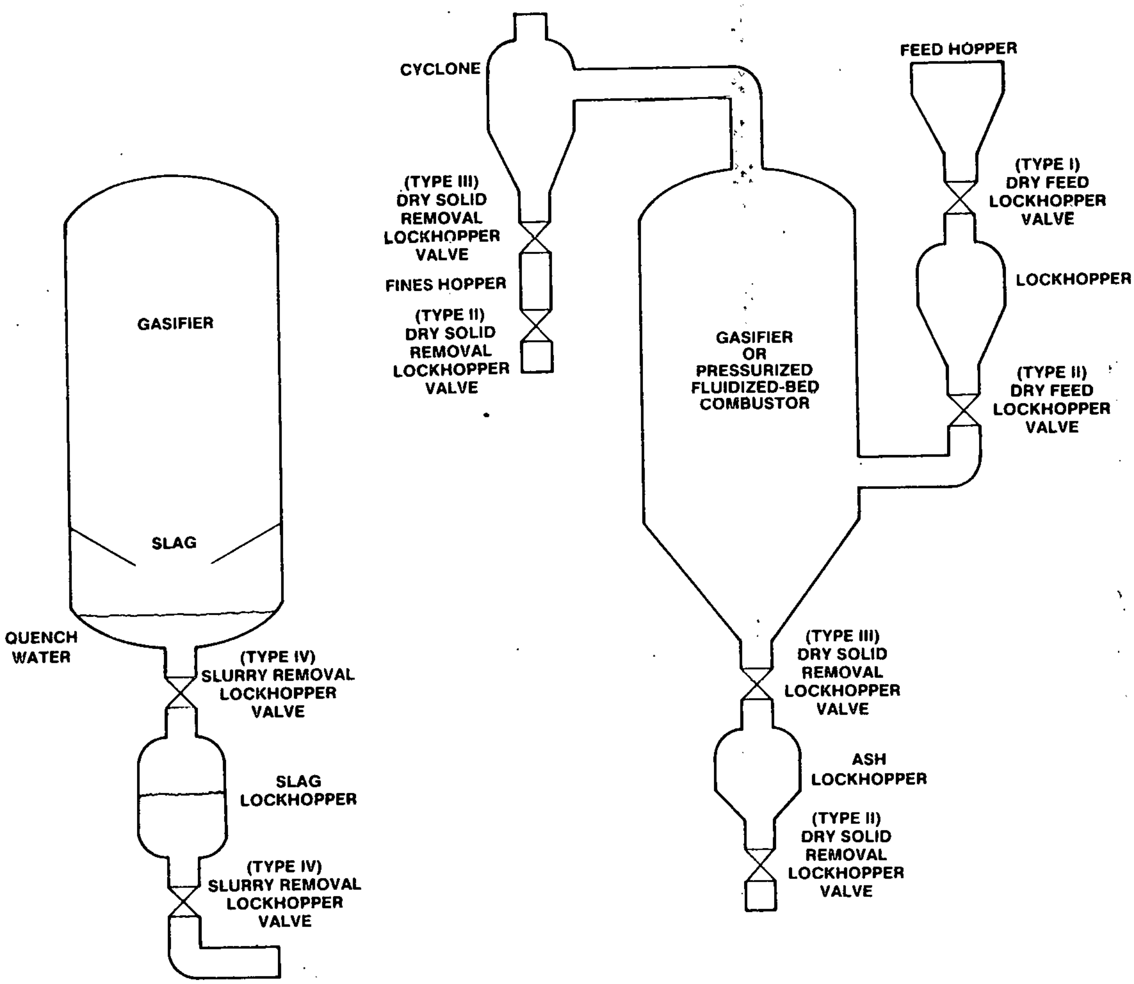


Figure 2-1. Typical Lockhopper Valve Applications for Coal Conversion and Uitlization

loading lockhoppers or from the loading lockhoppers to the injection lockhopper. They are required to operate at temperatures from ambient to 350°F and at pressures from atmospheric to 1,600 psig. Leakage requirements shall be satisfied at any pressure from 20 psig to the maximum operating pressure. They only actuate at balanced pressure, either atmospheric or operating. Solid material flows in only one direction through the valve, from inlet to outlet. The valve must seal in only one direction, which is reverse to the solids flow direction, i.e., the differential pressure is applied from outlet to inlet across the valve.

- Type II Valves — These valves are located between the loading lockhoppers and the gasifier or at the outlet of char lockhoppers. They permit flow of coal and similar solid media to enter the gasifier at pressure, and char or similar material to be discharged from the char lockhopper to atmosphere. They are required to operate at temperatures from ambient to 600°F and at any internal pressure ranging from atmospheric to 1,600 psig. Leakage requirements shall be satisfied at any pressure from 20 psig to the maximum operating pressure. They only actuate at balanced pressure, either atmospheric or operating. Solid material flows in only one direction through the valve, from inlet to outlet. The valve must seal in both directions, i.e., with the differential pressure from inlet to outlet across the valve and with the differential pressure from outlet to inlet across the valve.

- Type III Valves — These are located at the outlet of a gasifier or at the outlet of an ash lockhopper. The discharge from the gasifier is typically into an ash lockhopper. The discharge from the ash lockhopper is to atmosphere. These valves are designed to operate with media temperatures as high as 2,000°F and at internal pressures from atmospheric to 1,600 psig. Leakage requirements shall be satisfied at any pressure from 20 psig to the maximum operating pressure. They only actuate at balanced pressure, either atmospheric or operating. Solid material flows in only one direction through the valve, from inlet to outlet. The valve must seal in only one direction, which is the same as the material flow direction, i.e., the differential pressure is applied from inlet to outlet across the valve.

- Type IV Valves — These are used for slurry discharge and are located at the discharge outlet of a gasifier or slag lockhopper. They are required to operate at temperatures from ambient to 600°F and at internal pressures from atmospheric to 1,600 psig. Leakage requirements shall be satisfied at any pressure from 20 psig to the maximum operating pressure. They only actuate at balanced pressure, either atmospheric or operating. Slurry material flows in only one direction through the valve, from inlet to outlet. The valve must seal in only one direction, which is the same as the material flow direction, i.e., the differential pressure is applied from inlet to outlet across the valve.

Consolidated Controls Corporation is contracted to fabricate two nominal 8-inch diameter valves of each type for METC testing and evaluation purposes. Due to the change in scope of the FSD contract, only two valves each of Types II and III at a nominal 8-inch diameter are contracted to be fabricated for METC testing and evaluation purposes. Each contractor has a different design approach, but each contractor's design approach is similar for all valve types they are to design and fabricate.

The Prototype Lockhopper Valve Testing and Development contracts were originally segregated into three phases. Phase I consisted of conceptual design and functional analysis. During this phase, each contractor conducted design analysis and individual component testing necessary to verify its design approach. The Phase I testing was conducted by each individual contractor. These tests verified design assumptions, proved operability of unique mechanisms, obtained materials wear and hardness data, and in general obtained all necessary data and information required prior to initiation of fabrication of the prototype lockhopper valves for Phase II.

Phase II, the current phase, consists of detailed design, fabrication, and testing at METC of 8-inch valves. The previously mentioned change of scope has resulted in FSD to deliver only four values, two each of Types II and III. CCC will deliver a total of eight values, two each of all four types. The testing of the Phase II prototype valves is being conducted in the METC valve test facilities.

The final phase of each contract, Phase III, will consist of design with potential fabrication, installation, and testing of lockhopper valves in pilot plant service. CCC will design and fabricate 4-inch nomimal diameter Types I and IV valves and 12-inch nominal diameter Types II and III valves for potential installation and testing in selected pilot plants that are sponsored by the DOE. Again, due to the change in contract scope, FSD will only conduct design activities for the lockhopper valves. The results from the proof of validity of each selected design concept in Phase II will be the basis for the design of these values. The prototype designs will be revised as necessary, to improve the life of high-wear components and to facilitate simple replacement of parts by maintenance crews without special training or special tools. Design specifications, including manufacturing technology, will be developed for the valves.

METC, as previously indicated, is responsible for the State-of-the-Art Lockhopper (SOA) Valve Testing and Development project in addition to the prototype project presented in this plan. The SOA testing project is described in the State-of-the-Art Lockhopper Valve Testing and Development Project Test Plan, DOE/METC/SP-139.

Supporting research, materials evaluation, and failure analysis are being provided by the Albany Research Center (ARC) of the U.S. Bureau of Mines, Argonne National Laboratory (ANL), and Oak Ridge National Laboratory (ORNL) for both lockhopper valve testing and development projects. ARC is conducting erosion and abrasion tests on potential seat materials and evaluating the abrasiveness of various gasifier products. ANL is providing materials research and failure analysis support. ORNL is also providing materials consultation and failure analysis support.

The remainder of this plan describes the METC Prototype Testing and Development project. Section 3.0 presents an overview of the project and introduces the overall test sequence and its component tests. Section 4.0 describes the four test units and presents test conditions and test data for each test sequence. Section 5.0 summarizes the documentation related to the project, while Section 6.0 describes project reviews. Section 7.0 presents the bibliography that supported the development of this test plan.

3.0 PROTOTYPE PROJECT OVERVIEW

The Prototype Lockhopper Valve Testing and Development project is a U.S. Department of Energy, Morgantown Energy Technology Center-sponsored set of contracts to develop lockhopper valves capable of operating under the severe service conditions of coal conversion and utilization plants.

The following discussion presents the project's technical objectives and a summary description of the individual test types included in the project test sequence.

3.1 PROJECT TECHNICAL OBJECTIVE

The technical objective of the Prototype Lockhopper Valve Testing and Development project is to verify, through Phase II and III test sequences, prototype lockhopper valves with the capability of fulfilling the following service criteria:

- Pressures of 1,600 psig per stage of lockhopper
- Media temperatures to 350°F for Type I, 850°F for Type II, 2,000°F for Type III, and 600°F for Type IV
- Operating life of 30,000 cycles without internal refurbishment
- Initial internal leakage of less than 1.0 scfm per inch of nominal bore size
- Internal leakage at end of operating life less than 3.0 scfm per inch of nominal bore size
- External leakage at end of operating life less than 0.1 scfm
- Valve actuation time less than 30 seconds with no shock
- Valve operating force/torque - repeatable and within the rated limits of the supplied actuator.

