WSRC-RP-89-321

CHECKOUT AND START-UP OF THE INTEGRATED DWPF MELTER SYSTEM

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CHECKOUT AND START-UP OF
THE INTEGRATED DWPF MELTER SYSTEM (U)

The attached memorandum (WSRC-RP-89-321) includes a summary of the IDMS program objectives, system and equipment descriptions, and detailed discussions of the system checkout and start-up of the Integrated DWPF Melter System.

The following start-up and operating recommendations for the DWPF were concluded from the checkout and start-up of the IDMS facility:

- Low megger values on the lid heaters may be due to the configuration of their transformers. Voltage to ground checks with operating voltage applied to the lid heaters can be used to determine if the lid heaters are safe to operate.

- Low megger values on the electrodes may be due to moisture in the melter, and the melter should then be dried out to determine if the values increase, thereby indicating an initial moisture problem. This water does not pose a problem, as it will be vaporized out of the melter during the heatup of the melter.

- Verify that the process water pressure to the melter feed line three-way valves is below the design pressure of the Everlasting Three-way Valves.

- Run a test during cold runs to determine the cool down time of the melter from operating temperatures down to 1000°C.

- Add controller anti-windup programming in the DCS where applicable.

- Conduct a pour spout temperature profile after melter heatup and prior to the first pour.

- Ensure that a pressure regulator is installed (and set properly) on the melter/pour spout pressure control air line.

- Rerange the melter/pour spout delta pressure transmitter to at least 55" wc on the positive side.

- Calculate the volume of flush water required on the feed line to the melter, and ensure that the volume of the flush is sufficient to flush the piping volume at least one time.

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CHECKOUT AND START-UP OF THE INTEGRATED DWPF MELTER SYSTEM (U)

INTRODUCTION

The Integrated DWPF Melter System (IDMS) is a one-ninth-scale demonstration of the Defense Waste Processing Facility (DWPF) feed preparation, melter, and off-gas systems. The IDMS will be the first engineering-scale melter system at SRL to process mercury and flowsheet levels of halides and sulfates.

The IDMS project (9S-2659) was approved by DOE in March of 1986. The design effort was initiated shortly thereafter by the Du Pont Engineering Department. Construction of the IDMS was begun in October of 1986, and the project was mechanically complete May 31, 1988. After extensive mechanical and electrical checkouts, the system was started up in November of 1988.

This report includes a summary of the IDMS program objectives, system and equipment descriptions, and detailed discussions of the system checkout and start-up.

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SUMMARY/RECOMMENDATIONS

The IDMS facility was started up in November of 1988. The purposes of this report are to 1) give a detailed description of the various systems in IDMS, 2) provide a detailed equipment checkout of the facility, 3) provide basic operating parameters for equipment in the IDMS, and 4) document the first two sludge-only runs which were designed to checkout the operation of the facility.

The IDMS facility performed these two feed preparation (SRAT/SME) batches in 4Q 1988 and 1Q 1989. No Precipitate Hydrolysis Aqueous (PHA), trim chemicals, mercury compounds, or noble metals were added; thus the campaign is referred to as "sludge-only".

Upon completion of the startup and sludge-only campaign, the following recommendations for DWPF have been given:

1) Low megger values on the lid heaters may be due to the configuration of their transformers. Voltage to ground checks with operating voltage applied to the lid heaters can be used to determine if the lid heaters are safe to operate.

2) Low megger values on the electrodes may be due to moisture in the melter, and the melter should then be dried out to determine if the values increase, thereby indicating an initial moisture problem. This water does not pose a problem, as it will be vaporized out of the melter during the heatup of the melter.

3) Verify that the process water pressure to the melter feed line three-way valves is below the design pressure of the Everlasting Three-way Valves.

4) Run a test during cold runs to determine the cool down time of the melter from operating temperatures down to 1000°C.

5) Add controller anti-windup programming in the DCS where applicable.

6) Conduct a pour spout temperature profile after melter heatup and prior to the first pour.

7) Ensure that a pressure regulator is installed (and set properly) on the melter/pour spout pressure control air line.

8) Rerange the melter/pour spout delta pressure transmitter to at least 55" wc on the positive side.

9) Calculate the volume of flush water required on the feed line to the melter, and ensure that the volume of the flush is sufficient to flush the piping volume at least one time.

IDMS PROGRAM OBJECTIVES

The Integrated DWPF Melter Facility (IDMS) is a 1/9-scale demonstration facility for the DWPF feed preparation, melter, and off-gas systems. The IDMS is the fourth large scale melter system to demonstrate the DWPF process. A full scale SRAT/SME demonstration facility was operated at TNX for over three years. The main difference between the previous facilities and IDMS is that the feed material will contain flowsheet levels of mercury and halides, and that the system is designed for continuous melter feeding. Objectives of the IDMS include:

1) Demonstration of mercury behavior, particularly
   - scrubbing from off-gas,
   - Formic Acid Vent Condenser operation,
   - operation of the melter,
   - mercury steam stripping and recovery,
   - and mercury content and chemical form in the off-gas system.

2) Demonstration of long-term melter operation with continuous glass production,

3) Testing of anticipated sludge types (different compositions) before they are processed in the DWPF operability testing program (cold runs),

4) Demonstration of noble metals behavior, particularly
   - effects of noble metals on SRAT/SME processing, including mercury stripping, catalysis of formic acid destruction, and agglomeration,
   - evaluation of potential melter deposition,
   - evaluation of melter electrical characterization.

5) Demonstration of DWPF reference materials of construction,

6) Training of DWPF technical and operations support personnel.

The first two batches of feed produced and processed were sludge-only. The next three will use precipitate hydrolysis produced in the PHEF. Provided all systems are operating properly, mercury will be used in the sixth and all subsequent operations.

SYSTEM AND EQUIPMENT DESCRIPTION

The IDMS feed preparation, process vessel vent, feed delivery, melter, melter off-gas, and effluent treatment systems are located in Building 672-T at TNX. A flowsheet of the entire process is shown in Figure 1.

Feed Preparation System

The feed preparation system consists of a Sludge Receipt and Adjustment Tank / Slurry Mix Evaporator (SRAT/SME), a SRAT/SME Condenser, a Mercury Water Wash Tank (MWWT), and a Waste Water Pump Tank (WWPT).

Individual components of the feed preparation system are as follows:

1) Sludge Receipt and Adjustment Tank / Slurry Mix Evaporator

The SRAT/SME shown in Figure 2 is a 2000 gallon dished-head Hastelloy C-276 tank with separate internal Hastelloy steam and cooling water coils. The tank is vented to the Process Vessel Vent System (PVVS), which will be discussed in a later section. A conservation vent, which is discharged to the off-gas stack, provides protection from sudden over-pressuration. The IDMS SRAT/SME is approximately 1/5-scale compared to the DWPF tank.

The IDMS SRAT/SME agitation system is similar to that of the DWPF. The IDMS SRAT/SME has a 25-horsepower Hastelloy C-276 agitator which operates over a 42-125 rpm range. The DWPF SRAT agitator is 100-horsepower Hastelloy C-276 agitator which operates over a 65-130 rpm range. Both the IDMS SRAT/SME and the DWPF SRAT agitation systems are comprised of upper and lower impellers. The upper impeller of the DWPF agitator has three blades of a hydrofoil design while the upper impeller of the IDMS agitator is a four blade pitched design. The lower (for both the IDMS and the DWPF) is a four blade flat impeller that acts as a sweeper to keep solids from depositing on the bottom of the tank. The IDMS impellers have a 30 inch diameter while the DWPF impeller diameter is 36 inches. The DWPF SRAT agitator tip velocity is 20.42 ft/sec for the HIGH setting and 10.21 ft/sec for the LOW setting. In order for the IDMS SRAT/SME agitator to operate at the same tip velocity as the HIGH setting of the DWPF, the shaft would have to operate at 156 rpm. This is above the 125 rpm maximum of the IDMS agitator. The IDMS agitator will therefore be operated at a tip velocity which corresponds to the LOW setting of the DWPF SRAT agitator. This is calculated to be 78 rpm.

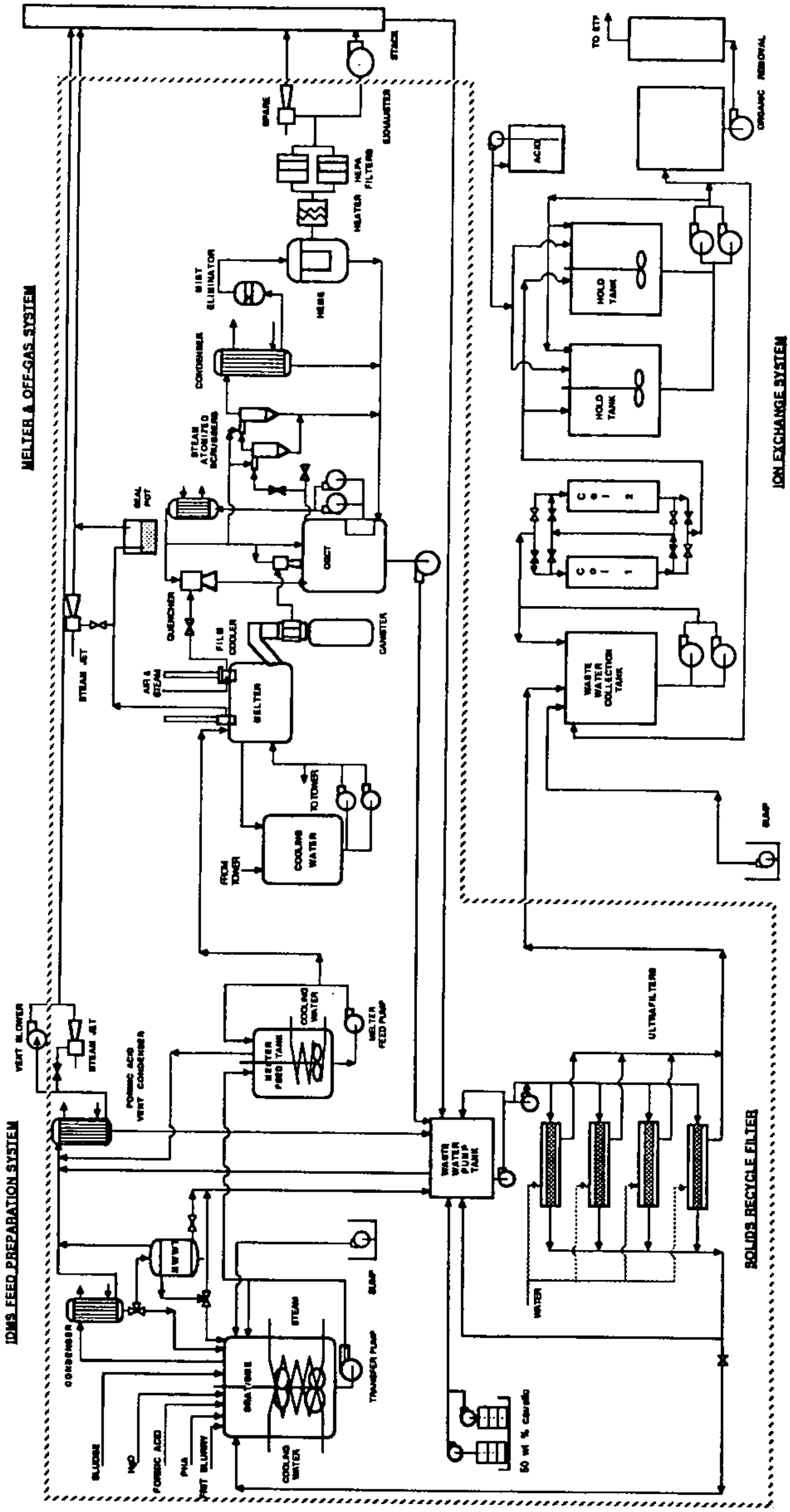
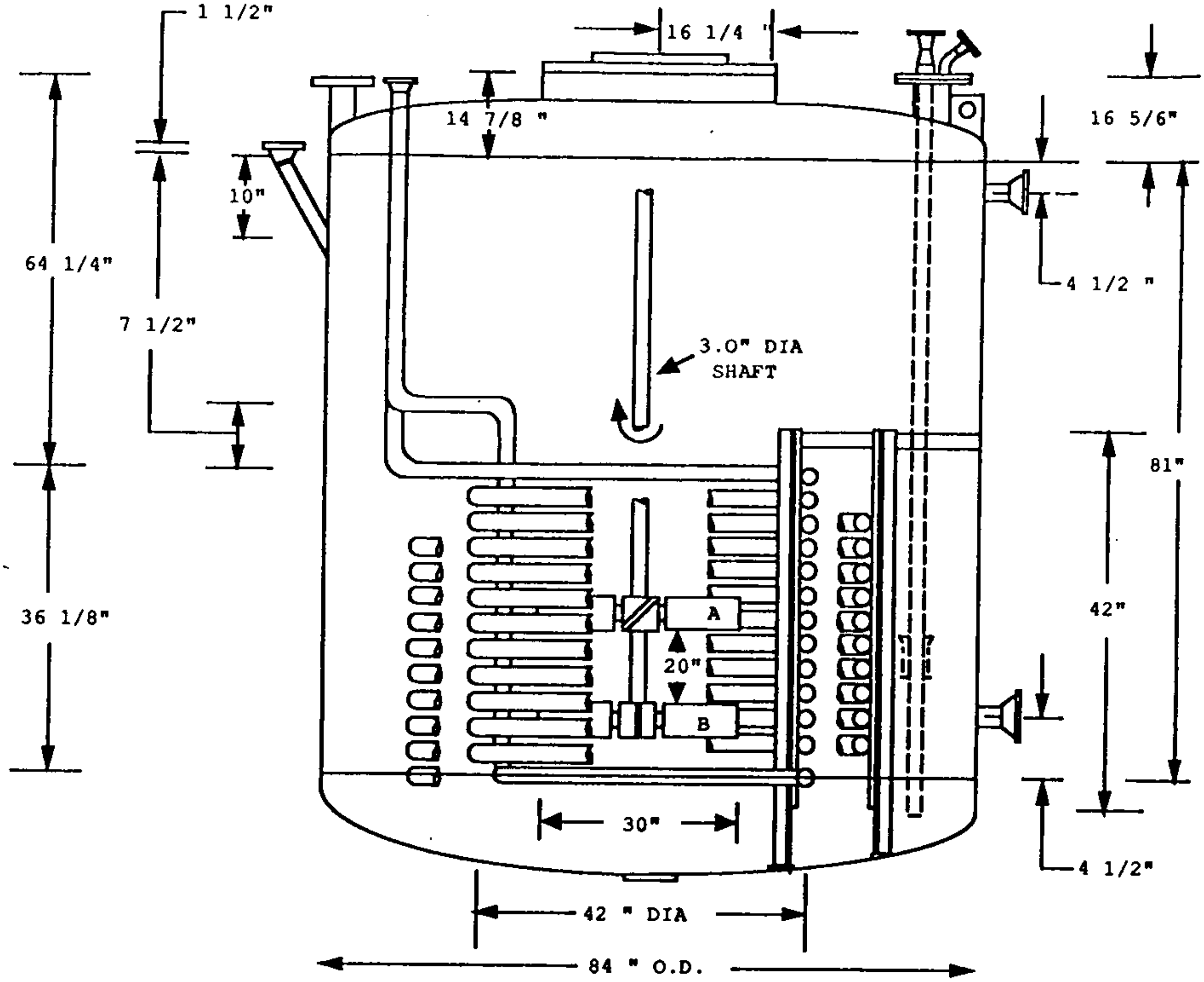


FIGURE 1. IDMS Process Schematic



A. 4" WIDE - 1/4" THICK BLADE
45 DEG PITCH

B. 4" WIDE - 1/4" THICK BLADE
STRAIGHT

<u>FIGURE 2</u>. IDMS SRAT/SME

2) SRAT/SME Condenser

The SRAT/SME Condenser shown in Figure 3 is a single-pass Hastelloy C-276 shell-and-tube heat exchanger. The condenser is scaled to handle a peak non-condensibles flow approximately 1/5 that of the DWPF SRAT condenser. The peak non-condensibles velocity through the IDMS SRAT/SME condenser is 55 lb/hr. The condenser is insulated, and uses cooling water from the 672-T cooling tower.

3) Mercury Water Wash Tank

The MWWT is a 100 gallon 304-L stainless steel tank, and is located above the SRAT/SME. Mercury is steam-stripped in the SRAT/SME tank during the boilup process, condensed in the SRAT/SME Condenser, and collected in the MWWT. The mercury then settles to the mercury sump in the bottom of the MWWT, which has a self-contained level probe to measure mercury accumulation. After each SRAT batch, the mercury that has settled to the bottom of the tank is washed with water, air agitated, drained, and collected in bottles. The remaining wastewater is transferred to the WWPT. The MWWT is vented to the Process Vessel Vent System (PVVS).

4) Waste Water Pump Tank

The WWPT is a 125 gallon dished-head Hastelloy C-276 tank. All condensate from the SRAT/SME operation and melter operation are collected in this tank, which is also vented to the PVVS.

5) Sludge Receipt Tank

The simulated sludge used in the IDMS is vendor-supplied and is delivered to TNX in a 5000 gallon tank truck. The sludge is stored in the 10,000 gallon Sludge Receipt Tank (SRT). This tank is agitated and has a steam heating coil to prevent freezing of the tank contents.

6) Formic Acid Pump

The formic acid pump is a metering pump capable of pumping up to 0.5 gpm.

7) Frit Slurry Makeup Tank

The Frit Slurry Makeup Tank (FSMT) is the same tank that was previously used for the Full Scale SRAT/SME. The air sparger was removed after its failure during a Full Scale SRAT/SME run, and will not be replaced. The FSMT is a 3000 gallon stainless steel tank with a 5-hP agitator. The tank has its own ventilation system.

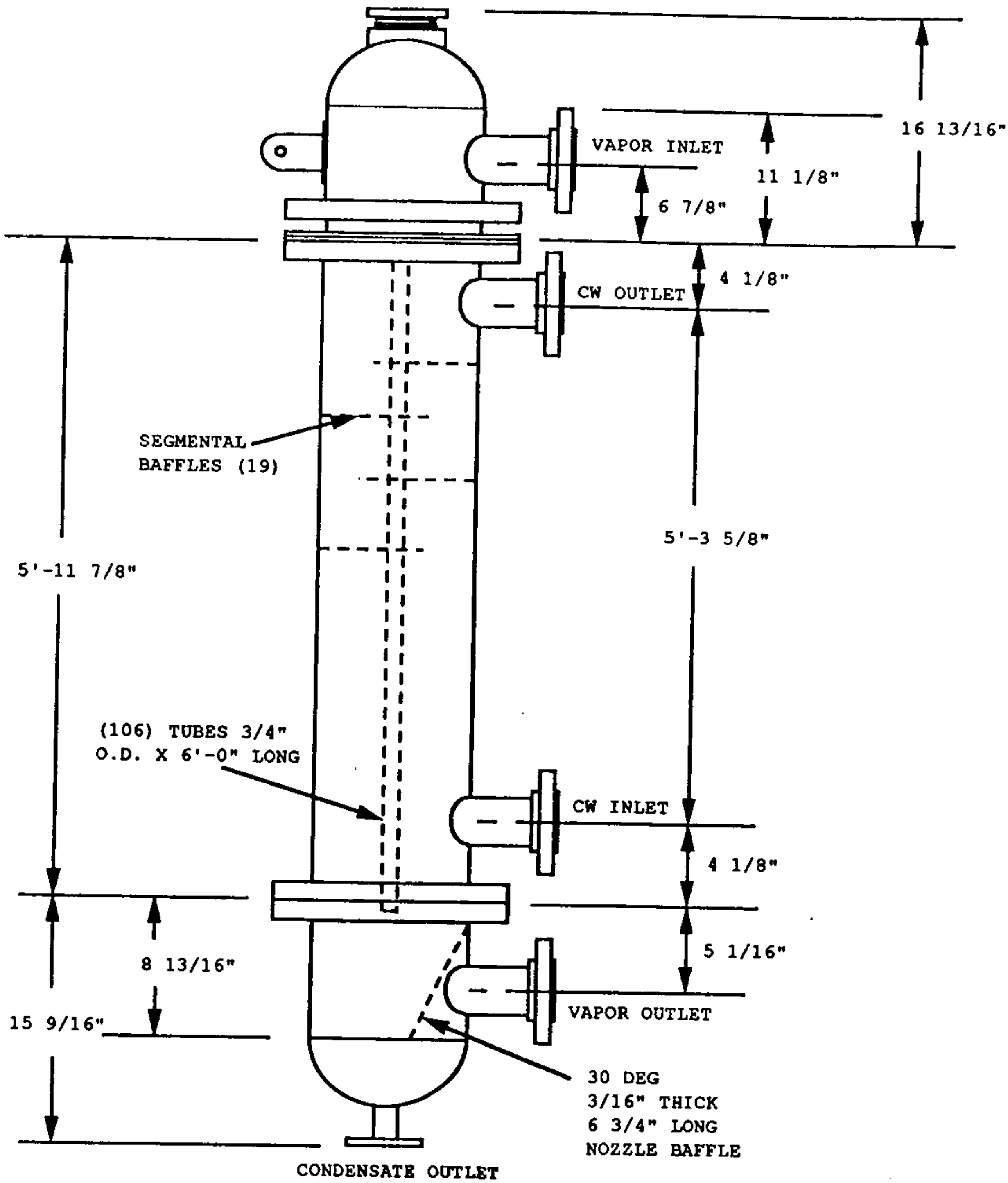


FIGURE 3. **IDMS SRAT/SME Condenser**

The feed preparation process consists of the following steps:

1) Sludge Receipt

The SRAT portion of the process begins with the transfer of about 1000 gallons of sludge from the SRT to the SRAT/SME. A flow totalizer is used to monitor the amount of sludge transferred. Changes in tank levels are also monitored to verify the totalizer reading. The transfer line is then flushed with water. Cooling water flows to the SRAT/SME cooling coils to maintain the sludge at a temperature of about 40°C. The sludge is agitated to ensure proper mixing. The SRAT/SME contents are then sampled to determine the total amount of solids and to confirm the composition. If needed, the contents of the SRAT/SME are then concentrated by boiling the slurry and routing the condensate to the WWPT.

2) Dry Chemical Addition

Mercuric nitrate ($Hg(NO_3)_2$), noble metals, and other trim chemicals are manually added to the SRAT/SME tank through a funnel. Mercuric nitrate reacts with the alkaline slurry to form mercuric oxide (HgO). Approximately 35 pounds of mercuric nitrate, 10 pounds of noble metals, and small amounts of other trim chemicals will be added.

3) Formic Acid Addition

Cooling water flow to the SRAT/SME is discontinued at this point and steam flow to the heating coils is initiated. The contents of the tank are then heated to ~95°C. Fifty gallons of 90 wt% formic acid are then pumped to the SRAT/SME at 0.3 gpm. A flow totalizer is used to monitor the amount transferred. The formic acid reacts with the mercuric oxide, and some of the metal hydroxides and oxides in the sludge, producing elemental mercury, formates, and gaseous CO_2. The formic acid also reacts with nitrites present to produce gaseous NO, which then oxidizes to NO_2. Sludge temperature and the rate of formic acid addition are carefully controlled to maintain an acceptable off-gas evolution rate.

4) Refluxing to Remove Mercury (Steam-stripping)

The SRAT/SME contents are then refluxed at the normal boiling point of about 101°C for six hours. At this temperature, the formic acid continues reacting with mercuric oxide, reducing it to mercury metal (Hg). This metallic mercury is removed by steam stripping during the refluxing step, and by routing the reflux stream through the MWWT, which serves as a decanter.

Approximately 25% of the mercury will remain with the slurry that is transferred to the Melter Feed Tank (MFT) and will be fed to the melter.

5) Precipitate Hydrolysis Aqueous Addition

In preparation for the addition of Precipitate Hydrolysis Aqueous (PHA) product, the SRAT/SME is heated to (97°C). PHA is added in four batches for a total of approximately 2000 gallons. A flow totalizer is used to monitor the amount of PHA transferred, and changes in tank levels are monitored to verify the totalizer reading. The PHA is added during refluxing.

The sludge is concentrated by sending the condensate through the MWWT to the WWPT instead of recycling it back to the SRAT/SME. After all of the PHA has been received and concentrated, total reflux resumes. The total time for refluxing during this step and steam stripping to remove mercury is 30 hours, and includes any time above 100°C for additional steam-stripping. At this point about 75% of the mercury should be removed. The sludge/precipitate slurry is then cooled and sampled.

Benzene is evolved during the PHA addition, refluxing, and concentration steps of the SRAT/SME cycle. To prevent formation of a flammable mixture of benzene and air, the air bleed lines to the tanks are closed during this processing step, and nitrogen is added to the PVVS to lower the oxygen concentration to below that which is required to burn benzene (Minimum Oxygen Concentration (MOC) for combustion). The MOC for the combustion of benzene is 11 volume %. The nitrogen flow is set such that the oxygen concentration in the vent system is less than 6 volume %. If the oxygen concentration exceeds 8 volume %, the PHA addition and the SRAT/SME boiling operation are stopped. The nitrogen purge flows are maintained until the SRAT/SME temperature is below 70°C.

6) Frit Slurry Addition

The SME portion of the operation includes the addition of frit to the SRAT/SME. A 50 - 60 wt% solids frit/water slurry is prepared in the FSMT. Three thousand pounds of glass frit (one tote bin) are added to the FSMT using a bin inverter and mechanical conveyor. About 3 gallons of formic acid is added to the FSMT from the formic acid unloading station. The entire contents of the FSMT are then transferred to the SRAT/SME.

7) Feed Concentration

After frit slurry addition, the sludge/frit slurry is concentrated to about 50 wt% solids. The batch is then cooled to 50°C, sampled, and analyzed before being transferred to the Melter Feed Tank.

Process Vessel Vent System

Primary containment of mercury and organic vapors in the feed preparation system is accomplished by maintaining all of the vessels under a vacuum using the Process Vessel Vent System (PVVS). The PVVS serves every mercury-containing vessel in the

IDMS except the Melter and the Off-Gas Condensate Tank. The vessels it serves are the SRAT/SME, the Mercury Water Wash Tank, the Waste Water Pump Tank, and the Melter Feed Tank. Air bleeds are provided on all four tanks, with the air addition flow rates set to simulate the air inleakage in the DWPF tanks. The overflow lines on each tank have water-filled seal pots to prevent uncontrolled air leakage into the tanks. The seal pots are arranged so that they provide additional pressure relief for the tanks.

The PVVS consists of the following equipment:

1) Formic Acid Vent Condenser

   The Formic Acid Vent Condenser (FAVC) shown in Figure 4 is a single-pass shell-and-tube heat exchanger with a built-in glass fiber mist eliminator. The stainless steel condenser is scaled for an exit vapor flow of 131 lb/hr, approximately 1/5 the design basis for the DWPF FAVC. Chilled water is used to lower the process vapor temperature to 10°C, condensing mercury in the inlet vapor. The mist eliminator removes particulate and further reduces the mercury concentration in the process vapor stream. A water spray is provided to wash the mist eliminator.

2) PVVS Blower

   A 1-1/2 hP rotary blower is the primary source of vacuum. A variable-speed drive is used to control the pressure in the SRAT/SME vapor space.

3) PVVS Steam Jet

   If the PVVS blower fails, the vapor stream from the PVVS is diverted to a steam jet, which is controlled to maintain the desired pressure in the SRAT/SME.

4) PVVS Stack

   Process vapors from the blower or the steam jet are discharged to the atmosphere via a 3-inch-diameter stack 70 feet in height.

5) Nitrogen Supply System

   Nitrogen for the PVVS is supplied either from of two vendor-maintained 6000 gallon liquid nitrogen supply tanks. The liquid nitrogen is vaporized in a heat exchanger and then regulated to 70 psi. The 70-psi supply is used in the IDMS sampling system. The nitrogen pressure is regulated to 40 psi for use in the PVVS. If the IDMS nitrogen header supply pressure drops below 20 psig, the nitrogen supply from the second tank (located at PHEF) is valved into the supply header.

Under normal operating conditions, the rotary blower is set to maintain a vacuum between 5" and 10" wc on the SRAT/SME. The tank air bleeds, along with any air inleakage and instrument air purges, give a total air flow of 100 to 125 lb/hr to the FAVC.

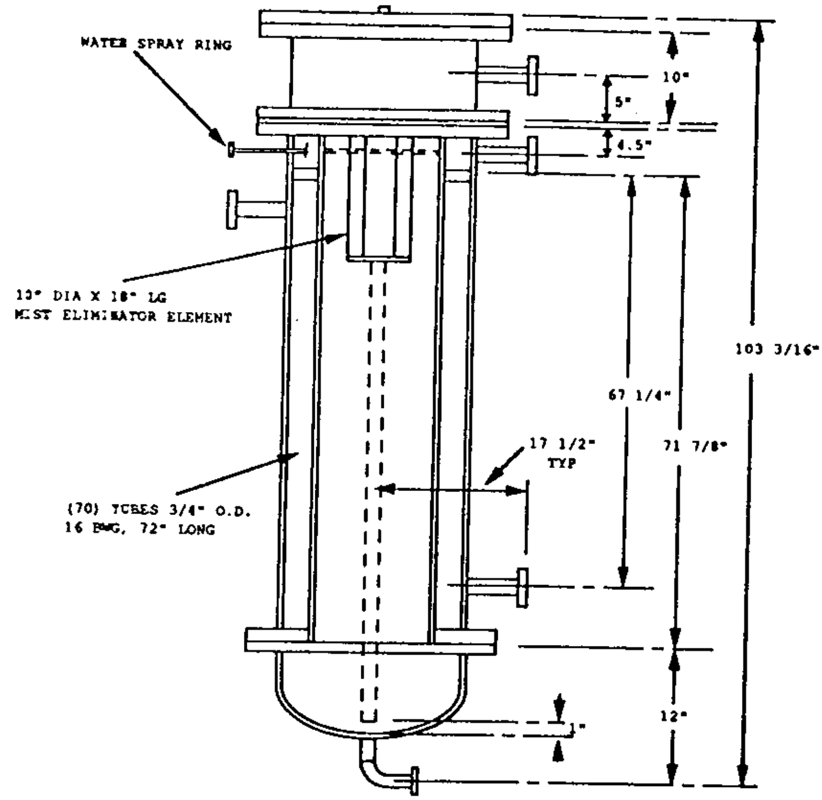


FIGURE 4. **Formic Acid Vent Condenser**

Feed Delivery System

The Melter Feed Tank (MFT) is the only IDMS vessel that operates as a batch-in/continuous-out process. It is a 1500 gallon dished-head Hastelloy C-276 tank with an internal Hastelloy C-276 cooling coil used to maintain the tank contents at a constant temperature. The tank contents are agitated continuously to prevent solids from settling in the tank bottom. Agitation is accomplished via a 15-hp variable speed agitator. The agitation system is similar to that of the DWPF Melter Feed Tank. The DWPF MFT agitation is exactly the same as the DWPF SRAT agitation system (described earlier). The IDMS MFT agitation system is the same as the IDMS SRAT/SME agitator except that the MFT impeller diameter is 24" compared to 30" for the SRAT/SME. The DWPF MFT agitator tip velocity is 20.42 ft/sec for the HIGH setting and 10.21 ft/sec for the LOW setting. In order for the IDMS MFT agitator to operate at the same tip velocity as the HIGH setting of the DWPF, the shaft would have to operate at 195 rpm. This is above the 125 rpm maximum of the IDMS agitator. The IDMS agitator will therefore be operated at a tip velocity which corresponds to the LOW setting of the DWPF MFT agitator. This is calculated to be 98 rpm.

Feed prepared in the SRAT/SME is transferred to the MFT using an air-operated double-diaphragm pump. Sampling is required in the MFT to provide an accurate description of the chemical makeup of the material going to the melter. Any out-of-spec material can be pumped back to the SRAT/SME for rework.

A recirculation loop feed system similar to that used in the DWPF is used in the IDMS. The slurry is recirculated through a two-inch pipe using an air-driven double-diaphragm pump. The loop pressure is adjusted using a manually-operated pinch valve at the return to the tank. The loop pressure forces the slurry through a strainer, a 3-way valve, and fifty feet of 1/4-inch ID piping to the melter feed tube. The flow rate to the melter is controlled by varying the pump air supply which controls the pump speed.

The feed tube (see Figure 5) extends through the melter lid past the lid heaters and discharges the slurry one foot above the melt pool. Slurry is fed through the innermost pipe of the feed tube which has an ID of 0.18 inch. The slurry feed pipe temperature is maintained at 30-40°C by a cooling water jacket that extends all the way to the feed discharge. Water cooling helps prevent slurry drying and pluggage in the feed tube. The water cooling jacket is insulated from the outermost pipe of the feed tube to avoid creating a heat sink and condenser in the melter.

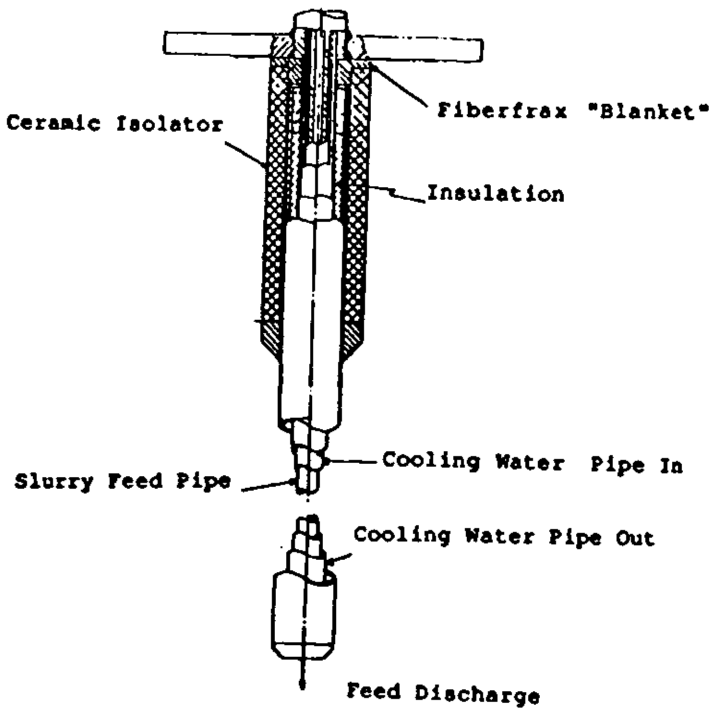


FIGURE 5. IDMS Melter Feed Tube

Process water is piped into the feed line at the three-way valve. This allows water flushing both forward to the feed nozzle and back through the strainer and recirculation loop. The feed nozzle is flushed with water prior to feeding in order to cool the feed tube at the entrance of the melter to prevent a line plug. The entire system, including the recirculation line and feed tube, is flushed each time the melter feed pump is stopped.
Feed to the melter is continuous, interrupted only by operating system interlocks, depletion of the contents of the MFT, or direction by the engineer to stop feeding. Melter feed rate may be maintained between 1 and 9 gallons per hour.

Melter

The IDMS Melter shell design is basically the same as that of the DWPF Scale Glass Melter. An additional 12 inches of Monofrax K-3 was added to the lower interior walls of the melt tank to reduce its diameter from 48 inches to 24 inches. This gives a melt pool surface area which is approximately 1/9 that of the DWPF Melter. Melt rate is directly proportional to the surface area. Therefore, the IDMS Melter can be slurry-fed to produce glass at 25 lb/hr, as compared to 228 lb/hr for the DWPF Melter.

A cross-sectional view of the melter is shown in Figure 6. The melter vessel is lined with K-3 refractory to provide containment of the molten glass. The entire shell is water-cooled to freeze any glass that may penetrate between the refractory blocks before it reaches the shell. Two pairs of diametrically opposed Inconel™ 690 electrodes provide about 35 kW of power to maintain the glass temperature between 1100°C and 1150°C. These electrodes heat the glass by passing an electric current through it, a process called joule heating. The A and C electrode stems are water-cooled, and the B and D stems are air-cooled to freeze any glass that could potentially leak out where the stems penetrate the refractory. Air (instead of water) is used on the B and D electrode stems to reduce heat loss in the unheated riser throat region. Each electrode pair (A-B and C-D) is controlled separately to permit diversion of power to the lower or upper melt pool. Figure 7 shows a view of the inside of the melter before heatup. The upper (B) and lower (D) electrodes, as well as the riser throat block, are shown.

Power supplies for the electrodes can provide up to 300 V single phase, but under normal conditions only 53 V single phase will be required. Power to the electrodes is controlled by silicon controlled rectifiers (SCR's) on the primary side of the power supply transformers. Due to the high current (approximately 400 amps), water-cooled power cables deliver the power to the electrodes from the secondary side of the transformer.

Two horizontally-entering Inconel™ 690 lid heaters, each made of two elements, provide an additional 60 kW of heat to vaporize water from the slurry feed, melt and the glass, and combust any organics in the feed. These heaters are also the primary source of heat during melter startup.

The lid heaters are maintained at 950°C by passing current through the tubes. The power supplies provide up to 8000 amps on the secondary side. Power to the lid heaters is controlled by SCR's on the primary side of the power supply transformers. Due to the very high amperage, the two transformers are water-cooled and located adjacent to the lid heaters so that a direct connection from the transformer to the lid heaters can be made. The surface temperature of the heaters is limited to 950°C because of thermal creep considerations. A short term limit (less than 24 hours) of 1050°C can also be used.

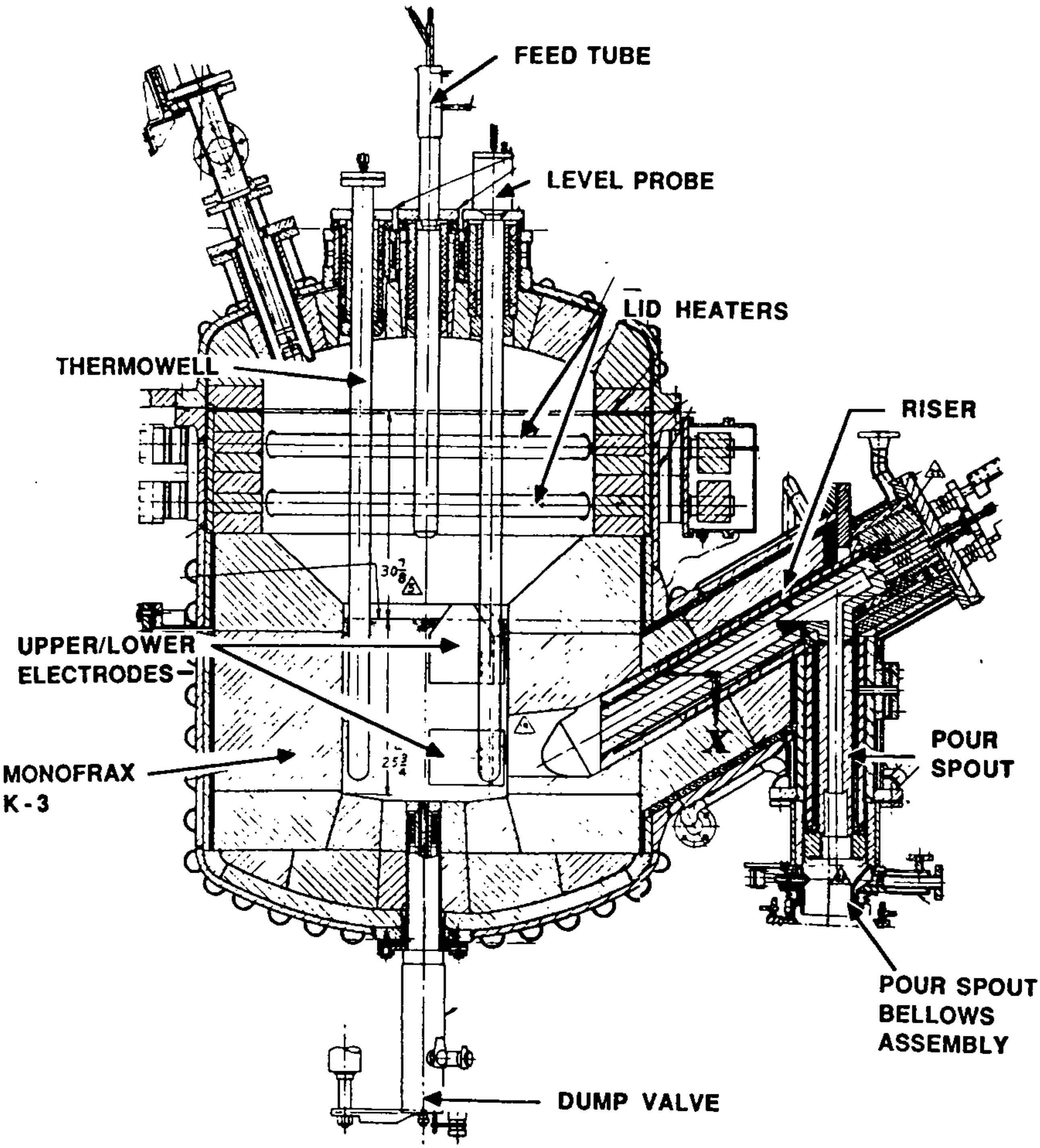


FIGURE 6. Cross-Sectional View of the IDMS Melter

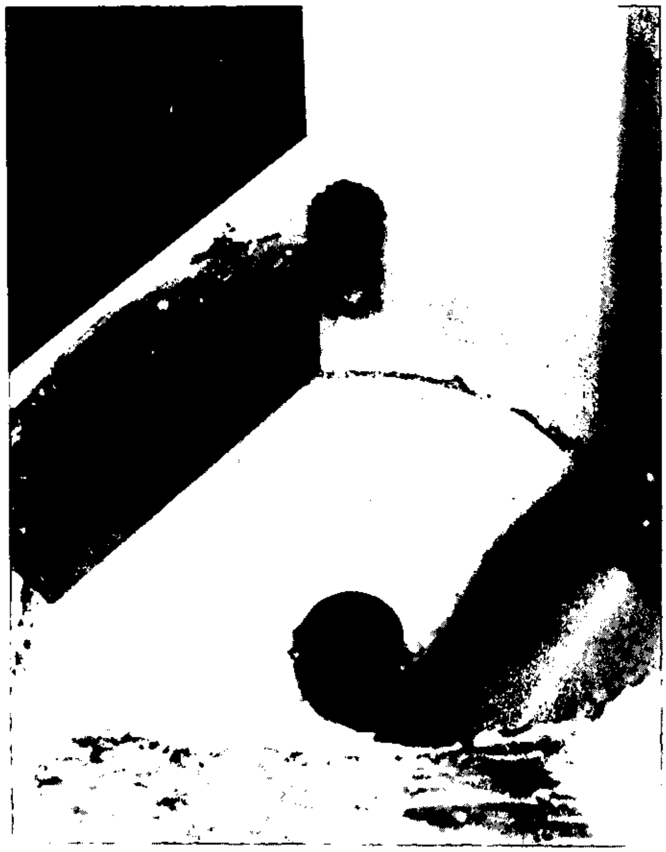


FIGURE 7. Inside of IDMS Melter Before Startup

Glass flows from the melter up through a heated riser channel and then down a heated pour spout channel into a canister which holds up to 200 lbs of glass. The riser is a 2-inch-diameter Inconel™ 690 pipe surrounded by a serpentine Inconel 690™ heater. The heater is isolated from the Inconel™ pipe and housing with ceramics. The heater is used to maintain the glass in the channel at 1100°C. Power requirements for the riser will be discussed in the IDMS Melter Heatup section.

