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Pacific Northwest National Laboratory

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System Design Description for the Whole Element Furnace Testing System

G. A. Ritter
S. C. Marschman
P. J. MacFarlan
D. A. King

May 1998

Prepared for
the U.S. Department of Energy
Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Richland, Washington 99352

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Summary

This document provides a detailed description of the Hanford Spent Nuclear Fuel (SNF) Whole Element Furnace Testing System located in the Postirradiation Testing Laboratory G-Cell (327 Building). Equipment specifications, system schematics, general operating modes, maintenance and calibration requirements, and other supporting information are provided in this document. This system was developed for performing cold vacuum drying and hot vacuum drying testing of whole N-Reactor fuel elements, which were sampled from the 105-K East and K West Basins. The proposed drying processes are intended to allow dry storage of the SNF for long periods of time. The furnace testing system is used to evaluate these processes by simulating drying sequences with a single fuel element and measuring key system parameters such as internal pressures, temperatures, moisture levels, and off-gas composition.

Quality Assurance

This work was conducted under the Quality Assurance Program, Pacific Northwest National Laboratory (PNNL) SNF-70-001, *SNF Quality Assurance Program,* as implemented by the PNNL *SNF Characterization Project Operations Manual.* This QA program has been evaluated and determined to effectively implement the requirements of DOE/RW-0333P, Office of Civilian Radioactive Waste Management *Quality Assurance Requirements and Description (QARD).* Compliance with the QARD requirements is mandatory for projects which generate data used to support the development of a permanent High-Level Nuclear Waste repository. Further, the U.S. Department of Energy has determined that the testing activities which generated the results documented in this report shall comply with the QARD. Supporting records for the data in this report are located in the permanent PNNL SNF Characterization Project records, *System Design Description for the Whole Element Furnace Testing System.*

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Acronyms

ATS	Applied Test Systems
CVD	cold vacuum drying
DACS	data acquisition and control system
DA/CU	data acquisition/control unit
GC	gas chromatograph
GDS	gas detection/analysis system
GPIB	general purpose interface bus
GSS	gas supply/distribution system
HP	Hewlett Packard
HVD	hot vacuum drying
IPS	Integrated Process Strategy
MS	mass spectrometer
PHS	process heating system
PID	proportional with integral and derivative
P&ID	piping and instrumentation diagram
PNNL	Pacific Northwest National Laboratory
PTL	Postirradiation Testing Laboratory
QA	Quality Assurance
QARD	Quality Assurance Requirements and Description
SAS	safety argon system
SNF	spent nuclear fuel
UHP	ultra high purity

UPS	uninterruptible power supply
VPS	vacuum pumping system
WEFTS	Whole Element Furnace Testing System

1.0 Introduction

This document provides a detailed description of the Whole Element Furnace Testing System (WEFTS), which was developed for cold vacuum drying (CVD) and hot vacuum drying (HVD) testing of N-Reactor spent nuclear fuel (SNF) elements sampled from the 105-K East and K West Basins as part of characterization studies on the Hanford SNF. An Integrated Process Strategy (IPS) has been developed to retrieve, package, dry, transport, and store SNF in an interim storage facility at the Hanford Site (WHC 1995). The proposed drying processes are intended to allow dry storage of the SNF for long periods of time. The WEFTS, located in the Postirradiation Testing Laboratory (PTL, 327 Building) G-Cell, is being used to evaluate these processes by simulating drying sequences with a single, whole fuel element and measuring key system parameters such as internal pressures, temperatures, moisture levels, and off-gas composition.

This document is intended to be the primary reference for all design information related to the WEFTS. The information is organized as follows. Section 2.0 provides an overview of the system, including the system arrangement within the PTL G-Cell and general performance characteristics. The sub-systems of the WEFTS are described in Section 3.0, which provides detailed equipment specifications, system interfaces, system schematics, and piping and instrumentation diagrams. Section 4.0 describes the general operation of the WEFTS, including the system configuration for the various operating modes. Section 5.0 provides a brief overview of the maintenance and calibration requirements for the WEFTS. Illustrations are shown following the main text. Appendices A through D contain itemized lists of drawings, instruments, valves, and other important WEFTS equipment. A copy of the operating manual for the data acquisition and control system is given in Appendix E. Appendix F illustrates miscellaneous system components. Appendix G lists supporting documents.

2.0 System Summary Description

2.1 Major Systems Overview

The WEFTS consists of the following seven sub-systems:

- Vacuum Pumping System (VPS) - The VPS consists of a scroll-type vacuum pump, a condenser with chiller, filters, valves, and piping, which provide the vacuum pressures and flows required for the proposed IPS vacuum processes.

- Process Heating System (PHS) - The PHS consists of a resistively heated, clam-shell furnace and a sample chamber (retort) to provide heating to the fuel element and to control process temperatures.

- Gas Supply/Distribution System (GSS) - The GSS consists of gas bottles, mass flow controllers, piping, and valves for metering argon, air, or oxygen through the system. A bubbler is also available for adding water vapor to the system if desired.

- Gas Detection/Analysis System (GDS) - The GDS consists of a 300-amu quadrupole mass spectrometer (MS) and a gas chromatograph (GC) for monitoring selected elements in the process gas stream.

- Process Instrumentation - The system is equipped with several instruments for measuring process temperatures, pressures, and moisture level. An auxiliary turbo vacuum pumping system provides low system pressures for zero adjustment of the high accuracy retort pressure sensor.

- Data Acquisition and Control System (DACS) - The DACS consists of an IBM-compatible computer and data acquisition/control unit (DA/CU) to monitor/store key system parameters (temperatures, pressures, flows, moisture level) along with controlling the PHS and the safety argon system (SAS).

- Safety Argon System (SAS) - The SAS consists of an argon gas bottle, solenoid actuated valves, and piping. The SAS functions with the DACS to shut down the system and provide an argon purge if the furnace temperature rises above a pre-determined set point.

Section 3.0 provides more detailed descriptions of the components for these systems.

2.2 System Arrangement

A plan view of the equipment arrangement in and out of G-Cell is shown in Figure 1. The furnace (including retort) and some of the process piping, instrumentation, and valves are located inside the hot cell. Figures 2 and 3 are photographs of the equipment located inside G-Cell. The furnace sits on the cell floor, and the process piping is routed to a rack that hangs on the west cell wall (Figure 3). As seen in the photographs, all of the process piping on the inside of the cell is heat traced to prevent any condensation in the lines. Process piping and electrical power and instrumentation wires pass through several split plugs on the west side of the cell. The process piping on the outside of the cell is contained within a glove bag, which provides a secondary containment as a precaution in case the process piping lines become contaminated. The vacuum pump, condenser, bubbler, gas chromatograph, and the remainder of the instrumentation and valves are located inside this glove bag. Figure 4 shows the equipment on the west outside wall of G-Cell. Instrumentation and electrical power wires are routed through pass-through sleeves on the sides of the glove bag to the instrument rack and computer console. The instrument rack contains the readout/control units for the pressure sensors, moisture sensor, and flow controllers, along with the heat trace temperature controllers, DA/CU, turbo pump controller, GC laptop computer, and uninterruptible power supplies (UPS). The computers for the DACS and MS are located next to the instrument rack.

Fuel elements are transferred to and from the cells using a transfer cask that is maneuvered through the hot cell canyon with an overhead crane. Typically, the transfer cask is positioned flush to the hot cell wall and a cell plug is removed to allow insertion/removal of the element. Once it is inside the cell, the fuel element is handled remotely with mechanical manipulators. Video cameras are located inside F-Cell (adjacent to G-Cell) and G-Cell to provide visual inspections of the fuel element before and after vacuum drying tests. A flange on one end of the furnace retort tube allows the fuel element to be inserted into/removed from the retort. After a fuel element has been loaded into the retort and the retort resealed, the system is completely controlled from equipment located outside the hot cell. For a typical drying test, all of the valve manipulations are performed inside the glove bag, and the components are controlled using the DACS along with equipment located in the instrument rack.

2.3 General Performance Characteristics

The system was designed to provide process pressures ranging from just above atmospheric to less than 1 Torr vacuum. The scroll pump is capable of pumping up to 250 L/min (8.8 cfm), but can be throttled using a metering valve that is installed on the pump inlet. The condenser also provides additional pumping capacity down to about 10 Torr and limits the amount of water vapor pumped through the vacuum pump. The system has over 30 valves to provide versatility in controlling process flows for a variety of different tests. Particulate filters help prevent the spread of contamination to the process lines outside the hot cell.

The furnace has a design temperature of 900°C and has three separate sets of heating elements, which allow the heating to be controlled in zones. The furnace controller can be programmed to provide a variety of different temperature profiles as required by the process. Fuel element temperatures are monitored using seven thermocouples installed along the length of the retort. Several other thermocouples are located throughout the system to provide key process temperature measurements.

Argon, air, and/or oxygen can be flowed through the system, depending on process requirements. Ultra high purity (UHP) argon is typically used as the purge gas for drying tests, and the flow can be varied from 0 to about 300 standard cm^3/min. If higher flows are desired, a different mass flow controller could be installed in the system.

The system is equipped with instrumentation to monitor key system parameters. A high accuracy pressure sensor is located at the retort inlet to provide system pressure measurement from 0.01 Torr to 1000 Torr. Moisture levels ranging from a dew point of -110°C to 20°C can be measured with the moisture sensor. The MS is capable of monitoring up to 64 components within a gas stream with a detection limit of less than 1 ppm. The MS is typically configured to monitor hydrogen, nitrogen (for air in-leakage), krypton, xenon, and other elements during a drying test. The GC provides a second method for detecting hydrogen, and is more sensitive to small concentrations of hydrogen than the MS.

3.0 Detailed System Descriptions

3.1 Vacuum Pumping System

The VPS provides the pressures and flows required for the proposed IPS processes. This system connects the furnace retort with all the other components of the test system through various valves, fittings, and piping. The VPS consists of the following components:

- scroll pump for evacuating the system to pressures below 1 Torr
- water condenser with refrigerated chiller for gross removal of water
- valves and piping for connecting the various components and controlling the flow direction

- particulate filters to prevent spread of contamination

- heating cords with temperature controllers for prevention of condensation in lines.

Each component is described in more detail below. Specifications for all of the valves, instruments, and system components are tabulated in Appendices B through D.

3.1.1 Varian Scroll Pump

The system vacuum pump is a Varian model #300DS scroll pump. The performance curve for this pump is shown in Figure 5. This pump has an ultimate vacuum pressure less than 10^{-2} Torr and a peak pumping speed of 250 L/min (8.8 cfm). These pressures and flows are more than adequate for simulating the conditions of the proposed IPS vacuum processes. For a single fuel element, this amount of flow may be more than desired. Therefore, a metering valve was installed on the pump inlet to throttle the flow to lower levels as required. The desired system pressure can be achieved by either using the throttling valve or metering UHP argon into the system through the entire gas loop or via a direct injection of ballast gas at the pump inlet. The use of argon gas helps to prevent the in-leakage of moisture-containing air through very small system leaks (which are difficult to eliminate) that would interfere with process monitoring equipment.

3.1.2 Water Condenser

The scroll vacuum pump can be damaged by condensation of liquid water in the scroll mechanism, and, since each element is wet at the start of each test, the possibility of pump damage was considered. A water condenser with corresponding chiller was installed in the system to condense the bulk of the water before it reaches the pump. This condenser can be valved into the system in series with the scroll vacuum pump or can be bypassed if not needed. The condenser cannot trap all the liberated free water, but is efficient at removing the majority of the free water in the system. The condenser is only used during the first few hours of a CVD test for a single fuel element.

The condenser was custom fabricated specifically for this system. A detailed sketch of the condenser is given in Appendix F. The condenser housing is constructed of 4-in. schedule 40 stainless steel pipe with 4-in., 150-lb flanges for the top where the inlet and outlet lines are connected. The bottom is bell-shaped to funnel the collected water into an acrylic 100-mL graduated cylinder located directly below the condenser housing. A valve on the bottom of the graduated cylinder allows samples of the collected water to be obtained. A 3/8-in.-OD by 4-ft-long copper tube was formed to a 2 3/4-in.-OD coil to provide the cold surface for condensing the free water. Chiller lines are connected to the copper coil, and a thermocouple is installed in the line to monitor the cooling water temperature. Another thermocouple is located inside the housing to provide the bulk gas temperature. The measured volume of the condenser is approximately 2.1 L (up to valves 26 and 27 - see Figure 7). The chiller is a Lauda Brinkmann model #RM6-S, which has an operating temperature of -30°C to 150°C. The chilling capacity is 320 W at 20°C and 250 W at 0°C, which is near the operating temperature used in the CVD tests. The chiller pump flow rate is 13 L/min.

3.1.3 Piping, Valves, and Filters

The VPS connects the system components through various valves, fittings, and piping. A piping and instrumentation diagram (P&ID) for the system is shown in Figure 6. This diagram illustrates the configuration of the piping and valves but does not indicate the lengths of the various lines. It also shows the interfaces between the instruments and the DACS, which will be discussed further in Section 3.6. Figure 7 is a stripped-down version of the P&ID, where all of the electrical and instrumentation wiring connections, along with other minor components, have been removed. This figure allows the process flows for various valve configurations to be more easily examined. Although the exact piping lengths are not available, the approximate lengths along with nominal sizes are given below:

Outside G-Cell

- Gas flow controller to G-Cell inlet (1/4 in. OD x 0.035 in. wall tubing): 9 ft
- G-Cell outlet to condenser inlet (1/2 in. OD x 0.035 in. wall tubing): 2 ft - 2 in.
- Condenser outlet to pump inlet (1/2 in. OD x 0.035 in. wall tubing): 3 ft - 10 in.

Inside G-Cell

- G-Cell inlet to furnace inlet (3/8 in. OD x 0.035 in. wall tubing): 17 ft
- Furnace outlet to G-Cell outlet (3/8 in. OD x 0.035 in. wall tubing): 21 ft

The primary volume of the system is approximately 11.4 L. This volume corresponds to the part of the system that is isolated during a pressure rebound test. A rebound test valve configuration is most similar to that shown in Figure 12. The exceptions are that V10 and V26 are closed, and V27 is positioned to bypass the condenser during a pressure rebound test.

As seen in Figure 7, over 30 valves in the system are used to direct the flow to and from the various components. Most of the valves in the system are ball valves and range from 1/4 in. to 1/2 in. nominal size. Appendix C contains a detailed list of all of the valves in the system. The system piping is constructed of thin wall tubing (1/4 in. to 1/2 in. OD) and is typically connected using simple Swagelok fittings (tees, elbows, unions, etc.). Ports for gas sampling/analysis and monitoring of system pressure, temperature, and humidity are also provided at key locations in the system piping. Special fittings and pipe-threaded fittings are used in some locations for connecting piping to the process instruments.

Particulate filters are installed in the system on both the inlet and outlet to the retort to help prevent the spread of contamination to the system piping on the outside of the hot cell. These filters are constructed of a microporous fiberglass media in a stainless steel housing. They are 99.9% efficient for particulates that are 0.2 microns and larger in size. Two different size filters, manufactured by Matheson, are used in the system. Appendix D provides part numbers and specifications for the filters.

3.1.4 System Line Heaters

All of the stainless steel tubing that carries gases into the furnace retort and resultant gases from the retort are heated to about 75 °C to ensure condensible water vapor remains in the gas phase. Simple heat "cords" capable of being wrapped upon each other (as required at tees, elbows, and other connections) were found to be a good heating method for this system. These cords were obtained from Cole Parmer and vary from 3 ft to 24 ft in length and 70 W to 560 W, respectively. Each heating cord is controlled by a simple proportional controller, Omega model #6102-K, which has a 10 A capacity, 115 VAC. A type-K thermocouple is installed on each heat-traced line, and the temperature is monitored and recorded by the DACS.

3.2 Process Heating System

The whole element furnace is a 4-ft-long, resistively heated, clam-shell furnace. The furnace, Series 3210 supplied by Applied Test Systems (ATS), has a temperature rating of 900°C and total heating capacity of 13,800 W. The internal dimensions are 5 in. ID by 45 in. long. The furnace has three separate sets of heating elements that allow the heating to be controlled in zones; each zone is 15 in. long and supplies up to 4600 W heating. The zones can be controlled separately to establish a flat temperature profile within the furnace even though heat is lost preferentially out the end with the retort entry flange. A heat reflector consisting of several thin Inconel plates is used to reduce heat loss from the flange end of the retort. Drawing H-3-307609 (B&W 1997a) provides detailed specifications for the heat reflector. Figure 8, a schematic of the furnace and retort configuration, shows the approximate locations of the fuel element, transfer boat, heat reflector, and thermocouples within the retort. The furnace controller is an ATS Series 3000, which consists of three programmable, self-tuning proportional with integral and derivative (PID) controllers. These controllers are also interfaced to the DACS, which is capable of providing limited input to the controllers as required.

The retort, an ATS Series 3910, is an Inconel tube fitted with a gas inlet tube at one end and a gasketed flange at the other. Of all high-temperature materials, Inconel series 600 was selected for use in the retort to reduce the amount of oxidation and water pickup by the retort and associated components. Experience has shown that stainless steel components were too easily affected by corrosion, which could then affect test results. The body of the retort is fabricated from schedule 40 Inconel pipe (4.5 in. OD, 4.026 in. ID). The inside length is about 44.5 in. Detailed specifications for the retort are given in drawing H-3-307608 (B&W 1997b). Seven type-K thermocouples are installed equidistant along one side of the retort and extend into the retort interior approximately 1/8 in. These thermocouples are used to monitor the retort temperature so that any reaction with the fuel element (which would locally raise the retort temperature) can be correlated with the approximate location on the fuel.

An Inconel sample/transfer boat is used to load the fuel element into the furnace. The boat is fabricated from an 11-gauge (0.120-in.-thick) Inconel 601 sheet, which is formed into a flattened u-shape. The boat has a weir and a swivel handle on each end. The weirs are used to keep free water or particulates contained in the boat as required. Drawing H-3-307609 provides the detailed specifications for the transfer boat.

Typical temperature profiles for the retort are shown in Figure 9. These temperatures were measured during a dry run of the furnace, without a fuel element inside the retort. Thermocouples TE-04 through TE-10 are located along the length of the retort, as shown in Figure 8. For the nominal temperature setting of 50°C, the retort is under a vacuum of less than 1 Torr without an argon gas purge. For the 75°C and 400°C settings, the retort pressure is approximately 18 Torr with an argon gas purge of about 300 sccm. As shown in Figure 9, the retort temperature drops off significantly after TE-09, especially at the 400°C setting. As previously discussed, this drop in temperature is caused by heat loss at the flange end of the retort. This dropoff was much worse before the heat reflector was installed. The fuel element is located between TE-04 and TE-09, as shown in Figure 8, and therefore is exposed to the desired flat temperature profile.

3.3 Gas Supply/Distribution System

The GSS and the VPS together are capable of controlling the fuel element environment to vacuum or moderate pressure conditions, and/or exposing the fuel element to a variety of gases or gas mixtures. The gas loop is typically operated as a single-pass system with no capability for recirculation. The GSS consists of gas bottles, mass flow controllers, piping, and valves for metering argon, air, or oxygen through the system. A bubbler is also available for adding water vapor to the process gas stream as required.

3.3.1 Mass Flow Controllers

The GSS contains three Matheson mass flow controllers calibrated for argon, air, and oxygen. All gases are typically specified "ultra high purity" and are additionally filtered for water using molecular sieve columns. Argon is the principal inert gas used; it is more dense than air, provides reasonable thermal conductivity, and requires simpler handling procedures than lighter gases such as helium. Air and oxygen are not typically used because any oxidative steps have been deleted from the current IPS for the SNF. The ranges of flow rates available using these controllers are 0 - 304 sccm argon, 0 - 1000 sccm air, and 0 - 10 sccm oxygen. The argon flow controller (FE-01) is an oxygen controller with a range of 0 - 200 sccm that was recalibrated for argon. If higher flow rates are desired, a new mass flow controller with a higher range could be procured and installed in the system.

3.3.2 Bubbler

A bubbler was installed in the system for tests that would expose the fuel element to a specified flow of steam. The bubbler consists of a 335-W heating mantle with a 1000-mL flask procured from Fisher Scientific. The gas stream is bubbled through the water in the flask through a dip tube to entrain water vapor. There are currently no plans to use the bubbler in these drying tests.

3.4 Gas Detection/Analysis System

3.4.1 Balzers Omnistar Mass Spectrometer

The Balzers Omnistar Mass Spectrometer is a compact, computer-controlled, quadrupole MS capable of scanning to 300 amu. The unit can monitor up to 64 components within a gas stream and has a nominal detection limit of less than 1 ppm for most gases other than hydrogen. The MS is typically used to monitor hydrogen, nitrogen (for air in-leakage), krypton, xenon, and other elements during the test.

The MS was modified as a result of early system testing and calibration to improve the time response to small changes in hydrogen pressure. Prior to testing, the MS was calibrated for hydrogen using mixtures of hydrogen and helium gas. The residence time of each gas could be measured in the quadrupole chamber, and it was observed that the hydrogen decay time was approximately four times as long as helium. This was not unexpected as turbomolecular pumps have a lower pumping efficiency for very light gases. In standard practice this is acceptable, but for these tests, where determining hydrogen could be very important, steps were taken to improve the hydrogen decay time. The MS vacuum system was modified by adding a stainless steel flanged tee, a gate valve, and a room-temperature hydrogen getter downstream from the quadrupole. Under vacuum the gate valve can be opened, exposing the getter to the system to help scavenge hydrogen from the system following the analysis. This modification reduces the background level of hydrogen in the system by about a factor of 2 and improves the system response to transient events that may result in the release of hydrogen.

3.4.2 MTI M200 Gas Chromatograph

The MTI M200 Gas Chromatograph is a high-speed GC that is used to monitor the quantities of hydrogen, nitrogen, and oxygen in the furnace testing system gas loop. This instrument is interfaced with a laptop computer to record data. The GC is designed to be operated at higher pressures, thus it may be configured in two different ways for measurement purposes. At system pressures near atmospheric, the GC is configured to sample directly from the gas loop ahead of the system vacuum pump. When the system is under vacuum, the GC is configured to sample from the exhaust side of the vacuum pump. The gas output from the pump is sufficiently compressed so that the GC can sample and analyze this gas. Under this sampling mode, the GC indicates an average gas composition and is less responsive to transient events.

3.5 Process Instrumentation

The WEFTS contains several analytical instruments for monitoring moisture content, pressure, and temperature. The key instruments are as follows:

- Panametrics moisture monitor
- MKS Baratron pressure transducers
- Cole Parmer pressure transducers
- Varian multi-gauge pressure transducers
- Type-K thermocouples.

3.5.1 Panametrics Moisture Monitor

The Panametrics moisture monitor model #MMS35 uses a solid electrochemical probe (model #M2L), which measures moisture by measuring the characteristic capacitance of the probe as a function of the moisture in the gas phase. The sensor has a dew point range of -110°C to 20°C. Previous testing indicated that contamination by radioactive elements (e.g., cesium) causes the probe to go out of calibration and moisture readings to drift as a function of time. To prevent contamination of the probe tip, the probe is installed in the gas loop downstream of two particulate filters. Further, the probes will be changed following each test and surveyed for radioactive contamination. If no contamination is found, and the data correlate well with the data obtained from the MS, the readings will be accepted. A calibration verification procedure can be performed using calibrated water "leak" tubes. These tubes can be placed inside the furnace and, when heated, will establish a known water vapor pressure in the system. However, this procedure is time intensive; approximately 2 weeks are required to calibrate one probe over the range of moisture likely to be encountered in these tests. This procedure will only be used should the moisture monitor results vary widely from the MS data.

3.5.2 MKS Baratron Pressure Transducers

Two MKS Baratron Model 690 calibrated pressure transducers coupled with MKS Model 270 signal conditioners are used as the primary measurement for the overall system pressure. As shown in Figure 7, PE-01 measures the system pressure downstream of the retort outlet, whereas PE-06 measures the system pressure at the retort inlet. PE-01 indicates pressure ranging from 0.1 Torr to 10,000 Torr. The pressure range of PE-06 is 0.01 Torr to 1000 Torr. PE-06 was installed after the first two fuel element drying tests to provide more accurate measurements than PE-01 for low pressures. PE-06 is therefore considered the primary system pressure measurement. In addition, the 270 signal conditioner procured with PE-06 has a special capability to remotely zero the transducer, which provides more accurate pressure measurements below 1 Torr. An auxiliary high vacuum turbo pump (P2 in Figure 6) is used to pull the inlet to PE-06 to well below 10^{-4} Torr, so that the transducer can be accurately rezeroed. The 270 signal conditioner for PE-01 does not have this capability. Both signal conditioners have analog outputs that are fed to the DACS so that system pressure is continuously recorded.