3.2 PROJECT TEST SEQUENCE

The Prototype Lockhopper Valve Testing and Development project is conducted according to the sequence shown in Figure 3-1. The formal acceptance tests and related inspections are conducted at the valve manufacturer for all valves. Upon receipt at METC, the valves are visually inspected for shipping damage without disassembly. All documentation is also reviewed and accepted at this time. Baseline leakage rate, actuation time,

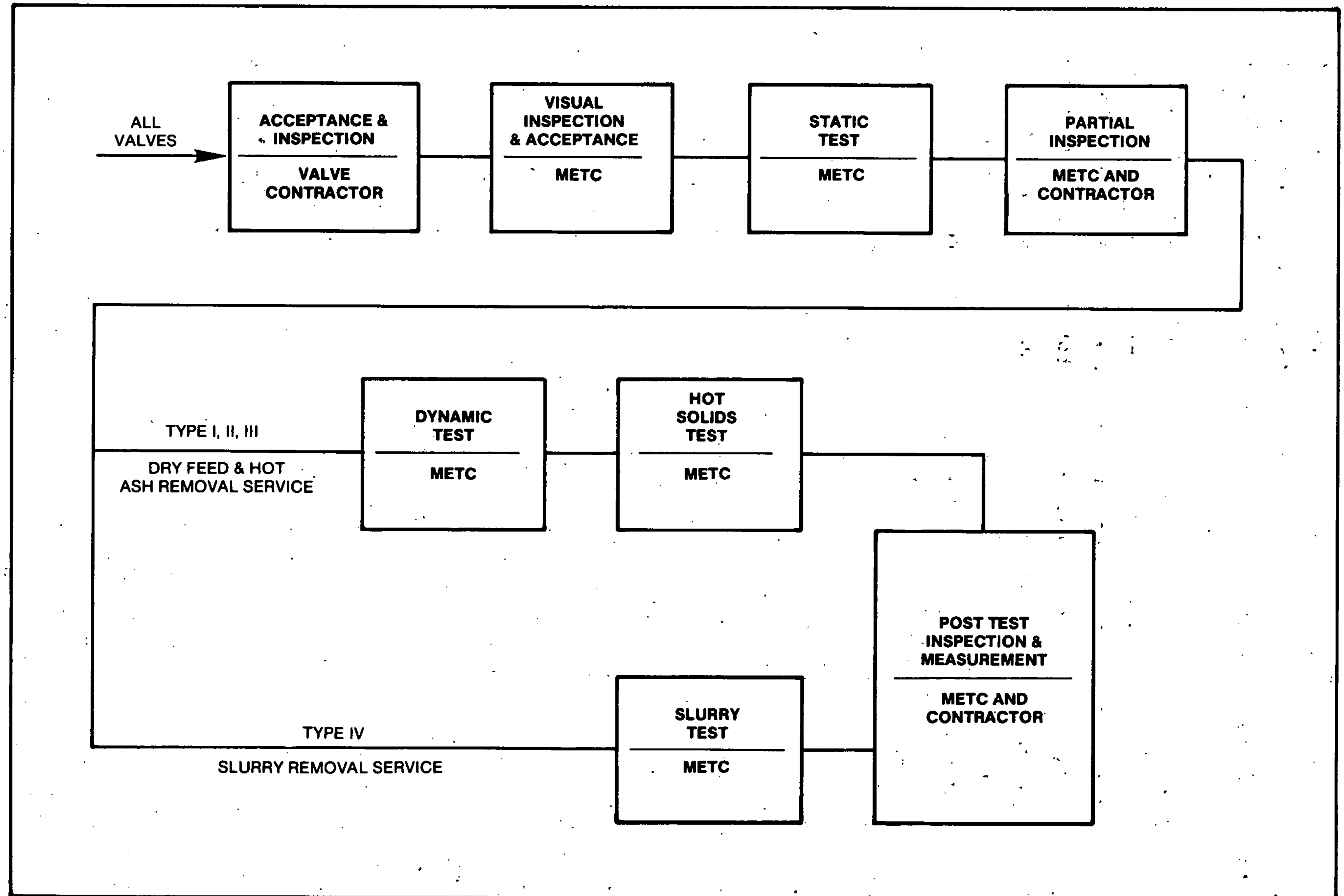


Figure 3-1. Prototype Lockhopper Valve Testing and Development Project Test Sequence

and operating force measurements are verified during the static test series, which is conducted on all valve types. Upon successful completion of the static test series, each valve undergoes a visual inspection to ensure no damage has occurred to components and surfaces accessible without disassembly. Test valves designated for dry feed and/or dry ash removal service (Types I, II, and III) participate in the dynamic test series. This test series subjects the valves to solids under simulated coal feed service conditions of solids and pressures at ambient temperatures. Valves that successfully complete these tests have the hot solid test series conducted to experience the conditions of solids and pressure with elevated solids temperature. Valves intended for water slurried slag or ash removal (Type IV) lockhopper valve service experience the slurry test series after successful static test series. Upon completion of the specific test sequence for the particular service, each valve undergoes a post-test metrology inspection and evaluation to determine the effects of testing on the critical internal components. If a valve experiences failure during any of these tests, a detailed inspection and analysis is typically conducted to determine the causes and recommended solutions. Depending on the situation, this may be accomplished either at the valve manufacturer's facility or METC.

The following portions of this section present more details on the objectives, test requirements, and success criteria of each of the portions of the test project. This and subsequent sections of this test plan provide only general summary descriptions of the tests and test units. Detailed test procedures have been prepared and should be referred to for specific information on each test unit of this project.

3.2.1 Acceptance Test and Inspection

The objective is to verify that the valve meets the specified performance and dimensional requirements prior to shipment to METC. The valve manufacturer will conduct the testing required by the applicable contract and will prepare all required documentation. This documentation will certify test results, valve critical dimensions, valve configuration, and all items required by the contract.

3.2.2 Receiving Inspection and Acceptance

The objective of the METC visual inspection and acceptance is to verify that the valve is ready for testing. The visual inspection conducted without disassembly is to assure that no damage to accessible surfaces and components has occurred during shipment. Accompanying documentation is also inspected for completeness and accuracy. The success of this step is compliance with performance criteria, any additional test criteria, proper and accurate documentation, and configuration.

3.2.3 Static Test

The objective of this test series is to determine baseline leakage, internal and external, response time, and operating force data with a dry gas medium from atmospheric to rated pressure, 1,600 psig, at ambient to elevated valve body temperature. This series will determine the effect of pressure and temperature on external leakage, internal leakage, operating force, and actuation time.

The requirements of the static test series call for approximately 500 test valve cycles. These are achieved through automatic sequences interspersed with leak test series. The automatic sequences consist of 75 to 150 test valve cycles (25 to 50 automatic cycles of the VSTU itself). Each valve cycle is closed to open to closed. The test valve is operated only with a balanced pressure across the closure member (either atmospheric or higher). Each time the test valve is in the closed position during an automatic test sequence, a differential pressure (i.e., test pressure) is applied across the closure member. The operations performed during a sequence simulate the various conditions of pressure and actuation that can occur in a valve in lockhopper service while also working (i.e., ageing) the valve. Sequences are performed with the valve body at ambient temperature, one or more intermediate temperatures, valve rated temperature up to the facility capability, and again at ambient temperature. Type I valves are tested to 350°F; Types II and III tested to 850°F, the facilities capability; and Type IV tested to 600°F. At each temperature level, a leak test series consisting of actuation time, operating force, external leakage, and internal leakage measurements is obtained at the beginning and conclusion of each sequence. The leak test series is described further in Section 3.2.7. The medium for these tests is clean dry air or nitrogen, determined by the pressure requirements of the individual valve.

The test is successful if the criteria specified in Section 3.1 and the applicable contract are met. Since the valve has been cycled only in clean, non-corrosive gases, no degradation in performance is expected, so the criteria for initial leakage still applies. The exact operating force criteria is provided in the valve specification. If these performance criteria are exceeded, the valve will be disassembled, inspected, and measured as required to determine the cause of the failure.

3.2.4 Dynamic Test

The objective of this test series is to determine performance capability, leakage, actuation time, and operating force, while operating with solid media and the valve body at ambient temperature. This test series will determine the effect of operating pressure, solids hardness, and particle size distribution independent of temperature on performance parameters of the Types I, II, and III valves.

The dynamic test series exercises the valve for approximately 8,000 total operating cycles. A cycle is defined as opening the valve under a head of material, the material flowing through the valve, closing the valve with possible intermittent flow of solids, establishing a differential pressure across the valve, venting the pressure, and accumulating a new head of material. The test material is dolomite, limestone, silicon carbide, or aluminum oxide of selected particle size distributions. Subseries of 250 to 500 cycles are conducted at rated and intermediated pressure levels, ambient and optional elevated valve body temperatures, different particle size distributions, and, possibly, various materials. Baseline performance data is obtained by performing a leak test series before the test, after each subseries at ambient temperature, and at the conclusion of the test. These baseline performance data are internal and external leakage, valve actuation time, and valve operating force. Control of particle size distribution is maintained by periodic sampling and replenishment to achieve acceptable distributions.

The test is considered successful if the criteria specified in Section 3.1 and the applicable contract are met. If these valve performance criteria are exceeded, the valve will be disassembled, inspected, and measured as required to determine the cause of the failure.

3.2.5 Hot Solids Test

The objective of this test series is to determine the performance capablity, leakage, actuation time, and operating force, while operating with heated solid material. This series will determine the effect of pressure, media hardness, and particle size distribution with heated media on valve performance parameters.

The requirements of the hot solids test series are very similar to those of the dynamic test series. Approximately 8,000 cycles are conducted with the same definition of a cycle as with the dynamic test. The test material is dolomite, limestone, aluminum oxide, or silicon carbide of selected size distributions and is heated in a fluid bed heater. The significant difference in these tests is the heated media. Therefore, the additional parameter varied with the 500-cycle subseries is media temperature. An intermediate and rated temperature subseries is run at intermediate and rated 1,600 psig pressures. The valve may require controlled preheating and cooling for these tests. As with the dynamic tests, leak test series are performed periodically during the testing. The media size distribution is controlled as in the dynamic testing.

The test is successful if the criteria specified in Section 3.1 and the applicable contract are met. If these performance criteria are exceeded, the valve will be disassembled, inspected, and measured as required to determine the cause of the failure.

3.2.6 Slurry Test

The objective of this test series is to determine the performance capability, leakage, actuation time, and operating force, while operating with a water solids slurry. This test series will determine the effect of operating pressure and percent by weight solids in slurry mixture on valve performance parameters. It is a simulation of lockhopper valve ash/slag water slurry removal service such as encountered on slagging gasifiers and conducted only on Type IV valves.

The requirement of the slurry test series is to conduct approximately 8,000 total operating cycles. A cycle for a pressurized series consists of filling the slurry charge tank; pressurizing test sections on both sides of the test valve, including the full slurry charge tank; opening the test valve; allowing time for slurry to flow through test valve; closing the valve; depressurizing; opening the system valves to remove slurry; and pumping a new charge of slurry to the charge tank. The slurry is a mixture of water and limestone at various percentages by weight of limestone. Subseries of approximately 250 cycles are conducted at several pressure levels from atmospheric to rated pressure, ambient and slightly elevated slurry temperatures, and several slurry mixtures. Baseline performance data are obtained at the beginning and end of the test and between each subseries. These data are internal and external leakage, valve response time, and valve operating force.

The test is successful if the criteria specified in Section 3.1 and the applicable contract are met. If these performance criteria are exceeded, the valve will be disassembled, inspected, and measured as required to determine the cause of the failure.

3.2.7 Leak Test Series

The objective of the leak test series is to determine the performance parameters of the test valve over the range of specified pressures and at the specified test conditions. These series are conducted in conjunction with the static, dynamic, hot solids, and slurry test series.

The requirement is to conduct leak tests before, during, and after the static, dynamic, hot solids, and slurry tests previously described. The leak tests are conducted every 75 to 500 cycles as specified in the individual valve test plan. Static test series have leak test series every 75 to 150 valve cycles, while the dynamic, hot solids, and slurry units perform leak tests every 250 to 500 valve cycles. Leakage measurements are obtained from pressure decay and flowmeter techniques. Internal leakage (i.e., valve seat) is obtained over a range of pressures to the valve rated pressure. The initial pressure during static tests is 50 psig, followed by 100 psig, and additional 100 psig increments to rated pressure. Dynamic, hot solids, and slurry testing start at 100 psig followed by 100 psig increments to rated valve pressure. External valve stem leakage is measured with the valve open at rated pressure only. The data is converted to standard conditions by temperature and pressure factors. The pressurization gas is air or 99 plus percent nitrogen depending upon pressure requirements, nitrogen to 1,200 psig (600 psig in the slurry tests), and air to 2,500 psig. In conjunction with the leakage test, measurements are made of the actuation time and operating force of the test valve, both at atmospheric pressure and with a balanced elevated pressure.