The pour spout heater is constructed similarly to the riser heater. It is used to keep the glass above 1050°C to keep it free flowing. Power to the riser and pour spout heaters is controlled by SCR's on the primary side of the power supply transformers.

Pouring is initiated by creating a vacuum at the canister relative to the melter vapor space. A flexible set of stainless steel bellows provides a vacuum seal between the melter and the canister during pouring. These canisters are 31 inches tall and 10 inches in diameter. Although the slurry is fed continuously to the melter, glass is poured in batches. This is due to the fact that the minimum acceptable pour rate to prevent wavering of the pour stream (about 60 lb/hr) is higher than the melt rate of 25 lb/hr for the IDMS Melter.

A cart on rails is used to transport canisters to and from the Tertiary Containment Room (melter room). The cart is moved by a pneumatic propulsion system which is operated outside the Canister Storage Room. A series of sliding doors is used for entry into the Secondary and Tertiary rooms. Only one door is open at a time to prevent the secondary room from being open to the canister handling room.

The canister weight is determined using a load cell. The canister weight is tared with the bellows up before pouring is started. An accurate glass weight can then be determined after glass pouring is stopped, and the bellows is raised. Due to the small weight of glass that can poured in one canister (200 lbs) relative to the change in the compressive forces exerted by the bellows, meaningful canister weights cannot be determined during glass pouring. A radiation level detector is provided as the primary means to determine the glass level in the canister. A sealed cesium-137 source is positioned in front of the canister, and a radiation detector is positioned behind the canister. The detector is calibrated such that the amount of radiation transmitted corresponds to a canister level. The pour system is shut down if the glass level in the canister reaches 95%. The cesium source is shielded in all directions except towards the detector. Personnel exposure has been measured at less than 0.05 mR/hr at a distance of one foot. A TLD badge is not required for operating personnel. An air-operated shutter is closed from outside of the melter room to completely shield the source from personnel. The shutter is automatically closed if the canister is not located below the bellows. OHP will monitor the source on a semi-annual basis.

The melter cannot be completely drained by using the normal vacuum pouring procedure. Therefore, a non-prototypic dump valve is located at the bottom of the melter. It is comprised of three heater zones which keep the glass fluid during draining. The uppermost zone (Zone 1) is always energized, while Zones 2 and 3 are only energized during draining. A more detailed description of the dump valve is given in the Melter Heatup - Glass Plugs section of this report.

Figure 8 shows a top view of the IDMS Melter. The top head components consist of a feed tube, a borescope, a melt pool thermowell, a vapor space thermowell, a level probe, an off-gas film cooler, and a melter vent line. Descriptions of the film cooler and the melter vent line are in the off-gas description section, while a discussion of the feed tube can be found in the feed system description section.

The borescope is used for continuous visual monitoring of the cold cap, including the recording of any unusual occurrences. The borescope is the same one that was used in the Scale Glass Melter. It is a long Inconel tube with an eyepiece and nine optical lenses. The inner lenses relay the image being observed from the viewing head to the attached camera. The borescope is cooled with air, and the outer lens in the melter vapor space is periodically cleaned with steam. Loss of the cooling air would result in the melting of the copper lens spacers and some of the lens.

Glass level and melter pressure are measured by the level probe (Figures 9 & 10). The original level probe was composed of a hollow Inconel™ 690 chamber (3-inch O.D. and 1-inch I.D.) which had two tubes running inside of it. These pressure sensor tubes were welded to a lower section which had two holes drilled into it. Previous experimentation on the Scale Glass Melter[1] demonstrated that this design was inadequate. Failure of two probes in the Scale Melter has led to a new design that is now

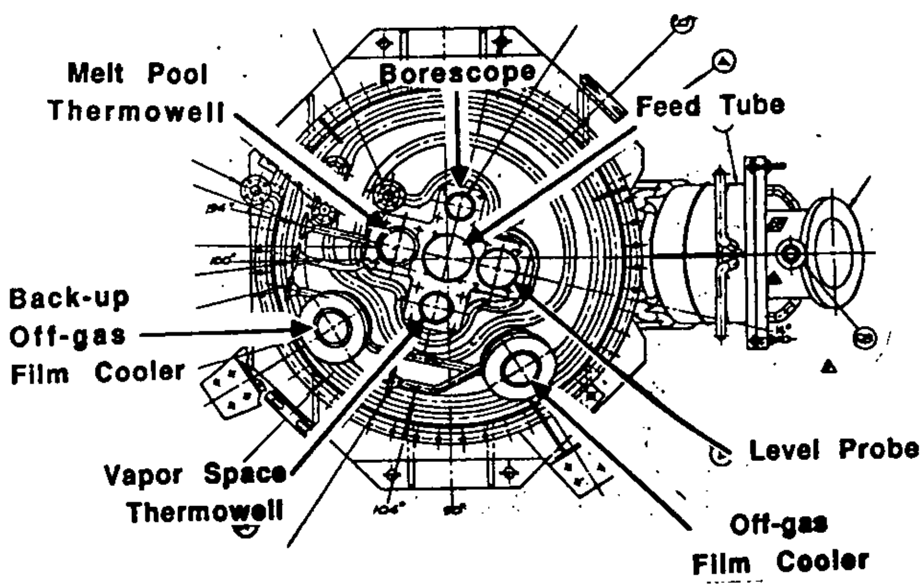


FIGURE 8. Top View of the IDMS Melter

used in the IDMS Melter and the DWPF Melter (Figure 10). This new probe is composed of two solid Inconel™ 690 pieces that have two deep drilled holes which will serve to measure vapor space pressure and melt level. This design eliminates the failure point of the old probe (at the sensor tube/solid section weld). Per the consent of DWPF engineering, this new probe will not measure specific gravity. This is warranted by the fact that the deep drilling of three holes is not feasible. The new level probe design was installed in the IDMS Melter in March of 1989.

The melt and vapor space thermowells are hollow Inconel™ 690 chambers (3-inch O.D. and 1-inch I.D.) with type B thermocouples located inside the respective chambers. The vapor space thermowell extends into the melter vapor space to a point 5.6 inches above the glass pool melt line (overflow level). Three thermocouples, located 3.6 inches above the end of the vapor space thermowell, are used to measure the vapor space temperature. It should be noted that the vapor space temperature is not directly controlled from these thermocouples. The lid heaters have thermocouples which measure their skin temperatures. By controlling these skin temperatures, the vapor space temperature is indirectly controlled.

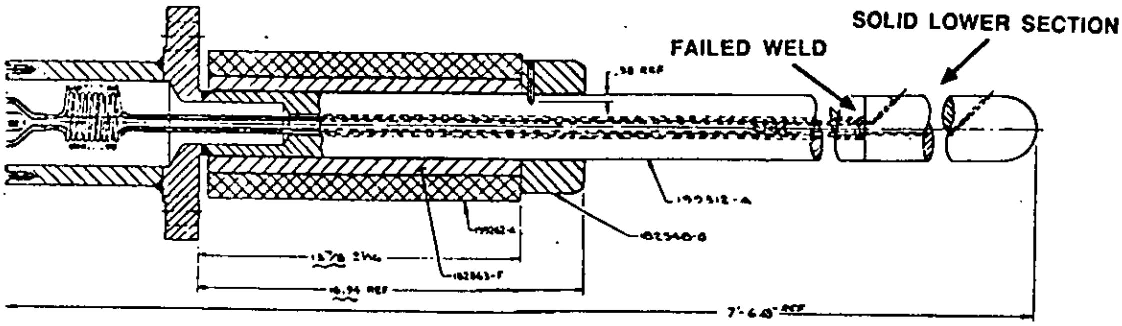


FIGURE 9. **Old Design of the IDMS Melter Level Probe**

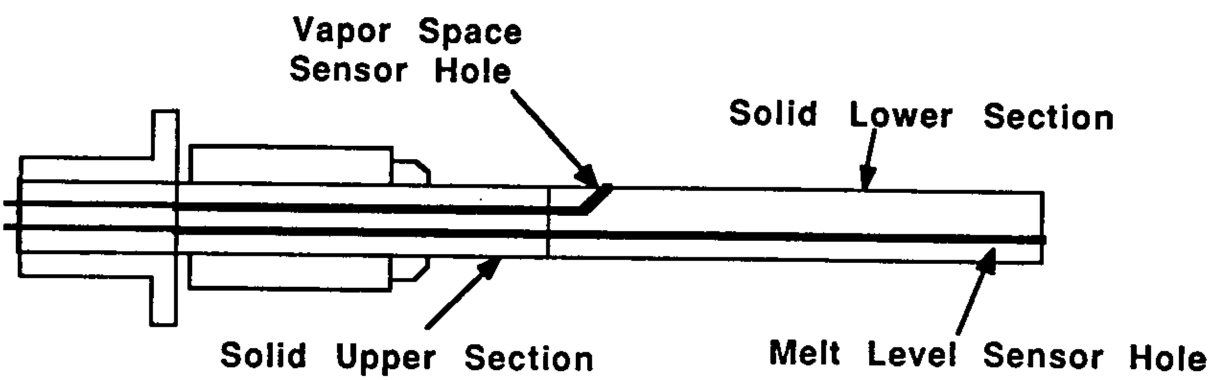


FIGURE 10. **New Design of the IDMS Melter Level Probe**

The melt pool thermowell extends into the glass pool to within 2.5 inches of the melter floor. Three thermocouples which are used to control the lower glass pool temperature (via the C-D electrodes) are located at the very end of the thermowell. Three other thermocouples are located 12 inches above the lower glass pool thermocouples. These are used to control the upper glass pool temperature via the A-B electrodes. For each electrode pair, a control thermocouple is chosen to be used by the PID cascade controllers on the Metra.

Melter Off-Gas System

The IDMS Melter Off-Gas System is a scaled simulation of the DWPF system. It was designed for an off-gas flow rate of 350 lb/hr entering the SAS's, compared with 1900 lb/hr for the DWPF. The off-gas consists of steam, non-condensible gases from sludge decomposition, air from inleakage and purges, mercury vapor, and particulate matter from entrainment and volatilization. The purposes of the off-gas system are to maintain a negative pressure in the melter plenum, to provide adequate combustion in the melter vapor space, ensure ventilation and treatment of the reaction gases and steam released from the melter, and provide melter pour spout vacuum to initiate and control glass pouring. Since there are no radionuclides present in the IDMS, the demand on the IDMS off-gas system is less than for the DWPF off-gas system. However, to enable adequate evaluation of the processing efficiency, mechanical reliability, corrosion, and fouling of filters, demister pads, and heat exchange surfaces, all of the DWPF processing steps are incorporated into the IDMS. Unlike the DWPF, the IDMS does not have a redundant backup system. Instead, it has a bypass system which can be used if the primary system is not operative.

The melter off-gas is normally processed through the primary off-gas system. This system cools the off-gas, condenses most of the water and mercury vapor, and removes the particulates in a series of scrubbers and filters. It consists of the following equipment: an Off-Gas Film Cooler (OGFC) to reduce deposits at the entrance to the off-gas system; a film cooler brush to clean the film cooler; a Quencher (ejector venturi) to cool the off-gas and remove large particulate; an Off-Gas Condensate Tank (OGCT); a two-stage Steam Atomized Scrubber (SAS) to remove submicron particulates; a Mist Eliminator and a High Efficiency Mist Eliminator (HEME) to remove fine mists and particulates; a High Efficiency Particulate Air filter (HEPA) with a preheater; and a blower with a steam jet back-up. A bypass system, which is driven by a steam jet, is used on the melter vent line to the seal pot to insure a negative melter pressure when the primary system is not operating. It is also equipped with a brush to clean deposits from the section of the line adjacent to the melter. A water-driven spout jet pulls a vacuum on the melter pour spout to control glass pouring.

Individual equipment components, listed in sequence of flow through the treatment line, consist of the following:

1) <u>Off-Gas Film Cooler</u>

The Off-Gas Film Cooler (OGFC) is mounted on the melter lid and serves as the inlet to the off-gas system. It is a slotted pipe assembly through which cooling air and steam are injected, reducing the temperature of the off-gases and the potential for hard glassy deposit pluggage. The injected air forms a cool boundary layer along the pipe wall, preventing particles from reaching and bonding with the wall. The OGFC operates in a temperature control mode (a constant flow of air with the steam flow varying to control off-gas temperature).

The IDMS OGFC is a prototypical design of the DWPF OGFC, consisting of nine slots inclined at 10° to the vertical. Seven slots are equally spaced with 0.09-inch openings. The remaining two slots are wider, 0.15- and 0.16-inch, and are positioned at the film cooler entrance to increase air flow and reduce deposits in this more critical region. All exposed surfaces are constructed of Inconel™ 690, while the remainder is 304 stainless steel.

2) Off-Gas Film Cooler Brush

A brush assembly is mounted above the melter on top of the OGFC and is actuated to remove deposits that could plug the OGFC if allowed to further accumulate. Its design is prototypical of the DWPF design.

A motor-driven screw drive rotates the brush at 68 rpm with a travel of 34 inches per minute. The brush rotates clockwise (as viewed from above) as it moves down through the film cooler and it rotates counterclockwise on the way up.

The OGFC brush rests in the upper portion of the tee connecting the OGFC to the off-gas line. The maximum temperatures expected for the brush are 450°C when not in use and 800°C when fully extended. Thermocouples are placed in the brush housing to monitor the drive shaft and brush tip temperatures.

3) Quencher

The Quencher is an ejector-venturi gas scrubber which reduces the gas temperature below the dew point to disengage most of the water vapor from the non-condensibles and allow semi-volatile particles to coalesce. The Quencher is also necessary for maintaining a negative pressure in the melter. The quenching is accomplished using recirculated condensate at 40°C, pumped from the Off-Gas Condensate Tank (OGCT). This motive fluid is propelled through the venturi's one-inch OD inlet which leads to the nine 5/16-inch OD holes and exits through the six-inch OD outlet. This is a scaled-down version of the DWPF Quencher.

4) Two-Phase Line

The two-phase line connects the Quencher to the OGCT. In this horizontal pipe, liquid and gas flow concurrently. This type of concurrent flow has been classified as either stratified, wave, or slug, depending on the quencher water flow rate.

At low liquid flow rates, a stratified flow pattern is observed, in which the liquid flows along the bottom of the pipe and the gas flows over a smooth liquid-gas interface. At higher flow rates, the flow pattern passes through a stage of wave flow which is similar to stratified flow, except that the interface has waves traveling in the direction of flow. At high flow rates, the phenomena of slug flow occurs which is when a wave is picked up periodically by the rapidly moving gas to form a frothy slug which passes along the pipe at a greater velocity than the average liquid velocity. This type of flow is undesirable because the slugs can cause severe vibrations in the pipelines from their impact against pipe bends.

5) Off-Gas Condensate Tank

The Off-Gas Condensate Tank (OGCT) collects the aqueous effluent from the Quencher, Steam Atomized Scrubbers, Off-Gas Condenser, HEME, and the Melter Spout Jet. The effluent is recycled to the Quencher as the coolant, to the SASes as the scrubbing agent, and to the Melter Spout Jet as the motive fluid. The process heat absorbed by the circulating water is removed by a heat exchanger between the OGCT and the Quencher. Liquid effluent from the OGCT will be purged and sent to the Waste Water Pump Tank (WWPT).

6) Off-Gas Condensate Cooler

The Off-Gas Condensate Cooler is specific to the IDMS and is not included in the DWPF design. Its purpose is to maintain the temperature of the liquid in the OGCT at 40°C. The DWPF uses cooling coils in the OGCT to perform this function.

7) Steam Atomized Scrubbers

The two-stage Steam Atomized Scrubbers (SAS) remove submicron and micron-sized particulates from the melter off-gas. Recirculated condensate is directed into the wake region of an expanding supersonic steam jet, producing tiny water droplets which will contact and capture particles in the entering off-gas. These droplets are accelerated in the mixing tube where turbulence is sufficient to promote coalescence, but low enough so as not to cause significant re-entrainment of the liquid. The droplets are separated from the vapor in a cyclone separator. The SAS technology was developed and patented by the Lone Star Steel Company, which refers to the equipment as Hydro-Sonic Scrubbers.

The SAS units are protected from over-pressurization by means of a seal pot.

8) Off-Gas Condenser

The Off-Gas Condenser is a shell-and-tube heat exchanger that separates the condensibles from the off-gas stream and removes virtually all of the elemental mercury. The separated condensibles in the off-gas stream are drained to the Off-Gas Condensate Tank. The Condenser also condenses the steam from the SAS units, reducing the load on the exhauster. The cooling medium used is 25% ethylene glycol which is regulated to the condenser to maintain the off-gas at 10°C.

The off-gas enters at the top of the condenser and flows through 45 3/4-inch OD tubes. The tubes are each 84 inches long and are arranged on a one-inch triangular pitch. The effluent vapor and condensed gases exit at the bottom of the condenser through separate pipes. The vapor continues on to the Mist Eliminator and the condensibles are drained to the Off-Gas Condensate Tank. The cooling medium enters the shell side of the 10.75-inch OD shell and flows upward around 25 segmental baffles.

9) <u>Mist Eliminator</u>

The Mist Eliminator (ME) consists of a 10.7-inch diameter by 6-inch thick York demister with top and bottom grids. An atomized water spray wets the surface intermittently, similar to the HEME operation. The Mist Eliminator separates any suspended liquid droplets from non-condensible gases.

10) <u>High Efficiency Mist Eliminator</u>

The High Efficiency Mist Eliminator (HEME) consists of a densely-packed Fiberglas filter element wetted continuously with an atomized water spray. It traps particulates and flushes soluble materials to the condensate tank.

The IDMS HEME shares three basic characteristics with the DWPF HEME, including similar pad construction, face velocity, and liquid loading. It consists of one 24-inch diameter by 51-inch long filter element. The off-gas flows from the inside of the element to the outside. There is a coarse 0.5-inch layer of 30-micron glass fiber on the face followed by a 2.5-inch layer of fine 8-micron glass fiber packed at 11 lbs/ft^2. The latter layer has been shown to act as a prefilter and extend the life of the HEME filter.

The HEME element was designed to operate at a 5 fpm superficial face velocity. Air-atomized water is injected into the entering off-gas stream at a rate of 50 milligrams per actual cubic foot of off-gas. At 500 lb/hr of off-gas flow, the water flow is 0.08 gal/hr. The lowest available water spray nozzle flow is 0.36 gal/hr. Therefore an intermittent spray is used.

The IDMS HEME is protected from over-pressurization by means of a seal pot.

11) <u>Heater/High Efficiency Particulate Air Filter</u>

The Heater raises the off-gas temperature 10°C above its dew point. This prevents condensation which could cause a large pressure drop across the High Efficiency Particulate Air (HEPA) Filters. Two HEPA filters in parallel serve as the final treatment step before the off-gas is released to the environment via the stack. However, only one HEPA filter is valved in at a time. The filters remove the remaining submicron sized particles from the off-gas. The filter element area is 12 X 12 X 5.875 inches and houses an 0.008-inch thick, transparent PVC bag.

12) Exhauster

The Exhauster maintains a negative pressure throughout the Melter/Off-Gas System. It is a variable speed, positive-displacement device which draws the melter off-gas through the off-gas system. An isolation valve, connected to the OGCT-to-SAS line, is provided for exhauster restart protection during startup and switchover; mechanical damage will occur if the exhauster is operated with insufficient air flow. The exhauster speed is varied to control the pressure in the OGCT at about -6 inches of water. The two-lobe rotary exhauster, which is directly coupled to a 7.5-hP motor, discharges, at constant speed, a relatively constant volume of air under variable pressure conditions.

A steam jet vacuum pump is used as an emergency back-up to the blower. This unit has a 2.5-inch suction opening designed to handle a process load of 500 lb/hr while utilizing 52 lb/hr of steam. It ensures primary off-gas system operation in the event of blower failure for any reason.

13) Melter Seal Pot

The Melter Seal Pot protects the Melter from over-pressurization by means of 2-inch water seal. Any overflow from the seal pot goes to the WWPT, and the seal pot vents directly to the stack.

14) Melter Spout Jet

The Melter Spout Jet is used to initiate and control glass pouring by creating a vacuum in the pour spout relative to the melter plenum. It is an ejector-venturi gas scrubber with a 2-inch OD inlet and a 3-inch OD outlet. The motive fluid is recirculated condensate from the OGCT, which is maintained at 40°C. It is propelled through the venturi's nine 5/16-inch OD holes at a fixed rate of either 15 gpm for idle (non-pouring) conditions or 35 gpm for glass pouring. Vacuum control air is bleed into the vacuum line via 754PV to control the pressure to +3"wc in idle, and from -5 to -14"wc during glass pouring.

Bypass Off-Gas System

The Bypass System is intended to operate only when feed to the Melter is discontinued. It is used when the primary system is not operative. This auxiliary steam jet blower is unique to the IDMS and is not included in the DWPF design. This steam jet insures that a negative pressure is maintained in the Melter in the event that the Off-Gas System is out of service for any reason.

The unit has a 1.5-inch suction opening designed to handle a process load of 165 lb/hr while utilizing 58 lb/hr of steam.

Solids Recycle Filter System

The Solids Recycle Filter System, shown in Figure 11, is a set of four ultrafilter (UF) units designed to remove particulates and colloids from the combined wastewater of the IDMS. The system is located on the first level of Building 672-T. The purpose of the filter system is to reduce the volume of mercury-containing solid waste generated by the IDMS by recycling the solids to the SRAT/SME. It will also reduce the amount of spent ion exchange resin generated by wastewater treatment.

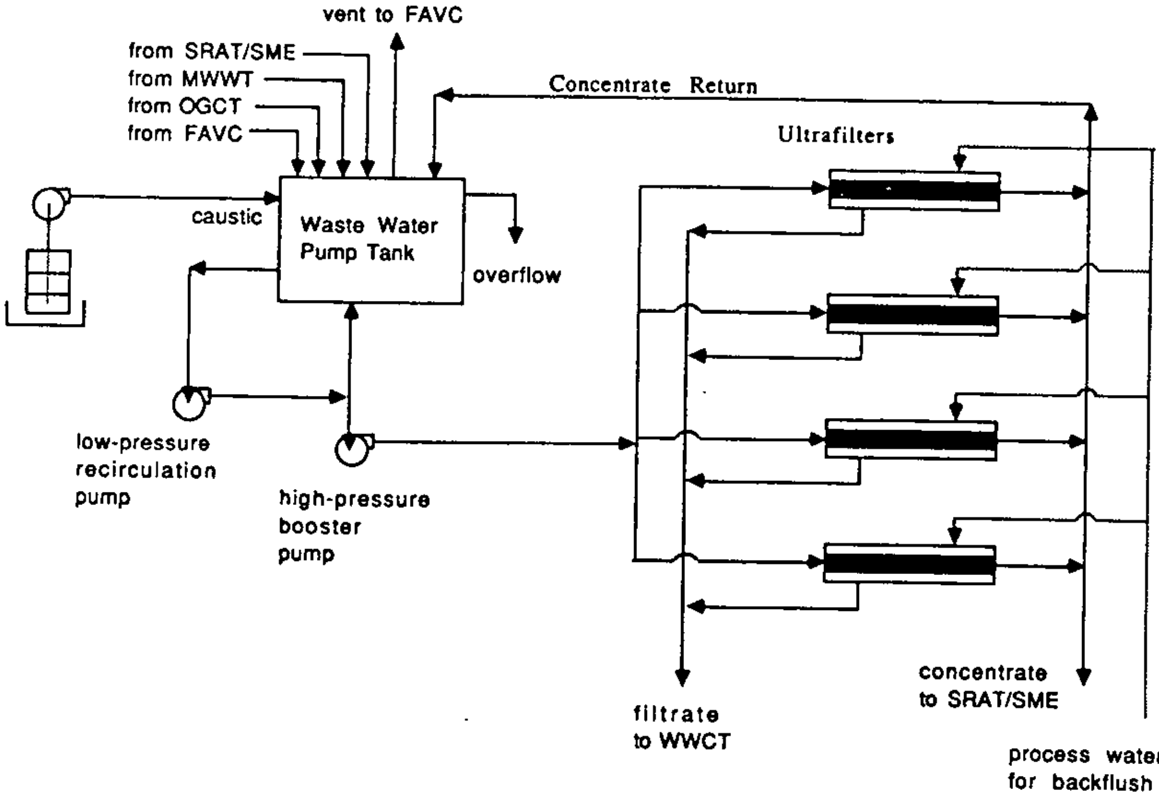


FIGURE 11. **Solids Recycle Filter System**

Wastewater is received in the Waste Water Pump Tank (WWPT) from the Mercury Water Wash Tank (MWWT), the Formic Acid Vent Condenser (FAVC), the Off-Gas Condensate Tank (OGCT), the Process Vessel Vent System (PVVS), and the off-gas stack (condensate from process and steam jets). The filter system is fed from the WWPT by two pumps. The first is a low-pressure pump which provides some agitation by recycling wastewater back to the WWPT. This pump also feeds a high-pressure booster pump, which provides the 700 psi differential pressure required for operation of the filters at their design rate of 3.6 gpm.

The filters consist of a membrane deposited on the interior of a sintered metal tube, which is contained within a high pressure shell. The solids are carried through the tubes with the main flow, while part of the wastewater passes through the membrane and tube wall to the area between the tubes and the shell. The solid-containing portion, called the concentrate, is then recycled to the WWPT, and is periodically transferred from the WWPT to the SRAT/SME. The portion of the wastewater that passes through the membrane, known as the filtrate or permeate, travels to the Waste Water Collection Tank (WWCT). From there it is sent to the TNX Ion Exchange Facility and the Organic Removal Facility.

The ultrafilters are made of stainless steel and could be corroded by an acid environment. The wastewater pH must therefore be adjusted to between 12 and 13 pH units to prevent corrosion of the ultrafilters. This pH adjustment also causes precipitation of additional compounds (including mercury), which further decreases the volume of hazardous solid waste to be disposed of in the liquid stream. Sodium hydroxide at is pumped from 55 gallon drums to the WWPT on an as-needed basis as wastewater is received in the WWPT.

The pH adjustment step is automatically controlled by the IDMS process control system. Other process parameters that are controlled through the control system include booster pump discharge pressure (1201PC), booster pump discharge flow rate (1202FC), and permeate flow rate (1203FC).

Components of the Solids Recycle Filter System include the following:

1) <u>Low-Pressure Pump</u>

The low-pressure pump provides agitation for the WWPT and feeds the high pressure pump. This pump is a Gould model 3196 "ST" self-priming centrifugal pump made of 316 stainless steel. Its performance characteristics curve is included as Appendix A.

2) <u>High-Pressure Booster Pump</u>

The high-pressure pump provides the 700 psi differential pressure required to operate the ultrafilters at their design rate of near 4 gpm. The pump used for this application is a Hydra-Cell model D25SS16 positive displacement diaphragm pump. Its pumping head is made up of 316 SS and the diaphragm of Viton. The pump is driven by a 10-hP motor. Its performance characteristics curve is included as Appendix B.

3) <u>Caustic Transfer Pump</u>

The caustic transfer pump (actually two parallel pumps) delivers the caustic from a 55 gallon drum to the WWPT. The pumps used for this application are Zenith submersible metering pumps IBMP size C. The pumps are made of 316 SS.

4) Ultrafilters

Two of the four ultrafilter units will be operated simultaneously to meet the predicted process demand. The other two units will serve as back-ups. The dimensions of the filter units are given in Appendix C. Each unit consists of two separate bundles of sintered metal tubes, each tube coated with a ZrO_2 membrane. The two bundles are connected externally. All connections (feeding, connection of the bundles, concentrate outlet, and filtrate outlet) are on one end of each pressure vessel.

Each unit holds a total of 13 square feet of surface area for filtration. The surface can accommodate 100 to 150 gals/ft^2/day at 700 psi, or 0.9 gpm per unit. This gives a total capacity of 3.6 gpm for the four filters, exceeding the process requirement.

Sampling System

Off-Gas Composition Measurements

In order to perform material balances on the IDMS system, it is necessary to determine the composition of the off-gas streams (PVVS and melter off-gas). Table 1 shows the on-line analyzers installed in the IDMS system. Some of the analyzers can be connected to several different points in the off-gas system, as shown in Figures 12 and 13.

The Feed Preparation System has three process gas analyzers connected to the Process Vessel Vent System (PVVS) which are used for process control and process safety in addition to general process monitoring.

A Siemens Oxymat 5F oxygen analyzer, equipped with a Combustion Engineering sample system, is connected to the PVVS between the SRAT Condenser and the nitrogen addition point. A second identical oxygen analyzer is located in the PVVS after the FAVC.

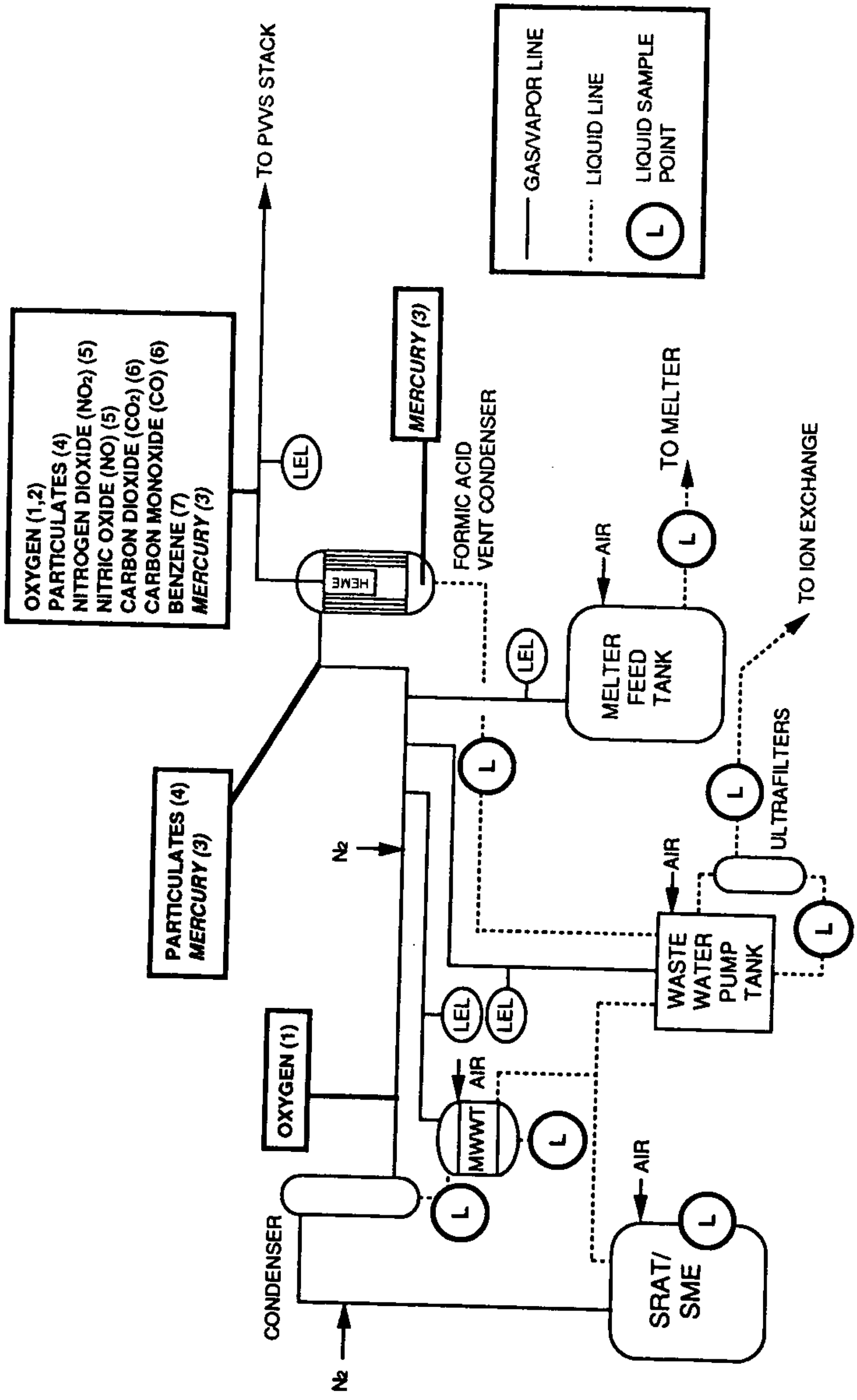
During PHA addition, the oxygen content of the PVVS must be maintained below 8 volume % (70% of the MOC). Nitrogen is introduced both before and after the SRAT Condenser to achieve this. The oxygen analyzers monitor the performance of the nitrogen dilution system. If the oxygen content at either location exceeds 8%, the PHA feed and refluxing are stopped by an interlock. PHA feeding and refluxing will also be stopped under the following conditions:

1. Low sample flow to either analyzer
2. Analyzer power failure
3. Analyzer failure

A Combustion Engineering Model 501B benzene analyzer is connected to the PVVS after the FAVC. This analyzer measures benzene from 0-5% (volume). The remaining analyzers are used strictly for research purposes.

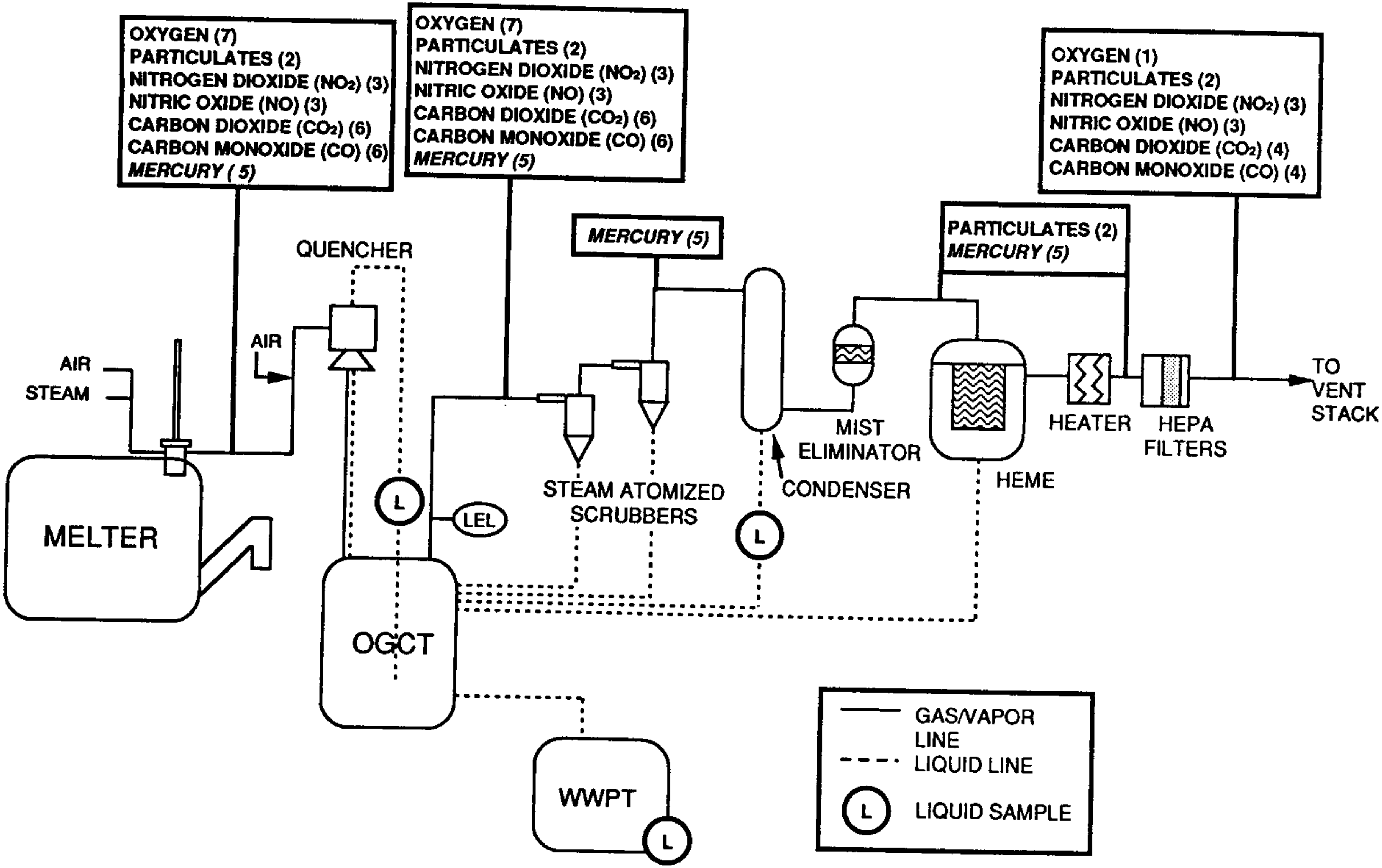
TABLE 1. IDMS On-Line Analyzers

Component Measured	Analyzer	Location(s)	Expected Concentration	Analyzer Full-Scale Full-Scale Range
Oxygen 100%	Siemens Oxymat 5F	SRAT Condenser Outlet	0-21% (formic add'n, boilup) 0-8% (PHA add'n)	variable, up to
100%	Siemens Oxymat 5F	FAVC Outlet	0-21% (formic add'n, boilup) 0-8% (PHA add'n)	variable, up to
	Infrared Industries 2100 and 2200	FAVC Outlet	0-21% (formic add'n, boilup) 0-8% (PHA add'n)	25%
		HEPA Outlet	19-21%	25%
100%	Siemens Oxymat 5E	Melter Off-Gas after Film Cooler OGCT to SAS	0-21% diluted to 0-2% with dry N_2 by dilution probe	variable, up to
CO_2	Infrared Industries 7712 and 7742	FAVC Outlet	0-20% (formic add'n, boilup)	0-6% (7712); 0-20% (7742)
		HEPA Outlet	0-2%	
	Siemens Ultramat 22P	Melter Outlet; OGCT to SAS	0-2% diluted to 0-100 ppm by dry N_2	
CO	Infrared Industries 7712 and 7742	FAVC Outlet	<100 ppm	0-2000 ppm
		HEPA Outlet	0-1800 ppm	
NO	Monitor Labs 8840	FAVC Outlet	0-2% diluted to 30 ppm with dry N_2 by dilution probe and add'l dilution system	0-5000 ppm
		Melter Outlet; OGCT to SAS	0-1000 ppm diluted to 50 ppm with dry N_2 by dilution probe	
		HEPA Outlet	0-500 ppm	
NO_2	Monitor Labs 8840	FAVC Outlet	0-13% diluted to 175 ppm with dry N_2 by dilution probe and add'l dilution system	0-≈200 ppm
		Melter Outlet; OGCT to SAS	0-500 ppm diluted to 25 ppm with dry N_2 by dilution probe	
		HEPA Outlet	0-250 ppm	
benzene	Combustion Engr 501	FAVC Outlet	0-1%	0-5%



1. by paramagnetism (Siemens Oxymat 5F)
2. by electrochemical method (IR Industries 2100 or 2200)
3. *by UV absorbance (future)*
4. by modified EPA method 5 procedure
5. by chemiluminescence (Monitor Labs 8840)
6. by IR absorbance (IR Industries 7712 or 7742)
7. by IR absorbance (Combustion Engr.)

FIGURE 12. Feed Preparation Analyzer Points



1. by electrochemical method (IR Industries 2100 or 2200)
2. by modified EPA Method 5 procedure
3. by chemiluminescence (Monitor Labs 8840)
4. by infrared absorbance (IR Industries 7712 or 7742)
5. *by UV absorbance (future)*
6. by IR absorption (Siemens Ultramat 22)
7. by paramagnetism (Siemens Oxymat 5E)

FIGURE 13. Melter Off-Gas Analyzer Points

Oxygen in the SRAT/SME off-gas can also be measured by the Siemens the IR Industries 2100 or 2200. During PHA addition, the two IR Industries analyzers can be used to check the Siemens analyzer readings, if desired. During formic acid addition, the Siemens analyzer cannot be used directly, due to interference from NO and NO_2. However, NO and NO_2 do not affect the performance of the IR Industries analyzers. During boiling or concentration, when no NO or NO_2 are produced, any of the three oxygen analyzers can be used.

Nitrogen oxides is measured by the NO_x analyzer only up to 5000 ppm for NO and 200 ppm for NO_2. The concentration of NO + NO_2 during formic acid addition may reach 10-15%. Hence, an extractive dilution system has been installed to dilute the off-gas sample to the NO_x analyzer. The sample is diluted with dry nitrogen by a factor of ≈225:1. This dilution will be adequate only if the NO2 concentration does not exceed 4.5%. If it does, an additional dilution system consisting of several needle valves and rotometers is available to dilute the sample by an additional factor of 10:1. The actual concentrations of NO and NO_2 can be calculated from the measured values and the dilution ratios. The dilution ratios are determined during the calibration procedure.

Carbon dioxide is measured by an IR Industries 7742 or 7712 CO/CO_2 analyzer. The expected concentration of CO_2 in the off-gas during formic acid addition is about 15-20%. Although no formation of CO is expected, it can be monitored in the range 0-2000 ppm by the IR Industries analyzers.

In order to perform a material balance on the melter system, it is necessary to determine the composition of the off-gas exiting the melter. In order to achieve this objective, the melter off-gas is sampled and analyzed at the melter outlet, the Off-Gas Condensate Tank (OGCT) outlet, and the High Efficiency Particulate Air (HEPA) filter outlet.

Due to the high particulate and water content of the melter off-gas, a special system was devised to perform measurements on this sample stream. A dilution probe which dilutes the off-gas sample with dry nitrogen by a 20:1 ratio is used. The dilution probe is designed to handle high particulate loads without plugging. Dilution by a factor of 20:1 with nitrogen also reduces the water content of the sample below the dew point (for off-gas concentrations up to 50% water). In addition, dilution reduces corrosiveness of the off-gas sample.

