ALTERNATE HIGH EFFICIENCY PARTICULATE AIR (HEPA) FILTRATION SYSTEM

Phase IIA Final Report

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DISCLAIMER

ACKNOWLEDGEMENTS

CeraMem wishes to especially recognize the invaluable technical contributions made by and moral and technical support provided by Mr. Duane Adamson of Westinghouse SRS (Aiken, SC). Mr. Michael T. Terry, Los Alamos National Laboratory (assigned to Tanks Focus Area, Richland, WA site) and Mr. Jagdish Malhorta of the Office of Project Management, US DOE, FETC (Morgantown, WV) also provided substantial technical and support.

SUMMARY

In Phase IIA of this project, CeraMem has further developed and scaled up ceramic HEPA filters that are appropriate for use on filtration of vent gas from HLW tanks at DOE sites around the country. This work included procuring recrystallized SiC monoliths, developing membrane and cement materials, and defining a manufacturing process for the production of prototype full sizes HEPA filters. CeraMem has demonstrated that prototype full size filters can be manufactured by producing 9 full size filters that passed DOP aerosol testing at the Oak Ridge Filter Test Facility. One of these filters was supplied to the Savannah River Technical Center (SRTC) for process tests using simulated HLW tank waste. SRTC has reported that the filter was regenerable (with some increase in pressure drop) and that the filter retained its HEPA retention capability. CeraMem has also developed a Regenerable HEPA Filter System (RHFS) design and acceptance test plan that was reviewed by DOE personnel. The design and acceptance test plan form the basis of the system proposal for follow-on work in Phase IIB of this project.

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I. INTRODUCTION

This report summarizes CeraMem's activities in the development of a regenerable ceramic filter to replace currently used disposable HEPA filters on the vents of tanks containing high level radioactive wastes. A full background description can be found in publications generated from this work, which are appended.[1, 2] In addition, there are a number of publications produced by DOE.[3, 4, 5]

Throughout the evaluation period, CeraMem was in contact with Duane Adamson, Mike Terry, Jagdish Malhotra, and other DOE personnel regarding filter performance, filter vessel and system design, and other exchanges of information. These interactions are summarized in the appended monthly reports.

Based on the excellent results of this test work, CeraMem is confident of being able to design and supply full-scale ceramic filtration systems to replace the HEPA filters currently in use.

II. EXPERIMENTAL RESULTS AND DISCUSSION

Based on the statement of work in Phase IIA, CeraMem was to conduct the following tasks:

Task B.2.1.1. – Full-scale RHFS Design
Task B.2.1.2. – Full-scale HEPA Filter Element Delivery
Task B.2.1.3. – Acceptance Test Plan of Full-scale RHFS

The following will summarize the results from each task.

A. Task B.2.1.1. – Full-scale RHFS Design

The full-scale design approach involved a two-step process: 1) integrating the new ceramic HEPA filters into the existing SRS HEPA filter skid design; and 2) modifying several existing components to accommodate the new operating conditions. The design intent was to comply with all the applicable requirements of the lead SRS Specification G-SPP-H-00022 with as little change as possible. However, integration of the new ceramic HEPA filter technology will necessitate a few modifications to the existing SRS skid design. The major design modifications are as follows:

1. The process line size between the existing reheater and existing HEPA filter is reduced to 8" to facilitate the physical installation of the new filter vessel within the existing skid layout;
2. The existing blower will be replaced with a new blower with a higher vacuum capacity at the desired flow rates of between 800 and 1100 acfm. The new blower will provide additional capacity for the new ceramic HEPA filters;
3. The process scheme will allow for operation of the two HEPA filters in series or only the existing HEPA filter. This would be accomplished by removing the ceramic HEPA filter vessel and replacing it with an 8" pipe spool piece. The selected blower is provided with a two-speed motor to allow for these operating modes;
4. The existing HEPA filter housing will be upgraded to a new reinforced housing to allow operation at the new negative pressure of –60"wc, lower than the current rating of the HEPA filter specified by SRS.

The details of the RHFS design are given in the Alternate HEPA Filter System Design Book that is appended.

There are three additional appendices on the HEPA filter technology that are attached to this report. The first is CeraMem's responses to DOE's questions after the first system design review held in June 2000. The second is the ASME evaluation report that comments on the ceramic filter status and system design as of September 2000. The information in the review is dated since significant progress was made on the project after this point in time but it is included for completeness. The third is the draft report from International Union of Operating Engineers for the Technology Safety Data Sheet on the ceramic HEPA filter technology. The contents of this draft report are based on the current CeraMem HEPA filter technology and system design.

B. Task B.2.1.2. – Full-scale HEPA Filter Element Delivery

Based on CeraMem's Phase II Technical Proposal, this task was split into two parts: 1) Task B.2.1.2.a - Lab-scale HEPA Filter Element Delivery and 2) Task B.2.1.2.b – Full-scale HEPA Filter Element Delivery. These subtasks will now be summarized.

1. Task B.2.1.2.a – Lab-scale HEPA Filter Element Delivery

In Phase I of this program, a lab-scale membrane element was fabricated that passed the SRTC's polydisperse aerosol (poly (alpha olefin), PAO) HEPA filter leak check test. The membrane element was based on a porous SiC monolith that was 1.07" in diameter and 12" long. The passageway size was nominally 0.079" and the wall thickness was nominally 0.031". The membrane was a chemically durable, mixed oxide material. The cells were plugged with a low thermal expansion epoxy in the alternating checkerboard pattern to form the dead-ended flow configuration. The ceramic element had stainless steel end rings attached with this same epoxy. The seals to the stainless steel housing used for this element were made on the internal diameters of the end rings. See Figures 1 and 2 for a schematic of the filter construction used in this program and a photograph of a lab scale filter element and housing.

There were three significant improvements to be made to the membrane prior to scaling up to full size prototype filters. These were the ability to pass a monodispersed aerosol HEPA filter media challenge, the utilization of inorganic cements instead of epoxy to plug the filters in the dead-end configuration, and improved manufacturing reliability. An additional desirable improvement was the reduction in gas flow pressure drop. Alternate membrane materials and modifications of the Phase I membrane were undertaken prior to production of full size filters.

The general procedure for developing membranes was to formulate an initial casting slip composition and then prepare coatings from that slip on porous SiC monoliths. These coatings would then be fired to a selected temperature and the membrane-coated monolith passageways would be plugged with an organic or inorganic sealant to form the dead-ended filter. The pressure drop of these filters was measured using a blower and a flowmeter for generating the desired airflow and a U-tube manometer for measuring pressure drop. The retention of the filters were measured using monodispersed SiO_2 particles either 1.5 µm or 0.5 µm in diameter suspended in water. The retention was calculated using the turbidity of the feed and filtrate in the following equation:

$$\% \text{ retention} = [(\text{Feed}_{NTU} - \text{Filtrate}_{NTU})/\text{Feed}_{NTU}] \times 100 \qquad [1]$$

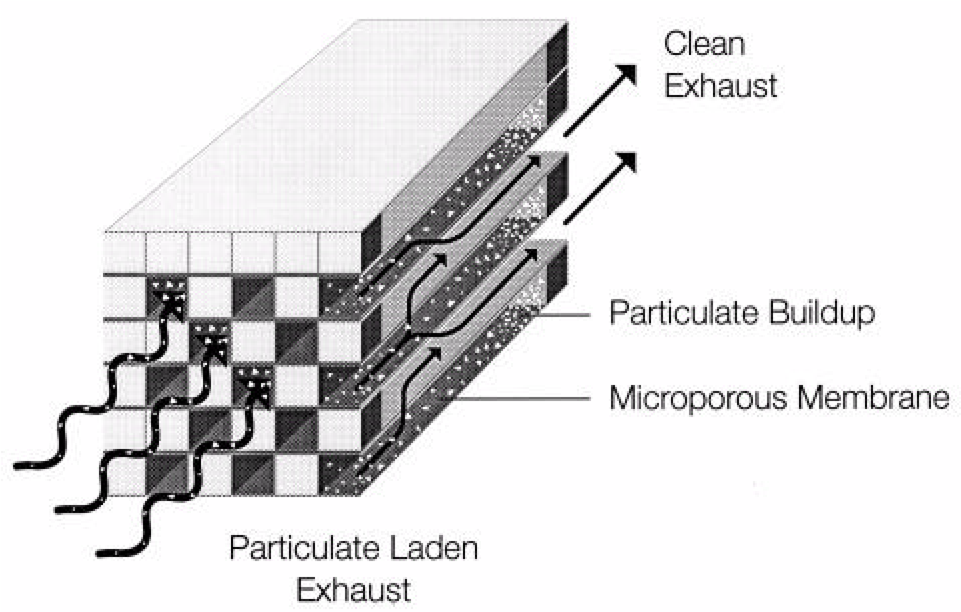

Figure 1. HEPA filter schematic

Figure 2. Photograph of a lab-scale HEPA filter and housing

Those parts that had acceptable pressure drop and high silica retention were sent to Air Techniques Inc. (ATI, Owings Mills, MD) for subsequent aerosol testing. It was found that filters that had high silica retention generally had higher aerosol retention but there was no true correlation between silica and aerosol retention. Due to this limitation, CeraMem typically had filters tested for aerosol retention when the 1.5 µm SiO_2 retention was in excess of 98% just to ensure that badly defective filters were screened out prior to further testing. However, this did not guarantee that the filters would pass the aerosol test.

As part of membrane development, SiC-based and mullite-based cements for plugging passageways were developed. They were evaluated by comparing the retention of monodisperse SiO_2 particles in water for filters first plugged with silicone sealant then with inorganic cement after thermally removing the silicone. When retentions were the same or better with the inorganic cement as compared to the silicone sealant, then that formulation was deemed acceptable. Acceptable formulations for both mullite and SiC were found and the SiC-based cement was selected since the monolith itself was SiC.

Table 1 summarizes the types of membranes evaluated by CeraMem in Phase II. The comments on the various attributes of the membranes are qualitative and reflect the status of the membrane at the end of the development work in Phase II.