3.5.3 Cole Parmer Pressure Transducers

Two diaphragm-type calibrated pressure transducers are installed on the MS and GC sample lines, as indicated by PE-07 and PE-08 in Figure 7. These pressure measurements are used to normalize the MS and GC data so that actual gas concentrations in the system can be calculated from the relative concentrations measured. These sensors have a range of 0 to 1500 Torr with a resolution of 0.1 Torr and an accuracy of ±1%, or ±1 Torr, whichever is larger. Both readout units have analog outputs that are fed to the DACS to continuously record these pressures.

3.5.4 Varian Multi-Gauge Pressure Transducers

The Varian multi-gauge pressure transducers are uncalibrated Convectorr-type sensors that provide qualitative pressure measurements at several locations within the system. These locations include the scroll vacuum pump inlet (PE-03), the interior of the water condenser (PE-02), and the system pressure (PE-05) on the MS sample line upstream of the leak valve (LV-01). The sensors have a range of 1 mTorr to 1000 Torr. PE-04 is a spare Convectorr sensor that is not currently being used. These pressures are also recorded using the DACS through an RS-232 communications link.

3.5.5 Thermocouples

Thermocouples provide a simple, reliable method for measuring system temperatures. As shown in Figures 6 and 7, over 20 thermocouples are installed at various locations in the system to provide key temperature measurements. The retort temperatures are of primary importance, and these temperatures are measured by thermocouples TE-04 through TE-10, which are positioned equidistant along the length of the retort. Other key temperature measurements include the retort center temperature (TE-20, which is a 30-in.-long thermocouple installed through the outlet end of the retort), retort inlet temperature (TE-21), condenser gas temperature (TE-19), and the condenser coolant temperature (TE-22). Thermocouples TE-11 through TE-17 are used for controlling the temperature of the heat-traced lines. All thermocouple readings are continuously recorded using the DACS.

3.6 Data Acquisition and Control System

The DACS monitors system parameters and controls the furnace and the SAS. The DACS consists of a Hewlett Packard (HP) 3497A DA/CU and an IBM-compatible computer. A National Instruments general purpose interface bus (GPIB) card, installed in the IBM-compatible computer, is used to communicate with the HP 3497A. The computer communicates with the furnace temperature controllers over serial port 0 using an RS-232/RS-485 converter. The computer also receives data from the Varian pressure meter over serial port 1. The DACS uses National Instruments LabView for Windows as the control software. The DACS operating manual (included here as Appendix E) provides more details.

The DACS is designed to measure critical system parameters during fuel conditioning tests, including temperatures, pressures, flow rates, and moisture level. The measured parameters are converted to engineering units, displayed on the computer screen, and stored to disk at user-defined intervals. The data files are stored in a tab-delimited format to allow importing into a standard spreadsheet or plotting program. A plotting screen also allows for plotting of up to six parameters at a time.

Limited control of the furnace can be performed with the DACS. Each of the three furnace zone temperatures can be remotely set by the DACS. In addition, the DACS allows the operator to start and stop the furnace and select one of four temperature profiles that are pre-programmed in the furnace temperature controllers. Note that these profiles must be programmed manually in the furnace controllers before using the DACS to select them.

The DACS monitors the temperatures inside the retort tube (TE-04 through TE-10) and generates an alarm if any three of the temperatures exceed the user-defined temperature limit. Additionally, the DACS closes the reactant gas solenoids, opens the safety argon solenoid, and shuts down the furnace heaters when an alarm condition is detected. The alarm stays latched until it is reset by the operator.

In addition to controlling the furnace and the SAS, the DACS allows the operator to control the oxygen gas solenoid for oxidation tests. This solenoid can be toggled open or closed, as well as configured by the operator to automatically open and close on delay, based on user-defined start and stop times.

3.7 Safety Argon System

The SAS is a temperature-activated safety system that is designed to shut down a furnace test if the furnace temperature rises above a user-defined set point. Such a temperature rise could indicate that rapid oxidation was beginning to occur on a fuel element (if rapid oxidation occurs, it is desirable to stop the reactions and examine the fuel to determine the cause). As described in Section 3.6, if the monitored temperatures exceed the temperature limit, the DACS immediately initiates the following operations:

- The in-cell portion of the gas loop is isolated from the ex-cell portion by a series of solenoid actuated valves. (In Figure 6, VS01 and VS03 close to isolate the system, while VS02 opens to inject UHP argon into the retort tube inlet).

- A "STOP" command is sent to the furnace controllers that shuts off power to the furnace, and the furnace is allowed to cool to room temperature.

- A flow of UHP argon is initiated through VS02 and allowed to pressurize the system to 25 psig, at which time a pressure relief valve (V16) on the retort outlet opens. This configuration creates a gas purge through the retort and allows the gas to escape into the hot cell. The entire contents of a 220 ft^3 gas bottle are allowed to flow through the system if the system is unattended at the time of the event. The inert gas purge and reduced temperature should stop all reactions.

- An alarm is actuated on the DACS computer screen, and a large red light on top of the instrument rack is illuminated. This light provides a visual warning so that if the event happens off shift, the first work crew entering the facility can be alerted and take appropriate actions.

As noted in Section 3.6, the user must manually reset the high-temperature alarm using a toggle button on the main display of the DACS. The DACS will not allow the alarm to reset until all of the retort temperatures are below the alarm temperature limit.

3.8 System Interfaces

The only support system necessary to operate the WEFTS is electrical power from the PTL facility. Other than electrical power, the WEFTS is a stand-alone system. Additional electrical circuits and receptacles were added to the west outside wall of G-Cell to support operation of the WEFTS. Figure 10 shows the electrical power modifications at G-Cell. These new receptacles are located inside the glove bag so the power wires pass through the glove bag to the instrument rack. This figure also identifies the PTL facility electrical circuits and may be useful in troubleshooting electrical power problems.

To protect the computers and instrumentation from potential power failures, three battery-backed UPSs are installed in the instrument rack. All of the power for the WEFTS equipment is supplied through a UPS, except power for the furnace, the vacuum pump, and the heat trace controllers. These components are powered from a 240 VAC source, which does not have a UPS. Figure 11 shows the electrical power distribution used to support WEFTS operation.

4.0 Operation

4.1 Overview

The versatility of the WEFTS allows for a variety of tests to be performed. Drying tests can be conducted using several different configurations. An overview of the system operation is given in this section. A typical drying test consists of the following steps:

- CVD at 50°C under vacuum until system pressure drops below 0.5 Torr
- Pressure Rise Test under static vacuum conditions at 50°C for 1 hour
- Gas Evolution Test at 75°C under vacuum and gas purging conditions
- Residual Water Removal Verification Test up to 400°C under vacuum and gas purging conditions for about 10 hours.

For a typical test, the temperature is ramped up each step to attempt to remove additional water, while the valve configuration and flowing conditions may or may not change. For these drying tests, the system can be configured to operate in three basic modes:

- Vacuum Drying
- Vacuum Drying with Gas Purging
- Gas Purging.

For each of these modes, the valves can be configured to allow sampling with or without the GC and/or MS. In addition, the system temperature can be varied for each of these configurations, and the type of gas or gas mixture can be varied for gas purging. The following sections describe each of these operating modes in more detail.

4.2 Operating Modes

4.2.1 Vacuum Drying

Figure 12 shows the valve configuration for the vacuum drying mode. The flow path for this mode is highlighted to show what parts of the system are being evacuated. As seen in Figure 12, the system is being evacuated from the GSS isolation valve (V1) to the inlet of the vacuum pump. The vacuum drying mode can be operated with or without the condenser. Figure 12 shows operation with the condenser. To bypass the condenser, V27 is positioned to the vacuum pump inlet line and V26 is closed.

The condenser is typically used only for the first part of the CVD test to remove the bulk of the water from the system, which limits the amount of water pumped through the scroll pump. After the non-condensible gases have been evacuated from the system, the evaporation of water is no longer diffusion limited and the condenser becomes a very effective pump. The pressure in the condenser is reduced to the saturation pressure for water corresponding to the temperature of the condenser cooling coils. This low pressure becomes the driving force for pumping water from the system. As long as no air in-leakage occurs, the condenser will continue to pump water vapor until the system pressure approaches the condenser pressure. The coolant temperature is typically maintained at about 5°C, so the condenser pressure is reduced to about 6.5 Torr after the non-condensible gases are evacuated. The rate at which water can be removed is limited by heat transfer to the water in the system; steam pumping capacity; and pressure losses in the piping, valves, and filters. The temperature at which the CVD process is performed is typically 50°C, but can easily be varied if desired.

Even with the condenser in-line, a small amount of water vapor bypasses the condenser and is pumped by the vacuum pump. After all of the non-condensible gases have been removed from the system, this water vapor will be saturated and will condense in the pump internals. To determine if water vapor has condensed in the pump, the pump is isolated from the system by closing V10, and the pump inlet pressure is monitored using PE-03. If the inlet pressure does not immediately drop to near the pump ultimate pressure (10^{-2} Torr), there is most likely water in the pump. To purge out the water, ballast gas is injected into the pump inlet by opening V29 and setting flow controller FE-04 as desired. If purging with ballast gas for several minutes does not help reduce the pump inlet pressure, then the vacuum pump may be in need of repair.

After the system pressure has been reduced to the condenser pressure, water vapor removal ceases, and the system is then filled with water vapor with a partial pressure equal to the saturation pressure at the condenser coil temperature. At this time, the condenser is valved out of the system, and the vacuum pump is used to remove the rest of the free water from the system. The vacuum pump is capable of pumping the system to pressures below 0.5 Torr.

To evaluate the "dryness" of the system after CVD has been performed, a pressure rise/rebound test is typically performed. A limited pressure rise (less than about 0.6 Torr) during a 1-hour period indicates that the system has attained an acceptable level of dryness according to the IPS. To perform the dryness test, the system is isolated by closing the vacuum pump isolation valve (V10) and then monitoring the subsequent pressure rise, if any, using the high accuracy pressure sensor (PE-06).

4.2.2 Vacuum Drying with Gas Purging

The system configuration and flow path for vacuum drying with a gas purge is shown in Figure 13. As shown in Figure 13, valve V1 is opened along with a valve for the particular gas bottle or bottles being used. Typically UHP argon is used for the purge gas. Valve V23 is opened and flow controller FE-01 is set as desired to flow UHP argon through the system. Typically, the condenser is bypassed in this mode by closing V26 and positioning V27 appropriately, as shown in Figure 13.

Gas purging during vacuum drying is desirable for three reasons. First, gas purging helps to sweep away gases during the drying process, especially air caused by system in-leakage. Second, purging allows for gas sampling with the GC. The GC is not able to pull in a sample under vacuum conditions and therefore must sample the vacuum pump exhaust line. This required configuration was a primary driver for using an oil-less vacuum pump to prevent contaminating the gas stream. After most of the water has been removed and the system is under a low vacuum, the steam flow is very small. Without additional gas flow through the system, the GC will sample the hot cell air that back flows into the GC sample line because the pump exhaust flow is negligible. The gas purge carries the water vapor and other gases through the pump exhaust and GC sample line, preventing any back flow from the hot cell. The third reason is for totalizing the amount of water removed from the system. A known gas flow combined with a real-time dew point measurement provides the data for calculating the amount of water removed from the system. Without the gas flow, the only way to determine water removed is by accurately measuring the pump inlet temperature and pressure, and then using the pump curve to calculate the mass flow of water vapor. This method assumes that all of the flow is water vapor (negligible air in-leakage) and may prove difficult.

4.2.3 Gas Purging

The system configuration for gas purging at atmospheric conditions is shown in Figure 14. The vacuum pump and condenser are bypassed, and the flow is redirected through V25 and V12 to exhaust to the hot cell. This configuration is typically used between drying tests to keep the system dry, but can also be used during a drying test if desired. If this configuration is used, V25 should not be opened until the system pressure has increased to slightly above atmospheric pressure. Otherwise, hot cell air will back flow into the system, which could be very detrimental to the data during a test.

4.2.4 Gas Sampling

For each of the three configurations described in the previous sections, the system can also be configured to allow sampling using the MS and/or GC. As mentioned in Section 4.2.2, the GC cannot sample without some gas purge through the system. Figure 15 shows a vacuum drying with gas purge configuration where the flow path has been modified for MS and GC sampling. Valve V13 is opened for MS sampling, and the pump exhaust is redirected to the GC sample line by closing V12 and opening V11, V33, and V34.

A "leak" valve (LV01, also called a gas dosing valve) was installed on the MS sample line so that the MS can sample under a large range of system pressures. Without the leak valve, system pressures above about 40 Torr produce too much flow through the MS capillary tube, which overwhelms the turbo pump used to pump down the MS sample chamber. The leak valve allows the flow to be continuously varied from 0.4 L/s to 10^{-11} L/s. The MS inlet pressure can therefore be controlled to any pressure desired, even if the system pressure varies dramatically. The MS sample line pressure is monitored using PE-07.

5.0 Maintenance

5.1 Maintenance Philosophy

No specific maintenance plans or procedures have been developed for the WEFTS. Equipment functional checks and other miscellaneous tasks are performed before and after testing, and these activities are typically covered in the test procedure. Because the equipment is operated within a radiation and contamination area, performing routine equipment maintenance and repairs can be a difficult task. At times it may be easier to simply replace items rather than repairing them.

5.2 Routine Maintenance Tasks

This section describes typical system maintenance tasks, most of which are covered in the test procedure. The following tasks, as a minimum, must be performed for proper function of the WEFTS:

Daily:

- Check capacity of gas bottles
- Check glove bag integrity

Prior to test:

- Perform general functional check of all equipment
- Check operation of SAS
- Synchronize computer clocks
- Drain/dry condenser
- Clean fuel element transfer boat
- Bake out GC and MS
- Regenerate MS hydrogen getter
- Replace moisture sensor
- Check coolant level in chiller reservoir
- Check gas traps

Other tasks may be performed as required by a particular test.

5.3 Instrument Calibration

The WEFTS has several instruments that require periodic calibration. The instruments that require calibration were calibrated prior to installation in the system. Appendix B provides an instrument list that includes the calibration number and expiration date for each calibrated instrument. The calibration period is typically 1 to 2 years, so many of the instruments will maintain their calibration for the duration of the fuel element drying tests. Some of the sensors are located in the hot cell, where it is difficult to perform calibration adjustments on them. For pressure sensors, the calibration can be checked by using a reference sensor connected to the system via a port installed through a glove bag sleeve. However, if an instrument is found to be out of calibration, it may be easier to replace the sensor, rather than trying to make in-cell adjustments. The moisture sensor, for example, is typically replaced before the start of each drying test to ensure that it is fully functional and in calibration. The mass flow controllers are located outside the hot cell, inside the glove bag, so that calibration can be performed more easily.

5.3.1 High Accuracy Pressure Sensor

The high accuracy pressure transducer and corresponding signal conditioner used to measure the retort pressure (PE-06) was purchased with a "remote-zero" option. In order to maintain accurate pressure measurements below 1 Torr, checking and adjusting the zero of the sensor must be performed periodically. To re-zero the sensor, a pressure well below the sensitivity of the transducer is applied using the auxiliary turbo vacuum pumping system (P2 in Figure 6). During drying tests, the turbo pump is isolated from the system (V37 is common to PE-06 and the retort inlet, and V38 is closed). For re-zeroing the sensor, V37 is positioned to be common with PE-06 and the turbo pump inlet while V38 is opened, as shown in Figure 16. This configuration allows the turbo pump to pump down the sensor head and be roughed through V38 using the scroll vacuum pump (P1). After the entire system is roughed below about 5 Torr, the turbo pump can be powered on and allowed to reach full speed, which takes several minutes. After the turbo pump has reached full speed, the pressure on the sensor head is well below 10^{-4} Torr and the zero adjustment can be performed in accordance with the manufacturer's instructions.

5.3.2 Gas Chromatograph and Mass Spectrometer

Calibration of the GC and MS is performed periodically by connecting gas standards to the system via a line routed through the glove bag to the calibration gas port. A known mixture of gases is injected into the system, and samples are drawn into the GC or MS and analyzed for comparison with the standard. There are several different ways to configure the valves to calibrate the GC and MS. To calibrate the MS, V36 is typically opened to allow calibration gas to flow past the MS sample line, as shown in Figure 17. This calibration gas is either allowed to flow through the system using the vacuum pump (by opening V10) or bypassing the vacuum pump (opening V25), depending on the system pressure desired. The GC and MS could be calibrated at the same time by flowing through the GC sample line by closing V12 and opening V11, V33, and V34. Typically, the GC is calibrated by opening V4, V5, V33, and V34 to flow calibration gas past the GC sample line, as shown in Figure 17. After a sample reference standard has been acquired, the GC and MS are then calibrated according to the manufacturer's instructions.

6.0 References

Babcock & Wilcox Hanford Company (B&W). 1997a. *SNFC Furnace Tray Assembly and Tools*. Drawing H-3-307609, Rev. 0, April 1997, Richland, Washington.

Babcock & Wilcox Hanford Company (B&W). 1997b. *SNFC Furnace Retort Inlet Assembly*. Drawing H-3-307608, Rev. 0, April 1997, Richland, Washington.

Westinghouse Hanford Company (WHC). 1995. *Integrated Process Strategy for K Basins Spent Nuclear Fuel*. WHC-SD-SNF-SP-005, Rev. 0, July 1995, Richland, Washington.

