Research and Development Division

Babcock & Wilcox

a McDermott Company

Test Plan

for

Glass Melter System Technologies for Vitrification of High-Sodium Content Low-Level Radioactive Liquid Wastes

Project Number RDD-43288

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TEST PLAN

"GLASS MELTER SYSTEM TECHNOLOGIES FOR VITRIFICATION OF HIGH-SODIUM CONTENT LOW-LEVEL RADIOACTIVE LIQUID WASTES"

PHASE I

SBS DEMONSTRATION WITH SIMULATED LOW LEVEL WASTE

REVISION 0 OF THE TEST PLAN WAS REVIEWED FOR PROPRIETARY INFORMATION, AND WAS FOUND TO BE ACCEPTABLE AS ISSUED. THEREFORE, THE REVISION 0 DOCUMENT IS AVAILABLE FOR PUBLIC INFORMATION.

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ACRONYMS AND ABBREVIATIONS

Al_2O_3	-	Aluminum Oxide
ANSI	-	American National Standards Institute
ARC	-	Alliance Research Center
B&W	-	Babcock & Wilcox
B_2O_3	-	Boron Oxide
C_2H_6	-	Ethane
C_3H_8	-	Propane
$CaCO_3$	-	Calcium Carbonate
CaO	-	Calcium Oxide
CH_4	-	Methane
Cl	-	Chlorine
CO	-	Carbon Monoxide
Cr_2O_3	-	Chromium Trioxide (Chromic Acid)
Cs_2O	-	Ceric Oxide
DAF	-	Dry Ash Free
DAS	-	Data Acquisition System
DP	-	delta P - change in pressure
DREs	-	Destruction and Removal Efficiencies
EPA	-	Environmental Protection Agency
ETS	-	ETS Professional Training Institute
F	-	Fluorine
Fe_2O_3	-	Ferric Oxide
H_3BO_3	-	Boric Acid
HCl	-	Hydrochloric Acid
HF	-	Hydrofluoric Acid
HI	-	Hydriodic Acid
HVT	-	High Velocity Thermocouple

I	-	Iodine
ID	-	Induced Draft
IEEE	-	Institute of Electronics and Electrical Engineers
K_2O	-	Potassium Oxide
LLW	-	Low-Level Radioactive Liquid Waste
MgO	-	Magnesium Oxide (Magnesia)
MnO	-	Manganese Oxide
Molec	-	Molecular
MoO_3	-	Molybdenum Trioxide
MW_t/m^3	-	Mega Watt per cubic meter
Na_2O	-	Sodium Oxide
NDIR	-	Non-Dispersive Infrared
NG	-	Natural Gas
NH_3	-	Ammonia
NO_x	-	Nitrous Oxide Compounds
O_2	-	Oxygen
Orif	-	Orifice
P_2O_5	-	Phosphorus Pentaoxide
POHC	-	Principle Organic Hazardous Constituents
psig	-	Pounds per Square Inch Gauge
QA	-	Quality Assurance
Recirc	-	Recirculation
SBS	-	Small Boiler Simulator
scfm	-	Standard Cubic Feet per Minute
SiO_2	-	Silicon Dioxide (fume silica, fine sand)
SiO_3	-	Silicon Trioxide
SITE	-	Superfund Innovative Technology Evaluation
SNCR	-	Selective Non-Catalytic Reduction

SO_2	-	Sulfur Dioxide
SO_3	-	Sulfur Trioxide
TC	-	Thermocouple
TCLP	-	Toxicity Characteristic Leachate Procedure
TLV	-	Threshold Limiting Value
USEPA	-	United States Environmental Protection Agency
USGS	-	United States Geological Survey
UV	-	Ultraviolet
V	-	Volt
WHC	-	Westinghouse Hanford Company

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I. Introduction/Background

The Babcock & Wilcox (B&W) Cyclone Furnace is a well-proven coal combustion device that has been used in commercial steam generation since the 1940's. In a coal-fired cyclone furnace, most of the mineral matter in the coal is transformed into a molten slag which flows by gravity out of the furnace. Upon cooling, this slag has a glassy appearance with many characteristics of glass including non-leachability of constituent chemical elements.

More recently, several studies have been performed to demonstrate the usefulness of the cyclone furnace for vitrification of wastes. The most comprehensive of these studies was the Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Demonstration using the B&W pilot-scale Small Boiler Simulator (SBS), cyclone furnace. In the EPA SITE Demonstration a synthetic soil was successfully vitrified to produce a glassy slag that passed Toxicity Characteristic Leachate Procedure (TCLP) tests for several heavy metals (USEPA SITE Report EPA540/AR-92/017, August, 1992). In addition, the SITE Demonstration showed that Destruction and Removal Efficiencies (DREs) for each of the Principal Organic Hazardous Constituents (POHC) were above 99.99 percent. For this project, the technology will be demonstrated for the Hanford High Sodium Content Low-Level Radioactive Liquid Waste (LLW) by adding glass formers to the feed for vitrification of the waste constituents. The Phase 1 demonstration will be performed using a simulated LLW feed that is being supplied by Westinghouse Hanford Company (WHC).

Pretest work will include project planning, laboratory testing, and site preparations. Planning and site preparations are discussed in Section I, and a discussion of laboratory testing is provided in Section II.

A. Planning

The project planning phase involved detailing the work scope, QA requirements, and safety concerns, and documentation of the resulting information. This document constitutes the detailed test plan. A quality assurance plan was prepared and issued to WHC under separate cover. Safety concerns specific to the project were identified in a project safety plan that was distributed to the test personnel.

B. Site Preparation

The ARC Chemistry Laboratory and the pilot-scale Small Boiler Simulator (SBS) will be prepared as necessary to perform the test activities required to demonstrate the process on simulated LLW provided by WHC.

There are multiple activities under site preparation for the SBS and its supporting systems. The activities identified are: implementation of the safety and QA plans, preparation of the furnace, preparation of the flue gas system, instrument calibration and standardization, and preparation of the feed system for the glass former/simulant.

The furnace preparations will include replacement and repair of insulation and setting the SBS up for cyclone firing. The furnace refractory will be replaced to allow evaluations of the deposit buildup, compatibility between glass constituents and the refractory materials, and partitioning of glass constituents. Preparing the SBS for cyclone firing involves two primary activities. First, the pulverized coal burner will be removed and replaced with a wall that will be lined with refractory. Then the cyclone furnace will be inspected and repairs and maintenance will be performed as required.

The convection pass and all downstream equipment to include the dry scrubber and baghouse will be cleaned out to remove residual ash from previous tests in the SBS facility. This will be done using sootblowers in the convection pass and the dry

scrubber to free up the ash, and the facility ID fan to carry the ash to the system baghouse. The final step will be to clean the baghouse bags with sootblowers and remove the solids in the baghouse hoppers. In addition, the flue gas cleanup equipment will be prepared for use in these tests. The dry scrubber will be readied for removal of acid gases, and the reburn and Selective Non-Catalytic Reduction (SNCR) systems will be installed for NO_x control.

The instrumentation associated with the SBS will be inspected and calibrated or standardized in accordance with the Quality Assurance Plan for this project. In addition, instrumentation specific to this test will be prepared for use and calibrated as required.

Based on results obtained in the laboratory testing, a mixing system will be established to thoroughly mix the glass formers and the simulant. Details are contained below in Section III, "Melter System Description".

II. Laboratory Testing

There will be two types of testing performed in this project: laboratory-bench testing and pilot-scale tests in the SBS. The laboratory tests will be run prior to any attempts to produce glass in the SBS. The primary goals of laboratory testing are to identify the properties of the feed mixture, and to use the information to assist in feeding the mixture during the SBS pilot tests.

The following laboratory procedures will be performed:

A. Characterization of the Glass Formers

The ARC Analytical Chemistry Section will perform several analyses on the glass formers in order to better define the feed inputs for the Phase 1 demonstration. The glass formers will be comprised of a silica source (fine sand and microsilica), limestone, boric acid, and hydrated aluminum oxide. Table II-1 provides a listing of the glass formers to be used in Phase I. Analytical measurements will be used to identify the purity and physical properties of each of the additives. These results will be used to define the characteristics of the feed materials being used in the Phase 1 feed and melter systems, and as a starting point for evaluating the Phase 2 systems. Samples of the glass formers also will be taken in case additional characterizations are required after testing. One complete set of glass former samples will also be provided to WHC.

B. Characterization of Waste Simulant

Limited analyses will be performed on the LLW simulant at the ARC, since WHC is providing B&W with a detailed analysis. The Phase 1 simulant is a 10 molar sodium solution that contains approximately 400 g/L of dissolved solids. Measurements to be performed at the ARC will include density and pH to provide inputs for the mixing and

feed system, and sodium concentration to confirm that the simulant is 10 Molar. B&W will rely on analyses from WHC for the detailed composition of the simulant.

Table II-1. Glass Former Constituents

Glass Former	Supplier	Designation	Particle Size
Fine Sand	Best Sand P.O.Box 87 Chardon, Ohio 44024	130	1200 microns (top size); 160.39 microns (mass mean diameter)
Microsillica	Elkem Materials, Inc. Park West Office Ctr. P.O.Box 266 Pittsburgh, PA 15230	EMS 965-L18	1.5% of +45 microns (max.)
Limestone	J. M. Huber Corp. 3150 Gardner Expwy. Quincy, Illinois 82301	Hubercarb Q325 Lot No. 304348	19.63 microns (mass mean diameter)
Boric Acid	National Borax 3690 Orange Place Suite 495 Cleveland, Ohio 44122	Technical grade	5.9% of +425 microns
Hydrated Alumina	Whittaker, Clark & Daniels, Inc. 1000 Coolidge Street South Plainfield, NJ 07080	C-330 Case No. 21645-51-2 Lot No. R-4978 (29) Lot No. R-4755 (1)	2% of +45 microns 7.5 microns (median particle size)

C. Preparation of Mixtures of Glass Former and Waste Simulant

The main objectives set for the laboratory testing are to obtain the desired feed consistency and to identify the mixing and handling requirements of the feed. The laboratory tests will examine the effects of varied particle sizes and different mixing techniques, and will identify changes in the feed with time.

First testing will be performed to identify the particle size requirements of the glass formers needed to get the desired feed consistency. For these tests, the ratios of fine sand to microsilica will be varied in the glass formers. The glass former will then be added into the waste simulant while the waste simulant is under stirring. The stability of the mixtures will be determined by making visual observations of the rate at which the liquid/slurry interface drops after stirring is stopped. These tests will allow determination of the best ratio of fine sand to microsilica for the feed system.

Next, different approaches will be used to mix the simulant and glass formers. One approach is to premix all the components of the glass former prior to adding into the waste simulant. The other approach is to add each component of the glass former individually into the waste simulant. The sequence of addition into the waste simulant will be varied. Both of these techniques will be evaluated in the laboratory environment to identify the advantages and disadvantages of each.

Once the final feed mixture and procedure are identified, a batch will be made for further evaluation. Investigations on the final feed batch will include:

- Observations to determine if there are any property changes with time that will impact the feed system.
- Periodic mixing will be performed on several samples to examine how easily the solids can be resuspended after partial settling or jelling.

- A single sample of the final feed mixture will be placed in the B&W slag viscometer where the water will be slowly driven off, a glass melt will be formed, and the glass viscosity-temperature relationship will be determined.
- A large batch of the feed will be prepared (about 95 liters, 25 gallons), and recirculated in a portable pumping unit with a tank and progressive cavity pump. This will allow the feed properties to be examined in a system that closely resembles the planned Phase 1 feed system.

All of these activities will provide information that will be used to determine if the planned feed system will be adequate. The goal is to be able to expeditiously make any required changes to the planned Phase 1 feed system which is described below.

III. Melter System Description

A. Feed System

The purpose of the feed system is to thoroughly mix the glass forming materials and the simulant and inject the resultant mixture into the cyclone furnace so that a suitable vitrified product is prepared. The feed system includes equipment for measuring and mixing the feed ingredients, feed storage, pumping, and injection into the cyclone.

The Phase 1 feed system will be set up in batch mode to more easily accommodate required changes as the feed properties are identified. In Phase 2, the system will more closely reflect a commercial feed system such as the one described in the Phase 1 proposal.