Table 1. Developmental Lab-scale HEPA Filter Membrane Types

Membrane Type	Manufacturability	Retention	Pressure Drop	Chemical Durability	Bonding
Oxide-bonded SiC Type I	Requires improvement	Good	Acceptable	Adequate	Variable
Oxide-bonded SiC Type II	Acceptable	Acceptable	Too high	Good	Good
SiC	Requires Improvement	Good	Acceptable	Excellent	Good
Mixed Oxide Type I	Requires Improvement	Requires Improvement	Acceptable	Good	Good
Original Mixed Oxide (modified)	Good	Good	Acceptable	Adequate	Adequate

The first alternate membrane to be attempted was an oxide-bonded SiC material (Oxide-bonded SiC Type I). This material was used to produce the first lab-scale membrane that passed the monodispersed aerosol challenge at ATI. This membrane element had a retention of 99.995% for DOP and a pressure drop of 15” wc (measured at CeraMem) at 10 ft/min face velocity. Other similar membranes were made that also passed the DOP test at ATI and had pressure drops of between 20”wc and 25”wc at 10 ft/min face velocity. Unfortunately, the processing of the oxide-bonded SiC was not as reproducible as desired. Therefore, this membrane type of not developed further.

In order to improve on these SiC membranes, an alternative oxide binder was evaluated for the SiC (Oxide-bonded SiC Type II). The bonding was more reliable indicating that the membrane would be more manufacturable. However, the pressure drop for membranes that had HEPA filter retention was much higher than other membranes types. Filters with DOP aerosol retentions of 99.99% had airflow pressure drops greater than 36"wc at 6 ft/min face velocity.

Due to the general performance success of the oxide-bonded SiC membrane types, an additional SiC membrane material was investigated. Formulations for essentially pure SiC membranes were developed that would be bonded at temperatures in excess of 2,000ºC in an inert atmosphere. Membranes were prepared that had airflow pressure drops of 15"wc to 20"wc at 10 ft/min face velocity and a DOP retention of 99.9992%. The membranes had very good bonding and due to the pure SiC materials would have excellent chemical durability. However, there were limited locations where full-scale filters could be fired. Due to this manufacturing concern, development on this membrane material was stopped but this membrane certainly has promise and should by pursued in the future.

An alternative oxide-bonded membrane (Mixed Oxide Type I) was also explored. This mixed oxide membrane type was developed for liquid filtration applications and an attempt was made to modify the slip formulation so that it could be used as a HEPA filter membrane. Over 30 different formulations were attempted. In general, the filter gas flow resistances were comparable to other membrane types developed in Phase II but the retention of 1.5 µm SiO_2 was never higher than 96%. This retention was too low to be considered for a HEPA filter and this membrane was not further developed.

Modification of the original Phase I membranes in Phase IIA was also pursued. For these membranes, there were many modifications evaluated in the membrane processing. These changes included the ratio of refractory filler to oxide binder, type of refractory filler, overall solids content, the number of coatings, and firing temperature. This work culminated in lab-scale membranes prepared on 6 µm (nominal) pore size SiC monoliths that had monodisperse DOP aerosol retentions of 99.9998% or greater and airflow pressure drops of about 20"wc at 6 ft/min and between 30"wc and 35"wc at 10 ft/min. These filters had the best overall performance and most of the scale-up work to full size prototypes was performed using this membrane type or ones similar to it.

2. Task B.2.1.2.b – Full-scale HEPA Filter Element Delivery

Porous SiC monoliths 5.6" in diameter and 12" long were procured from LiqTech Aps (Denmark). The passageway size was nominally 0.079" and wall thickness was approximately 0.031". The nominal pore size and porosity were 6 µm and 40% respectively. These monolith supports were then coated with membrane by slip casting and fabricated using the same process as was used for lab scale filter elements.

The housings used for these prototype filters were very different from those used for the lab scale filters. The full size prototype housings consisted of 6" schedule 10 304 stainless steel pipe with 6" ANSI 150 lb 304 stainless steel flanges welded onto both ends. Snap ring grooves were machined into both flanges after both ends of the housing were honed to the desired diameter. The filter was installed using a custom installation tool using EPDM boot seals on both ends of the filter. The boots sealed on the end faces as well as the circumference of the filter and the boots where held axially in the housing with the snap rings. Please see Figures 3 and 4 for a photograph of a full-scale filter element and a drawing of the filter housing.

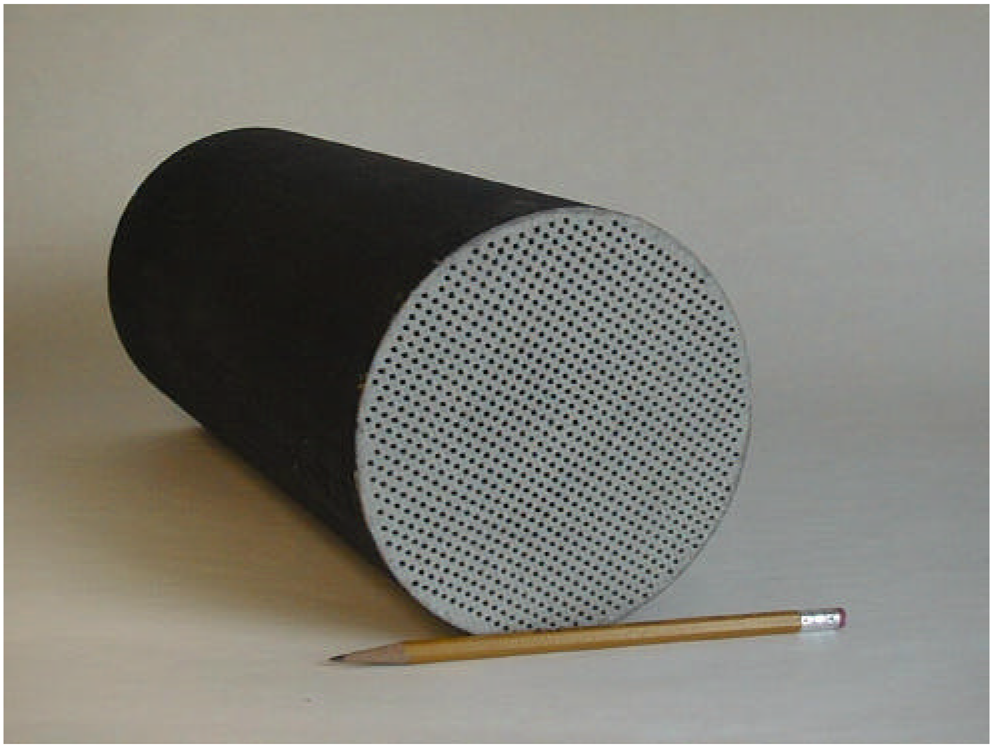

Figure 3. Photograph of a prototype full-scale HEPA filter element

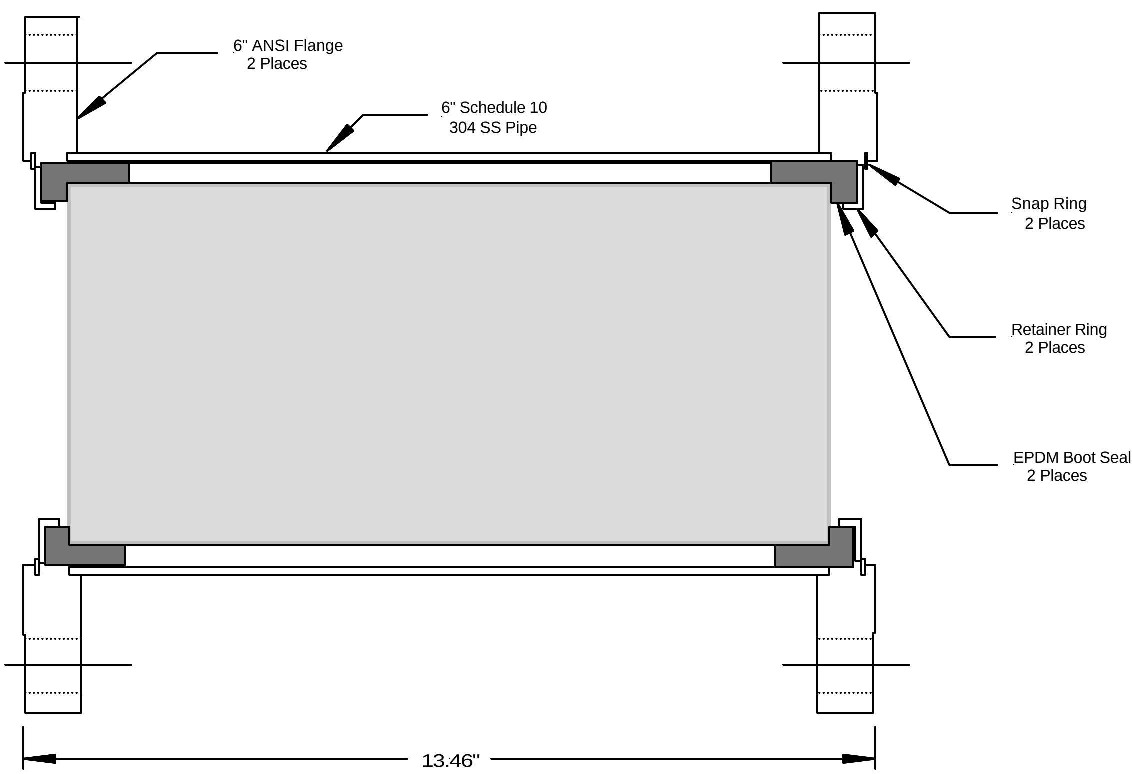

Figure 4. Schematic of the full-scale HEPA filter housing with filter installed

Three sets of full-scale filter elements were tested at the Oak Ridge Filter Test Facility. The first set of filters consisted of four filters with the original mixed oxide membranes and two filters with Oxide-bonded SiC Type I membranes. The results are shown in Table 2.