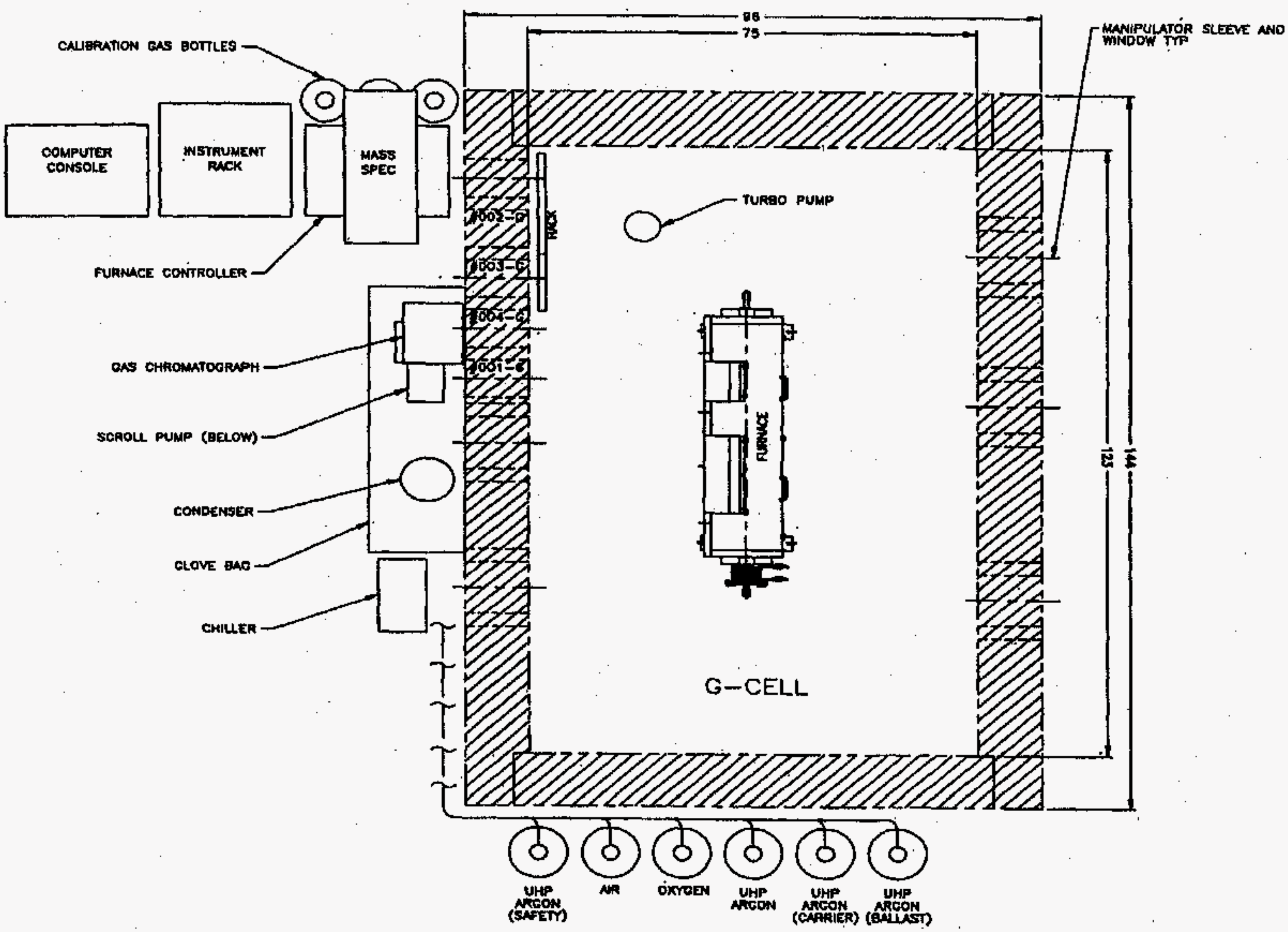

Figure 1. Plan View of the Furnace System Equipment at G-Cell

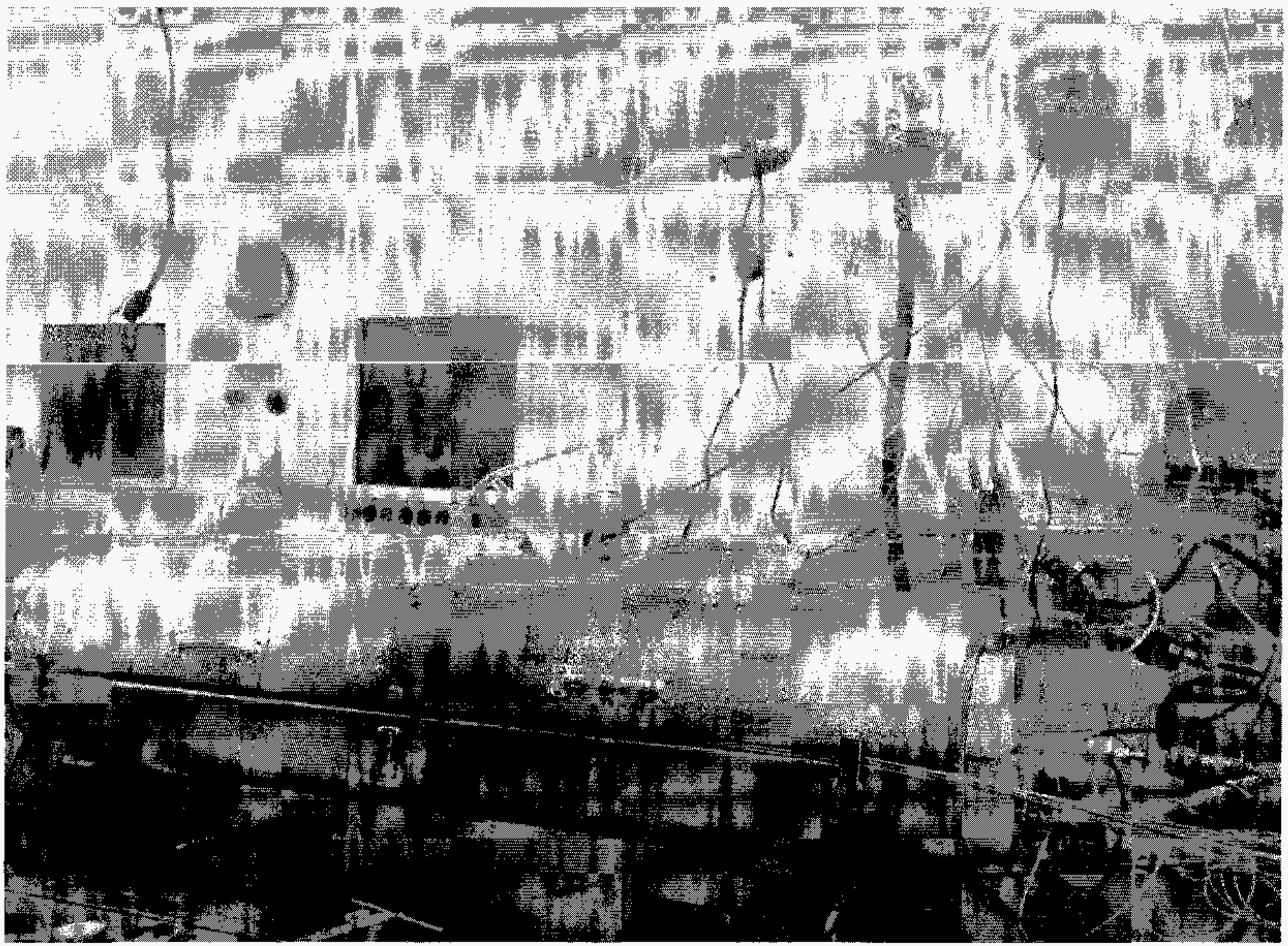

Figure 2. Photograph of Furnace and Related Equipment Inside G-Cell

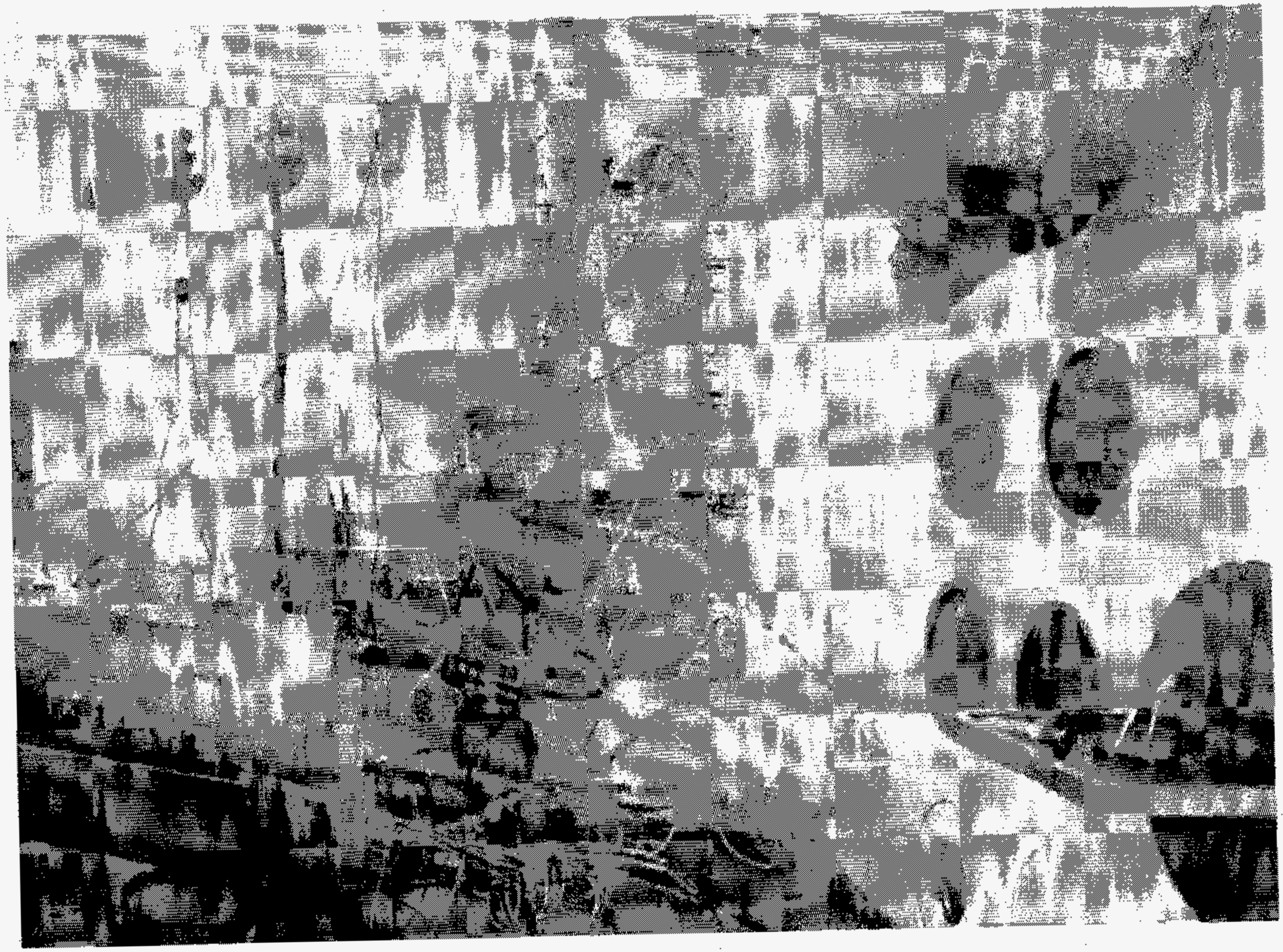

Figure 3. Photograph of Furnace and Piping Rack Inside G-Cell

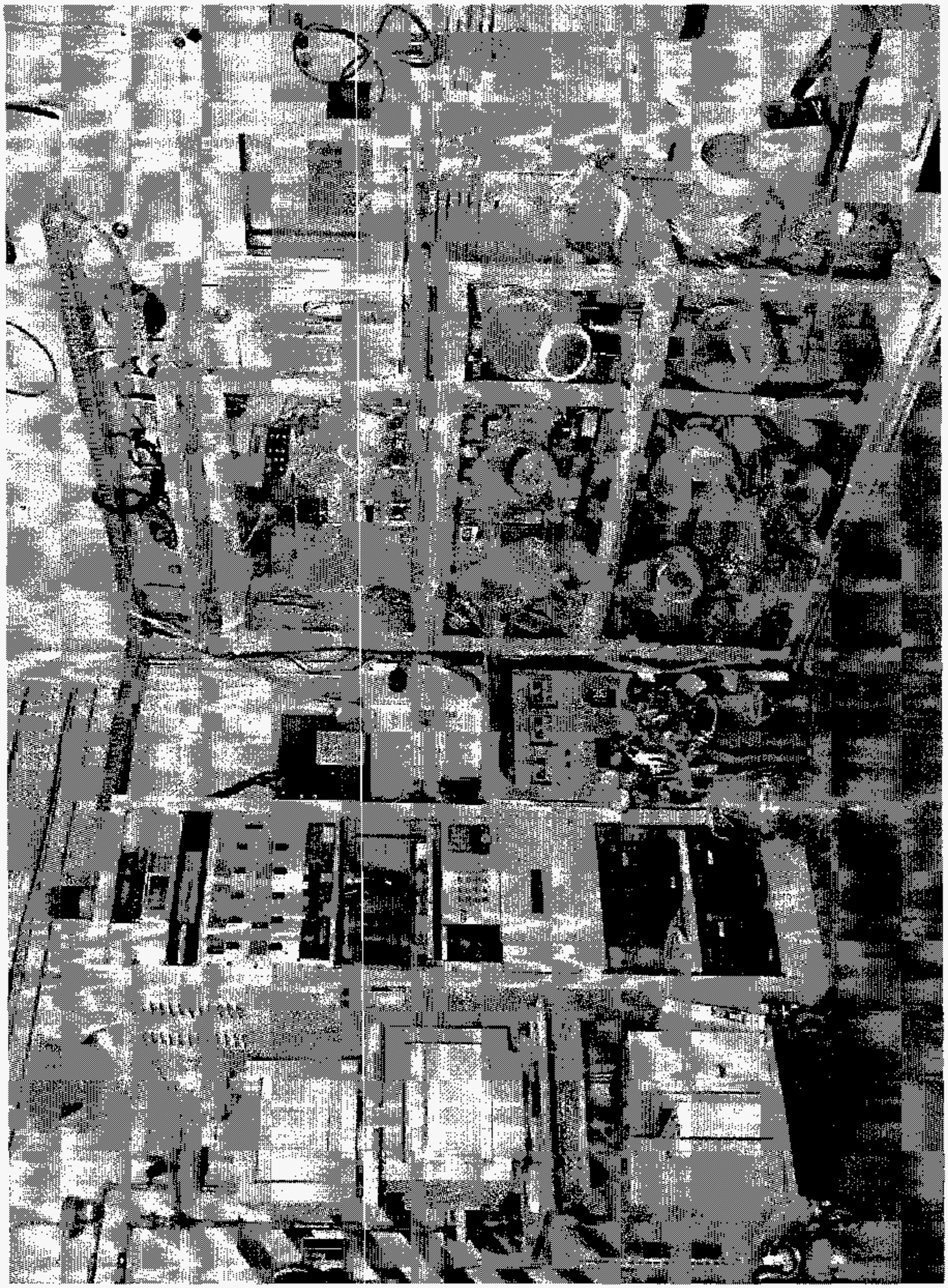

Figure 4. Photograph of Furnace System Equipment Outside G-Cell

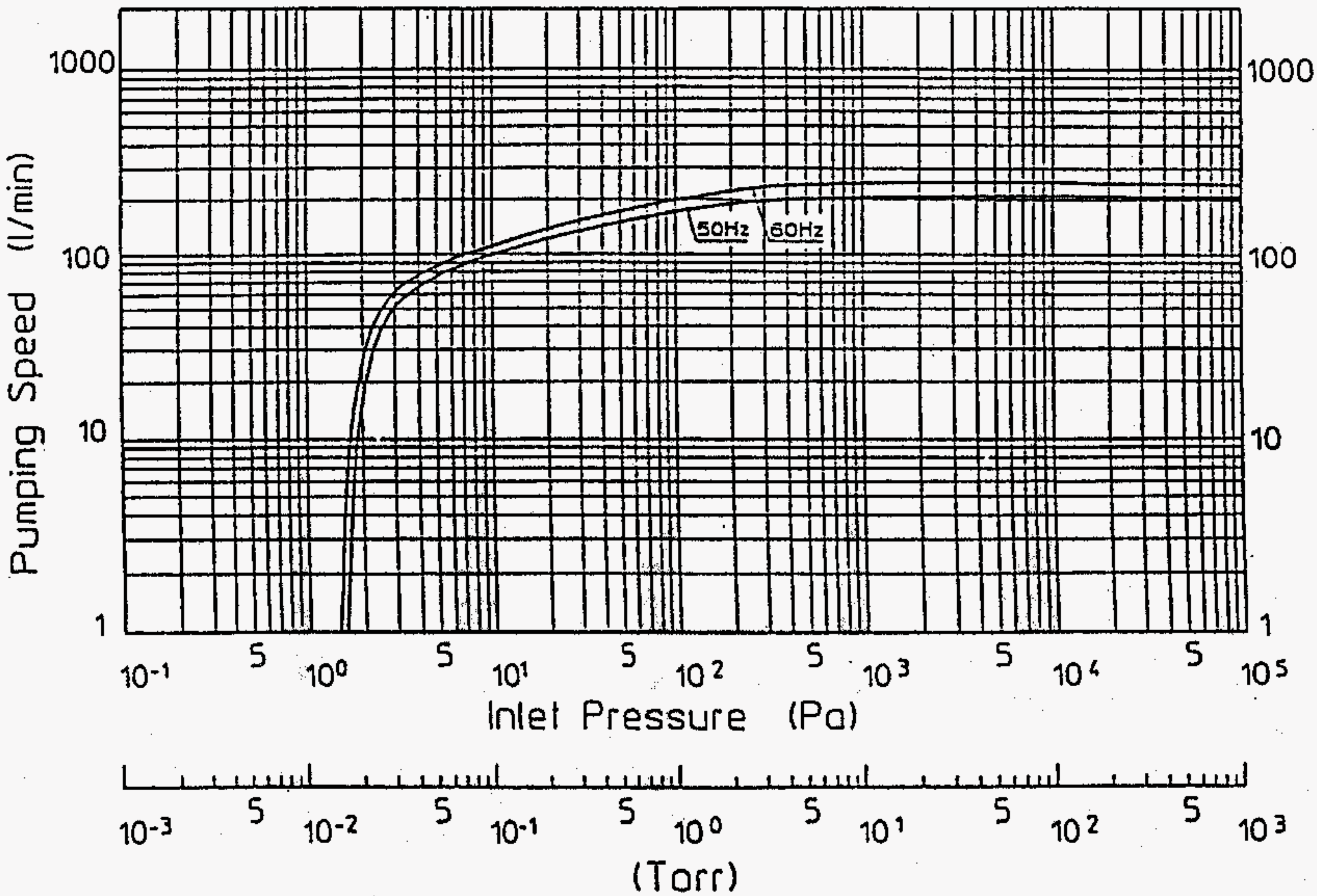

Figure 5. Performance Curve for the Varian 300DS Scroll Pump

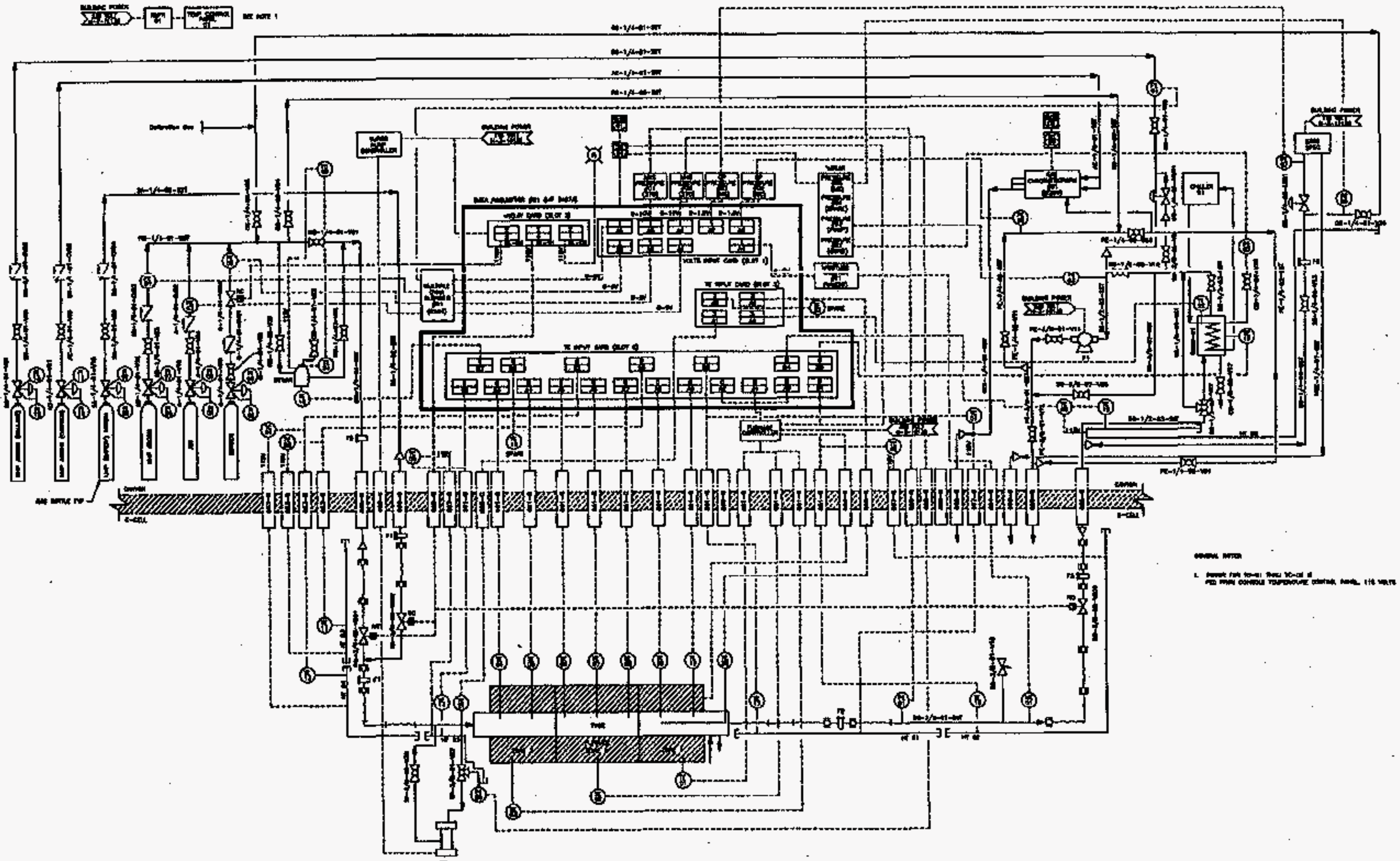

Figure 6. Piping and Instrumentation Diagram for the Furnace System

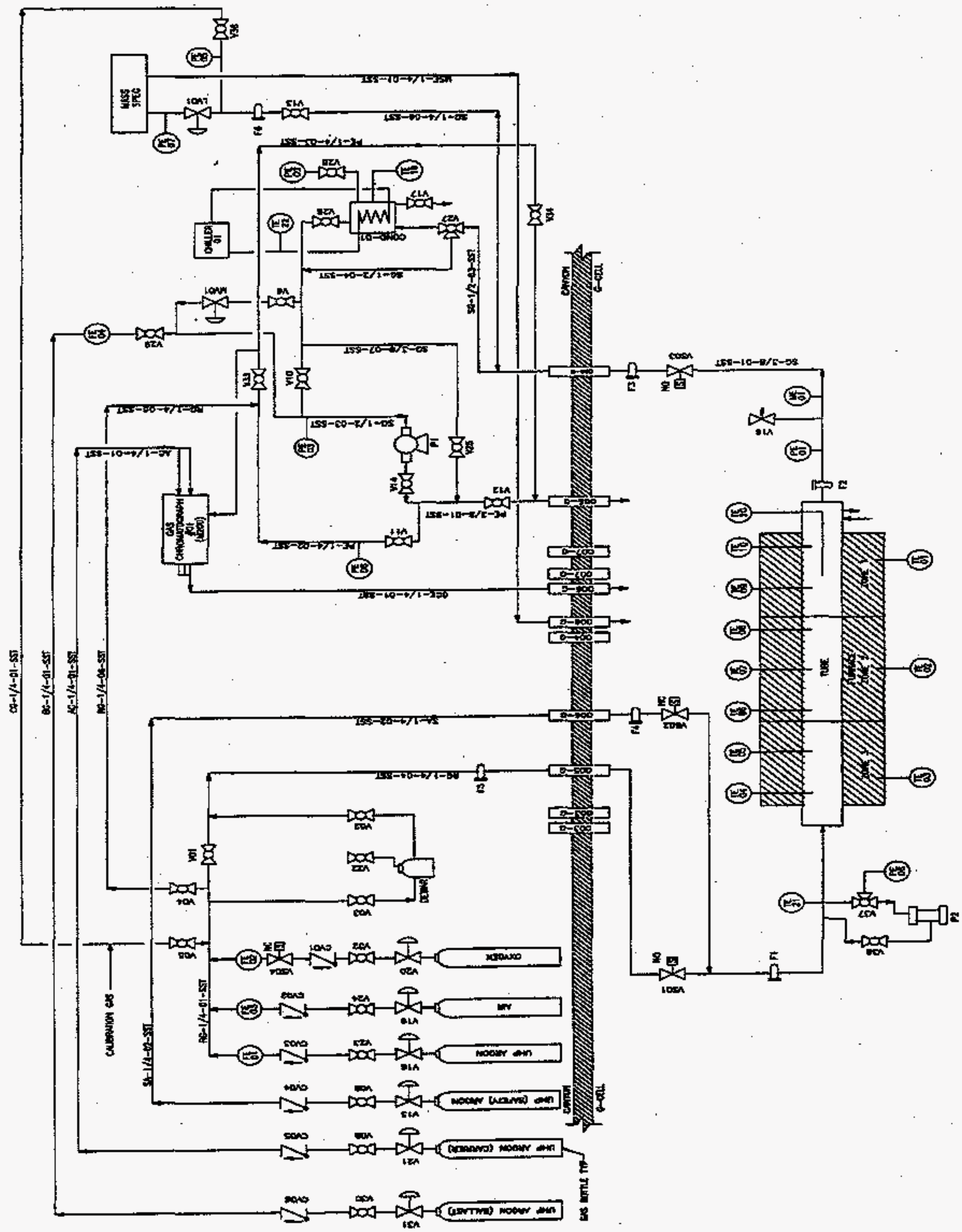

Figure 7. Piping Schematic for the Furnace System

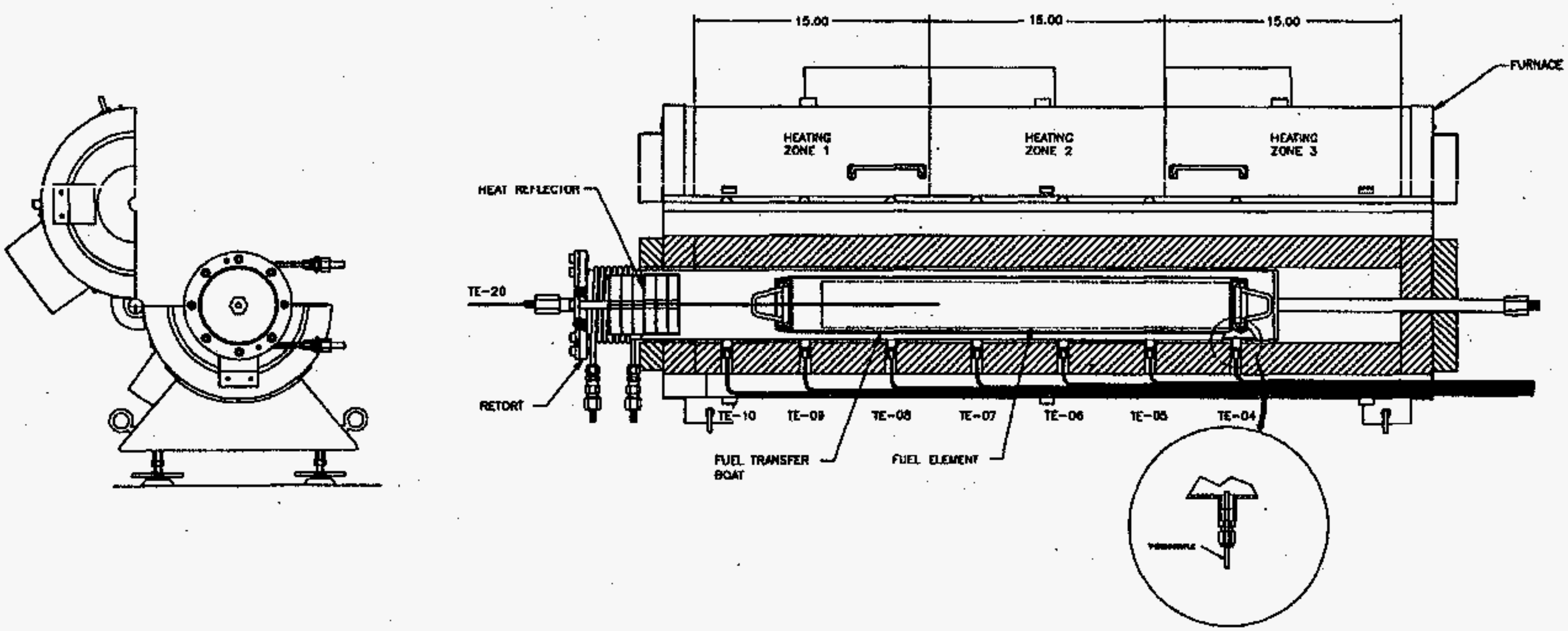

Figure 8. Schematic of the Furnace and Retort Configuration

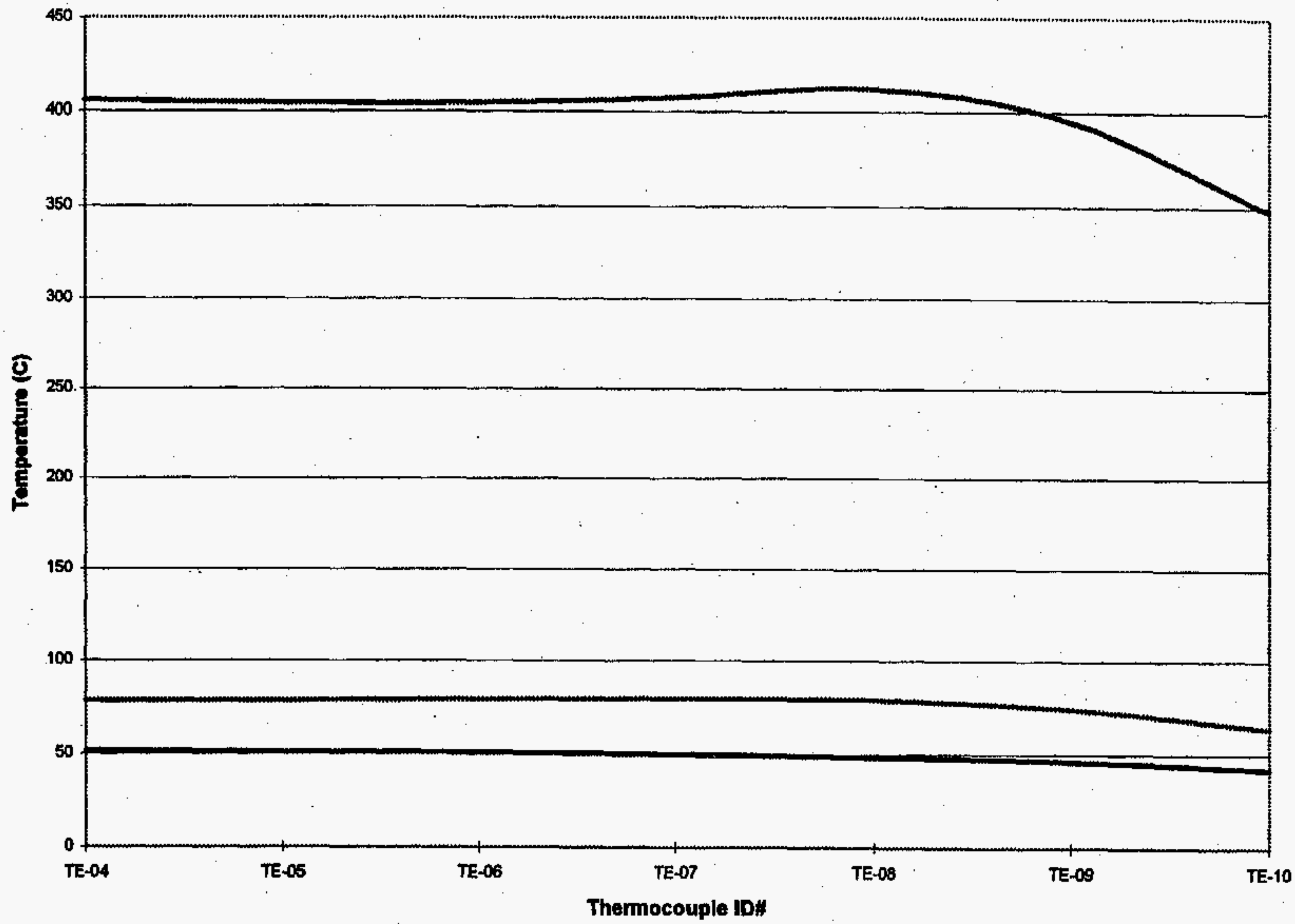

Figure 9. Typical Temperature Profiles for the Furnace Retort Without a Fuel Element