The expected concentrations of gases in the off-gas, both before and after dilution, are:

	Before Dilution	After Dilution
CO	1500 ppm	75 ppm
CO_2	2%	1000 ppm
NO	1000 ppm	50 ppm
NO_2	100 ppm	5 ppm
O_2	21%	1%

The Siemens Ultramat 22 CO/CO_2 analyzer will be used to measure CO and CO_2 in this sample stream. The NO and NO_2 will be measured with the NO_x analyzer, set on one of its lower ranges (e.g., 50 ppm). Oxygen will be measured in this sample stream using the Siemens Oxymat 5E analyzer. With the diluted concentration values and the dilution factors determined during calibration, the actual off-gas concentrations are determined.

1) OGCT Outlet

This sample point is equipped with the identical sample probe as the melter outlet sample point, and is connected to the same analyzers.

2) HEPA Filter Outlet

At this point in the off-gas system, the amount of particulates and water is minimal, so direct measurement of the CO, CO_2, NO, NO_2, and O_2 concentrations can be made. The analyzers used to make these measurements are noted in Table 1.

Comparisons of data from the melter outlet and OGCT outlet can be used to determine the efficiency of scrubbing CO, CO_2, NO, and NO_2 in the Quencher. The oxygen readings at these same two points, combined with measured purge flows (e.g., control air) can be used to determine the air inleakage rate into the off-gas system between the sample points. Similarly, the HEPA filter outlet measurements can be used to determine the air inleakage rate after the OGCT and also the effect of the SASes on scrubbing CO, CO_2, and NO_x.

3) Mercury Analyzer

In the future, a mercury vapor analyzer will be procured and installed in the IDMS system to analyze for mercury at the seven locations indicated in Figures 12 and 13.

Liquid Sampling

Liquid sampling points in the IDMS System are indicated in Figures 12 and 13.

EQUIPMENT CHECKOUTS

Summary

The IDMS equipment checkout was done over a period of approximately 8 months. Appendix D shows the IDMS checkout/commissioning schedule that was used during this time frame. DWPT engineers were given oversight responsibility for one or more of the systems. Daily morning meetings, which included DWPT, TOD, Construction, Projects, and Works Engineering representatives, were held to track the progress of the installation/checkout. Procedures were written by TOD and reviewed by DWPT. The following sections give more detailed information on selected topics.

Melter

Checkout of the IDMS Melter was done per Job Plan 672T-88-7-2[2]. For future reference, Appendix E gives a chronological overview of the checkout.

Process Control System

System Description

The IDMS uses a Modicon 984 Programmable Logic Controller (PLC) to control all of the facility's processes. The Modicon control logic is accessed via Gould software through IBM XT and IBM AT personal computers located in the IDMS control room in Building 672-T. The IDMS facility uses a Metra operator interface to display the processes and updated process variables. The Metra system has been programmed to display approximately 40 graphics pages, including IDMS processes and the Ion Exchange facility. Most all process operation can be completed via the Metra keyboard, (e.g., the remote actuation of control valves, starting/stopping an agitator, etc.). In a few cases, process operation may not be done via the Metra system (e.g., some pumps must be started in the field). The Metra system displays programmed messages to the control room operator explaining the status of the operating system (e.g., equipment failure, interlock shutdown of a process, etc.). All system alarms are displayed to and acknowledged by the control room operator through the Metra system.

Improvements Made to Metra Interface System

Because of the high number of system input/output (I/O) and process alarms to the Metra system, the scan time (the time lapse between information transfer from the Metra system and the Modicon PLC) was initially as high as fifteen seconds. The Metra system is programmed via a variable list which details the I/O from the Modicon PLC. The variable list is broken into blocks of variables. These blocks may be as large as 128 for discrete input and 125 for numerical (decimal) information input. These blocks may also be as small as one; however the speed at which the Metra system reads these blocks is the same for a block of one as for a block of 128. A variable list which maximizes the number of large blocks and minimizes the number of small blocks is therefore a faster, more efficient program.

The first phase at lowering the interface scan time was to consolidate all small blocks into a few large blocks. After combining the many small, inefficient blocks and making large, very efficient variable blocks, the scan time dropped from a maximum of fifteen seconds to a maximum of eight seconds.

The next phase at lowering the scan time consisted of reprogramming the method of reading the process alarms. Initially, all alarm levels (e.g., high, high-high, low, low-low, etc.) and alarm numerical limits were stored in and calculated by the Metra system. This forced the Metra system to do several hundred mathematical calculations per scan, thus slowing the system scan time. All alarm calculations were transferred to the Modicon PLC. The Modicon is a much larger and faster computer and is not slowed noticeably by this transfer of math. The Modicon now calculates whether or not the variable is in alarm and then sends discrete information (alarm ON/alarm OFF) to the Metra system. This programming modification cut an additional three seconds from the scan time. The Metra variables may be prioritized so that they may be scanned with each Metra/Modicon communication (e.g., the system alarms) or only when the variable is displayed on the current graphics page. On the "busiest", and hence the slowest, graphics page, the scan time is now reduced to approximately five seconds. On the fastest graphics page, the scan time is now approximately two seconds.

Another enhancement to the Metra interface system was the creation of INTERLOCK SUMMARY graphics pages. These pages list selected processes and summarize all interlocks which may prevent the control room operator from running that process. All interlocks which are in a permissive state are listed as green. Conversely, if an interlock is in a non-permissive state (i.e., preventing the operation of a process), it is listed as red. These graphics pages give the control room operator a quick reference as to what may be preventing the operation of desired processes.

Control Loop Tuning

The IDMS facility has thirty-eight control loops. These control loops are Proportional-Integral-Derivative (PID) software blocks built into the Modicon PLC process logic. They control selected pressures, temperatures, flows, and levels in the IDMS facility. Some loop tuning (the determination of the PID controller parameters) was done during the system check-outs prior to the water runs, while some loops required actual operation for proper tuning.

All control loop tuning was done with the Protuner™ 1200PC. The Protuner™ 1200PC is an IBM-compatible hardware/software tool designed to automate the time-consuming trial-and-error methods commonly used to tune PID controllers. The Protuner™ 1200PC used to tune the IDMS facility control loops is an interface board within a Toshiba laptop computer. This use of the hardware/software makes the Protuner™ very mobile and thus suitable for process area applications.

IDMS Power Supplies

All of the power supplies for the IDMS melter heaters were load-tested (full kW power) at the vendor's shop (Spang, Inc.) in Sandy Lake, PA. These tests were conducted by the Wilmington design engineer with SRP Construction, TNX Projects, DWPT, and Du Pont QA personnel in attendance. These operability tests included remote and local input control signals as well as signals from output transducers to the control room for the power supply variables. The hardwire interlocks were also checked for operability.

Several safety concerns were found and recommendations were made accordingly to Wilmington design. One recommendation was to place shields over exposed terminals supplied with more than 50 volts. Other suggestions included moving the calibrating terminals for the electrodes to a more convenient place and moving several of the power disconnect locations on the power supply cabinets.

The power supplies were shipped to SRP Construction, who installed them in the Electrical Control Room (ECR) in Building 672-T. Then Construction electrically wired the power cables from the heaters to each power supply, the input control signals from the Instrument Control Room (ICR), the process variables signal from the power supply to the ICR, and any control power needed.

After the installation of the power supplies was completed, TNX Operations and Technical personnel checked all wiring, fuses, electrical disconnects, and disconnect heaters for correct hookup. These connections and power supply parts were checked against Wilmington prints. Any errors or loose wires were corrected. Other items checked were the proper phasing of the electrodes, the cooling air and water to the electrodes, and water-cooled lines carrying current to the electrodes.

Meg-Ohm Testing

After installation of the lid heater transformers, they were megger tested before cooling water was introduced to the system. The readings were 55 MΩ for Lid Heater Transformer #1 and 100 MΩ for Lid Heater Transformer #2 with a megger setting of 500 V DC on the primary side of the transformer.

Before energizing Lid Heaters #1 and #2, megger tests from the power supply cabinets (SCR's) to the lid heater transformers were performed. These tests revealed approximately 75 kΩ resistance to ground (with cooling water circulating). These low megger readings were then investigated. For Lid Heater #1, the reading was 75 kΩ, and for Lid Heater #2 the reading was 70 kΩ.

Next, the cooling water was turned off, but the hoses connecting the lid heater transformers to the cooling lines were left in place. Both transformers gave readings of 300 kΩ.
The next step was disconnecting the hoses from the lid heater

transformers and flushing the transformers with process water. After 30 minutes of flushing, the megger readings for Lid Heater #1 and Lid Heater #2 went to 900 kΩ and 1000 kΩ, respectively. Flushing continued overnight and megger readings were taken again and the results are in Table 2.

TABLE 2. **Lid Heater #1 Megger Results After Flushing**

Water hoses disconnected	200 MΩ
Water hoses connected, no water	35 MΩ
Water hoses connected, water circulating	0.07 MΩ

Due to the fact that the resistance readings were low and the cooling water looked dirty, the water quality (conductivity in mhos) was further investigated. Results are given in Table 3.

TABLE 3. **TNX Water Conductivity/pH**

	Conductivity (μmhos)	pH
Process water (used for flushing)	80	N/A
Cooling water (tower) 9/29/88	280	7.7
Cooling water (tower) 10/3/88	500	>8
Cooling water (tower) 10/10/88	240	7.6

With the above resistance and water quality information, the vendor of the lid heater transformers, Tech Tran Corporation, was contacted. The technical representative pointed out that the nature of the design of this transformer's primary coil consists of round copper tubing directly connected to the cooling water supply. The secondary coil consists of square copper tubing, which is also used for cooling (cooling water flows into the primary side of the primary coil of the transformer, then through a hose into the primary side of the secondary coil, and finally back to the cooling tower). Therefore high megger readings as seen on dry type or oil-filled transformers cannot be expected; i.e., these lower readings are not out of the ordinary.

With the conductivity at 240 μmhos, the megger reading was 95-100 kΩ with the megger setting at 1000 VDC. Power was turned on and voltage to ground was checked by connecting a voltmeter from the copper cooling tubing to ground. Results are given in Tables 4 and 5. The low volts to ground readings showed that the lid heaters were safe to operate at their normal operating voltages.

TABLE 4. Lid Heater #1 Voltage to Ground

Lid heater #1 (primary volts)	Volts to Ground
50 V	0.025 V
100 V	0.025 V
150 V	0.025 V
200 V	0.620 V
300 V	1.600 V

The megger reading after "heat-up" for Lid Heater Transformer #1 was 110 kΩ.

TABLE 5. Lid Heater #2 Voltage to Ground

Lid heater #2 (primary volts)	Volts to Ground
100 V	.015 V
200 V	.017 V
300 V	.021 V
360 V	.066 V
375 V	.079 V

The megger reading after "heat-up" for Lid Heater Transformer #2 was 190 kΩ. The water conductivity was 194 µmhos at a pH of 7.6.

RECOMMENDATION #1 - Low megger values on the lid heaters may be due to the configuration of their transformers. Voltage to ground checks with operating voltage applied to the lid heaters can be used to determine if the lid heaters are safe to operate.

The cables for the pour spout heater, riser heater, and three dump valve heaters were megger tested at 500 V DC. No problems were found during these tests. A type "Megger"-BM10 instrument was used for all the tests. Transformer taps H0 and H4 were used for all the above heaters. Primary and secondary megger readings are given for each of the heaters in Table 6.

TABLE 6. **Resistance Heater Megger Tests**

Heater	Primary Megger Reading (MΩ)	Secondary Megger Reading (MΩ)
Pour Spout	1000	500
Riser	1000	500
Dump Valve Zone #1	1000	1000
Dump Valve Zone #2	1000	>100
Dump Valve Zone #3	1000	1000

Initial megohm tests on the electrodes showed that all the electrode-ground megohm values were in the 100 to 500kΩ range. Moisture in the melter was the most feasible reason for these lower resistance values. The lid heaters were energized in August of 1988 to achieve a vapor space temperature above 100°C for approximately one day to evaporate some of this water out of the melter. The megger values on the upper electrodes did increase to 2MΩ, while the bottom electrodes remained unchanged. The increase in the upper electrode values supported that water was indeed the problem. Because the rest of the water in the melter would be vaporized during the startup of the melter, it was decided that the lower megger values first seen would not be a problem.

RECOMMENDATION #2 - Low megger values on the electrodes may be due to moisture in the melter, and the melter should then be dried out to determine if the values increase, thereby indicating an initial moisture problem. This water does not pose a problem, as it will be vaporized out of the melter during the heatup of the melter.

Power Supply Operability Testing

This checkout included the three dump valve power supplies, the riser heater power supply, the pour spout heater power supply, and the lid heater and electrode power supplies. All cabinet meters that monitor the power supply variables or are used as hardwired interlocks and transducers which send signals to the Modicon were checked for operability, as was the ability to start, stop, and control in both Local and Remote control modes.

Each power supply was turned on in the Local Control mode and powered up to the calculated operating level set by the design engineer. The supplies were maintained at these levels and the accuracy of the power supply's voltmeter, ampmeter, and wattmeter were checked. Any adjustments that were needed or problems that were noted would have been corrected after the checkout of all of the power supplies. No major problems were found.

The electrode power supplies could not be powered up using the electrodes without glass in the melter, since glass is required to complete the circuit. The electrode power supplies were connected to the primary side of the lid heater transformer, which allowed the electrode power supply to be tested using the lid heaters as the load. This calibration was completed using less than 25% of the calculated power needed for each supply.

A full calibration of each power supply was completed after the melter startup.

IDMS Instrument Checkouts

Prior to any instrument being checkout, loop sheets for each instrument loop were drawn. These loop sheets were then divided into instrument types, and instrument calibration procedures with tables for QA data were written and approved for every instrument in the IDMS facility.

The first item to be checked before instrument calibration could be started was the Modicon. When power was initially applied to the field instruments, the Modicon went into a failure mode. This failure came about as a result of many improper field grounds, primarily due to improper installation of the instrument cable shield. Several shorts of instrument wiring were also found in the field. This situation was corrected by disconnecting each instrument at the Modicon cabinet and checking each loop to make sure it was clear. Several wires had not been removed when the simulator used for training was disconnected. When these wires were removed, the Modicon failure problem cleared.

After the above problems had been solved, the instrument checkout began. All instruments were checked for operability, and were calibrated using equipment that were traceable to the National Bureau of Standards. These calibrations were documented, and a label was placed on each instrument as it was completed. These labels indicated the instrument number, the calibration date, and the date by which the next calibration should be performed. All electrical loops such as motor starters were checked for correct wiring, heater and fuse size, and operability.

Tank Calibrations

Tank level transmitters were calibrated per TNX Job Plan 672T-88-1-1. Results of the calibrations are plotted in Appendix F.

Holledge Gauges

The Holledge gages were selected for use in DWPF liquid level measurement applications. Because the IDMS LEVEL measurement system is prototypic of DWPF, it was decided to use the same kind of probes in the SRAT/SME and Melter Feed Tanks of IDMS. The SRAT and MFT tank probes are 96.375 and 83.5 inches long respectively. During the first run these probes were not used because the sensors had been damaged during fabrication. The probes must be calibrated as a function of temperature, as results of earlier tests indicated that the Holledge gauge pressure readings increase with temperature.

Late in 1987 a Liquid Level Task Team recommended that the Holledge liquid level probe design be modified. The modification increased spacing between the Holledge Gages in the probe to a minimum of 30 inches. However, if the IDMS SRAT probe sensor spacing is 30 inches, then the probe would not be able to measure the liquid level over the entire range of the tank. The same holds true for the MFT probe as well. Therefore it was decided to keep the sensors at 10" for both the probes.

The SRAT/SME and MFT Holledge gauges have been retrofitted with new hastelloy and stainless steel sensors respectively. Calibration tests were conducted in a temperature controlled calibration facility located in building 672-T. Five tests were conducted for the SRAT probe to evaluate the consistency of the data and one test was conducted for the MFT probe. All tests were conducted in the temperature range of 30°C to 100°C.

Because the existing calibration stand uses a 3" flange, a 4" flange spool piece was made to fit the IDMS level probes. The distance from the top of the spool piece (6" long) flange to the top of the overflow is 18 inches. Approximately 20 inches of the total calibration length is not considered as available calibration length due to the expansion of water as the temperature increases. The length of the SRAT probe is 96.375 inches. The actual calibration length available (bottom sensor) for the SRAT and MFT probes equals 58.375 and 46.5 inches respectively.

PB-15 transmitters are used for the SRAT/SME Holledge gauge. All wetted (external) and internal parts are Hastelloy. The maximum pressure rating is 300"wc, and the thickness of the diaphragm is 0.003". PB-15 transmitters have been irradiated to 10^8 R by submerging them in a cobalt pit. It has been determined that they will last at least two years in a radioactive environment. All radiation tests are documented in laboratory notebook E43303.

PB-35 transmitters are used for the Melter Feed tank Holledge gauge. All external parts of this transmitter are Hastelloy, while all the internal parts are 316 stainless steel. The maximum pressure rating is 150 psi, and the thickness of the diaphragm is 0.0042". These transmitters have not been irradiated.

Model

The Hydrostatic equation is the only model that will be used:

$$P_1 = \rho(g/g_c)\ h_1 + P_0$$

Where:

P_1 = The pressure at some point in the tank
ρ = The density of fluid in the tank
g = The acceleration due to gravity
g_c = The conversion factor from mass to force
h_1 = The height of fluid above the point in the tank
P_0 = The pressure above the fluid in the tank

This is the basic equation that is used to correct for the difference between the calibration stand zero level and the zero level of the each Holledge gauge. It is also used to predict the ideal response of each Holledge gauge.

The density and level can be derived as follows for Holledge gauge having two pressure transmitters 10 inches apart (see Figure 14 for schematic of setup).

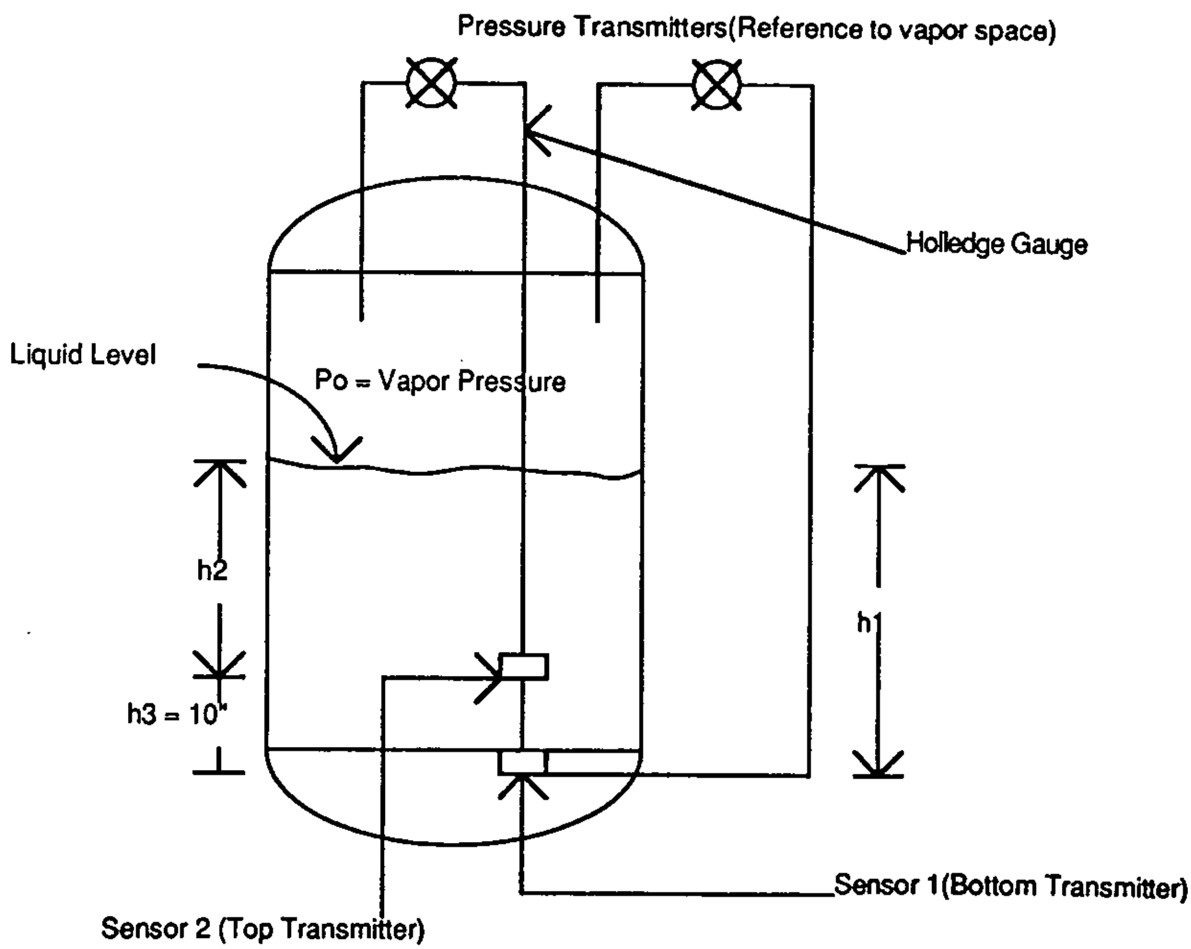


FIGURE 14. Schematic of Holledge Gauge Setup

Pressure at the bottom transmitter (#1) can be written as

$P_1 = \rho\ (g/g_c)\ h_1 + P_0$

$P_1 - P_0 = \rho\ (g\ /g_c)\ h_1$

delta $P_1 = \rho\ (g\ /g_c)\ h_1$

h_1 = (delta P_1/ρ) (g_c/g)-------------------------------(1)

Pressure at the top transmitter (# 2) can be written as

$P_2 = \rho\ (g/g_c)\ h_2 + P_0$

$P_2 - P_0 = \rho\ (g/g_c)\ h_2$

delta $P_2 = \rho\ (g/g_c)\ h_2$--------------------------------(2)

The distance between two transmitters is 10"(h_3 = 10").

h_2 can then be written as follows:

$h_2 = h_1 - h_3$

Substituting for h_2 and h_1 in equation (2) gives

ρ = delta P_1 - delta P_2/ h_3

$\rho = P_1 - P_0 - P_2 + P_0$ /10"

ρ = (delta P1- deltaP2)/10"--------------------------(3)

Substituting equation 3 in 1 gives the following:

h1= [delta P1(10)]/[delta P1- delta P2]

Discussion of Calibration Results

The Temperature Controlled Calibration stand located in 672-T building was used to collect data over the temperature range of 30 to 100°C. The complete description of calibration stand and data acquisition system is documented in WSRC-RP-89-779. SRAT and MFT probes were tested four to five times with the Holledge gauge referenced to the vapor space pressure inside the calibration vessel. The calibration stand holds the temperature constant while it systematically increases the liquid level from the bottom of the probe to the top of the calibration vessel.

The programs used to compile and transfer the data in to a readable form are documented in a registered laboratory notebook E58063.

The measurement listed below are recorded on floppy disk by the calibration stand:

1. TT2 - Water inlet temperature(^oC)
2. LT4 - Liquid level in the calibration vessel(inches of water column)
3. TT9 - Water outlet temperature (^oC)
4. PT10 - Vessel vapor space pressure (inches of water columns)
5. HG1 - Holledge gauge 1 (inches of water column)
6. HG2 - Holledge gauge 2 (inches of water column)

During a level probe calibration , 15 data points at each temperature and liquid level are recorded. This data is transferred to a Macintosh Excel spread sheet where the calculations are performed. After the data is evaluated in EXCEL, it is transferred to STATVIEW 512 + for graphic representation.

The following curves are generated for each probe and are documented in appendix G.

1) HG1 vs L1 @30^oC to 100 ^oC (SRAT bottom transmitter)
2) HG2 vs L2 @30^oC to 100 ^oC (SRAT top transmitter)
3) L1 vs ER1 @30^oC to 100 ^oC (SRAT bottom transmitter)
4) L2 vs ER2 @30^oC to 100 ^oC (SRAT top transmitter)
5) HG1 vs L1 @30^oC to 100 ^oC (MFT bottom transmitter)
6) HG2 vs L2 @30^oC to 100 ^oC (MFT top transmitter)
7) L1 vs ER1 @30^oC to 100 ^oC (MFT bottom transmitter)
8) L2 vs ER2 @30^oC to 100 ^oC (MFT top transmitter)

The graphs were generated from raw data documented in registered laboratory notebook E51787. Variables L2, ER1, and ER2 were computed as follows:

L2 = L1 - (density correction @ different temperature for water x 10")
Where distance between two transmitters = 10"

ER1 = HG1 - L1
ER2 = HG2 - L2

When the data were plotted for HG1 vs. L1 and HG2 vs. L2 @ 30 to 100^oC, it was found that computed curve fit equation did not fit well above 70 inches of probe length. Therefore it was decided to separate the curve into a non-linear and a linear region.

The separate curve fit equations were generated to satisfy consistency of data at all levels. It was later realized that the IDMS Modicon had no capability to perform floating point mathematics because necessary software and hardware are not installed in the system. Therefore the curve fit equations and the IDMS Modicon were not utilized as intended.

Meanwhile, it was decided to use "Data Desk Professional" software to do a multiple regression and generate one three dimensional equation. However, these surface equations introduce too much error to accurately calculate liquid level and specific gravity. After discussing the options available, it was decided

1) To write a FORTRAN program which calculates level and specific gravity by using a 'SPLINE' fit algorithm using the model described earlier and to use the data previously collected during the calibration,

2) To store variables in the VANTAGE database, and

3) To write a new IDMS VANTAGE scanner to send these variables to the Modicon memory.

The system was tested for the SRAT/SME probe after completing all the software modifications mentioned above. During the testing of the system, a jump of 10 to 14% in the liquid level reading was observed. The jump was mainly attributed to a lesser degree of accuracy of the Modicon analog to digital conversion card(jump in address register was found to be 27 to 35 counts). The resolution of the analog to digital card was also suspected to be inadequate because of geometry of IDMS Holledge Gauges. The geometry problem could be caused because agitation creates vortexes and turbulence in the water that will create fluctuation in the pressure, and because separation between the two transmitters is only 10".

Even after introducing the dampening time constant of 32 seconds on both the transmitters, it was very hard to stabilize the signal to give a reasonable accuracy. It was decided to install a Hewlett-Packard Data Acquisition System as a front end device to resolve this random noise in the analog to digital card.

Data Acquisition System

The data acquisition system is comprised of an HP87A microprocessor and an HP3497A data acquisition controller. The system was installed in March of 1989. The HP3497A collects data from field transmitters and forwards this data to the HP87A for processing. Field inputs from the tank temperatures and the liquid level probes are monitored. Using this collected data as well as calibration data for each of the Holledge gauges, the level probe readings are corrected for pressure and temperature.

The Holledge gauge readings are corrected by comparing the measured pressure value to the calibration data collected in the temperature controlled calibration stand. These corrected hydrostatic pressures are used to calculate the density and level of the fluid in the vessels. The equations for both density and level are described in the model. A BASIC program was written to calculate the density and level by using a 'SPLINE ' fit algorithm, the hydrostatic pressure model, and the data collected in the calibration stand. This program was used in the HP micro processor and is documented in the laboratory book E58063. The jump in liquid level went down to less than 1% after installation of Data Acquisition System.

BASIC OPERATING PARAMETERS

Feed Preparation System - Heat Transfer Coefficients

The Feed Preparation system contains three heat exchangers: 1) the SRAT/SME Condenser, 2) the steam heating coil in the SRAT/SME, and 3) the cooling coil in the SRAT/SME. The Heat Transfer Coefficients (HTC's) will be used to monitor equipment fouling and performance during the life of the IDMS facility. The method of calculation of the HTC's is detailed in Laboratory notebook No. E 58052 (DPSTN-4715). During water boil runs these Heat Transfer Coefficients were calculated assuming clean tubes/coils. These HTC's are shown in Table 7.

TABLE 7. **Feed Preparation Heat Transfer Coefficients**

Heat Exchanger	Heat Transfer Coefficient (BTU/hr-ft^2-°F)
1. SRAT/SME condenser	175.25*
2. SRAT steam coil	112.66 (@ boiling)
3. SRAT cooling coil	146.96 (@ 102°C)

* The data used was taken on the SRAT/SME condenser with stainless steel tubes. The tubes have since been replaced with Hastelloy C-276 tubes of the same area.

Feed Preparation System - Decontamination Factors

Particulate sampling was performed at the FAVC inlet and FAVC outlet of the Feed Preparation System during the water runs. Decontamination factors defined for the Feed Preparation System are:

$$\text{SRAT/SME DF} = \frac{\text{Solids in SRAT/SME}}{\text{Solids in SRAT condenser condensate}}$$

$$\text{SRAT condenser DF} = \frac{\text{Solids in SRAT condenser condensate}}{\text{Solids at FAVC Inlet (particulates)}}$$

$$\text{FAVC DF} = \frac{\text{Solids at FAVC Inlet}}{\text{Solids at FAVC Outlet}}$$

The "solids" can be either total solids as measured by weighing or the weights of individual elements. Sodium, manganese, calcium and aluminum were measured by Neutron Activation Analysis.

The SRAT/SME and SRAT condenser DF values could not be determined during the water runs because the condensate flow transmitter was inoperable. FAVC DF values determined from four filter paper samples at each location are 1.1 (for sodium), 1.2 (manganese), 1.4 (calcium), 3.6 (aluminum), and 4.0 (total solids).

Some of the data necessary to determine DF values for the sludge runs is not yet available. It should be possible to determine all of the DF values for the Feed Preparation System; this data will be reported in a later report. The particulate sampling equipment was not yet installed in the Melter Off-Gas system, so no DF values for this system can be determined for the water or sludge-only runs.

Process Vessel Vent System

During the water runs, the operating curves for the Process Vessel Vent System (PVVS) were developed. The test was performed by valving each vessel (*ie.* SRAT/SME, MWWT, WWPT, and MFT) into the system one at a time. The vessel pressure was recorded using the local gauge on each vessel. The vessel air bleed was recorded using a local flow meter and the total system flow was recorded using 214 FT (*ie.* the ΔP across the orifice plate was recorded as 214 PG). The PVVS blower speed was varied to produce a range of vacuum from 0 to -20 inwc in each vessel. The vessel air inleakage was then calculated as the difference between the total system flow and the vessel air bleed flow. Appendix H details the calculation methods used.

SRAT/SME

Table 8 shows the operating conditions and air inleakage data used to develop the operating curve of the SRAT/SME vessel. The vessel pressure was varied from 5.0 to 17.0 inwc vacuum. Figure 15 shows a plot of the SRAT flow and the measured SRAT air bleed.

TABLE 8. SRAT/SME Air Inleakage Data

Pressure (inwc)	214-PG (inwc)	214-FT (inwc)	Air Bleed (pph)	Air Inleakage (pph)
5.00	0.21	13.75	11.00	2.75
6.75	0.36	18.00	13.25	4.75
7.50	0.46	20.35	14.50	5.85
9.75	0.56	22.45	17.00	5.45
11.75	0.72	25.46	20.00	5.46
15.25	0.90	28.46	24.00	4.46
17.00	0.98	29.70	25.50	4.20

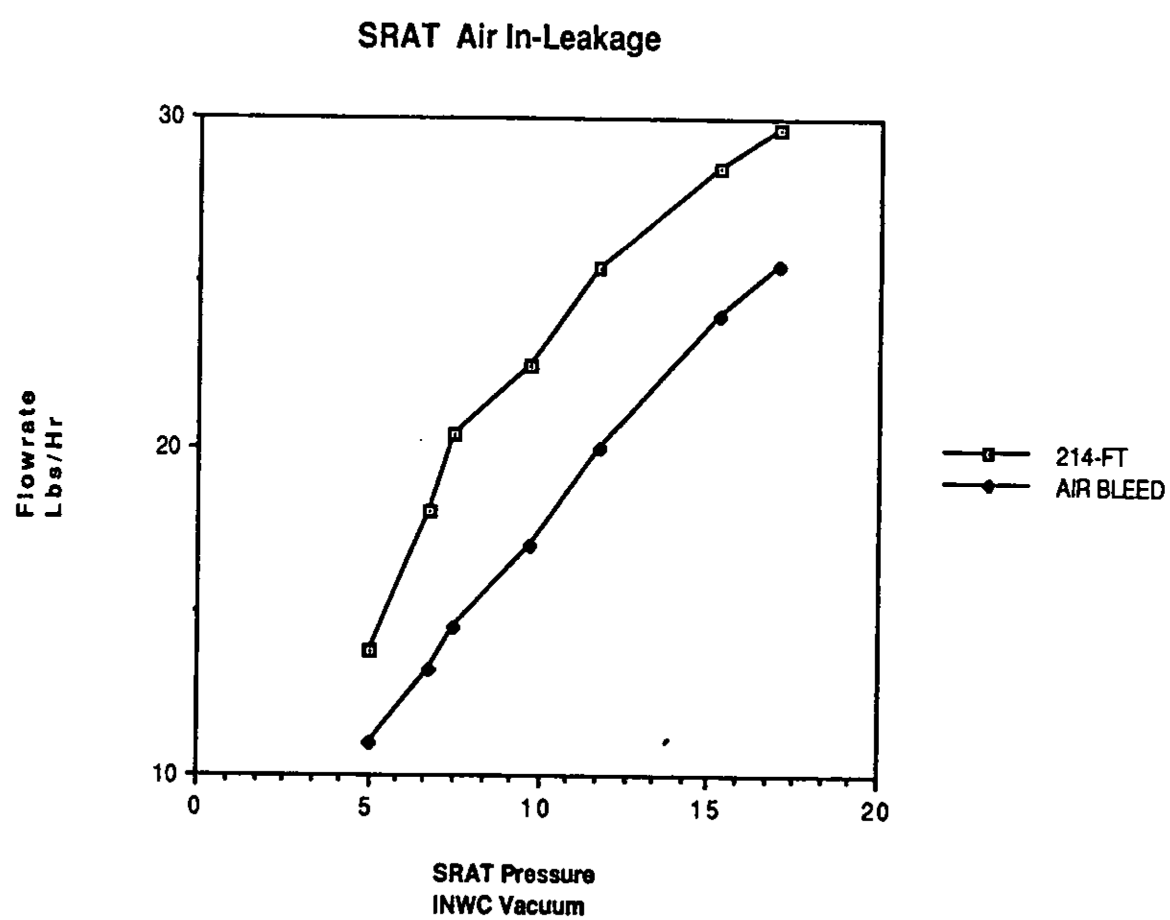


FIGURE 15. SRAT/SME Operating Curve

Melter Feed Tank

Table 9 shows the operating conditions and air inleakage data used to develop the operating curve of the MFT vessel. The vessel pressure was varied from 3.25 to 14.0 inwc vacuum. Figure 16 shows a plot of the MFT flow and the measured MFT air bleed.

TABLE 9. MFT Air Inleakage Data

Pressure (inwc)	214-PG (inwc)	214-FT (inwc)	Air Bleed (pph)	Air Inleakage (pph)
3.25	0.20	13.42	12.00	1.42
4.75	0.30	16.43	13.00	3.43
6.00	0.39	18.73	15.00	3.73
7.50	0.51	21.42	16.25	5.17
9.80	0.70	25.10	19.50	5.60
12.00	0.80	26.83	22.00	4.83
12.50	0.83	27.33	22.50	4.83
14.00	0.97	29.55	25.00	4.55

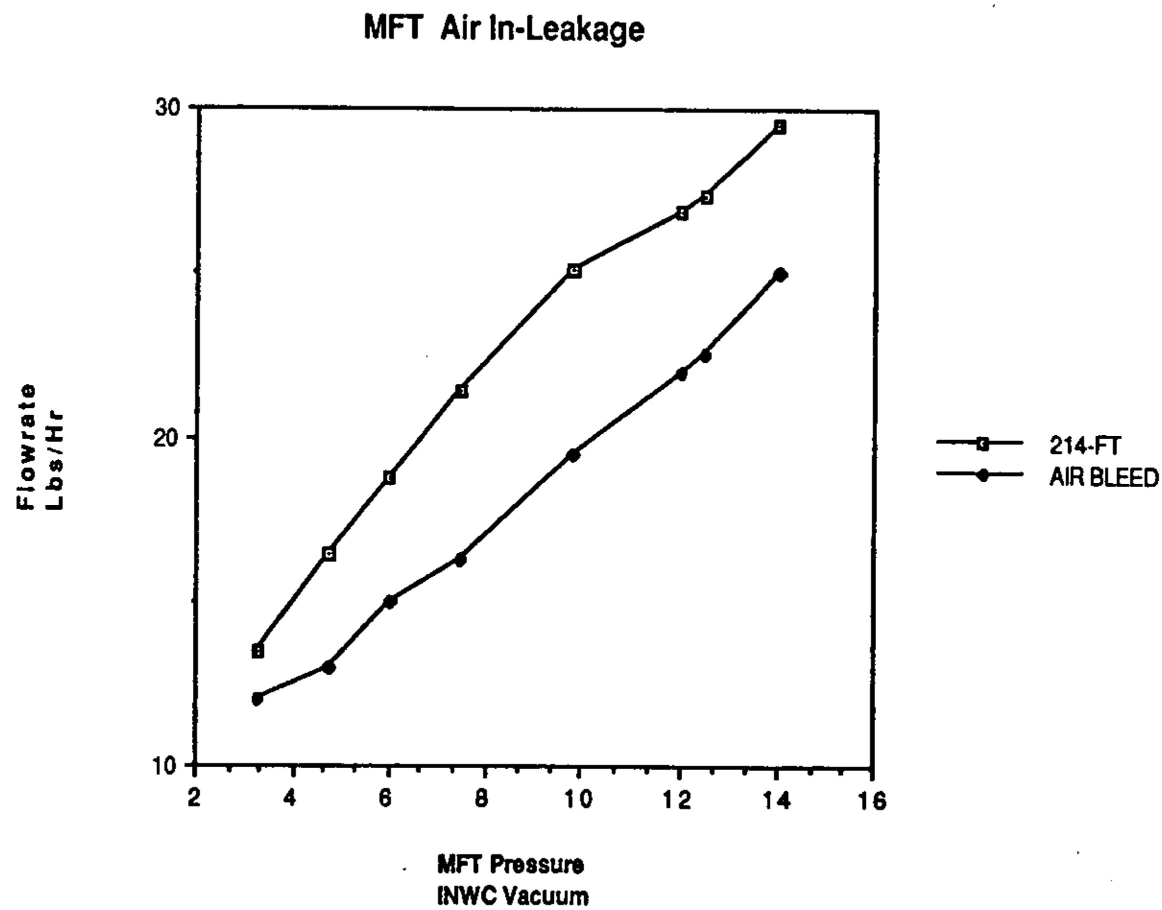


FIGURE 16. MFT Operating Curve

Mercury Water Wash Tank

Table 10 shows the operating conditions and air inleakage data used to develop the operating curve of the MWWT vessel. The vessel pressure was varied from 2.1 to 27.5 inwc vacuum. Figure 17 shows a plot of the MWWT flow and the measured MWWT air bleed.

TABLE 10. MWWT Air Inleakage Data

Pressure (inwc)	214-PG (inwc)	214-FT (inwc)	Air Bleed (pph)	Air Inleakage (pph)
2.10	0.10	9.49	0.00	9.49
5.50	0.21	13.75	4.00	9.75
10.00	0.30	16.43	7.00	9.43
12.20	0.38	18.37	10.00	8.37
15.50	0.46	20.35	14.00	6.35
19.50	0.58	22.85	16.50	6.35
23.20	0.70	25.10	18.50	6.60
27.50	0.83	27.33	20.50	6.83

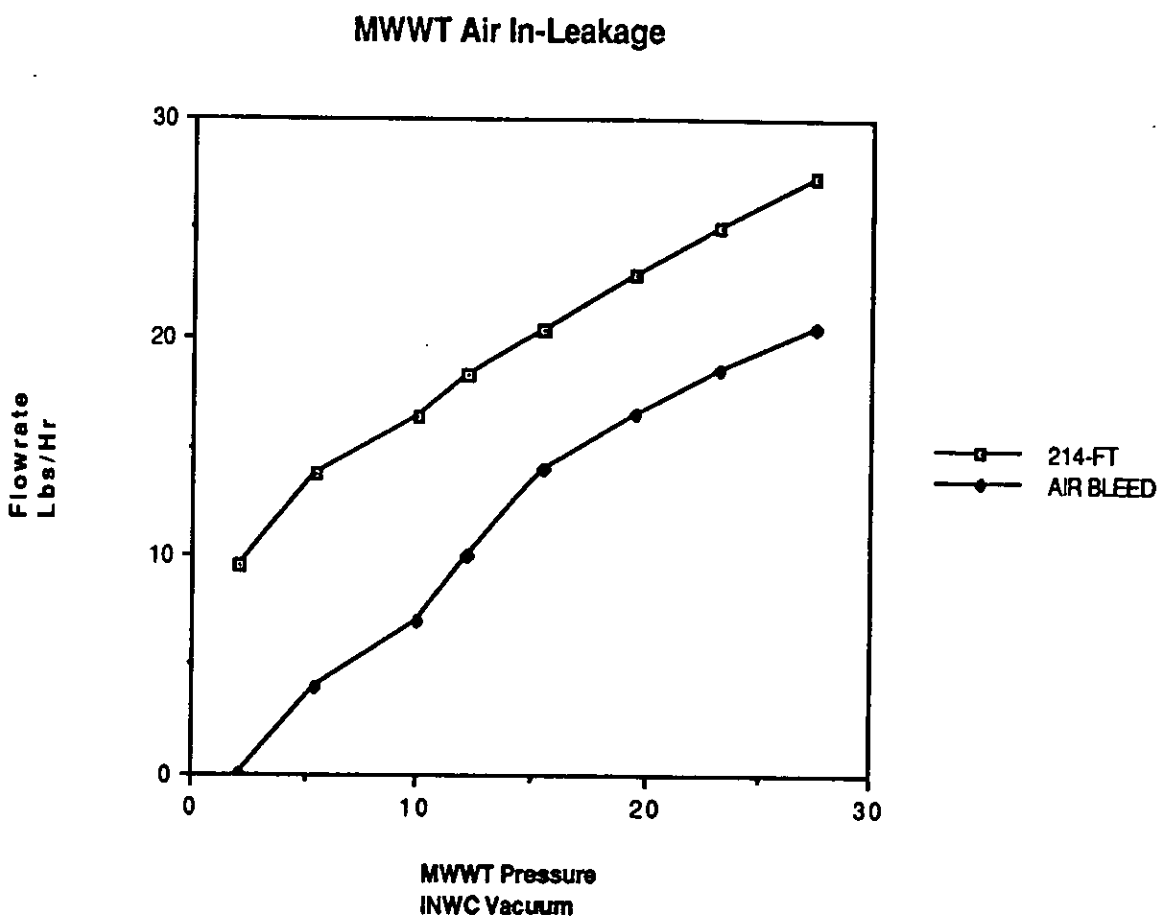


FIGURE 17. MWWT Operating Curve

Waste Water Pump Tank

Table 11 shows the operating conditions and air inleakage data used to develop the operating curve of the WWPT vessel. The vessel pressure was varied from 2.1 to 27.5 inwc vacuum. Figure 18 shows a plot of the WWPT flow and the measured WWPT air bleed.