Figure III-1 provides a schematic of the planned Phase 1 feed system. In this system a Moyno progressive cavity pump with speed controller (Frame 2J3, Type CDR AAA) will be used to feed the high viscosity, high solids feed. A maximum feed rate of 280 kilograms per hour (617 lb/h) is possible with this pump. The pump stator material is natural rubber and the rotor is chromium steel. The speed controller is designed to maintain a constant motor speed and, thus, a constant feed rate to the cyclone furnace. The simulant and glass formers will be added in a barrel and mixed using the barrel turner. The drum lid will then be replaced with a discharge cone, and emptied into the feed hopper by way of two valves. Particles larger than 13 millimeters (0.5 inch) will be screened from the feed during transfer to the feed hopper. After loading the hopper, a two-blade mixer will be turned on. The system

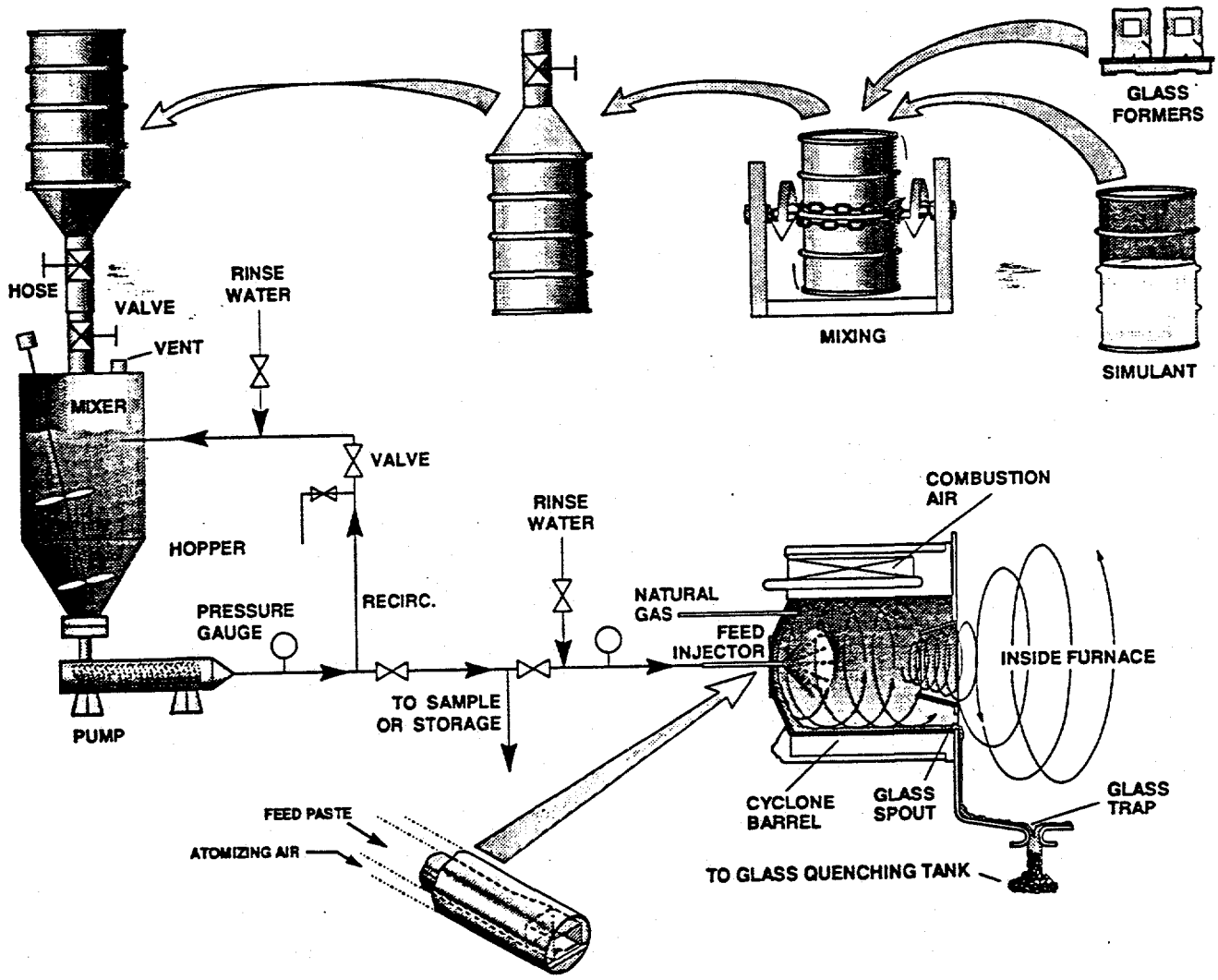

Figure III-1. Schematic of the Planned Feed System

will be flow calibrated using the feed slurry. The mixture will be introduced into the cyclone furnace through the feed injector. The feed recirculation line will be closed while the cyclone is being fed, and feed uniformity will be maximized by use of the two-blade mixer. Feed samples will be taken at the beginning and end of a single feed batch to determine if settling in the feed hopper is a problem.

An atomizer was developed during previous work to inject and disperse a paste into the cyclone combustor. Figure III-2 shows this atomizer which will be used as the feed injector for these tests.

The atomizer consists of two concentric tubes. The inner tube provides the flow passage for the feed, while compressed air is supplied in the annular space between the two tubes. At the outlet end of the atomizer, flow passages between the soil tube and the annulus provide the high-velocity air streams for breakup of the paste and transport to the cyclone walls. The outlet end of the paste tube is shaped in a rectangle and attached to a tungsten carbide insert. This insert is in the form of a billet with a machined slot. A wear-resistant tungsten carbide insert forms three of the four walls of the rectangular opening, while a flow distributor plate forms the fourth wall. In the commercial system the injector insert would be made from a ceramic that has proven to be even more wear resistant.

B. Cyclone Melter System

The melter system will be the cyclone burner on the 1.5 million kilocalories per hour (6 million Btu/hr) Small Boiler Simulator (SBS), a pilot-scale combustor in the B&W Research Center in Alliance, Ohio. The SBS, as configured for this project, is fired by a single, scaled-down version of a commercial coal fired cyclone furnace

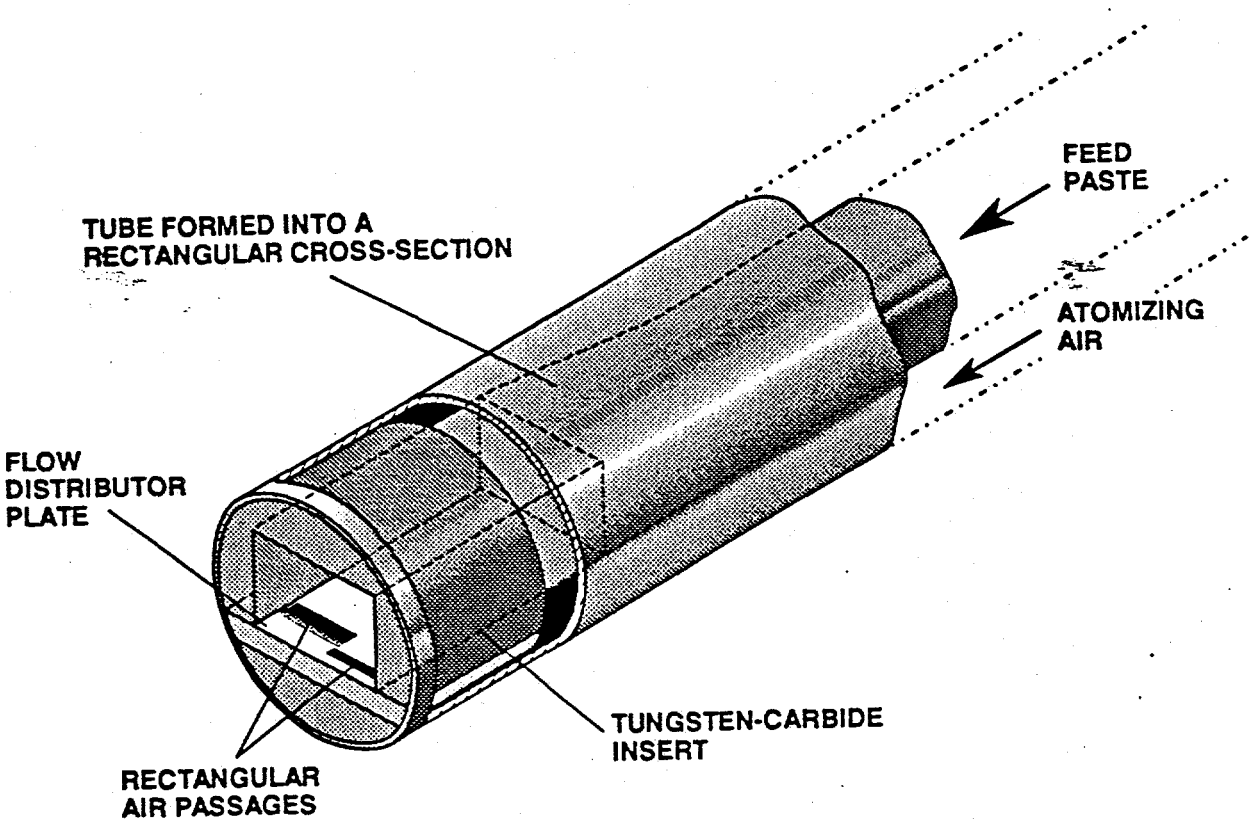

Figure III-2. Feed Injector

(See Figure III-3). On an energy basis, the SBS cyclone is approximately 1/30 scale for a 100 metric ton per day (4.6 tons/hr) unit utilizing a single cyclone burner. The furnace geometry is a horizontal cylinder (barrel). For the present application, natural gas and preheated primary combustion air (440°C, 820°F) will enter tangentially into the cyclone furnace. For feed processing, an atomizer is used to spray the paste directly to the furnace. The feed is captured and melted, any organics are destroyed in the molten glass layer that is formed and retained on the furnace barrel wall by centrifugal action. The feed melts, exits the cyclone furnace from the tap at the cyclone throat, and is dropped into a water-filled slag tank where it solidifies. A small quantity of solids also exits as fly ash with the flue gas from the furnace. During Phase 1 testing these solids will mix with dry scrubber solids and will be collected in the dry scrubber hopper and baghouse. The rate of solids capture during the 24-hour run will be determined by weighing the solids removed from the baghouse hoppers over a known period of time. Chemical analyses performed on these samples will be used to quantify the fraction of these solids that originates from the feed verses the dry scrubber solids.

In Phase 2, or the commercial application, the baghouse would be placed upstream of the dry scrubber or other acid gas removal system. The baghouse catch could then be recycled back to the cyclone in order to improve the overall waste capture efficiency. Alternatively, the baghouse solids could be vitrified with the HLW in a commercial system since they would be greatly reduced in volume from the original LLW in the feed.

The cyclone furnace is a water-cooled, horizontal cylinder attached to the main furnace. In the configuration designed to melt and vitrify wet soil, natural gas was added directly to the barrel of the cyclone. The cyclone is lined with a thin layer of ceramic (20 mm, 0.75 inch) which is troweled onto a dense array of metal studs. The combustion air enters the top of the cyclone tangentially inducing intense turbulence yielding combustion rates as high as 8.3 MW/M^3 (80 million $Btu/hr\text{-}ft^3$). This can

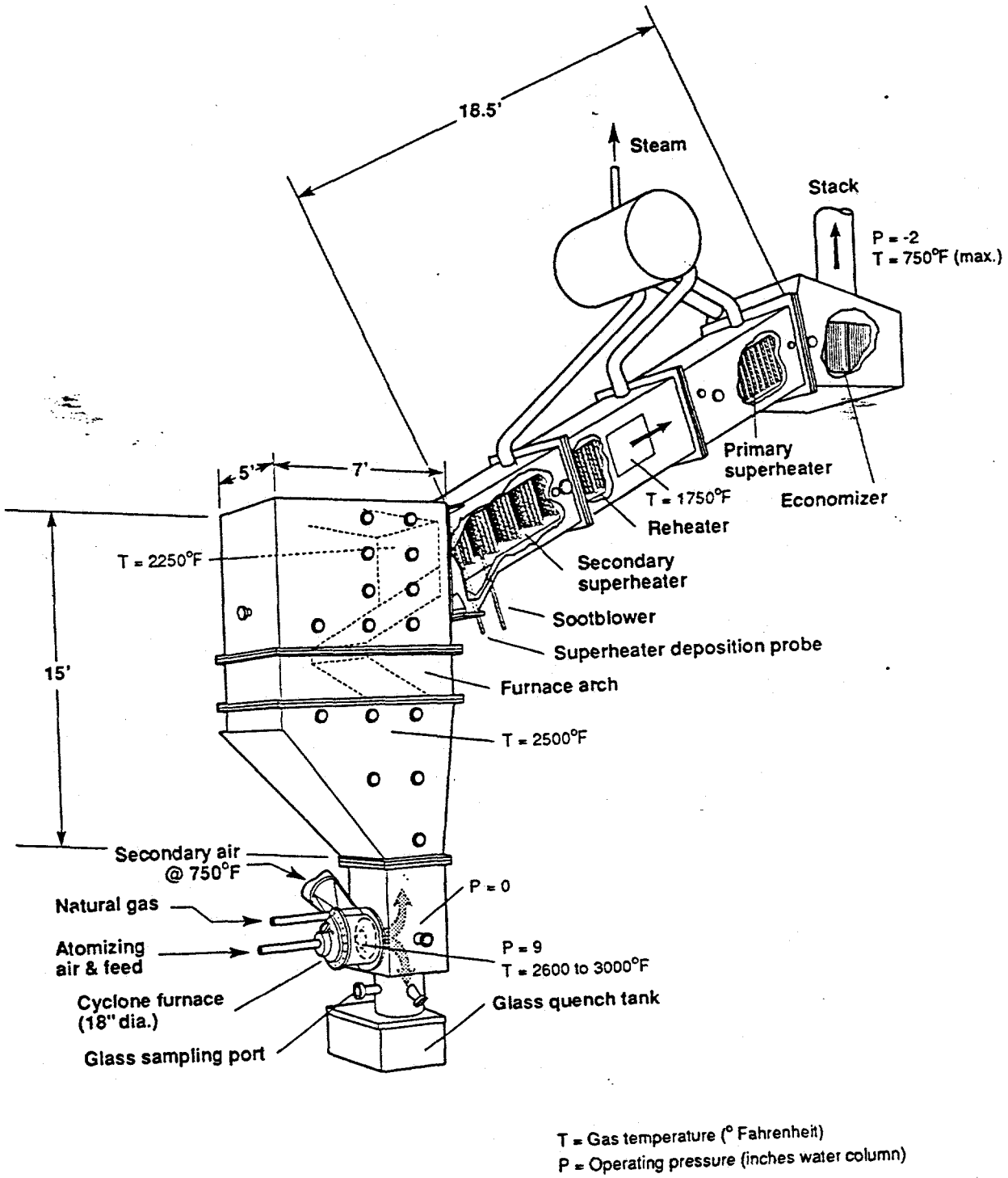

Figure III-3. SBS Pilot Facility Configured for Glass Formation

produce flue gas temperatures approaching the adiabatic flame temperature. Our soil vitrification experience showed that flue gas temperatures in the range of 1540-1650°C (2740-3000°F) and corresponding molten slag temperatures of 1300-1350°C (2370-2460°F) were required to produce the desired end product, e.g., vitrified soil. The reason the slag (glass) temperature lags the flue gas temperature is that the molten slag loses some heat to the walls of the water-cooled cyclone. During shakedown we will identify the operating requirements for keeping the glass flowing.

Currently, Plibrico 85-S Special refractory is installed both in the cyclone and the lower portion of the SBS furnace. Although, the refractory has performed very well during PC firing in the SBS, it is still untested in the cyclone. Therefore, a section of Shamrock® refractory, for which proven reliable performance in the cyclone has been well established over the years, will be installed on the target wall of the lower boiler opposite the re-entrant throat of the cyclone. This will make direct comparisons of the two refractories possible regarding their relative resistance to chemical attack from the vitrified waste stream.