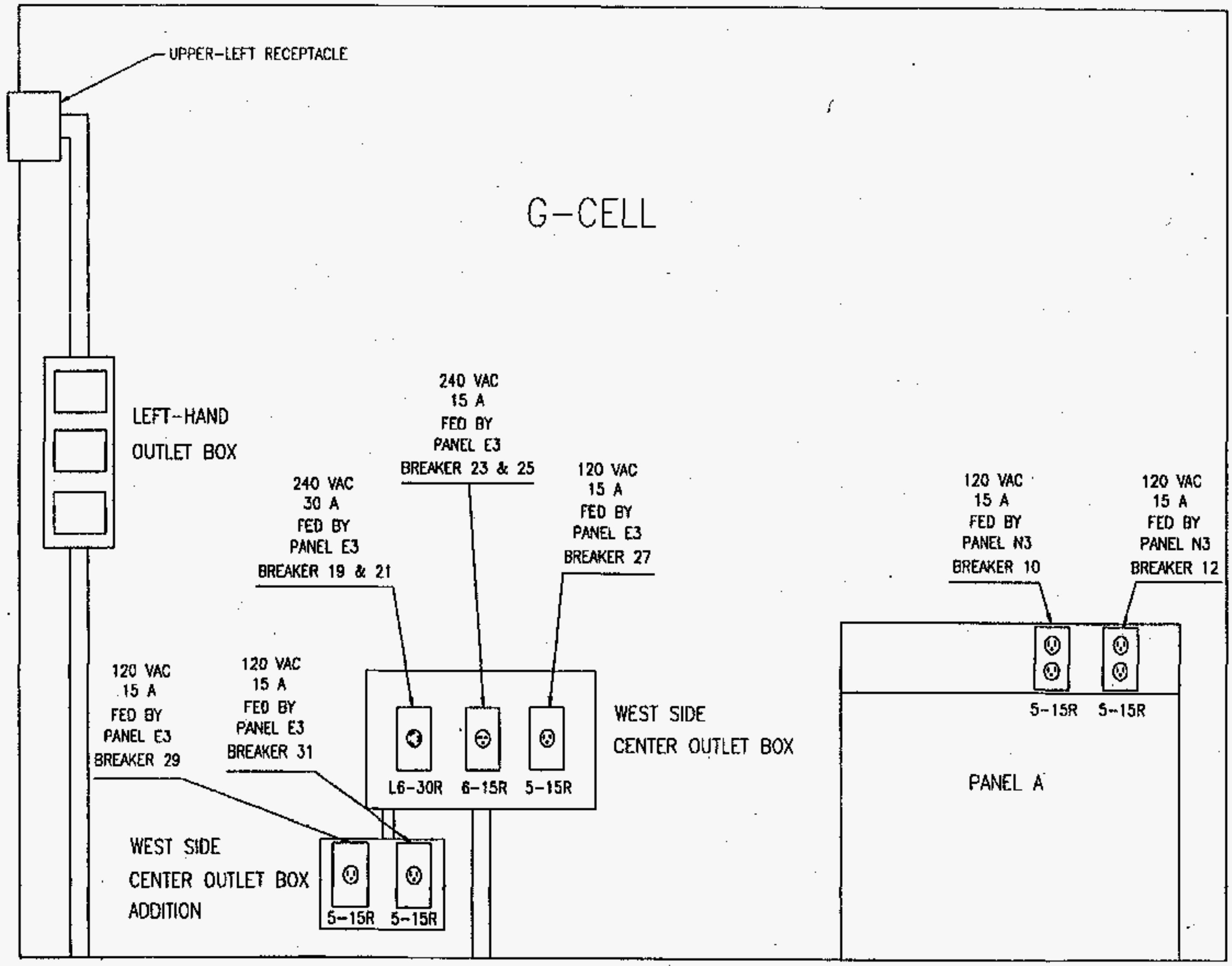

Figure 10. G-Cell Electrical Power Modifications

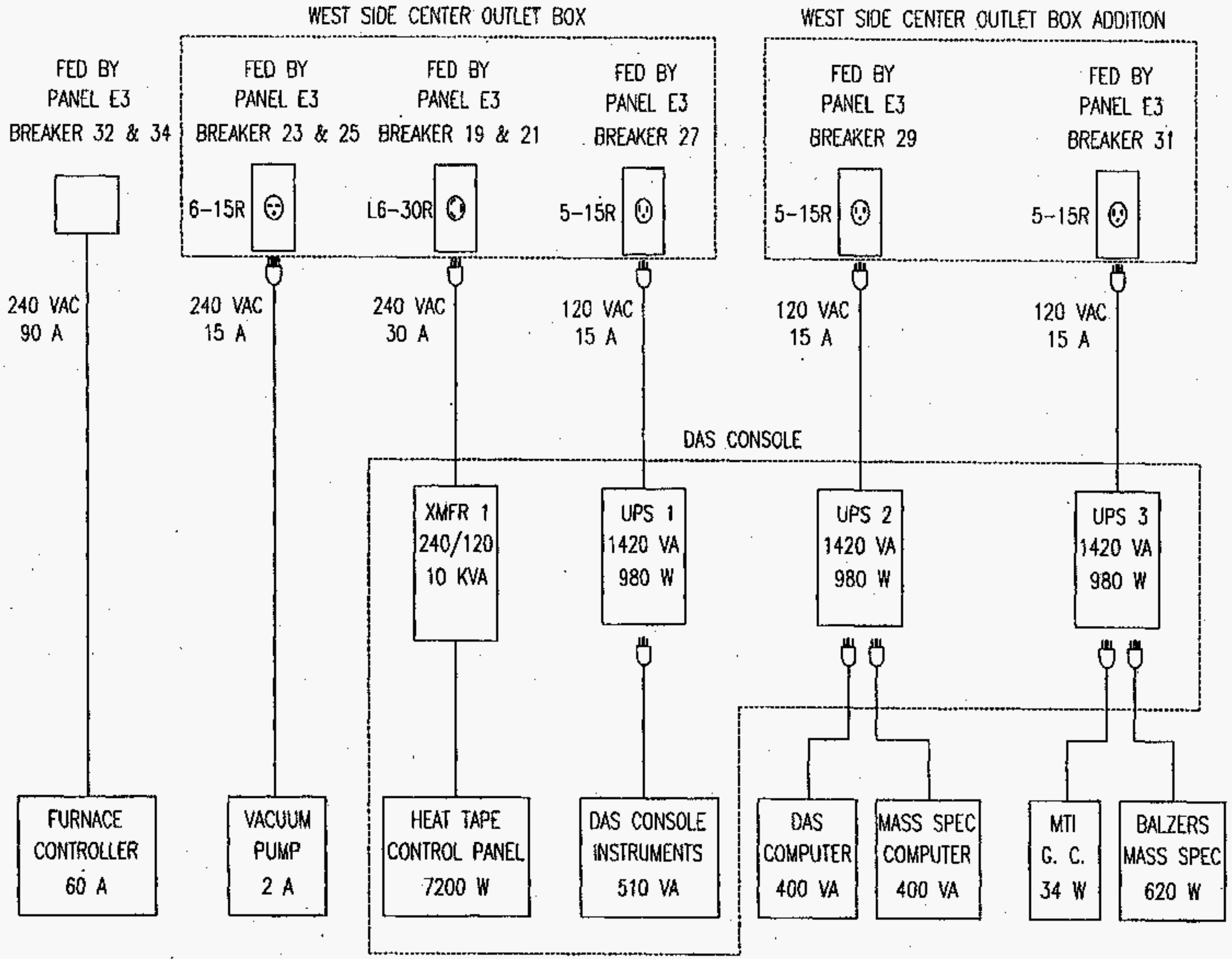

Figure 11. Power Distribution Diagram for the Furnace System

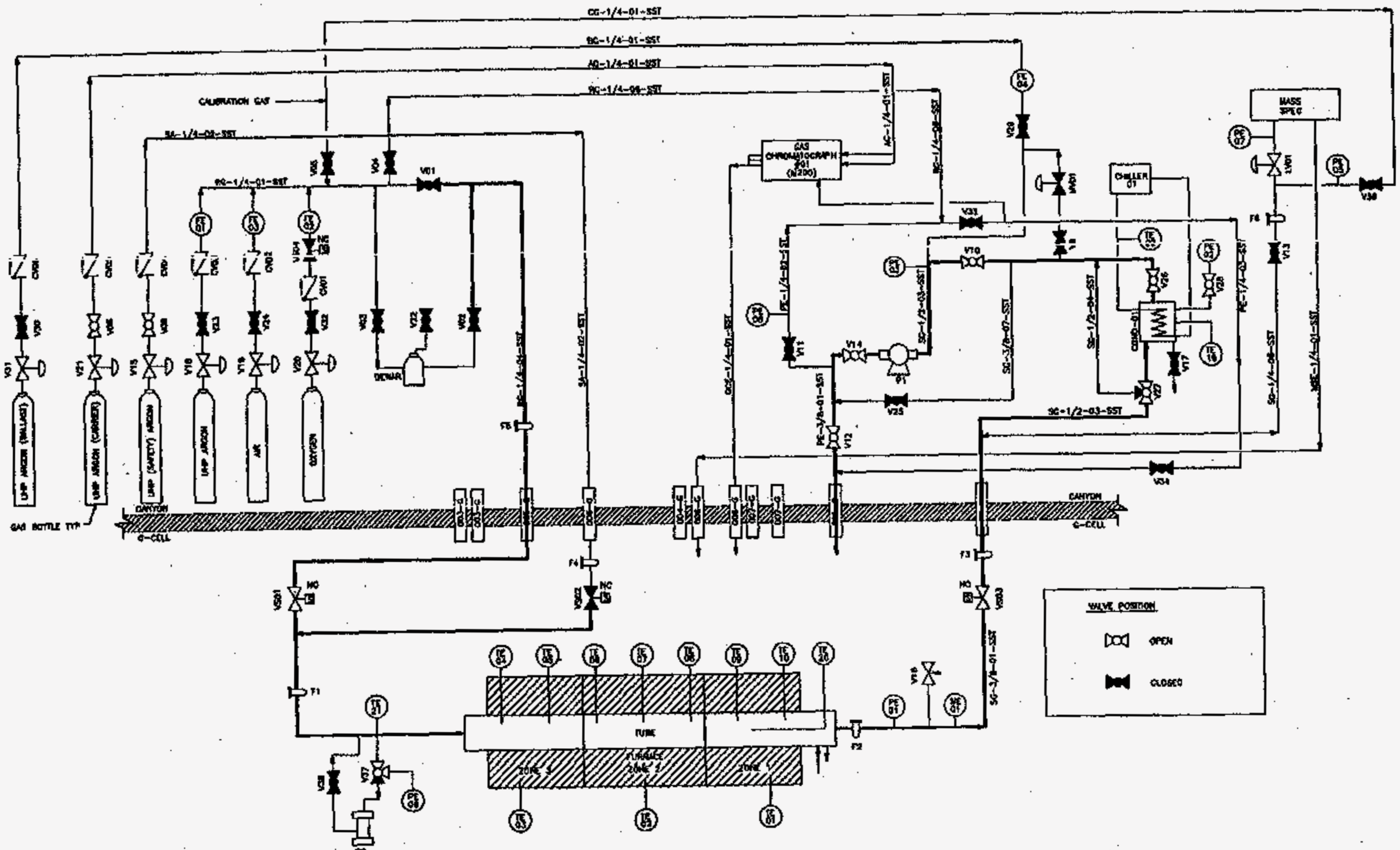

Figure 12. System Valve Configuration and Flow Path for Vacuum Drying Mode

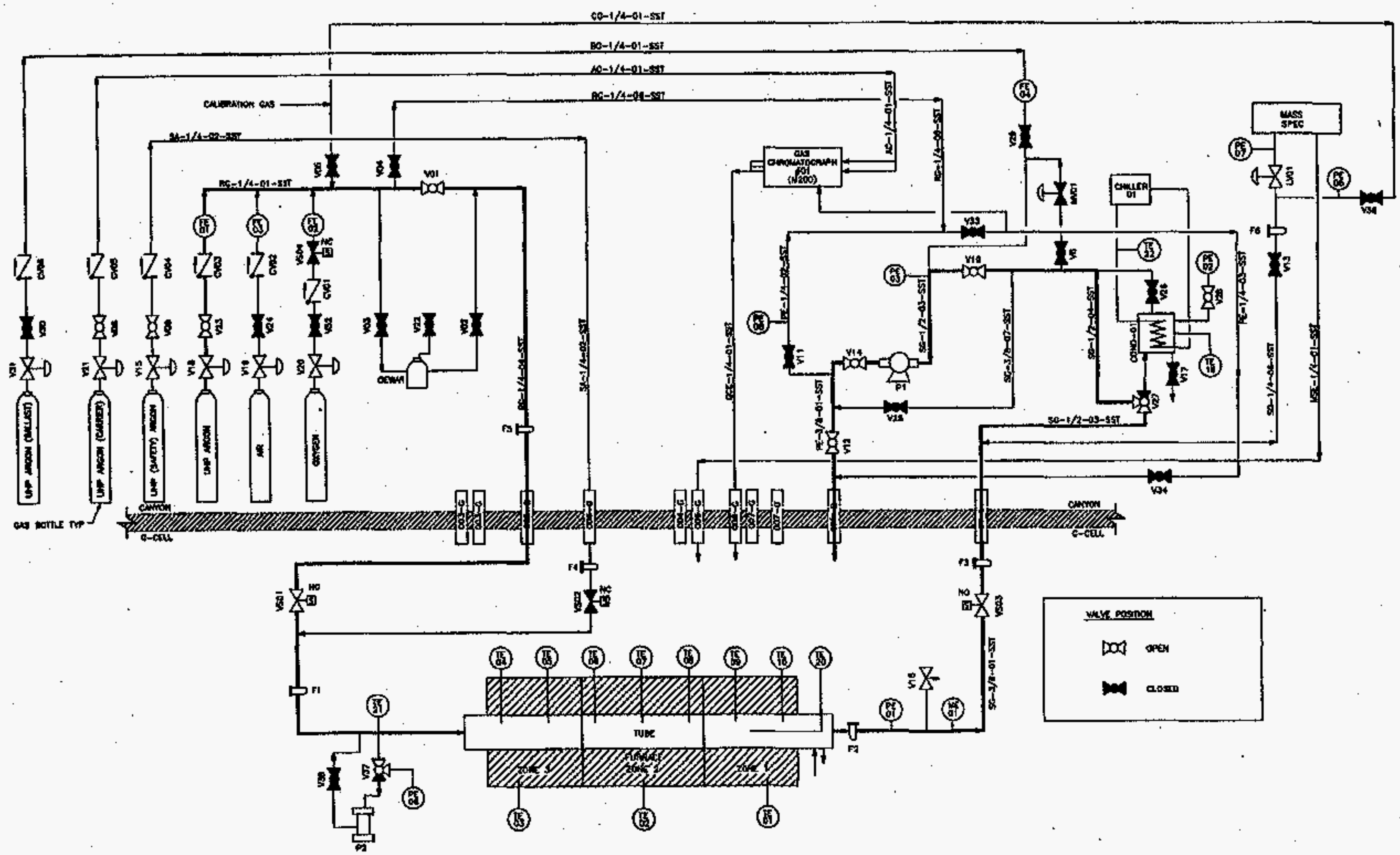

Figure 13. System Valve Configuration and Flow Path for Vacuum Drying Mode with Gas Purging

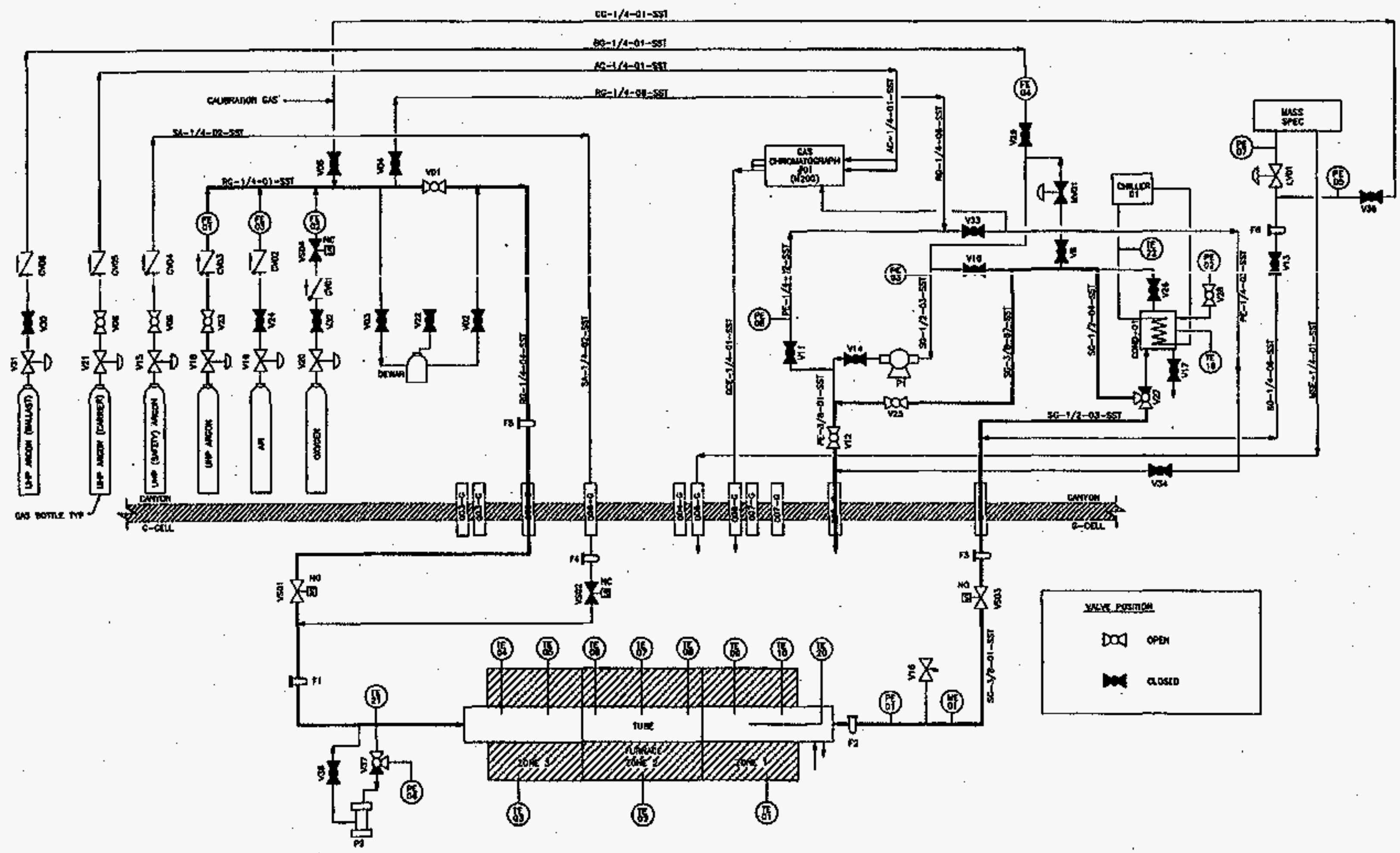

Figure 14. System Valve Configuration and Flow Path for Gas Purging Mode

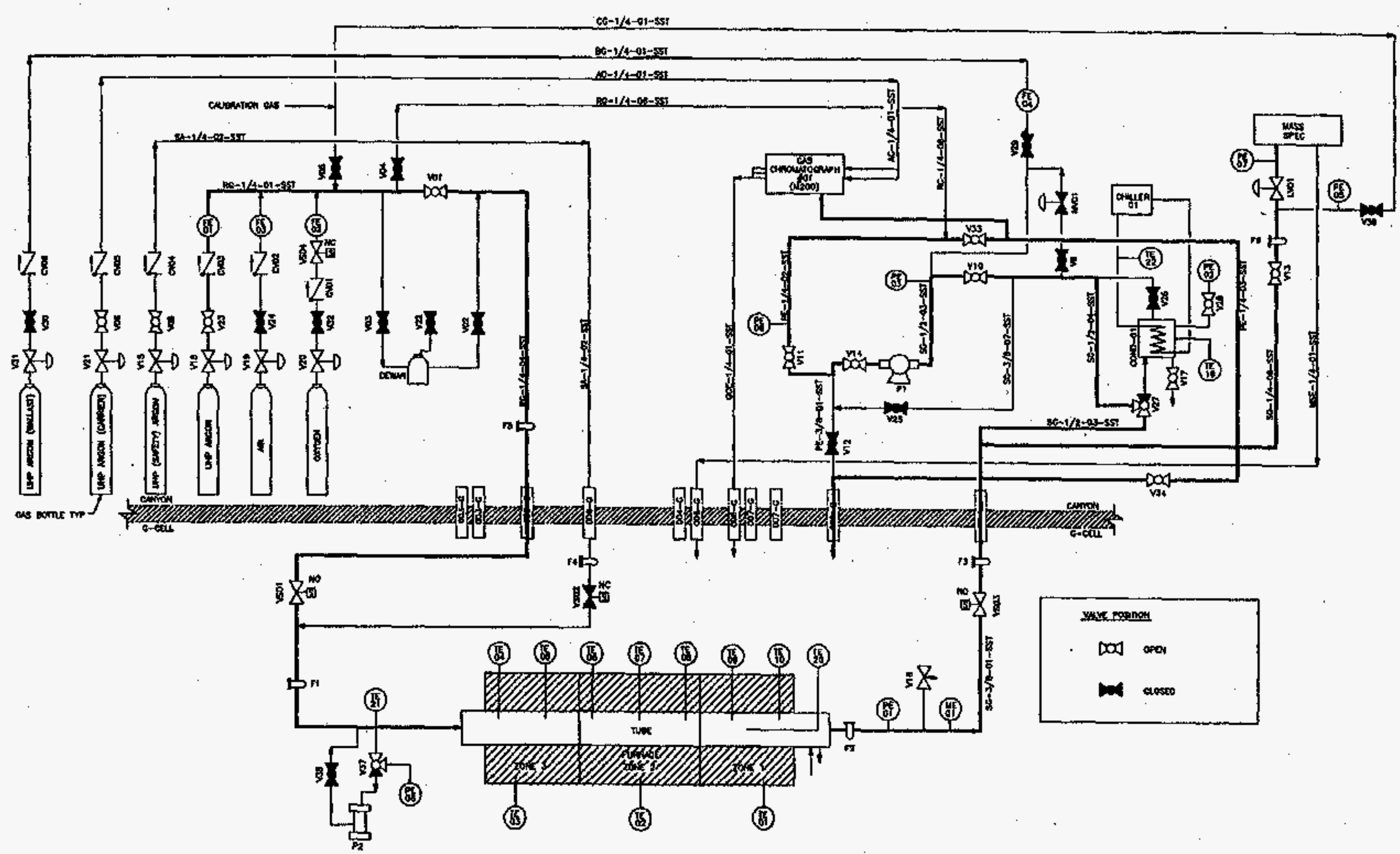

Figure 15. System Valve Configuration and Flow Path for Vacuum Drying with Gas Purging and Gas Sampling