The test is successful if internal and external leakage, actuation time, and operating forces meet the criteria of Section 3.1.

3.2.8 Post-Test Inspections

The objective of the post test metrology inspections and measurements is to provide data on the wear, degradation, and damage incurred during the METC testing. The data will be used for failure analysis activity and design improvement recommendations where failures have occurred and for projections of valve life where tests are successfully completed.

The requirement is to conduct detailed inspections of test valves before and after testing, to determine wear, degradation, or damage incurred during testing. Dimensional, photographic, and surface finish measurements are taken to provide a baseline for determination of degradation or wear and for failure analysis, if required. Measurements will be made of any critical parameter that may affect sealing performance or operating force and will include flatness, roundness, sphericity, hardness, concentricity, and alignment. Other methods of nondestructive examination are conducted, including dye penetrant and magnetic particle inspections. Extensive photo documentation provides a visual evaluation and history of test valve components. The post-test inspection and measurements will be compared to the data prepared by the valve manufacturer prior to shipment to METC.

A determination typically is made on wear, erosion, corrosion, surface deterioration, spalling, cracking, and seal area contamination, for example. These inspections, compared with those conducted at the valve manufacturer's facility, enable the extrapolation of valve life and assist in failure analysis.

4.0 METC LOCKHOPPER VALVE TEST UNITS AND OPERATIONS

The previous section presented the typical test sequence and the objectives and general test requirements of each category of test of the Prototype Lockhopper Valve Testing and Development project. This section describes the METC lockhopper test units and provides information on typical individual test operations, conditions, materials, measurements, and other characteristics of each test category.

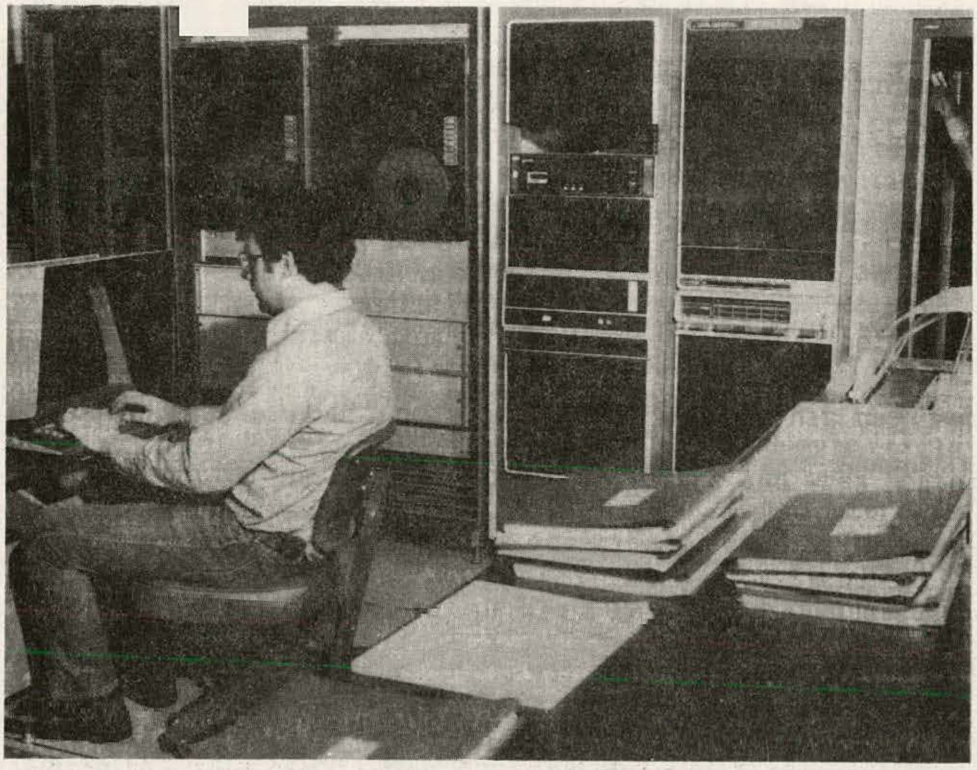
The individual tests conducted on a specific valve may vary from those described. These tests will be a function of the requirements of each valve and will be presented in the individual test plan developed for each specific valve. Modification is also possible as a valve progresses through the test sequence based on information and results obtained during testing.

The facility for static tests is the Valve Static Test Unit (VSTU); for dynamic tests, it is the Valve Dynamic Test Unit (VDTU); for hot solids tests, the Valve Hot Solids Test Unit (VHSTU); and for slurry tests, the Valve Slurry Test Unit (VSLTU). The Valve Testing-Data Acquisition and Control Center (VT-DAC) provides for data acquisition for all the test units and automatic computer control for all units. The control console for the VSTU is located adjacent to the unit; however, the VSTU utilizes the computer in the Control Center. Figure 4-1 presents two views of the VT-DAC. The metrology inspection activities are conducted in the Metrology Laboratory. Figure 4-2 is a view of the laboratory.

4.1 VALVE STATIC TEST UNIT

The Valve Static Test Unit is designed to determine the initial baseline leakage and the effects of dry cycling on the leakage (i.e., non-solid and non-slurry). A schematic of the test installation is shown in Figure 4-3. Figure 4-4 is a photograph of a SOA test valve in the VSTU.

The pressurization gas, air or nitrogen, is supplied at ambient temperature. The valves are heated by induction or resistance heaters to the temperatures required by the individual test plan. All test operations are conducted under technician-monitored computer control with the exception of operating force measurements.