TABLE 11. WWPT Air Inleakage Data

Pressure (inwc)	214-PG (inwc)	214-FT (inwc)	Air Bleed (pph)	Air Inleakage (pph)
4.75	0.12	10.39	6.00	4.39
7.25	0.24	14.70	11.00	3.70
12.00	0.44	19.90	13.00	6.90
13.50	0.48	20.78	14.00	6.78
15.50	0.59	23.04	15.00	8.04
18.50	0.74	25.81	16.00	9.81

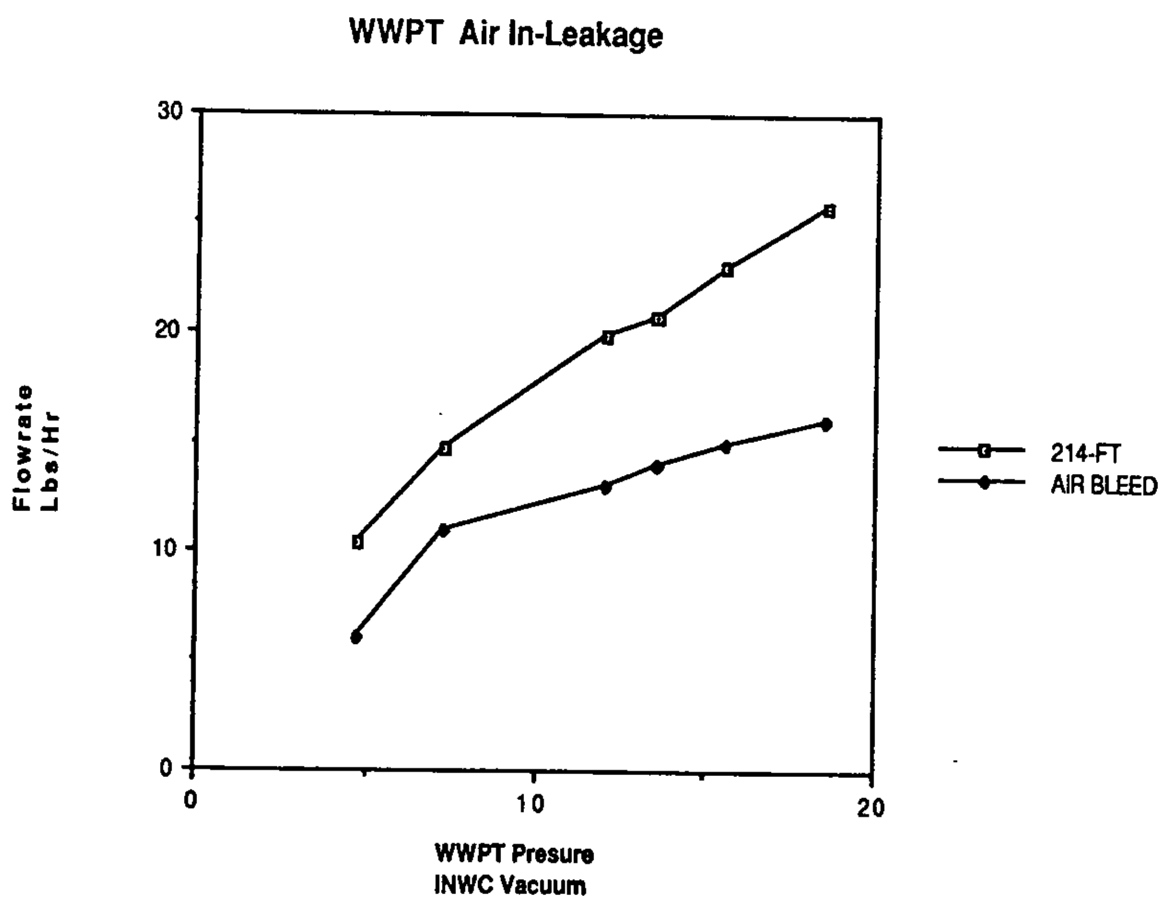


FIGURE 18. WWPT Operating Curve

Melter Off-Gas System Water Runs

During water runs, operating curves were developed for each applicable piece of off-gas equipment.

Melter Spout Jet

Operation of the melter spout jet was tested before glass was charged to the melter by temporarily plugging the pour spout with a clay substance. This allowed a differential pressure to be created between the melter plenum and the bellows area. This test confirmed that the spout jet was capable of pulling enough vacuum on the pour spout to initiate glass pouring (>5" wc differential pressure).

After the melter had been started up with a full charge of glass, another test was performed to obtain performance curves for the spout jet. Water flow to the spout jet and control air flow to the bellows were varied and results were recorded. By plotting control air flow versus melter-to-pour spout differential pressure at constant water flow, then repeating for different water flow rates, a graph was constructed representing all points (air flow vs. water flow) at which the differential pressure was approximately equal to the melter vacuum (i.e., the bellows pressure was approximately equal to the pressure in the melter room). This curve is shown in Figure 19.

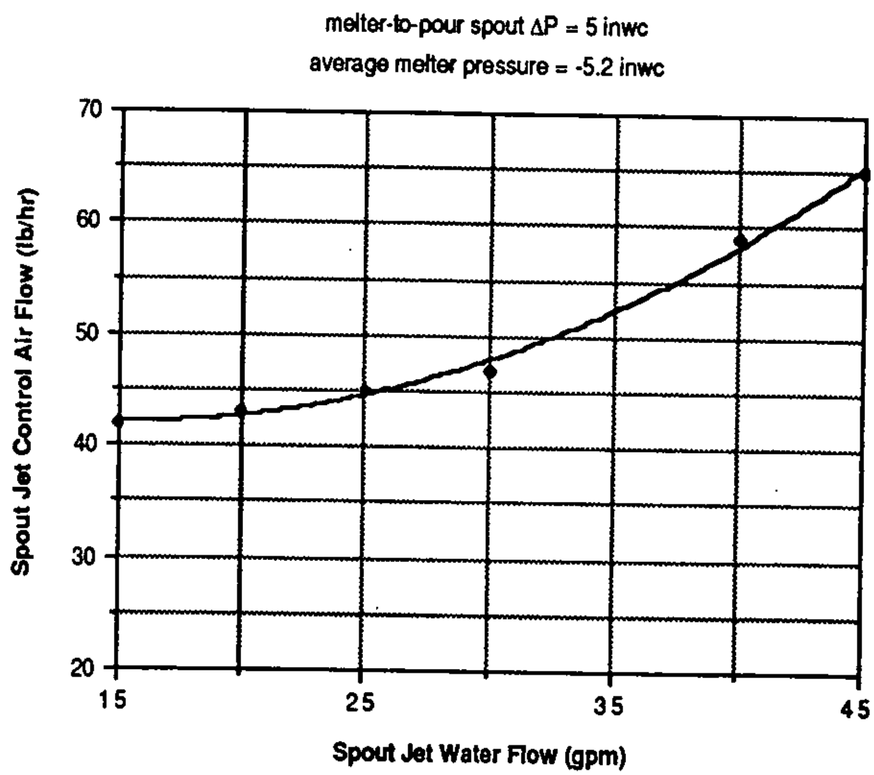


FIGURE 19. **Melter Spout Jet Capacity**

Off-Gas Film Cooler

The air flow to the Off-Gas Film Cooler (OGFC) for startup was based on the ratio of the IDMS Melter surface area to the DWPF melter surface area and the current DWPF flowsheet value for the OGFC air flow. A constant air flow of 135 lb/hr was set on the OGFC. With the melter plenum at 880°C, the OGFC outlet temperature was 340°C and steam cooling was not required during idling conditions.

Quencher

Pressure drop across the quencher was measured for various quencher condensate flow rates. These measurements were taken at a melter pressure of -5" wc and a vapor space temperature of 837°C. The results are plotted in Figure 20.

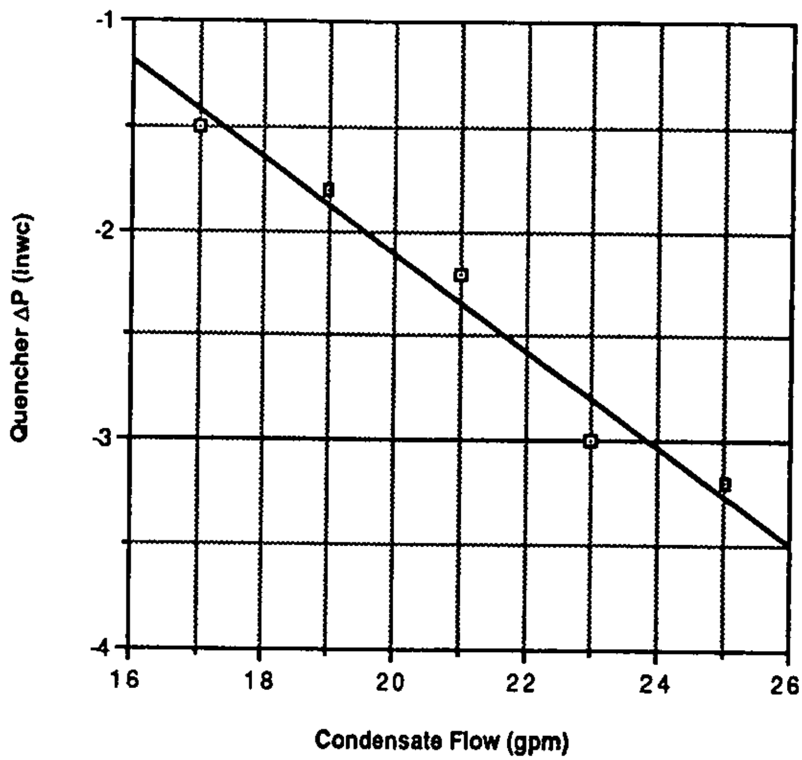


FIGURE 20. Quencher ΔP versus Condensate Flow

Steam Atomized Scrubbers

The IDMS Steam Atomized Scrubber (SAS) units were sized for an inlet flow of 355 lb/hr of dry off-gas. The operating basis is 0.2 pounds of steam per pound of dry gas and 4.5 pounds of water per pound of dry gas. The SASes were fabricated to operate from 60% to 120% of the design gas flowrate.

The SAS pumping action can result in a net positive pressure increase across the unit. This would be a problem only if the increase results in a positive line pressure at the SAS #2 outlet. For this reason, a butterfly valve is present upstream of SAS #1 (same as the DWPF) to control the SAS inlet pressure and prevent a positive line pressure at the SAS #2 exit.

The manufacturer (Hydro Sonic Systems, Inc.) predicted a pressure increase of 13" wc at the design flowrate of 355 lb/hr of off-gas. However, at 350 lb/hr, an overall pressure decrease of 14.7" wc was observed. The operating data with steam and water flow is shown in Table 12.

TABLE 12. **SAS Operating Data**

	Operating Conditions				Pressures (in" wc)		
Air in lb/hr	Water gpm #1	Water gpm #2	Steam lb/hr #1	Steam lb/hr #2	SAS #1 ΔP	SAS #2 ΔP	SAS #2 Outlet
151	3	3	0	0	-4.1	-2.0	-1.8
185	3	3	0	0	-8.1	-3.0	-7.6
217	3	3	0	0	-7.4	-5.1	-13.3
242	3	3	0	0	-9.4	-7.1	-21.2
269	3	3	50	50	-0.7	-0.3	-5.2
272	3	3	50	50	-3.3	-2.8	-11.3
287	3	3	54	54	-3.6	-4.2	-15.5
316	3	3	62	62	-4.2	-5.6	-20.3
350	3	3	66	66	-5.6	-9.1	-27.8

This data was taken while the melter was still cold. For an inlet off-gas flow rate of 350 lb/hr, a vacuum of -11.6" wc was observed in the melter. To avoid placing excessive vacuum on the melter, the tests were discontinued at this point. The SAS units will be tested again at higher off-gas flow rates at a later date.

Mist Eliminator, HEME, and HEPA Filter

Pressure drops were measured across the mist eliminator, High Efficiency Mist Eliminator (HEME), and High Efficiency Particulate Air (HEPA) filter during off-gas system operation. The results are plotted versus off-gas flow in Figures 21, 22, and 23.

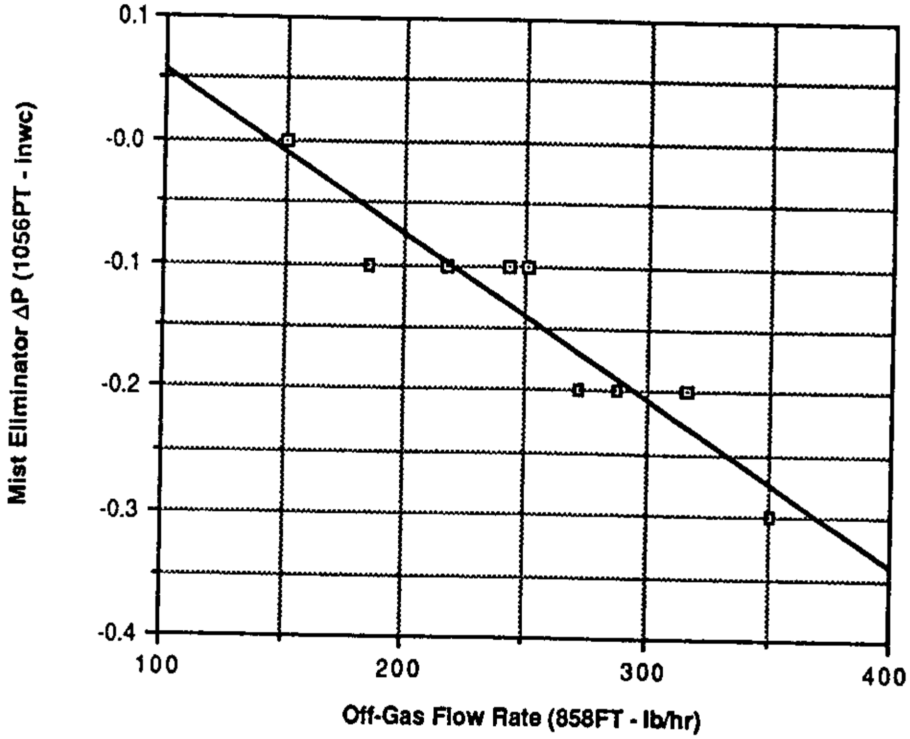


FIGURE 21. Mist Eliminator Pressure Drop

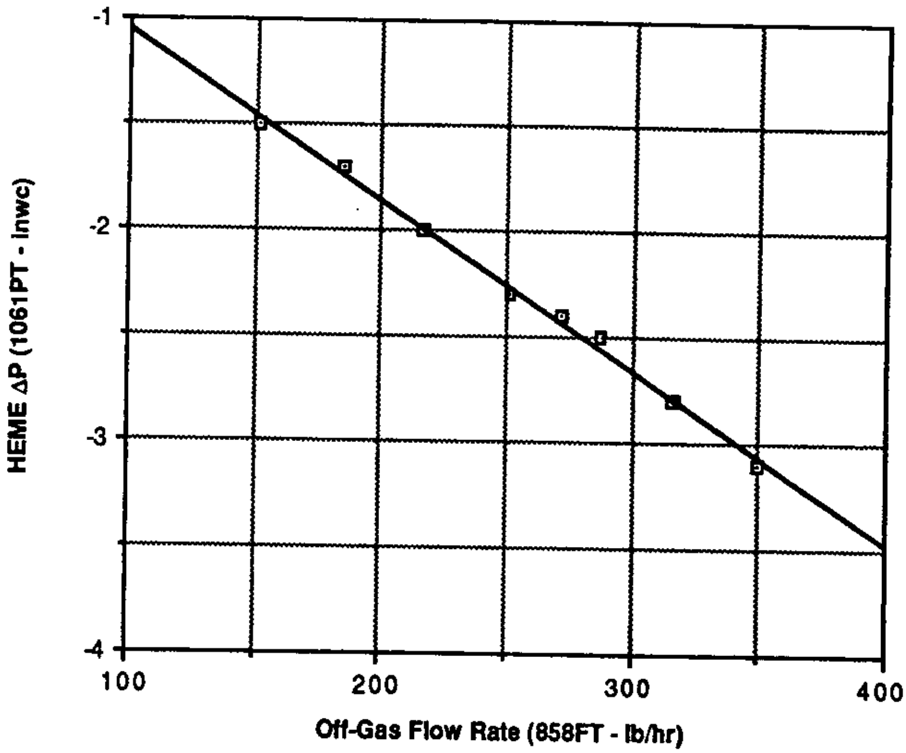


FIGURE 22. HEME Pressure Drop

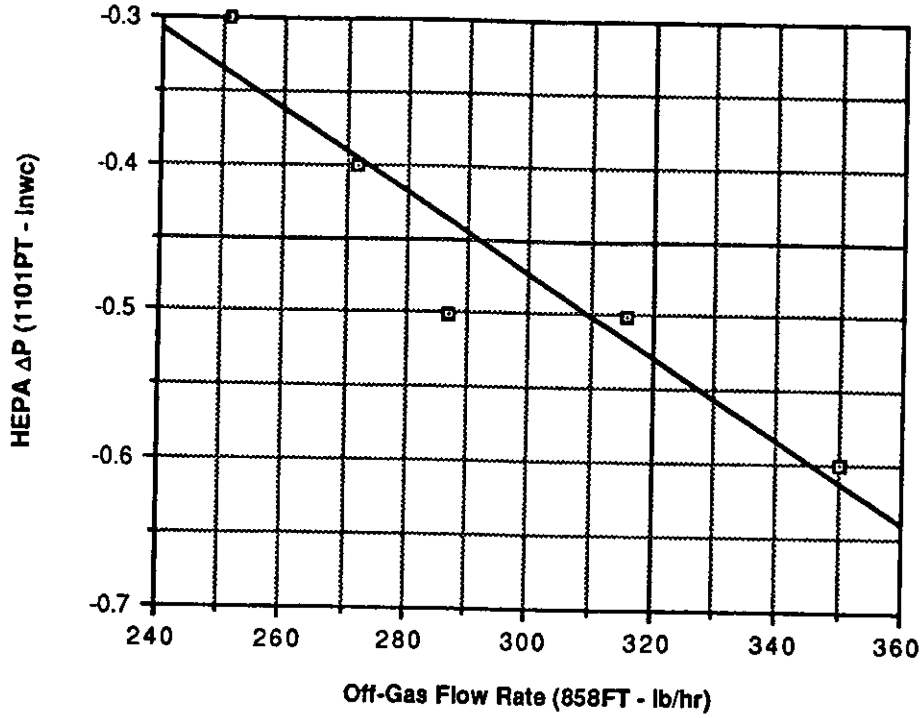


FIGURE 23. **HEPA Filter Pressure Drop**

Blower Performance

The off-gas blower was run at various outputs to determine a baseline curve for total off-gas flowrate versus controller output. This curve is shown in Figure 24. Since the melter was cold with no pour control air or OGFC air entering, flowrates greater than 300 lb/hr would have resulted in excessive melter vacuum; therefore the line was extrapolated to 60%.

Primary Off-Gas Steam Jet Performance

The primary steam jet was tested by varying the controller output to the automatic steam valve. Off-gas flowrate was measured at the outlet to the SAS units, since there is no flow transmitter on the outlet of the steam jet. The resulting curve is shown in Figure 25.

Backup Steam Jet

The backup steam jet was tested by varying the controller output and recording the steam rate to the jet and the melter vacuum. Results are plotted in Figure 26.

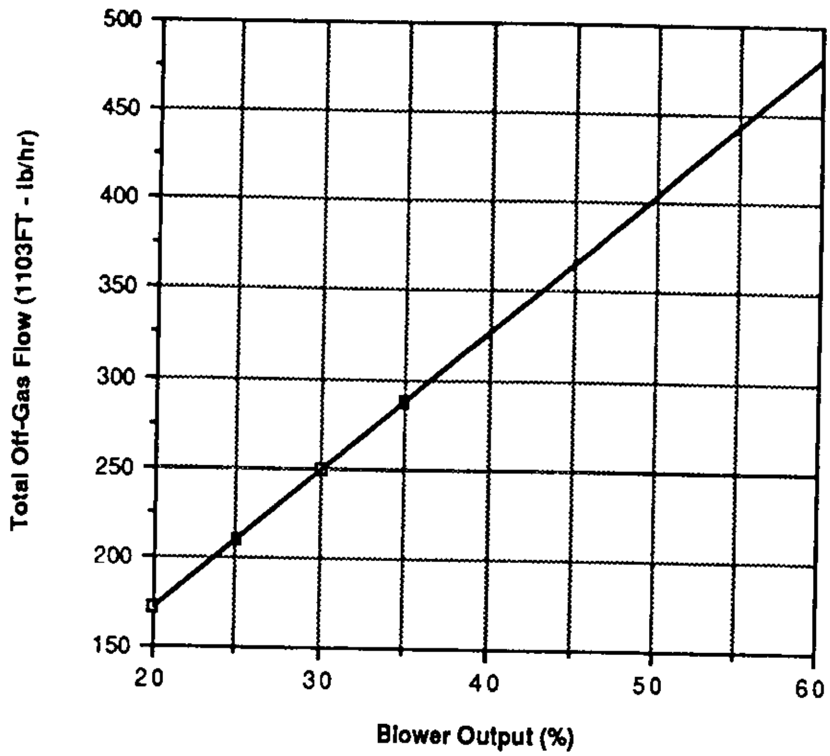


FIGURE 24. Off-Gas Blower Performance

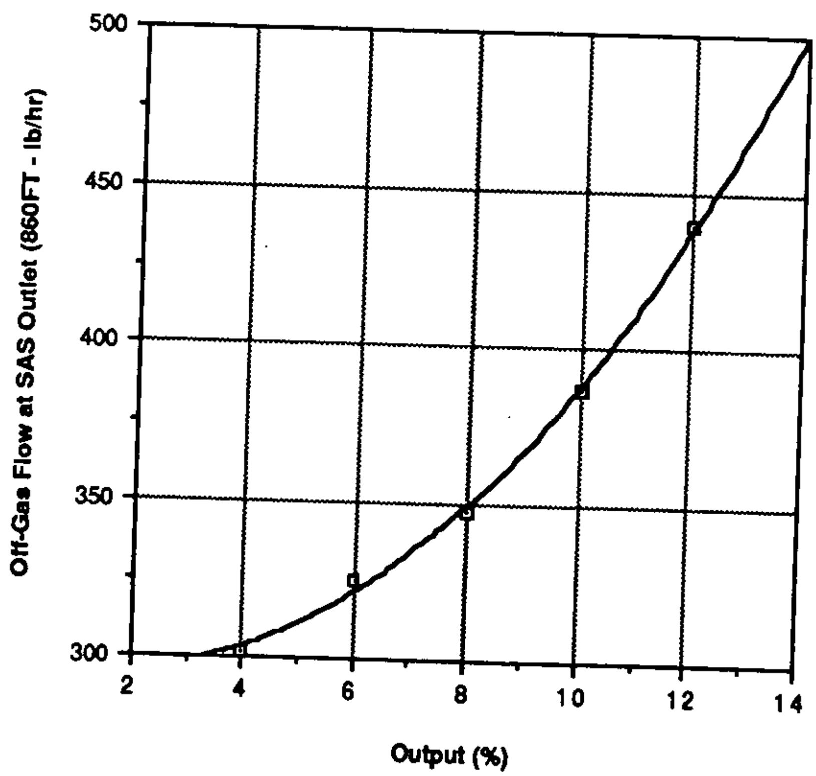


FIGURE 25. Primary Off-Gas Steam Jet Performance

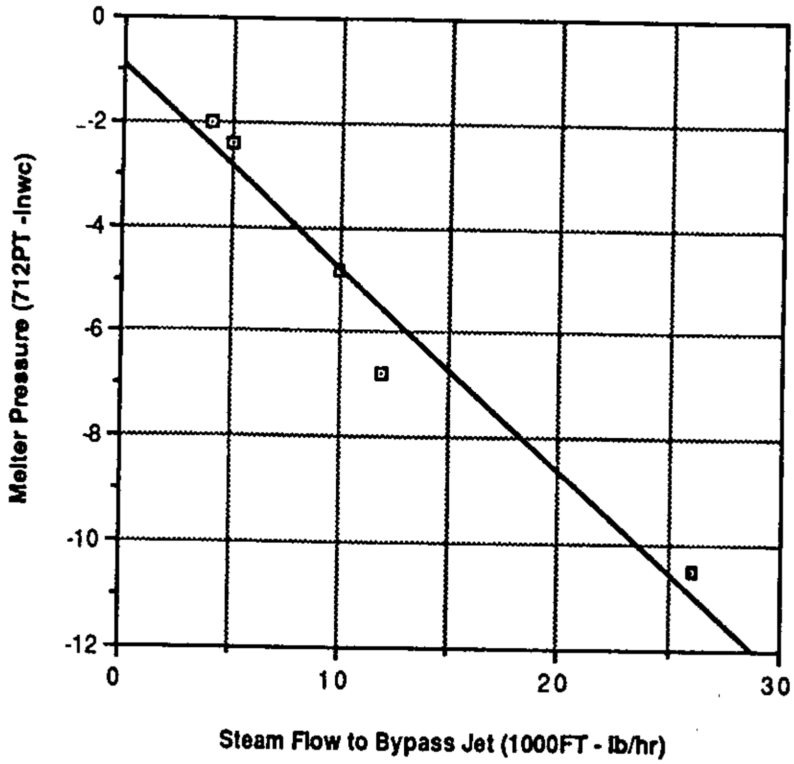


FIGURE 26. **Bypass Steam Jet Performance**

Melter Air Inleakage

Air leakage into the melter was calculated as the difference between the off-gas flow rate measured in the off-gas header (using an anemometer) and the flow of control air into the melter. Since the melter was at room temperature during data collection, no corrections were necessary. The curve for melter air inleakage at room temperature is shown in Figure 27. At the normal operating pressure of -5" wc, melter air inleakage was <50 lb/hr.

During melter heatup, the anemometer failed, making further air inleakage determinations impossible. However, a pitot tube is being fabricated by Construction and will be installed in the off-gas header prior to the organics runs so that melter air inleakage can be determined.

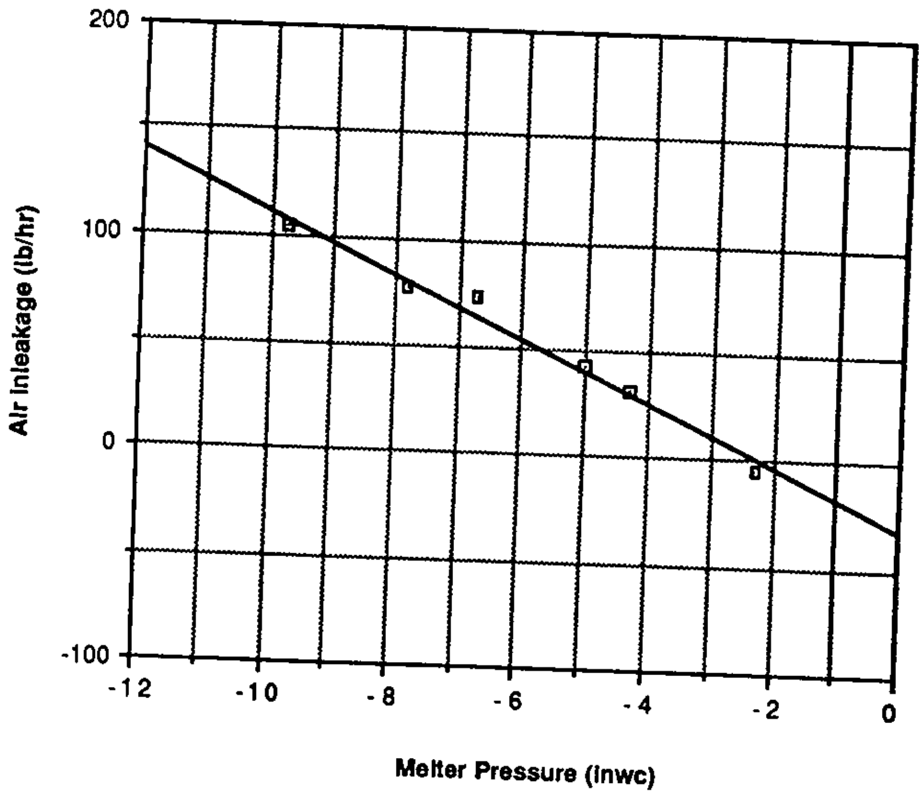


FIGURE 27. Melter Air Inleakage

Solids Recycle Filter System

During the month of June 1988, the Waste Water Pump Tank (WWPT), ultrafiltration system, and the caustic addition system of the IDMS were flushed and operated with deionized water. The objectives of these runs were:

- to test valves, pumps, and fittings for leaks,
- to collect operational data on the pumps and ultrafilter units,
- to check the operation of the control system, and
- to determine if any design flaws or operational problems might delay long-term operation of the system.

Waste Water Pump Tank

The WWPT recirculation pump was operated with the tank at the overflow level of 80% and the manual valves in the recirculation line open. No water was allowed to flow to the ultrafilters during these initial tests. The pump discharge pressure was measured to be 18.5 psig. All flanges, fittings, and joints were checked for leaks and repaired as necessary.

Following the test of the WWPT recirculation loop, the WWPT and ultrafilters were operated simultaneously. Initially the system was operated with water flow through all four filters, and both the upstream and downstream control loops (1202FC and 1203FC respectively) were kept in manual control to achieve the desired flow rates through the solids return lines and into the ion exchange bypass tank. During these tests the permeate stream, which would normally flow to the Ion Exchange Facility (IXF), was diverted back to the WWPT in order to conserve our limited supply of deionized water.

During operation of the WWPT and UF systems, it was observed that the WWPT seal pot was draining as though from tank overflow. Subsequent investigations revealed that the drainage was due to a design problem with the solids return line from the ultrafilters. The line is attached to the WWPT at the top of the tank and above the overflow line. During operation, a portion of the return stream drains down the side of the tank and into the overflow line. The problem has been rectified by installing a dip-tube in the solids return line flange.

During the water runs, it was also observed that the liquid siphons through the OGCT diaphragm pump to the WWPT. This problem has been corrected by modifying the pump discharge line to break the siphon.

Ultrafilter Units

The ultrafilters were operated in a temporary recirculation loop with the WWPT as described above. Performance curves for each filter were generated by running each filter over a range of about 300 to 740 psig. Pressure was controlled by changing the 1203FV controller output at the Metra. The booster pump discharge pressure (1201PT) and permeate flow rate (1203FT) measurements were recorded from the Metra. Since the filtrate line pressure gauge had not been installed at that time, it was assumed that the pressure drop across the ultrafilters was approximately equal to the booster pump discharge pressure. This assumption is valid since pressure upstream of the filters is several hundred psig and the downstream pressure is less than 5 psig. The data were plotted as permeate flow rate versus filter pressure, Figures 28-33, and are linear as expected. The "characteristic flux", in gallons/ft^2/psi/day for each ultrafilter unit was calculated at 700 psig (see sample calculation for ultrafilter #1 shown below). The filter manufacturer has stated that the characteristic flux of a sound, functional membrane should be 0.50 or less at 700 psig operating pressure. As shown in Table 13, the performance of all four filters is within the desired range.

TABLE 13. **Ultrafilter Characteristic Fluxes**

FILTER	FLUX (GAL/FT^2/DAY/PSI)
1	0.37
2	0.51
3	0.49
4	0.38

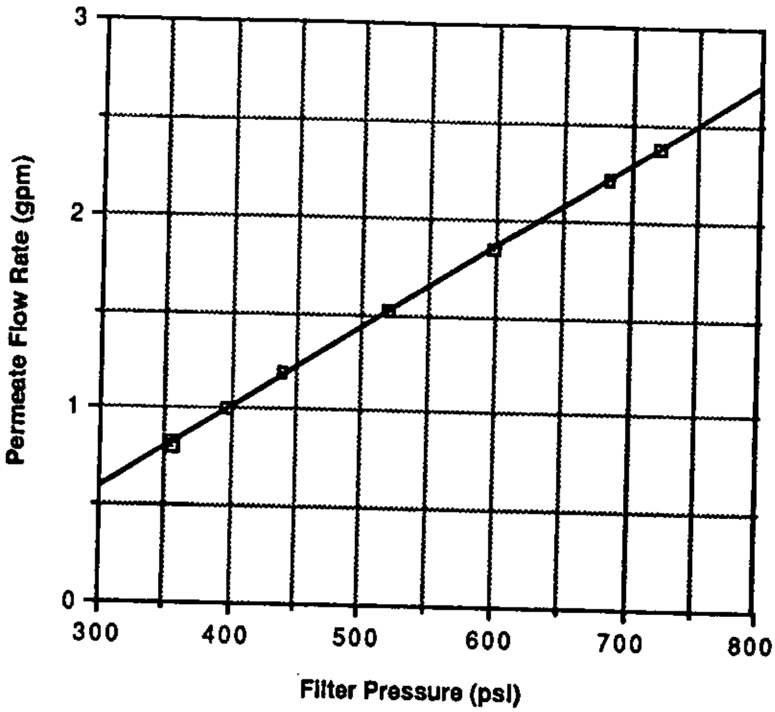


FIGURE 28. **Ultrafilter #1: Flow Rate versus Pressure**

Sample Flux calculation for ultrafilter #1:

From above graph, flow @ 700 psi = 2.3 gpm

FLUX = 2.3/700 (gal/min/psi) 1440 (min/day) 1/13 (1/ft^2)

= 0.3639 gals/day/psi/ft^2

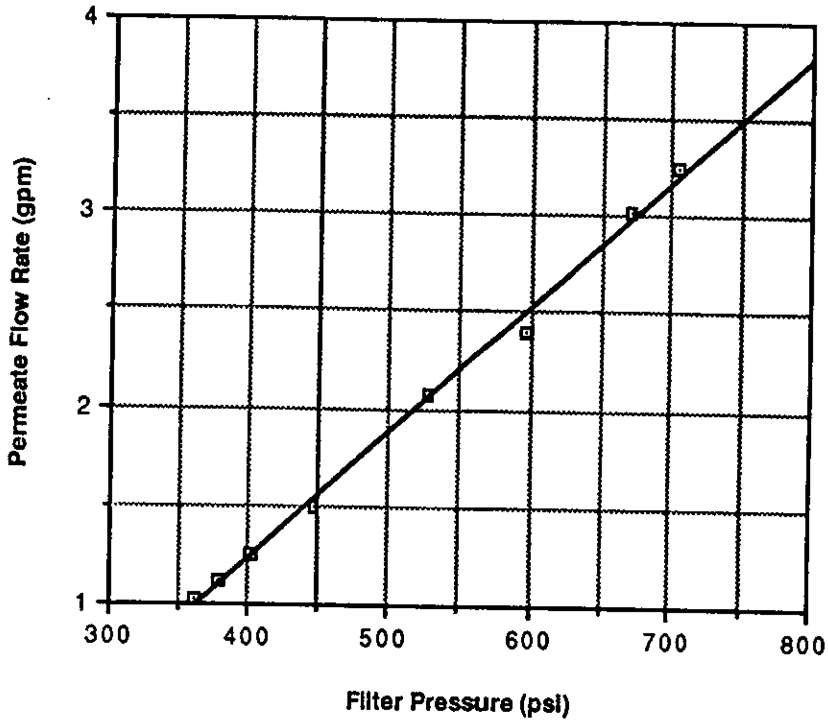


FIGURE 29. Ultrafilter #2: Flow Rate versus Pressure

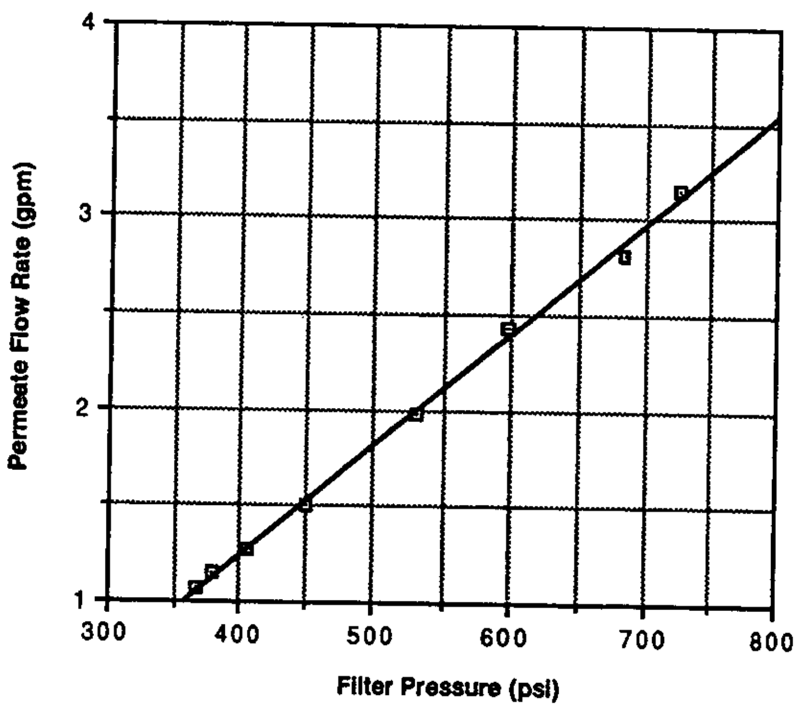


FIGURE 30. Ultrafilter #3: Flow Rate versus Pressure

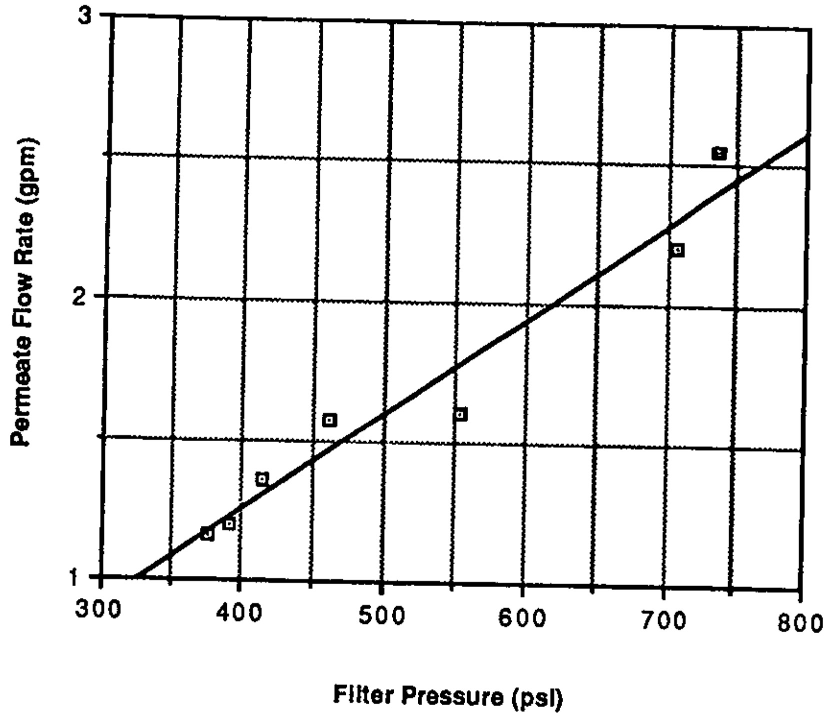


FIGURE 31. Ultrafilter #4: Flow Rate versus Pressure

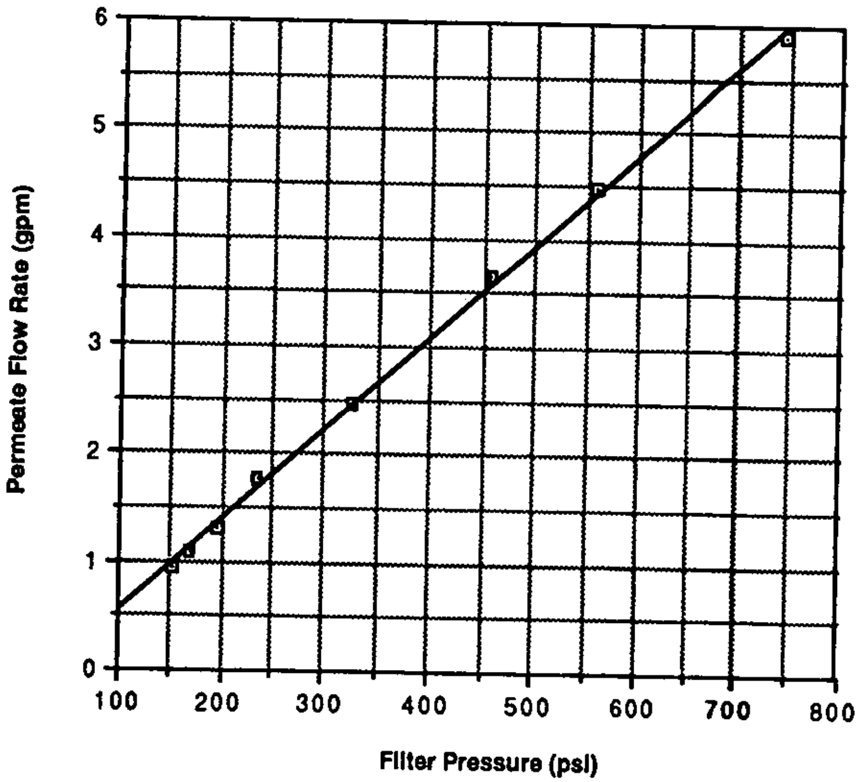


FIGURE 32. Combined Flow From UF #1 and UF #2

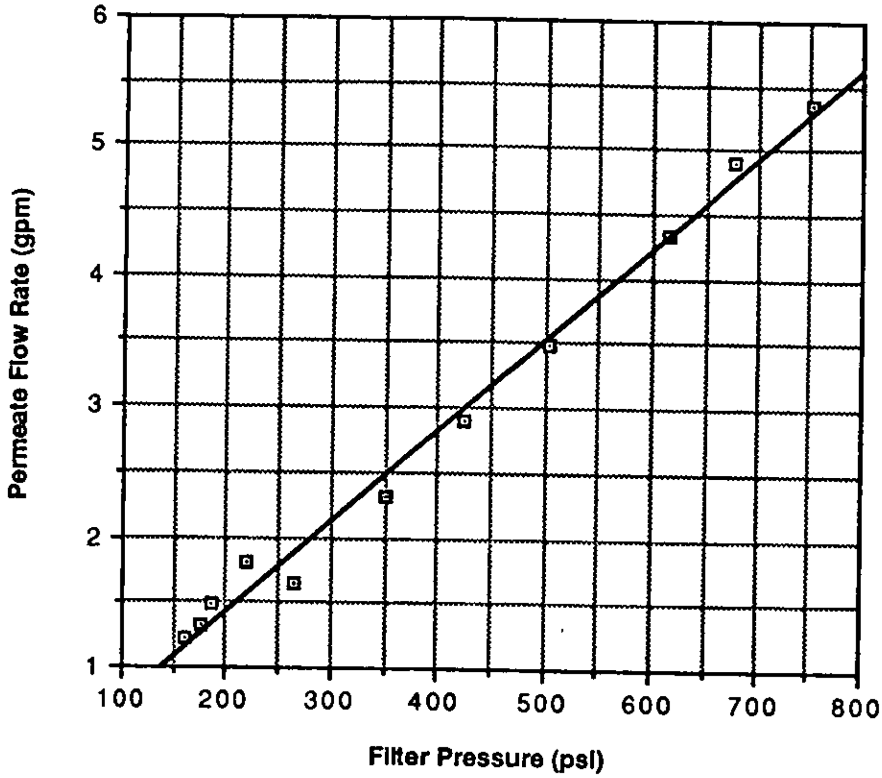


FIGURE 33. Combined Flow From UF #3 and UF #4

Throughout the runs, the equipment and instruments were checked for leaks and repaired as required. One immediate observation was that the ultrafilter booster pump produced intense noise and vibration. The vibration was so severe that the local pressure gauge at the pump discharge was ruined within a matter of minutes. The noise level was measured to be 96 db at a distance of 5 feet. The vibration also appeared to cause several leaks at connectors and fittings.