Three of the objectives in Phase 1 are to evaluate buildup of deposits on the refractory, compatibility of the glass and refractory, and partitioning of the feed constituents. The relining of the furnace insulation during site preparations will enable these evaluations to be made. Starting testing with fresh refractory will allow buildup to be measured and the glass deposits will have intimate contact with the refractory. Information on partitioning will be more reliable since contamination by slag from past SBS operation will be greatly reduced. The furnace conditions will be documented in the logbook and through photographs taken inside the SBS before and after Phase 1 testing. These observations and photographs will be included in the final report.

Hot gases exit the cyclone through the vortex finder and pass through the main furnace. The slag leaves the cyclone through the slag spout and flows by gravity to

the slag tank. The slag tank is filled with water. The glass produced by the rapid quench produces a material that easily passes EPA's TCLP test. A port below the slag tap will be used as access for sampling the molten glass during the Phase 1 tests.

Natural gas will be used as the fuel for the Phase 1 demonstration. Current plans are to use oil in the Phase 2 testing. During the initial Phase 1 testing, a natural gas sample will be drawn from the SBS supply line, and analyzed by Columbia Gas.

Particulate control is achieved by way of the dry scrubber and baghouse. To maximize the capture of volatile species, a heat exchanger is used to cool the stack gases to approximately 150°C (300°F) before entering the dry scrubber.

C. Off-Gas System

Off-gas treatment will be used to control the emissions of at least three distinct pollutants. These include NO_x resulting from the decomposition of the nitrates and nitrites in the simulant, relatively coarse particulate (which B&W normally refers to as fly ash) which results largely from physical entrainment of inorganic matter leaving the cyclone, and finally, fumes which leave the cyclone initially as vapors but rapidly condense or nucleate into fine fumes whose particle size is often less than one micron.

The first stage of off-gas treatment for the pilot scale system is a technology known to the power industry as "reburning". To address the special needs of the cyclone boiler population with respect to NO_x reduction, B&W developed the reburning technology. Reburning is a process by which NO_x produced in the cyclone is reduced (decomposed to molecular nitrogen) in the main furnace by injection of a secondary fuel. The secondary (or reburn) fuel creates an oxygen-deficient

(reducing) region in the main furnace downstream of the cyclone which accomplishes the NO_x decomposition. Since reburning, which occurs downstream of the cyclone, can be applied while operating the cyclone under its normal oxidizing conditions, its effects on cyclone performance can be minimized.

Additional NO_x removal will be obtained using SNCR. In SNCR, ammonia is injected in the convection pass where the gas temperatures are around 1000°C (1800°F). The ammonia reacts with the NO_x at this temperature to form elemental nitrogen. An ammonia analyzer will be used to maintain ammonia slip within 20 ppm.

A dry scrubber will be used to remove acid gases and cool the flue gas. The scrubber was previously designed and built as part of a flue gas desulfurization demonstration. The scrubber is a cylindrical, down -flow reactor measuring 1.5 meters in diameter (5 ft.) and 5.2 meters long (17 feet) from the atomizer to the exit. Flue gas enters the top through an expansion containing several flow straightening devices. A single B&W DuraJet® atomizer is installed at the top center of the scrubber. The atomizer is rated at 3 liters (0.8 gpm) per minute and sprays a slurry that will be comprised of hydrated lime and water for these tests. Mixing is achieved by the rapid entrainment of flue gas into the high velocity atomized jet stream. The flue gas exits near the bottom of the chamber and flows to the baghouse. The reaction chamber is designed for a gas residence time of 5-10 seconds. The diameter is large enough to prevent direct-wall impingement of the atomized spray. A hopper is located at the base of the scrubber to facilitate solids handling, although a great majority of the solids are collected in the baghouse. The scrubber is completely instrumented with thermocouples, gas analyzers, manometers, and flow meters.

The flue gas passes from the dry scrubber into a baghouse where solids collection occurs. The baghouse was purchased form MikroPul Inc. and consists of two modules each containing 23, 11.75 centimeter diameter (4.6 inches), 3 meter long (10 ft.), bags. The baghouse is insulated with high temperature material to allow

the SBS to operate without the cooling derived from dry scrubbing. The baghouse required the installation of a 19 kilowatt, 2550 normal cubic meters per hour (1500 SCFM), 6 kilopascal (25 inches of water gauge), induced draft fan used to balance the pressure drop created by the ductwork, heat exchanger, dry scrubber, and baghouse. The inlet damper is automatically controlled to balance the draft created by the forced draft fan of the SBS facility.

D. Secondary Streams

There will be three secondary streams in the pilot scale system. First the solids removed from the dry scrubber hopper. These will primarily be large solids that can build up in the scrubber, and the quantity is relatively small. Next will be the solids collected in the baghouse hoppers. In a commercial application the amount would depend on the melter carryover and the volatility of the feed constituents. For the Phase 1 demonstration, most of these solids will be from the dry scrubber sorbent since the scrubber precedes the baghouse in the pilot system. The third stream is the flue gas which will be about 2180 kg/hr (4800 lb/hr). The composition will be monitored to ensure that State and local permitting requirements are met as is described in Section 6.

E. Flowsheet

A flowsheet for this glassification process is depicted in Figure III-4. The glass former and simulated LLW will be premixed as described in Section A above. The premixed batches will be added manually to the reservoir above the suction of the progressive cavity pump. We do not anticipate the need to make any modifications to the LLW formulation. The analyses of the glass former components supplied by the vendors of each component will be used for the initial assessment about impurities. To supplement that data, B&W's Analytical laboratories will be used to perform an independent analysis in each glass former constituent. In addition to

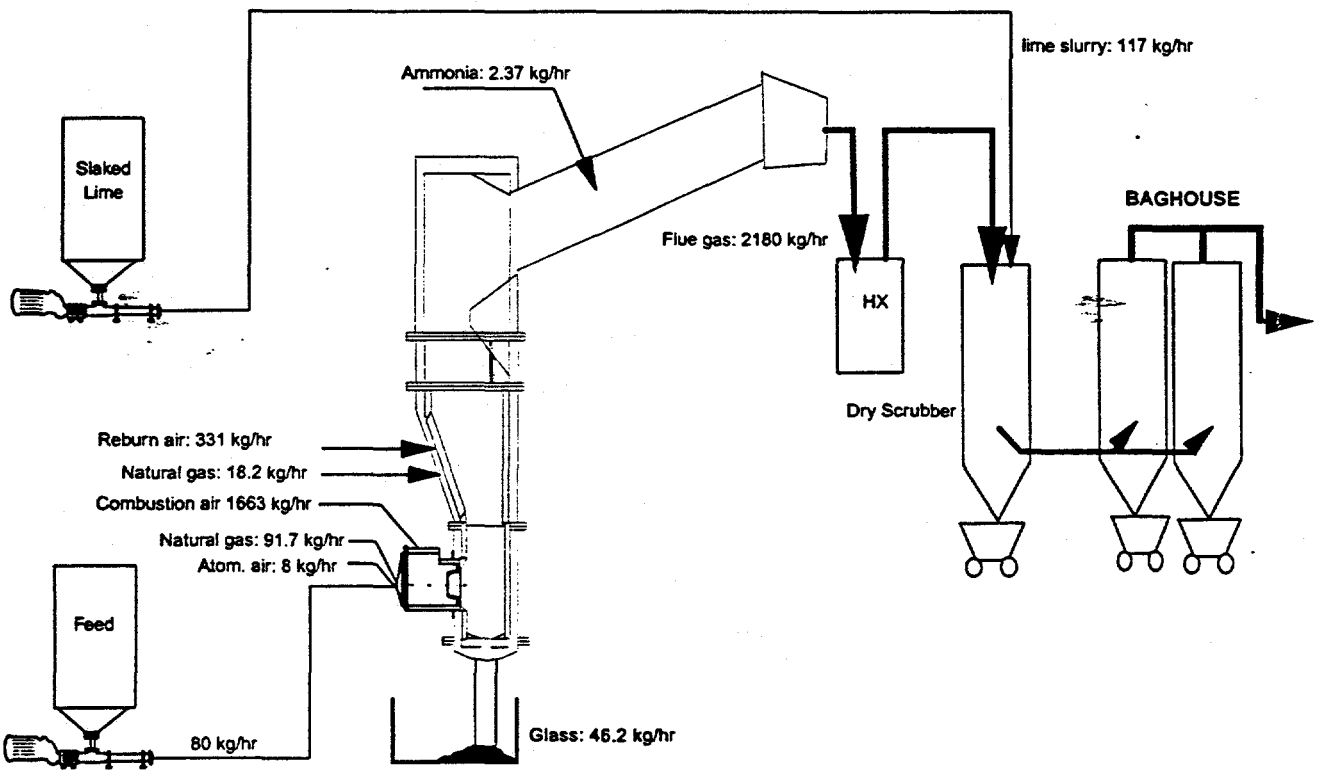

Figure III-4. Phase-1 Process Flowsheet

composition, the particle size distribution of each glass former will be determined by Microtrac analysis. The reason for this determination, is that the feed (mixture of glass formers and LLW) will be prepared with glass former constituents and size distributions such that the feed will have a viscous composition suitable for delivery to the cyclone furnace.

Table III-1 presents the computed composition and flow rate of each component of the feed mixture to the cyclone melter at a total rate of about 80 kilograms per hour (176 lb/hr). As can be seen, the total moisture content of this mixture is about 27.9%. The composition of the feed was selected to produce a glass composition identified by WHC as LD6-5510. (See Table III-2). This glass has a viscosity of 10 Pascal seconds (100 Poise) at a temperature of 1296°C (2365°F). The corresponding T_{250} for this glass is 1183°C (2161°F). The T_{250} represents the glass temperature in degrees Fahrenheit at which the viscosity is 250 Poise. Cyclone furnaces are typically designed for coals whose T_{250} is less than 1343°C. Therefore, this glass composition falls comfortably within the historic range of cyclone furnace applications. One hundred percent of the silica and boron oxide will originate from the glass formers. About 33% of the alumina in the glass will originate with the simulated LLW and the remainder will be added as glass former. Essentially all of the calcium in the glass will originate in the glass former (less that 0.1% will come from the simulated LLW.) In total, the goal for this glass is for simulant constituents to constitute 26.3% of the weight of the glass.

The pump used to feed the mixture of glass former and simulated LLW is classified as a progressive cavity pump. For relatively low pressure applications such as this situation, this pump behaves as a positive displacement pump. The volumetric feed rate is, therefore, proportional to the rotational speed of the pump. We will, therefore, use pump speed as the primary means for monitoring the feed rate. As a secondary means, the weight of each batch of the feed will be known. Thus, the total weight of feed consumed will be known over time.

Table III-1. Target Feed Composition and Flowrate

Constituent	Mass Flow, kg/hr	Percent of Total, wt.
SiO_2 (fume silica)	7.83	9.79
SiO_2 (fine sand)	18.28	22.85
H_3BO_3	4.07	5.09
$CaCO_3$	4.10	5.13
Al_2O_3	3.11	3.89
Water	22.28	27.85
Sodium, Na^+	6.79	8.49
Aluminum, Al^{+++}	0.813	1.016
Chromium, Cr^{++}	0.0134	0.1675
Potassium, K^+	0.579	0.7238
Molybdenum, Mo^{++}	0.0483	0.0604
Strontium, Sr^{++}	0.0441	0.0551
Cesium, Cs^+	0.0669	0.0836
Phosphate, $PO_4^{=}$	0.1209	0.151
Iodate, IO_3^-	0.088	0.1000
Carbonate, $CO_3^=$	0.474	0.5925
Chloride, Cl^-	0.172	0.215
Fluoride, F^-	0.1406	0.1758
Sulfate, $SO_4^=$	0.1223	0.1529
Nitrate, NO_3^-	5.709	7.1363
Nitrite, NO_2^-	2.175	2.719
Hydroxide, OH^-	1.9272	2.409
Organics	0.4794	0.5993
Total	79.45 kg/hr	

Table III-2. Target Glass Composition*
LD6-5510

Constituent	Percent of Total, wt.
SiO_2	56.91
B_2O_3	5.0
Na_2O	20.0
CaO	5.0
Al_2O_3	10.0
Cr_2O_3	0.04 (400 ppm)
Cs_2O	0.15 (1500 ppm)
Fe_2O_3	0.003 (30 ppm)
K_2O	1.46 (14600 ppm)
MgO	0.003 (30 ppm)
MnO	0.002 (20 ppm)
MoO_3	0.15 (1500 ppm)
P_2O_5	0.19 (1900 ppm)
SO_3	0.21 (2100 ppm)
Cl	0.35 (3500 ppm)
F	0.29 (2900 ppm)
I	0.13 (1300 ppm)

*This composition was predicted by Westinghouse Hanford Company

The liquid/slag/glass residence time in this cyclone is quite short when compared to conventional glass melting furnaces. At a feed rate of 80 kg/hr (176 lb/hr), and glass production rate of about 46.2 kilograms per hour (102 lb/hr), the average glass residence time is probably less than 18 minutes. That estimate is based on assuming an average molten glass thickness of about 13 mm (0.5 inch) uniformly distributed on the walls of the cyclone. B&W has not attempted in the past to make residence time distribution measurements for slag in a cyclone furnace. If this measurement is found to be an important factor in glass quality or cyclone

capacity, B&W could attempt to make "C Test" type residence time distribution measurements by doping the feed with a tracer and measuring the response function.

The glass leaving the cyclone will flow by gravity to a water quench tank where the solidified, fragmented glass will accumulate. The glass will be removed manually by the test crew. They will "scoop" the glass from the quench tank with coarse sieves and place the material into 55 gallon drums for weighing and disposal. The glass samples to be sampled for analysis will be sampled before the water quench by the procedure described in Section IV-C.

At the request of WHC, the LD6-5510 PNL glass formulation will be adjusted to reach 0.5 percent $F3_2O_3$ during the 24-hour continuous run. This change will be made to enable WHC to make glass redox measurements. When the iron addition is made to the feed, the SiO_2 will be reduced by an equal amount.