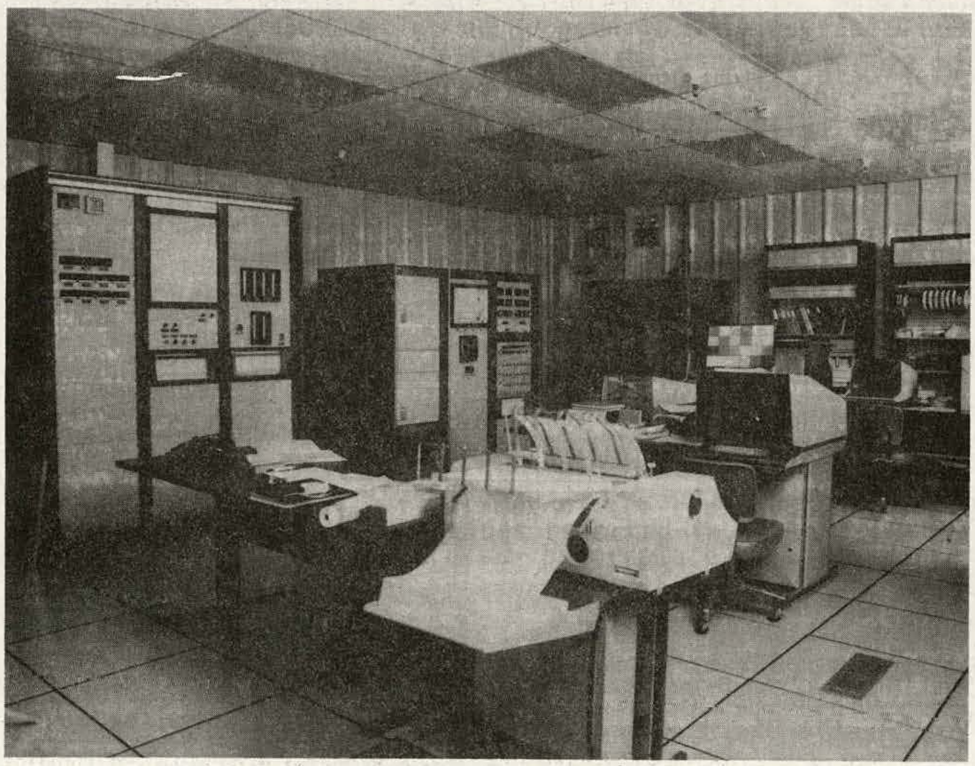


Figure 4-1. Photographs of Valve Testing-Data Acquisition and Control Center

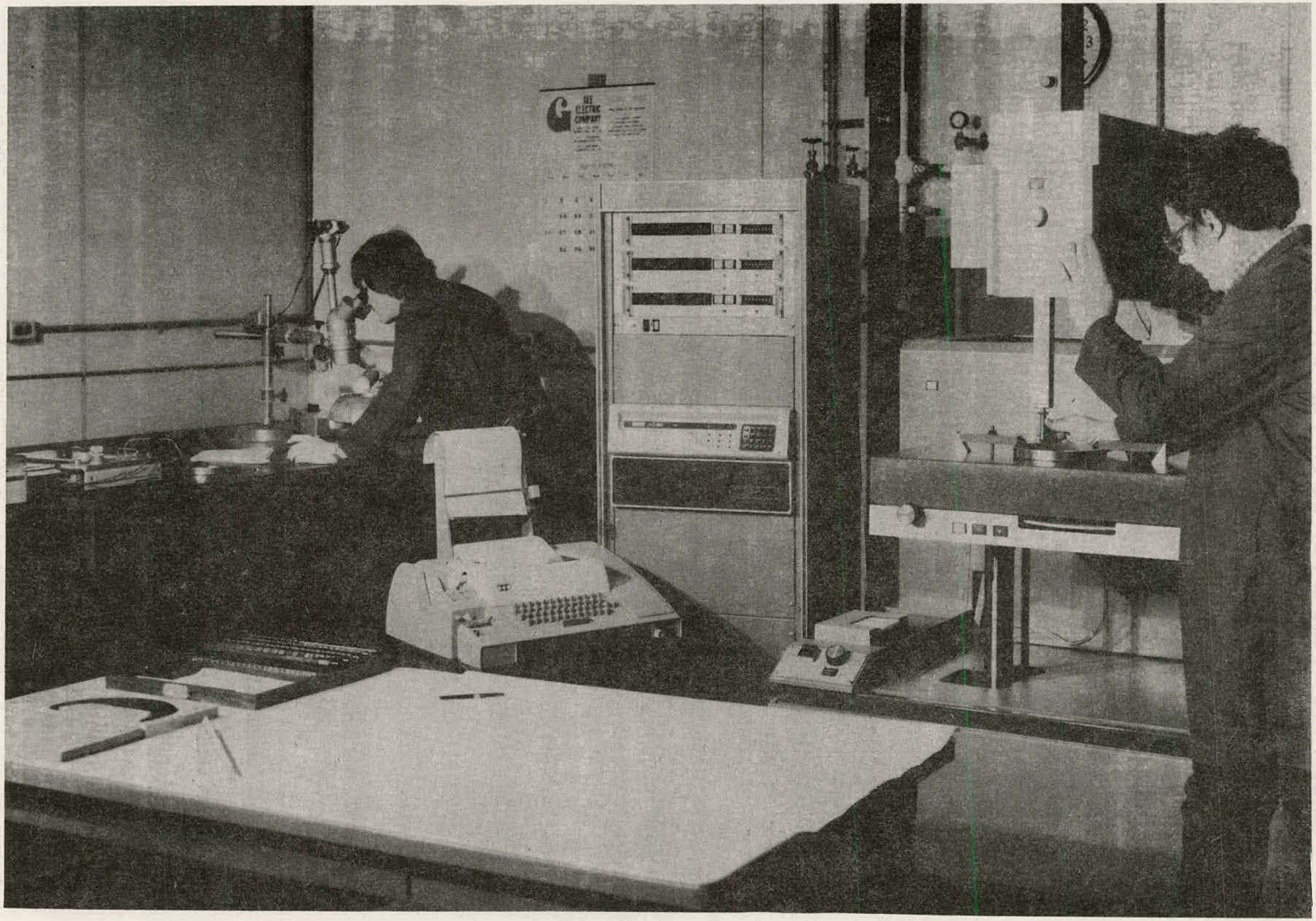


Figure 4-2. Photograph of Metrology Laboratory

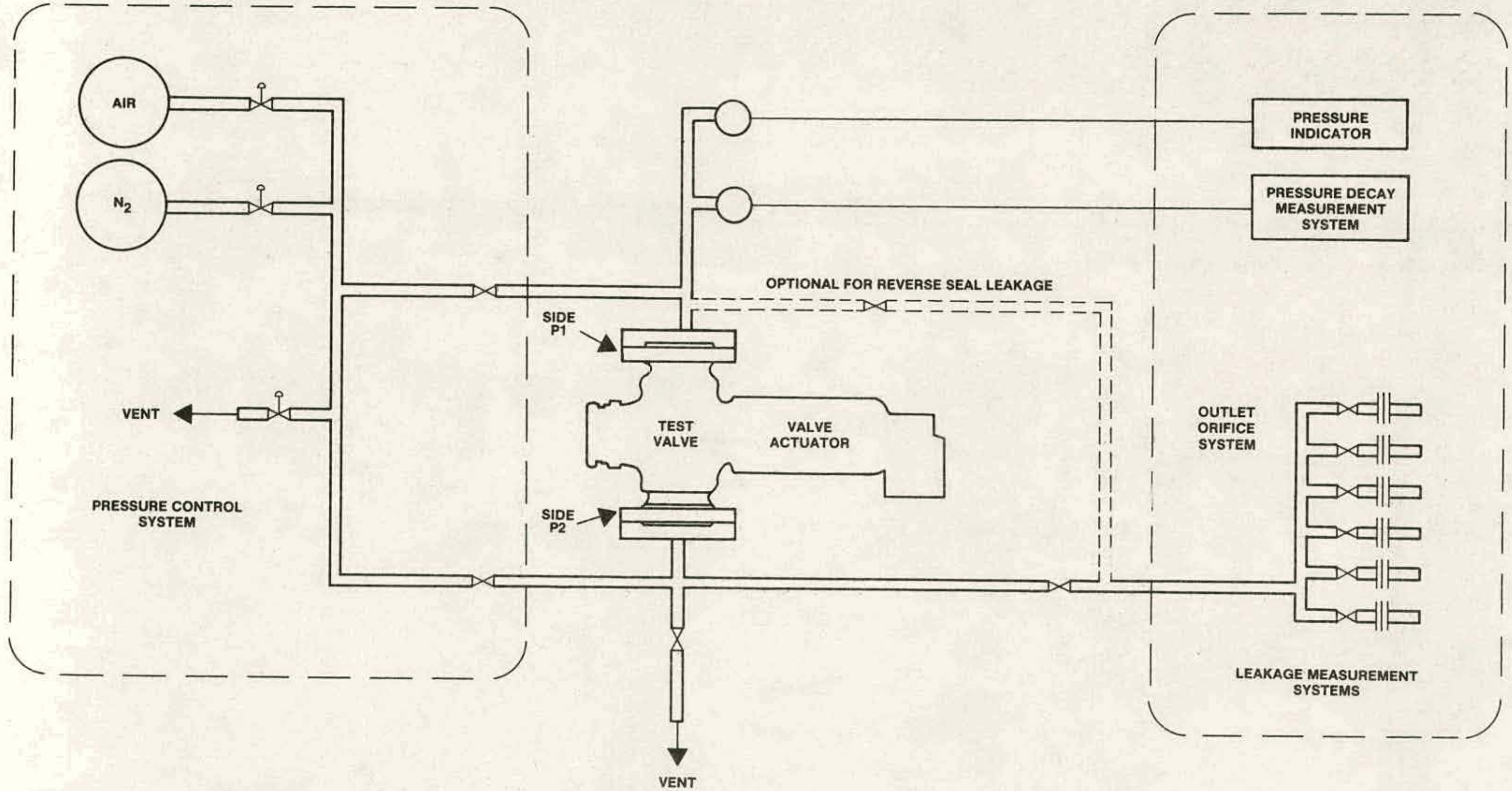


Figure 4-3. Schematic of Valve Static Test Unit Installation

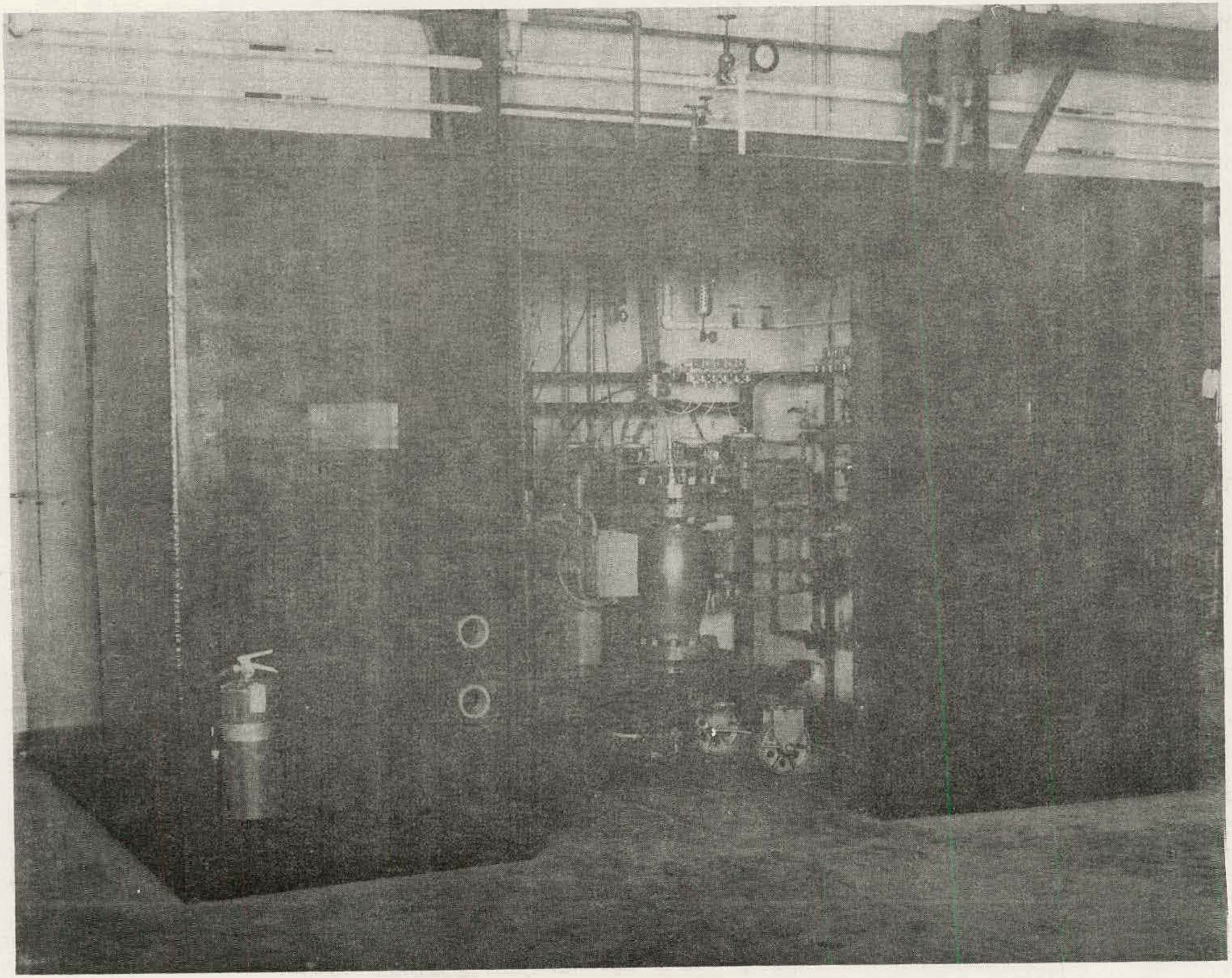


Figure 4-4. Photograph of VSTU

A typical VSTU test sequence is shown in Table 4-1. This sequence presents the typical events with estimated completion times and any pertinent remarks. For sequences at elevated valve temperature, a preheat period may be required, which is a function of required temperature and the test valve requirements, prior to the automated testing. The manual operating force measurements are scheduled with each leak test series. A major time variable is the number of automatic valve cycles during each subseries. For this test sequence, 75 valve cycles were assumed for each automatic cycle sequence.

The range of test conditions for a static test series is:

- Pressure
  - 50 psig to 2,000 psig (maximum pressure depends on valve rating)
- Valve temperature
  - Ambient to rated valve temperature (maximum of 850°F based on current experience and power limitations of heaters)
  - Intermediate value (optional).

The measured and computed data obtained from VSTU tests are:

- Internal leakage at range of pressures
- External leakage at rated pressure
- Gas temperature
- Gas pressure
- Valve body temperature
- Valve actuation time
- Valve operating force/torque
- Valve strain gage measurements (if installed).

4.2 VALVE DYNAMIC TEST UNIT

The Valve Dynamic Test Unit is designed to determine the effects of valve operation with ambient temperature solid material and pressure on valve performance and life. A schematic of the test installation with a

TABLE 4-1. TYPICAL VSTU TEST SEQUENCE

EVENT	EST. TIME-SEC	REMARKS
1. Actuation Time (Atmospheric)	10 - 60	
2. Operating Force (Atmospheric)	N/A	
3. Pressurize P1 & P2	60 - 200	
4. Operating Force (Rated Pressure)	N/A	
5. Actuation Time (Rated Pressure)	10 - 60	
6. External Leak Test	300	
7. Depressurize	120 - 140	
8. Internal Leak Test	45 - 225	45 Sec Per Test Flow-Meter Leg
9. Close Test Valve	5 - 30	
10. Automatic Valve Cycling Sequence		Assume 75 Valve Cycle (25 Auto Cycles)
— Pressurize P1 & P2	(60 - 200)	
— Open Test Valve	(15 - 90)	3 Valve Cycles.
— Close Test Valve	(15 - 90)	
— Depressurize P1 & P2	(120 - 400)	
— Accumulative Computer Pauses	(30)	
— Total 75 Valve Cycles (25 Auto Cycles)	1920 - 6960	
11. Internal Leak Test	45 - 225	
12. Auto Cycle 25/75 Valve Cycles	1920 - 6960	
13. Internal Leak Test	45 - 225	
14. Depressurize	120 - 400	
15. Repeat Events 1 Through 6	380 - 620	
16. Depressurize	120 - 400	
Total	5100 to 17065	

NOTES: (1) Assumes 25 Auto Cycle Automatic Sequences.

(2) For Elevated Temperature Tests, Preheat May Be Required at Approximately 100° F Per Hour and Cooling at 100° F Per Hour.