Existing local pressure gauges on the ultrafilters were replaced with oil-filled gauges. An additional local pressure gauge was installed on the permeate (filtrate) line just downstream of the filters. This will help to determine pressure drop across the filters, which may indicate pluggage.

Since the realization of the vibration problem, several corrective actions have been undertaken. First, a surge suppressor was installed on the booster pump discharge line to dampen the hydraulic pulses. Implementation of this solution resulted in a noise level drop of only 2 db.

The Equipment Enginnering Division (EED), Wanner Engineering (the manufacturer of the pump), and the Engineering Services Division (ESD) were all consulted concerning the vibration problem. An ESD engineer visited the facility and measured piping vibration and fluid pulsation. He determined that severe cavitation had occurred on the pump suction, and suggested that the pump be replaced. These pressure pulsations are shown in Appendix I, for discharge pressures of 420 psig and 338 psig, respectively. These figures show large pressure spikes and indicate that cavitation was occurring. The following recommendations were given by the three groups to alleviate the problem:

1. The pulsation dampener should be relocated close to the pump discharge.
2. A larger size dampener would be ideal. However, he stressed the importance of correct sizing of a dampener.
3. The 1202 FV bypass should be redirected to the Waste Water Pump Tank in order to reduce turbulence and eventual cavitation.
4. Since the pump is running at its maximum speed of approximately 1000 rpm, it would be ideal to reduce the pump speed if process conditions permit.
5. It would be ideal to reroute the pump inlet line so that more flow can be provided to the suction, to reduce the effect of cavitation.
6. Add 6 feet of flexible hose to the inlet and discharge sides of the pump.

Recommendations 1, 2, 3, and 5 were implemented. At present, the filter system requires approximately 17 gpm of inlet flow to achieve 2 to 3 gpm of filtrate flow with two units on line. This corresponds to a linear velocity of approximately 13.65 ft/sec through the filter membrane, which satisfies the vendor's specified range of 10 to 15 ft/sec. After comparison, it seems that it will be difficult to reduce the inlet flow rate and still achieve the design rate of 3 to 4 gpm of filtrate flow. This limitation will not allow implementation of recommendation 4.

A 6 foot flexible hose was later added (see recommendation 6) to the inlet side of the pump, and this greatly reduced the vibration of the pump to an acceptable level.

Caustic Addition System

The WWPT caustic addition system was operated with process water to check the operation of the pumps, valves, and associated Modicon logic. These tests did not access the operation of the Modicon-controlled pH adjustment algorithm.

The first attempt to measure water flow at the WWPT was unsuccessful since no flow to the tank could be attained, even with the pumps operating at maximum speed. Each pump has a recirculation loop to prevent pressure build-up in the discharge piping when 1252XV is closed. It was determined that the recirculation loop hoses were so large that there was insufficient head to pump water to the WWPT. Each hose was replaced with 0.25-inch OD stainless steel tubing and a needle valve. The needle valve will serve as a variable choke if further adjustment of recirculating flow is required during future operations.

Performance curves, Figures 34 and 35, for the caustic addition pumps were obtained by measuring volumetric flow rate from the caustic line at the WWPT as a function of pump speed. Both pumps performed satisfactorily.

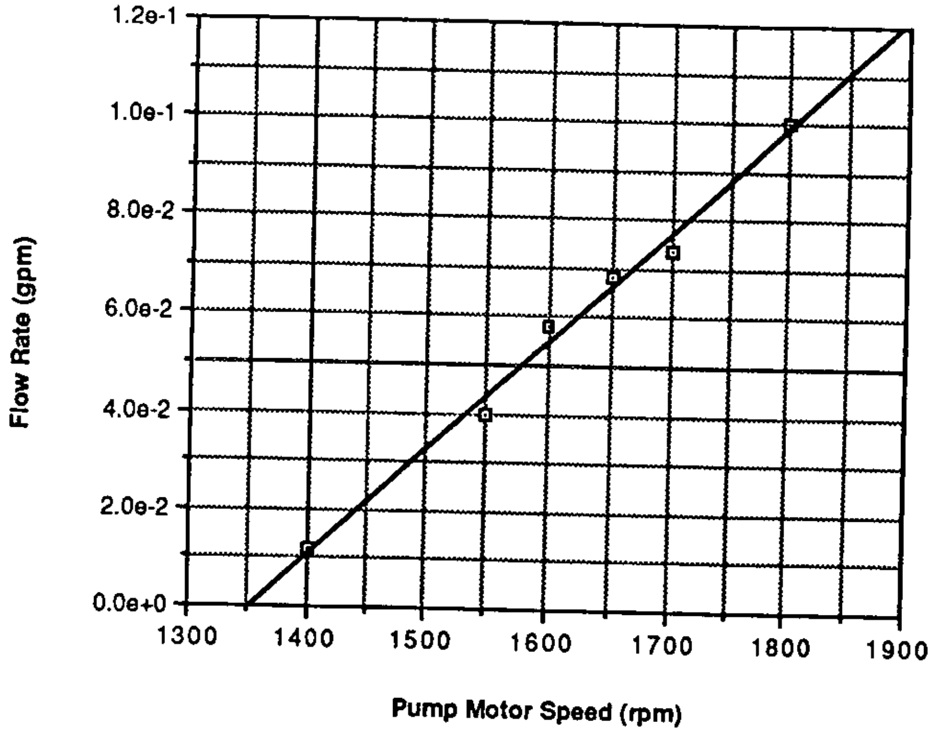


FIGURE 34. **Caustic Pump #1 Performance**

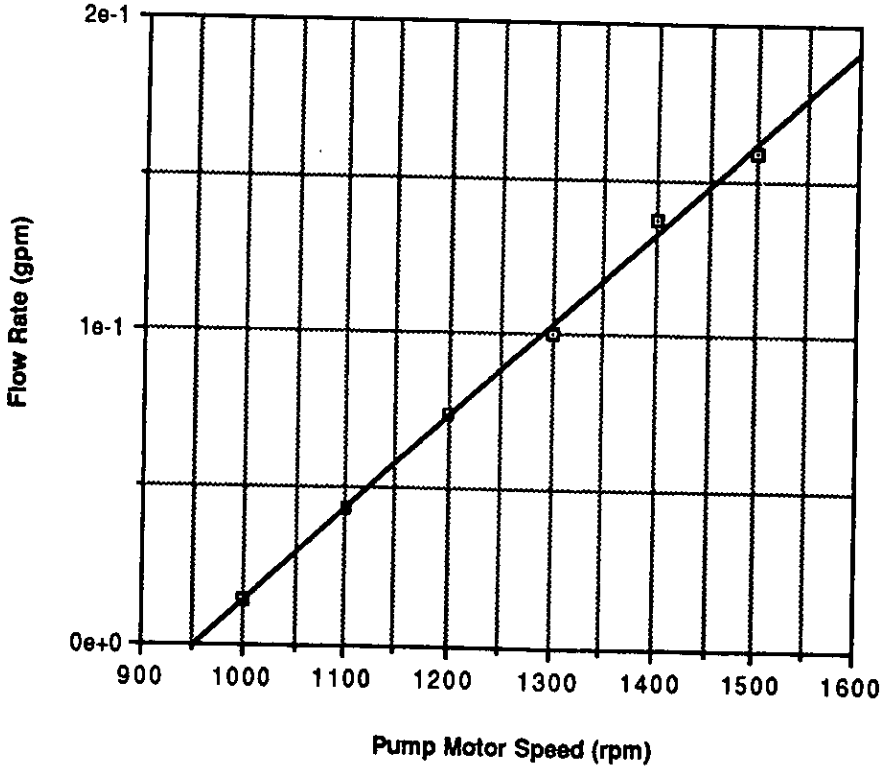


FIGURE 35. **Caustic Pump #2 Performance**

The WWPT caustic addition system was used during the first feed batch. The following problems were found with the system:

- Caustic pump #1 failed during the pH adjustment process. The pump head was dismantled and a weir plate was found to be broken. It was discovered that the vendor had stopped manufacturing these pumps and had very few spare parts. Future replacement of these pumps may be necessary due to limited spare parts availability.

- A sudden jump in pH was observed during caustic addition. Moving 1254XV did not help the sudden jump in pH during the caustic addition. The pH algorithm was reworked, and will be evaluated during later runs.

IDMS MELTER HEATUP

After the IDMS Melter had been completely checked out, it was successfully heated up to operating temperatures in October 1988. TNX Job Plan #672T-88-9-3[3] was used for the heatup. The heatup simulated, as closely as possible, the present DWPF strategy. TNX Job Plan #675T-88-3-1[4] was used as a guideline for the IDMS Melter heatup plan. The total amount of time to complete the IDMS Melter heatup was ~10 days.

Melter Startup Constraints

The startup sequence of both the DWPF Melter and the IDMS Melter is based on operating and material constraints within the melter systems. These constraints must be considered to complete the startup while minimizing operating problems and refractory damage.

Controlling the rate of temperature increase is necessary during melter heatup to protect the refractory. The Carborundum Company had previously recommended a maximum heatup rate for their Monofrax K-3™ glass contact refractory of 10°C per hour to minimize thermal stresses in the brick. This conservative rate mitigates the potential for refractory damage during startup.

The melter startup consists of heating an initial dry frit charge until it is transformed into a molten glass. The following characteristics of the frit must be considered for startup:

- The frit simulation is essentially non-conductive below 700°C.
- The frit charge volume is about two times that of the resulting molten glass.
- The waste glass/frit material will crystallize if maintained below 950°C for an extended period of time.
- The frit is an excellent thermal insulator.

In addition, the small inside diameter of the IDMS Melter (24 inches) increased the possibility of cold slurry feed splattering on the K-3™ refractory wall, which includes the throat block. Due to the fact that the throat block was machined to form a large 9-inch-wide slot, it was seen as having a greater chance of experiencing thermal shock problems than the other K-3™ blocks.

DPST-88-481[5] ("Summary of the Drain and Restart of the DWPF Scale Glass Melter") gives a more detailed summary of general melter startup constraints, as well as knowledge gained from both the original startup and the restart of the Scale Glass Melter.

Proposed DWPF Melter Startup Sequence

Prior to heatup of the melter interior, several prerequisite operations, including the following, must take place:

- Verify that all melter dip tubes which will extend below the surface of the frit charge are installed.
- Charge the melter with frit to the top of the lower electrodes.
- Seal the melter pour spout to the canister with the melter vapor space/pour spout differential pressure set at zero to minimize the air flow across the frit charge.
- Confirm operation of the off-gas system.
- Confirm operation of all melter support systems (e.g., cooling water, glass level dip tube, TV camera).

During the original startup of the Scale Melter (1Q86) and for the proposed startup of the DWPF Melter, a sacrificial layer of Fiberfrax™ paper is applied to the bricks exposed to the increase in glass level. This was done for the IDMS Melter as well. This layer dissolves into the molten glass pool while minimizing thermal stresses in the brick.

The proposed DWPF melter startup sequence is illustrated in Figure 36 and is explained in the following paragraphs. The lid heaters and top heater of the three-zone dump valve are used to heat the frit charge from room temperature to ~700°C. Radiant energy provided by the lid heaters is the primary source of heating the frit charge during this step. After the lid heaters reach 950°C, the riser and pour spout heaters are energized and amperage is increased such that their skin temperatures reach 1100°C at a rate less than 10°C per hour.

Joule heating is established using the lower electrodes when the top of the frit charge reaches ~700°C. The combination of energy input from the lid heaters and joule heating via the lower electrodes raises the melt pool temperature from ~700°C to 1150°C.

The melt level is slowly brought up to normal by slurry feeding the melter at ~0.1 gpm (based on melt pool size). The electrical resistivity of the glass at 1150°C is about 1/100th of that at 700°C. The resistance of the glass pool also decreases as the melt level increases. During the initial stages of joule heating, the melter electrode power supply taps are configured to supply maximum voltage to act as an impetus for passing current in the circuit. The current available to the electrodes must be increased during the filling of the melt pool to raise melt pool temperatures to within normal operating limits. This is accomplished by changing the electrode power supply transformer settings.

When the molten glass is brought up to the normal level, slurry feeding is stopped and the upper electrodes are energized. At this point the startup phase is considered complete.

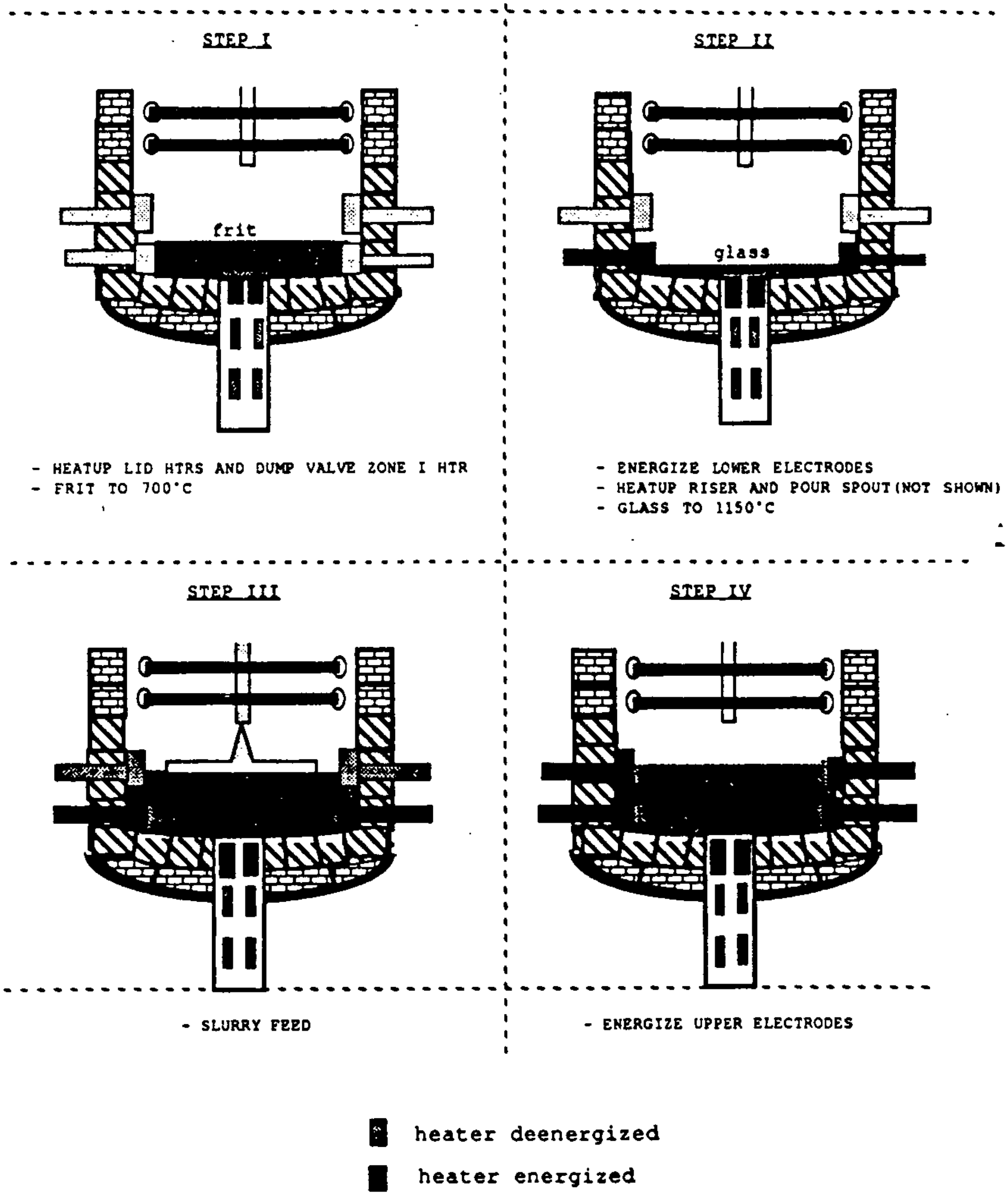


FIGURE 36. Proposed DWPF Melter Startup Sequence

IDMS Melter Heatup

The heatup of the IDMS Melter varied slightly from the proposed DWPF Startup Sequence described above. The major difference was that the melt level was brought up to operating level by charging the melter with dry frit instead of slurry feed. This was done to avoid splattering cold feed on the K-3™ refractories, especially the machined K-3™ throat block. This splattering on the unsupported throat block could have caused cracking and possible collapse of the throat block. Another difference was that the melt pool heated up faster than expected due to the higher ratio of lid heater surface area to melt pool surface area. Measures to 700°C were not necessary, although the lid heater skin temperatures were increased to 1050°C for approximately 12 hours. The melter pressure was kept at about -3" wc for the heatup. Highlights from each step of the heatup sequence follow in chronological order. Startup notes were kept in SRL laboratory notebook E58053.

After the checkout was completed, the IDMS Melter was charged with 200 lbs of Black Frit 165, bringing the frit level with the top of the bottom electrodes. Inspection through the feed tube top head flange and measurement of the frit charge using a rod inserted through this flange confirmed that the frit was level.

A low temperature monitoring system (LTMS) was used to control the heatup of the IDMS Melter heating systems below 300°C. This LTMS was utilized because the thermoelectric voltage of type B thermocouples in these heaters is <1 mV below 300°C. This voltage is below the range of conventional transmitters. On October 19, 1988, both of the lid heaters and the zone 1 dump valve were started. Below 300°C, amperage was manually ramped to the lid heaters and the zone 1 dump valve heater based on measurements from the LTMS. These increases were gauged such that the surface temperatures of the heaters increased less than 10°C per hour. When heater temperatures reached 300°C, the temperature controllers were tuned, the heaters were switched to automatic temperature control, and the heatup continued.

In the DWPF, the thermoelectric voltage from a thermocouple is converted to a temperature by the Distributed Control System (DCS) without a temperature transmitter. The DCS is capable of accurately reading the microvolt signal which the type B thermocouples output in the low temperature range. Therefore, an LTMS is not necessary for the DWPF Melter Startup.

Heatup of the lid heaters and the zone 1 dump valve continued without any major problems. A tripped breaker at the main substation did cause a delay in the heatup for a few hours. After the lid heaters reached 950°C, the riser and pour spout heaters were brought on line on October 23 at 19:20. At this time the bottom melt pool temperature was 500°C. It should be noted that the melt pool thermowell had thermocouples at only two different levels (see Figure 37), versus thermocouples placed at 1-inch increments in most previous melter heatups. Past experience on melter heatups had shown that this setup was not necessary. Power was increased to cause a temperature rise of

10°C per hour on the surface of the riser and pour spout heaters.

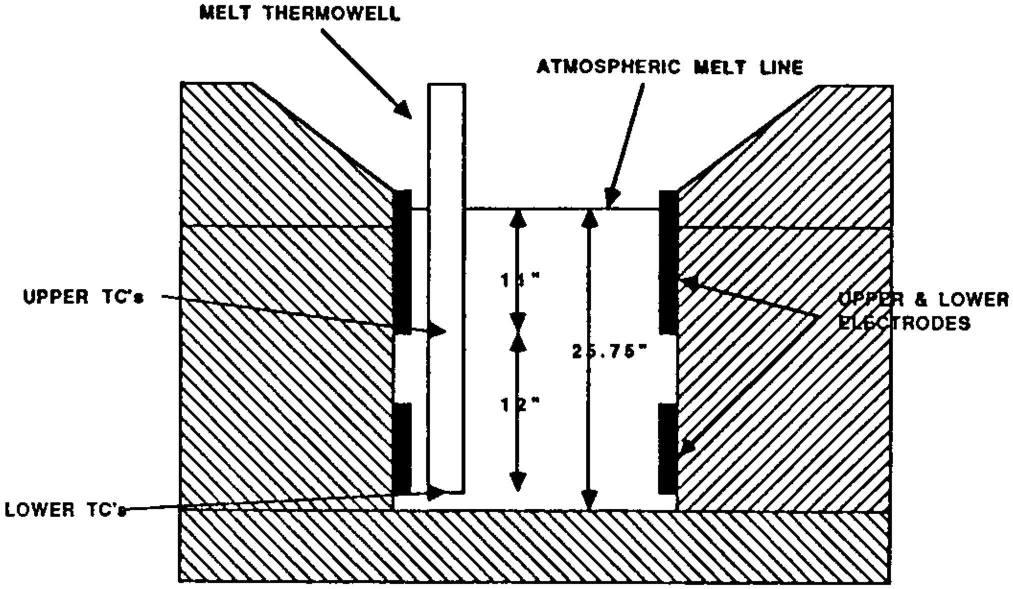
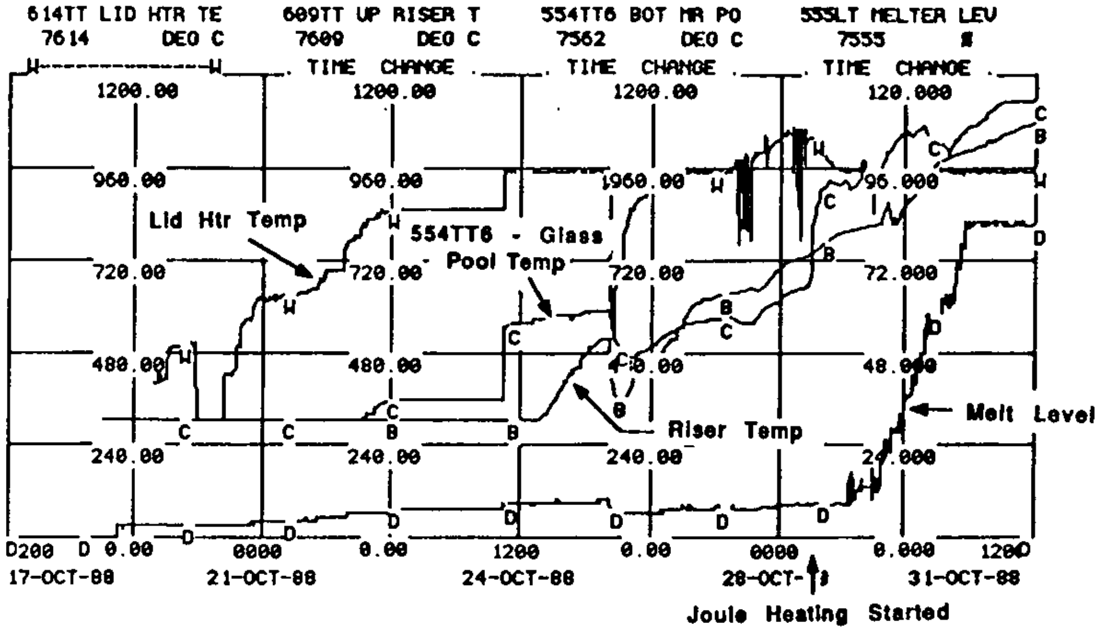


FIGURE 37. IDMS Melt Pool Thermocouple Heights

The temperature of these heaters was increased so as not to exceed the temperature of the frit charge at the bottom of the melter. Temperature monitoring and control of the riser and pour spout heaters was executed using the LTMS in a similar manner to the lid heaters and the zone 1 dump valve.

During the heatup of the riser and pour spout, it became apparent that the bottom pool temperature would reach 700°C well before the riser and pour spout. The unheated throat block was the cause for the slow heatup of the riser, and the high ratio of lid heater surface area to melt pool surface area caused the frit to heat up faster than in the Scale Glass Melter. Figure 38 shows the heatup of the lid heaters, the riser, the bottom melt pool, and the melt level during the startup. Prolonged soak times at 700°C or slightly higher temperatures can result in acmite and spinel formation (see Figure 39). Accumulation of these crystalline materials could partially block the riser throat block. Acmite will redissolve at temperatures above 800°C, but the spinels will remain in a crystalline form indefinitely. Therefore, an effort was made to keep the bottom pool temperature below 750°C.

At this time, the concerns for slurry feeding also surfaced. It was decided to fill the melter to the normal level by the addition of Black Frit 165. The slurry feed tube was removed, and a modified Scale Melter dry frit feed tube was installed in its place on October 25.



(Note: The data acquisition system was down from 18:00 on 10/22 to 10:00 on 10/24)

FIGURE 38. Summary of the Heatup of the IDMS Melter-Melt Level, Lid Heater, Riser, and Bottom Melt Pool Temperatures.

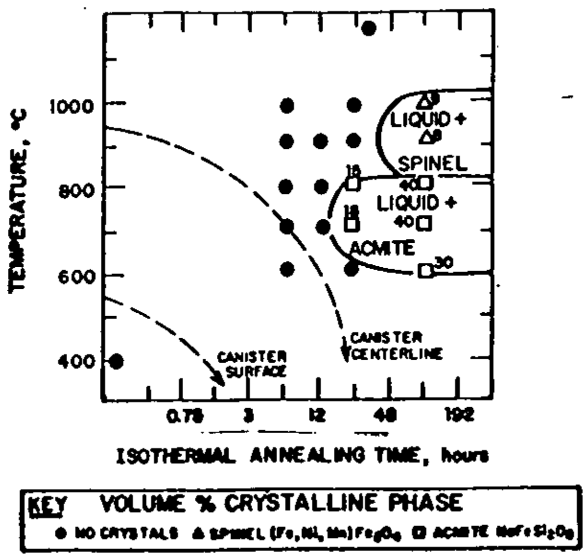


FIGURE 39. Time-temperature-transformation Diagram of 165 Black Frit Without RuO_2[6]

By October 27, the rise in the bottom melt pool temperature had slowed down to a few degrees Centigrade per hour. The surface skin temperatures of both pairs of lid heaters were therefore increased from 950°C to 1050°C. This temperature was held at 1050°C for 12 hours. The maximum allowable time for the lid heaters to be at 1050°C is 24 hours. Longer times than this may result in thermal creep of the lid heaters. Twelve hours was sufficient time to bring the bottom melt pool temperature up to 640°C. This corresponds to an estimated temperature of 750°C at the top of the frit charge.

On October 28, joule heating was established via the lower (C-D) electrodes. The amperage on the C-D electrode circuit was too small to accurately monitor during the initial stages of joule heating. Because of the low initial amperage, a jumper had been placed across the C-D power cables in the SCR before the heatup began. A clamp-on ammeter placed on the jumper was used to monitor these low-amperage readings. Table 14 shows the amperage readings during the initial stages of joule heating, beginning at the time that the C-D power supply was activated at 8:30 a.m.

Initially the heatup of the glass pool was about 20°C (instead of 10°C) because of problems in using the C-D controller in the power control mode. This controller was not properly tuned because it had not been used previously. In DWPF, the power controller should be tuned during the power supply checkout timeframe when the electrode power supplies are hooked to the lid heaters. The controller was put in manual in amperage control after approximately 2 hours, and the temperature monitored closely. The normal mode of control is amperage after the glass pool is up to operating temperature.

TABLE 14. **C-D Secondary Amperage and Voltage During Initial Joule Heating**

Time	Amperage	Voltage
8:30	0.1	191
8:43	1.1	191
8:45	1.2	191
8:50	1.3	191
8:55	1.5	191
9:00	2.1	191
9:05	2.5	191
9:15	3.4	191
9:35	5.8	191
10:45	12.5	191

Heatup of the riser and pour spout, along with the glass pool, continued on schedule. It soon became apparent, however, that the riser would not reach the setpoint temperature of 1100°C for control thermocouple 609TT. The current limit was reset from 170 to 185 amps, but it was still believed that this would not give the desired temperature. Based on the previous failure of the Scale Glass Melter riser heater during its initial startup, 185 amps was the maximum allowable current that was deemed safe to use on the riser. It was decided to begin slowly adding frit into the melter to increase the melt level. This would cause hot glass to flow into the riser channel, thereby providing additional heat to the riser.

Charging of the melter with buckets of frit began on October 29 at 11:25 a.m. One bucket of frit (approximately 37 lbs) was added every one to two hours until the melt level reached 80%. This level was achieved at 13:09 on October 30 after 564 pounds of frit had been added. This gave a total of 764 pounds of frit charged into the melter. Figure 40 shows the increase in the melt level during this time frame, as well as the increase in the riser 609TT temperature.

As the melt level increased, the resistance of the C-D electrode circuit decreased. This occurred because the cross-sectional area for current flow in the circuit increased, thereby decreasing the voltage required to drive a given amount of current. Therefore, the current available to the C-D electrodes was increased by

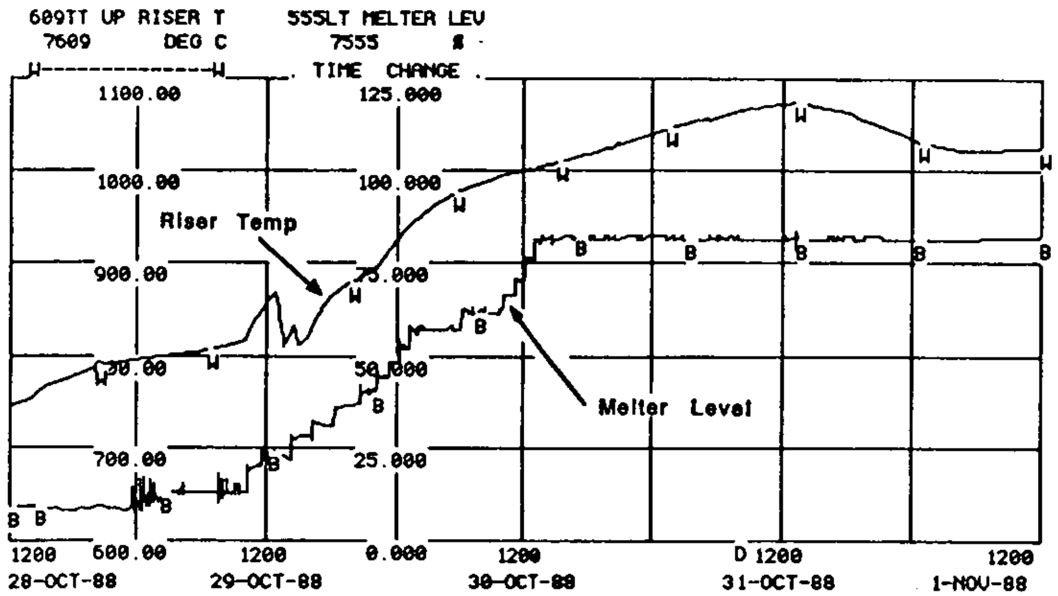


FIGURE 40. **Effect of Melt Pool Level on Riser Temperature at a Constant Riser Power Level**

changing the C-D electrode power supply transformer settings. The transformer was changed from the 379 amp/190 volt tap to the 1360 amp/53 volt tap (normal operating tap setting). This was necessary to provide enough amperage to raise the melt pool temperature to within normal operating limits.

Finally, after the melt pool was filled to 80%, the upper electrodes were brought on line.

Glass Plugs for Dump Valve

The dump valve system for IDMS was designed to be like the SGM's. It consisted of an insulated Inconel™ 690 stem that could be raised to allow glass flow. Glass plugs were placed inside the stem and then melted in place by energizing all three dump valve zone heaters to approximately 700°C. After the first drain on the SGM in February of 1988, the stem could not be lowered to make a good seal. The glass which solidified in the stem at the end of the drain was used as the only means of preventing glass from draining out of the SGM. The glass was then successfully remelted at the end of the melter run life to allow the contents to be drained. A drain can capable of holding the entire contents of the melter was kept under the melter at all times.

The IDMS dump valve is slightly different because the bottom end of the drain tube was necked down. This prevented the insertion of the plugs from the bottom of the stem. The stem had to be removed to expose the cylindrical Inconel™ 690 portion of the drain valve. Removing the stem required the removal of the feed tube from the melter top head. This gave a straight access to the top of the tube. The actuator arm was engaged to lift the tube 3-1/2" from the bottom of the melter floor. A rod was inserted into the melter to hook and retract the dump stem. The possibility of noble metals plating out on the top flange and soldering the stem to the tube was also a concern on the IDMS. This concern and the SGM experience prompted the removal of the dump stem.

The glass plugs were made using graphite molds. The SGM molds were modified by machining them to produce the proper diameter plugs for IDMS. The glass composition was selected to minimize devitrification products which could potentially block the drain tube. The composition chosen is stable over the range of temperatures that will be present in the drain valve tube. Table 15 shows the composition.

Several problems arose during the manufacture of the plugs. The first was the deterioration of the graphite molds during annealing. The molds began to oxidize on the exterior surfaces. This caused them to become weaker and started to expose the bolts holding the three pieces together.Two of the molds became unusable and the third had to be reused several additional times. An unforeseen consequence was the increased diameter of the plugs caused by wear around the junction of the mold pieces. This resulted in several of the glass plugs being slightly too large to fit into the dump valve. These plugs had to be ground down using a diamond belt sander in the glass shop. Since the plugs would be remelted and annealed in the valve, stresses caused by the grinding were not a problem. One mold leaked glass during an annealing cycle and caused the rebuilding of the furnace.The loss of the furnace in 773 forced the last plugs to be made at TNX.

This required that the powders be melted in 773 and poured into crucibles. This premelted glass was taken to TNX where it could be remelted at a lower temperature. A one piece mold was fabricated at TNX to complete the last plugs.

The actual insertion and heating of the plugs took place over a 4 day period from August 15 to 18th. TNX Job Plan 672T-88-8-1 was used to fuse the plugs. A rod of Inconel™ (1.245" Dia. by 4.50" long) was used to hold the plugs in place while the heaters were energized.The temperature was brought from room temperature to 750°C at approximately 10°C/hr. This temperature was chosen to lessen the chance of shocking the refractory. After the zones had been heated and cooled, the dump valve was checked for glass leakage. A small amount of glass had leaked around the Inconel plug. This confirmed that the bottom zone had reached sufficient temperature and also helped seal the Inconel rod as a permanent physical stop. The rod was later supported by modifying the existing dump valve actuator arm. This will allow the Inconel™ rod to be remotely removed prior to draining the melter contents.

TABLE 15. **IDMS Dump Valve Glass Plug Components**

RAW MATERIAL:	WEIGHT %
BORAX	39.3
Na_2CO_3	19.8
SILICA SAND	37.7
$CaCO_3$	3.2
	100.0

IDMS Melter Heaters - Real versus Expected Power Requirements

Prior to the startup, IDMS Melter heater power requirements and current limits were calculated. Table 16 gives a summary of these requirements.

TABLE 16. IDMS Melter Heater Power Requirements - Calculated versus Actual

Heater	Calculated kW Needed	Actual kW Needed
Electrodes	40 (both)	35
Lid Heaters	60 (both)	60
Riser	3.3	4.6
Pour Spout	2.1	3.5
Dump Vlv. Z-1	0.7	0.9

Both the lid heater and electrode calculated power requirements were close to the actual power that is being used for those heaters. The riser and pour spout, however, are using larger amounts of power than expected. This is true even though both were being run at temperatures lower than the Scale Melter riser and pour spout. The riser temperature for 609TT (the calculated hot spot) was 1050°C at 4.6 kW. Higher power levels were not initially used for concern of burning out the riser heater. Calculations have shown that 6 kW is a conservative maximum kW usage for the riser[7]. The higher riser power requirement is attributed to the unheated riser throat block, as it is a heat sink where much of the heat from the glass pool is lost before it enters the riser channel.

With the lower riser and pour spout temperatures, no problems were encountered with glass pouring during the initial attempts after the startup, as 740 pounds of glass were poured in November, 1988. Pluggage of the pour spout occurred, however, at least seven times during the sludge-only batch #2 run. It is believed that the low riser/pour spout temperatures contributed to the problem. The riser and pour spout were then gradually heated so that 604TT (pour spout heater control TC - located at the hot spot), and 609TT (riser heater control TC, located at the hot spot) were both at 1100°C. The heater requirements were 5.1 kW for the riser and 3.7 kW for the pour spout. More details of the power increase are given in the Pouring Problems section included in the Second Sludge part of this report.

Glass Pouring

In order to initiate glass pouring, a vacuum is created in the pour spout relative to the vacuum in the melter plenum. This is accomplished by pumping recirculated condensate through the melter spout jet. Control air is added to the vacuum line (between the pour spout and spout jet) to control the differential pressure between the pour spout and the melter plenum.

The vacuum pour system may be operated in two modes: IDLE or POUR. Each mode has separate setpoints for spout jet water flow and differential pressure. In the IDLE mode, the spout jet water (714FT) is controlled at a relatively low flow rate, usually 15 gpm. The differential pressure controller (754PT) is set at some positive setpoint between 0" and 5" wc. This pressure is controlled by the addition of air into the vacuum line. In the POUR mode, the spout jet water is controlled at 30 gpm, increasing the amount of vacuum available to the pour spout. The differential pressure controller is set to control at the ΔP required for pouring.

With the melter level at 105%, a melter-to-pour spout differential pressure of -9" wc was necessary to initiate glass pouring. The vacuum was then immediately increased to -14" wc to avoid wavering and splitting of the glass stream. The pouring operation was observed on CCTV via a camera mounted at the pour spout bellows. The glass stream appeared to flow steadily, with no wavering or splitting observed.

FEED PREPARATION OF SLUDGE-ONLY BATCHES 1 AND 2

Campaign Overview

The IDMS facility performed two feed preparation (SRAT/SME) batches. No Precipitate Hydrolysis Aqueous (PHA), trim chemicals, mercury compounds, or noble metals were added; thus the campaign is referred to as "sludge-only".

Some general objectives for the sludge-only SRAT/SME campaign were to: 1) produce feed for the start-up of the IDMS melter (batch 1 only), 2) checkout the SRAT/SME system operation using simulated sludge and frit to verify tank heat transfer and SRAT/SME condenser performance, 3) checkout the PVVS operation and FAVC performance during actual SRAT/SME operation, and 4) checkout the WWPT operation and Ultrafilters with actual SRAT/SME condensate.[8]

Raw Materials Used

These SRAT/SME runs were performed using simulated sludge purchased from AFF, Inc., and Frit-165 purchased from Ferro Corporation. 1469 lbs of sludge, 3000 lbs of Frit-165, and 328 lbs of formic acid were used in each sludge-only run (see Appendix J for batch spreadsheet calculations). Table 17 shows the assumed and analytical compositions of the simulated sludge[6] and the assumed and analytical compositions of the Frit-165[9].

TABLE 17. Assumed and Analytical Compositions of Simulated Sludge and Frit 165

SIMULATED SLUDGE

COMPONENT	ASSUMED	ANALYSIS
Al	6.823	6.146
B	0.000	0.000
Ba	0.000	0.028
Ca	2.827	3.220
Cr	0.239	0.359
Cu	0.288	0.362
Fe	23.014	28.790
Group B	0.560	0.000
K	0.230	0.475
Li	0.000	0.000
Mg	0.000	0.000
Mn	4.765	0.603
Na	3.929	3.628
Ni	2.203	2.817
P	0.046	0.064
Si	3.373	0.000
Ti	0.000	0.000
Zn	0.000	0.278
Zr	0.000	0.000

FRIT-165

COMPONENT	ASSUMED	ANALYSIS
B2O3	10.00	9.58
Li2O	7.00	6.60
MgO	1.00	0.94
Na2O	13.00	12.70
SiO2	68.00	65.80
ZrO2	1.00	1.29
Al2O3	0.00	0.26
TiO2	0.00	0.72
Fe2O3	0.00	0.04
CaO	0.00	0.13
BaO	0.00	0.06
K2O	0.00	0.40
SUM	100.00	98.52

Sludge-only Batch 1 (SRAT BATCH NO. 10-3-88)

The first sludge-only feed preparation batch (referred to as SRAT BATCH NO. 10-3-88) was begun on 10/3/88 by transferring sludge from the Slurry Receipt Tank (SRT) to the IDMS SRAT/SME. The contents were then concentrated to 20 wt% solids. The formic acid was then added and the contents were refluxed for 6 hours. The batch was then completed by adding a 50 wt% frit-water slurry from the Frit Slurry Make-up Tank (FSMT) to the SRAT/SME and concentrating the contents to 44 wt%. All processes in sludge-only run 1 went as planned. The resulting melter feed composition and predicted liquidus temperature and viscosity is shown in Table 18.

Sludge-only Batch 2 (SRAT BATCH NO. 1-13-89)

The second sludge-only feed preparation batch (referred to as SRAT BATCH NO. 1-13-89) was begun on 1/13/89 by transferring sludge from the Slurry Receipt Tank (SRT) to the IDMS SRAT/SME.

Sludge Transfer

The required amount of simulated sludge was approximately 977 gallons (1469 lbs sludge solids). A totalizer which integrates the flow rate of the entering sludge (106FT) was used to determine the amount of sludge added. This totalizer was verified by the change in volume of the SRT. The sludge transfer flow meter during transfer was ranged for flows of 0-50 gpm. However, when the sludge was transferred, it was pumped at a flow rate exceeding the 50 gpm upper range of the transmitter. The totalizer summed the sludge transferred at 977 gallons but actually, based on the change in the SRT volume, the amount added was 1250 gallons. The flow transmitter (106FT) was recalibrated at 0-60 gpm and the sludge transfer procedure was revised to caution against exceeding 50 gpm.