IV. Test Monitoring and Sampling

A. Test Monitoring

Test monitoring will include automatic data acquisition, manual data readings, and manual system measurements (e.g. HVT and EPA Method 5 sampling). This section provides a discussion of these measurements.

Voltage signals from instruments, sensors, and metering devices are collected, converted to a digital signal, and stored by the Data Acquisition System (DAS). STARS/LabVIEW software is utilized to convert these signals to engineering units for on-line real time display in tabular or graphical form at time intervals specified by the operator. Derived quantities such as fuel input (load) and cyclone exit flow are calculated utilizing other measured instrument values converted to engineering units. A list of all continuously measured and calculated quantities to be collected in this study are shown in Appendix A. A brief list of the more important quantities to be monitored by the DAS are shown in Tables IV-1and IV-2.

The fuel and combustion flows are measured by the DAS electronically utilizing pressure transducers and thermocouples at the flow orifices. Raw voltages from these devices are converted to static pressure, pressure drop, and flow temperature at the orifice by utilizing calibrations based on reference signals. Engineering units for flow are calculated with a calibrated flow orifice equation expressing flow as a function of the above variables.

Table IV-1: Continuously Monitored Test Parameters by the DAS	
Test Parameter	Method
Flowrates	
Combustion Air - Cyclone, Reburners, Overfire	ASME orifices (a)
Natural Gas - Cyclone, Reburners	ASME orifices (a)
Feed Input Rate	Calibrated positive displacement pump
Feed Dispensing Air Flow Rate	ASME orifice (a)
Temperatures	
Cyclone/Cyclone Exit Gas Temperature	Flameview (d)
Cyclone Glass Temperature	Optical Pyrometry (e)
Cyclone Water Jacket Temperatures	K-Type (c)
Gas Species Concentrations	
O_2, CO_2, CO, NO_x, SO_2 after convection pass	Beckman Analyzers (b)
Particulate Concentration	
Stack Opacity*	Light Extinction
Other Continuously Monitored Derived Quantities	
Total Heat Input	Calculated
Cyclone Exit O_2	Calculated
Cyclone Exit Mass & Volumetric Flow	Calculated

Table IV-2: Manually Collected Data		
Test Parameter	Sampling Frequency	Instrument
Furnace Exit Gas Temperature	Scoping Tests - Twice 24 Hr Test - Three Times	HVT - Type K Thermocouple (d)
Cyclone/Cyclone Exit Gas Temperature	Every Four Hours	HVT - Type B thermocouple (d)
Cyclone Water Jacket Flow	Hourly	Cumulative Volumetric Meter

(a) ASME orifices utilize pressure transducers and K type thermocouples (TCs). Pressure transducers are calibrated annually or when their zero values shift more than 2%.

(b) Calibrated at least twice daily with two levels of gas per Beckman manual. Calibration gases are industrial grade from LINDE. LINDE's certificate of analyses shows 2% accuracy.

(c) TCs are obtained from vendors audited by the B&W ARC Quality Assurance Department. TC wires conform to the standard limits of error as defined by ANSI MC96.1

(d) Use of the B&W Flameview pyrometer for providing the cyclone gas temperature is experimental.

(e) Calibrated yearly by a QA-approved vendor.

* Relative value to indicate trends - for indication only

The glass former/simulant flow is metered by setting the tachometer on a volumetric progressive cavity pump. The voltage output from the tachometer is also

monitored by the DAS. The calibration on the pump will be checked before and after each test to ensure that slippage in the pump has not changed.

Beckman gas analyzers are used for the monitoring of O_2, NO_x, CO, NO, SO_2, and CO_2 on a dry basis at the boiler stack. Table IV-3 describes the type of instrument for these measurements as well as the physical principle on which it is based. The stack analyzer system is set up with a heated capillary tube system which allows a heated, filtered stack sample to be directly input to the analyzer (wet basis). The purpose for this arrangement is to eliminate the loss of NO_2 through moisture contact (NO_2 is soluble in water). In addition to the DAS, all analyzer output signals were connected to both digital volt meters and Chessel multi-pen strip chart recorders to provide a continuous readout.

During the 24-hour run, the solids accumulation in the dry scrubber and baghouse hoppers will also be measured. The solids from both pieces of equipment will be put in barrels and weighed to make this determination.

For the standard Beckman emissions system (and Anarad SO_2 analyzer) all emissions are recorded on a dry basis. The samples are drawn from the convection pass outlet by a vacuum pump, filtered, and then transported in a heated sample line to a refrigeration unit. The flue gas clean-up system utilizes a water trap system to drop out the moisture content of the gases so that they are saturated at a temperature of about -16°C (3°F). A Perma Pure dryer is connected for dehumidifying prior to the analyzers.

The analyzers are calibrated at the beginning of each test day, and periodically throughout the day, as determined by the test engineer. A final calibration check is performed at the end of each day and data qualified accordingly.

Table IV-3 Gas Analysis Instrumentation			
Gas Species	Analyzer	Model Number	Measurement Principle
O_2	Beckman	755	Paramagnetic
CO_2	Beckman	864	NDIR
CO	Beckman	864	NDIR
SO_2	Anarad	AR-30	UV Absorption
NO_x	Beckman	951A	Chemiluminescent

In addition to DAS acquired data and continuously recorded strip chart data, operators also periodically record all operational data manually as a backup to the DAS. A list of this data is shown in Appendix A after the Table describing all DAS acquired data. The manual collection of data is performed hourly by the system operators.

Note that since the NO_x reduction is achieved before the convection pass outlet, baseline data will have to be obtained using a short test without SNCR or reburning. This measurement will either be made during scoping tests or at the beginning or end of the 24-hour demonstration. The back calculated permit limit of NO_x at the SBS stack is 988 ppm. During these tests, the NO_x from the feed is expected to be about 830 ppm or higher depending on the feed rate. Thermal NO_x will depend on the final cyclone conditions selected for the test. SNCR and reburning combined can be used to reduce NO_x by as much as 75 percent.

B. Sampling

Sampling will be performed to evaluate process control and the ability to consistently produce the target glass composition, glass uniformity and quality, and mass balance across the melter. Samples will be identified by type of sample, sampling location, date, time, and the identification of the individual taking the sample. Samples will be analyzed by a laboratory contracted directly by WHC. During the 24-hour run, the WHC sampling procedure will be followed. The details of this procedure are provided in Appendix B.

Isokinetic samples of the stack gas particulates are taken according to EPA Method 5 regulations using an Anderson Emissions Parameter Analyzer. Samples are collected on 12.5 cm, 3 micron Whatman glass filters. The moisture content of the flue gas will be determined gravimetrically from water vapor trapped in the impingers. In addition, ETS will measure the particle size distribution of an isokinetically extracted flue gas sample utilizing a cascade impactor. The composition of each impactor stage will be analyzed for: Al, B, Ca, total Cr, Fe, K, Mn, Mg, Mo, Na, Si, Sr, Cs, P, I, Cl, F, S, and carbonate. These measurements will be made at both the rear of the convection pass and downstream of the baghouse.

All measurements and sampling will be performed by B&W unless otherwise noted. During the 24-hour run an EPA certified independent lab will take five cascade impactor and five EPA Method S samples at the convection pass exit, and one of each at the baghouse exit. Additional gas sampling will be performed by B&W to provide backup data and permitting information. Additional information on sampling is provided in Section V.

Archive samples will be provided to WHC. The following solids samples will be taken: Feed (as-fired glass formers/simulant blend, molten glass, baghouse and dry scrubber solids, off-gas entrained particles, and refractory surfaces) which will have

been in contact with the glass. Molten glass samples will be collected with a cast iron ladle through a port located below the slag tap. Figure IV-1 is a schematic of the test facility, illustrating the locations for sampling.

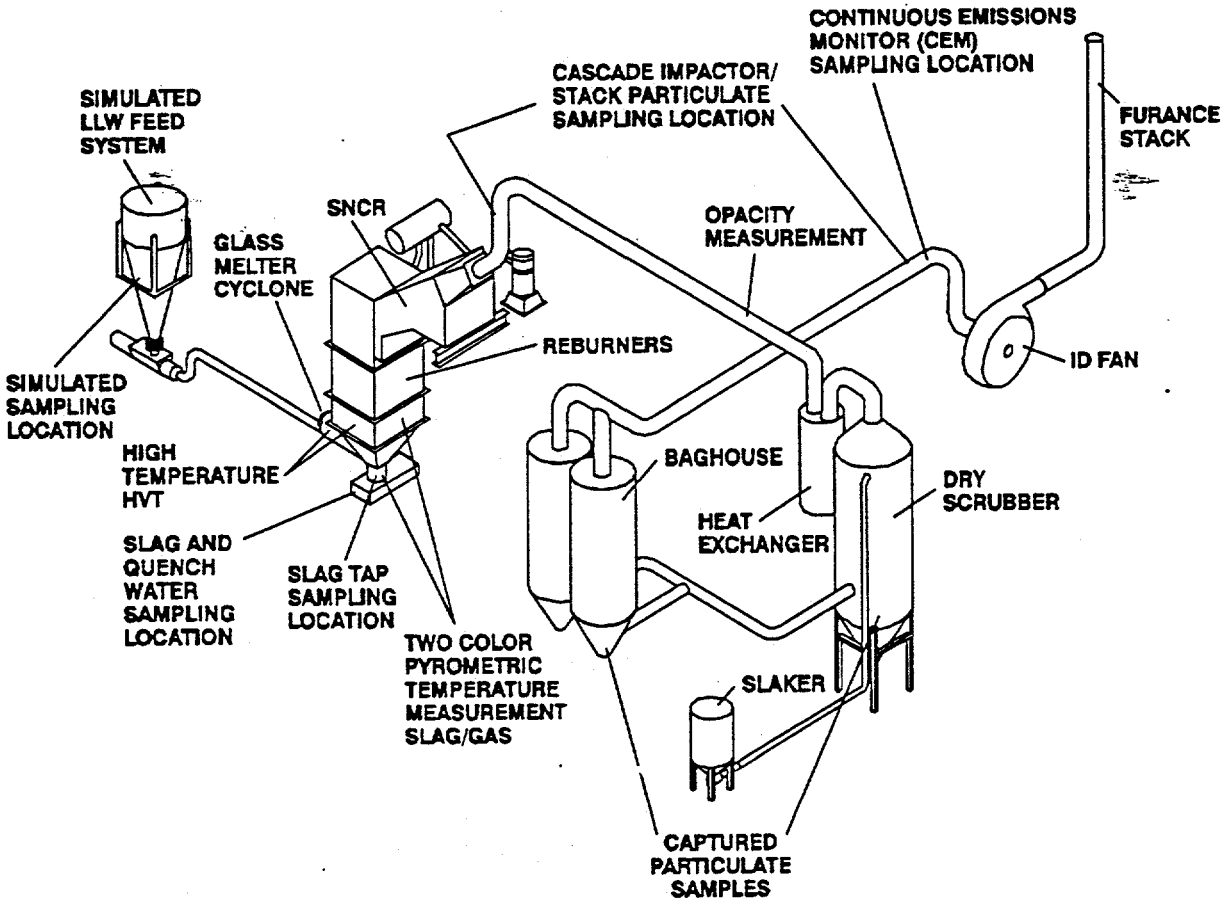

Figure IV-1 Small Boiler Simulator Test Facility

V. Test Description

A. Planned Chronology of Test Events and Duration

Laboratory tests at B&W ARC are planned on the glass former/simulant formulation with input from B&W Lynchburg. The planned activity for the laboratory tests was discussed in Section II of this test plan. These laboratory tests will be performed during the site preparation for the glass melter.

A duration of approximately two weeks is required for testing for the cyclone glass melter prior to the 24-hour continuous test. This would actually involve approximately six days of testing, with a day of downtime between each test for the assessment of test measurements and performing any necessary equipment or test modifications. The objective of these scoping tests are to observe the behavior of the SBS Cyclone while processing the glass former/simulant formulation, and to make the appropriate equipment modifications and experimental adjustments that will make a successful 24- hour test possible. The purpose of the 24-hour test is to demonstrate the feasibility of the B&W cyclone furnace as a treatment method for vitrification of low level waste streams. The test matrix is illustrated in Table V-1.

The first week of testing is for the purpose of functional checkout. Some of the measurement techniques which will be assessed include the molten glass sampling method, the system for monitoring the molten glass temperature and cyclone gas and cyclone exit gas temperatures, and on-line convection pass light extinction measurements for monitoring relative changes in opacity due to changes in cyclone particulate carryover. Equipment checkout includes debugging the glass former/simulant feed system and injector gun to provide a steady spray of the appropriate pattern to promote slagging. It also includes setting up the reburn system, SNCR, and dry scrubber to achieve particulate, acid gas, and NO_x emissions

Table V-1: Test Matrix					
Excess Oxygen	Cyclone Firing Rate (Million kcal/hr)	Feed Rate (kg/hr)	Burner	Burner Parameters	
				Combustion Air	Atomizer
1%-2%	1.2*	~45**	plate w/inj.	vary secondary air	pressure and position
1%-2%	1.2*	~45**	optimum	optimum	design
1%-2%	1.2*	vary	optimum	optimum	optimum
1%-2%	vary	optimum	optimum	optimum	optimum
vary	optimum	optimum	optimum	optimum	optimum
optimum	optimum	optimum	optimum	optimum	optimum

*4.75 mbtu/hr

**100 lb/hr

control. Burner operational hardware adjustments will be performed during testing to optimize fuel/air mixing to maximize cyclone heat release and promote the desired glass flow characteristics. Operational adjustments include changing the position of combustion air flow dampers, changing natural gas injection patterns, and changes in glass former/simulant atomizer position and atomizing air pressure. Cyclone performance can be quickly evaluated as a function of operational changes through on-line measurements. Indicators of cyclone furnace performance include glass, cyclone, and furnace exit gas temperatures, cyclone cooling water heat absorption patterns, and convection pass flue gas opacity.