Table 2. Retention and Pressure Drop Results from First Set of Full-scale HEPA Filters

Filter No.	Membrane Type	1.5 µm SiO_2 Retention (%)	DP ("wc) at 6 ft/min (CeraMem)	Oak Ridge Filter Test Facility Results at Stated Flow Rates			
				125 cfm (6.8 ft/min)		25 cfm (1.4 ft/min)	
				DOP Retention (%)	DP ("wc)	DOP Retention (%)	DP ("wc)
2	Oxide-bonded SiC	69	10	95.2	11.6	95.2	2.4
7	Oxide-bonded SiC	99.4	19	99.963	21.8	99.927	4.8
9	Mixed Oxide	98.8	11	99.923	18.8	99.79	4.4
10	Mixed Oxide	99.1	10	99.87	15.4	99.82	3.6
13	Mixed Oxide	98.4	13	99.956	18	99.961	3.6
14	Mixed Oxide	99.5	12	99.85	15	99.86	1.2

None of the first set of filters passed the criterion for a HEPA filter of 99.97% or greater retention of DOP aerosol at 0.3 µm. As stated above, higher silica retention generally resulted in high aerosol retention (Filter No. 2) but above 98% silica retention there is no assurance that the filter will be a HEPA filter. It was clear that there were defects in the filters and it was decided to focus on the original mixed oxide membranes and removal of defects to prepare HEPA filters.

The first approach was to heal the defects by caulking them with particulate that could be subsequently bonded to the membrane by firing. Two different particulate caulking slurries (finer particle size than the membrane itself) were filtered through filters 9 and 10 and fired. The filters were then tested at the Oak Ridge Filter Test Facility at 125 cfm. The DOP aerosol retention did not change significantly. The retention for Filter No. 9 stayed essentially the same at 99.925% and the retention for Filter No. 10 increased only slightly to 99.935%.

Another set of filters was fabricated using mixed oxide membranes and these were caulked using mixed suspensions of submicron powder and colloidal sol particles. It was believed that the finer colloidal particles would help heal the membrane defects while helping to bind the submicron powder to the membrane surface. The results of this set of filters are shown in Table 3.

Two out of the seven filters tested passed the retention criterion for a HEPA filter. Those filters that were more heavily caulked had the highest pressure drop and low aerosol retention even though the silica retention was quite high. This indicated that aerosol was quite likely flowing through defects remaining in the membrane after caulking. When caulking increased the membrane resistance, a proportionally higher flow of aerosol went through the defects resulting in very low aerosol retention. Although full-scale HEPA filters were prepared using a combination of the mixed oxide membrane and particulate/sol caulking, the data from the first two sets of filters indicated that the membrane had to be changed in order to obtain good HEPA filters without caulking.

Table 3. Retention and Pressure Drop Results for Second Set of Full-scale HEPA Filters

Filter No.	Caulking Material	1.5 µm SiO_2 Retention (%)	DP ("wc) at 6 ft/min (CeraMem)	Oak Ridge Filter Test Facility Results at Stated Flow Rates			
				125 cfm (6.8 ft/min)		25 cfm (1.4 ft/min)	
				DOP Retention (%)	DP ("wc)	DOP Retention (%)	DP ("wc)
H19	Particulate	99.2	> 17	99.965	17	99.965	1.8
H20	Particulate + sol Type I	99.7	16	99.972	14.8	99.981	1.8
H21	Particulate + sol Type II	99.7	90	55	28	95.2	7.0
H22	Particulate + sol Type II	99.5	> 60	52	28	86	6.4
H24	Particulate + sol Type II	99.9	49	78.5	18.5	95.8	4.8
H25	Particulate + sol Type I	99.1	35	99.982	26	99.984	2.0
H26	Particulate	99.0	> 17	99.90	14.2	99.89	1.0

These observations led to the development of the lab-scale filters and the filtration results described for the modified original mixed oxide membranes in Task B.2.1.2.a. These membranes did not require caulking to attain HEPA filter capability. Prototype full-scale HEPA filters were prepared using this membrane technology in two separate processing runs. These were Filters Nos. H28 - H34 and Filters Nos. H39 - H47 (excluding H45).

Due to the lack of correlation with the silica retention test, these filters were not silica tested prior to shipment. The pressure drop was measured and a test was conducted to detect coarse defects. This test utilized carbon black that was sifted into the inlet channels while drawing air through the filter. If any passageway had a large defect, the carbon would stain a white cloth that was placed over the filter outlet. No defects were observed in these filters. The carbon was then removed from the filter by oxidation at elevated temperature in air. The data from the Oak Ridge Filter Test Facility are reported for both groups in Table 4.

Two out of five of the first set met the HEPA filter retention criterion. Unfortunately, two filters were damaged in shipment. Five out of eight of the second set met the HEPA filter retention criterion. It is interesting to note that the filters were either very good or very poor indicating a common defect in the poor filters. Additional analysis of the poor filters may reveal this defect and CeraMem feels that the defect problem in the poor filters will be correctable.

Table 4. Retention and Pressure Drop for Third Set of Full-scale HEPA Filters

Filter No.	Oak Ridge Filter Test Facility Results at Stated Flow Rates			
	125 cfm (6.8 ft/min)		25 cfm (1.4 ft/min)	
	DOP Retention (%)	DP (“wc)	DOP Retention (%)	DP (“wc)
H28*	99.982	26.1	99.999	1.8
H29	95.9	26.0	98.5	1.9
H30	93.2	21.2	99.67	8.5
H31*	99.986	22.5	99.999	1.8
H32	Damaged in Shipment			
H33	96.4	27.2	99.28	2.1
H34	Damaged in Shipment			
H39	94.2	26.8	97.6	2.2
H40	96.8	26.5	99.44	2.1
H41*	99.993	25.2	99.999	1.6
H42*	99.984	25.6	99.999	1.4
H43*	99.989	25.1	99.999	1.6
H44*	99.986	23.2	99.999	1.4
H46	97.9	26.8	99.05	2.8
H47*	99.992	22.6	99.999	1.8

* Meets the retention criterion for a HEPA filter.

A total of nine HEPA filters were fabricated in this task out of a total number of twenty-eight that were sent for testing at Oak Ridge. The yield from each set of prototypes increased as CeraMem improved the fabrication processes. In the last set of 13 filters tested, 7 passed the retention test. While this yield is not at manufacturing levels, the trend toward higher yield as the process was improved is promising.

Filter Number H-20 was sent to the Savannah River Technical Center for testing on simulated waste. Details on the procedures and results for these full-scale filter evaluations will be described in a soon to be released report by SRTC (Report Number WSRC-TR-2002-00238); in addition, SRTC test procedures for lab-scale filters that are similar to the full-scale filters are included in Reference 1, which is appended. CeraMem has been told that after approximately 10 filtration and cleaning cycles, the pressure drop of Filter No. H-20 increased from 13”wc to 18”wc under SRTC test conditions and the DOP aerosol retention did not changed, remaining at 99.97%. Testing at SRTC indicates that the filters are regenerable (although additional cleaning improvements are desirable due to the higher than expected increase in pressure drop) and maintain their HEPA filter capability after many filtration and cleaning cycles.

While the present filters meet the DOE needs for long-life HEPA filters, a new filter development at CeraMem should be noted. Under funding from DOE in a separate program[6], lab-scale HEPA filters were fabricated with half the gas flow resistance of the full-scale filters reported above. If the membranes developed in this other program were applied to monoliths 36" long, then the pressure drop at 125 cfm would drop from 20"wc to 25" wc to 3"wc to 4"wc. However, these new membranes would have to be evaluated at SRTC to ensure that the membranes would be cleanable and durable for the intended application.

C. Task B.2.1.3. – Acceptance Test Plan of Full-scale RHFS

Standard N510 defines an acceptance test as a field test made upon completion of fabrication, receipt and installation of an installed component, air-cleaning unit or system to verify that it meets the requirements specified. For this project, the major challenge is the substitution of the novel, ceramic, regenerable HEPA filter developed by CeraMem. The acceptance test plan is limited to the new filter technology or aspects of the related piping, ducts, frames, tube sheets, vessels, or housings that are directly affected. The testing plans for the remaining standard system process components (i.e., blower, heater, moisture separator, etc.) would be identical since their basic designs are unaffected by the filter technology.

For the fabrication of a demonstration system, CeraMem would conduct a pre-delivery, shop acceptance test to be conducted in the skid supplier's shop using the appropriate and applicable acceptance test procedures and criteria of N510 to verify 1) proper assembly, 2) structural capability, 3) leak tightness, 4) functionality, 5) air-aerosol retention and 6) limited air flow performance.

The acceptance test plan developed in Phase IIA for the new ceramic HEPA filter technology and related hardware is included in the Design Book referred to in Section A above and appended to this report.

III. CONCLUSIONS AND RECOMMENDATIONS

The conclusions from this work are as follows:

1. Membrane-coated, ceramic honeycomb filters with HEPA quality retention have been successfully produced as full-scale prototypes.
2. A significant number of full-scale prototypes have been produced indicating that the filters are manufacturable.
3. One prototype full-scale HEPA filter has been tested at SRTC by filtering simulated HLW tank vent gas and then cleaning with water and/or dilute nitric acid multiple times. The filter was regenerable but did have a 38% increase in pressure drop over 10 filtration/cleaning cycles indicating a need for further cleaning protocol development. There was no change in DOP aerosol retention. This data indicates that the filters will operate much longer than standard glass fiber HEPA filters on the HLW tank vent gas application.
4. The design for the DOE HEPA filter skid was modified to include the new ceramic HEPA filters. The modified design is capable of meeting DOE's need of a long-life HEPA filter system that satisfies the required specifications.

5. The acceptance plan for the filters, filter vessel, and filtration system has been developed and meets DOE specifications.

6. The technology developed in Phase II is ready to be demonstrated in Phase III of this project.

The recommendations for the project are as follows:

1. The project proceeds to the demonstration phase.

2. Membrane development work be continued to further reduce filter element pressure drop.

3. Filter element development be continued to fabricate larger diameter and longer filters, a direct extension of the current technology. This will reduce costs and more significantly allow the addition of additional filter area, further reducing pressure drop.

IV. REFERENCES

1. Robert Goldsmith, Bruce Bishop, Karsten Nielsen, and Duane Adamson, "*In Situ* Cleanable HEPA Filter for HLW Waste Tanks" Presented at the Industry Partnerships for Environmental Science and Technology Conference, Morgantown, WV, October 17-19, 2000.

2. Bruce Bishop, Robert Goldsmith, Karsten Nielsen, and Duane Adamson, "*In Situ* Cleanable HEPA Filter for Clean-up of Vent Gas from HLW Waste Tanks," Presented at the Industrial Partnerships for Environmental Science and Technology Conference, Morgantown, WV, October 30 – November 1, 2001.