Formic Acid Addition

To prepare for formic acid addition the contents of the SRAT were heated to approximately 96°C. 33 gallons of 90 wt% formic acid were added to the SRAT. This was followed immediately by a six hour digestion period (boiling at total reflux). On the following day 8 more gallons were added to the SRAT to compensate for the extra sludge solids which were added in error. Again the contents were boiled at total reflux for 6 hours. This completed the "SRAT cycle" of the sludge-only SRAT/SME operation.

Antifoam Agent

No antifoam agent was added prior to the formic acid digestion period. In all subsequent boiling periods, 100 ml of Dow Corning #544 antifoam agent was added to the SRAT/SME prior to initializing heat-up. In all cases where the antifoam agent was added prior to boiling, very little solids carryover was observed.

oxide	mole wt	Free Energ	Oxide Fac	lbs oxide	Wt% Oxide	Wt% elemt	Lb moles	Mole %	Del G hyd
Ag2O	231.760		1.0000	0.000	0.000		0.000	0.000	0.000
Al2O3	101.940	3.040	1.8890	2.834	3.588	1.500	0.028	2.281	0.069
B2O3	69.640	-9.930	3.2190	6.245	7.907	1.940	0.090	7.360	-0.731
BaSO4	233.420	-30.570	1.6997	0.034	0.043	0.020	0.000	0.012	-0.004
CaO	56.080	-16.116	1.3990	1.203	1.523	0.860	0.021	1.761	-0.284
Cr2O3	152.020	37.360	1.4610	0.102	0.129	0.070	0.001	0.055	0.021
Cs2O	281.810	-46.820	1.0602	0.000	0.000		0.000	0.000	0.000
CuO	79.570	1.790	1.2510	0.063	0.079	0.050	0.001	0.065	0.001
Fe2O3	159.700	15.500	1.4290	10.832	13.715	7.580	0.068	5.567	0.863
FeO	71.850	-14.609	1.2860	0.051	0.065	0.040	0.001	0.059	-0.009
Grp B	122.970		1.0000	0.000	0.000		0.000	0.000	0.000
HgO	216.610		1.0800	0.000	0.000		0.000	0.000	0.000
K2O	94.190	-41.735	1.2020	0.361	0.457	0.300	0.004	0.314	-0.131
Li2O	29.880	-22.740	2.1520	4.282	5.422	1.990	0.143	11.763	-2.675
MgO	40.320	-13.880	1.6580	0.613	0.777	0.370	0.015	1.249	-0.173
MnO	70.930	-14.871	1.2910	2.169	2.746	1.680	0.031	2.510	-0.373
Na2O	61.990	-28.815	1.3480	8.762	11.094	6.500	0.141	11.600	-3.343
NiO	74.690	-14.347	1.2720	1.056	1.337	0.830	0.014	1.160	-0.166
P2O5	141.890	-53.620	2.2910	0.000	0.000	0.000	0.000	0.000	0.000
Pd	122.700		1.1500	0.000	0.000		0.000	0.000	0.000
PbO	223.210	-8.810	1.0772	0.000	0.000		0.000	0.000	0.000
PuO2	274.000		1.1229	0.000	0.000		0.000	0.000	0.000
Rh	134.900		1.3110	0.000	0.000		0.000	0.000	0.000
Ru	165.700		1.3230	0.000	0.000		0.000	0.000	0.000
SeO2	110.960		1.4052	0.000	0.000		0.000	0.000	0.000
SiO2	60.060	5.590	2.1390	38.716	49.021	18.100	0.645	52.905	1.210
SrO	103.630	-24.400	1.1830	0.000	0.000		0.000	0.000	0.000
TeO2	159.600		1.2508	0.000	0.000		0.000	0.000	0.000
ThO2	264.120		1.1383	0.000	0.000		0.000	0.000	0.000
TiO2	79.900	15.990	1.6680	0.434	0.549	0.260	0.005	0.445	0.071
UO2	270.000	-6.800	1.1344	0.000	0.000		0.000	0.000	0.000
Y2O3	225.810	-12.950	1.2690	0.000	0.000		0.000	0.000	0.000
ZnO	81.380	-2.400	1.2450	0.237	0.300	0.190	0.003	0.239	-0.006
ZrO2	123.220	45.100	1.3508	0.986	1.249	0.730	0.008	0.657	0.296
				78.979	100.000	43.010	1.218	100.000	-5.363
			Alk+B / Si	0.5867					
			Alk / Si	0.4475	Predicted Liquidus (Deg C)			1021	
			B /Si	0.1391					
			Alk+B / Si+Al	0.5624					
			Alk+B / Si+Al+Fe	0.5106					
			Fe+Ni / Si	0.1277	Predicted Viscosity (Poise)			44	
			Fe/Si	0.1058					

TABLE 18. Sludge-Only Batch #1 - Melter Feed Composition, Predicted Liquidus and Viscosity

Solids Adjustment

The amount of sludge solids added in the SRAT/SME batch was based on a sludge solids to frit ratio. The frit is added from a tote bin which holds 3000 lbs of the Frit-165. Since the frit solids are constant, adding extra sludge solids increases the sludge solids to frit ratio and increases the glass liquidus temperature. In order to reduce the sludge solids in the SRAT/SME, 69 gallons of formatted sludge (158 lbs of sludge solids, see Laboratory No. E 58052 - p.54-58 for calculations) were transferred to the Melter Feed Tank (MFT). The MFT contained about 650 gallons of melter feed made in the first sludge-only run. This balance of sludge solids lowered the SRAT/SME contents estimated liquidus temperature from 1029°C (with the extra sludge solids) to 1012°C.

SME Cycle

The "SME cycle" of the SRAT/SME operation was then started by making a 50 wt% frit-water slurry mixture in the Frit Slurry Make-up Tank (FSMT). This frit slurry was made by adding 3000 lbs (one tote bin) of Frit-165 to 460 gallons of water. This frit slurry was then transferred to the SRAT/SME tank. Additional water was added to the system in order to flush the FSMT of residual frit and to flush the transfer line to the SRAT/SME. The fritted sludge was then concentrated to the desired 45 wt% solids. The SME product was then cooled and sampled. The resulting melter feed composition and the predicted liquidus temperature and viscosity are shown in Table 19.

3-Way Valve Failure

The IDMS uses DWPF reference three-way valves in the melter feed system. These valves are made by the Everlasting Valve Company and are called "The Everlasting Three-Way All-Way Valve". The three-way valves are simple in design and operation (Figure 41). The valve has three ports for fluid flow. Feed slurry normally flows through one port and out a second with the third, flush water, closed. Water pressure is maintained on the closed flush water port to prevent the possibility of back flow of slurry through the flush water piping. A manual water flush is accomplished by stopping slurry flow (*ie.* stopping the melter feed pump) and opening the flush water port to either the slurry supply port or the slurry exit port. All fluid flow takes place within the valve body cavity. Tight sealing of the body plating insures that no fluid will leak out of the valve body cavity. The valve is positioned by the use of an Auma electrical actuator which rotates the transmission shaft which thereby rotates the attached spring loaded disks to either open or cover the valve ports. The diameter of the disk contact surface is larger than the outer diameter of the seat bushing to provide for more than adequate coverage of the inlet and outlet piping ports. The springs are used to apply pressure to seat the disks on the seat bushings.

oxide	mole wt	Free Energ	Oxide Fac	lbs oxide	Wt% Oxide	Wt% elemt	Lb moles	Mole %	Del G hyd
Ag2O	231.760		1.0000	0.000	0.000		0.000	0.000	0.000
Al2O3	101.940	3.040	1.8890	3.060	3.920	1.620	0.030	2.482	0.075
B2O3	69.640	-9.930	3.2190	5.859	7.504	1.820	0.084	6.956	-0.691
BaSO4	233.420	-30.570	1.6997	0.034	0.044	0.020	0.000	0.012	-0.004
CaO	56.080	-16.116	1.3990	1.399	1.792	1.000	0.025	2.063	-0.332
Cr2O3	152.020	37.360	1.4610	0.102	0.131	0.070	0.001	0.056	0.021
Cs2O	281.810	-46.820	1.0602	0.000	0.000		0.000	0.000	0.000
CuO	79.570	1.790	1.2510	0.113	0.144	0.090	0.001	0.117	0.002
Fe2O3	159.700	15.500	1.4290	9.201	11.786	6.439	0.058	4.764	0.738
FeO	71.850	-14.609	1.2860	0.832	1.066	0.647	0.012	0.958	-0.140
Grp B	122.970		1.0000	0.000	0.000		0.000	0.000	0.000
HgO	216.610		1.0800	0.000	0.000		0.000	0.000	0.000
K2O	94.190	-41.735	1.2020	0.288	0.370	0.240	0.003	0.253	-0.106
Li2O	29.880	-22.740	2.1520	3.766	4.824	1.750	0.126	10.422	-2.370
MgO	40.320	-13.880	1.6580	0.613	0.786	0.370	0.015	1.258	-0.175
MnO	70.930	-14.871	1.2910	2.143	2.745	1.660	0.030	2.498	-0.372
Na2O	61.990	-28.815	1.3480	9.005	11.534	6.680	0.145	12.011	-3.461
NiO	74.690	-14.347	1.2720	0.941	1.206	0.740	0.013	1.042	-0.150
P2O5	141.890	-53.620	2.2910	0.000	0.000	0.000	0.000	0.000	0.000
Pd	122.700		1.1500	0.000	0.000		0.000	0.000	0.000
PbO	223.210	-8.810	1.0772	0.000	0.000		0.000	0.000	0.000
PuO2	274.000		1.1229	0.000	0.000		0.000	0.000	0.000
Rh	134.900		1.3110	0.000	0.000		0.000	0.000	0.000
Ru	165.700		1.3230	0.000	0.000		0.000	0.000	0.000
SeO2	110.960		1.4052	0.000	0.000		0.000	0.000	0.000
SiO2	60.060	5.590	2.1390	38.930	49.865	18.200	0.648	53.598	1.289
SrO	103.630	-24.400	1.1830	0.000	0.000		0.000	0.000	0.000
TeO2	159.600		1.2508	0.000	0.000		0.000	0.000	0.000
ThO2	264.120		1.1383	0.000	0.000		0.000	0.000	0.000
TiO2	79.900	15.990	1.6680	0.517	0.662	0.310	0.006	0.535	0.086
UO2	270.000	-6.800	1.1344	0.000	0.000		0.000	0.000	0.000
Y2O3	225.810	-12.950	1.2690	0.000	0.000		0.000	0.000	0.000
ZnO	81.380	-2.400	1.2450	0.361	0.462	0.290	0.004	0.367	-0.009
ZrO2	123.220	45.100	1.3508	0.905	1.159	0.670	0.007	0.607	0.274
				78.070	100.000	42.616	1.209	100.000	-5.322
			Alk+B / Si	0.5531					
			Alk / Si	0.4233	Predicted Liquidus (Deg C)			1000	
			B /Si	0.1298					
			Alk+B / Si+Al	0.5286					
			Alk+B / Si+Al+Fe	0.4834					
			Fe+Ni / Si	0.1173	Predicted Viscosity (Poise)			55	
			Fe/Si	0.0978					

TABLE 19. **Sludge-Only Batch #2 - Melter Feed Composition, Predicted Liquidus and Viscosity**

One such valve is a 2" three-way valve located in the feed recirculation loop. The three possible positions of this valve are: 1) feed to pump, 2) flush to tank, and 3) flush to pump. Flush water to this three-way valve is usually valved off since excessive flushing of the recirculation loop will dilute the feed in the Melter Feed Tank.

After a period of feeding the melter, the valve was actuated to the"flush to pump" position to flush the recirculation line. The valve was then put back into the "feeding" position. However, the flush water line which is usually manually valved out was left in the open position. Since the valve was in the feed position, the flush water inlet port was closed by a disk. The maximum vendor specified inlet pressure is 80 psig. The flush water pressure, which was in excess of 110 psig, was greater that that exerted by the springs and the disk became unseated. This allowed flush water to leak into the valve cavity and dilute the feed recirculation flow. The flush water pressure was brought down to below that recommended by the vendor by the installation of a regulator. Since the installation of the regulator, no leakage has occurred.

RECOMMENDATION #3 - DWPF should verify that the process water pressure to the three-way valves is below the design pressure of the Everlasting Three-way Valves.

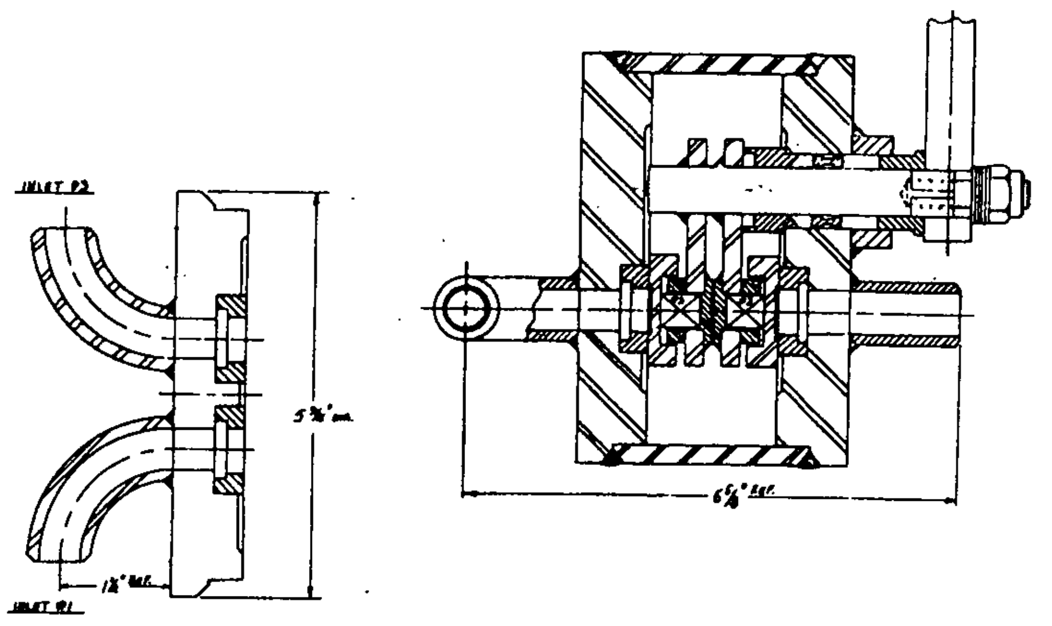


FIGURE 41. MFT Three-Way Valve

The flush water leak to the pump filled and eventually overflowed the MFT before all process water to the tank was valved shut. The resulting material in the MFT was 1200 gallons at 14 wt% solids. The SRAT/SME contained 1250 gallons of the just completed second sludge-only feed batch at 45 wt% solids. The contents of the MFT (excluding the 240 gallon heel) were sent to the SRAT/SME in 50 gallon batches and boiled in order to remove the excess water. The entire contents of the SRAT/SME were then transferred back to the MFT.

INITIAL FEED AND OFF-GAS SYSTEM OPERATION

When melter feeding was first attempted, a problem was encountered due to off-gas system dynamics. When melter feeding is initiated, vaporization of water in the melter feed causes a sudden pressure increase in the melter. The system responds by sharply cutting back the flow of control air. This sudden loss of about 100 lb/hr of non-condensibles in the off-gas causes the total off-gas flow to decrease significantly. The pressure throughout the off-gas system also increases momentarily, until the off-gas blower adjusts to the change. Originally, interlocks were present in the feed system logic which stopped feeding instantaneously if the off-gas flow dropped below 100 lb/hr or if the SAS exit pressure went above -1" wc. In order to permit the system to stabilize after initiating melter feeding, 30-second timers were added to the programming logic for these two interlocks.

Another interlock was originally present that prevented feeding and pouring from occurring simultaneously. This interlock stopped feeding if the melter-to-pour spout differential pressure went below -10" wc. As mentioned in the Glass Pouring section, a differential pressure of -9" wc was necessary to initiate glass pouring, and the vacuum was immediately raised to -14" wc once pouring was achieved. Therefore, this interlock stopped feeding each time glass pouring was initiated. The interlock was removed from the programming logic, thereby allowing simultaneous feeding and pouring.

The equilibrium of the off-gas system operation was also disturbed by one other set of interlocks. "Low quencher water flow", "bellows up", "cart not at melter", and "High High canister level" shut off water flow to the spout jet and caused the spout jet control air to go to its maximum flow rate of 150 lb/hr. The addition of the extra air into the system can overload the blower, making it difficult to maintain the melter at the desired pressure of -5" wc. After evaluating the situation, it was determined that if one of these conditions occurs, glass pouring should be stopped, but the spout jet should be allowed to stay on. Therefore, the interlock was changed to switch operation from POUR mode to the IDLE mode in the event that one of these situations occurs. The differential pressure controller for the IDLE mode was also modified so that a negative setpoint cannot be entered into the controller, preventing inadvertent pouring if an interlock condition exists.

POST-STARTUP TESTING

Heat Loss During Power Failure

The rate of heat loss in the melter during power outages is an important parameter to determine. This information is needed to predict the response time available during an outage before the glass pool temperature falls into an acceptable range. The resistance of the glass increases significantly with lower temperatures, in turn slowing down the reheat rate. The formation of spinels at sustained lower temperatures is also a problem that must be avoided.

The time-temperature relationship was observed under two conditions of electrode power failure. The first was with all heaters being turned off. The second condition allowed the lid heaters to remain on during the electrode outage. Table 20 shows the information derived from Vantage during the two power outages.

TABLE 20. Temperature Loss on Electrode Power Failure (°C/minute)

	Lid Heaters On	Lid Heaters Off
Top Pool (554TT-3)	1.40	1.83
Bottom Pool (554TT-6)	1.25	1.33

The data indicates that any scheduled outage should be kept under 1-1/2 hours in duration. This will prevent the bottom pool temperature from dipping below 1000°C, provided that the melter is in a normal condition prior to the outage.

RECOMMENDATION #4 - DWPF should run a test during cold runs to determine the cool down time of the melter down to 1000°C.

Cooling Water Loss

The cooling system for the IDMS melter consists of a 1000-gallon tank and a 470-gpm pump for circulating water through the system. A backup pump is also available, and automatically comes on line if the first pump stops for any reason. The water to fill the tank is provided by the 672-T cooling tower, which is a Marley Model 2-8906 twin cell tower with a flow capacity of 1000 gpm. There is also a backup cooling system that allows process water to be valved into the system in case of a pump failure. This water does not recirculate, but goes directly to the building contact drain.

Operation of the cooling water system can be affected by several events. Loss of electrical power will stop both circulating pumps, which will cut off all flow to the melter system.

Secondly, a loss of replacement water from the cooling tower will cause an increase in the temperature of the cooling water.

The effect of makeup cooling water loss was observed during several outages to determine the rate of temperature rise at several points in the melter cooling system. With the melter at normal idle conditions, the valve that controls the makeup water was closed. The temperature rise was observed and found to be approximately 10°C/hr. This increase was consistent throughout the system, since recirculation tends to equalize the water temperature.

The loss of all cooling water flow was not tested due to the possibility of overheating the water in the melter feed tube. It was decided to instead calculate the effect by means of a mathematical model. The results of the model indicate that a loss of water flow for a period in excess of two hours may cause the water in the lines to boil[10].

MELTER/OFF-GAS PERFORMANCE FOR SLUDGE-ONLY BATCH #2

Melter

During the second sludge-only run, a total of 5278 pounds of glass was produced. It should be noted that a portion the feed for this glass came from the first sludge-only feed preparation campaign. Several problems occurred during the run, including glass pluggage, feed tube pluggage, and an event which caused the pour spout, riser, and upper glass pool to cool down, even with maximum power going to the respective heaters. These problems are discussed in detail below.

Glass Pluggage in the Pour Spout

In at least seven instances, the pour spout was restricted with glass during pouring. This necessitated removing the canister and knocking the plug out of the pour spout. Initially, the pluggages were attributed to processing problems, as several low-rate pours were made inadvertently when the bellows was lowered onto a new canister. This was due to the melter pour spout delta pressure controller (754PC) going to a high output (and resultant high pour spout vaccum) when the pouring program was reset because of controller windup. The 754PC setpoint was 15 gpm, but the actual flow was 0 gpm when the glass pouring program was E-stopped. Therefore, the controller would try to open the spout jet water valve (754PV) more and more. A solenoid valve on 754PV prevented it from actually opening.

When the pouring program was reset, 754PV would open to the amount called for by the controller (much higher than normally needed), and a momentary high flow of water occurred, thereby causing a high vacuum in the bellows until the controller settled out to the correct flow of 15 gpm. This problem was fixed with a software change. When the glass pouring program is now E-stopped, 754PC is put into manual and a default output of 10% is set. This output is close to the output needed when the program is reset, and no windup occurs.

RECOMMENDATION #5 - DWPF should add controller anti-windup programming in the DCS where applicable.

Pluggages, however, continued to occur after this fix. These pluggages started on the melter side of the pour spout, and seemed to be in the region of the secondary channel exit (see Figure 42). The glass stream normally disengages from the pour spout at the primary channel exit point, but it can make contact with the channel below this point if the pour stream wavers. A major contributor for a wavering glass stream is a pour spout which is not hot enough.

Figure 43 shows the temperature profile of the pour spout with pour spout control thermocouple temperatures (604TT) of 1020°C and 1090°C. Initially the 604TT setpoint was 1020°C due to the higher than expected power required on the pour spout (see the section entitled - "IDMS Melter Heaters - Real Versus Expected

Power"). After some heat transfer calculations, the maximum allowable 604TT setpoint was increased from 1020°C to 1100°C. The primary channel exit point temperature was increased from 932°C to 974°C as shown on the temperature profile. The observed primary exit point temperature would have been a few degrees higher if the profile had been done at a setpoint of 1100°C versus 1090°C.

Glass pouring was improved after the setpoint was increased to 1100°C. Work will be done in the future to investigate the possibility of insulating the pour spout in the area near the secondary channel exit points, as increasing the 604TT setpoint does not raise the secondary exit point temperature.

RECOMMENDATION #6 - DWPF should conduct a pour spout temperature profile after melter heatup and prior to the first pour.

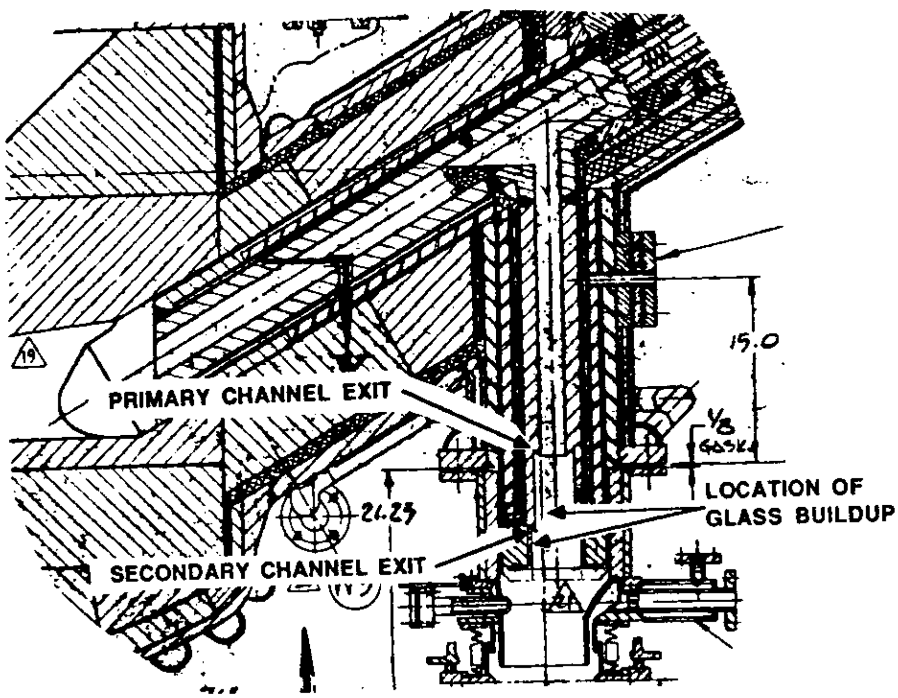


FIGURE 42. Location of Glass Buildup in the Pour Spout

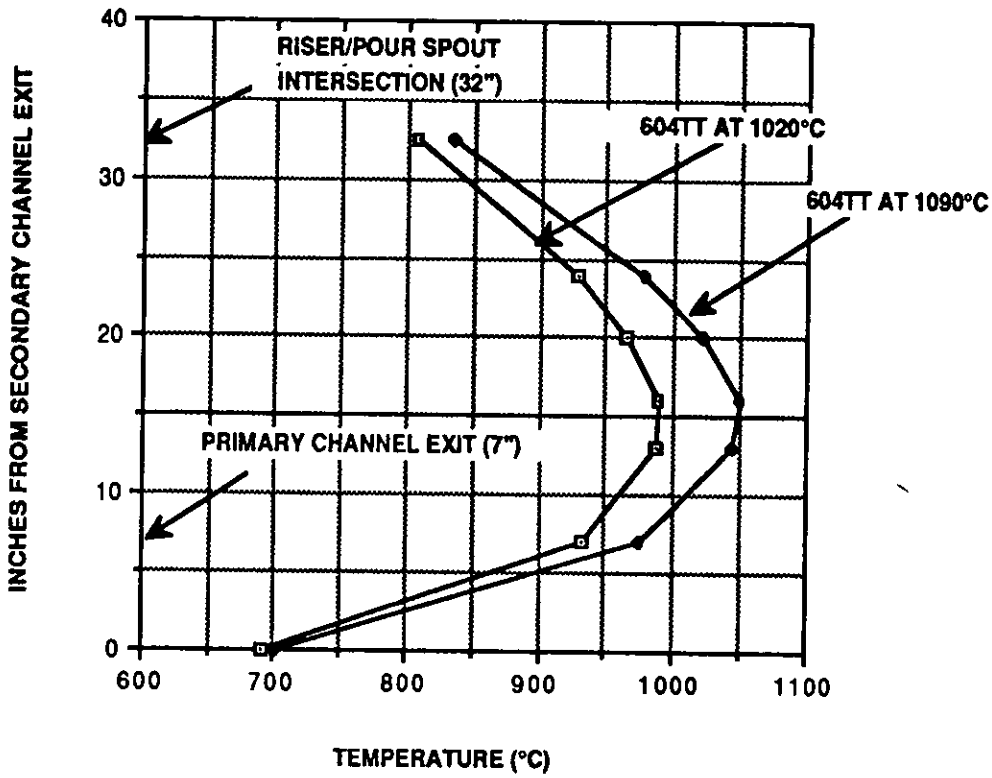


FIGURE 43. **Temperature Profile of Pour Spout With 604TT Setpoints of 1020°C and 1090°C.**

Loss of Temperature Phenomena in Melter

On February 3, 1989, the upper glass pool, riser, and pour spout began to cool down for no obvious reason. The temperatures continued to drop, even though all three heaters were receiving the maximum power available. The following gives a scenario of the problem. It should be noted that Vantage (the data acquisition system for IDMS) was down during this time, so no time plots are available.

At 14:00, wiring work in the Modicon caused a fuse to blow to an input card containing many of the melter/off-gas pressure readings. These false readings caused an interlock to shut down the pour system, opening 754PV (melter/pour spout differential pressure control valve) to 100% (see Figure 44 below for schematic) and completely closing the spout jet water flow valve. The control air flow through 754PV was above 751FT's range (150 pph), so the actual flow is unknown. The melter/pour spout differential pressure (754PT) was also above the maximum range for the transmitter of +15" wc.

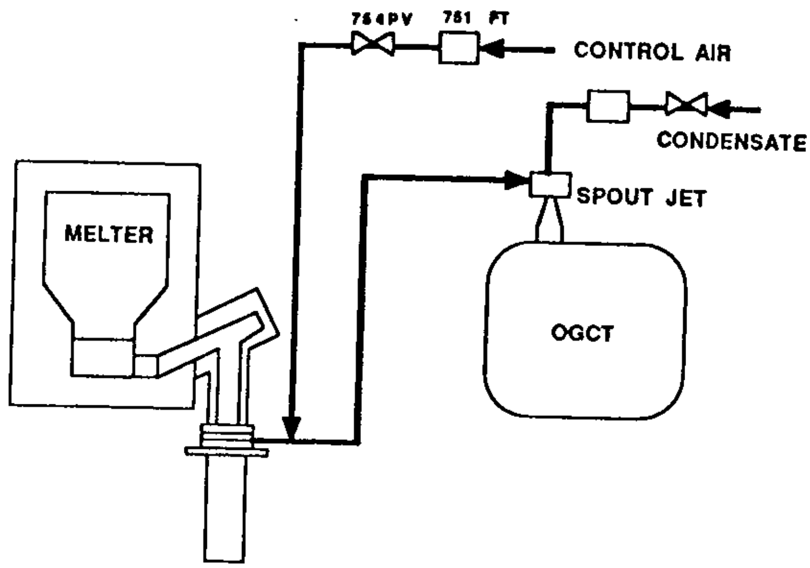


FIGURE 44. **Schematic of Vacuum Pour System**

The large flow of air came through the pour spout and pushed the glass down in the riser. This air bubbled through the glass in the riser, and into the melter. These air bubbles lowered the specific gravity of the glass, and the indicated melt level began to decrease from 95% to 77%, even though the actual glass level was the same. The indicated reading changed, however, because the melt level calculation uses a constant value for specific gravity. At the same time, the air cooled the riser, pour spout, and upper glass pool by 110°C, 240°C, and 90°C, respectively. The lower glass pool temperature stayed the same because the riser entrance in the glass pool is above the lower glass pool thermocouples.

When the bellows was raised, the temperatures began to increase. After this event, a pressure regulator was placed on the 754PC air line, and the maximum allowable air flow was decreased to 130 pph. The 754PT was also reranged from -15/+15" wc to -50/+50" wc. This problem has not reoccurred since the regulator was installed.

RECOMMENDATION #7 - DWPF should ensure that a pressure regulator is installed (and set properly) on the melter/pour spout pressure control air line.

RECOMMENDATION #8 - DWPF should rerange the melter/pour spout delta pressure transmitter to at least 55" wc on the positive side.

Feed Tube Pluggage

The feed line to the melter plugged on three occasions during the sludge #2 run. The main cause of these blockages is thought to be the need for frequent stops and starts of the feed system. The flow of the feed when the system first starts up is very slow. The rate increases and will stabilize at the set point of 6 GPH within about 10 minutes.

The most common causes of the shut downs have been loss of steam to the SAS and low feed flow to the melter. The SAS steam problem is caused by an elevated temperature prior to the mist eliminator. When this reaches 20°C, the steam to the SAS's is turned off. This interlocks the feed system. Work is currently underway to alleviate this condition. The low flow problem usually occurs during the first 5 minutes of the feed program. This time is when the rate oscillates between the low and high limit. A low flow for 15 seconds will cause the system to interlock.

Each time that the feed cycle is started or stopped, a timed flush of the feed line and the strainers automatically occurs. The amount of water during this flush was initially not enough to clean the entire line. The time on the cycle was extended to provide for a more complete flush.

Each time that the feed tube has plugged, it has been difficult to push the plug out with a rod. One time required the removal of the tube from the melter so the plug could be drilled out. It appears that the plug is glass rather than dry feed. The low flow rate and frequent starts probably account for a buildup of glass on the tip of the tube.

RECOMMENDATION #9 - DWPF should calculate the volume of flush water required on the feed line to the melter, and ensure that the volume of the flush is sufficient to flush the piping volume at least one time.

The actions to reduce feed pluggages with the current feed system are:

1. To speed up the control so the flow does not remain low for a long time during the initial cycling. This must be tempered with the knowledge that a high flow will also interlock the feeding.

2. Relocate the temperature transmitter that measures the off gas temperature after the condenser. The current location gives an artificially high reading (see the following section for details of the relocation).

Off-Gas System

During sludge-only run #2, the steam to the Steam Atomized Scrubber (SAS) units interlocked shut several times due to a high temperature at the Off-Gas Condenser exit. The temperature reading at the OG Condenser exit, 1060TT, is physically located at the inlet to the Mist Eliminator. Since the off-gas line between the OG Condenser and the Mist Eliminator is not insulated, the off-gas is picking up heat in this line, and 1060TT is not providing an accurate indication of the OG Condenser exit temperature. 1060TT was relocated to the actual OG Condenser outlet.

QUALITY ASSURANCE

DPST-88-870 (Revision 1) was the Quality Assurance Assessment document for the melter heatup and the two sludge-only runs on the IDMS facility. In this document it is stated that a Quality Assurance Action Plan was not required because the results of these campaigns were not intended to directly affect DWPF equipment design. In order to fulfill the campaign objectives of final equipment checkout and of bringing the melter to normal operating temperatures and level, the QAA stated the following criteria:

1) Feeds prepared for testing must be representative of DWPF feeds, both with respect to elemental concentrations and rheological properties. A sample schedule was followed throughout the campaigns.

2) All measuring and test equipment used to monitor temperatures, flows, power, current, voltage, and pressure throughout the IDMS were calibrated before the melter heatup and the initial SRAT/SME run. Calibration procedures, frequency, categories, and records are available for review.

3) The IDMS would be operated using approved procedures and job plans. Any new procedures and any procedures requiring revision will be in accordance with TNX procedure GE-1040. The SRAT/SME procedure is retained as a permanent record, and the melter was heated using an approved job plan. Existing procedure approval methods were in effect.

All process run data is stored in the Vantage data collection system running on the Vax computer located in 679-T. Registered laboratory notebooks containing information related to this report are E58052, E58053, E58063, and E51827.

ACKNOWLEDGEMENTS

The success of the startup and the sludge-only campaign reflects the cooperation and effort put forth by the TNX Operations Division. Special thanks are in order for J. F. Sides and R. L. Norris for procedure writing, O. C. Gibson, J. DeHart, V. Chinn, T. Young, and R. Abee for the electrical checkout, and V. Wimberly for the mechanical checkout.

C. M. Jantzen provided the startup frit analysis data and helped in the fabrication of the melter dump valve glass plugs.

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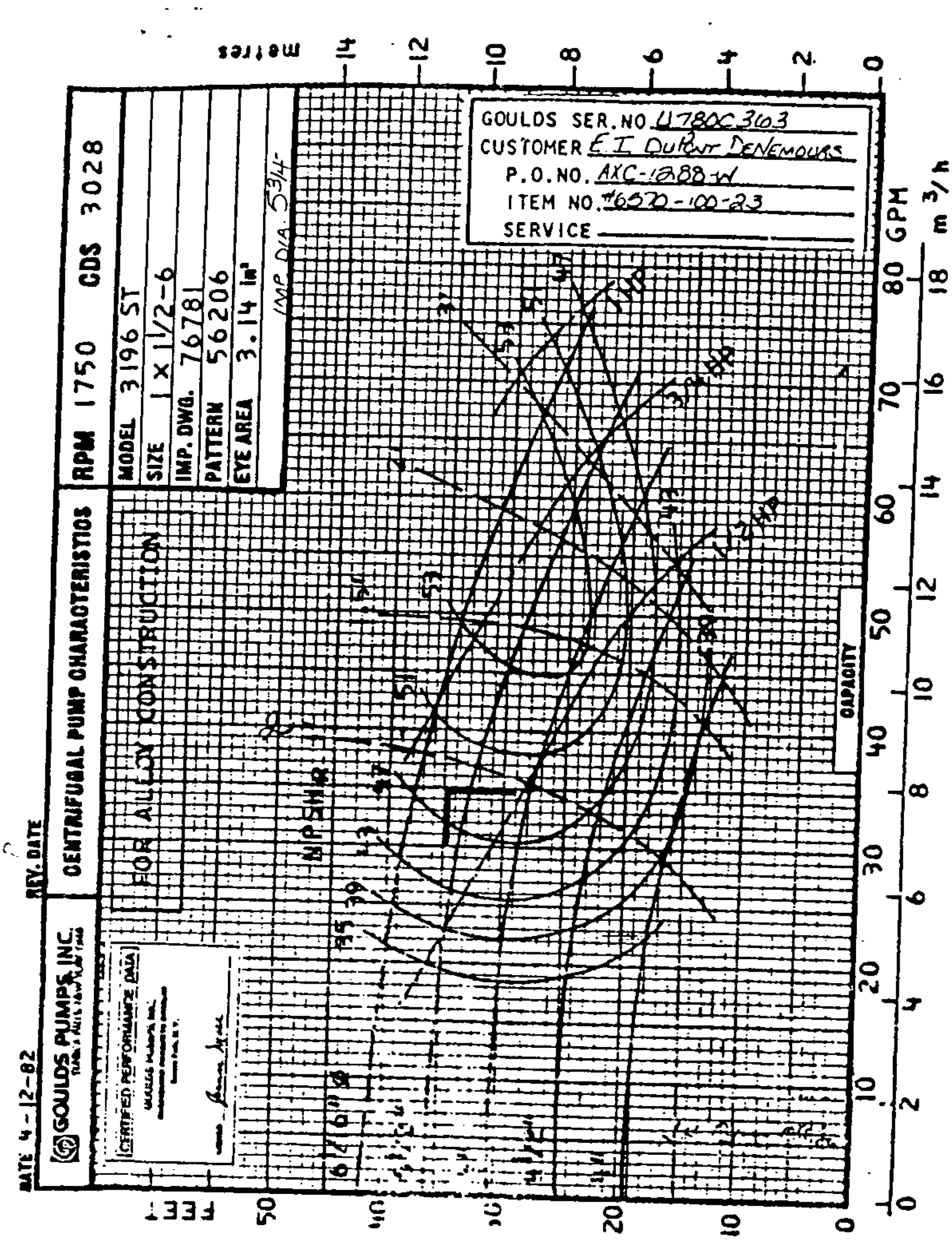
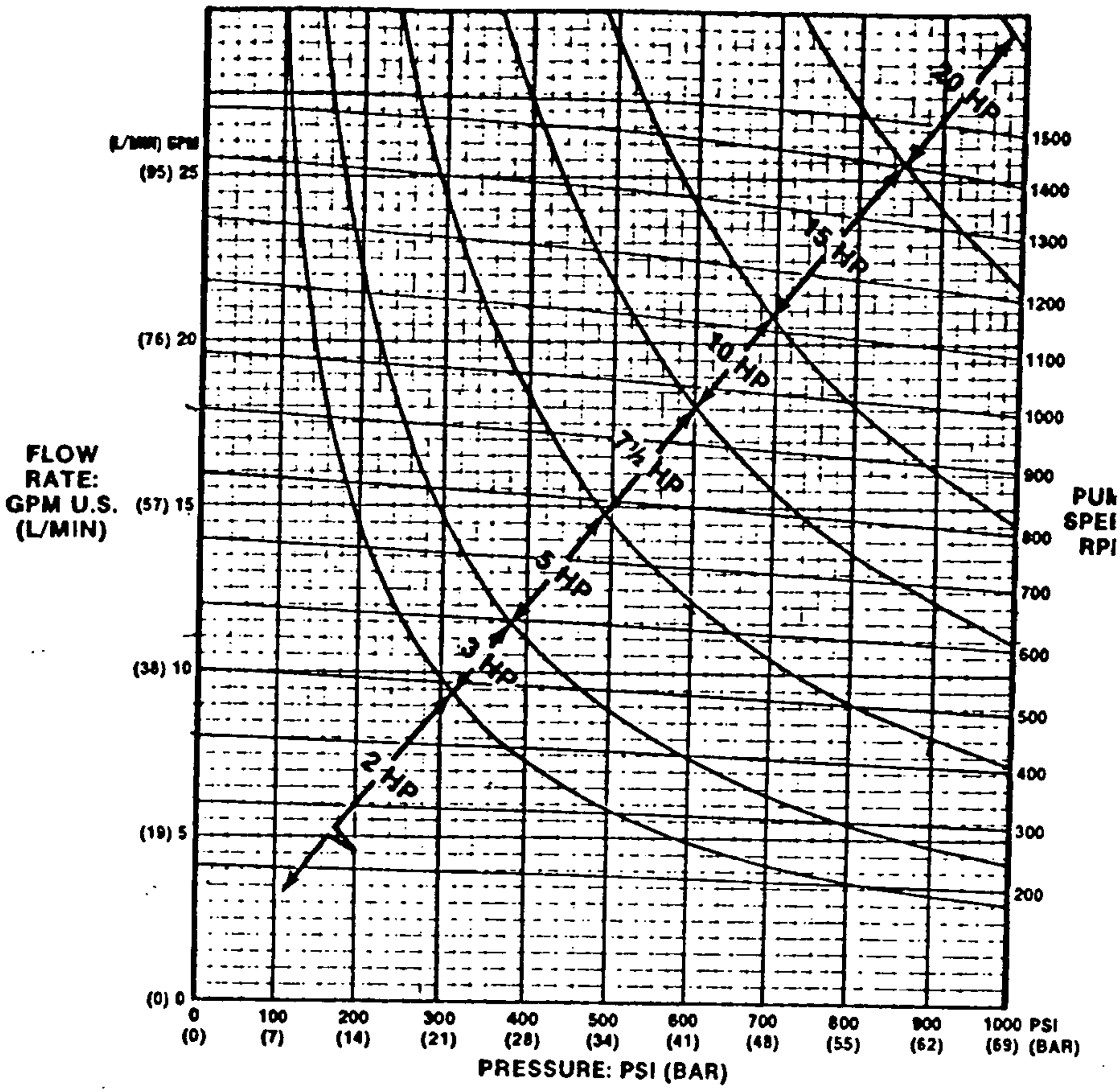


FIGURE A-1. WWPT Low-Pressure Pump Characteristic Curve Performance

Model: D-25XL
(ALL MATERIALS OF CONSTRUCTION)



MAXIMUM ALLOWABLE PRESSURE = 1000 PSI (69 BAR)
MAXIMUM ALLOWABLE FLOW RATE = 25 GPM U.S. (95 L/MIN)
MAXIMUM ALLOWABLE SPEED = 1500 RPM