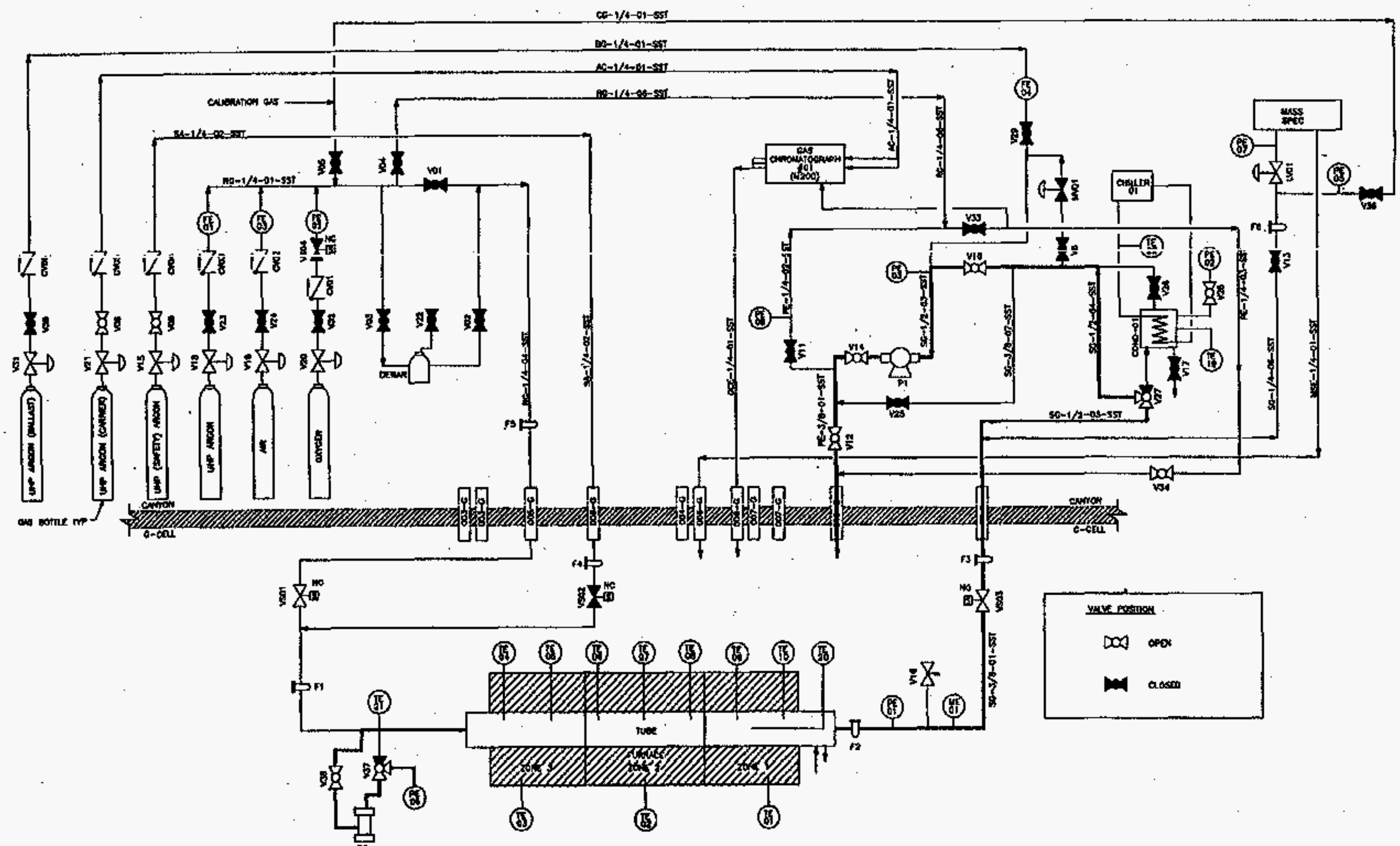

Figure 16. System Valve Configuration and Flow Path for Re-zeroing the High Accuracy Pressure Transducer

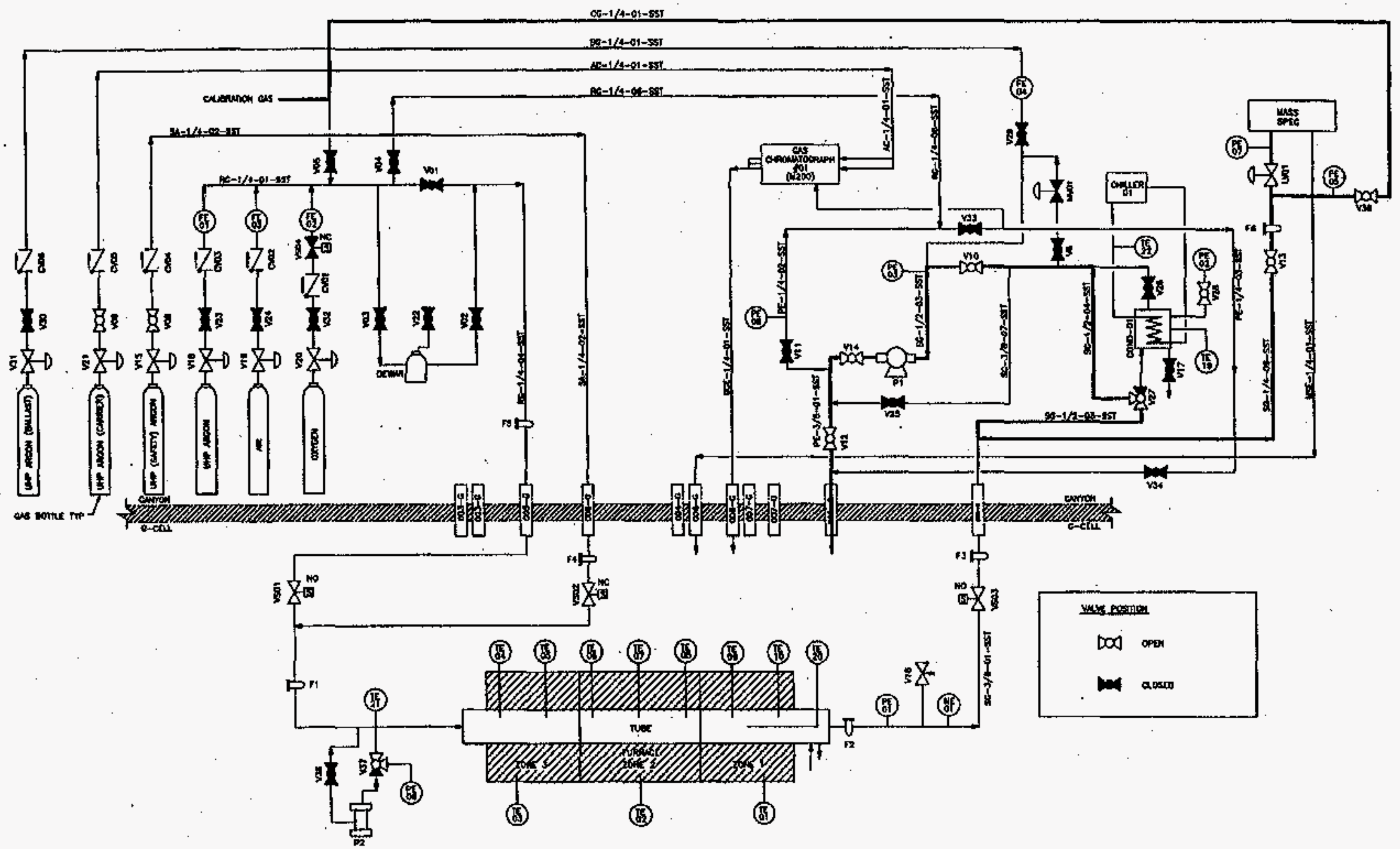

Figure 17. System Valve Configuration and Flow Path for Mass Spectrometer Calibration

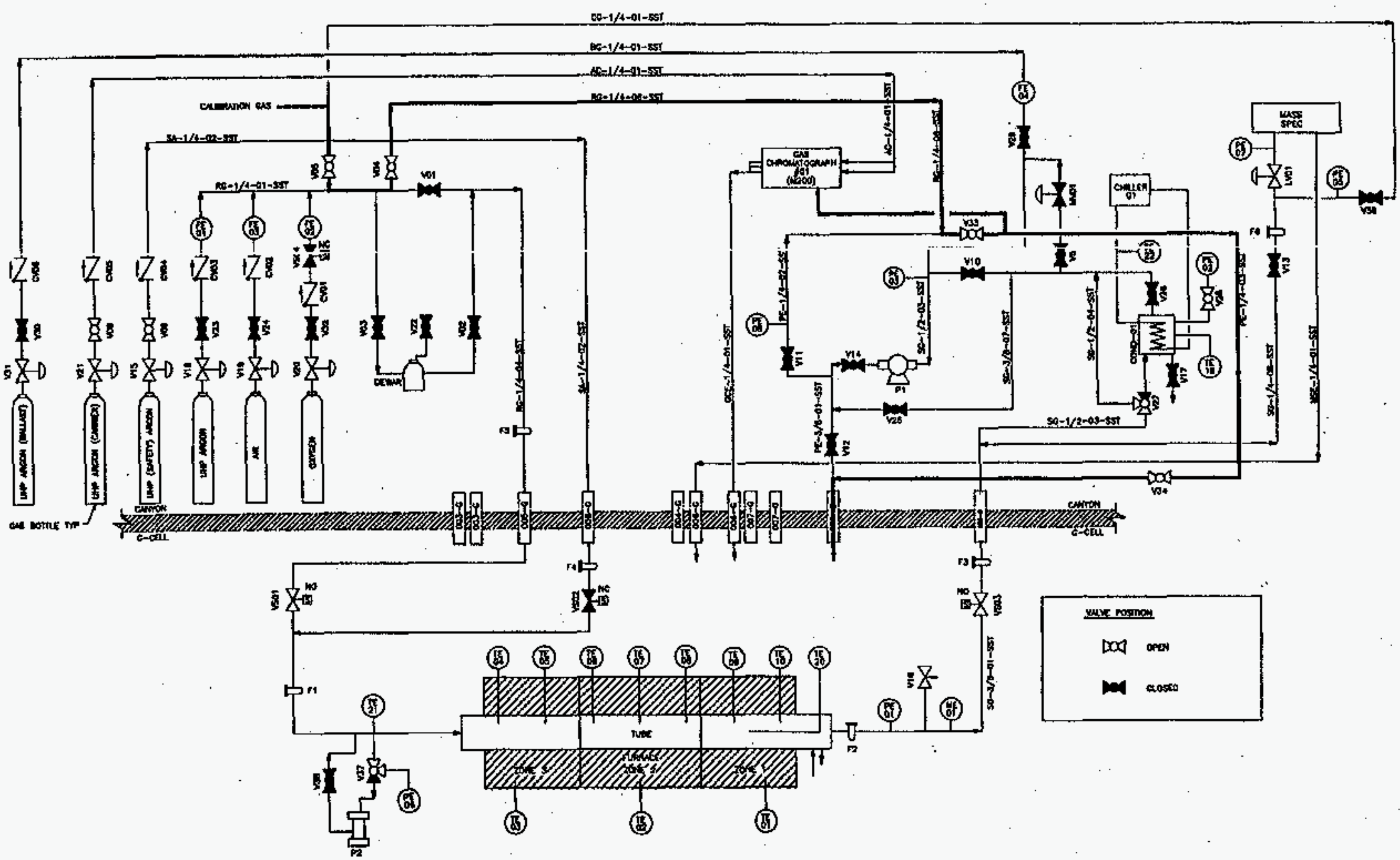

Figure 18. System Valve Configuration and Flow Path for Gas Chromatograph Calibration

Appendix A

Drawing List

Appendix A

Drawing List

Drawing#	Sheet#	Rev#	Title
H-3-307605	1	0	SNFC Furnace Equipment Arrangement
H-3-307605	2	0	SNFC Furnace Equipment Arrangement
H-3-307605	3	0	SNFC Furnace Equipment Arrangement
H-3-307606	1	0	SNFC Furnace P&ID Key Sheet and General Notes
H-3-307606	2	0	SNFC Furnace P&ID (G-Cell)
H-3-307607	1	0	SNFC Furnace Rack Assembly General Notes and Parts List
H-3-307607	2	0	SNFC Furnace Rack Assembly and Plug Arrangement
H-3-307607	3	0	SNFC Furnace Plug Assemblies
H-3-307607	4	0	SNFC Furnace Rack Sub Assembly and Views
H-3-307608	1	0	SNFC Furnace Retort Inlet Assembly
H-3-307608	2	0	SNFC Furnace Retort Inlet
H-3-307609	1	0	SNFC Furnace Tray Assembly and Tools
H-3-307609	2	0	SNFC Furnace Tray Assembly and Tools
H-3-307609	3	0	SNFC Furnace Heat Shield Assembly
H-3-307610	1	0	SNFC Furnace Assembly
H-3-307610	2	0	SNFC Furnace Assembly
H-3-307610	3	0	SNFC Furnace View
H-3-307610	4	0	SNFC Furnace View
H-3-307610	5	0	SNFC Furnace Sub Assemblies and Views
H-3-307611	1	0	SNFC Furnace Interconnection Diagram
H-3-19170	1	0	327 Bldg Split Plug 1
H-3-19170	2	0	327 Bldg Split Plug 1
H-3-19170	3	0	327 Bldg Split Plug 1

Appendix B

Instrument List

Appendix B

Instrument List

Tag#	Line#	Calibration#	Exp. Date	Description	Manufacturer & Part#
TE-01	N/A	327G001	12/98	furnace zone 1 control thermocouple (TC), type K, accuracy: ± 2°C	supplied with ATS 3210 furnace
TE-02	N/A	327G002	12/98	furnace zone 2 control TC, type K, accuracy: ± 2°C	supplied with ATS 3210 furnace
TE-03	N/A	327G003	12/98	furnace zone 3 control TC, type K, accuracy: ± 2°C	supplied with ATS 3210 furnace
TE-04	SG-3/8-01	444-78-02-009 S/N 008	2/4/98	retort zone 3 TC, type K, accuracy: ± 2°C	PYROCOM #MFK53U24F07P0
TE-05	SG-3/8-01	444-78-02-009 S/N 009	2/4/98	retort zone 3 TC, type K, accuracy: ± 2°C	PYROCOM #MFK53U30F07P0
TE-06	SG-3/8-01	444-78-02-009 S/N 010	2/4/98	retort zone 3 TC, type K, accuracy: ± 2°C	PYROCOM #MFK53U36F07P0
TE-07	SG-3/8-01	444-78-02-009 S/N 011	2/4/98	retort zone 2 TC, type K, accuracy: ± 2°C	PYROCOM #MFK53U42F07P0
TE-08	SG-3/8-01	444-78-02-009 S/N 012	12/14/98	retort zone 2 TC, type K, accuracy: ± 2°C	PYROCOM #MFK53U48F07P0
TE-09	SG-3/8-01	444-78-02-009 S/N 013	2/4/98	retort zone 1 TC, type K, accuracy: ± 2°C	PYROCOM #MFK53U54F07P0

Tag#	Line#	Calibration#	Exp. Date	Description	Manufacturer & Part#
TE-10	SG-3/8-01	444-78-02-009 S/N 014	2/4/98	retort zone 1 TC, type K, accuracy: ± 2°C	PYROCOM #MFK53U60F07P0
TE-11	N/A	N/A	N/A	trace heat 3 control TC, type K	PYROCOM #MFK43U04M10P0
TE-12	N/A	N/A	N/A	trace heat 2 control TC, type K	PYROCOM #MFK43U04M10P0
TE-13	N/A	N/A	N/A	trace heat 4 control TC, type K	PYROCOM #MFK43U04M10P0
TE-14	N/A	N/A	N/A	trace heat 5 control TC, type K	PYROCOM #MFK43U04M10P0
TE-15	N/A	N/A	N/A	trace heat 6 control TC, type K	PYROCOM #MFK43U04M10P0
TE-16	N/A	N/A	N/A	trace heat spare, type K	PYROCOM #MFK43U04M10P0
TE-17	N/A	N/A	N/A	trace heat 1 control TC, type K	PYROCOM #MFK43U04M10P0
TE-18	RG-1/4-03	N/A	N/A	bubbler TC, type K	PYROCOM #MFK43U12M10P0
TE-19	SG-1/2-03	N/A	N/A	condenser gas TC, type K	PYROCOM #MFK43U04M10P0
TE-20	SG-3/8-01	444-78-02-010 S/N 002	2/5/98	retort center TC, type K, accuracy: ± 2°C	PYROCOM #MFK53U30F07P0
TE-21	RG-3/8-05	TC-325-30	8/99	retort inlet TC, type K, accuracy: ± 2°C	PYROCOM #MFK53U04F07P0
TE-22	CHWS-3/8-01	N/A	N/A	condenser cooling coil inlet TC, type K	PYROCOM #MFK43U04M10P0
TE-23	N/A	N/A	N/A	spare TC	PYROCOM #MFK43U04M10P0
TE-24	N/A	N/A	N/A	bubbler heater control TC, type K	PYROCOM #MFK43U04M10P0

Tag#	Line#	Calibration#	Exp. Date	Description	Manufacturer & Part#
PE-01	SG-3/8-01	02289	10/26/96	sample gas pressure element, high accuracy capacitance manometer type with signal conditioner, 0 to 10000 Torr, accuracy: ± 0.12% of reading, 0 - 10 VDC analog output	MKS #690A14TRC (sensor) MKS #270D-4 (readout/signal conditioner)
PE-02	CD-1/4-01	N/A	N/A	condenser pressure element, Convectorr type, 1 milliTorr to 1000 Torr RS-232 board, PC board, and control/readout unit are used with PE-02 through PE-05	VARIAN Convectorr transducer #L9090301 multi-gauge RS-232 board #L6439301 multi-gauge control/readout unit #L8350301 Convectorr PC board #L9887301
PE-03	SG-1/2-03	N/A	N/A	pump inlet pressure element, Convectorr type, 1 milliTorr to 1000 Torr	VARIAN Convectorr transducer #L9090301
PE-04	N/A	N/A	N/A	spare pressure element, Convectorr type, 1 milliTorr to 1000 Torr	VARIAN Convectorr transducer #L9090301
PE-05	SG-1/4-06	N/A	N/A	mass spec system pressure element, Convectorr type, 1 milliTorr to 1000 Torr	VARIAN Convectorr transducer #L9090301
PE-06	RG-3/8-06	0059432-56	5/4/98	retort inlet pressure element, high accuracy capacitance manometer type with signal conditioner, 0 to 1000 Torr, accuracy: ± 0.08% of reading, 0 - 10 VDC analog output	MKS #690A13TRB (sensor) MKS #270D-4-RZ-LO (readout/signal conditioner)

Tag#	Line#	Calibration#	Exp. Date	Description	Manufacturer & Part#
PE-07	SG-1/4-06	670-31-05-014	3/28/99	mass spec inlet pressure element, diaphragm type, 0 to 1500 Torr, accuracy: ± 1% of reading or ± 1 Torr, 0 - 1.5 VDC analog output	COLE-PARMER #68801-53 (sensor), #68801-03 (readout)
PE-08	PE-1/4-02	670-31-05-013	3/28/99	gas chromatograph inlet pressure element, 0 to 1500 Torr, accuracy: ± 1% of reading or ± 1 Torr, 0 - 1.5 VDC analog output	COLE-PARMER #68801-53 (sensor), #68801-03 (readout)
FE-01	AR-1/4-01	user calibration	8/98	UHP argon flow element, 0 to 304 sccm, 0 - 5 VDC analog output, accuracy: ± 1% full scale	MATHESON #8272-0422 MATHESON #8284 (readout/controller for FE-01 through FE-04)
FE-02	O-1/4-01	user calibration	8/98	oxygen flow element, 0 to 10 sccm, 0 - 5 VDC analog output, accuracy: ± 1% full scale	MATHESON #8272-0411
FE-03	A-1/4-01	user calibration	8/98	air flow element, 0 to 1000 sccm, 0 - 5 VDC analog output, accuracy: ± 1% full scale	MATHESON #8272-0413
FE-04	BG-1/4-01	N/A	N/A	argon ballast gas flow element, 0 - 200 sccm, 0 - 5 VDC analog output, accuracy: ± 1% full scale	MATHESON #8272-0422
ME-01	SG-3/8-01	manufacturer calibration	replaced each test	sample gas moisture element, -110°C to 20°C dew point range, aluminum oxide type, 0 - 2 VDC analog output, accuracy: ± 2°C for 20°C to -65°C, ± 3°C for -66°C to -110°C	PANAMETRICS #M2L PANAMETRICS #MMS35-121-1-100 (readout)

Appendix C

Valve List

Appendix C

Valve List

Valve#	Line#	Description	Manufacturer & Part#
V01	RG-1/4-01	reactant gas isolation	WHITEY SS-43S4
V02	RG-1/4-03	bubbler outlet isolation	WHITEY SS-43S4
V03	RG-1/4-02	bubbler inlet isolation	WHITEY SS-43S4
V04	RG-1/4-06	GC calibration isolation	WHITEY SS-43S4
V05	CG-1/4-02	GC calibration gas supply isolation	WHITEY SS-43S4
V06	SG-3/8-05	pump metering valve isolation	WHITEY SS-43S6
V07		not used	
V08	AC-1/4-01	GC carrier gas bottle isolation	WHITEY SS-43S4
V09	SA-1/4-01	safety argon bottle isolation	WHITEY SS-43S4
V10	SG-1/2-03	pump suction isolation	WHITEY SS-45S8
V11	PE-1/4-02	pump exhaust to GC sample line	WHITEY SS-43S4
V12	PE-1/4-01	pump exhaust to G-cell	WHITEY SS-44S6
V13	SG-1/4-06	mass spec isolation	WHITEY SS-42S4
V14	PE-3/8-01	pump exhaust isolation	WHITEY SS-44S6
V15	SA-1/4-01	safety argon bottle regulating valve, CGA 580	AIRCO 8069481
V16	SG-3/8-01	system pressure relief valve (25 psi)	NUPRO SS-2C4-25
V17	CD-1/8-02	condenser drain isolation	WHITEY SS-41S2
V18	AR-1/4-01	UHP argon bottle regulating valve, CGA 580	VICTOR EQUIP #VTS450E
V19	A-1/4-01	air bottle regulating valve, CGA 346	ACCU-TROL #CS-346
V20	O-1/4-01	oxygen bottle regulating valve, CGA 540	HARRIS #96-100
V21	AC-1/4-01	UHP argon carrier bottle regulating valve, CGA 580	MATHESON #8H 580
V22	DW-1/4-01	bubbler fill/vent	WHITEY SS-43S4
V23	RG-1/4-01	UHP argon bottle isolation	WHITEY SS-43S4

Valve#	Line#	Description	Manufacturer & Part#
V24	A-1/4-01	air bottle isolation	WHITEY SS-43S4
V25	SG-3/8-07	pump bypass	WHITEY SS-44S6
V26	SG-1/2-03	condenser outlet isolation	WHITEY SS-45S8
V27	SG-1/2-03	condenser inlet/bypass (3-way)	WHITEY SS-45XS8
V28	CD-1/4-01	condenser pressure isolation	WHITEY SS-43S4
V29	BG-1/4-01	pump ballast gas isolation	WHITEY SS-43S4
V30	BG-1/4-01	argon ballast gas bottle isolation	WHITEY SS-43S4
V31	BG-1/4-01	argon ballast gas bottle regulating valve, CGA 580	VICTOR EQUIP #SR250C
V32	O-1/4-01	oxygen bottle isolation	WHITEY SS-43S4
V33	PE-1/4-02	GC isolation	WHITEY SS-43S4
V34	PE-1/4-02	GC sample line outlet isolation	WHITEY SS-43S4
V35		not used	
V36	CG-1/4-01	mass spec calibration gas supply isolation	WHITEY SS-43S4
V37	TP-3/8-01	retort inlet pressure/turbo pump inlet isolation (3-way)	WHITEY SS-44XS6
V38	TP-3/8-02	turbo pump exhaust isolation	WHITEY SS-44S6
MV01	SG-3/8-05	pump suction metering valve	NUPRO SS-4MG-MH
LV01	SG-3/8-06	mass spec gas dosing (leak) valve	GRANVILLE-PHILLIPS 203019-02
CV01	O-1/4-01	oxygen supply check valve	NUPRO SS-4C-10
CV02	A-1/4-01	air supply check valve	NUPRO SS-4C-10
CV03	AR-1/4-01	UHP argon supply check valve	NUPRO SS-4C-10
CV04	SA-1/4-01	UHP safety argon supply check valve	NUPRO SS-4C-10
CV05	AC-1/4-01	argon carrier gas supply check valve	NUPRO SS-4C-10
CV06	BG-1/4-01	ballast gas supply check valve	NUPRO SS-4C-10
VS01	RG-3/8-05	retort inlet isolation solenoid valve (NO)	ASCO 8210G33VM
VS02	SA-3/8-03	safety argon supply solenoid valve (NC)	ASCO 8030G13VM
VS03	SG-3/8-02	retort outlet isolation solenoid valve (NO)	ASCO 8210G33VM
VS04	O-1/4-01	oxygen supply isolation solenoid valve (NC)	ATKOMATIC S24C-16-V-N