A second week of testing will be dedicated to the optimization of combustion conditions, following the debugging of the glass melter system's operational hardware, verification of monitoring equipment and sensors, evaluation of the sampling methods, and optimization of the cyclone burner hardware. This will include the variation of load, glass former/simulant feed rate, and excess air to obtain a steady throughput of vitrified waste that is the least likely to eventually result in cyclone plugging, yet result in a vitrified glass product and flue gas emissions stream with acceptable properties. This will maximize the probability of a successful 24-hour continuous run for the glass melter during the third week of testing.

The type and frequency of test samples to be acquired are illustrated in Table V-2. Other critical test measurements such as the optical measurements for temperature and opacity, as well as gaseous emissions measurements of CO_2, CO, O_2, and NO_x are continuously monitored by the DAS as described in the Section IV-B. Therefore, no discussion of sampling frequency is required for those variables. However, all measurements that are not electronically acquired continuously will require a test measurement schedule.

The EPA Method 5 dust loading samples require approximately one hour to sample. During cyclone scoping tests, a dust loading sample will be acquired for baseline conditions (after startup). Dust loadings will be obtained both at the convection pass outlet and the baghouse outlet. The 24-hour test will require a dust loading every 5.75 hours (5 samples) at the convection pass outlet to determine the particle carryover from the glass former (cyclone) and also to confirm steady state operation. Dust loadings are comprised of both re-entrained particles and condensed fume from vaporized materials that escape the feed stream in the cyclone. Therefore, dust loading measured at the convection pass outlet will be utilized to determine the efficiency of the glass melter at processing the feed stream. Cascade impactor samples taken by an outside contractor in conjunction with these dust

Sampling Plan for the 24 Hour Test						
Run Time	Temperature Measurements		Flue Gas - Cascade Impactor & Method 5		Feed Prep Samples	
Hours from Start	Cyclone Exit HVT	Furnace Exit Gas Temp (FEGT)	Convection Pass Exit	Baghouse Exit	Simulant (4 @250ml)	Glass Formers (4 @100 g)
0	✓		✓ [1]	B&W EPA 5[2]	One Sample Per Barrel of Simulant[3] (As Used)	One Sample Per Vendor Lot of each Additive[4] (Any Time)
2		✓	B&W EPA 29[2]			
4	✓					
6			✓ [1]			
8	✓					
10		✓				
12	✓		✓ [1]	✓ [1]		
14						
16	✓					
18			✓ [1]			
20	✓					
22		✓	B&W EPA 29[2]			
24	✓		✓ [1]	B&W EPA 5[2]		

Sampling Plan for the 24 Hour Test (Continued)						
Run Time	Waste Feed	Glass & Quench Water		Baghouse (BH) & Dry Scrubber (DS)		
Hours from Start	Feed Supply (4 @250ml)	Quench Tank H2O (6 @1 l)	Molten Glass (4 @100g)	BH Solids @ Rotary Valve (4 @100g)	DS Solids (4 @100g)	DS Feed Slurry (6 @1 l)
0	One Sample Every 2 Hours & Minimum of One Per Batch[5]	✓ [6]	One Sample Every 2 Hours[4]	One Sample Every 4 Hours[3]	One Blend Sample at the End of Testing[3]	One Per Tank Fill[4]
2		Plant H_2O[6] Once During the Test				
4						
6						
8						
10						
12						
14						
16						
18						
20						
22						
24		✓ [6]				

[1]One aliquot with custody to the EPA approved laboratory.
[2]Either permitting data or backup measurements. One aliquot with custody to B&W Analytical Chemistry laboratory.
[3]Four aliquots with custody to B&W, PNL, Quantera, and WHC.
[4]Four aliquots with custody to B&W, Corning, USGS, and WHC.
[5]Six aliquots with custody to B&W, Corning, PNL, Quantera, USGS, and WHC, with one extra sample for WHC (222-S) every six hours.
[6]Six aliquots with custody to B&W, PNL, Quantera (3), and WHC.

loadings will give information on the particle size distribution. Subsequent chemical analysis and electron microscopy on the size segregated samples may give an indication to the relative proportionment of dust originating from re-entrained particles, or vaporization in the cyclone followed by condensation downstream. These will also be collected at steady-state conditions every 5.75 hours during the 24-hour test, but the measurements will not be made concurrently with the EPA method 5 samples. Dust loadings collected at the baghouse outlet will determine the effectiveness of the backend flue gas cleanup equipment, and will be collected less frequently (every 11.5 hours - 3 samples). Only one dust loading at the baghouse outlet will be performed by the independent lab; B&W will perform the other two. Solids samples will also be collected from the baghouse and dry scrubber ash hoppers during these dust loadings.

A molten glass sample will be acquired at every steady state condition during the scoping tests for cyclone operation since these samples can be collected relatively quickly. Samples during the 24-hour test will be collected every 2.75 hours. Each sample will require four aliquots; one for WHC, a second for B&W, a third for the Corning analytical lab, and a fourth for United States Geological Survey (USGS) lab in Boulder, Colorado. However, subsequent analytical chemistry will only be performed on selected samples. Examination of the glass melter's run time operational data will help determine the most suitable samples for this analysis.

A sample of the glass former/simulant feed will be taken from each feed drum which are adequate for approximately 3 to 4 hours of operation. Once again, enough sample will be extracted for four aliquots for all groups involved in the analysis. These samples will be mostly for the purpose of confirming the pre-designed feed composition for these tests. The feed drum will be well stirred prior to and during feeding to prevent any separation of feed materials. Feed rates are preset by a calibrated screw feeder set to a specific rpm value on the tachometer, from which a voltage output is wired to the DAS.

The solid samples obtained above will also be aimed at attaining mass closure, as closely as possible, for all waste streams leaving the system. This will require measurements on the amount of glass former/simulant throughput, the quantity of glass produced, and the flue gas dust loading. Mass closure will not be exactly attained due to experimental error, gas loses, and particle loses to the internal surfaces of the SBS.

B. Schedule For Completion of Reports

The schedule items critical to this project include the date for initial demonstration of the melter, and expedient completion of the project reports. The milestone date to be met is to perform a melt demonstration by September 29, 1994. This will include daytime tests that produce glass from the glass formers and waste simulant. The 24-hour continuous run is scheduled to be performed during the first two weeks of October. The preliminary data report will be submitted between one and two weeks after testing is completed. Projected dates for completion of drafted/full test report, the engineering study report, and the life/reliability report are December 2, November 29, and December 29, 1994, respectively. The exact dates for these reports will also be dependent upon the completion date for testing and the availability of WHC personnel for correspondence. Figure V-2 provides the project schedule with projected dates for these reports and the other major project tasks. Phase 2 proposal preparations and issuance are not shown since these dates will depend upon the availability of WHC project personnel for a preproposal meeting.

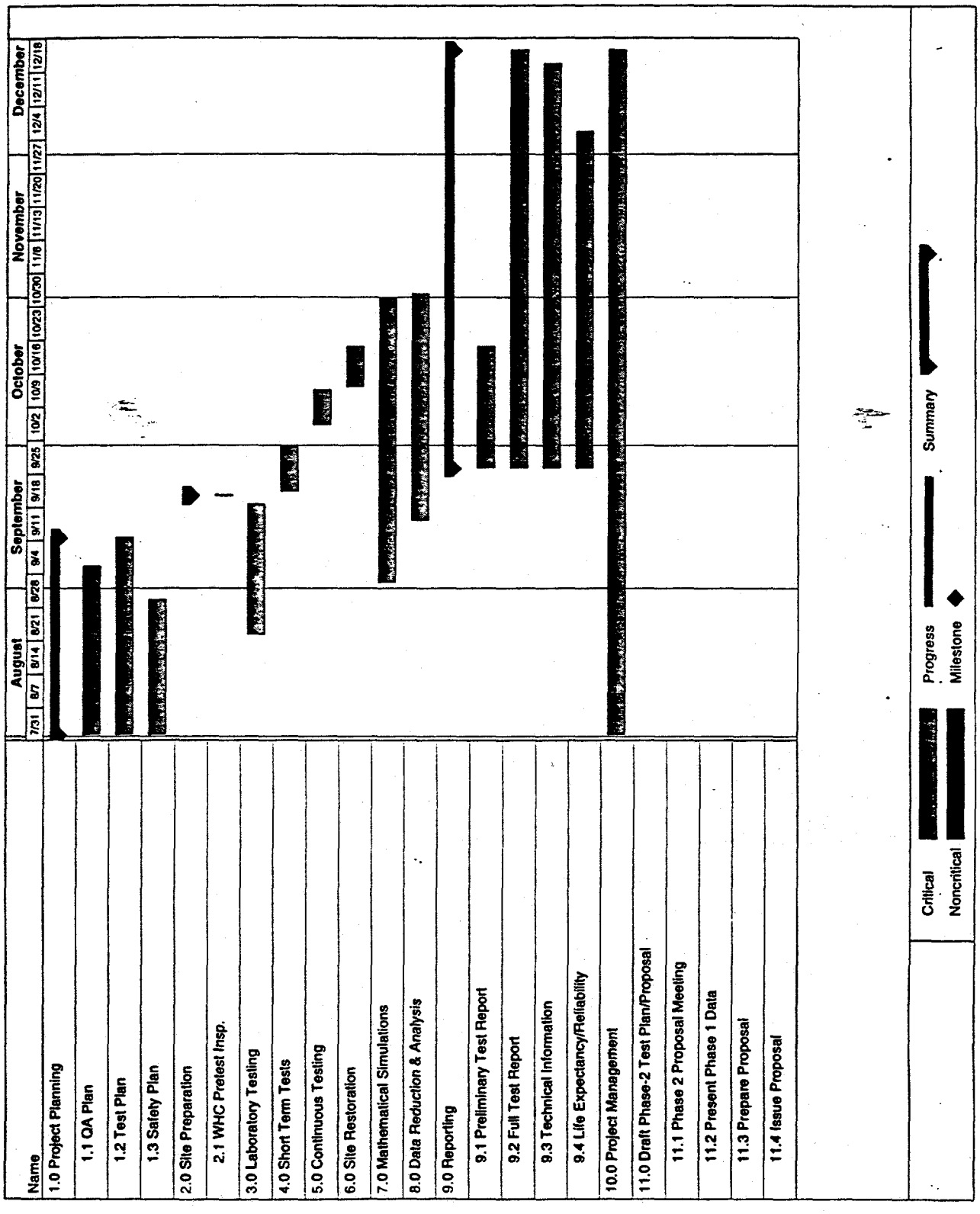

Figure V-1. Phase-1 Schedule

VI. Environmental

A. Compliance with local limits

Permitting was performed with the Ohio EPA to ensure that State and local permitting requirements will be met. The process involved plume dispersion modeling of the flue gases to determine expected levels of flue gas constituents at the ARC property line. The results of this modeling were compared to our required limits of one one-hundredth of the Threshold Limit Values (TLV). During this evaluation, it was determined that the dry scrubber would be required for removal of acid gases (HF, HCl, and HI), and that reburning and SNCR would be needed for control of NO_x. Emissions will be monitored throughout testing to confirm that our permit limits are being met.

B. Unused Feed, Glass Product, And Other Wastes

The remaining feed, glass product, and waste solids will be disposed of following testing. The remaining feed will be vitrified in the cyclone. This should take less than a couple of hours of furnace operation since the feed will be made up in a batch mode. The glass product and solids from the flue gas cleanup will be stored in a waste hopper, and landfilled after testing is completed. TCLP measurements will be performed at the ARC during testing and at the completion of testing to confirm that the solids are acceptable for landfilling.

Appendix A

Data Acquisition

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Example of Data Acquisition for DAS:

Selected primary elements for flow and temperature measurements are connected to the SBS data acquisition system (DAS). This gives real-time data on test conditions and calculates performance data. Pressure transducer readings are used in orifice equations to calculate the air flow rates. The analog voltage signals are converted to digital signals by a HP3497A data acquisition subsystem. This subsystem is the data acquisition front-end for a PC-based computer system running an in-house developed STARS/LabVIEW data acquisition software package. This software collects the data received from the HP3497A subsystem and allows the user to store, and monitor important process variables and stores a complete set of all process variables upon command.

An example of data acquisition processing shall involve a NOx gas analyzer instrument. The NOx analyzer delivers a 1V-5V range output signal, which is linearly proportional to a ppm engineering unit. The output signal is wired to an analog voltage input card connected to an HP3497A data acquisition subsystem. The STARS/LabVIEW data acquisition system (DAS) software is loaded with an instrument database which includes an entry which fully describes the NOx analyzer input to the DAS system. In this database entry, assignments are defined that acquisition will be obtained from a specific physical channel on an HP3497A which is at a specific IEEE-488 address. From this instrument database, a list is generated of all instruments which are scheduled to be acquired. This list is used by the ACQUIRE_LOW module to periodically request a scan of voltages from the HP3497A instrument. The following describes the sequence that occurs for a single scan. First, a timestamp is associated with each scan at the beginning of the scan. The ACQUIRE_LOW module requests the HP3497A integrating voltmeter measurements to be made at 5-1/2 digit accuracy, using autoranging to best match input scaling with the input voltage. The range used by the HP3497A instrument for 1-5V signals would be a +-10V range. The HP3497A returns a 15 character ASCII string for the

resulting digitized voltage measured. The STARS/LabVIEW DAS converts this ASCII string into a single precision IEEE floating point value, and places it into an array, at an element position corresponding to the NOx analyzer database entry position in the full instrument database. When a single scan is completed, this array holds all raw voltage values for all physical instruments. ACQUIRE_LOW sends a signal to other STARS/LabVIEW modules that new data is now available for further processing. The raw voltage array has global read access by a number of processes: DISKSTR_LOW, MONITOR, and STRIPC. The DISKSTR_LOW module will, upon receiving a signal, takes the current raw array contents and the current timestamp, and stores them in a binary form to a disk file. The MONITOR module, upon signal, will take the current raw voltage array and calculate a list of engineering unit values according to a user-defined list of instrument entries. If the NOx analyzer entry was included in a user list, and the calculation had not already been performed during the current scan, the calculation is done based on a reduction equation number assigned to the NOx analyzer instrument database entry. The NOx analyzer reduction equation would typically reference Type 040 - 4th Order Polynomial Evaluation of Raw Value. This equation requires 5 polynomial evaluation constants, in addition to a raw value zeros offset value. These values would be obtained from assignments in the NOx analyzer instrument database entry. The resultant single precision floating point engineering value is placed in an engineering data array, at an element position corresponding to the NOx analyzer instrument database entry. A boolean array value is also set, indicating that this engineering value has already been calculated for this scan. Other modules will check the status of this boolean value and use the calculated value in the engineering array if it is already available. The STRIPC module duplicates the user-defined calculation capabilities of MONITOR, but output is displayed in the form of a graphical strip chart.