FIGURE B-1. WWPT High-Pressure Booster Pump Characteristic Curve Performance

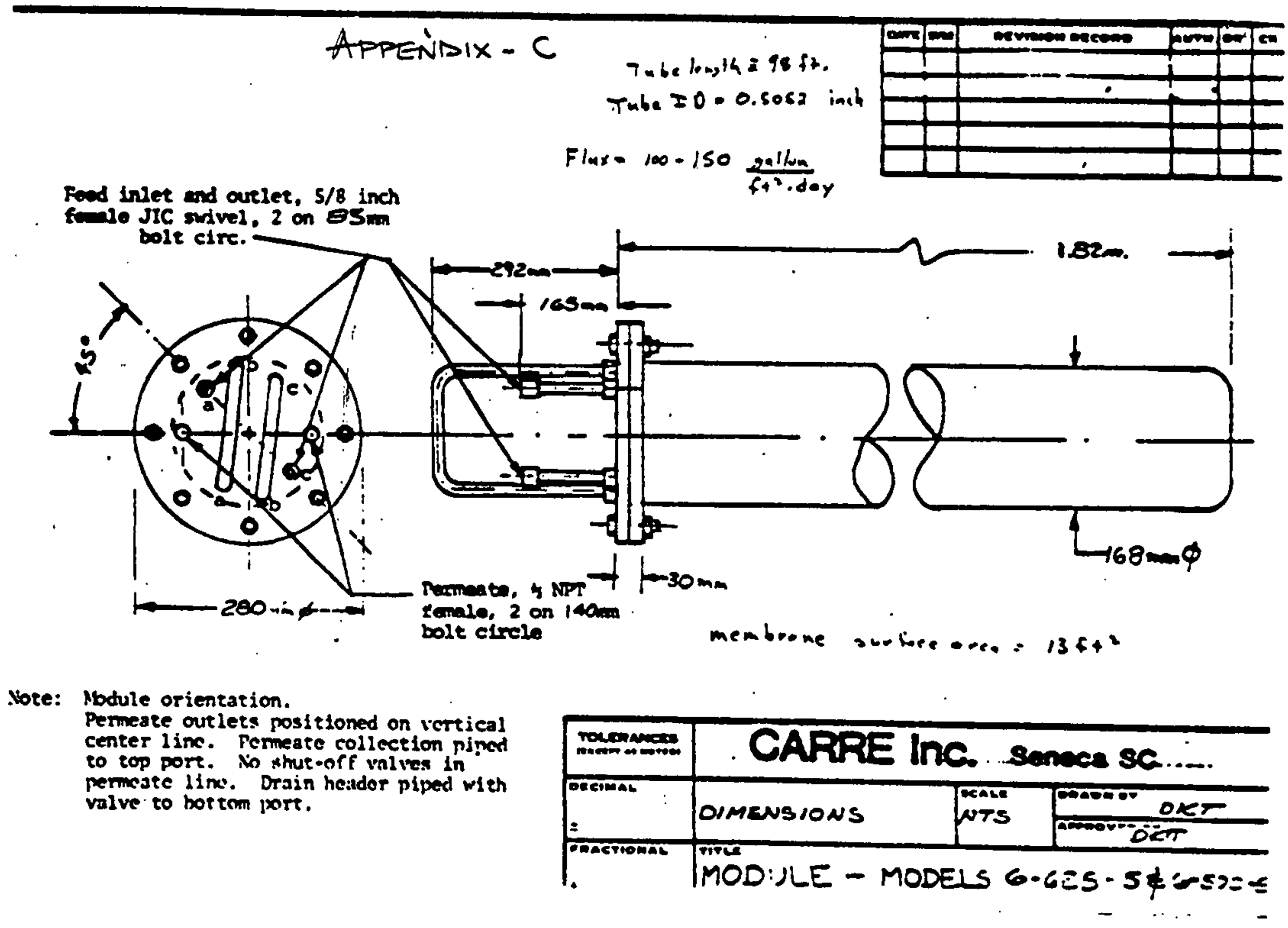
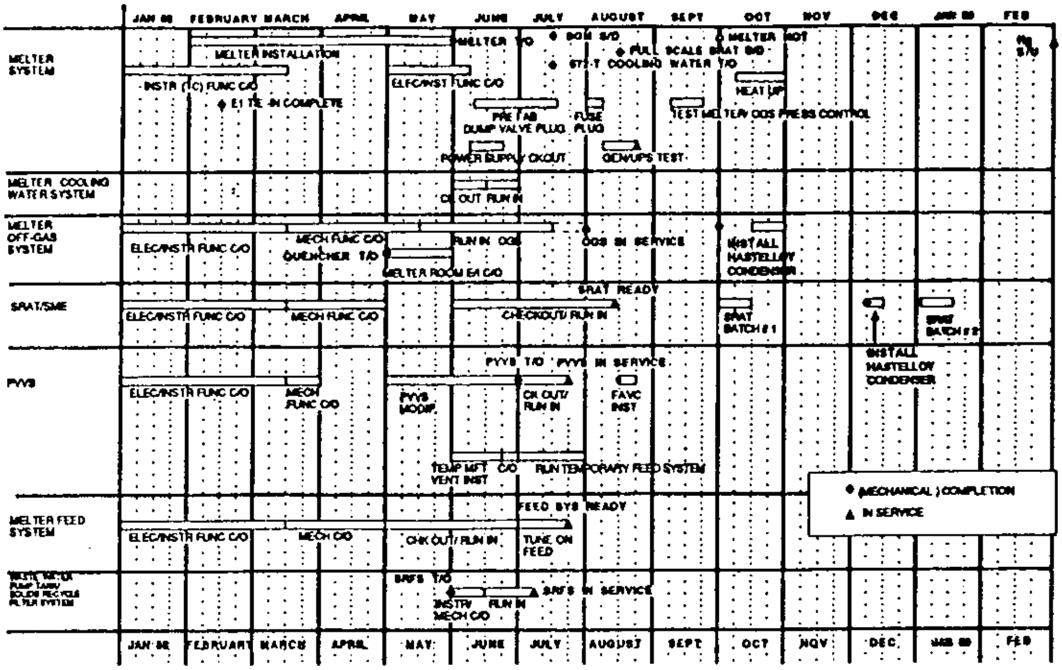


FIGURE C-1. Ultrafilter Dimensions

IDMS CHECK OUT/COMMISSIONING SCHEDULE



IDMS SUPPORT PROJECTS

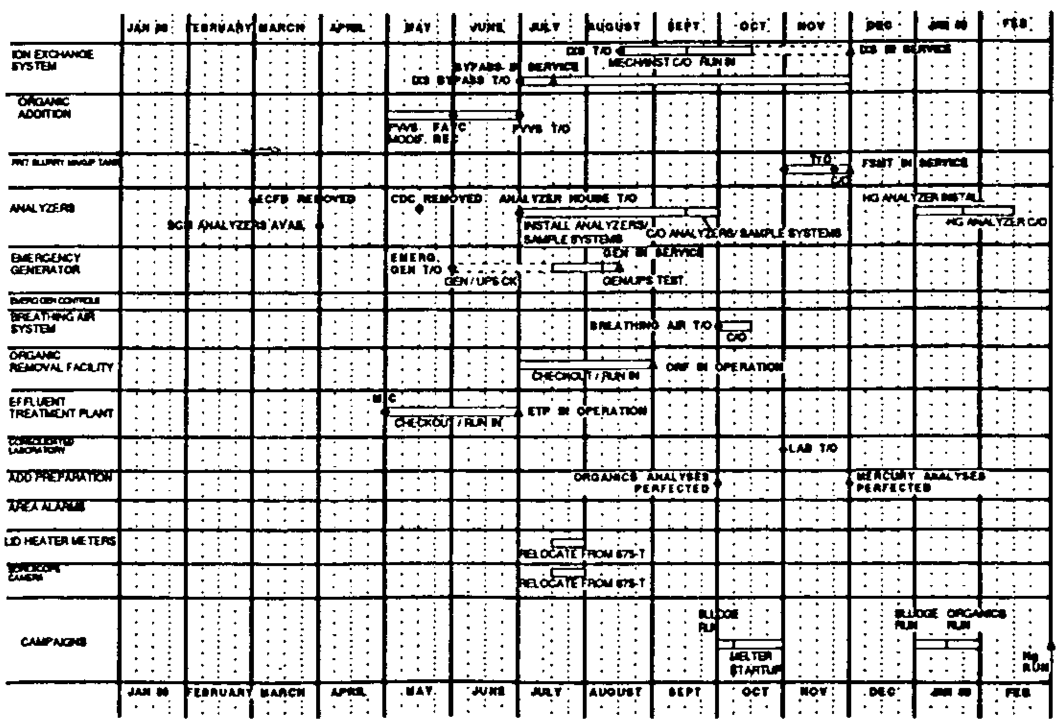


FIGURE D-1. IDMS Checkout/Commissioning Schedule

TABLE E-1. A Summary of the IDMS Melter Checkout

Checkout Item	Comments
• P&I checkout	
• Electrical and instrument	Includes QA calibration of T/C's, transmitters, etc.
• Mechanical checkout of bellows/ siphon break systems	
• Canister conveyor system	
• Test top head removal	
• Checkout of canister level/weight systems	
• Meg-ohm test melter heaters after installed without water hoses, and after cooling	Do test at fabrication site, with cooling water running
• Melter cooling water supply checkout/run-in	
• Power supply run-in/calibration/ limits.	Includes setting current polarity check on electrodes. Need dummy loads for electrodes -- may use lid heaters for load.
• Interlock checkout	
• Generator/UPS tests	
• Fabrication/fusing of dump valve glass plugs	
• Installation of Low Temperature Monitoring System for type B thermocouples	
• Heater sequencer checkout	
• Test melter/off-gas pressure control system	Involves isolating bellows from pour spout
• Checkout failure mode of control valves	
• Checkout operation of sightglass and borescope cameras	
• Charge melter with frit	Must be level

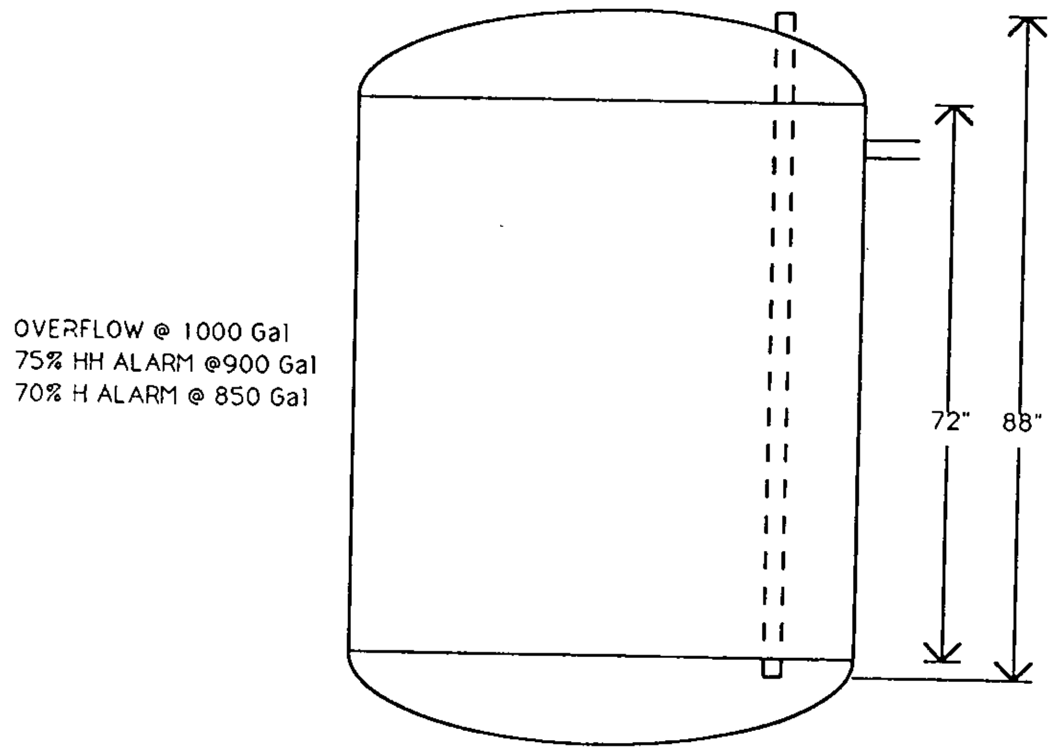


FIGURE F-1. MCWT Level Probe Schematic

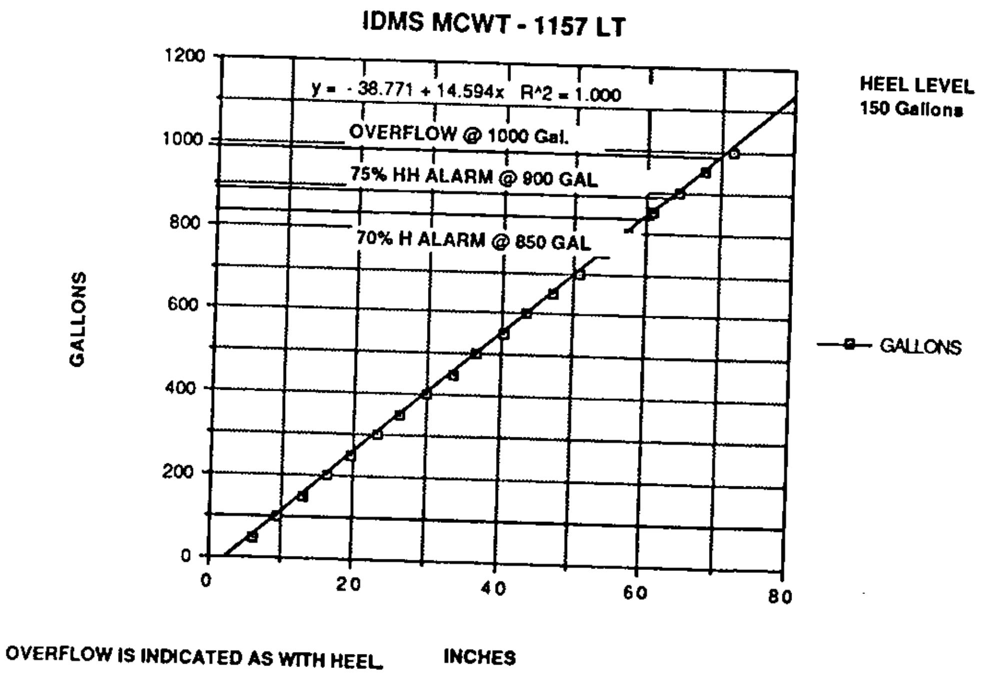


FIGURE F-2. MCWT Calibration Curve

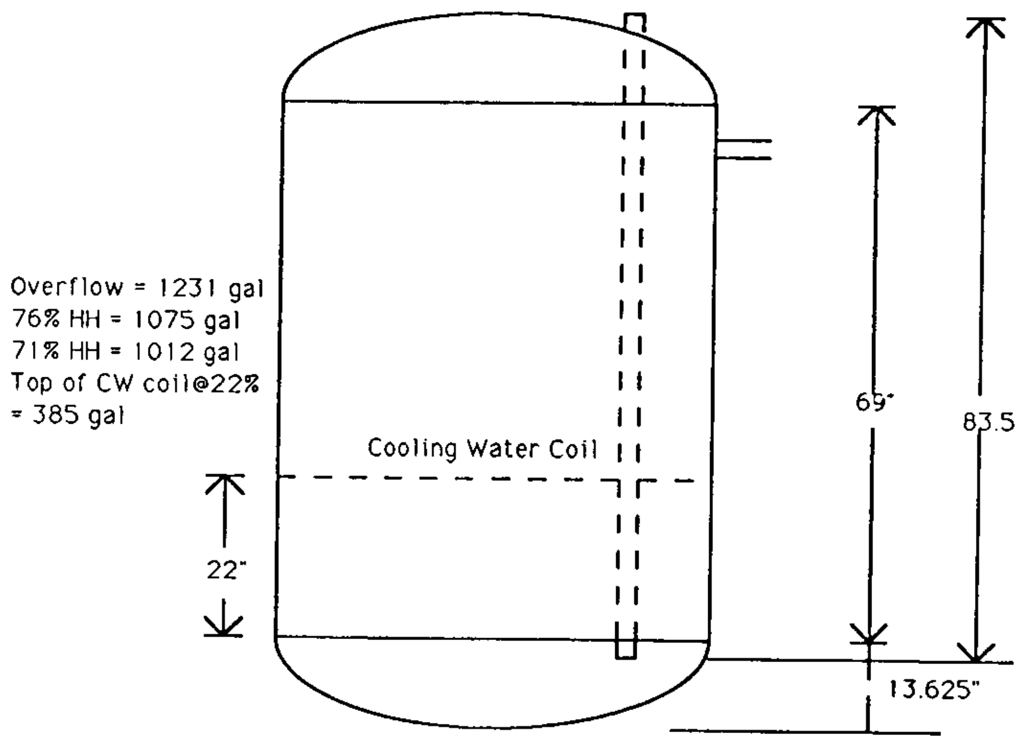


FIGURE F-3. **MFT Level Probe Schematic**

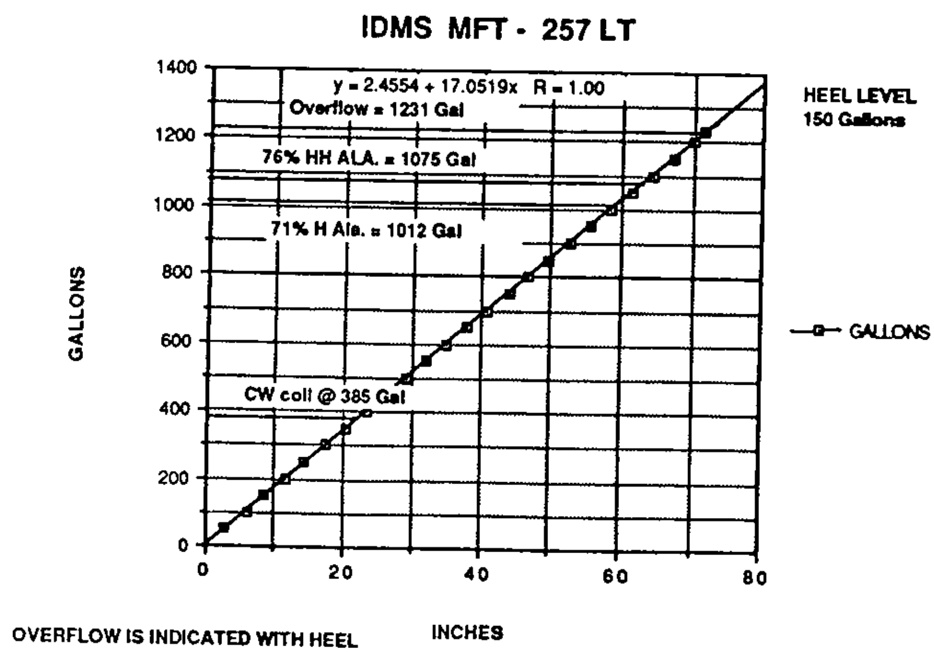


FIGURE F-4. **MFT Calibration Curve**

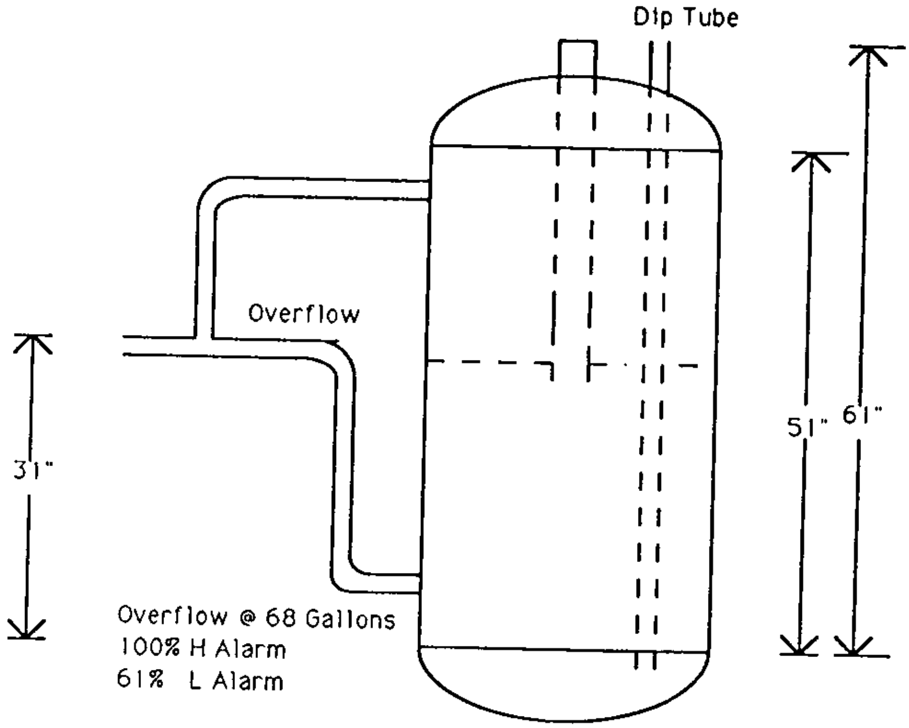


FIGURE F-5. **Melter Seal Pot Level Probe Schematic**

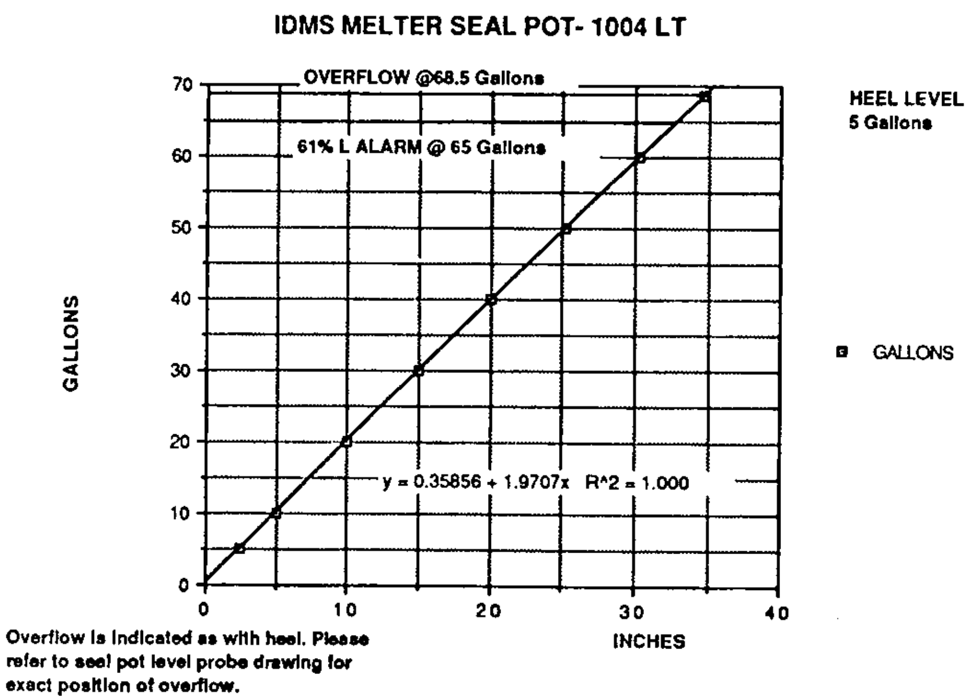


FIGURE F-6. **Melter Seal Pot Calibration Curve**

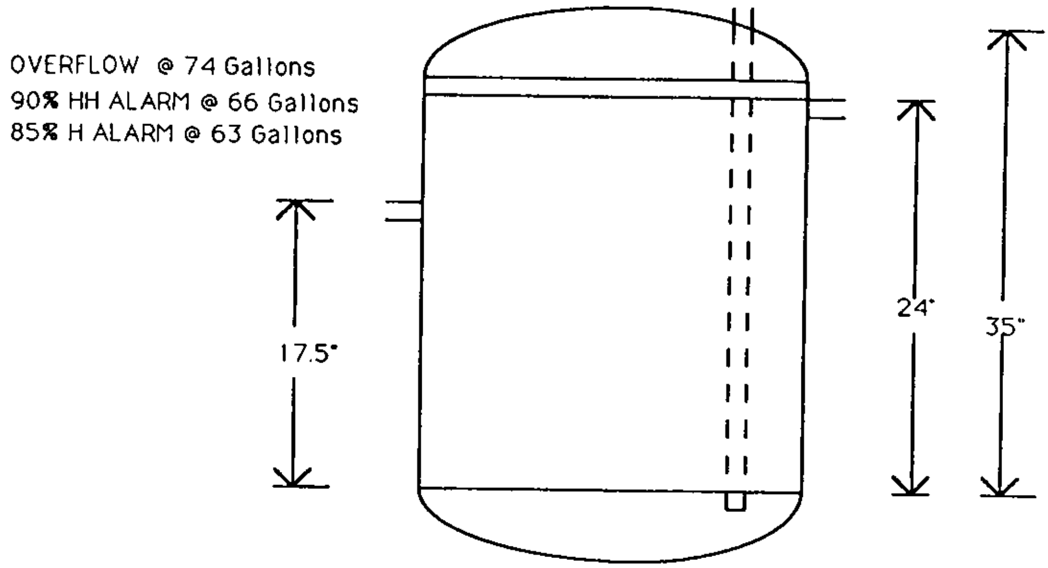


FIGURE F-7. MWWT Level Probe Schematic

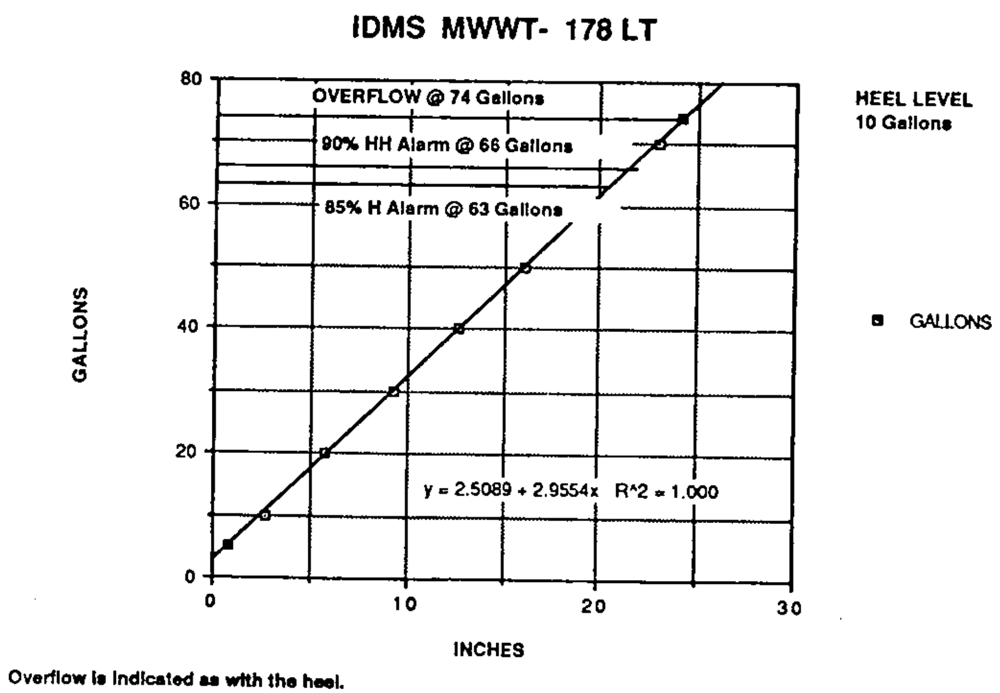


FIGURE F-8. MWWT Calibration Curve

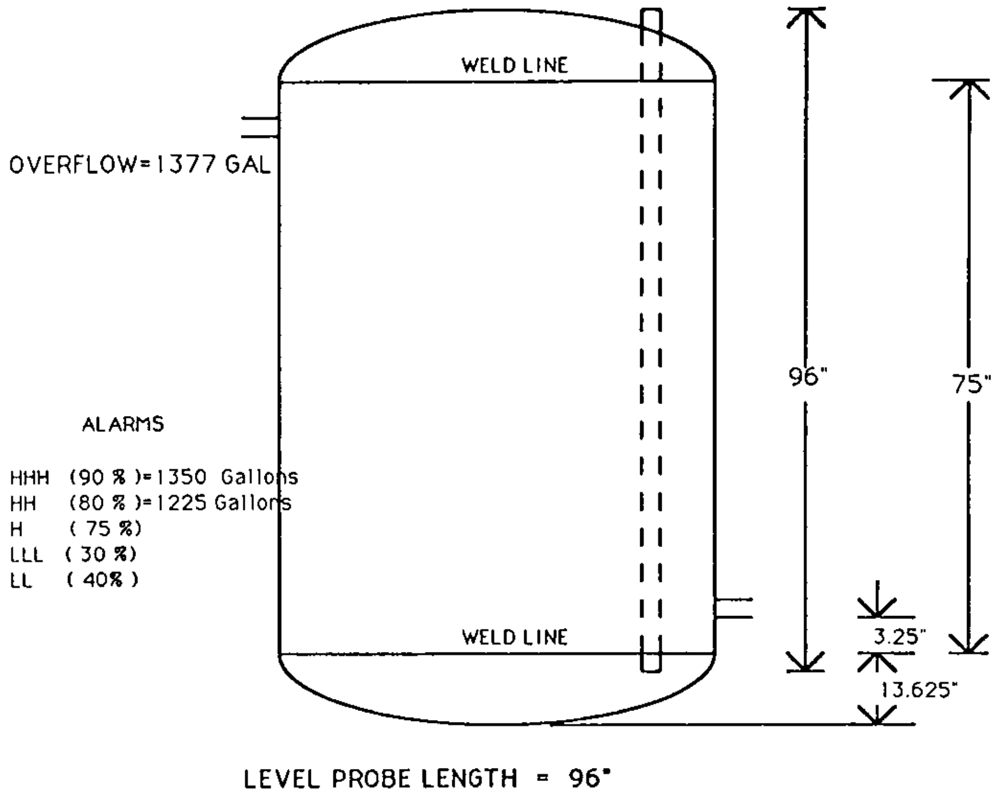


FIGURE F-9. **OGCT Level Probe Schematic**

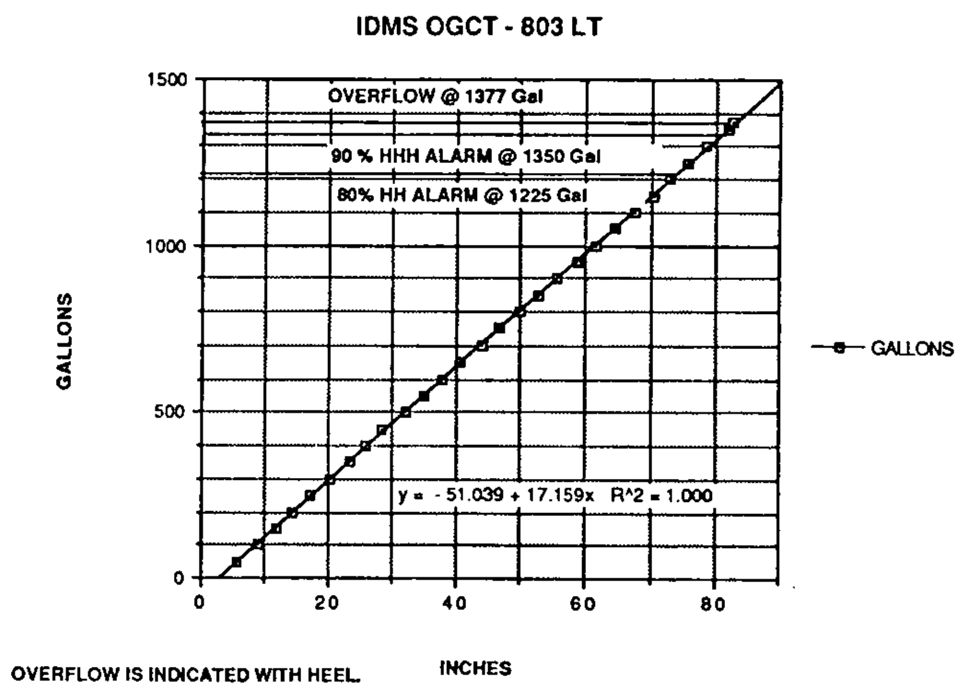


FIGURE F-10. **OGCT Calibration Curve**

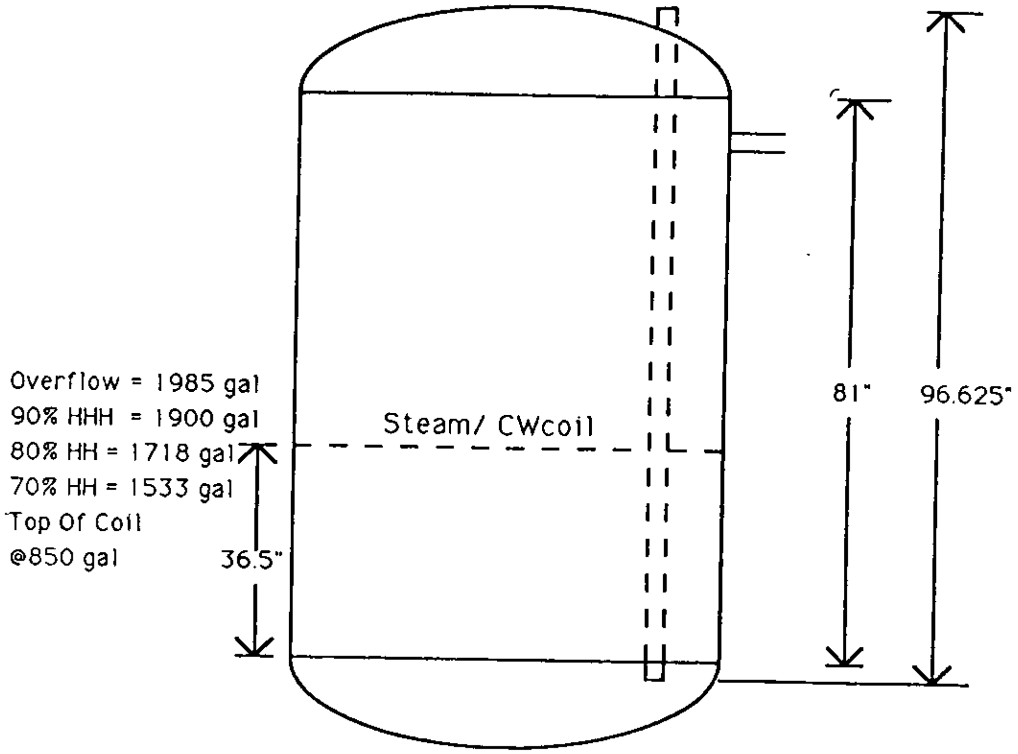


FIGURE F-11. **SRAT/SME Level Probe Schematic**

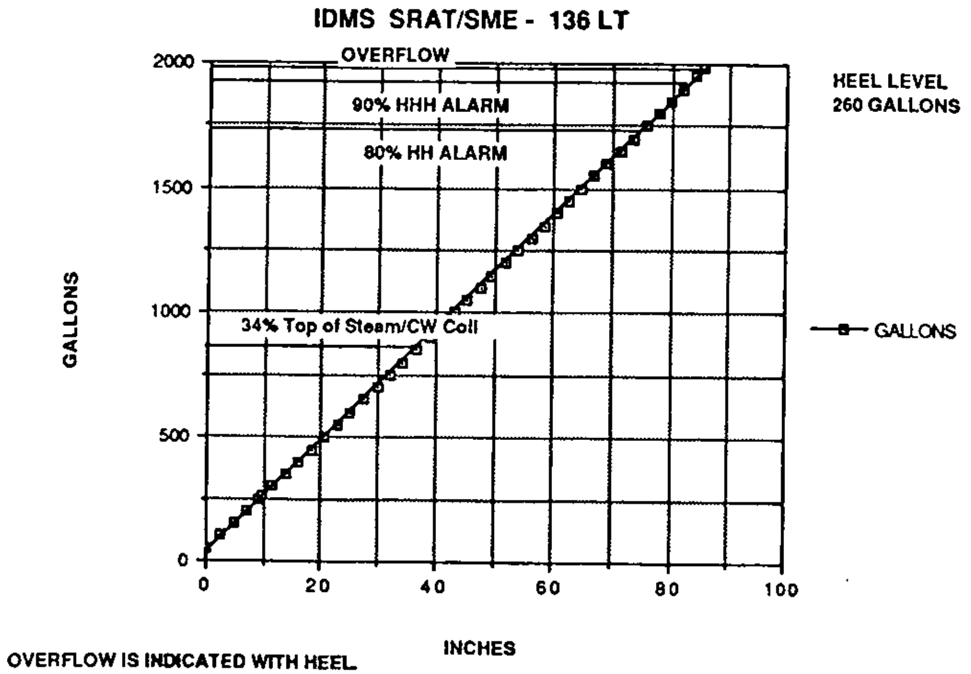


FIGURE F-12. **SRAT/SME Calibration Curve**

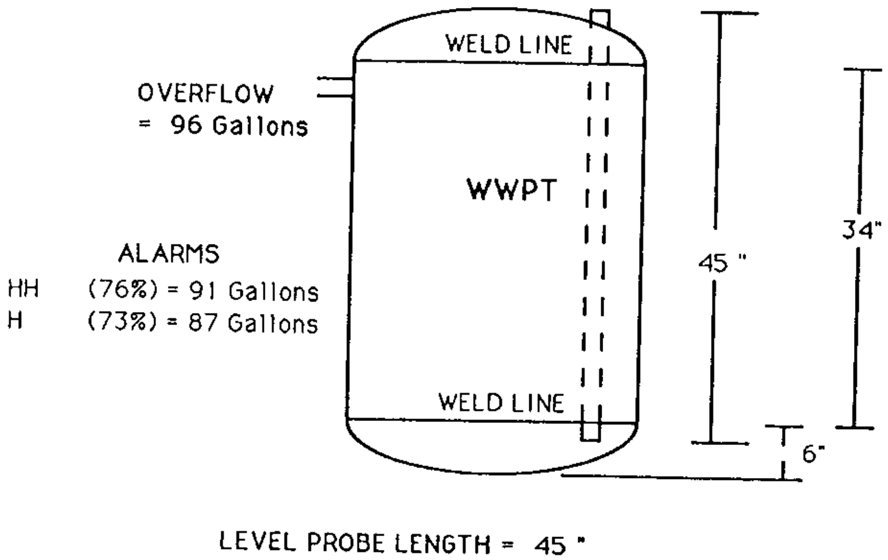


FIGURE F-13. WWPT Level Probe Schematic

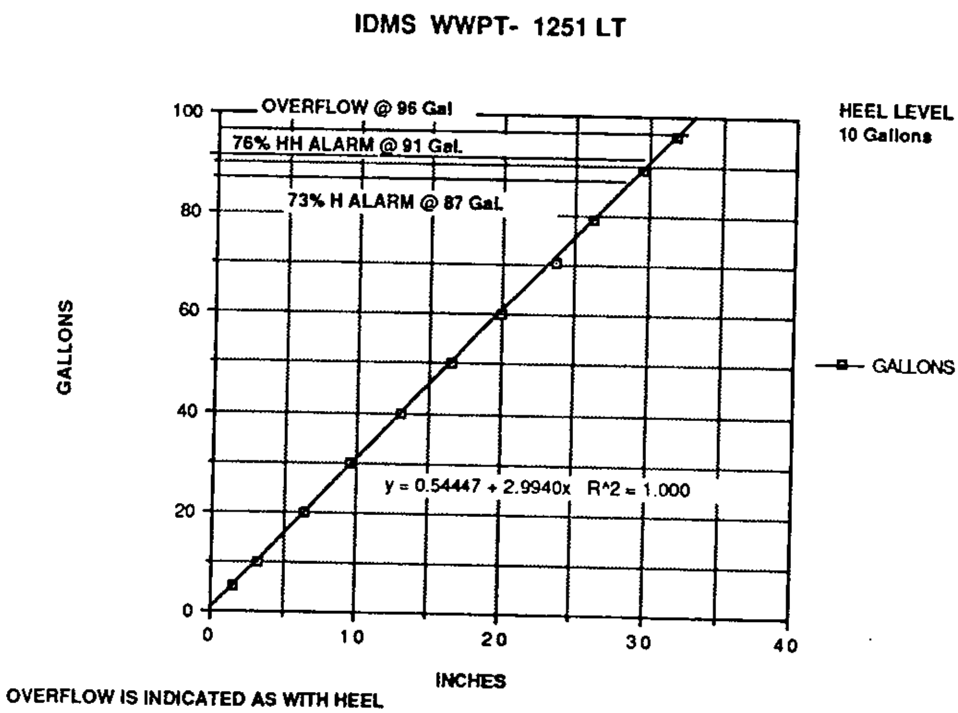
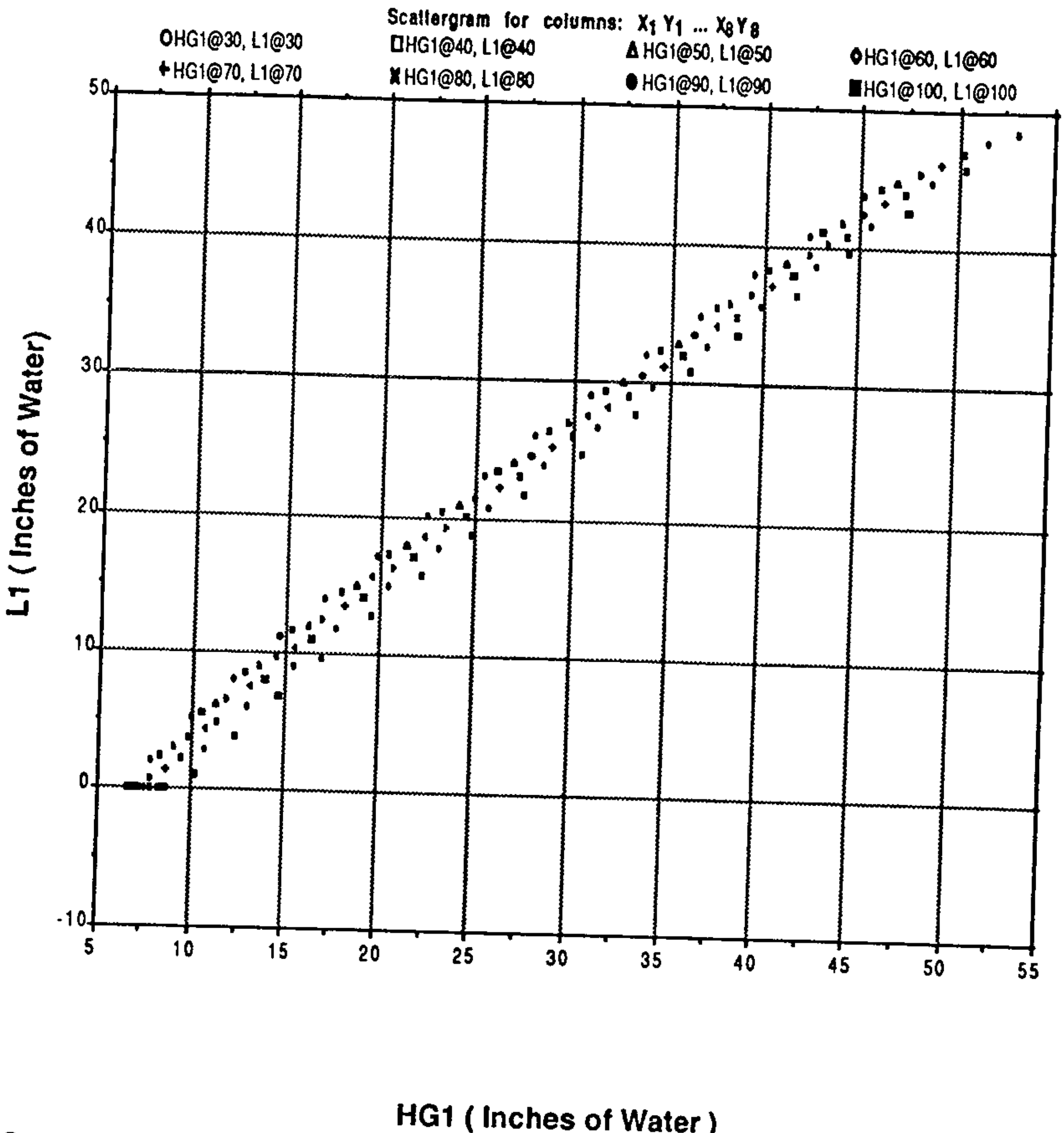
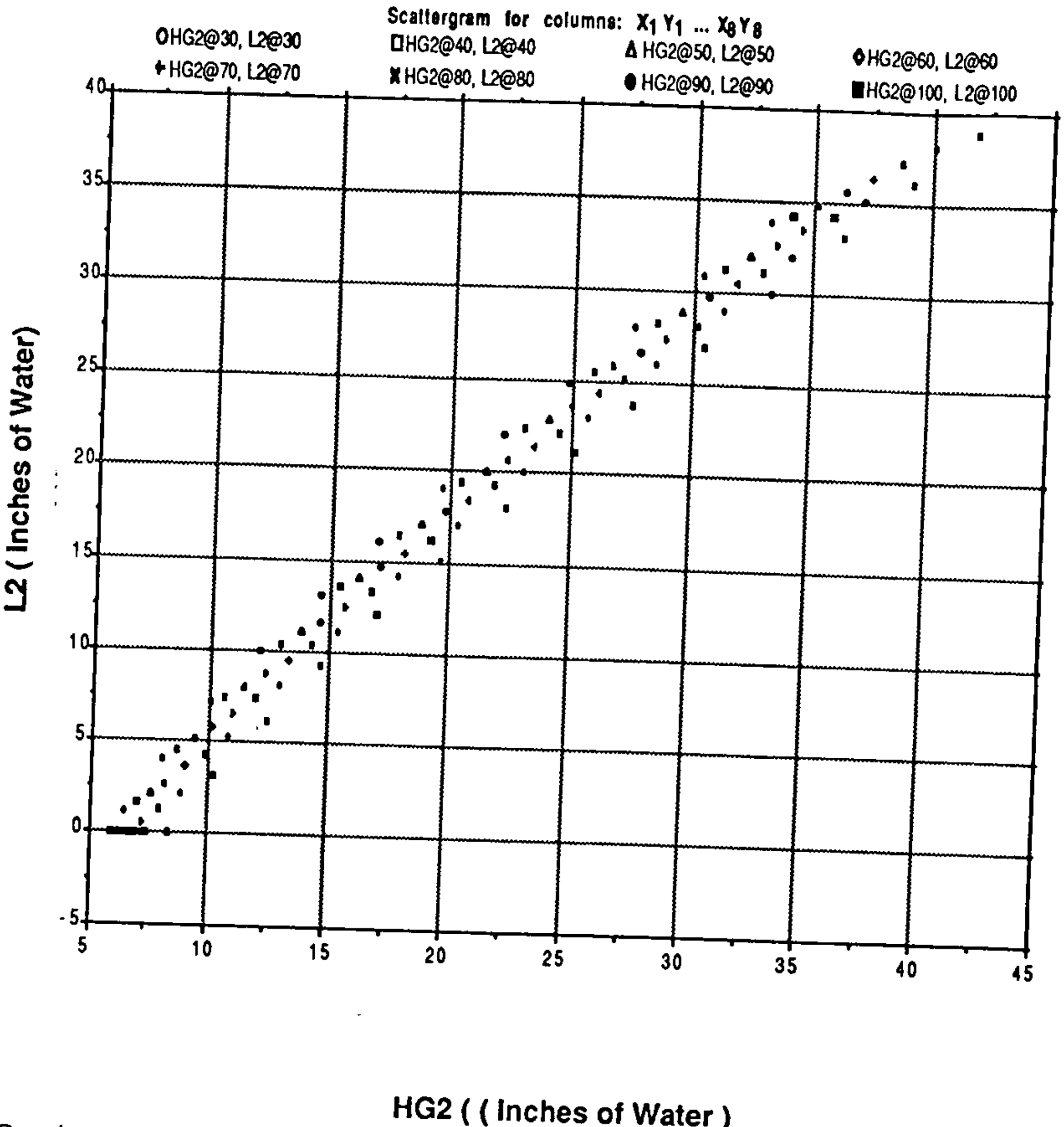