(3) USON Leak Test is Available as Option.

(4) CCC Type III valve shall not be depressurized at a rate greater than 1500 psi/minute.

three-valve test train is shown in Figure 4-5. The VDTU has the flexibility of operating with a two- or three-valve test train. Types I, II, and III prototype lockhopper valves are tested in the VDTU.

The top inlet valve in both test configurations simulates a feed lockhopper inlet valve while the bottom last valve in either train simulates the outlet valve of a removal lockhopper. The second valve in a three-valve train simulates, for the feed service, an inlet valve to a process reactor or combustor, or, for the removal service, the exit valve from a reactor or combustor. Figure 4-6 is a photograph of the building housing the VDTU.

Dolomite, limestone, silicon carbide, or aluminum oxide at ambient temperature is fed from a solids storage hopper into the valve test train. The test section(s) between the valves is filled with solids and pressurized with air or nitrogen with corresponding valve operation. A slide valve is used to meter the required quantity of solids into the test train so the test valves do not close while full of solids. The solid materials are recycled to the hopper for reuse. These tests are normally conducted with the test valves and solids at ambient temperature. However, the test unit can use induction heaters to elevate the valve body temperature. If this option is selected, controlled preheating and cooling may be required as determined by individual valve constraints.

The VDTU tests are composed of subseries of 500 to 1,000 cycles. Each subseries is a set of test sequences. A typical set of sequences is:

- Baseline performance data (leakage measurements at 100 psig to rated pressure, actuation time measurement, and operating force measurement)
- Automatic valve cycling
- Gross performance data (leakage measurements at a specified pressure, actuation time measurement, and operating force measurement)
- Automatic valve cycling
- Gross or baseline performance data.

The baseline performance data are obtained without solids flow and require the installation of blind flanges if only two test valves are

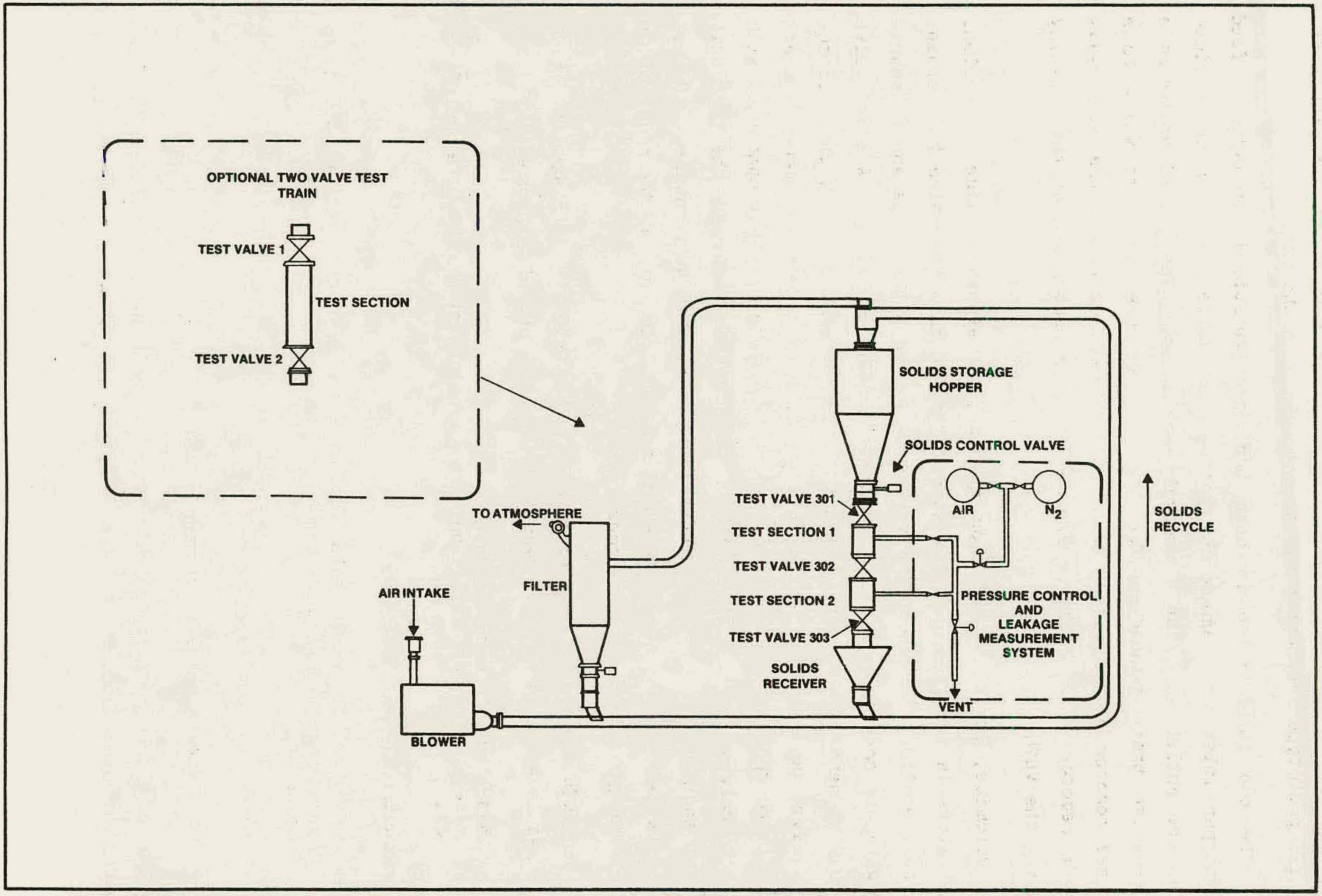


Figure 4-5. Schematic of VDTU Installation

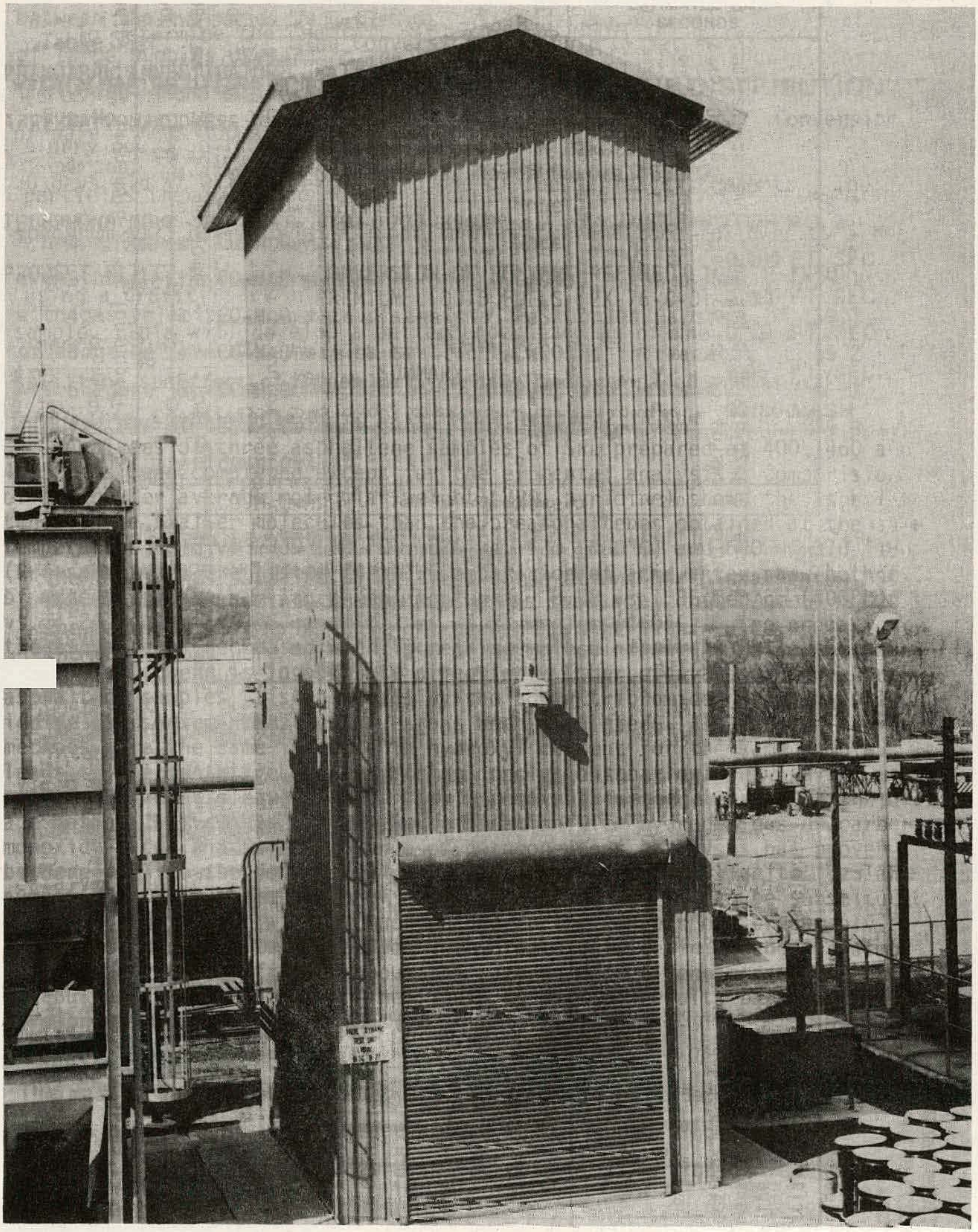


Figure 4-6. Photograph of VDTU Building

installed. Each automatic valve cycling sequence consists of 250 to 500 cycles as specified in the individual test plan. A typical automatic cycle sequence is shown in Table 4-2 for two-valve configurations and in Table 4-3 for three-valve configurations. Gross leakage is measured during each cycle. External leakage is checked periodically during the test with a leak detecting solution.

The test conditions for a dynamic test series are:

- Solids temperature - ambient
- Pressure - 100 psig to 2,000 psig (or maximum rated pressure)
- Valve temperature - ambient (optional to valve rated temperature up to 850°F flange temperature)
- Solid material - particle size distribution as specified in valve test plan
- Pressurization gas - air or nitrogen (99 percent plus).

The measured and computed data obtained from VDTU tests are:

- Leakage rate
- Valve actuation time
- Valve operating force/torque
- Gas temperature and pressure
- Valve body temperature
- Valve strain gage measurements (if installed).

4.3 VALVE HOT SOLIDS TEST UNIT

The Valve Hot Solids Test Unit is designed to simulate the cyclical flow of hot solids through lockhoppers. The test series evaluates the ability of valves to provide up to one year of service under simulated operating conditions. A schematic of the VHSTU installation is shown in Figure 4-7. Types I, II, and III prototype lockhopper valves are tested in the VHSTU. The unit has two trains for valve testing: Train A is capable of testing two prototype valves with material temperature to 2,000°F; while Train B is capable of testing a two- or three-valve set-up with material temperature to 600°F. Photographs of the solids return system and the fluid bed heater are shown in Figure 4-8.

TABLE 4-2. TYPICAL AUTOMATIC CYCLE SEQUENCE - TWO VALVE TRAIN

EVENT	ESTIMATED TIME SECONDS
1. Open Test Unit Feed Valve	15
2. Solids Flow to Test Valve 1	15
3. Close Test Unit Feed Valve	15
4. Open Test Valve 1	5 - 30
5. Solids Flow into Test Section	30
6. Close Test Valve 1	5 - 30
7. Pressurize Test Section	60 - 200
8. Gross Leak Test (every 5 cycles)	15 (75÷5)
9. Depressurize Test Section	60 - 200
10. Open Test Valve 2	5 - 30
11. Solids Flow from Test Section	30
12. Close Test Valve 2	5 - 30
Total Time Per Cycle	260 to 640

Notes:
(1) CCC Type III valve shall not be depressurized at a rate greater than 1500 psi per minute.
(2) USON leak test is available as option.