Off-line operations of data involve the CONVERT and TRANSLATE modules. The CONVERT module would take each scan of data from the saved binary raw data file, apply it against a restored version of the original instrument database used when

acquiring the data, calculate engineering values for each instrument entry in the database. The calculation routines used on-line and off-line are the same. Each scan of engineering data would be then written to a binary format disk file containing a corresponding time stamp and an array of engineering values. The TRANSLATE module allows the user to translate raw or engineering data files into ASCII files which can be imported into Microsoft Excel. When loaded into Excel, a spreadsheet row corresponds to a single scan, and each column represents an instrument database entry, including a timestamp column.

The following table is a list of all test variables that can be monitored by the DAS. "Active" means that the parameter is automatically collected by the DAS. "Inactive" means that this data is manually added to the final spreadsheet.

Variable Name	Description	Status
Atmospheric Pressure, PSI	Barometric Pressure in PSI, references Atmospheric Pressure, in Hg	Active
Atmospheric Pressure, in Hg	Manual Entry, in Hg	Active
Atomizing Air Flow Waste Feed	Calculated Quantity	Active
Atomizing Air Static	Pressure Transducer	Active
Atomizing Air TC	K Thermocouple	Active
Atomizing Fluid DP	Pressure Transducer	Active
Average Baghouse Orifice TC	Dummy channel	Active
Average Primary Air TC	Dummy Calculated Value	Active
BTU Value of Fuel DAF Basis	Manual Entry	Active
Baghouse Air Flow	Calculated Quantity	Active
Baghouse DP	Pressure Transducer 0-5 in H2O	Active
Baghouse Orifice TC	Temperature	Active
Baghouse Static	Pressure Transducer 0 - 10 in H2O	Active
Beckman O2	Gas Analyzer 0-5V - 0-10%	Active
Burner DP, in 2.96 Oil	Calculated Quantity	Active
Burner DP/Tertiary Air	Pressure Transducer 0 - 20 in H2O	Active
Burner Static	Pressure Transducer 0 - 150 in H2O	Active
CO low	Gas Analyzer - 1-5V - 0-100%	Active
Calculated Convection Pass Outlet CO2	Calculated Quantity	Active
Calculated Convection Pass Outlet H2O	Calculated Quantity	Active
Calculated Convection Pass Outlet N2	Calculated Quantity	Active
Calculated Convection Pass Outlet O2	Calculated Quantity	Active
Calculated Cyclone Exit CO2	Calculated Quantity	Active
Calculated Cyclone Exit H2O	Calculated Quantity	Active
Calculated Cyclone Exit N2	Calculated Quantity	Active
Calculated Cyclone Exit O2	Calculated Quantity	Active

Variable Name	Description	Status
Cyclone Combustion Stoich	Calculated Quantity	Active
Cyclone Exit Mass Flow	Calculated Quantity	Active
Cyclone Exit TC	Manual Input	Active
Cyclone Exit Volumetric Flow	Calculated Quantity	Active
Cyclone Load	Calculated Quantity	Active
Cyclone Natural Gas Flow	Calculated Quantity	Active
Dry Bulb TC	Temperature	Active
Flameview Aspiration Air	Calculated Quantity	Active
Flue Gas Molec Wt		Active
Flue Gas Recirc TC	Temperature	Active
Humidity	lb dry air per lb of moist air	Active
Humidity Correction		Active
Humidity Ratio	lb of moisture per pound of dry air	Active
Lbs of Moist Air		Active
Moles of Natural Gas		Active
NG Analysis Ar	Manual Entry	Active
NG Analysis C2H6	Manual Entry	Active
NG Analysis C3H8	Manual Entry	Active
NG Analysis C4HActiveInactive	Manual Entry	Active
NG Analysis C5HActive2	Manual Entry	Active
NG Analysis C7HActive6	Manual Entry	Active
NG Analysis C8HActive8	Manual Entry	Active
NG Analysis CH4	Manual Entry	Active
NG Analysis CO2	Manual Entry	Active
NG Analysis H2	Manual Entry	Active
NG Analysis N2	Manual Entry	Active
NG Analysis O2	Manual Entry	Active
NG Gas Analysis C6HActive4	Manual Entry	Active

Variable Name	Description	Status
NH3 DP	Pressure Transducer	Active
NH3 Flow Rate	Calculated Quantity	Active
NH3 Static	Pressure Transducer	Active
NH3 TC	K Thermocouple	Active
NOx	1-5V 0-1000 ppm	Active
NOx Factor Active	term Active of 2 for conversion of Stack NOx to (#NO2/MBTU)	Active
NOx Factor 2	Factor 2 of 2 to convert Stack NOx to (#NO2/MBTU)	Active
Natural Gas Co-Firing %	percent of total heat input that is gas firing	Active
Natural Gas DP	Pressure Transducer	Active
Natural Gas Flow	Fixed Value	Active
Natural Gas Load		Active
Natural Gas Molecular Wt	Calculated Quantity	Active
Natural Gas Orif TC	Temperature	Active
Natural Gas Static	Pressure Transducer	Active
Natural Gas TC	K Thermocouple	Active
O2 at Dry Scrubber Inlet	0-1V Range 0 - 10% O2	Active
Overall Combustion Stoich	Overall Combustion Stoichiometry	Active
Overall NG Combustion Stoich	Calculated Quantity	Active
Overfire Air TC	Temperature	Active
Prim Air to Pulverizer Flow		Active
Primary Air DP	Pressure Transducer 0 - 10 in H2O	Active
Primary Air DP, in 2.96 Oil		Active
Primary Air Flow	Primary Air to Pulverizer - Baghouse Air Flow + Compressed Air Flow for PC	Active
Primary Air TC	Temperature	Active

Variable Name	Description	Status
Primary Air to Aspirator		Active
Primary Static	Pressure Transducer 0 - 150 in H2O	Active
Primary Static, in Hg		Active
REF03 Constant		Active
Reburn Combustion Air Flow	Calculated Quantity	Active
Reburn Combustion DP	Pressure Transducer	Active
Reburn Combustion Static	Pressure Transducer	Active
Reburn Combustion Stoich	Calculated Quantity	Active
Reburn Combustion TC	K Thermocouple	Active
Reburn Load	Calculated Quantity	Active
Reburn Natural Gas DP	Pressure Transducer	Active
Reburn Natural Gas Flow	Calculated Quantity	Active
Reburn Natural Gas Static	Pressure Transducer	Active
Reburn Natural Gas TC	K Thermocouple	Active
Reburner Windbox TC	Temperature	Active
SA Static	Pressure Transducer 0- 150 in H2O	Active
SA Static, in Hg		Active
SA to Burner TC	Secondary Air to Burner Temperature	Active
SA to Cyclone Static	Pressure Transducer 0- 150in H2O	Active
SA to Cyclone Static, in Hg		Active
SA to Cyclone TC	K Thermocouple	Active
Secondary Air DP	Pressure Transducer 0 - 16 in H2O	Active
Secondary Air TC	Temperature	Active
Stack NOx	conversion of NOx value into #NO2/MBTU	Active
Sum of Natural Gas Constituents	Sum must equal 100%	Active
Tertiary Air DP	Pressure Transducer	Active
Tertiary Air Flow	Calculated Quantity	Active

Variable Name	Description	Status
Tertiary Air Static	Pressure Transducer	Active
Theoretical Moles of Air		Active
Theoretical Moles of NG	Calculated Quantity	Active
Total DAF Flue Gas Flow		Active
Total Primary Air Flow		Active
Total Secondary Air Flow		Active
UNITY	Unity value of 1.0	Active
Waste Feed Flow	Calculated Quantity	Active
Waste Feed Mole Pct H2O	Calculated Quantity	Active
Waste Feed Mole Pct NO2	Calculated Quantity	Active
Waste Feed Off Gas H2O	Calculated Quantity	Active
Waste Feed Off Gas NO2	Calculated Quantity	Active
Waste Feed RPM	Voltage Input	Active
Wet Bulb TC	Temperature	Active
Actual Core Air Flow	Calculated Quantity	Inactive
Atomizing Air for Orimulsion	Calculated Quantity	Inactive
Calc Fired Coal Flow	as Fired	Inactive
Calc Received Coal Flow	as Received	Inactive
Comp Air DP	Delta Pressure - 0- 20 in H2O	Inactive
Comp Air Flow for PC		Inactive
Comp Air Static	Pressure Transducer 0- 200 psig	Inactive
Comp Air to Asp TC	Compressed Air to Aspirator Temp	Inactive
Core Air Rotameter Flow	scfm	Inactive
Core Air Rotameter Pres	PSIG	Inactive
Cyclone TC	Temperature	Inactive
Fuel Analysis Ash	Weight % as Received	Inactive
Fuel Analysis Carbon		Inactive
Fuel Analysis Chlorine		Inactive

Variable Name	Description	Status
Fuel Analysis Hydrogen		Inactive
Fuel Analysis Moisture		Inactive
Fuel Analysis Nitrogen		Inactive
Fuel Analysis Oxygen		Inactive
Fuel Analysis Sulfur		Inactive
Furnace Pressure	Burner static less the pressure drop across Burner DP	Inactive
Inner Vane Angle	degrees open	Inactive
NO2 Pressure	Pressure Transducer	Inactive
Outer Vane Angle	degrees open	Inactive
PC Burner Load	Calculated Quantity	Inactive
PC Burner Natural Gas Flow	Calculated Quantity	Inactive
Primary Air to as Fired Coal Rate		Inactive
SA to Cyclone DP	Delta Pressure - 0 - 20 in H2O	Inactive
Sliding Disk	position	Inactive
Stoich # dry air/ #DAF Fuel		Inactive
Sum of Fuel Constituents	Verify that sum of all Fuel Constituents adds to 100 %	Inactive
Tertiary Air TC	Temperature	Inactive
Total Fuel as Fired		Inactive
Total Fuel as Received		Inactive
Total Load	Calculated Quantity	Inactive
Wt % Ash as Fired		Inactive
Wt % Moisture as Fired		Inactive

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Appendix B

WHC Sampling Procedure

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Sampling Instructions

1.0 Purpose

The following sampling instructions are intended to standardize the sampling for the Melter System Technology Evaluation testing for all vendors involved in this project. This document provides a concise set of instructions relating to sample integrity issues involved with this effort. Though the use of the following instructions, positive chain of custody, sample identification, and sample tracking will be achieved.

2.0 Scope

The sampling instructions included in this document deal with sample integrity issues (e.g., control of samples, chain of custody, etc.) involved with obtaining samples to submit for analysis or archive. This document is not intended to provide methods for obtaining actual samples. These instructions are specifically written for vendor samplers for use in Phase I tests associated with the Melter System Technology Evaluation project.

3.0 Supplies

Supplies necessary to ensure good sample integrity and positive chain of custody for sampling are as follows:

- Labels
- Evidence Tape
- Chain of Custody Forms
- Locked Sample Storage Area (e.g., locked room or cabinet)
- Sample Log

4.0 Procedure

4.1 Sample Numbering

To facilitate data evaluation and sample identification by Westinghouse Hanford Company (Westinghouse), a sample identification system has been developed. Westinghouse requests that the vendors utilize this system for sample identification during Phase I testing. The system consists of seven separate identifiers and below, each of the fields and expected information are described (Figure 1):

- First Character: Vendor Identification, Consists of the first letter in the vendor's name.
- Second Character: Phase identifier (e.g., "1" for Phase I testing).
- Third Character: Sample type. The vendor is free to supplement this with additional sample types specific to each individual process. Westinghouse has identified seven different types of samples:
  - S = LLW Simulant

- A = Additives
- F = Feed, Mixed
- I = Intermediate (e.g., samples between feed and glass product)
- G = Glass
- O = Offgas
- W = Waste

- Fourth Character: Sample point number. Used to designate multiple sample points for a specific sample type.
- Fifth through Seventh Characters: Serial sample number. Corresponds to the time samples are taken (e.g., assuming a four hour sampling schedule, 10:00 AM on the first day of testing, all samples taken have an -001 extension, 2:00 PM on the first day of testing, all samples taken have an -002 extension, 10:00 AM on the second day of testing, all samples have an -007 extension, etc.)
- Eighth Character: Complete sample set identifier. This is used to designate samplings where samples are taken from all applicable sample points.
- Ninth Character: Laboratory identifier. Used to designate sample destination (Figure 1).

4.2 Sample Labeling

Sample labels can be supplied by Westinghouse or generated by the vendor. There are five fields of information required for sample labeling:

- Sample Number: Described in section 4.1
- Sample Date: Date sample taken.
- Time Sampled: Time sample taken.
- Sampler Initials: Initials of sample collector. This will also be the individual who initiates the Chain of Custody form.
- Laboratory: Destination for the sample:
  - Quanterra
  - Battelle Pacific Northwest Laboratory
  - Westinghouse Hanford Company - 222-S Laboratory
  - Westinghouse Hanford Company - Geotechnical Engineering Laboratory
  - Corning
  - USGS

4.3 Chain of Custody

Chain of Custody (COC) for samples is initiated by the sample collector at the time of sampling. COC forms can be left at sampling stations as long as the area is reasonably secure. More than one sample can be listed on a COC but, at the end of the shift, the COC should be placed in the same locked storage area as the samples. Boxes on the Chain of Custody form not mentioned in this section will be completed by Westinghouse representatives.

- Collector: Name of person collecting sample. This person initiates the Chain of Custody form.
- Matrix: The type of sample (e.g., simulant, additive, feed, etc.).