FIGURE F-14. WWPT Calibration Curve



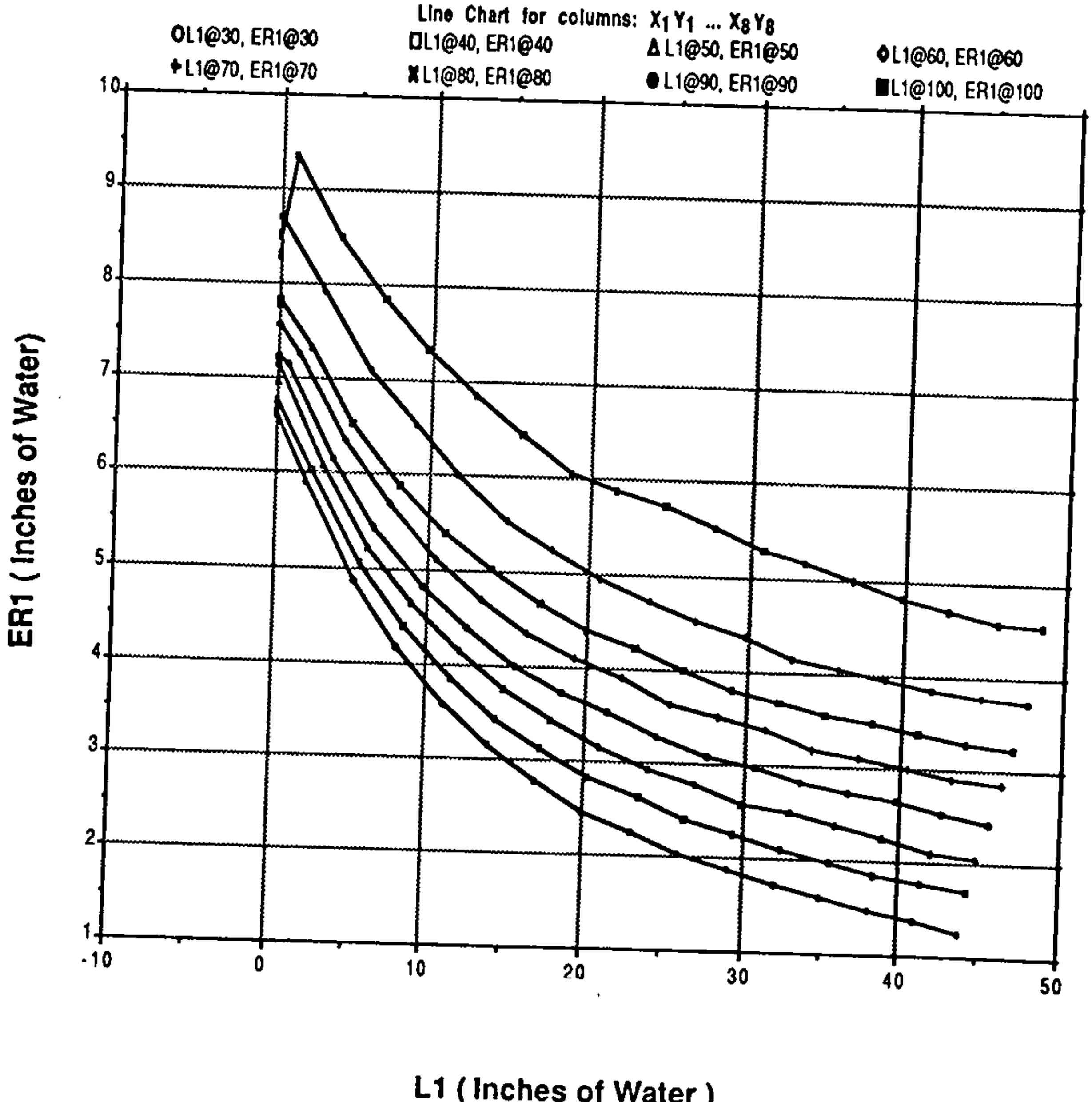
Graph represents SRAT Holledge gauge bottom transmitter(HG1) reading versus Actual level(L1) in the calibration stand at temperature range of 30°C to 100°C.

FIGURE G-1. SRAT/SME Holledge Gauge - HG1 vs. L1 From 30°C to 100°C



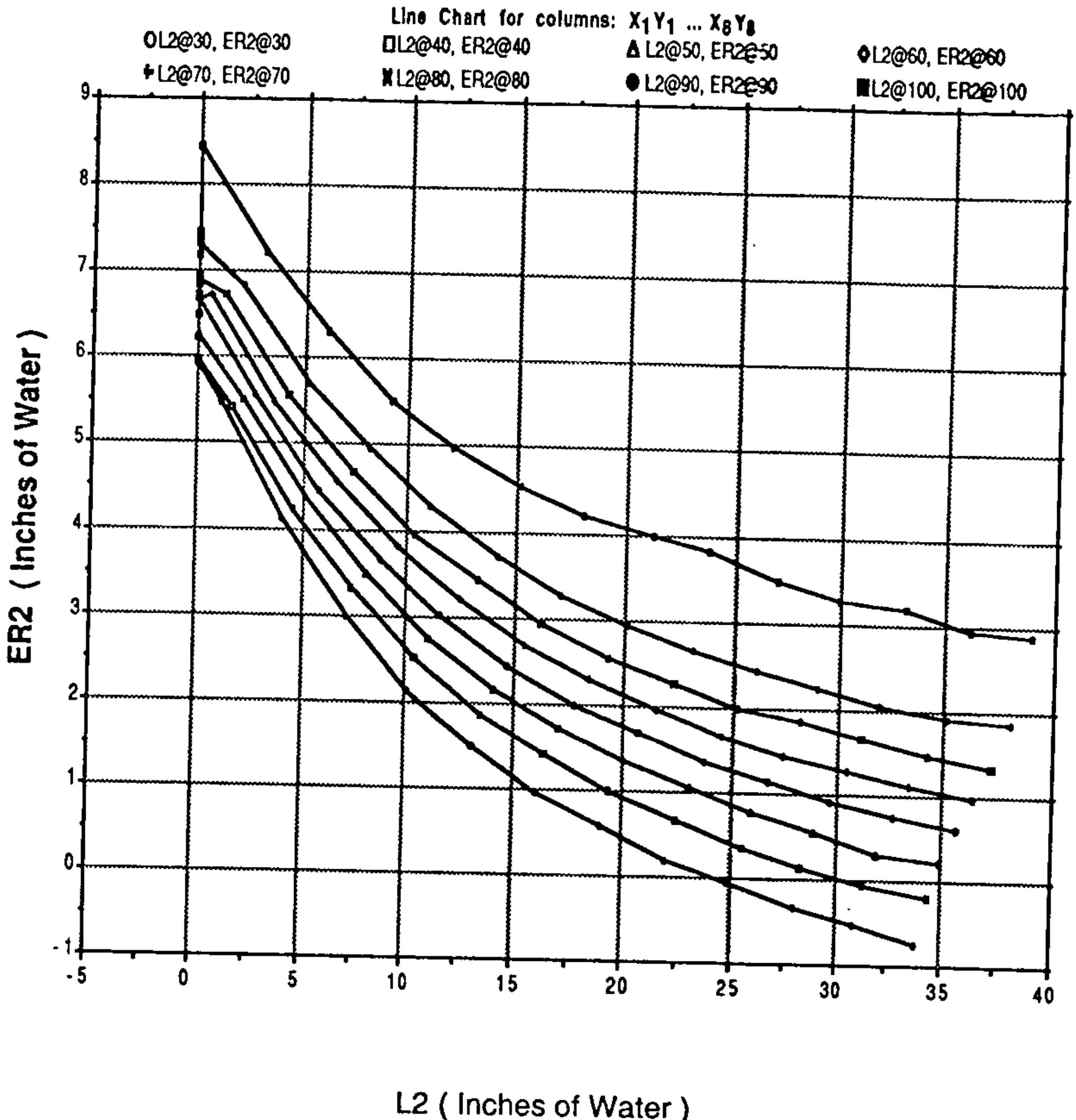
Graph represents SRAT Holledge gauge top transmitter reading versus computed L2 where L2 = L1 -(Density Correction x 10") at temperature range of 30°C to 100°C.

FIGURE G-2. SRAT/SME Holledge Gauge - HG2 vs. L2 From 30°C to 100°C



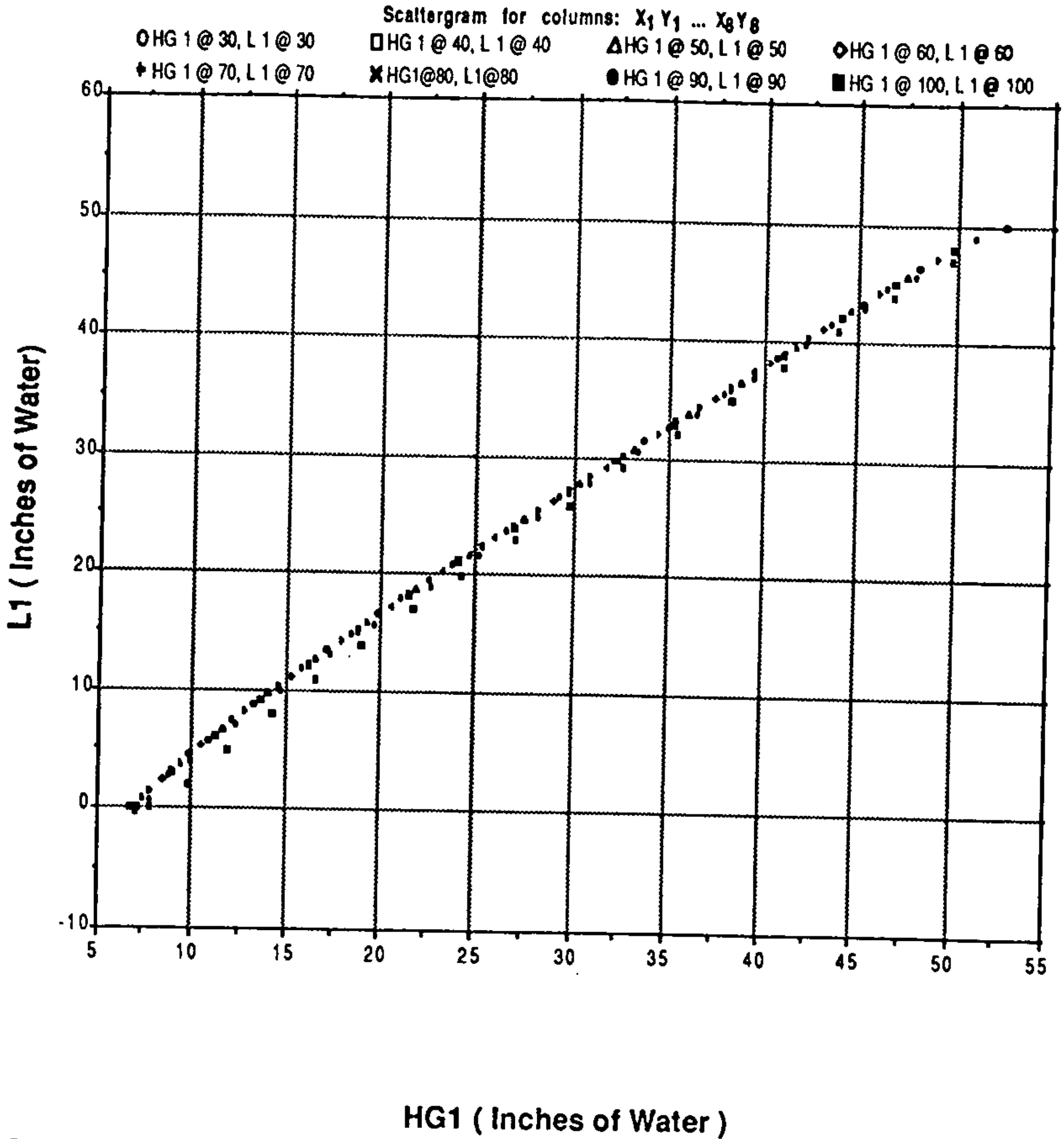
Graph represents actual level(L1) in the calibration stand versus error ER1, which is Holledge Gauge reading minus actual level reading (HG1-L1), at temperature range of 30°C to 100°C for SRAT bottom transmitter.

FIGURE G-3. SRAT/SME Holledge Gauge - L1 vs. ER1 From 30°C to 100°C



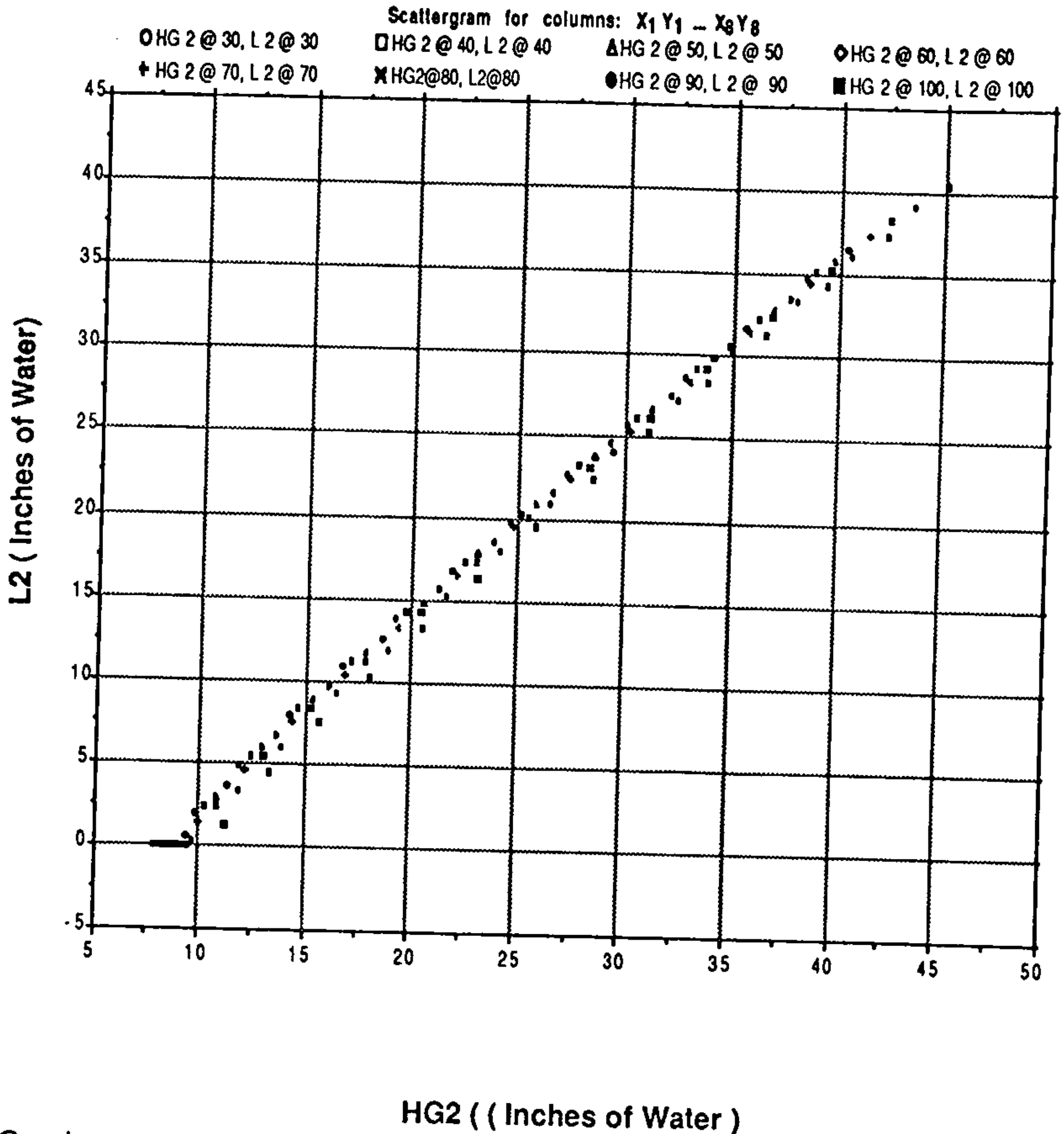
Graph represents actual level (L2 = L1- Density Correction x 10") in the calibration stand versus error ER2 , which is Holledge Gauge reading minus actual level reading (HG2-L2) at temperature range of 30°C to 100°C for SRAT Holledge Gauge top transmitter.

FIGURE G-4. SRAT/SME Holledge Gauge - L2 vs. ER2 From 30°C to 100°C



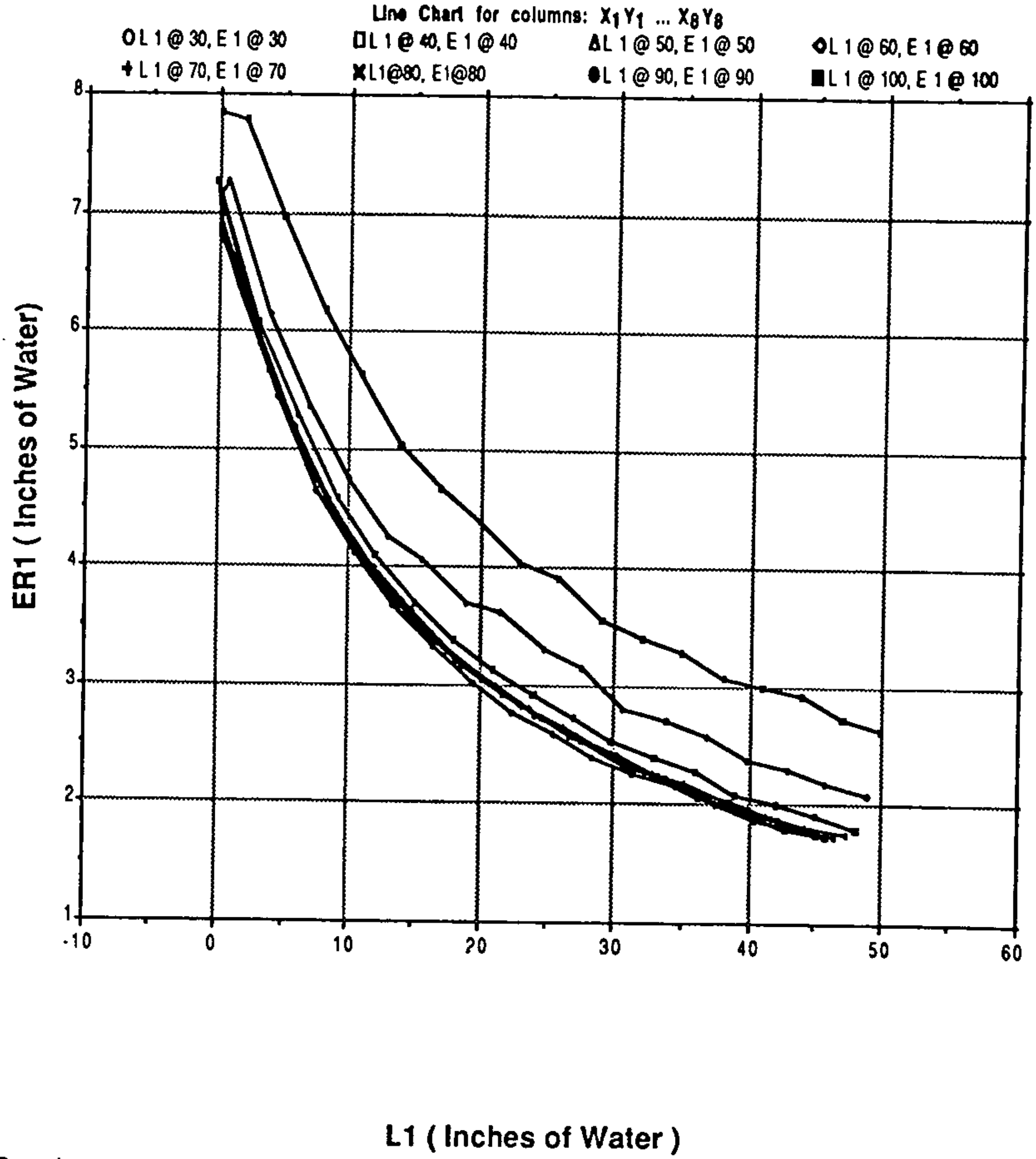
Graph represents MFT Holledge gauge bottom transmitter reading versus Actual level(L1) in the calibration stand at temperature range of 30°C to 100°C.

FIGURE G-5. **Melter Feed Tank Holledge Gauge - HG1 vs. L1 From 30°C to 100°C**



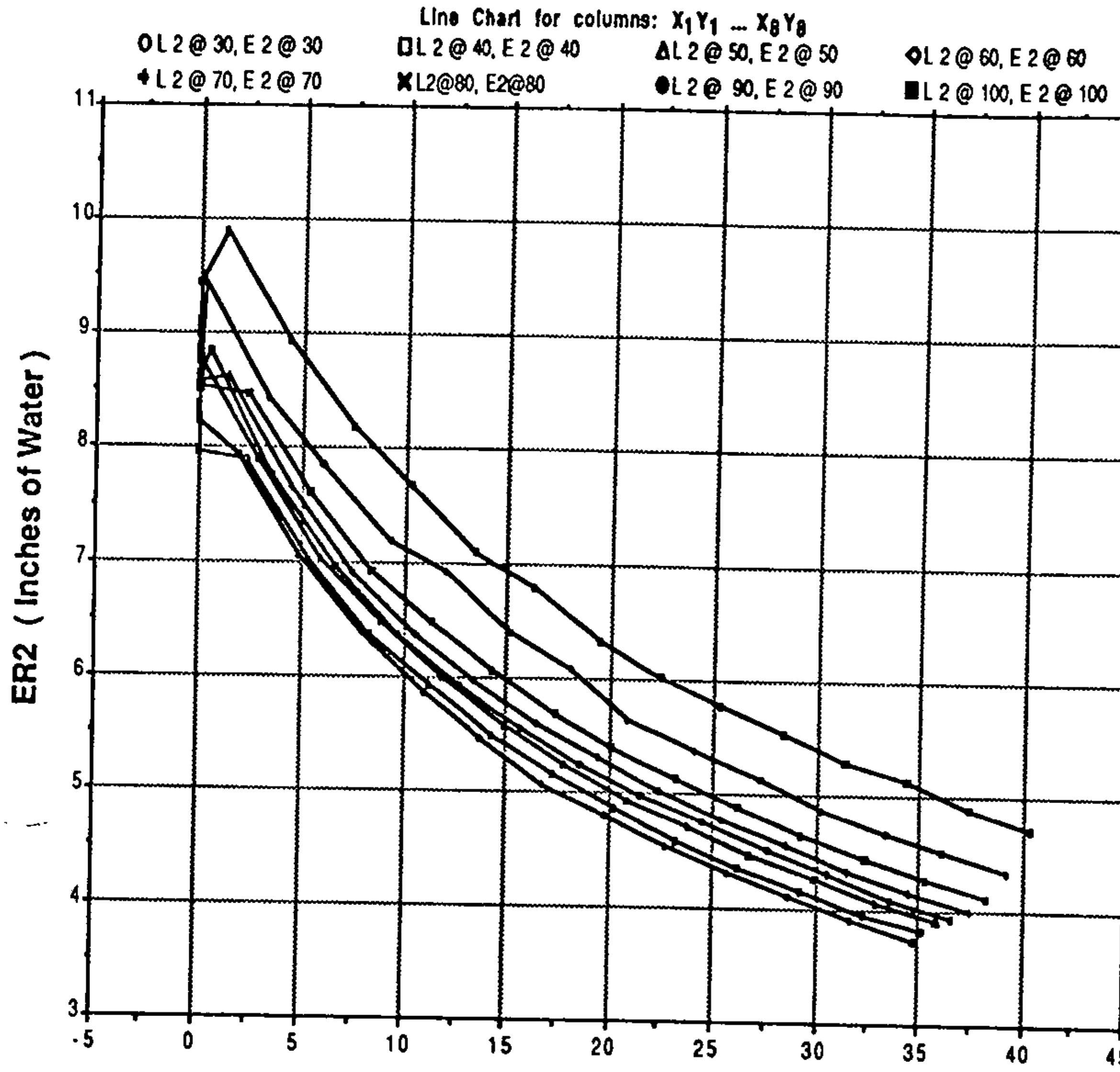
Graph represents MFT Holledge gauge top transmitter reading versus computed L2 where L2 = L1 -(Density Correction x 10") at temperature range of 30°C to 100°C.

FIGURE G-6. Melter Feed Tank Holledge Gauge - HG2 vs. L2 From 30°C to 100°C



Graph represents actual level(L1) in the calibration stand versus error ER1, which is Holledge Gauge reading minus actual level reading (HG1-L1), at temperature range of 30°C to 100°C for MFT bottom transmitter.

FIGURE G-7. Melter Feed Tank Holledge Gauge - L1 vs. ER1 From 30°C to 100°C



Graph represents actual level (L2 = L1- Density Correction *10") in the calibration stand versus error ER2 , which is Holledge Gauge reading minus actual level reading (HG2-L2) at temperature range of 30°C to 100°C for MFT Holledge Gauge top transmitter.

FIGURE G-8. Melter Feed Tank Holledge Gauge - L2 vs. ER2 From 30°C to 100°C

APPENDIX H

CALCULATION OF PVVS OPERATING CURVES

Method of calculation:

Note: The original 214-FT orifice plate was used in these tests.

Range = 0-30 pph
ΔP = 0-1 inwc

since flow = c*sqrt(ΔP)

30 = c*sqrt(1)

c = 30

The total flow is then

F = 30*sqrt(ΔP)

where ΔP = 214-PG

And the vessel air inleakage is given by:

inleakage = total flow - air bleed flow

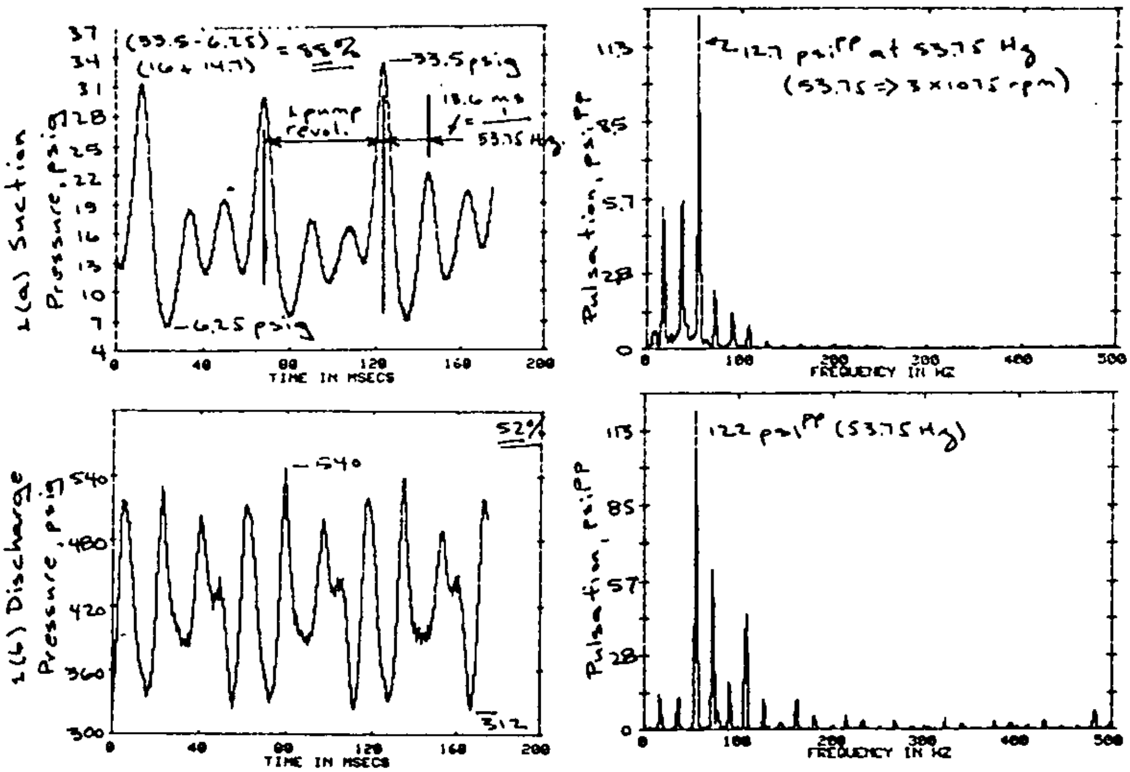


FIGURE I-1. **Booster Pump Pressure Pulsations for 420 PSIG Discharge and 16 PSIG Suction Pressures**

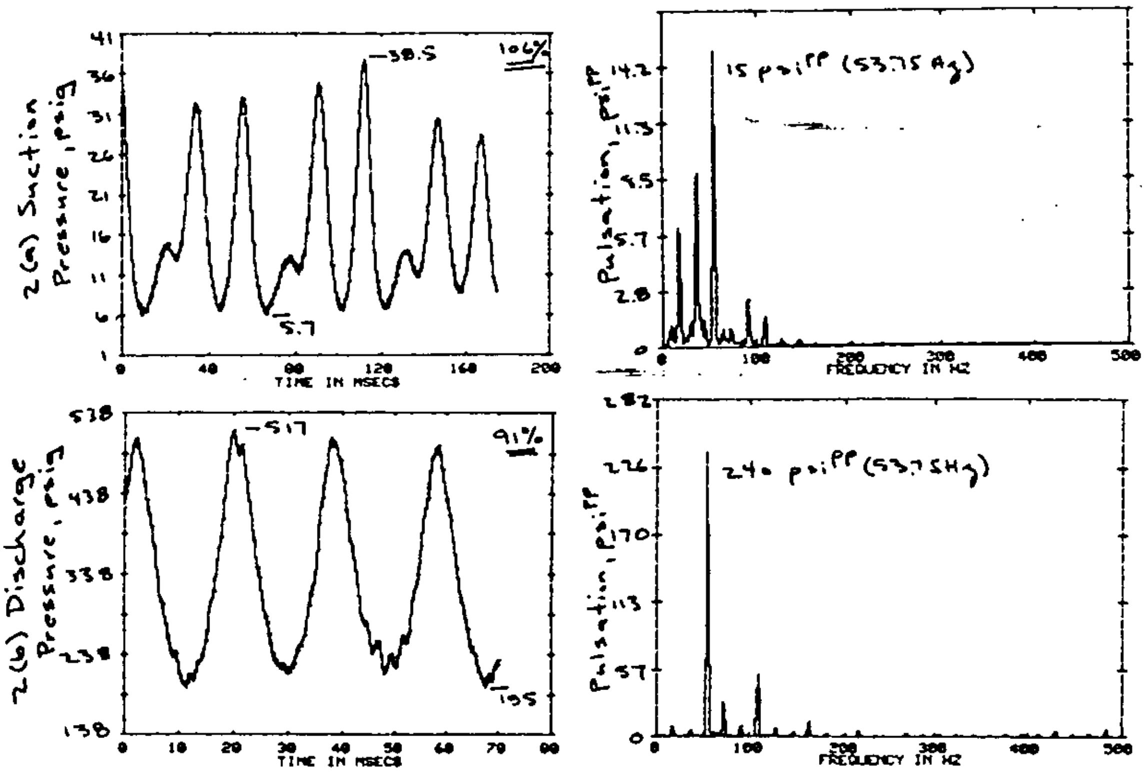


FIGURE I-2. **Booster Pump Pressure Pulsations for 338 PSIG Discharge and 16 PSIG Suction Pressures**

APPENDIX J

IDMS Sludge-Only Cold Feed Specifications

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1																
2							Simulated Sludge			PHP Simulation						
3	component	Mole Wt					Lb/Hr	Wt% Solids		lbs/hr	Wt% Solution		Sim Frit			Feed solids
4														Wt%		lbs/hr
5	Ag2O	231.76					0.0000									0.0000
6	AgNO3	169.87					0.0000									0.0000
7	Ag	107.87														0.0000
8	Al(OH)3	77.99					16.3350	18.1500		0.0000	0.0000					16.3350
9	Al2O3	101.94					0.0000			0.0000	0.0000					0.0000
10	B2O3	69.64											18.379	10.000		18.3795
11	BaSO4	233.42					0.0000			0.0000	0.0000					0.0000
12	Ca(COOH)2	130.12								0.0000	0.0000					0.0000
13	Ca3(PO4)2	310.18					0.1890	0.2100								0.1890
14	CaC2O4	128.10					0.0000									0.0000
15	CaCO3	100.09					5.1840	5.7600								5.1840
16	CaF2	78.08					0.0000									0.0000
17	CaSO4	136.14					0.0000	0.0000								0.0000
18	Cr2O3	152.02					0.3150	0.3500								0.3150
19	CsNO3	194.95					0.0000	0.0000								0.0000
20	Cs2O	281.81					0.0000									0.0000
21	CsCOOH	177.92								0.0000	0.0363					0.0000
22	Cu(COOH)2	153.61								0.0000	0.2435					0.0000
23	CuO	79.57					0.3240	0.3600								0.3240
24	Fe(OH)3	106.77					39.5820	43.9800								39.5820
25	Fe2O3	159.70					0.0000			0.0000	0.0000					0.0000
26	GROUP B	122.97					0.5040	0.5600		0.0000	0.0000					0.5040
27	H3BO3	61.83								0.0000	1.4577					0.0000
28	HCOOH	46.03								0.0000	0.1929					0.0000
29	Hg	200.61								0.0000	0.0000					0.0000
30	HgO	216.61					0.0000	0.0000								0.0000
31	K2O	94.19					0.0000			0.0000	0.0000					0.0000
32	KCOOH	84.12								0.0000	1.9305					0.0000
33	KOH	56.10					0.2970	0.3300								0.2970
34	Li2O	29.88											12.866	7.000		12.8656
35	Mg(COOH)2	114.35								0.0000	0.0000					0.0000
36	MgO	40.32					0.0000			0.0000	0.0000		1.838	1.000		1.8379
37	Mn(COOH)2	144.98								0.0000	0.0000					0.0000
38	MnO2	86.92					6.7860	7.5400								6.7860
39	NH4COOH	63.06								0.0000	0.0000					0.0000
40	Na2C2O4	134.00					0.0000			0.0000	0.0000					0.0000
41	Na2CO3	105.93					0.0000									0.0000
42	Na2CrO4	162.00					0.0000			0.0000	0.0007					0.0000
43	Na2O	61.99											23.893	13.000		23.8933
44	Na2SO4	142.05					0.0000	0.0000		0.0000	0.0257					0.0000
45	Na2SiO3	122.05					0.0000			0.0000	0.0006					0.0000
46	Na3PO4	163.97					0.0180	0.0200		0.0000	0.0000					0.0180
47	NaAl(OH)4	118.00					0.2250	0.2500								0.2250
48	NaCOOH	68.01								0.0000	0.7605					0.0000
49	NaCl	58.45					0.0000	0.0000		0.0000	0.0045					0.0000
50	NaF	41.99					0.0000	0.0000		0.0000	0.0009					0.0000
51	NaI	149.92					0.0000	0.0000		0.0000	0.0000					0.0000
52	NaNO2	69.01					0.0000	0.0000								0.0000
53	NaNO3	85.01					4.0500	4.5000		0.0000	1.1109					4.0500
54	NaOH	40.08					4.0500	4.5000								4.0500
55	NaTi2O5H	199.73								0.0000	0.2629					0.0000
56	Ni(COOH)2	148.72								0.0000	0.0000					0.0000
57	NiO	74.69					0.0000			0.0000	0.0000					0.0000
58	Ni(OH)2	92.71					3.1320	3.4800								3.1320
59	PbCO3	267.22					0.0000	0.0000		0.0000	0.0000					0.0000
60	PbSO4	303.27					0.0000	0.0000		0.0000	0.0000					0.0000
61	PdNO3•xH2O	230.72					0.0000	0.0000								0.0000
62	PdO	122.70					0.0000									0.0000
63	PuO2	274.00					0.0000									0.0000
64	Rh	102.91								0.0000	0.0000					0.0000
65	Rh(NO3)3•3	324.90					0.0000	0.0000								0.0000
66	RhO2	134.90					0.0000			0.0000	0.0000					0.0000
67	RuO2	133.08					0.0000			0.0000	0.0000					0.0000
68	Nitro Ru	382.07					0.0000	0.0000								0.0000
69	SeO2	110.96					0.0000	0.0000								0.0000
70	SiO2	60.06					4.3560	4.8400		0.0000	0.0000		124.980	68.000		129.3365
71	SrCO3	147.64					0.0000	0.0000								0.0000
72	TeO2	159.60					0.0000	0.0000								0.0000
73	ThO2	264.12					0.0000			0.0000	0.0000					0.0000
74	U3O8	842.20					0.0000			0.0000	0.0000					0.0000
75	Y2(CO3)3	357.87					0.0000									0.0000
76	zeolite	507.86					4.4550	4.9500		0.0000	0.0000					4.4550
77	Zn(COOH)2	155.42								0.0000	0.0000					0.0000
78	ZnO	81.37					0.0000			0.0000	0.0000					0.0000
79	ZrO2	123.22					0.0000						1.838	1.000		1.8379
80																0.0000
81	Coal	12.00					0.0000	0.0000								0.0000
82	(C6H5)2	154.00								0.0000	0.0323					0.0000
83	(C6H5)2 C6	230.00								0.0000	0.0022					0.0000
84	(C6H5)2NH	169.00								0.0000	0.0042					0.0000
85	(C6H5B(OH)	121.79								0.0000	0.0026					0.0000
86	(C6H5OH)	93.99								0.0000	0.7251					0.0000
87	C6H6	78.00								0.0000	0.0012					0.0000
88																0.0000
89	Water	18.02								0.0000	93.9724					0.0000
90										0.0000						0.0000
91	Total Solids						90.0000	99.7800		0.0000	100.0000		183.7949	100.0000		273.5969
92																
93																
94																
95																
96	90% Formic Acid Requirement						20.0760									