TABLE 4-3. TYPICAL AUTOMATIC CYCLE SEQUENCE - THREE VALVE TRAIN

EVENT	ESTIMATED TIME SECONDS
1. Open Test Unit Feed Valve	15
2. Solids Flow to Test Valve 1	15
3. Close Test Unit Feed Valve	15
4. Open Test Valves 1 & 3	5 - 30
5. Solids Flow into Test Section 1 & from Test Section 2	30
6. Close Test Valves 1 & 3	5 - 30
7. Pressurize Test Section 2	60 - 200
8. Gross Leak Test (every 5 cycles)	15 (75÷5)
9. Pressurize Test Section 1	60 - 200
10. Gross Leak Test (every 5 cycles)	15 (75÷5)
11. Open Test Valve 2	5 - 30
12. Solids Transfer Test Section 1 & 2	30
13. Close Test Valve 2	5 - 30
14. Depressurize Test Sections 1 & 2	60 - 200
Total Time Per Cycle	335 to 855

Notes: (1) CCC Type III valve shall not be depressurized at a rate greater than 1500 psi per minute.
(2) USON leak test is available as option.

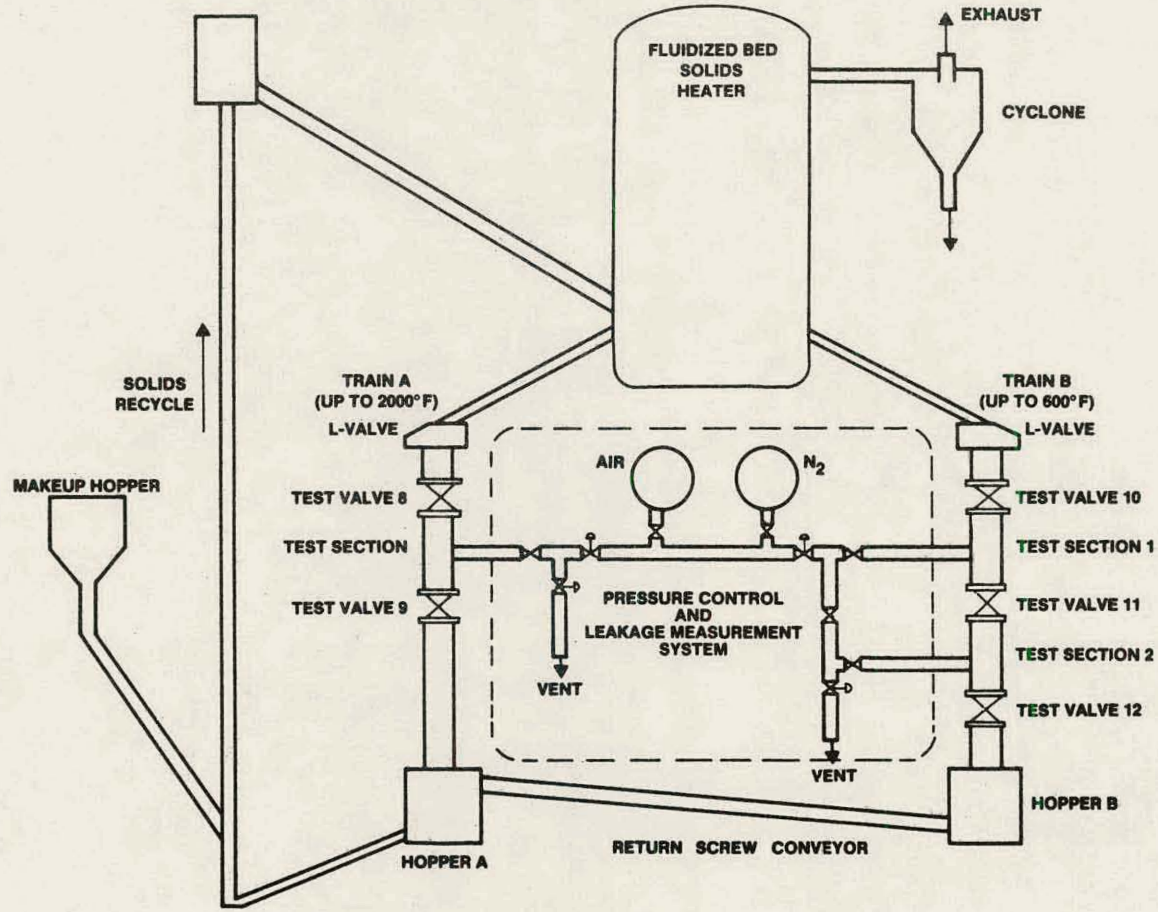
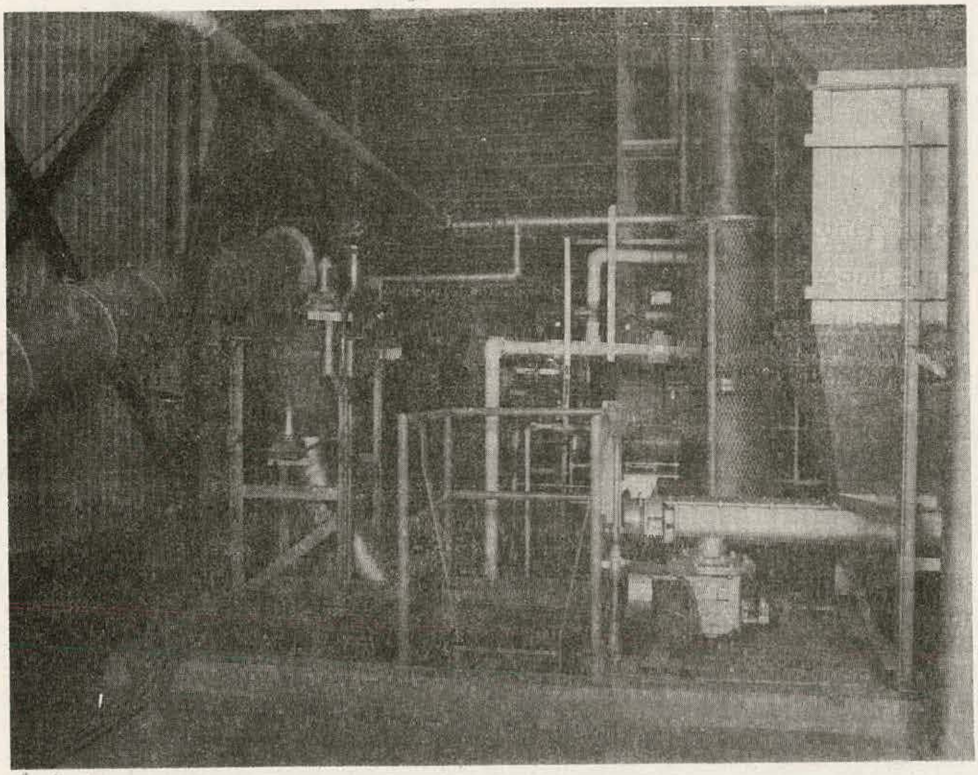


Figure 4-7. Schematic of VHSTU Installation



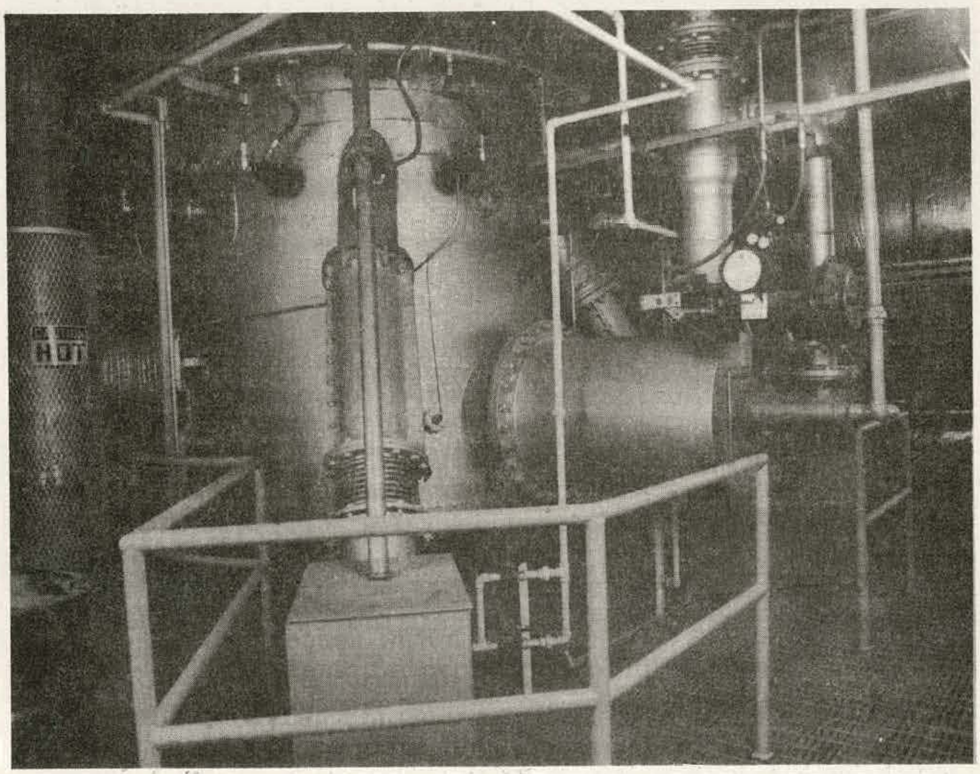


Figure 4-8. Photographs of VHSTU

Limestone, alumina, dolomite, silicon carbide, or a similar material is heated in a fluid bed heater to the temperature specified in the individual valve test plans. Limestone and dolomite are used up to $600^{o}F$; alumina and silicon carbide are used for tests with temperatures above $600^{o}F$. The VHSTU testing procedure is essentially the same as that of the VDTU. The only basic difference is the heated solid material. The VHSTU tests are set up with a similar approach and are controlled by an identical technician-monitored computer control and testing sequence. Controlled preheating and cooling may be necessary as a function of an individual valve's requirements and constraints. Refer to Section 4-2 for a discussion of the test sequences within a subseries and to Tables 4-2 and 4-3 for the automatic valve sequence for two- and three-valve test configurations. The test conditions for a hot solids test series are:

- Solids temperature - to $2,000^{o}F$ (rated valve temperature or as specified in test plan)
- Pressure - 100 psig to 2,000 psig (or maximum valve rated pressure)
- Solid material - particle distribution as specified in individual valve test plan
- Pressurization gas - air or nitrogen (99 percent plus) (dependent on pressure requirements).

The measured and computed data obtained from the VHSTU tests are:

- Leakage rate (internal and external)
- Valve actuation time
- Valve operating force
- Valve body temperatures
- Valve interior temperatures
- Gas temperature and pressure
- Test section temperatures
- Solids temperature - fluid bed exit, test section, and test train exit
- Valve strain gage measurements (if installed).