Appendix D

Equipment List

Appendix D

Equipment List

Equipment#	Description	Manufacturer & Part#
TC-01	temperature controller for heat trace HT-01, 10 A capacity, 115 VAC, time proportional control	Omega #6102-K
TC-02	temperature controller for heat trace HT-02	Omega #6102-K
TC-03	temperature controller for heat trace HT-03	Omega #6102-K
TC-04	temperature controller for heat trace HT-04	Omega #6102-K
TC-05	temperature controller for heat trace HT-05	Omega #6102-K
TC-06	temperature controller for heat trace HT-06	Omega #6102-K
TC-07	spare temperature controller	Omega #6102-K
TC-08	temperature controller for bubbler	Omega #6102-K
TC-09	spare temperature controller	Omega #6102-K
TC-10	spare temperature controller	Omega #6102-K
N/A	furnace controller, 0 - 900°C, 230 VAC, 1 PH, 60 HZ, three zone 30 A SCR type 3000 temperature controllers, RS-485 communications link	Applied Test Systems Series 3000
N/A	furnace, three-zone, 900°C rating, 13,800 W total (4600 W/zone), 60 A, 230 VAC, 1 PH, Kanthal A1 type embedded elements, 5" ID x 45" L (inside dimension), 12" OD x 49" L (outside dimension)	Applied Test Systems Series 3210
N/A	furnace retort tube, 4.5" OD, 4.026" ID (SCH 40 pipe), 44.58" L (inside chamber dimension), 62.68" L (overall including inlet/outlet connections), Inconel Series 600, Viton o-ring	Applied Test Systems Series 3910
HT-01 through HT-06	flexible electric heating cords, 3 ft to 24 ft long, 70 to 560 W, 120 VAC, and extension adapters for standard three-prong plug	Cole Parmer #E-03122-30 (3 ft) #E-03122-60 (6 ft) #E-03122-12 (12 ft) #E-03122-18 (18 ft) #E-03122-24 (24 ft) #E-03122-71 (adapter)

Equipment#	Description	Manufacturer & Part#
UPS-1	uninterruptible power supply for DACS console instruments, 1420 VA, 980 W	Best Power #LI1420U (Fortress #1420)
UPS-2	uninterruptible power supply for DACS, mass spec, and gas chromatograph computers, 1420 VA, 980 W	Best Power #LI1420U (Fortress #1420)
UPS-3	uninterruptible power supply for gas chromatograph and mass spec, 1420 VA, 980 W	Best Power #LI1420U (Fortress #1420)
XFMR-01	power transformer for heat trace temperature controllers, 240/120 VAC, 10 kVA	General Electric #T-1-53545-S
GC-01	gas chromatograph, type 5A molecular sieve for both columns A & B	MTI #M200
MS-01	mass spectrometer, 300 AMU range	Balzers Omnistar
P-1	system vacuum pump, scroll type, 250 L/min (8.8 cfm) peak pumping speed, 1.2 x 10^{-2} Torr ultimate pressure, 0.4 kW (1/2 hp) motor, 1730 rpm, 230 VAC	Varian 300DS1UNIV
P-2	turbo pump for PE-06 calibration, 50 L/s pumping speed, air cooled, 120 VAC.	Pfeiffer TPH-050
N/A	turbo pump controller for P-2, 120 VAC	Pfeiffer #TCP 121
COND-01	condenser, 4" SCH 40 SST pipe housing w/4" 150-lb flanges, 3/8" OD x 4 ft long copper cooling coil (2 3/4" outside diameter coil), acrylic 100-mL graduated cylinder for condensate collection	custom fabricated, see sketch Appendix F
CHILLER-01	chiller for condenser, -30 to 150°C, 320 W @ 20°C chilling capacity, 250 W @ 0°C, 13 L/min, 6 L reservoir, 1200 W, 115 VAC	Lauda Brinkmann #RM6-S catalog #27 80 540-0
N/A	bubbler, consists of 1000 mL, 115 VAC, 335 W heating mantle and flask, 450°C maximum temperature	Fisher Scientific 11-847-15B (heating mantle) 11-847-30A (kettle clamp) 11-847-10B (flask bottom) 11-473-37 (eltromantle spill pr)
F1	filter, retort inlet line, 99.9% efficient at 0.2 micron, microporous fiberglass media, SST housing, 0 to 165°F, 150 slpm @ 15 psig DP	Matheson #6164-T6FF
F2	filter, retort outlet line, 99.9% efficient at 0.2 micron, microporous fiberglass media, SST housing, 0 to 165°F, 400 slpm @ 15 psig DP	Matheson #6134-T6FF

Equipment#	Description	Manufacturer & Part#
F3	filter, retort outlet line, 99.9% efficient at 0.2 micron, microporous fiberglass media, SST housing, 0 to 165°F, 400 slpm @ 15 psig DP	Matheson #6134-T6FF
F4	filter, safety argon line, 99.9% efficient at 0.2 micron, microporous fiberglass media, SST housing, 0 to 165°F, 150 slpm @ 15 psig DP	Matheson #6164-T6FF
F5	filter, hot cell inlet line, 99.9% efficient at 0.2 micron, microporous fiberglass media, SST housing, 0 to 165°F, 150 slpm @ 15 psig DP	Matheson #6164-T6FF
F6	filter, mass spec sample line, 99.9% efficient at 0.2 micron, microporous fiberglass media, SST housing, 0 to 165°F, 150 slpm @ 15 psig DP	Matheson #6164-T6FF
N/A	quick disconnects, 3/8" Swagelok, double-sealing, SST, for miscellaneous system lines	Swagelok SS-QC6-B-600K1 Swagelok SS-QC6-D-600K1
N/A	quick disconnects, 1/4" NPT, SST, for chiller lines	Hansen LL2-H16 (plug) Hansen LL2-K16 (socket)
N/A	flexible hose, braided, 3/8", SST, for miscellaneous system lines	Swagelok SS-6HO-6-L6 (long) Swagelok SS-6HO-6-S6 (short)
N/A	flexible hose, braided, 1/4", SST, for miscellaneous system lines	Swagelok SS-4HO-6-L4 (long) Swagelok SS-4HO-6-S4 (short)
N/A	vacuum flexible tubing, 3/8", SST, for miscellaneous system lines	Cajon 321-6-X-3B2 Cajon 321-6-X-6B2 Cajon 321-6-X-24B2
N/A	moisture trap for gas bottles, 1/4" fittings	Restek 20604
N/A	oxygen trap for gas bottles, 1/4" fittings	Restek 20625
N/A	molecular sieve for gas bottles, 1/4" fittings	Restek 20685
N/A	glove bag & glove bag frame, see sketches in Appendix F for description	DA Services UCON771656-R
N/A	HEPA filter for glove bag, 30 cfm, 2 each	DA Services QCA-0106
N/A	Data acquisition/control unit with 1 AC relay actuator card, 1 analog voltage input card, and 2 type-K input thermocouple cards	Hewlett Packard HP3497A
SC-01	computer for DACS, IBM-compatible, Pentium 75 MHz CPU, 530 MB hard drive, with National Instruments general-purpose interface bus (GPIB) card (#776786-01) for HP3497A communication, RS-232/RS-485 converter for furnace controller communication	Dell Dimension P75t

Equipment#	Description	Manufacturer & Part#
SCM-01	computer monitor for DACS, 15" SVGA	NEC 4FG
SC-02	computer for gas chromatograph, laptop, 16 MB RAM, 1.4 GB hard drive	Fujitsu Lifebook 400 series
SCM-02	computer monitor for gas chromatograph	see above
SC-03	computer for mass spectrometer, Pentium 166 MHz CPU, 32 MB RAM, 3.1 GB hard drive	Micron Millenia, M55HIPLUS-P166-MT
SCM-03	computer monitor for gas chromatograph, 17" SVGA	Magnavox MAG-MB7000
N/A	official clock timer	Cole Parmer E-94440-10

Appendix E

Spent Nuclear Fuel Conditioning Furnace Data Acquisition System Operating Manual

Spent Nuclear Fuel Conditioning Furnace Data Acquisition System Operating Manual

Prepared by: D. A. King

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SPENT NUCLEAR FUEL CONDITIONING FURNACE DATA ACQUISITION SYSTEM OPERATING MANUAL

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide operating instructions for using the Spent Nuclear Fuel Conditioning Furnace Data Acquisition System (DAS).

1.2 SCOPE

The operating instructions included in this document apply to the software that comprises the Conditioning Furnace DAS. Specifically, this document applies to the computer system LabVIEW for Windows application software. This document is intended to be used for operating the DAS and developing procedures for operation and maintenance.

1.3 DEFINITIONS

CRT	Cathode Ray Tube computer monitor
DA/CU	Data Acquisition/Control Unit, HP 3497A
DAS	Data Acquisition System
DOS	Disk Operating System for IBM compatible computers
GPIB	General Purpose Interface Bus
HP	Hewlett Packard[R]
IBM	International Business Machine[R]
SNF	Spent Nuclear Fuel

1.4 OVERVIEW

The SNF Conditioning Furnace Data Acquisition System (DAS) monitors system parameters and provides control of the furnace and supply gas solenoids. The DAS is designed to measure critical system parameters during fuel conditioning tests, including temperature, pressure, flow rate, and moisture. The measured parameters are converted to engineering units, displayed on the computer screen, and stored to disk at user defined intervals. A plotting screen also allows for plotting of up to six parameters at a time.

The DAS monitors the temperatures inside the retort tube and generates an alarm if any three of the temperatures exceed the user defined temperature limit. Additionally, the DAS closes the reactant gas solenoids, opens the safety argon solenoid, and shuts down the furance heaters when an alarm condition is detected. The alarm stays latched until it is reset by the operator.

In addition to controlling the sample gas and safety argon solenoids, the DAS allows the operator to control the oxygen gas solenoid. This solenoid can be toggled open or closed, as well as configured by the operator to automatically open and close on delay, based on user-defined start and stop times.

Each of the three furnace zone temperatures can be remotely set by the DAS. The DAS also allows the operator to start and stop the temperature controllers and select one of four temperature profiles that are pre-programmed in the furnace temperature controllers.

2.0 SYSTEM DESCRIPTION

2.1 HARDWARE

The DAS hardware consists of a Hewlett Packard 3497A data acquisition/control unit (DA/CU) and an IBM-compatible computer. A National Instruments general-purpose interface bus (GPIB) card installed in the IBM compatible computer is used to communicate with the HP 3497A. The computer sends commands to the furnace temperature controllers over serial port 0 using an RS-232/RS-485 converter. The computer also receives data from the Varian pressure meter over serial port 1.

2.1.1 Data Acquisition/Control Unit

The HP 3497A receives all analog inputs and provides the required digital outputs to control the gas solenoids and console warning light. A type-K thermocouple input card is used to measure temperatures and an analog voltage input card is used to measure pressure, flow, and moisture signals. An AC relay actuator card is used to control the sample gas, safety argon, and oxygen gas solenoids, as well as the console alarm warning light. The HP 3497A GPIB address is set to Address 9.

2.1.2 IBM Compatible-Computer

A Dell Pentium computer serves as the IBM-compatible computer for the DAS. It communicates with the DA/CU to receive and record data. The computer also serves as the operator interface to display data and change DAS operating parameters. The computer features a user-friendly, graphics-oriented operator interface. It communicates with the DA/CU through a GPIB card to receive, display, and record DAS data.

2.2 SOFTWARE

Microsoft MS-DOS 6.0 is the operating system that automatically loads when power is first applied to the IBM-compatible computer. At start-up, the file AUTOEXEC.BAT launches the Windows operating system. Microsoft Windows 3.1 provides the graphical multi-tasking environment that runs the compiled LabVIEW Control Furnace DAS software program and allows for other Windows and DOS operations.

The Conditioning Furnace DAS uses National Instruments' LabVIEW for Windows as the control software. The LabVIEW Control Furnace DAS software program is a compiled executable file that runs under Windows. This program can be automatically launched by locating the LabVIEW Control Furnace DAS program item in the Windows "StartUp" program group. LabVIEW for Windows files LVDEVICE.DLL, SERPDRV, and GPIBDRV work in conjunction with the Control Furnace DAS program to interface with the operating system hardware.

3.0 PREREQUISITES

1. The system startup (See Section 5.1) assumes that the DAS is de-energized.

2. Blank, IBM-formatted 3.5 inch disks must be available prior to energizing the DAS if data is to be logged to the 3.5 inch disk drive.

3. Users must be familiar with operating Windows 3.1.

4.0 PRECAUTIONS AND LIMITATIONS

Although the system contains no exposed electrical circuits, dangerous voltages exist. The DAS should be serviced only by qualified personnel.

5.0 SYSTEM OPERATION

5.1 STARTUP

To activate the Conditioning Furnace DAS, perform the following steps:

1. Energize the computer and CRT display.

   Wait for the operating system software to load and run. The LabVIEW software program will run automatically if the LabVIEW Control Furnace DAS program item is located in the Windows "StartUp" program group. If the DAS program item is not located in the Windows "StartUp" program group, double-click the "FURLAB" icon to run the program.

2. Verify the DAS setup parameters are set correctly per Section 5.2, Normal Operation.

5.2 NORMAL OPERATION

This section addresses operation of the Conditioning Furnace DAS software program and associated computer system. For normal operation, the computer power LED will be illuminated and the LabVIEW DAS software program will be actively running. The computer CRT will display the furnace operating system parameters, updated every five seconds, and the current time and date.

5.2.1 Description of Display Screens

The DAS program provides three display screens to display operating system parameters and allow for changing of DAS setup parameters. A description of each display screen is provided below.

5.2.1.1 MAIN DISPLAY Screen. This screen displays the furnace operating system parameters in engineering units. The parameters displayed are temperature, pressure, flow rate, and moisture. A list of the DAS channels is shown in Appendix A. Also displayed are the time, date, solenoid positions, furnace temperature setpoints, and alarm status.

5.2.1.2 PLOTTING Screen. This screen displays the operating system parameters in engineering units and allows for up to six parameters to be plotted on the display chart. Plotting is intended for real-time trending only.

5.2.1.3 SETUP Screen. This screen displays the system time and date, alarm status, furnace controls, and setup parameters. The setup parameters include the furnace temperature alarm limit setpoint, oxygen solenoid valve controls, and data logging controls. The setup parameters are initially set to the following default values:

Temperature Alarm Limit Setpoint : 720 Deg. C
Oxygen Solenoid Valve Auto Start Time : 10 HOURS
Oxygen Solenoid Valve Auto Stop Time : 2 HOURS
Oxygen Solenoid Valve Status : CLOSED
Data Logging Interval : 1 MINUTE
Data Logging Control : STOP

The controls are bounded to prevent data from being entered that is out-of-range or not valid data.

5.2.2 Using the Display Screen Selector

The Display Screen Selector is located at the top of each display screen. Below the Display Screen Selector title block, the selector shows the currently active display screen. The selector is used to select the desired display screen or end the LabVIEW DAS program.

To change display screens, perform the following steps:

1. Use the mouse to position the on-screen pointer over the Display Screen Selector.

2. Press and hold the left mouse button. A list of the display screens and the END PROGRAM option will appear.

3. Use the mouse to position the on-screen pointer over the desired display screen title.

4. Release the left mouse button. The selected display screen will then appear.

5.2.3 Remote Furnace Controls

The conditioning furnace can be controlled remotely by the DAS to change temperature setpoints and operating modes. All LabVIEW DAS furnace controls are located in the SETUP screen.

5.2.3.1 Temperature Control Setpoints. Each of the three furnace temperature control setpoints can be remotely set. The new setpoints will not take effect until the UPDATE button located below the setpoint displays is pressed.

To change the temperature control setpoints, perform the following steps:

1. Select the SETUP screen per Section 5.2.2.

2. Position the on-screen pointer to the right of the desired temperature control setpoint value. The pointer will change to a vertical bar.

3. Click the left mouse button and use the keyboard "BACKSPACE" key to erase the current value.

4. Enter the new temperature control setpoint value and press "ENTER". The new value will now be displayed.

5. Repeat steps 2-4 to change additional setpoint values as required.

6. Position the on-screen pointer over the UPDATE button and click the left mouse button to update the temperature control setpoint values in the DAS.

5.2.3.2 Temperature Profile Selector. The Temperature Profile Selector allows the user to select one of four temperature profiles that are pre-programmed in the furnace temperature controllers. The selected profile will not take effect until the UPDATE button is pressed, located below the selector. If NONE SELECTED is chosen, the controllers will control to the DAS temperature setpoint with no ramp and hold profile.

To change temperature profiles, perform the following steps:

1. Use the mouse to position the on-screen pointer over the Temperature Profile Selector.

2. Press and hold the left mouse button. A list of profiles 1 through 4 and NONE SELECTED will appear.

3. Use the mouse to position the on-screen pointer over the desired choice.

4. Release the left mouse button. The selected choice will then appear.

5. Position the on-screen pointer over the UPDATE button and click the left mouse button to update the temperature profile selection in the DAS.

5.2.3.3 Furnace Control. The FURNACE CONTROL button allows the user to set the controllers to the START or STOP mode of operation. Selecting the START mode causes the controllers to begin controlling the furnace temperature to the DAS setpoint or to the temperature profile setpoint, depending on the temperature profile selected.

To start control, press the FURNACE CONTROL button. To stop control, press the FURNACE CONTROL button again.

5.2.4 Temperature Alarm Limit

The temperature alarm limit is a user-selected variable used to determine if any of the retort tube temperatures are out-of-limits. This control is located in the SETUP screen. Thermocouples TE-04 through TE-10 are compared to the alarm limit value every five seconds. If any three of the temperatures are above the alarm limit, the DAS will generate a high temperature alarm.

When a high temperature alarm is generated, the DAS closes the sample gas solenoids and opens the safety argon solenoid. The closed solenoids are indicated on the display screen as red and the open solenoids are indicated on the display screen as green. The HIGH TEMP ALARM indicator on each display screen also is illuminated, as well as the alarm warning light on top of the console. The alarm stays latched until it is reset by the operator.

When a high temperature alarm is generated, the DAS also sends a "STOP" control command to the furnace temperature controllers. This command sets the furnace heater power to 0% for all three controllers. Control can be restarted per Section 5.2.3.3.

To change the temperature alarm limit value, perform the following steps:

1. Select the SETUP screen per Section 5.2.2.

2. Position the on-screen pointer to the right of the temperature alarm limit value. The pointer will change to a vertical bar.

3. Click the left mouse button and use the keyboard "BACKSPACE" key to erase the current value.

4. Enter the new temperature alarm limit value and press "ENTER". The new value will now be displayed.

5. Position the on-screen pointer over the UPDATE button and click the left mouse button to update the temperature alarm limit value in the DAS.

To reset the high temperature alarm, press the ALARM RESET button on the MAIN DISPLAY screen.

Note : The high temperature alarm will not reset until all of the retort temperatures are below the alarm limit.

5.2.5 Oxygen Solenoid Valve Control

The DAS permits both automatic and manual control of the oxygen solenoid valve. The controls are located in the SETUP screen.

5.2.5.1 Manual Control. The oxygen solenoid valve can be manually toggled open and closed by pressing the MANUAL CONTROL button. The solenoid valve status is shown directly above the control button and also on the MAIN DISPLAY screen.

5.2.5.2 Automatic Control. The oxygen solenoid valve can be programmed to automatically open and then close at intervals set by the AUTO DELAY TIMERS. The AUTO START TIME value determines how many hours delay occurs before the oxygen solenoid valve automatically opens. The AUTO STOP TIME value determines how many hours the oxygen solenoid valve will stay open before automatically closing.

To change the auto delay timer values, perform the following steps:

1. Select the SETUP screen per Section 5.2.2.

2. Position the on-screen pointer to the right of the desired timer value. The pointer will change to a vertical bar.

3. Click the left mouse button and use the keyboard "BACKSPACE" key to erase the current value.

4. Enter the new timer value and press "ENTER". The new value will now be displayed.

5. Repeat steps 2-4 to change additional values as required.

To start the automatic control timer, press the AUTO TIMER button. The AUTO ENGAGED indicator will illuminate. To stop and reset the automatic control timer, press the AUTO TIMER button again. The AUTO ENGAGED indicator will extinguish.

NOTE: In the AUTO mode, the oxygen solenoid valve can be manually controlled without affecting automatic operation.

5.2.6 Data Logging

All DAS data can be logged to a user-selected drive at a user-selected interval. The information is stored in DOS ASCII format for ease of use. The data logging controls are located in the SETUP screen.

5.2.6.1 Logging Interval. The Logging Interval variable sets the rate at which DAS data is logged. Data will be logged to the selected disk drive (see Section 5.2.6.2) at this interval. The selector choices range from 5 seconds to 8 hours. Table 1 lists the maximum data storage times to a 1.44MB disk in the 3.5 inch disk drive based on the selected data logging interval.

To change the data logging interval, perform the following steps:

1. Select the SETUP screen per Section 5.2.2.
2. Use the mouse to position the on-screen pointer over the Logging Interval Selector.
3. Press and hold the left mouse button. A list of the available logging intervals will appear.
4. Use the mouse to position the on-screen pointer over the desired interval.
5. Release the left mouse button. The selected interval will then appear.

Table 1. DAS Maximum Data Storage Times To 1.44MB, 3.5 Inch Disk

DAS DATA LOGGING INTERVAL	MAXIMUM DATA STORAGE TIME
5 SECONDS	16.3 HOURS
10 SECONDS	32.6 HOURS
30 SECONDS	4.0 DAYS
1 MINUTE	8.1 DAYS
2 MINUTES	16.3 DAYS
5 MINUTES	40.7 DAYS
10 MINUTES	81.5 DAYS
30 MINUTES	244 DAYS
1 HOUR	1.3 YEARS
2 HOURS	2.6 YEARS
4 HOURS	5.2 YEARS
8 HOURS	10.4 YEARS

5.2.6.2 Enabling Data Logging. The LOG DATA control switch is used to start and stop data logging. Toggling the switch from the STOP to START position brings up a file dialog box for selecting the disk drive, directory, and file name under which to store data. After the correct information is entered, data logging begins at the selected data logging interval. The selected file name and path is displayed by the LOGGING TO FILE indicator. Toggling the switch from the START to STOP position or ending the program (See Section 5.3.1) ends data logging and closes the active data logging file.

To begin data logging, perform the following steps:

1. Select the SETUP screen per Section 5.2.2.

2. Press the LOG DATA control switch to toggle from STOP to START.

3. Enter the desired file name using standard DOS file name conventions.

4. Use the file dialog menus as required to select the desired disk drive and directory.

5. Press the file dialog OK button.

To stop data logging, press the LOG DATA control switch to toggle from START to STOP.

NOTE: Ending the DAS program also stops data logging and closes the active data logging file.

5.2.7 Data Plotting

The PLOTTING screen allows for real-time plotting of up to six parameters at a time. The plotted data is shown in strip-chart format and scrolls from right to left.

To plot data, perform the following steps:

1. Select the PLOTTING screen per Section 5.2.2.

2. Select the desired channel(s) to plot using the PLOT CHANNELS controls.

3. Change the Y axis maximum value as required by positioning the on-screen pointer over the value, clicking the left mouse button, and entering the new value.

4. Change the Y axis minimum value as required by positioning the on-screen pointer over the value, clicking the left mouse button, and entering the new value.

5.3 DAS SHUTDOWN

5.3.1 Ending the Program

Selecting the END PROGRAM option on the Display Screen Selector terminates the LabVIEW DAS program. Ending the program closes out the active data logging file and returns the operating system back to Windows.

WARNING:

If data is logged to floppy, the DAS program must be terminated prior to removing the data disk or data may be lost.

To end the program, perform the following steps:

1. Position the on-screen pointer over the Display Screen Selector.

2. Press and hold the left mouse button. A list of the display screens and the END PROGRAM option will appear.

3. Position the on-screen pointer over the END PROGRAM option.

4. Release the left mouse button. The LabView program will terminate and the "Main engine for CVDHC.vi" box will appear. When the program completes the termination process, the arrow in the upper left of the box will change from solid to outline.

5. Press "ALT-F4" to close the LabView "Main engine for CVDHC.vi" box.

6. If data was logged to floppy, remove the 3.5 inch data disk from the computer disk drive.

5.3.2 Removing DAS Data From the C: Drive

If the option was selected to log data to the C: hard disk drive, copy the data file(s) to the A: drive by using the Windows File Manager or DOS commands from the DOS prompt.

5.3.3 Setting the Computer Time and Date

If the LabVIEW DAS program displays the incorrect time or date, set the computer clock by selecting the Date/Time icon in the Windows "Control Panel" program group. Set the correct date and time and select "OK".

5.3.4 Re-starting the LabVIEW DAS Program From Windows

To re-start the LabView DAS program from Windows, double click the "FURLAB" icon. This icon may be located in the Windows "StartUp" group. The LabVIEW DAS program will automatically load and run.