- Possible Hazards: Any potential hazards associated with the samples.
- Sample Number: The number generated for the sample (section 4.1).
- Sample Point: Point in the process where the sample was taken.
- Date Sampled: Date sample was taken.
- Time: Time sample was taken.
- Check the boxes under the analyses being requested.
- Relinquished By: Sample is signed over by the collector to another custodian as needed. (e.g., this will also apply to the custodian, shipper, and transporter).
- Received By: Person receiving custody of the sample (e.g., custodian, shipper, transporter, laboratory).
- Note: Custody must be relinquished and received each time the sample changes hands. (e.g. from the collector to the shipper, sample must be relinquished just prior to shipment even though the transporter may not actually sign the form, and finally from the transporter to the lab custodian)
- Special Instructions/Remarks: Complete this section if there are any special instructions for the laboratory.

4.4 Sample Log

A sample log is required for summary sampling information and sample tracking. There are eight fields of information required for the sample log (Figure 2):

- Sample Number
- Sample Date
- Sample Time
- Sampler Initials
- Sample Type (Matrix): Type of sample (sample types listed above in section 4.1).
- Sample Point: Location in the process where the sample was taken.
- Sample Destination: Location the sample will be shipped to for analysis / archive (section 4.2)
- Shipment Date: Date samples sent to destination.

4.5 Sequential Steps

The following steps should be followed by the vendor to ensure positive chain of custody and sample tracking:

1. Obtain sample
2. Generate sample number (section 4.1)
3. Label sample (section 4.2)
4. Apply tamper resistant evidence tape supplied by Westinghouse and complete initials and date section on tape
5. Complete Chain of Custody form (section 4.3)
6. Complete sample log information (section 4.4)
7. Store sample in a locked area with the Chain of Custody form until shipment

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Appendix C

Responses To Test Plan Review Questions

About the SBS Gas Sampling System

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Answers to test plan review questions about the gas sampling system.

Question: The path taken by the analyzers is not entirely clear. If the sample passes through the refrigeration unit before analysis, SO_2 and NO_x will be lost in the condensate.

Answer: All of the flue gas does routinely pass through the refrigeration system before entering the bank of gas analyzers. In most cases this is done to protect the analyzers or to prevent interferences caused by water vapor. Only a small amount of SO_2 is lost in the condensate. For example, a flue gas containing 1000 ppm of SO_2 and having a humidity of 0.152 gm water vapor per gm of dry gas would lose only about 55 ppm into the condensate if it were cooled to 7 C. This situation is a result of Henry's Law which states that the solubility of a sparingly soluble gas is proportional to its partial pressure. In this example, if the total pressure were one atmosphere, the SO_2 partial pressure is only 0.001 atm or 0.76 mm Hg. This accuracy level is within acceptable limits.

In so far as NO_x losses are concerned, it is the NO_2 component that is of concern. The solubility of NO is sufficiently low to ignore condensate losses. But NO_2 solubility is relatively high. In combustion flue gases, the NO to NO_2 ratio at the boiler exit is typically about 95 to 5. Thus, condensate losses are not usually of a major concern. However, for these tests we will be looking more closely at the NO_2 emissions. The reason for this concern is that the major source of NO_x in this test will be the decomposition of nitrates not the oxidation of molecular nitrogen or fuel bound nitrogen. Fuel bound nitrogen exists primarily in C-N-C bonds in coal and oil not NO_3^-. It is our expectation that most of the NO_x leaving the cyclone furnace will be in the form of NO rather than NO_2. The reason for that expectation is that these gases exiting the cyclone in excess of 1700K tend to approach chemical equilibrium at that point. As the flue gases quickly quench in the down stream equipment, the chemical kinetics quickly slow and the composition of the flue gases become "frozen"

and thus reflect the composition of the furnace gases. But, because of the differences of this glass forming and melting process, we will be very cautious about the NO_2 measurement. One technique we can use is to use a separate NO_x analyzer placed upstream of the condensate stream. The second approach which will be used in Phase 1 testing is to collect samples of the condensate and analyze for nitrates and total nitrogen.

Question: Also, the effect on composition of passing through the Perma Pure" dehumidifier should be evaluated to ensure it doesn't change the gas composition.

Answer: Literature describing this device is attached. We have little concern that this device could introduce significant errors.

Question: Have the instruments been checked for Interferences?

Answer: Yes

Question: Will both NO and total NO_x be monitored or will only total NO_x be measured? I would recommend total NO_x with occasional measurements of the NO:NOx ratio.

Answer: We concur in general. But initially, we will look harder at the NO_2 to insure that it is not atypically high.

Question: Assuming that the NOx analyzer will be operated in the high range using oxygen rather than air, care should be taken in determining the

calibration above 0.25% NOx. Our experience has indicated linearity may not be maintained in the 0.25 to 1% range.

Answer: Because of the dilution by combustion products, the NOx concentrations will in all likelihood be less than 0.25% (=2500 ppm).

Question: If the detection limits allow accurate measurements, it would be preferable to prevent condensation through dilution with an inert gas rather than condensing or sending through a desiccant to remove water.

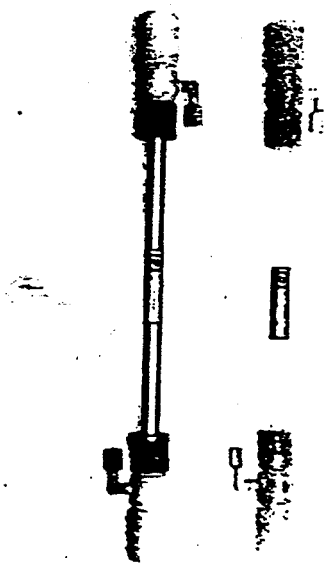
Answer: We agree that dilution is a very good approach. Unfortunately, these analyzers are not sensitive enough for that approach. By point of clarification, no flue gas sample is passes through a desiccant. The "Perma Pure" device mentioned above is a semipermeable membrane selective to water vapor. See the attached literature.

Question: The statement indicating "correction" of data based on the end-of-the-day calibration check should be changed to "qualification" since you may not know when the instrument drifted out of calibration. If the temperature in the environment of the analyzer changes after the system is started up it would be advisable to check for drift after the ambient temperature has increased.

Answer: These are good suggestions and will be implemented.

PERMA PURE

PERMA PURE DRYERS



PERMA PURE DRYERS—PD SERIES

FEATURES

- Continuous Drying—Self Regeneration
- Quantitative Drying of Gases and Liquids
- High Reliability—No Moving Parts
- Temperature Range (-100° F to +200° F)
- Dries 190° F dew point gas (90% water by volume)
- Water Removed as Gas — No Condensate
- Purge can be Product or Other Gas
- Interior Volume of Dryer 5 to 120 cc (PD)
- Interior Volume of Dryer .1 to 9 cc (MD)
- Product Flow Range 50 cc/min to 80 liter/min (PD)
- Product Flow Range 10 cc/min to 3 liter/min (MD)
- Sample and Purge can be at Pressure or Vacuum
- Stainless Steel Fittings with Stainless, Corrugated Stainless or Rubber Shell (PD)
- Polypropylene Fittings with Polypro, Stainless or Rubber Shell (PD)
- Fluorocarbon Fitting with Stainless or Rubber Shell (PD)
- Stainless, Polypropylene and Fluorocarbon Fittings and Shell (MD)

Principle of Drying

Perma Pure Dryers utilize a hygroscopic, ion exchange membrane in a continuous drying process to selectively remove water vapor from mixed gas streams. The membrane is a proprietary extrudible dessicant in tubular form. Either a single tube or bundle of tubes with a common header is fabricated in a shell and tube configuration and sealed into an impermeable shell, which has openings adjacent to the sample inlet and product outlet (*Figure 1*). If a wet gas stream flows through the tubes and a countercurrent dry gas stream purges the shell, water vapor molecules are transferred through the walls of the tubing. The wet gas is dried, and the dry purge gas becomes wet as it carries away the water vapor. The wet purge gas exits on the shell side at the purge outlet; the water vapor is usually vented to the atmosphere.

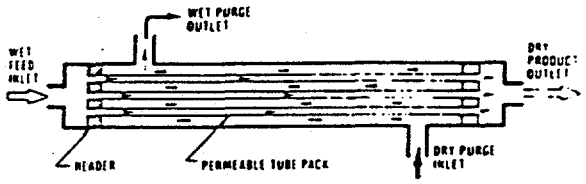


Figure 1

The key to continuous separation of the water vapor from its gas stream is the countercurrent flow. A wet gas sample flows continuously into the sample inlet and wets the inside wall or walls of the tubing, while a dry gas simultaneously passes through the purge inlet and flows as a reflux countercurrent along the outside of the tubes toward the feed end. The dryness of the purge gas establishes a much higher concentration of water vapor molecules on the tube side of the dryer; therefore, the water vapor pressure on the tube side is greater than the water vapor pressure on the shell side. The driving force for the reduction of water vapor in the wet sample is the difference in water vapor pressures between the two gas streams.

Drying is continuous as long as the actual volumetric purge gas flow rate exceeds the actual volumetric feed flow rate of the sample. Other variables that determine the reduction of water vapor in the wet sample include: the surface area of the membrane, sample flow, pressure or vacuum of the sample and purge, temperature and the humidity of the sample.

PERMA PURE PRODUCTS, INC.
8 Executive Drive, Box 2105, Toms River, NJ 08754
TEL 201-244-0010 • TLX 132621 • FAX 201-244-8140

Drying Process Variables

Flow

The efficiency and capacity of a dryer at constant temperature and humidity are based on the dryer's geometry (i.e., internal volume, outside surface area and shell volume), as well as the gas flows and pressures of the wet sample and the dry purge. The reduction of water vapor in the product of a dryer may be increased by reducing the sample flow or by increasing the dryer volume (e.g., more tubes in parallel or a longer tube length). Increasing the sample flow results in a higher dew point in the product.

A plot of water vapor reduction versus sample flow is shown in *Figure 2*. The data was obtained by saturating air at atmospheric pressure and 70° F. (21° C.). Inlet and outlet dew points were measured. The dry product was then expanded—15" to 20"/Hg @ 1/2-1/3 Atm—and used as purge gas (see *Figure 7*).

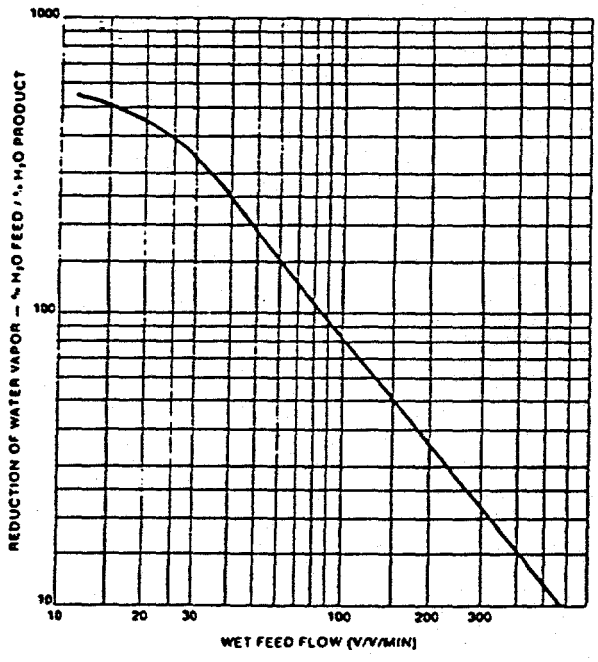


Figure 2

The reduction shown in *Figure 2* is the ratio of the percentage of water in the wet feed divided by the percentage of water in the product. The flow is the actual wet gas flow (cc/min) divided by the active internal volume in cubic centimeters of the dryer tubes. This wet feed rate of V/V/min can be used to calculate the residence time of the wet gas in the tubing (e.g., a flow rate of 60 V/V/min is equal to a residence time of one second).

The dryer performance of various models of PD-625, PD-750 and PD-1000 is shown in *Figure 3*. The product dew point (°C.) of each dryer is plotted against its product flow (liters/min). Air was saturated at 20° C. at atmospheric pressure; the dryer temperature was 23° C. The dryer was regenerated by expanding the product to 15"-20" Hg and using it for purge (see *Figure 7*).

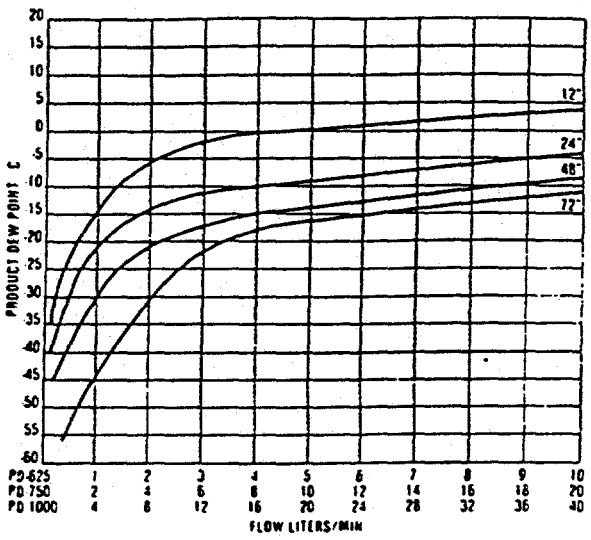


Figure 3

Pressure

Continuous drying requires the actual volumetric purge flow to be greater than the actual volumetric feed flow. The pressure of the feed and purge can be adjusted to optimize the reduction.

The product, which usually has value, should be maintained at a higher pressure than the purge. Increased pressure decreases the volume of gas; this produces a smaller V/V/min of flow. Care must be taken not to condense the water vapor during compression.

The purge gas, which contains the water vapor, is vented to the atmosphere. Decreased pressure requires less volume of purge gas at atmospheric pressure because of expansion: at reduced pressure, the purge gas has a lower partial pressure of water and, consequently, results in higher reductions of water vapor in the product.

The pressure drop caused by gas flow through the tubes can be calculated from the Poiseuille Equation, which correlates the flow, volume, tube diameter and viscosity.

Temperature

Drying of gases with the ***Perma Pure Dryers*** involves adsorption of water on the membrane surface. This reaction is exothermic and generates small quantities of heat. Evaporation of adsorbed water on the surface of the membrane is endothermic and produces cooling. As long as the product and purge are in the gas phase, the net result is no heat change in the system.