4.4 VALVE SLURRY TEST UNIT

The Valve Slurry Test Unit is designed to simulate the cyclical flow of water/slag/ash slurry through lockhoppers. The test series evaluates the test valve's capability of lockhoppering slurry at temperatures of ambient to 200°F. For the elevated temperature tests, controlled preheated and cooling may be necessary as a function of an individual valve's requirements and constraints. A schematic of the VSLTU is presented in Figure 4-9. Only Type IV prototype lockhopper valves are tested in the VSLTU. Figure 4-10 is a photograph of the unit.

Single valves are tested in the VSLTU as in VSTU testing. As with the other test units, the VSLTU is normally operated in a technician-monitored, computer-controlled automatic mode.

The typical VSLTU test sequence consists of pumping a slurry of water and limestone (or similar material) from the slurry mix-receiving tank to the slurry charge tank. For a pressurized cycle, the tank and both test sections, valve inlet and outlet, are pressurized. The slurry is then allowed to flow by gravity to the valve inlet test section. The valve is then opened with slurry flow through the valve; as always, a balanced pressure situation exists for valve operation. The test sections are then depressurized and the slurry is returned to the slurry mix-receiving tank. Test subseries are conducted at both atmospheric and individual valve test plan specified pressures.

The test philosophy is similar to that used on VDTU and VHSTU testing. The VSLTU tests are composed of subseries of 500 to 1,000 cycles. A typical set of sequences in a subseries is:

- Baseline performance data
- Automatic valve cycle (nominally 250 cycles)
- Baseline performance data
- Automatic valve cycling
- Baseline performance data.

The baseline performance data consists of leakage measurements from 100 psig to rated pressure, valve actuation time, and, periodically, valve operating force measurements, which are technician-conducted. The internal

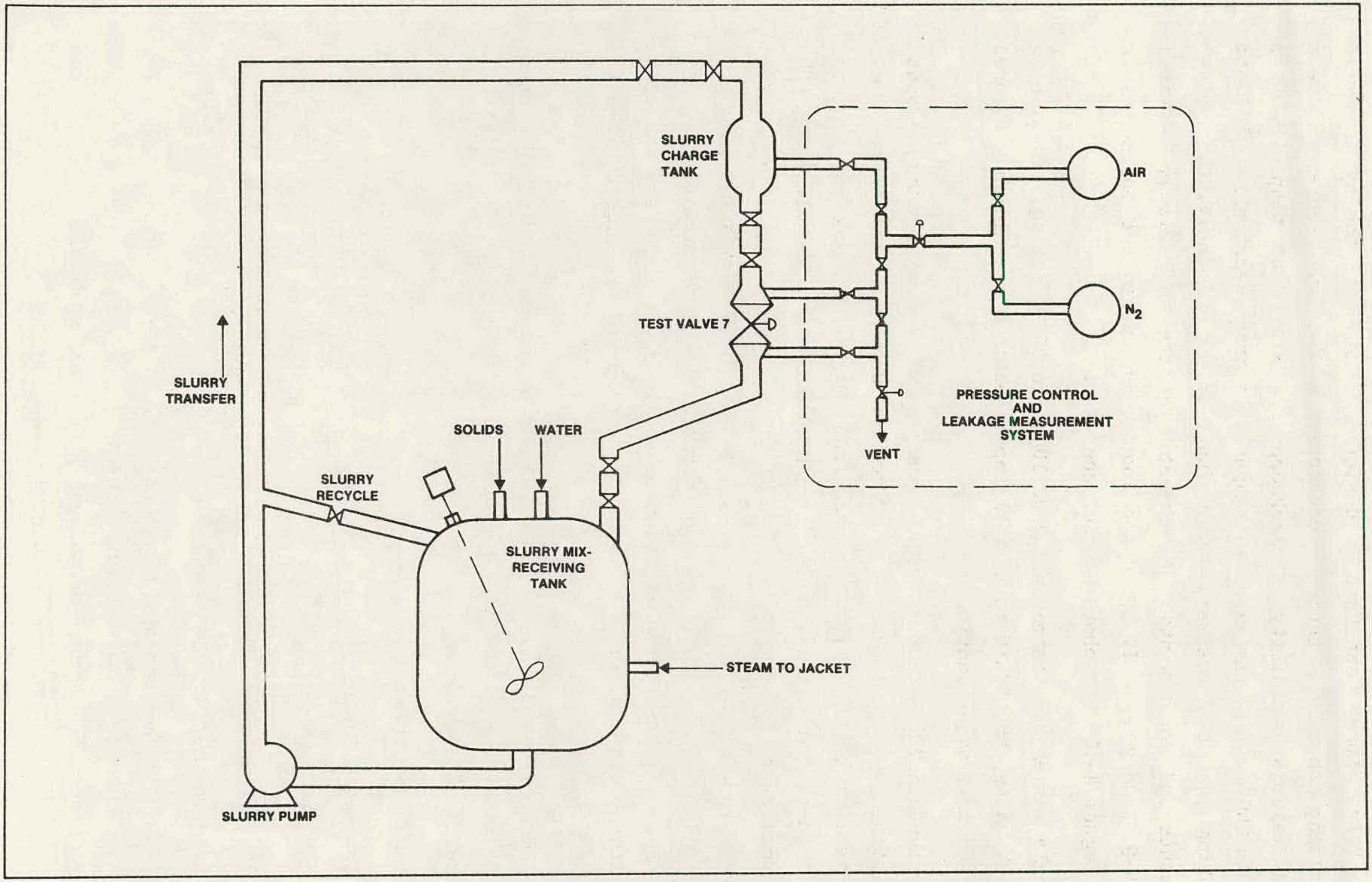


Figure 4-9. Schematic of VSLTU Installation

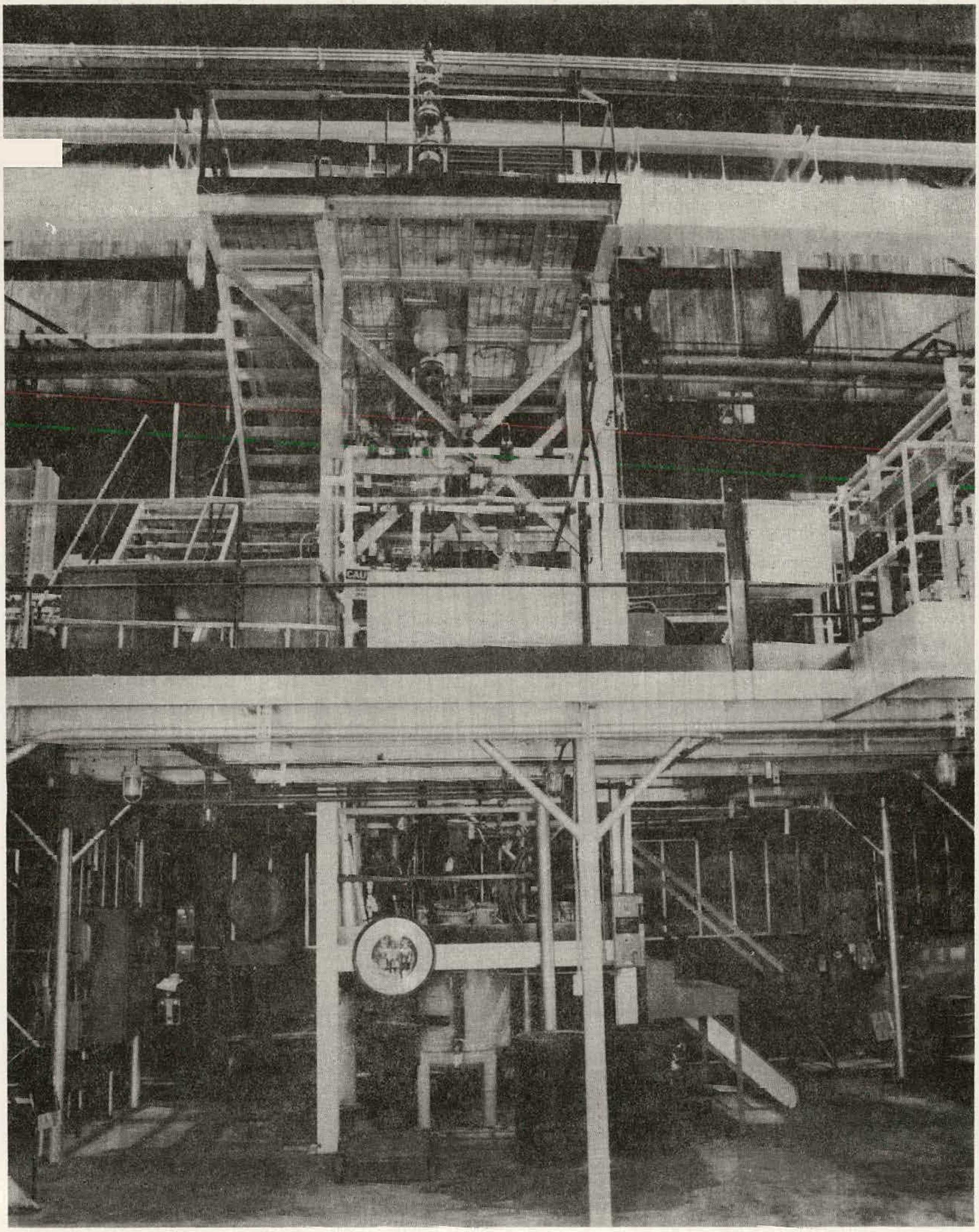


Figure 4-10. Photograph of VSLTU

leakage measurements to simulate sealing direction can be conducted in the slurry flow direction, or both directions. This enables the simulation of a valve location at the inlet or outlet of the slurry removal lockhopper. A typical automatic cycle sequence in the pressurized mode is shown in Table 4-4. The atmospheric cycling mode sequence time is approximately the same as in the pressurized mode, with the only significant difference being pressurization and depressurization. The atmospheric mode test sequence simulates a valve at the outlet to the slurry lockhopper (i.e., operation at balanced atmospheric pressure). The pressurized mode test sequence simulates a valve located between the quench tank and the slurry lockhopper (i.e., operation at balanced rated system pressure).

The test conditions for a slurry test series are:

- Slurry temperature - ambient to 200°F
- Slurry mixture - 25 to 50 percent solid material by weight
- Slurry and leak rate gas pressure - 100 psig to 2,000 psig (or valve rated pressure)
- Valve body temperature - ambient
- Pressurizing gas - air or nitrogen.

The measured and computed data obtained from VSLTU tests are:

- Internal valve leakage rate (gas)
- External valve leakage rate (gas)
- Gross leakage rate (slurry)
- Valve operating force/torque
- Valve actuation time
- Gas temperature and pressure
- Slurry temperature and pressure
- Strain gage measurements (if installed).

TABLE 4-4. VSLTU AUTOMATIC CYCLE SEQUENCE PRESSURIZED MODE

EVENT	ESTIMATED TIME SECONDS
1. Close Slurry Transfer Valve	5
2. Fill Slurry Charge Tank	15
3. Pressurized Test Section 1 & 2 and Charge Tank	60 - 200
4. Open Slurry Transfer Valves	5
5. Slurry Flow to Test Section 1	10
6. Open Test Valve	5 - 30
7. Slurry Flow to Test Section 2	10
8. Close Test Valve	5 - 30
9. Depressurize System	60 - 200
10. Open Slurry Outlet Valve	5
11. Slurry Transfer to Receiving Tank	15
Total Cycle Time	195 to 615

Note: USON leak test is available as option

5.0 DOCUMENTATION

Documentation is a necessary component in the success of any test project. The key functions provided by the supporting documentation are the guidance and direction in operation of the test facilities and the conduct of tests on an individual valve. Another important function of documentation is to specify test conditions, test sequences, test requirements, and success/failure criteria. The recording of test results, including problems and failures, and the reporting of these results with recommendations and conclusions are mandatory in order to disseminate the information to all interested parties.