3. Duane Adamson et al, "Experimental Investigation of In Situ Cleanable or Regenerable Filters for High-level Radioactive Liquid Waste Tanks," 26th Nuclear Air Cleaning Conference, September, 2000.

4. Duane Adamson et al, "In Situ Cleanable Alternative HEPA Filter Media," Waste Management Conference, Tucson AZ, February 2002.

5. Duane Adamson et al, "In Situ Cleanable Alternative HEPA Filter Media," ANS Spectrum 02, Reno NV, August 2002.

6. DOE SBIR Phase I project entitled "Process for Removal of Dioxin from Incinerator Off-gas," DOE Grant Number DE-FG02-01ER83159.

V. APPENDIX A: CERAMEM PROJECT PUBLICATIONS

In Situ Cleanable HEPA Filter for HLW Waste Tanks

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ABSTRACT

DOE has about 300 high-level waste liquid storage tanks at its various sites. These are maintained at a slight negative pressure to prevent leakage of radioactive contamination and avoid buildup of hydrogen in the headspace. The vent gas from these tanks is filtered through disposable glass fiber HEPA filters. Replacement of these filters generates both a waste disposal problem and a problem associated with operator exposure during filter replacement.

CeraMem Corporation has developed a ceramic monolith filter with a composite structure. The filter employs a fine-pored ceramic membrane barrier, which has HEPA filtration properties. A prototype filter has been supplied to SRS for DOP challenge tests and simulated vent gas tests. Results presented in this paper show >99.99% retention for 0.3 μm aerosol and the ability to be cleaned effectively by acid backflushing.

Continuing work in this program involves the development of "full size" filters and testing on simulated vent gas. Subsequently, a full size vent gas filtration system will be built and evaluated on a high-level waste tank vent line.

LIST OF ACRONYMS

ATI	Air Techniques International
DOE	U.S. Department of Energy
DOP	di-octyl phthalate
FTF	Filter Test Facility
HEPA	high efficiency particulate air
HFTA	HEPA filter test apparatus
HLW	High-level Waste
PAO	Poly-alpha olefin
SC	South Carolina
SRS	Savannah River Site
SRTC	Savannah River Technology Center

I. BACKGROUND

Conventional disposable glass-fiber HEPA filter cartridges are used throughout the U.S. Department of Energy (DOE) complex in various process systems. These filters require routine removal, replacement, and disposal. This process is not only expensive, but subjects site personnel to radiation exposure and adds to an ever-growing waste disposal problem. The conventional HEPA filters also have safety concerns regarding the strength of filter media, water damage, and operation in environments with elevated temperatures. The Defense Nuclear Facility Safety Board issued a report entitled “HEPA Filters used in the Department of Energy Hazardous Facilities”, DNFSB/TECH-23, in which these and other concerns pertaining to conventional HEPA filters were addressed. [1]

The SRS High Level Waste (HLW) tanks are designed to hold approximately 1.0 million gallons of radioactive liquid waste. Figure 1 depicts a typical HLW tank ventilation flow diagram. The tanks are located outdoors and buried in the ground except for the tank top. They are equipped with a ventilation system that provides approximately 500 cfm of filtered air within the headspace. The airflow maintains the tank contents at negative pressure (-1.0" water column). The air flows through a demister and condenser where water is removed from the air stream. The flow then enter a reheater where the air is heated above dew point before being filtered at the outlet HEPA Filter and released to the atmosphere. Tanks with secondary containment also have a separate ventilation system for the annulus space. The negative pressure maintained on the tank contents prevents the release of radioactive material to the environment. However, it also allows for atmospheric dust to be pulled into the tank during normal operation.

The glass fiber HEPA filter must exhibit a particle removal efficiency of 99.97% when challenged by thermally generated poly-alpha olefin (PAO) with a diameter of approximately 0.3 microns. It is common practice at SRS to refer to this test as a DOP test, in reference to di-octyl phthalate that was commonly used in the past as the standard test material in HEPA filtration. The acronym, DOP, will be used throughout the remainder of this report. The pleated glass fiber HEPA filter media has approximately 240 ft^2 of surface area and is typically contained in a 2 ft x 2 ft x 1 ft housing and exhibits a 1 inch of water column (w.c.) differential pressure (dP) across the filter media when clean. A HEPA filter remains in service until the filter media reaches a predetermined maximum pressure drop (approximately 5 inches w.c.) or a high source term due to radioactive buildup, and then the filter is replaced.

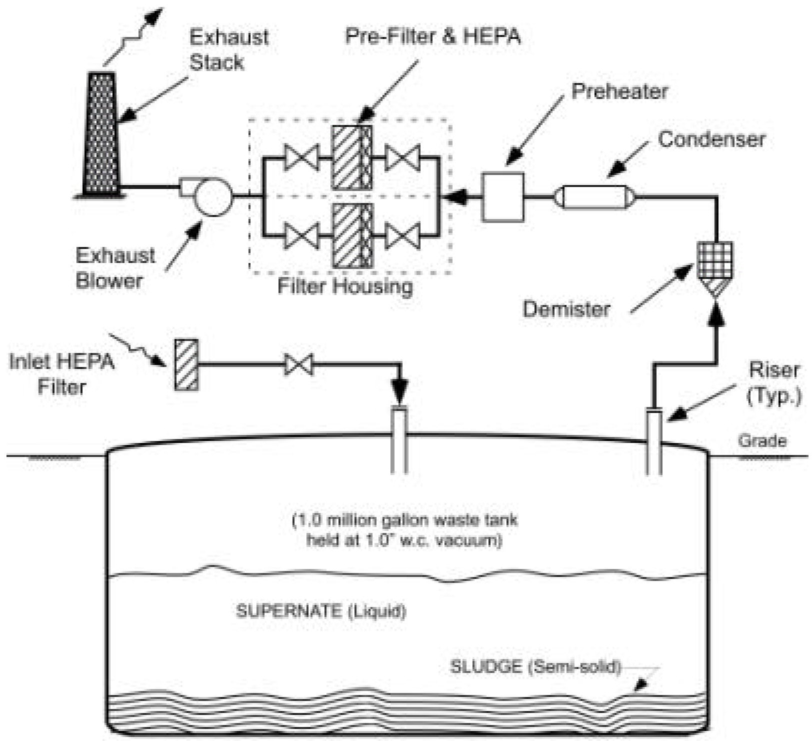

Figure 1: Typical HLW ventilation system flow diagram

SRS requires that all process HEPA filters pass an in-place leak test both before being placed into service, and periodically thereafter. DOP test connectors are designed into each HEPA installation to facilitate the routine in-place DOP test per national and site standards. Both the material challenge and the filter efficiency tests conducted on the filters in this study were designed to simulate conditions found in HLW tanks at SRS.

Previous research has been conducted at other DOE sites such as Lawrence Livermore National Laboratory and Oak Ridge National Laboratory to develop an in situ cleanable HEPA filter with high media strength. W. Bergman, et al. conducted research on various filter media, such as steel fibers, ceramic, and sintered metal, using reverse air pulse as the in situ cleaning method. [(2)] The results of these investigations indicate that commercially available filter media could be applied to the development of an in situ cleanable (using reverse air pulse) HEPA filter system that would meet the performance criteria established for a conventional HEPA filter system.

In FY98 SRS started working on the theory of using high-pressure drop filter media in an in situ regenerative filtration system. The in situ cleaning of the filter media used an aqueous solution to regenerate the media to a new filter status. Testing conducted in FY98 and FY99 indicated that an in situ cleanable filtration system is feasible for use on the HLW tanks.

A cost analysis conducted on cleanable HEPA filters showed that the in situ cleanable filters have the potential of being cost effective when compared to the conventional glass fiber HEPA filters. The study estimated that the DOE complex uses an average of 11,000 filters per year at an estimated cost of $55 million. Using in situ cleanable HEPA filters could save the complex $42 million a year in operating cost. The study did not include costs associated with glass fiber filter breakthrough or rupture, but these additional costs increase the cost benefit of the in situ cleanable filters for the complex.(2)

II. INTRODUCTION

The DOE Tanks Focus Area and The National Energy Technology Laboratory (formerly known as the Federal Energy Technology Center) issued a "Call for Proposals" to identify vendors conducting research in the area of in situ cleanable/regenerative filters or vendors interested in pursuing such technology.(3) A technical evaluation was conducted on the proposals.

Based on the proposals reviewed, CeraMem Corporation, located in Waltham, Massachusetts was selected to support this research program. CeraMem was asked to provide a test filter element of simulated testing at the Savannah River Technology Center (SRTC). Figure 2 below is a picture of the test filter element (H-18) tested at SRTC.

Figure 2: Ceramic monolith test filter

Figure 3 depicts the design of the CeraMem filter media and the airflow passage through the filter. As shown, the dirty air with particulate matter enters the filter media. The entrained particles are then filtered from the air in the microporous membrane. The clean air flows down the clean channels and is exhausted from the filter.