If water in the sample condenses and passes through the membrane on the purge side, a net cooling effect is obtained resulting in a temperature change equal to the latent heat of evaporation. This cooling effect can cause further condensation of water vapor when the sample has a dew point close to the dryer inlet temperature. It is, therefore, recommended that the dryer temperature be kept above the sample dew point in order to prevent condensation.

The membrane contains water and has a water vapor partial pressure, which is affected by its temperature. At higher temperatures it has a high water vapor pressure, and at low temperatures it has a lower vapor pressure. When the dry gas comes in contact with the membrane, a dynamic equilibrium occurs between the gas phase and the membrane. In order to achieve a low dew point in the product, it is necessary to keep the dryer output at ambient temperature or at a low temperature.

High reduction of water vapor in the sample is optimized by using a temperature gradient, which prevents the sample from condensing and minimizes the heating zone so as to reduce the product dew point. A graph, showing the effect of temperature on the product, which is caused by an increase in temperature of the dryer and the gas inlet dew point, is seen in *Figure 4*. The data was obtained with Model PD-625-48S

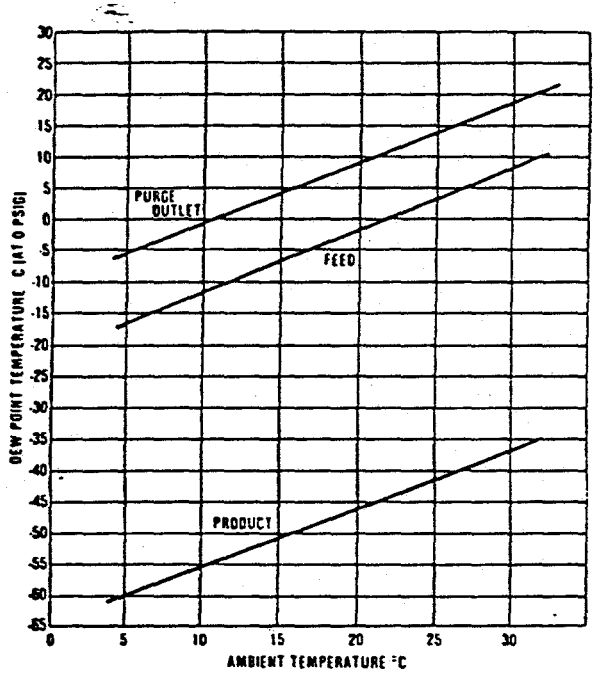


Figure 4

Gas Drying

There are several configurations for connecting the sample and purge gas inlets and outlets so as to obtain continuous drying. These include the external purge, split sample and reflux:

External Purge — The gas sample is passed through the dryer under pressure, or it may be connected to the discharge side of a pump. The total product is then passed into the system. Regeneration occurs with the use of an external dry gas at atmospheric pressure or at reduced pressure. The actual purge volume should exceed the sample volume by a factor of 1.5.

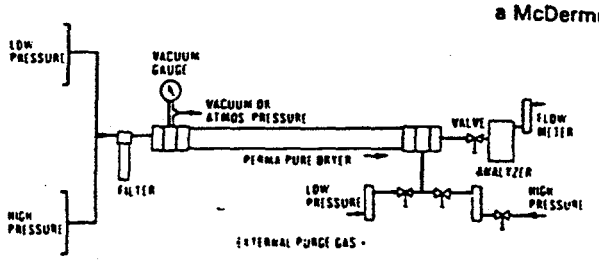


Figure 5

Split Sample — A portion of the wet sample can be used for regeneration by expanding the sample and subsequently using it as purge. To maintain the high purge ratio, the sample gas must be at high pressure and then expanded or, if the gas is at atmospheric pressure, the purge gas must be at reduced pressure to insure the proper ratio of purge to product.

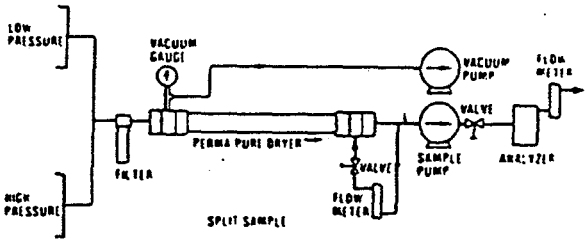


Figure 6

Reflux — The sample can be used for purge by passing it through the dryer at high or atmospheric pressure and then using the dry product at lower pressure by expanding it as purge. High pressure samples must be at 20 psig to obtain the proper expansion. Atmospheric pressure samples should be expanded by a factor of two to insure continuous drying.

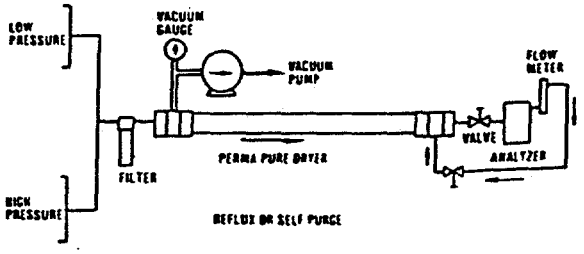


Figure 7

Temperature, Pressure and Chemical Resistance

The maximum temperature resistance of the *Perma Pure Dryer* is based on the materials used including the membrane, shell and header. The membrane is stable up to 160° C. The maximum temperatures used for the shells are 100° C. for polypropylene, 150° C. for fluorocarbon and 160° C. for stainless. Multi-tube headers have an upper temperature limit of 150° C., while the single-tube headers have a 160° C. limit.

The maximum internal pressure for multi-tube dryers is 80 psig, and for single tube dryers it is 30 psig.

The chemical resistance of the dryer to acid gases and liquids is shown below:

Sample	Conc. (%)	Shell	MD	PD
Chlorine	100	P, F	√	X
HCl	10	P, F	√	√
NO_2	.02	P, F, S	√	√
NO_2	.20	P, F, S	√	X
SO_2	.50	P, F, S	√	√
SO_2	1	P, F	√	X

Shell Material: Polypropylene (P)
Stainless (S)
Fluorocarbon (F)
(√) = Usable (X) = Not usable
(PD) — Multi-tube/thermoset resin header
(MD) — Single-tube header

Dryer Selectivity

Perma Pure Dryers remove water selectively from gases and other fluids. The dehydration is first order, and the residence time of most gases through the dryer is one second or less. Unless the product has complete solubility in hydrated water or reacts with the membrane, the selectivity of water from the product is quantitative.

The dryer selectivity for gases and liquids is listed below:

No Product Loss

Atmospheric Gases
N_2, O_2, H_2, A, He

Oxides
CO, CO_2, SO_2, SO_3, NOX

Halogen
Cl_2, HCl, HF, HBr, Fluorocarbons

Sulfur
H_2S, COS, Mercaptanes

Hydrocarbons
All HC gases-vapors-liquids

Toxic
HCN, $COCl_2$, NOCl

Organic Liquids
Aldehydes, THF
Cyanides, Esters

Low Product Loss

Gases, NH_3, Amines

Liquids: ketones, organic acids, ethers, DMF

Higher Product Loss

Alcohol, DMSO

Instrument and Apparatus Applications

The principle use of *Perma Pure Dryers* has been to dry and condition gas and vapor samples for analyzers and apparatus. Many instrument manufacturers incorporate the dryer into the gas conditioning system to improve the precision and accuracy of their equipment. Some of the analyzers and apparatus using *Perma Pure Dryers* include

Gas Analyzers
- Oxygen
- Thermal Conductivity
- Gas Chromatographs
- Electrochemical (gas)
- TOC, TOD, BOD
- Elemental Gas
- Infra-red
- Ultra-violet
- Mass Spectrometers
- Microwave Spectrometer

Apparatus — Gas Generators
- Hydrogen
- Ozone
- Zero Gas
- Humidifiers
- Organic Centrators

Process Applications

Thousands of *Perma Pure Dryers* are used to dry gases and liquids in many industrial processes and pollution measurements. The major industries and process include:

INDUSTRY	*PROCESS*	*GASES*
Petroleum Refining	Catalytic Crackers	CO, CO_2, O_2, NOX
	Boilers & Incinerators	CO, NOX, SO_2
	Sulfur Recovery	H_2S, SO_2, COS
	Flares	H_2S, SO_2
	Storage Tank	Hydrocarbons
Power Plants	Steam Generation (coal, oil, gas)	SO_2, NOX, CO
Chemical Plants	Sulfuric acid	SO, SO_3
	Nitric Acid	NOX
	Chlorine	Cl_2, H_2
	Ammonia	NOX
	Incinerator	HCl, Vinyl Chloride
Paper	Recovery Furnaces	H_2S, TRS
	Lime Kiln	H_2S, TRS
	Digestor & Evaporator	H_2S, TRS
Iron and Steel	Coking	H_2S, SO_2, CO, O_2
	Top Gas	CO, CO_2, O_2
	Arc Furnace	CO
Pharmaceutical	Fermentation	CO_2, O_2
Air Pollution Monitoring	Ambient Air	NOX, SO_2, O_3
	Mobile	NOX, SO_2, CO, HC
	Stationary	NOX, SO_2, CO
Water Treatment	Oxygenation	O_2, Combustibles
Nuclear	Safety	B-radiation
Nonferrous Metals	Smelting & Roasting	SO_2
Fossil Fuels	Tar Sands, Shale, Gasification	NOX, SO_2, CO, HC
Coated Paper, Film	Solvent Recovery	CO, CO_2

DISTRIBUTION SHEET

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TWRS LLW Program	TWRS Vitrification Development	Date 3/9/95
Project Title/Work Order		EDT No. 611541
Test Plan for Glass Melter System Technologies for Vitrification of High-Sodium Content Low-Level Radioactive Liquid Wastes		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ ECN Only
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OSTI (2)	L8-07	X			
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R. L. Gibby	H5-27	X			
D. W. Hendrickson	L5-31				X
B. A. Higley (4)	H5-27	X			
S. E. Kelly	H5-27				X
E. S. Mast	L4-69	X			
C. D. Meng	H5-27	X			
D. E. Mitchell	H5-49	X			
L. A. Palmer	H5-27	X			
R. H. Rieck	G6-06	X			
J. W. Shade	H5-27				X
K. R. Shah	G6-06	X			
J. S. Sparks	S1-57	X			
G. E. Stegen	H5-27				X
J. A. Swenson	H5-49				X
C. N. Wilson	H5-27	X			
Pacific Northwest Laboratory					
J. M. Perez	P7-41	X			
G. A. Whyatt	P7-19	X			
U.S. Department of Energy - Richland Operations					
C. V. Banks	S7-53				X
N. R. Brown	S7-53	X			
S. T. Burnum	S7-53				X
L. A. Huffman	S7-53	X			
J. C. Peschong	S7-53				X

MAR 15 1995
35 Station 21

ENGINEERING DATA TRANSMITTAL

1. EDT № 611541

2. To: (Receiving Organization)	3. From: (Originating Organization)	4. Related EDT No.:
TWRS Vitrification Development	TWRS Vitrification Development	N/A
5. Proj./Prog./Dept./Div.:	6. Cog. Engr.:	7. Purchase Order No.:
TWRS LLW Program	B. A. Higley, 376-5694	N/A
8. Originator Remarks: Babcock and Wilcox Final Test Plan for the Cyclone Combusiotn Melter, Phase 1 Test.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks:		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	WHC-SD-WM-VI-018	i - C-7	0	Test Plan for Glass Melter System Technologies for Vitrification of High-Sodium Content Low-Level Radioactive Liquid WAstes, Project Number RDD-43288	N/A	1, 2	1	1

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval	4. Review	1. Approved	4. Reviewed no/comment
	2. Release	5. Post-Review	2. Approved w/comment	5. Reviewed w/comment
	3. Information	6. Dist. (Receipt Acknow. Required)	3. Disapproved w/comment	6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.
1	1	Cog.Eng. B. A. Higley	B A Higley	3/1/95	H5-27					1	
1	1	Cog. Mgr. R. L. Gibby	R L Gibby	3/13/95	H5-27						
		QA									
		Safety									
		Env.									

18. B. A. Higley — B A Higley 3/7/95 — Signature of EDT Originator — Date

19. K C Burgard 3/13/95 — K.C. Burgard — Authorized Representative for Receiving Organization — Date

20. R. L. Gibby — R L Gibby 3/10/95 — Cognizant Manager — Date

21. DOE APPROVAL (if required) Ctrl. No.
[] Approved
[] Approved w/comments
[] Disapproved w/comments

BD-7400-172-2 (04/94) GEF097

RELEASE AUTHORIZATION

Document Number:	WHC-SD-WM-VI-018, Rev. 0
Document Title:	TEST PLAN FOR GLASS MELTER SYSTEM TECHNOLOGIES FOR VITRIFICATION OF HIGH-SODIUM CONTENT LOW-LEVEL RADIOACTIVE LIQUID WASTES, PROJECT ~~NUMBER~~ # RDD-43288
Release Date:	3/15/95

This document was reviewed following the procedures described in WHC-CM-3-4 and is:

APPROVED FOR PUBLIC RELEASE

WHC Information Release Administration Specialist:

Chris Willingham

C. Willingham 3/15/95

SUPPORTING DOCUMENT

1. Total Pages 77

2. Title	3. Number	4. Rev No.
Test Plan for Glass Melter System Technologies for Vitrification of Hign-Sodium Content Low-Level Radioactive Liquid Waste, Project #RDD-43288	WHC-SD-WM-VI-018	0

5. Key Words	6. Author
Combustion, Glass, LLW, Melting, Radioactive, Sodium, Testing, Treatment, Vitrification, Waste	Name: B. A. Higley Signature Organization/Charge Code 71250/D44A4

7. Abstract

This document provides a test plan for the conduct of combustion fired cyclone vitrification testing by a vendor in support of the Hanford Tank Waste Remediation System, Low-Level Waste Vitrification Program. The vendor providing this test plan and conducting the work detailed within it is the Babcock & Wilcox Company Alliance Research Center in Alliance, Ohio. This vendor is one of seven selected for glass melter testing.

8. RELEASE STAMP

OFFICIAL RELEASE
BY WHC
DATE MAR 15 1995
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