A significant aspect of all documentation is the communication of procedures, cautions, warnings, and instructions to ensure that personnel and equipment safety is accomplished during all testing activities. The safety procedures and criteria are practiced from receipt of valves through installation, testing, and post-test activities. These procedures are prepared not only for valve activities but for all test unit and laboratory activities in support of the Prototype Lockhopper Valve Testing and Development project.

The remainder of this section will discuss the key documentation that supports the Prototype Lockhopper Valve Testing and Development project at METC. These are the individual test unit operating manuals, valve test procedures, logs and data sheets, test reports, and valve-specific supporting documentation.

5.1 TEST UNIT OPERATING MANUALS

An operating manual is prepared for each of the four lockhopper project test units: VSTU, VDTU, VHSTU, and VSLTU. These manuals provide procedures, instructions, and requirements on equipment operations and maintenance, and test setup/checkout conduct and reporting. A paramount item included is safety procedures and criteria. The manual is also used for assistance in personnel training. Detailed instructions are included for conduct of all aspects of the unit's operation including supporting equipment such as the automated control system. These manuals are prepared by METC.

5.2 VALVE TEST PROCEDURES

A separate test procedure is prepared for each category of testing to be conducted on each individual valve or valve set for VDTU and VHSTU testing. The procedures will identify the configuration of the test valve(s); the test sequence; the test equipment and facilities required; the number of test personnel required, their location and their duties; instrumentation and data recording requirements, including provisions for recording visual readouts (e.g., gages); safety precautions; and other pertinent instructions necessary for safely performing the individual test. Coordination and approval of the procedure by management will be obtained prior to use. Revisions to the procedures also will require coordination and approval.

During test runs, it may be necessary to deviate from the sequence or technical requirements of procedures due to failure of peripheral or secondary test equipment or some other unforeseen circumstance. All such deviations must be recorded and a determination made as to whether the test run is acceptable under the circumstances. Furthermore, all adjustments to equipment or the test article, discrepancies, omissions, additions, failures, and any other occurrences not required by the procedure that could possibly affect the test results and the subsequent analyses should also be recorded.

5.3 LOGS AND DATA

The primary data acquisition and control system for lockhopper valve testing is provided automatically by the Valve Test-Data Acquisition and Control Center. On-line data reduction, graphical output, and data recording is provided by the Center. Manual logs and data sheets provide a backup means of data collection and recording. The test unit logs also provide supplemental information relating to maintenance and recording of events for each test unit.

5.4 TEST REPORTS

There are three categories of test reports prepared as part of the lockhopper valve test project: interim reports prepared at the conclusion of each major portion of a test; inspection reports prepared to document metrology laboratory inspections, including failure analysis; and summary reports, which are prepared at the conclusion of the test sequence on an individual valve. As the test units and the metrology laboratory are highly automated, a large percentage of the data included in each category of the report is computer-generated. The interim reports are distributed only to METC and to the manufacturer of the valve being tested. The summary reports, on the other hand, are available to any interested party through the DOE Technical Information Center, Oak Ridge, Tennessee.

An interim test report is prepared at the end of each major run and provides a quick-look-type presentation of the run's data and significant results. The summary report is a compilation of the interim reports. However, the summary report additionally provides an analysis of the test supported by results and conclusions. The inspection report provides the post-test metrology inspection results and includes the results of any failure analysis conducted on the valve at METC.

5.5 SUPPORTING DOCUMENTATION

Companion documentation is provided with the valve to support the conduct of tests, inspections, and analyses. These data include specifications, drawings, limitations, bills of material, etc. The exact makeup and content is defined in contractual documentation between the valve manufacturer and METC.

6.0 REVIEWS

Reviews are scheduled before, during, and after the testing of a valve. They assist in development of the testing plan for a specific valve to provide both the manufacturer and METC with the most comprehensive and useful set of conditions and results.

Periodic reviews during testing provide for an interchange of information on results to date and assist in the identification of changes to the plan. A review at the conclusion provides an interchange of recommendations relating to test results and assists in the potential improvement of the overall project through redefinition or revision due to the interchange.

7.0 BIBLIOGRAPHY

This Prototype Lockhopper Valve Testing and Development Project Test Plan was developed in part from information obtained from the documents listed below.

1. MERC-USERDA, Valve Testing and Development Program, December 15, 1975.

2. Lockhopper vs. Slurry Feeding: An Economic Comparison of Coal Feeding Systems, Process Evaluation Group, MMRD, June 1976.

3. Gardner, John F., Evaluation Report, Survey of Valve Industry Capability to Furnish 6-Inch Valves for Coal Conversion, U.S. Dept. of Energy, Morgantown Energy Technology Center, (METC 78/10), February 8, 1977.

4. TRW Energy Systems Planning Division, Lockhopper Valve Development Program, U.S. Dept. of Energy, FE 2213-016-11/R1, June 1977.

5. TRW Energy Systems Planning Division, Valve Testing and Development Program Test Procedures -- Valve Dynamic Test Unit, U.S. Dept. of Energy, (MERC 78/5), June 1977.

6. Gardner, John F., Test and Evaluation of an Aluminum Oxide Ball and Seat in a Ball Valve, U.S. Dept of Energy, Morgantown Energy Research Center, (MERC/RI-77/3), October 1977.

7. U.S. Dept. of Energy, Morgantown Energy Research Center, and Valve Manufacturers Association, Proceedings of the Workshop on Valves for Solids Handling Service in Coal Conversion, (MERC/SP-78/4), November 14-16, 1977.

8. TRW Energy Systems Group, State-of-the-Art Lockhopper Valve Test Plan, U.S. Dept. of Energy, (MERC-78/2), March 1978.

9. TRW Energy Systems Group, Design Criteria for Lockhopper Valve Development, U.S. Dept. of Energy, (MERC/SP-78/3), FE-2213-016-04/R2, May 15, 1978.

10. Gardner, John F., An Overview of the U.S. Department of Energy Lockhopper Valve Testing and Development Program at the Morgantown Energy Research Center, U.S. Dept. of Energy, Morgantown Energy Research Center, (MERC 78/7), May 1978.

11. Gardner, J. F. and F. D. Freeburn, Prototype Lockhopper Valve Test Plan, Revision 2, U.S. Dept. of Energy, Morgantown Energy Technology Center, (METC/RI-79/5-R/2), March 1979.

12. Gardner, John F. and F. Don Freeburn, Update on Lockhopper Valve Development, AIChE Houston Meeting Paper No. 2568, presented at the 86th National Meeting of the American Institute of Chemical Engineers, Houston, Texas, April 1-5, 1979.

13. Gardner, J. F., Testing, Evaluation and Development of Valves for Lockhopper Service in Coal Conversion Processes by the U.S. Dept. of Energy, U.S. Dept. of Energy, Morgantown Energy Technology Center, (METC/SP-78/5), May 1979.

14. Gardner, John F., Final Report - METC SOA Test Valve No. A-6, 6-Inch Rockwell Nordstrom Plug Valve, U.S. Dept. of Energy, Morgantown Energy Technology Center, (METC/RI-79/6), May 1979.

15. TRW Energy Systems Planning Division, Lockhopper Valve Testing and Development Projects - Valve Static Test Unit Operating Procedures, U.S. Dept. of Energy, (METC 79/1), May 1979.

16. TRW Energy Systems Planning Division, Valve Technology Development at the Morgantown Energy Technology Center, U.S. Dept. of Energy, (METC/SP-80/1), November 1979.

17. TRW Energy Systems Planning Division, Lockhopper Valve Testing and Development at the Morgantown Energy Technology Center, April 1980.

18. Gardner, John F., et al., Rockwell, Coal Lockhopper Valve, METC SOA Test Valve No. A-16, (DOE/METC/SP-80/8), July 1980.

19. Gardner, John F., In-Service Performance Results for a 10-Inch CVD-Tungsten Coated Lockhopper Valve, U.S. Dept. of Energy, (DOE/METC/SP-80/19), July 1980.

20. Gardner, John F., et al., Everlasting Sliding-Disc Valve, METC SOA Test Valve No. B-3, (DOE/METC/SP-80/30), August 1980.

21. Gardner, John F., et al., Everlasting Double-Disc, Coke-Oven Valve METC SOA Test Valve No. A-8, (DOE/METC/SP-80/25), September 1980.

22. Cutright, Ronald L., Prototype Lockhopper Valve Development, A Topical Report, U.S. Dept. of Energy, October 1980.

23. McGhee, Timothy A., Survey of Materials for Critical Valves in Coal Conversion Applications, U.S. Dept. of Energy, Morgantown Energy Technology Center, (DOE/METC SP-1040), January 1981.

24. TRW Energy Systems Group, Proceedings of the 2nd Symposium on Valves for Coal Conversion and Utilization, U.S. Dept. of Energy, (DOE/METC/SP-81/1), January 1981.

25. Gardner, John F., et al., Kamyr, P-D Series, Full-Bore, Ball Valve, METC SOA Test Valve No. A-17, (DOE/METC/SP-81/25), February 1981

26. TRW Energy Engineering Division, Lockhopper Valve and System Design Criteria and Guidelines for Coal Conversion and Utilization Applications, U.S. Dept. of Energy, (DOE/METC SP-138), April 1981.

27. TRW Energy Engineering Division, State-of-the-Art Lockhopper Valve Testing and Development Project Test Plan, U.S. Dept. of Energy, (DOE/METC/SP-139), April 1981.

28. Gardner, John F., et al., W-K-M, Dyna-Seal, Ball Valve, METC SOA Test Valve No. A-7, In preparation.

29. Gardner, John F., et al., Masoneillan, Camflex II Valve, METC SOA Test Valve No. A-15, In preparation.

30. Gardner, John F., et al., Anchor-Darling, Double-Disc Gate Valve, METC SOA Test Valve No. A-12, In preparation.

31. Gardner, John F., et al., Walworth, Solid-Wedge, Gate Valve, METC SOA Test Valve No. A-20, In preparation.

32. Gardner, John F., et al., W-K-M, Pow-R-Seal, Gate Valve, METC SOA Test Valve No. A-22, In preparation.

APPENDIX

ACRONYMS/DEFINITIONS

ARC	Albany Research Center, U.S. Bureau of Mines
ANSI	American National Standards Institute
ANL	Argonne National Laboratory
CCC	Consolidated Controls Corporation
DOE	U.S. Department of Energy
FSD	Fairchild Industries, Incorporated, Stratos Division
METC	Morgantown Energy Technology Center
ORNL	Oak Ridge National Laboratory
psig	Pounds per square inch - gage
scfm	Standard cubic feet per minute
SOA	State-of-the-Art
VDTU	Valve Dynamic Test Unit
VHSTU	Valve Hot Solids Test Unit
VSLTU	Valve Slurry Test Unit
VSTU	Valve Static Test Unit
VT-DAC	Valve Test - Data Acquisition and Control Center
^{o}F	Degrees Fahrenheit

☆U.S. GOVERNMENT PRINTING OFFICE: 1981-740-145/2125