Below are the characteristics of the "lab scale" ceramic monolith filter tested in this program

• Monolith Membrane Support:	Silicon carbide
• Membrane Coating:	Glass-frit-bonded zirconium silicate and alumina
• End Ring Adhesive and Plugs:	Zirconium-silicate-filled food-grade epoxy
• End Rings:	316L stainless steel

- Overall Element Dimensions: 1.28” diameter (end ring) x 13.1” long
- Ceramic Component Dimensions: 1.06” diameter x 12.0” long
- Filter Configuration: Flow-through, dead-ended filter
- Number of Active Inlet Channels: 30
- Channel Opening Size: 0.066”
- Channel Wall Thickness: 0.03”
- Channel Plug Depth: 0.12”
- Inactive Channel Sides: 16 (next to skin around circumference)
- Pressure Differential 75” w.c. @ 9 scfm
- Filtration Surface Area: 0.56 ft^2

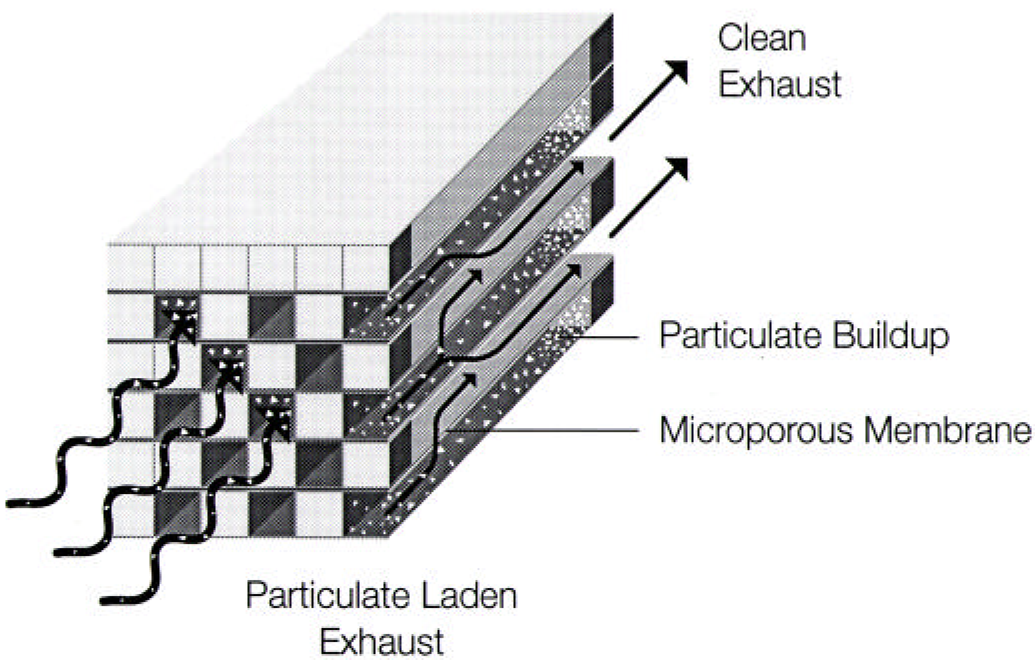

Figure 3: Airflow through ceramic filter media

Previous work has been conducted on earlier versions of a CeraMem honeycomb ceramic monolith filter as an in situ cleanable HEPA filter using reverse air pulse.(2) The ceramic filter was not recommended by the study as a cleanable (using reverse air pulse) HEPA filter due to high-pressure drop and particle removal efficiency less than 99.97%. But over the past few years CeraMem’s continuous research on ceramic membranes has improved retention efficiency while reducing pressure drop access the media. Figure 4 is a photomicrograph of a silicon carbide (SiC) monolith structure (left) with a membrane surface coating (right) with a pore size between 0.2 – 0.5 μm. This evolutionary ceramic membrane provides a low pressure drop while obtaining HEPA filter retention efficiency. Figure 5 is a photomicrograph of a cross-section view of the SiC monolith with a SiC coating.

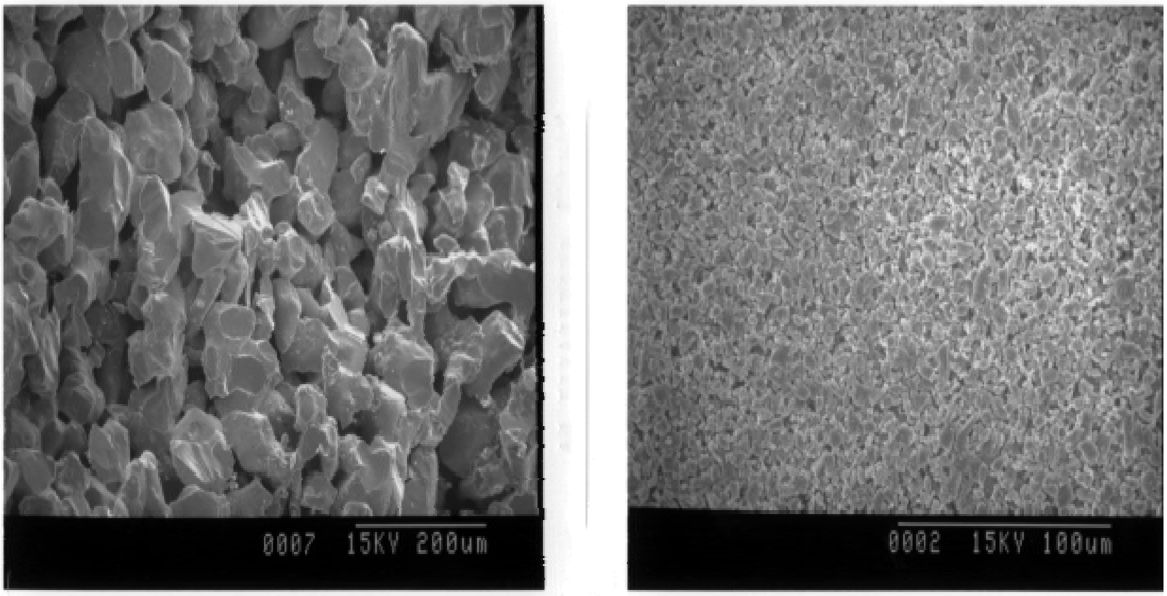

Figure 4: Monolith Pore Structure and Membrane Surface

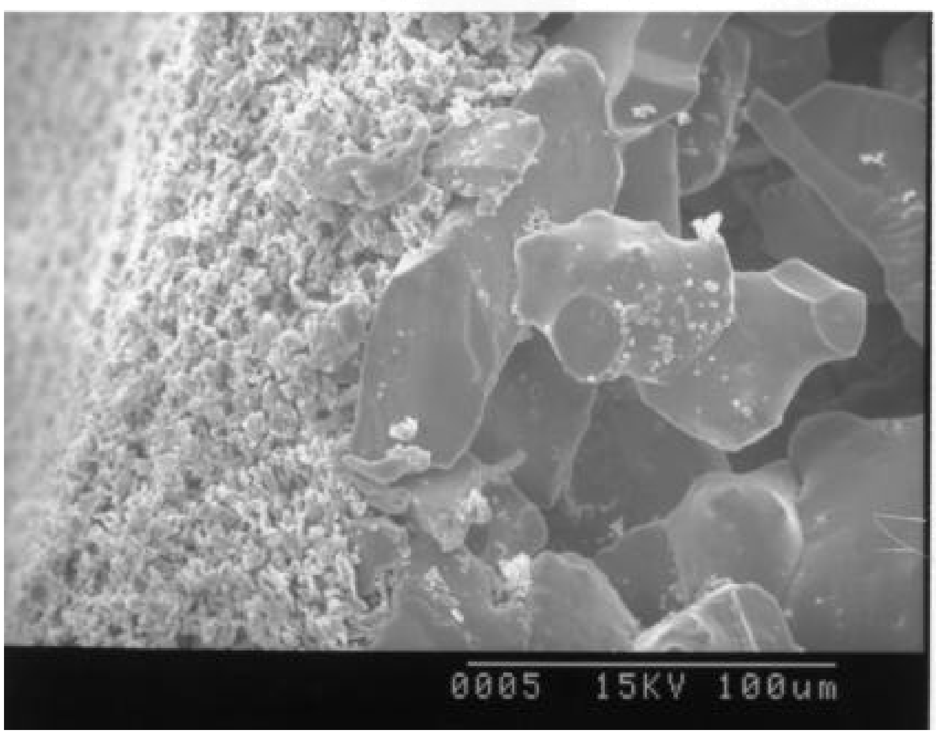

Figure 5: Cross-section view of membrane/monolith

III. TEST LOOP DESCRIPTION

A HEPA filter test apparatus (HFTA) was designed and constructed to simulate the conditions found on the HLW tanks at SRS. Figure 6 depicts the schematic of the HFTA constructed at the Thermal Fluids Laboratory at SRTC.

The test was designed for approximately 18 scfm of filtered air to flow into a simulated waste tank filled with approximately 30 gallons of heated (104° F - 140° F) simulated HLW solution. The simulant solution was mechanically agitated while the filtered air traveled through the headspace of the tank. This flow path simulated the HLW tank ventilation system. After exiting the tank, the airflow was split between the test filters, with 9 scfm of measured air passing through each filter. A separate vacuum pump was used to pull the air across each filter as shown in figure. DOP test connectors were designed into the HFTA to conduct in-place leak tests on the filter media.

The HFTA was designed such that one filter could be cleaned while the other remained online for testing. The system operated continuously (24 hours a day, 7 days a week) until the flow across the filter(s) decreased by 20% or more due to particulate matter build up on the surface of the filter. The time to plug a filter was determined by many variables such as test solution, speed of the agitator, liquid level in the tank, etc. Once a the CeraMem filter became soiled, a 10% nitric acid solution was back-flushed through the filter and allowed to soak in the filter for approximately 10 minutes. The filter was then back-flushed with water and a purge of air to remove residual liquid from the media.