5.3.5 Exiting Windows

To exit Windows, press "ALT-F", press "X", and press "ENTER". Windows will terminate and the DOS prompt will be displayed.

5.3.6 Re-starting the LabVIEW DAS Program From DOS

To re-start the LabVIEW program from the DOS prompt, type "WIN", and press "ENTER". After Windows loads, the LabVIEW DAS program will automatically load and run if the LabVIEW Control Furnace DAS program item is located in the Windows "StartUp" program group. Otherwise, perform Section 5.3.4, Re-starting the LabVIEW DAS Program From Windows.

5.3.7 Shutdown

WARNING:

The DAS program and Windows must be terminated prior to de-energizing the computer or system files could be corrupted.

To power down the DAS computer, perform the following steps:

1. End the LabVIEW DAS program per Section 5.3.1.

2. Exit Windows per Section 5.3.5.

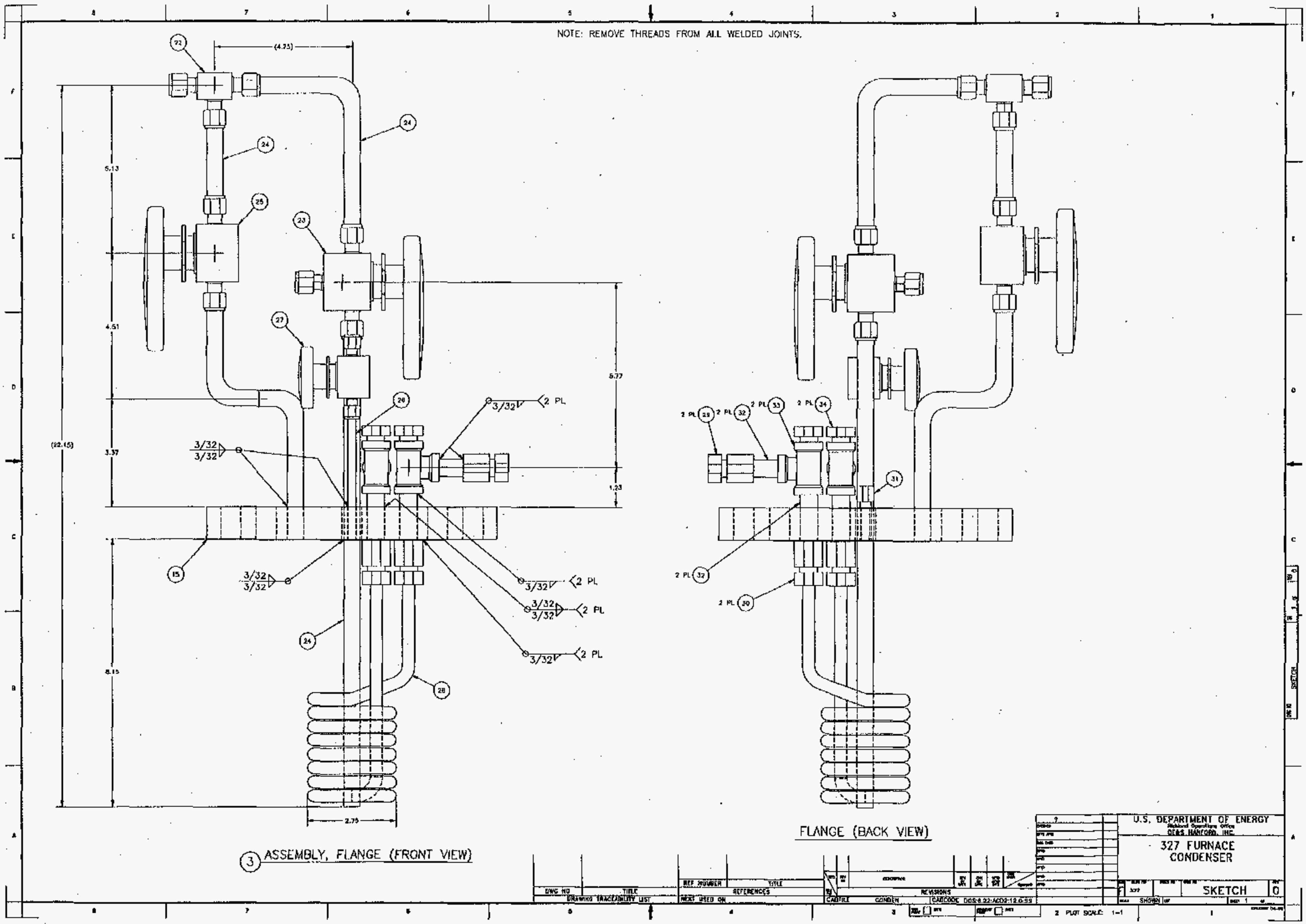
3. De-energize the computer and CRT display.

APPENDIX A - DAS CHANNEL LIST

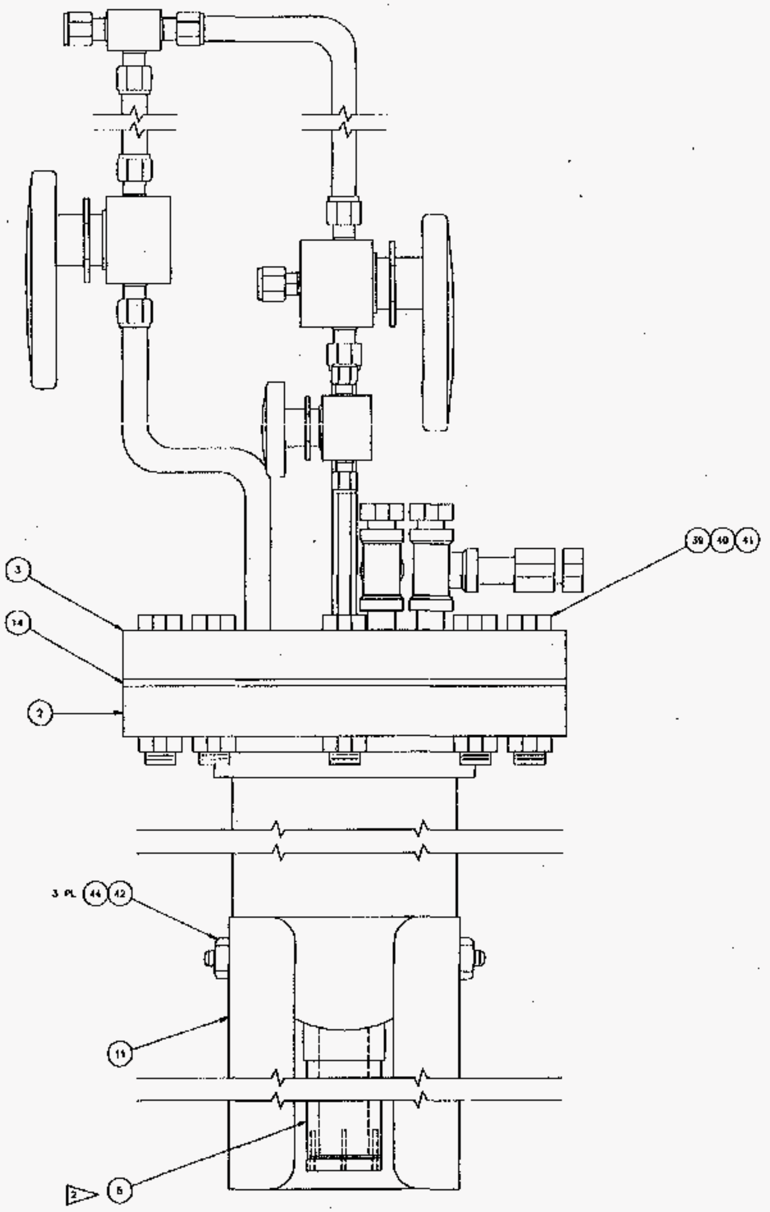
LabVIEW Channel	Tag	Description	DA/CU Channel	DA/CU Slot, Connection
0	TE-01	Furnace Zone 1 T/C	0	0, a0
1	TE-02	Furnace Zone 2 T/C	1	0, a1
2	TE-03	Furnace Zone 3 T/C	2	0, a2
3	TE-04	Tube Zone 3 T/C	3	0, a3
4	TE-05	Tube Zone 3 T/C	4	0, a4
5	TE-06	Tube Zone 3 T/C	5	0, a5
6	TE-07	Tube Zone 2 T/C	6	0, a6
7	TE-08	Tube Zone 2 T/C	7	0, a7
8	TE-09	Tube Zone 1 T/C	8	0, a8
9	TE-10	Tube Zone 1 T/C	9	0, a9
10	TE-11	Trace Heat 3 T/C	10	0, b0
11	TE-12	Trace Heat 2 T/C	11	0, b1
12	TE-13	Trace Heat 4 T/C	12	0, b2
13	TE-14	Trace Heat 5 T/C	13	0, b3
14	TE-15	Trace Heat 6 T/C	14	0, b4
15	TE-16	Trace Heat Spare	15	0, b5
16	TE-17	Trace Heat 1 T/C	16	0, b6
17	TE-18	Dewar T/C	17	0, b7
18	TE-19	Condenser T/C	18	0, b8
19	FE-01	Argon Flow Element	20	1, a0
20	FE-03	Air Flow Element	21	1, a1
21	FE-02	Oxygen Flow Element	22	1, a2
22	PE-01	Sample Gas Pres Elem	23	1, a3
23	ME-01	Sample Gas Moist Elem	24	1, a4
24	FE-04	Air Flow Element	25	1, a5
25	PE-06	Tube Inlet Pres Elem	26	1, a6
26	PE-07	Mass Spec In Pres Elem	27	1, a7
27	PE-08	G. C. Inlet Pres Elem	28	1, a8
28	TE-20	Tube Center T/C	60	3, a0
29	TE-21	Tube Inlet T/C	61	3, a1
30	TE-22	Condenser Coolant T/C	62	3, a2
31	TE-23	Spare T/C	63	3, a3
32	PE-02	Condenser Pres Elem	NA	NA
33	PE-03	Pump Inlet Pres Elem	NA	NA
34	PE-04	Spare Pres Elem	NA	NA
35	PE-05	Mass Spec Sys Pres Elem	NA	NA
NA	RL-01	Sample Gas Sol Relay	2,0	2, 0
NA	RL-02	Warning Light Relay	2,1	2, 1
NA	RL-03	Oxygen Solenoid Relay	2,2	2, 2

Appendix F

Miscellaneous Furnace System Component Sketches



NOTE: REMOVE THREADS FROM ALL WELDED JOINTS.
(4.25)
5.13
4.51
3.37
(22.15)
8.15
2.75
5.77
1.23
3/32 2 PL
3/32 3/32
3/32 3/32 2 PL
3 ASSEMBLY, FLANGE (FRONT VIEW)
FLANGE (BACK VIEW)
2 PL
U.S. DEPARTMENT OF ENERGY
DE&S HANFORD, INC.
327 FURNACE CONDENSER
SKETCH
0
DWG NO
TITLE
DRAWING TRACEABILITY LIST
REF NUMBER
REFERENCES
NEXT USED ON
REVISIONS
CADFILE
CONDEN
PLOT SCALE: 1=1



(1) CONDENSER, ASSEMBLY

PARTS/MATERIAL LIST

QTY REQD -050	-040	-030	-020	-010	PART/DASH NUMBER	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	SHEET	ITEM NO
				X	-010	ASSEMBLY, CONDENSER		1	1
			X		-020	ASSEMBLY, BOTTOM HOUSING		2	2
		X			-030	ASSEMBLY, FLANGE FRONT VIEW		3	3
	X								
X					-040	ASSEMBLY, COLLECTION VIAL		4	5
									6
									7
									8
			1		-001	EXTENSION, HOUSING, 5 1/2" ROUND	ANY SERIES SST	2	9
			1		-002	COUPLER, ALTERED, 1" PIPE	ANY SERIES SST	2	10
				1	-003	COVER, SHEATH, 16 GAUGE	ANY SERIES SST	4	11
1					-004	PLATE, BOTTOM, 1/4" PLATE	ACRYLIC	4	12
					-005	FLANGE, SLIP WELDNECK, #4"	ANY SERIES SST	2	13
1				1	-006	GASKET, 1/8" THK	NEOPRENE	5	14
		1			-007	FLANGE, BLIND, #150, #4"	ANY SERIES SST	5	15
1					-008	TUBE, VIAL, 1-1/2" OD -1/4" WALL	ACRYLIC	4	16
1					-008	GASKET, VIAL .05 THK	NEOPRENE	4	17
									18
									19
			1			PIPE, #4", SCH 40 5-1/2" L	ANY SERIES SST		20
			1			WELD-CAP, BUTT, #4"	ANY SERIES SST		21
		1			SS-810-3	UNION, TEE	SWAGELOK		22
		1			SS-45XS8	VALVE, 3-WAY	WHITEY		23
		AR			SS-810	TUBE, #1/2", .035 WALL	SWAGELOK		24
		1			SS-45S8	VALVE, 2-WAY	WHITEY		25
		AR			SS-400	TUBE, #1/4", .035 WALL	SWAGELOK		26
		1			SS-4H	VALVE, 2-WAY	WHITEY		27
		AR				TUBING, COPPER, 3/8"	COPPER		28
		2			SS-810-7-4	CONNECTOR, FEMALE, ALTERED	SWAGELOK		29
		2			SS-600-7-4	CONNECTOR, FEMALE, ALTERED	SWAGELOK		30
		1				CONNECTOR, MALE, 1/8 NPT	CONAX		31
		AR				PIPE, 1/4"	ANY SERIES SST		32
		2				TEE, 1/4 NPT	ANY SERIES SST		33
		2				PLUG, HEX HEAD, 1/4 NPT	ANY SERIES SST		34
									35
									36
									37
									38
			2			BOLT, 5/8-18 UNC 2A	ANY SERIES SST		39
			2			NUT, 5/8-18 UNC 2B	ANY SERIES SST		40
			2			WASHER, LOCK 5/8	ANY SERIES SST		41
				3		NUT, WING 5/16-18	ANY SERIES SST		42
			AR			THREADED, ROD 5/16-18	ANY SERIES SST		43
				3		LOCK WASHER, 5/16	ANY SERIES SST		44

GENERAL NOTES:

1. SECURE ITEM 12 TO ITEM 16 WITH 4-40 FLAT SCREWS.
2. APPLY LEAK-LOK (#694176-10001) TO ITEM 16 PRIOR TO INSTALLING TO ITEM 2.

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DE&S HANFORD, INC.

327 FURNACE
CONDENSER

PAUL MACFARLAN

F 327 SKETCH 0

SCALE SHOWN SHEET 1

DWG NO | TITLE — DRAWING TRACEABILITY LIST
REF NUMBER | TITLE — REFERENCES
NEXT USED ON
REVISIONS
CADFILE CONDEN
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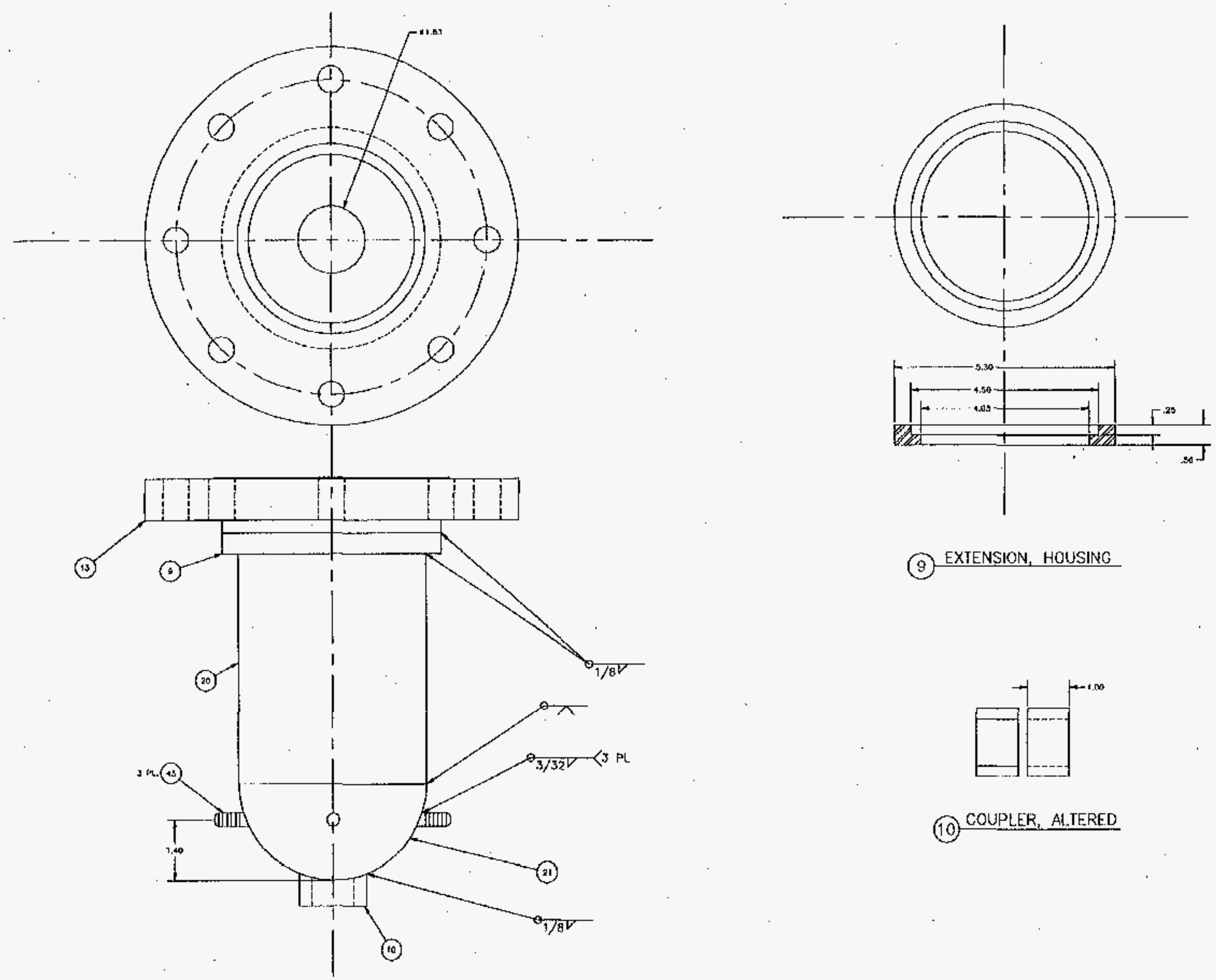
PLOT SCALE: 1=1



(2) BOTTOM HOUSING, ASSEMBLY

(9) EXTENSION, HOUSING

(10) COUPLER, ALTERED

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327 FURNACE CONDENSER

SKETCH

REV 0

SCALE: SHOWN

PLOT SCALE: 1=1

DWG NO | TITLE — DRAWING TRACEABILITY LIST

REF NUMBER | TITLE — REFERENCES

NEXT USED ON

REVISIONS

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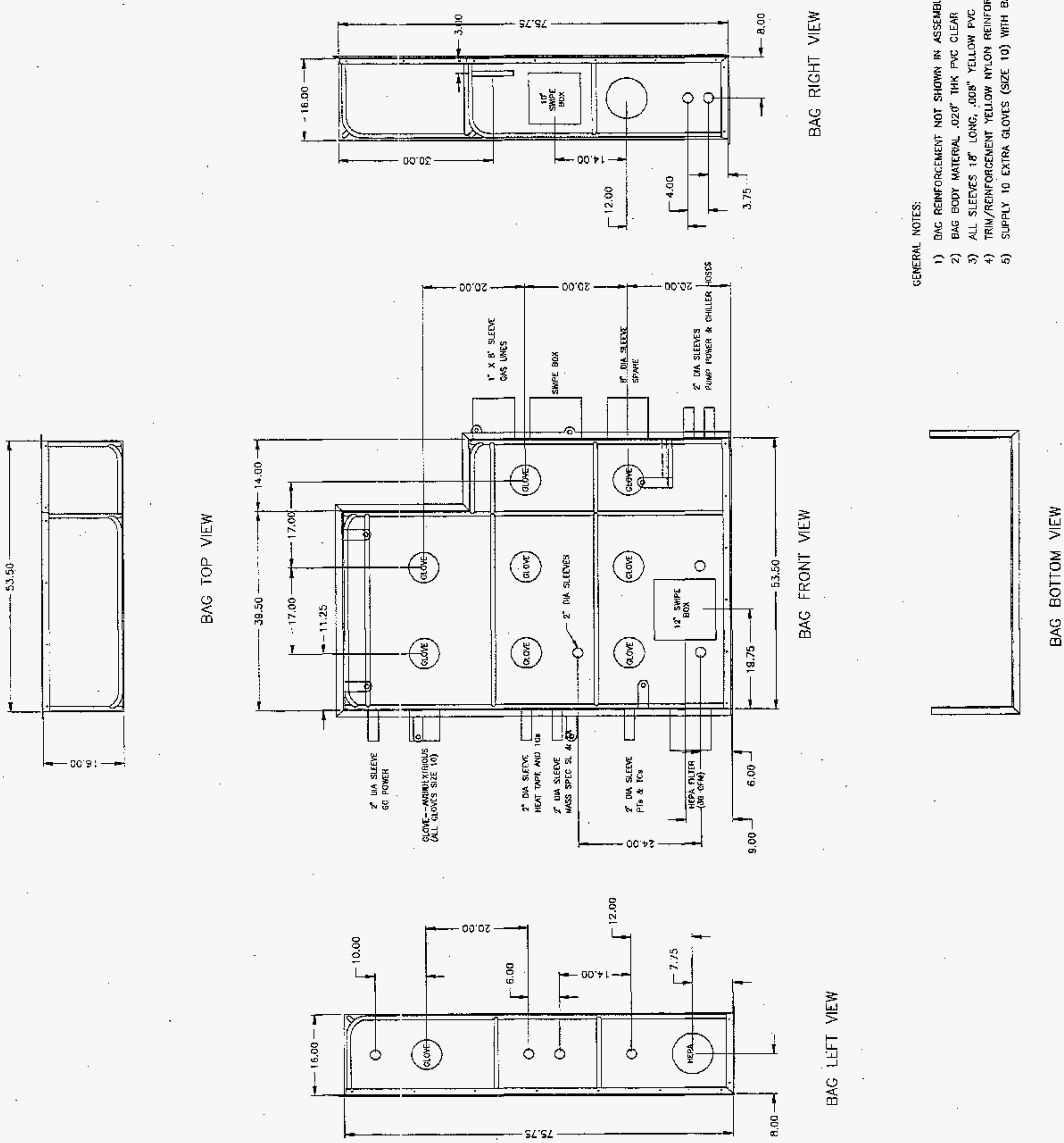
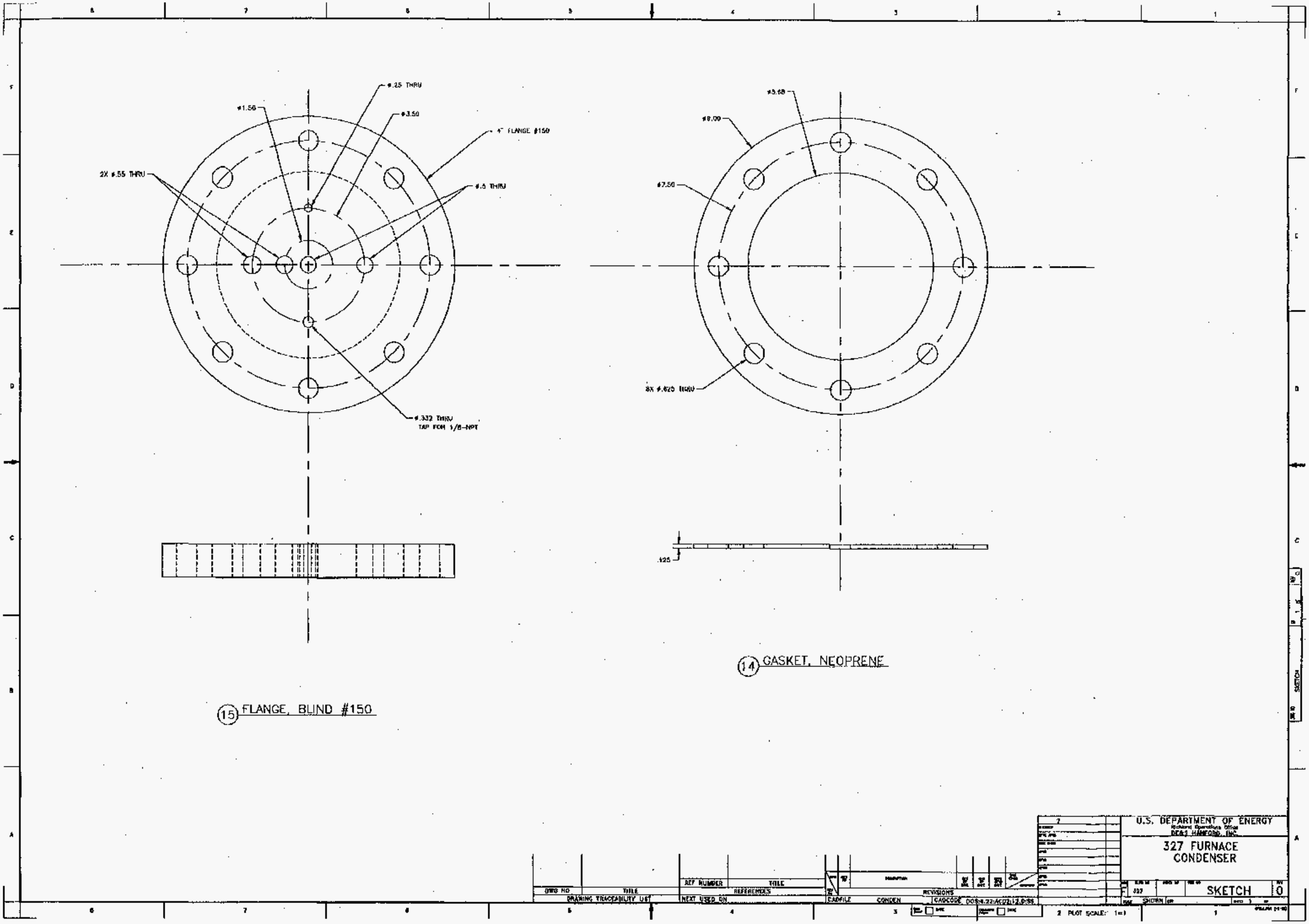
GLOVE BAG ASSEMBLY