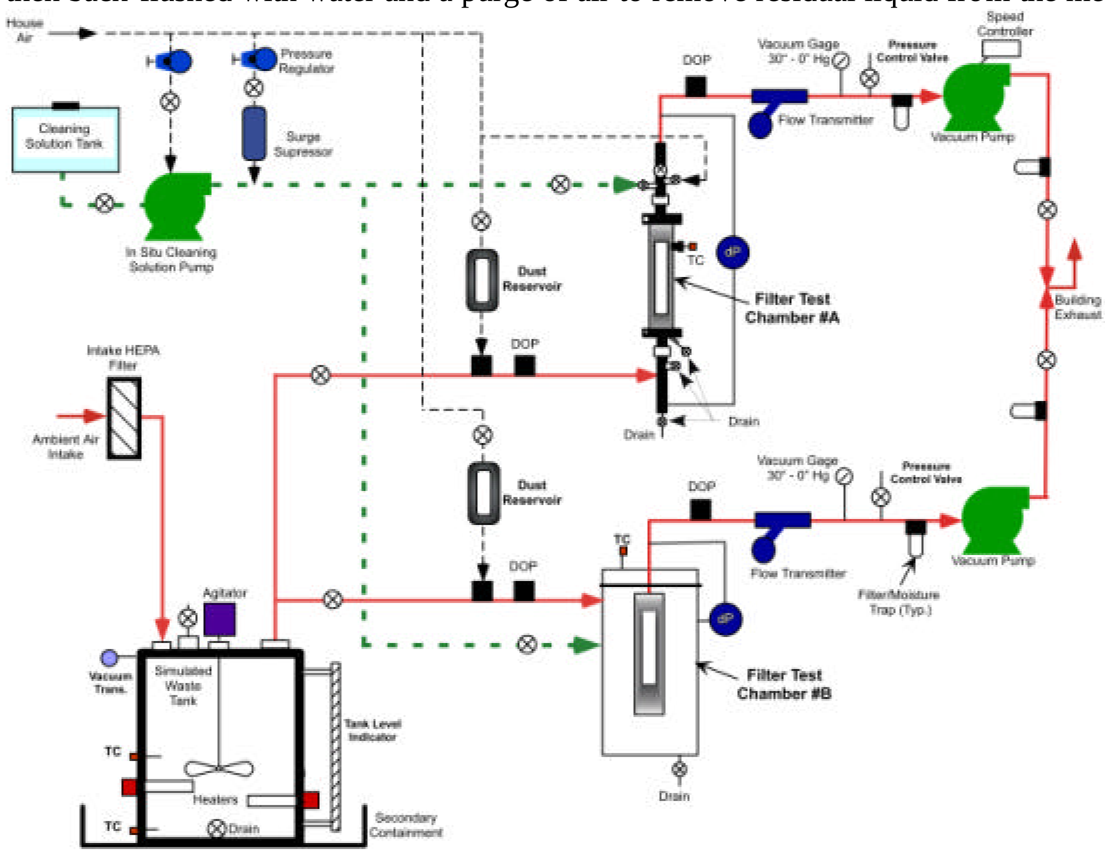

Figure 6: HEPA filter test apparatus

IV. TEST SOLUTIONS

Filtering entrained particulates of simulated HLW and atmospheric dust in the air stream challenged the filters. These materials, neglecting the radioactive constituents, are believed to be responsible for plugging the existing HEPA filters in the HLW tanks, especially under high humidity conditions found in the tanks. Two solutions were mixed to simulate the HLW found in HLW tanks at SRS. Only one solution was in the waste tank at a time to challenge the filters. The formulations for the HLW simulant constituents are shown below.

Simulated HLW Sludge

Element	wt %	Element	wt %
Al	17.66	Ba	0.40
Ca	2.32	Cr	0.24
Cu	0.20	Fe	31.76
Mg	0.26	Mn	10.50
Na	21.73	Nd	3.42
Ni	2.10	Pb	0.48
Sr	0.70	Zn	0.33
Zr	0.10	K	0.36
Cs	0.02	Si	7.42

HLW Simulated Salt

8.0 M NaOH (Sodium Hydroxide)
1.5 M $NaNO_3$ (Sodium Nitrate)
1.7 M $NaNO_2$ (Sodium Nitrite)
0.4 M $NaAl(OH)_4$ (Sodium Aluminate)

South Carolina Road Dust

South Carolina road dust was used to simulate atmospheric dust around SRS. The SC dust consisted of topsoil from Aiken County. The soil was dried in an oven to remove the moisture and particles larger than 75 microns were sifted out. The dust was slowly injected from the dust reservoir into the 9-scfm air stream using a small stream of air. The simulated waste tank was empty and the air temperature was approximately 70° F.

V. RESULTS AND DISCUSSION

- CeraMem test filter passed the in place leak DOP test with 99.97% particle removal efficiency at the beginning, middle and end of the test campaign.
- Operated in a high humidity environment with little or no effect on its operation.
- The performance of the CeraMem filter was adversely affected during the high humidity test conditions due to the presence of entrained liquid. However, this was due to the design of the filter housing which had no disengagement section.
- The CeraMem filter regenerated well during the in situ cleaning. That is, the airflow and dP across the filters returned to a clean filter status after being challenged with simulated HLW sludge, South Carolina road dust and simulated HLW salt. [5,6]
- Additional CeraMem test filters passed the DOP test at SRTC and at the Oak Ridge Filter Test Facility.

The first performance test on the CeraMem filter was a standard in-place leak (DOP) test of HEPA filters, conducted by the site HEPA Filter Test Group at SRS. The CeraMem (H-18) test filter passed the leak test with a 99.97% removal efficiency or greater. The same test filter was also DOP tested after the SC road dust test and at the end of the test campaign with an efficiency of 99.97% or greater each time. This proved that the filter media was not physically breaking down due to the simulants or the in situ cleaning during the test campaign.

The Principal Investigator of the Alternative Filtration Program has concerns on using organic challenge materials (PAO or DOP) for conducting leak testing on ceramic media due to the wetting effects that the organic have on the surface of the media. Small particle sodium chloride may be a better challenge material for this media. Sodium chloride testing has been used with great success in Great Britain and Continental Europe for the last 50 years.(7) A study should be conducted to optimize the method and challenge material for leak testing (DOP) the ceramic and other alternative media.

The CeraMem filter was tested with water in the simulated waste tank to determine if the filter could operate in a high humidity environment without operational problems. The water in the waste tank was agitated and heated until the humidity was approximately 100% in the filter housings. The ceramic filter media was not affect or damaged by the high moisture environment. However design attributes of the filter housing cause some operational concerns.

The CeraMem filter performed well during the simulated HLW sludge, salt and the SC road dust test. The airflow and dP across the CeraMem filter recovered overall after cleaning the filter in situ as depicted in Figure 7. The data shows that the CeraMem filter regenerated back to a clean filter status after each loading/cleaning cycle.

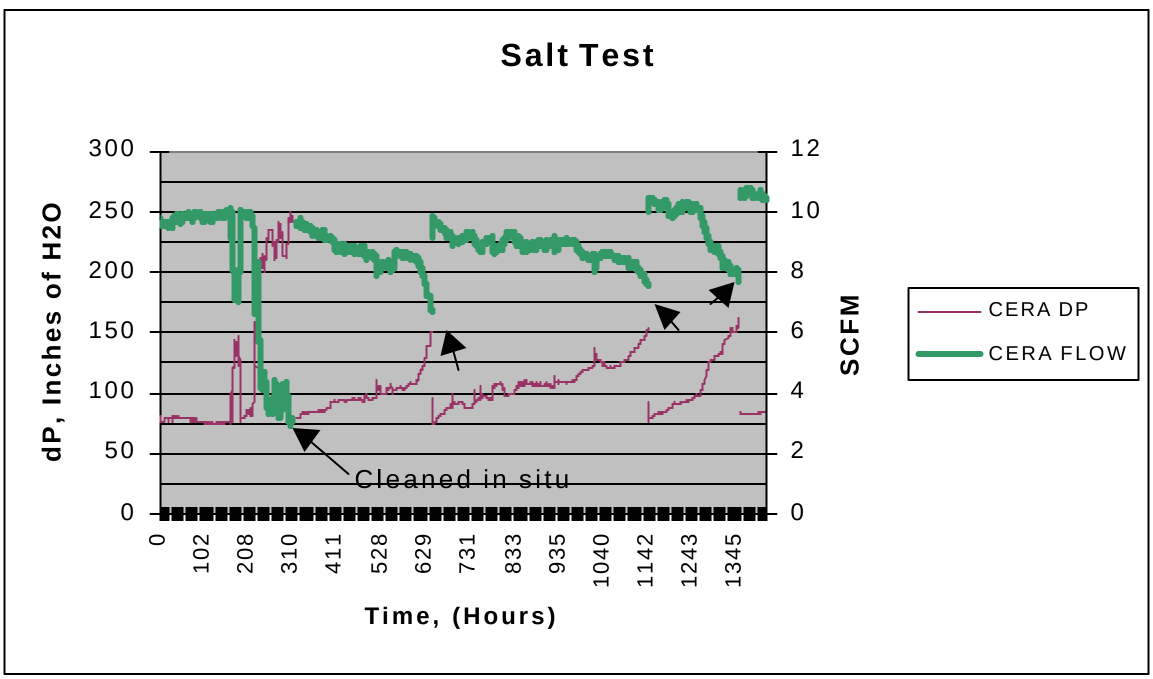

Figure 7: Filter loading and cleaning cycles

During the SC road dust test the CeraMem filter was deadheaded (i.e. vacuum being pulled on the filter with air flowing due to the plugged condition) to determine if the filter would break though or fail. The ceramic filter completely recovered to the original dP and airflow of a new filter from the in situ cleaning with no damage occurring to the filter media. This condition of filter plugging is a worst case operational scenario, where the vacuum pump was allowed to operate deadheaded for several hours allowing the small dust particles to be pulled into the filter's flow channels, potentially making it more difficult to regenerate the filter in situ.

The CeraMem filter operated in a controlled but very hostile environment so that the filters would plug in a relatively short period of time. The filter was plugged with HLW simulants and cleaned in situ many times with the airflow and dP across the filter completely recovering.

The unknown quantity of radionuclides that may accumulate on a HEPA filter is a concern for DOE sites in the case of a catastrophic HEPA filter failure. Application of in situ cleanable filters could potentially prevent the buildup of alpha and beta emitters. The in situ cleanable CeraMem filter could also be used in other applications such as to permit recovery of nuclear materials that collect on HEPA filters. Current design concepts for the CeraMem filter housing assembly system will eliminate components prone to fail under fire or other high temperature conditions. Heavy smoke and smoke borne particulates may plug the filter, but test results indicate that the plugged condition will not cause filter failure and breakthrough. Testing has proven that a full-scale in situ regeneration ceramic membrane is feasible. Note that a full scale filter would have no combustible materials used in the filter or seals.

Even though the CeraMem filter media has demonstrated great potential as an in situ cleanable HEPA filter, much work will be required to certify the filter per the requirements of the Code on Nuclear Air and Gas Treatment, ASME AG-1.(4) Work is ongoing with Air Techniques International (ATI) located in Baltimore, Maryland to conduct efficiency testing of the alternative filter media. ATI also operates the DOE Filter Test Facility (FTF) at Oak Ridge. The FTF is responsible for conducting efficiency tests on conventional HEPA filters before installation at DOE facilities. ATI is in the process of making modifications to their test equipment to conduct efficiency test on the CeraMem filter. This and other related certification issues will have to be resolved before full-scale commercial replacement of conventional disposable HEPA filters with a new generation of permanent, cleanable HEPA filters can be obtained.

We have shown the feasibility of developing an in situ cleanable filter system. However, the small-scale laboratory work must be scaled up to full-scale equivalents. This represents the next step in the development of the in situ cleanable HEPA filter for HLW tanks, which is discussed briefly below.

Research and testing is ongoing proving this technology of regenerating filters in situ using an aqueous solution. CeraMem and SRTC are working directly with ATI to conduct efficiency test on the ceramic media at their Baltimore facility and at the Oak Ridge FTF. ATI is in the process of making modifications to their test equipment to conduct efficiency test on the full-scale CeraMem filter later this fall.

Figure 8 below gives the results of testing the filters at SRTC (PAO) and at ATI (DOP). The figure depicts that filters both passed and failed the efficiency test. This is due to the ceramist engineer trying to optimize the retention verses the dP across the media. The figure also depicts that three filters had a much higher retention than the required 99.97%.

Figure 9 shows the dP vs. face velocity across the various filters tested. The design point in which CeraMem would like to obtain with greater than a 99.97% efficiency is approximately 15" wc dP with a 6 ft/min face velocity.

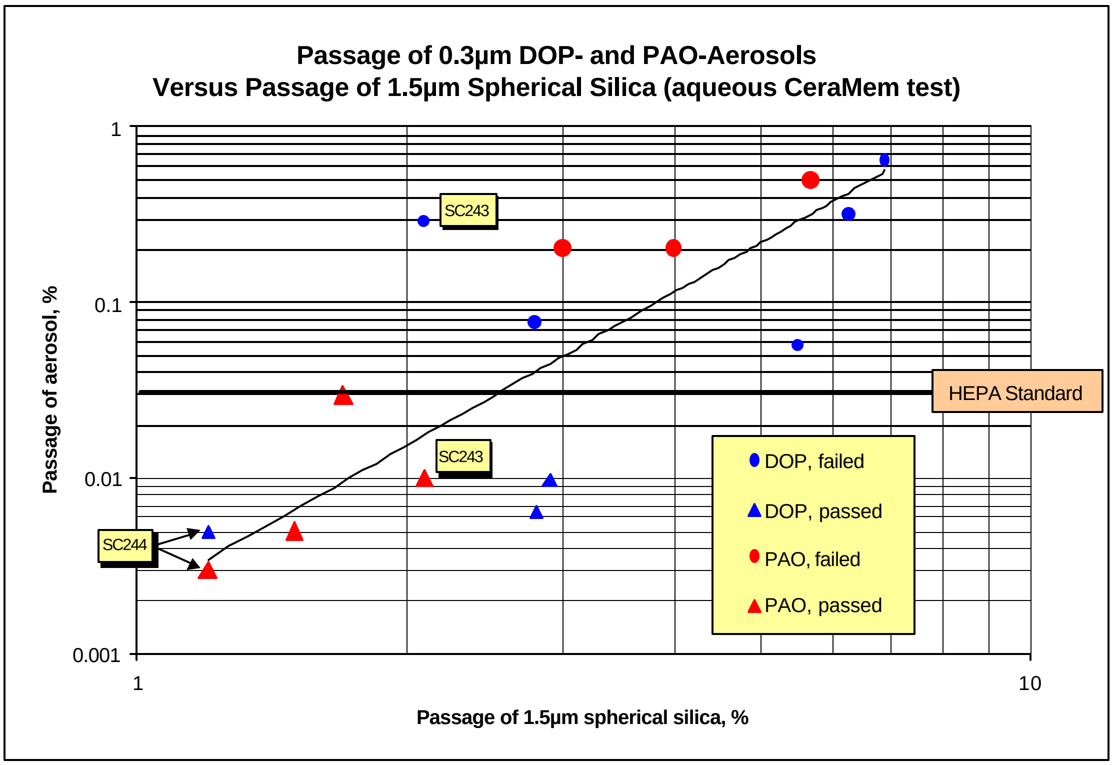

Figure 8: DOP retention test

VI. FULL SCALE SINGLE FILTER ELEMENTS

CeraMem corporation has designed full-scale filter elements for testing at SRTC. The full-scale single element test apparatus has been designed and constructed by SRTC. The testing will challenge a single full-scale filter element with HLW simulants. Figure 10 is a picture of two full-scale CeraMem filters. Each filter is 12 inches long and 5.66 inches in diameter with approximately 20 ft^2 surface area. The media has a pressure differential of approximately 15" wc at a face velocity of 6 ft/min. ATI will conduct efficiency test on the full-scale filters once the Oak Ridge FTF is modified. The filters will undergo the efficiency test before the simulant test is conducted at SRTC. The test will ensure 99.97% efficiency when challenged with a 0.3-micron hot DOP particle.

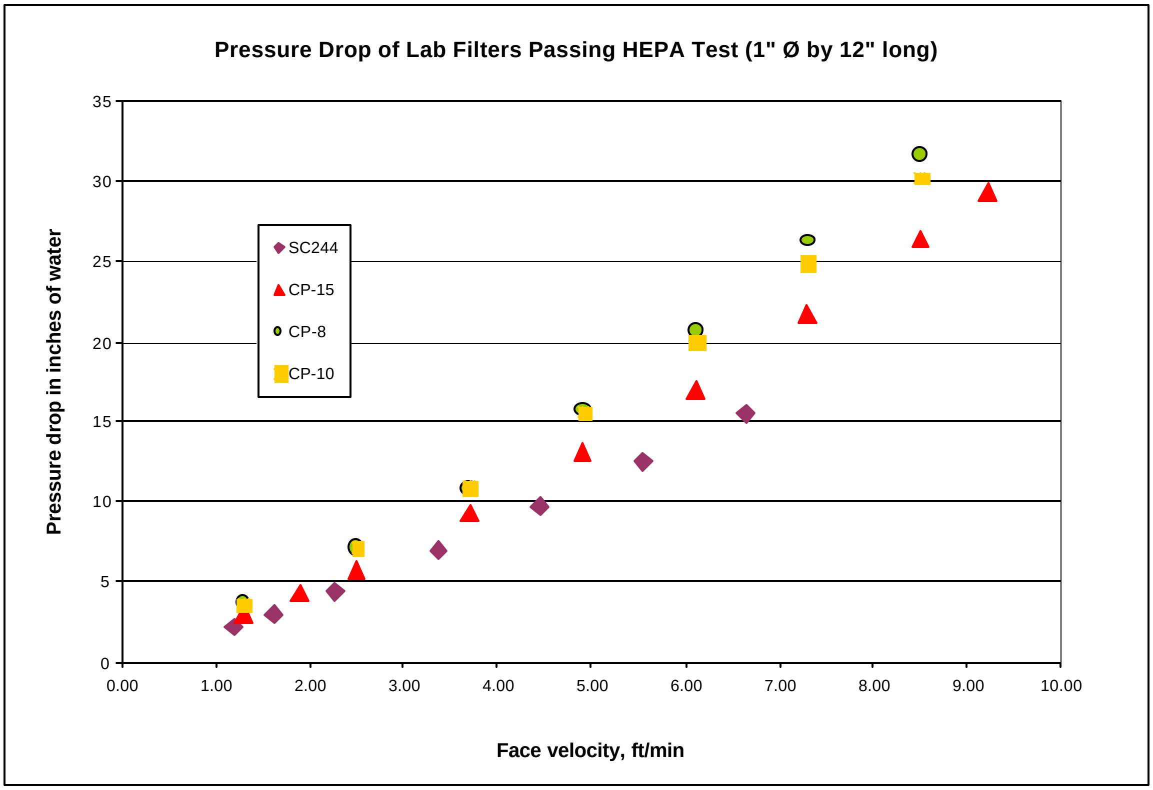

Figure 9: Representative pressure drop

Figure 10: Full-scale ceramic filter element

VII. ALTERNATIVE FILTRATION FULL SCALE SYSTEM DEPLOYMENT

A full-scale Alternative Filtration System is planned for construction with the hot demonstration of the system being conducted at SRS on HLW Tank 11. HLW tank 11 is a radioactive waste tank containing approximately 0.5 million gallons of radioactive waste. This is a waste removal tank that is scheduled for clean out and final closure in the near future. Before the hot deployment, the full-scale system will undergo cold testing at the SRTC.

Figure 11 is the conceived CeraMem full -scale filter housing for the ceramic media, which is being considered for the full-scale demonstration. The housing will consist of approximately 7 full-scale filter elements as depicted in Figure 12. The dirty air will be drawn into the bottom end of the housing and clean air will exit through the top of housing. After the filter becomes plugged with particulate or when the radioactivity from the accumulated particulate approaches area limits, the in situ cleaning system will be initiated. Note that the blowers are shut down before initiating the cleaning cycle. The elements are cleaned in situ via back flushing an aqueous solution through the media.