GENERAL NOTES:

1) BAG REINFORCEMENT NOT SHOWN IN ASSEMBLY VIEW FOR CLARITY
2) BAG BODY MATERIAL .020" THK PVC CLEAR
3) ALL SLEEVES 18" LONG, .008" YELLOW PVC
4) TRIM/REINFORCEMENT YELLOW NYLON REINFORCE VINYL (NRV).
5) SUPPLY 10 EXTRA GLOVES (SIZE 10) WITH BAG


⌀.25 THRU
⌀1.50
⌀3.50
4" FLANGE #150
2X ⌀.55 THRU
⌀.5 THRU
⌀.332 THRU
TAP FOR 1/8-NPT
⌀5.68
⌀8.00
⌀7.50
8X ⌀.625 THRU
.125
15 FLANGE, BLIND #150
14 GASKET, NEOPRENE
U.S. DEPARTMENT OF ENERGY
Richland Operations Office
DE&S HANFORD, INC.
327 FURNACE
CONDENSER
SKETCH
0
DWG NO
TITLE
DRAWING TRACEABILITY LIST
REF NUMBER
TITLE
REFERENCES
NEXT USED ON
REVISIONS
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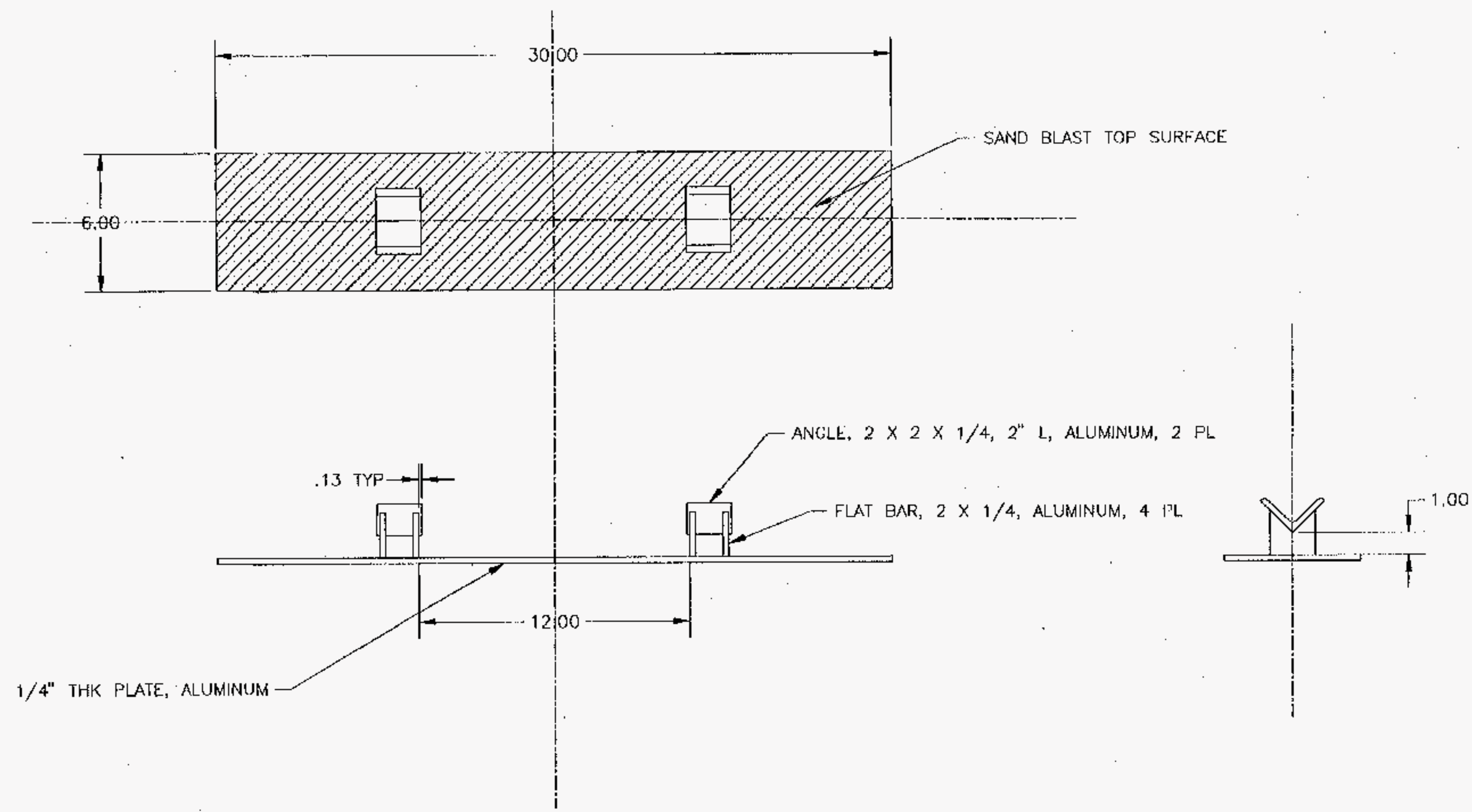
CONDEN
PLOT SCALE: 1=1



FOR GENERAL NOTES AND PARTS LIST, SEE SHEET 1

(1) ASSEMBLY

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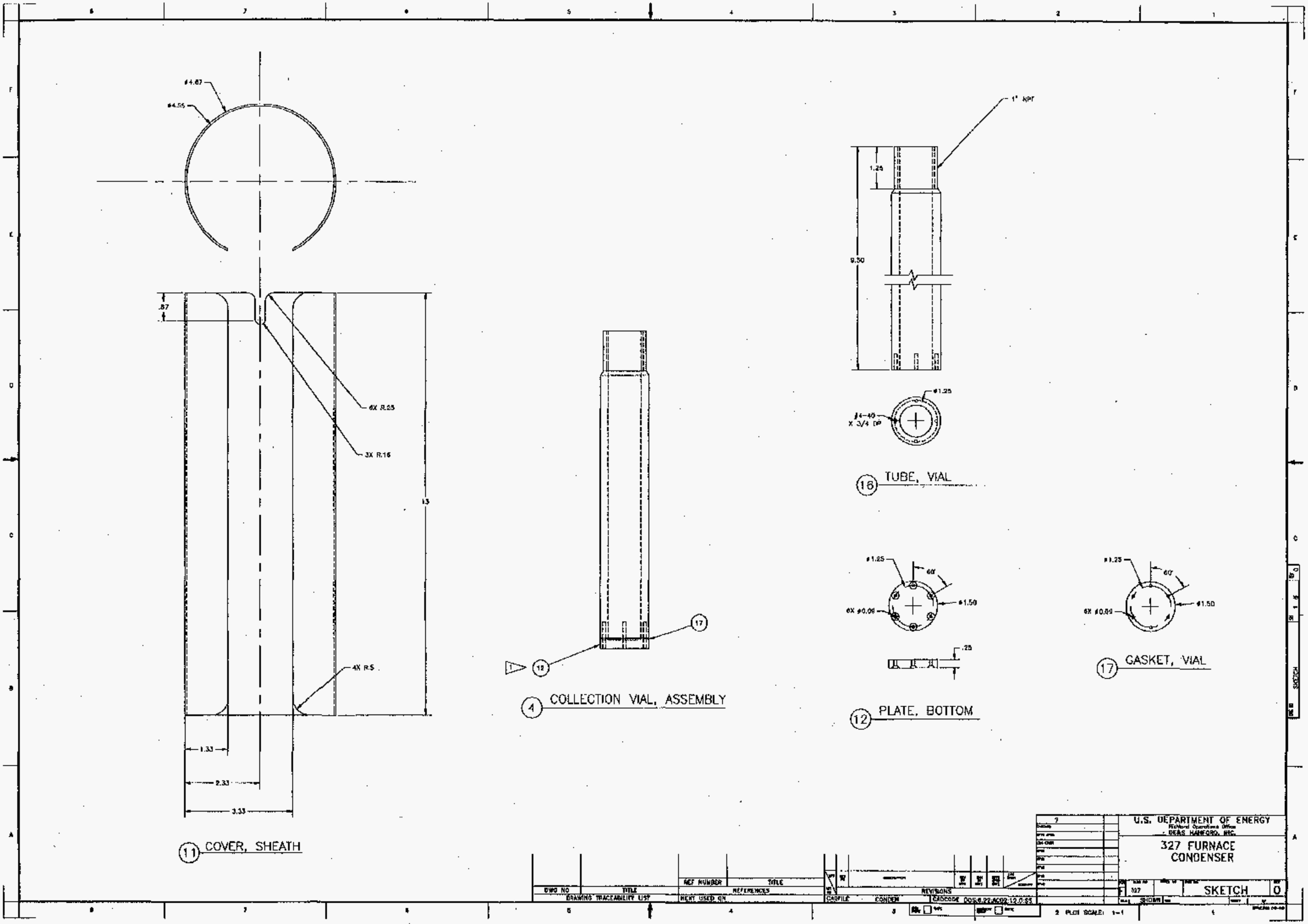
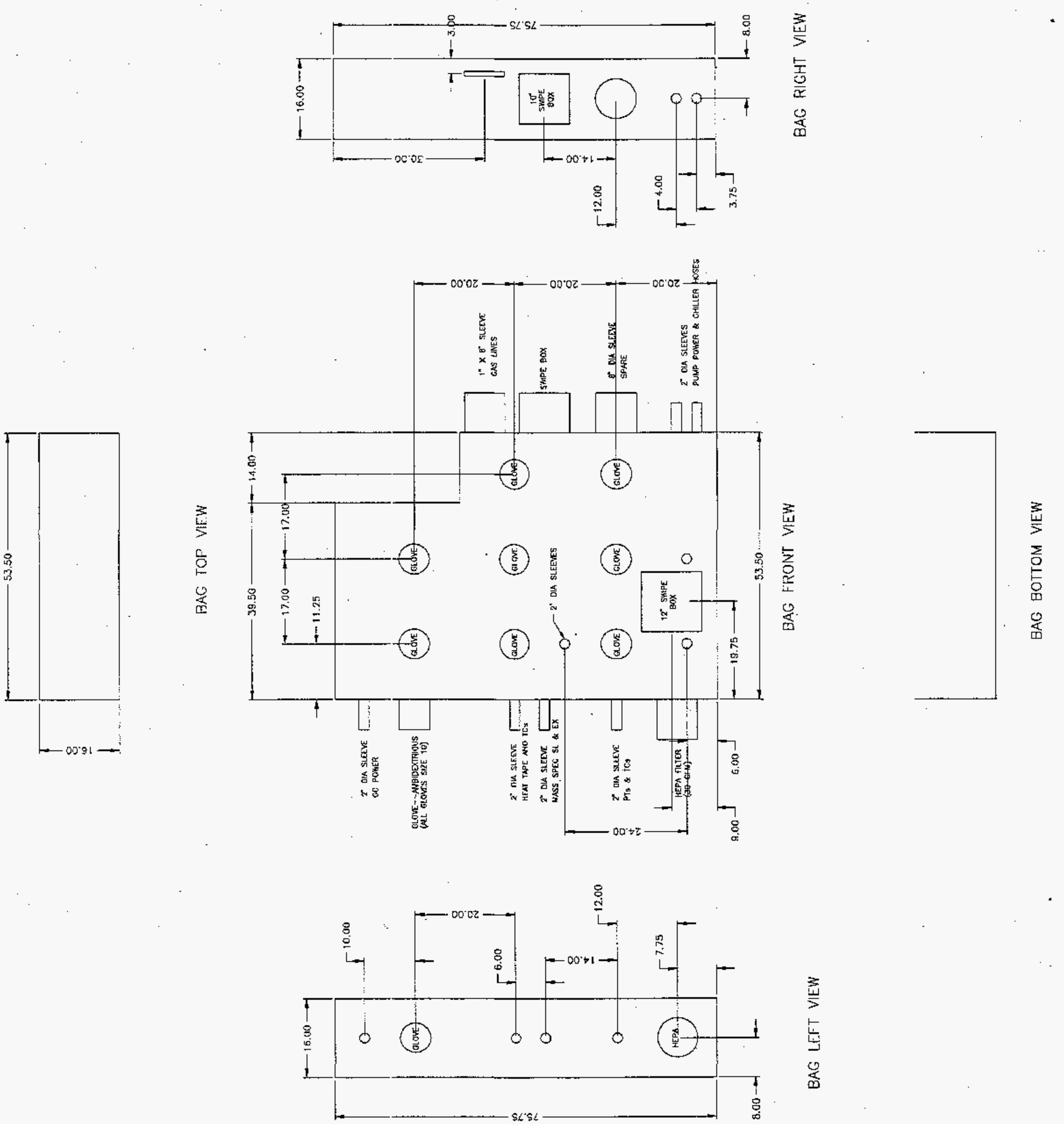
B&W Hanford Co.
SNFC FUEL
VIEWING
STAND
H-3-XXXXXX A

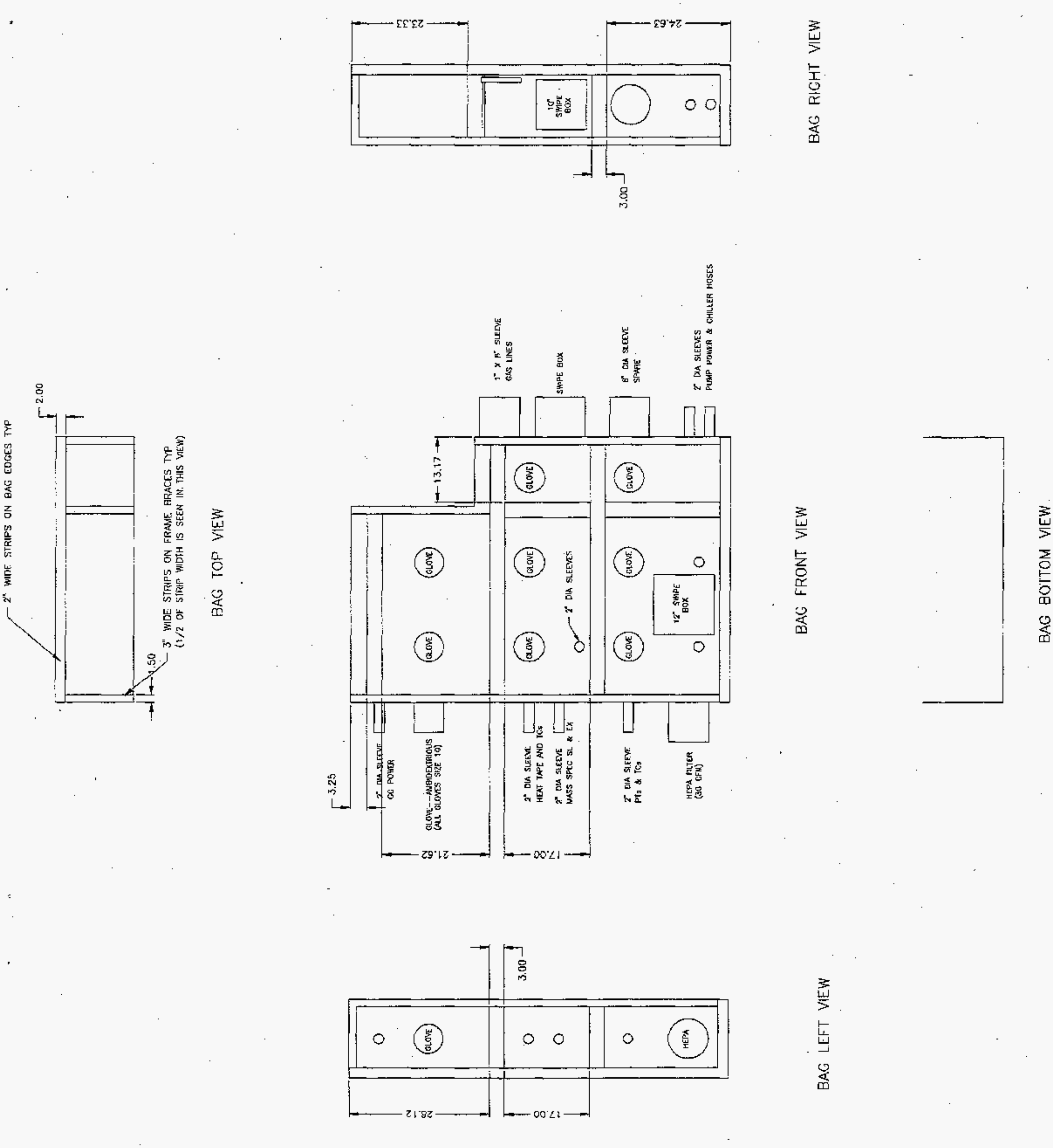


ø4.67
ø4.55
.87
6X R.25
3X R.16
13
4X R.5
1.33
2.33
3.33
11 COVER, SHEATH
17
12
4 COLLECTION VIAL, ASSEMBLY
1" NPT
1.25
9.30
ø1.25
#4-40 X 3/4 DP
16 TUBE, VIAL
ø1.25
60°
ø1.50
6X ø0.09
.25
12 PLATE, BOTTOM
ø1.25
60°
ø1.50
6X ø0.89
17 GASKET, VIAL
U.S. DEPARTMENT OF ENERGY
327 FURNACE
CONDENSER
SKETCH
0
DWG NO
TITLE
DRAWING TRACEABILITY LIST
REF NUMBER
TITLE
REFERENCES
NEXT USED ON
REVISIONS
CADFILE
CONDEN
PLOT SCALE: 1=1

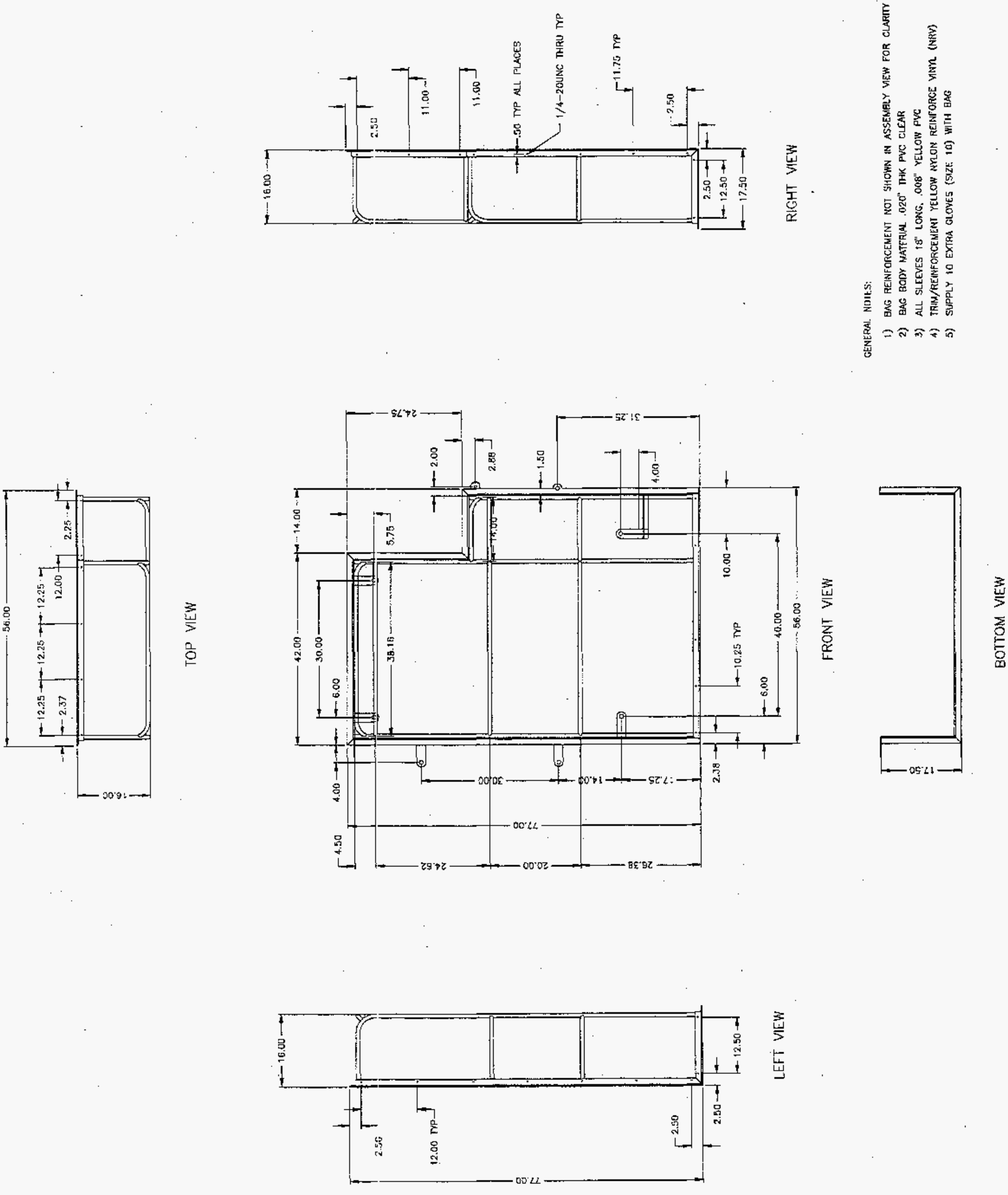
GLOVE BAG ASSEMBLY



GLOVE BAG REINFORCEMENT



GLOVE BAG FRAME ASSEMBLY



GENERAL NOTES:

1) BAG REINFORCEMENT NOT SHOWN IN ASSEMBLY VIEW FOR CLARITY
2) BAG BODY MATERIAL .020" THK PVC CLEAR
3) ALL SLEEVES 18" LONG, .008" YELLOW PVC
4) TRIM/REINFORCEMENT YELLOW NYLON REINFORCE VINYL (NRV)
5) SUPPLY 10 EXTRA GLOVES (SIZE 10) WITH BAG

Appendix G

Supporting Document List

Appendix G

Supporting Document List

This appendix provides a list of documents related to the WEFTS as of the date of this writing. This list may not represent a complete list of all WEFTS documents.

TEST PLANS

SNFCT97:053:R00, Test Plan for Whole Element Furnace Runs 1, 2, and 3

SNFCT98:008:R00, Test Plan for Whole Element Furnace Run 3

SNFCT98:012:R00, Test Plan for Whole Element Furnace Run 4

TEST PROCEDURES

3M-SOP-PTL-169, Furnace Testing of N-Reactor Fuel Element 1990

3M-SOP-PTL-170, Furnace Testing of N-Reactor Fuel Element 3128W

3M-TWD-PTL-001, Furnace Testing of N-Reactor Fuel Element 5427W

3M-TWD-PTL-002, Zeroing of Type 270 Signal Conditioner with Remote Zero Option

3M-TWD-PTL-003, Dry Run Testing of G-Cell Furnace Using a Water Sample

3M-TWD-PTL-004, Furnace Testing of N-Reactor Fuel Element 0309M

3M-TWD-PTL-005, Furnace Testing of N-Reactor Fuel Element 5744U

3M-TWD-PTL-006, Furnace Testing of N-Reactor Fuel Element 6603M

3M-TWD-PTL-007, Furnace Testing of N-Reactor Fuel Element 1164M

3M-TWD-PTL-008, Furnace Testing of N-Reactor Fuel Element 2660M

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