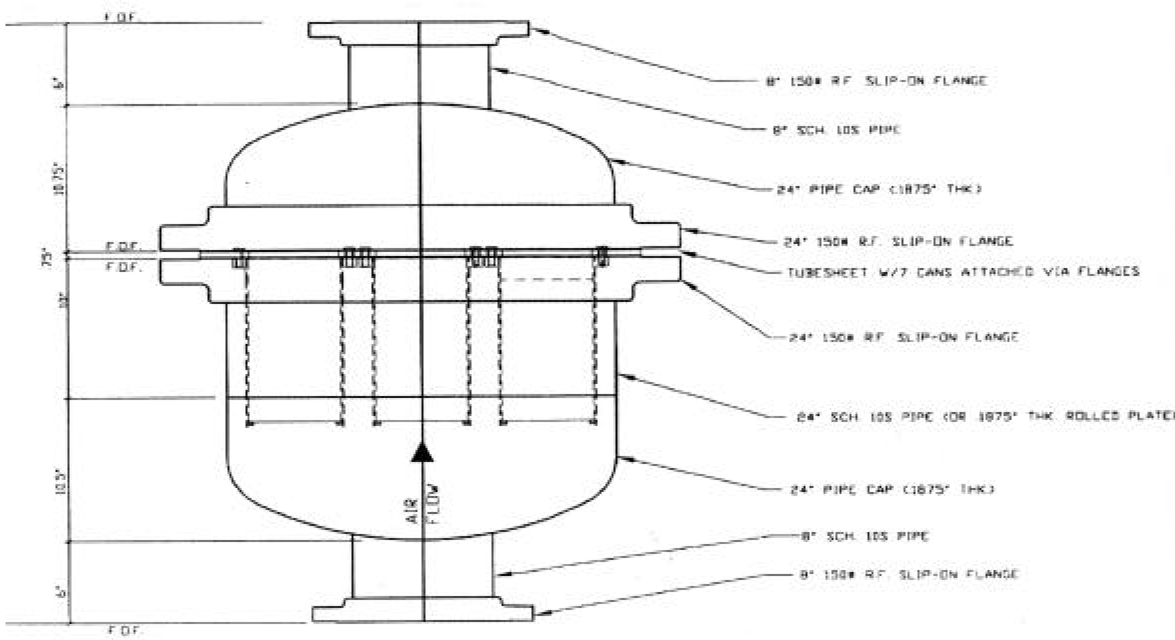

Figure 11: Ceramic full-scale filter housing

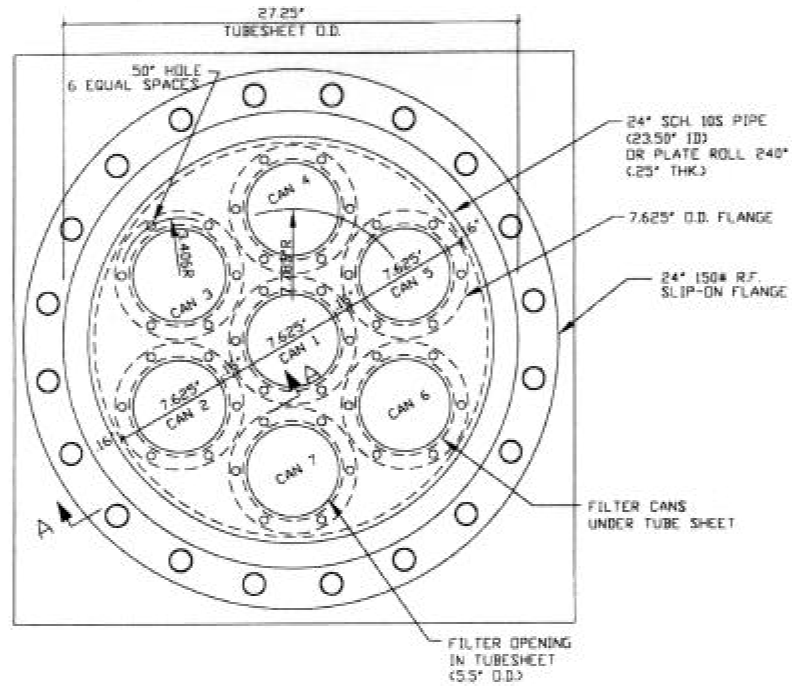

Figure 12: Filter bundle depicting element arrangement

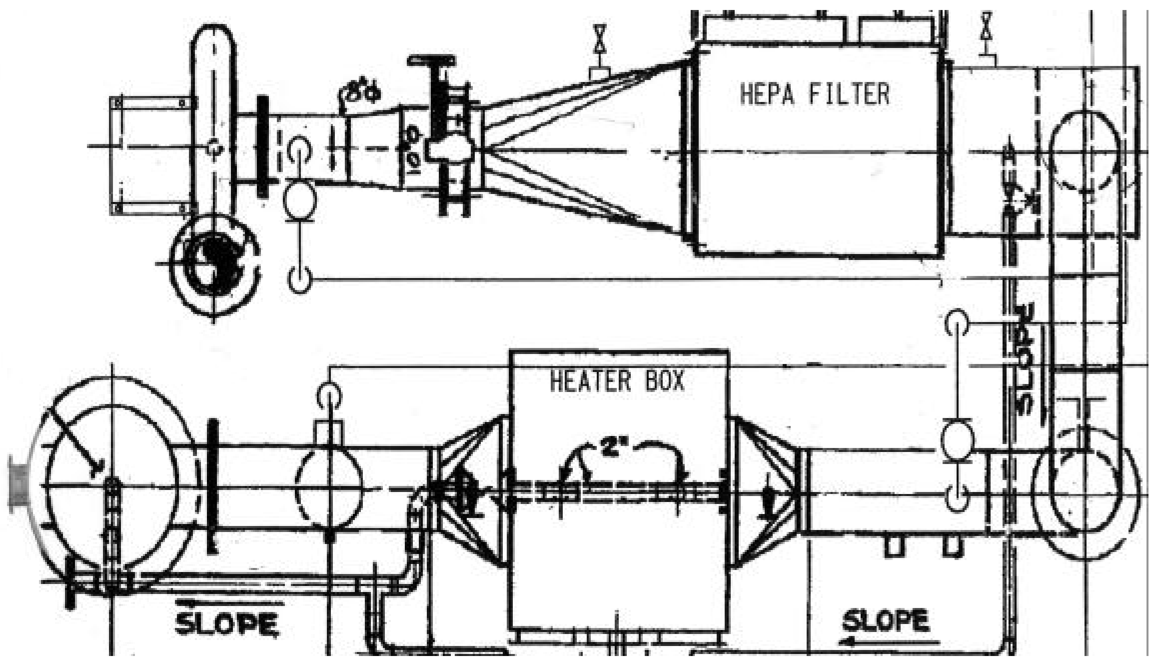

Figure 13: System layout, top view

The new HEPA filter assembly can be modified into an existing system with very little system design changes. For the full scale testing, The demister, reheater, HEPA filter assembly and blowers will be skid mounted. The system is design for 800 cfm. This system was conceived to allow for easy transport during the cold and hot testing.

VIII. CONCLUSIONS

Alternatives media such as CeraMem ceramic membrane holds great promise for use as an in situ cleanable/regenerative HEPA filter. The proof-of-principal testing has shown that the ceramic media could be suitable as an alternative HEPA filter media. During simulated testing the filter regenerated well in situ with a potential for 15 years plus life under actual field conditions of the HLW tanks. In addition to eliminating the costs associated with disposing of and replacing disposable filters, the strong filter media also reduce the potential of a catastrophic HEPA filter failure due to rupture of the filter media.

The CeraMem ceramic membrane filter was plugged and cleaned insitu many times. Each time the differential pressure and flow recovered to a clean filter status. The ceramic filter media has passed both the standard in-place leak test of and the efficiency test for HEPA filters at the DOE Oak Ridge Filter Test Facility with an efficiency of 99.97% or better.

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In Situ Cleanable HEPA Filter for Clean-Up of Vent Gas from HLW Waste Tanks

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ABSTRACT

DOE has about 300 high-level waste liquid storage tanks at its various sites. These are maintained at a slight negative pressure to prevent leakage of radioactive contamination and avoid buildup of hydrogen in the headspace. The vent gas from these tanks is filtered through disposable glass-fiber HEPA filters. Replacement of these filters generates both a waste disposal problem and a problem associated with operator exposure during filter replacement.

CeraMem Corporation has developed a ceramic monolith filter with a composite structure as a long-lived replacement for disposal HEPA filters. The filter employs a fine-pored ceramic membrane barrier, which has HEPA filtration properties. Prototype full-size filters (18.5 ft^2 each) have been developed and supplied to ORNL's HEPA Filter Test Facility for qualification testing and to the Savannah River Technology Center (SRTC) for simulated vent gas tests. Results presented in this paper show >99.97% retention in the standard 0.3 μm DOP aerosol challenge test (at ORNL) and the ability to be cleaned effectively by backflushing after plugging (at SRTC).

Continuing work in this program involves the possible supply of a full size vent gas filtration system for evaluation on a high-level waste tank vent line at the Savannah River Site (SRS). A decision on this demonstration installation will be made by DOE in FY 2002.

LIST OF ACRONYMS

ATI	Air Techniques International
DOE	U.S. Department of Energy
DOP	di-octyl phthalate
FTF	Filter Test Facility
HEPA	high efficiency particulate air
HFTA	HEPA filter test apparatus
HLW	High-level Waste
INEEL	Idaho National Engineering and Environmental Laboratory
SC	South Carolina
SRS	Savannah River Site
SRTC	Savannah River Technology Center

I. BACKGROUND

Conventional disposable glass-fiber HEPA filter cartridges are used throughout the U.S. Department of Energy (DOE) complex in various radioactive process systems. These filters require routine removal, replacement, and disposal. This process is not only expensive, but subjects site personnel to radiation exposure and adds to an ever-growing waste disposal problem. The conventional HEPA filters also have safety concerns regarding the strength of filter media, water damage, and operation in environments with elevated temperatures. The Defense Nuclear Facility Safety Board issued a report entitled "HEPA Filters used in the Department of Energy Hazardous Facilities", DNFSB/TECH-23, in which these and other concerns pertaining to conventional HEPA filters were addressed. [(1)]

The SRS High Level Waste (HLW) tanks are designed to hold approximately 1.0 million gallons of radioactive liquid waste. Figure 1 depicts a typical HLW tank ventilation flow diagram. The tanks are located outdoors and buried in the ground except for the tank top. They are equipped with a ventilation system that provides approximately 500 cfm of filtered air within the headspace. The airflow maintains the tank contents at negative pressure (-1.0" water column). The air flows through a demister and condenser where water is removed from the air stream. The flow then enters a reheater where the air is heated above the dew point before being filtered at the outlet HEPA Filter and released to the atmosphere. Tanks with secondary containment also have a separate ventilation system for the annulus space. The negative pressure maintained on the tank contents prevents the release of radioactive material to the environment. However, it also allows for possible atmospheric dust to be pulled into the tank during normal operation.

The glass-fiber HEPA filter must exhibit a particle removal efficiency of 99.97+% when challenged by thermally generated di-octyl phthalate (DOP) aerosol with a diameter of approximately 0.3 microns. The pleated glass-fiber HEPA filter media has approximately 240 ft^2 of surface area and is typically contained in a 2 ft x 2 ft x 1 ft housing and exhibits a 1 inch of water column (w.c.) differential pressure (ΔP) across the filter media when clean. A HEPA filter remains in service until the filter media reaches a predetermined maximum pressure drop (approximately 5 inches w.c.) or a high source term due to radioactive buildup, and then the filter is replaced.

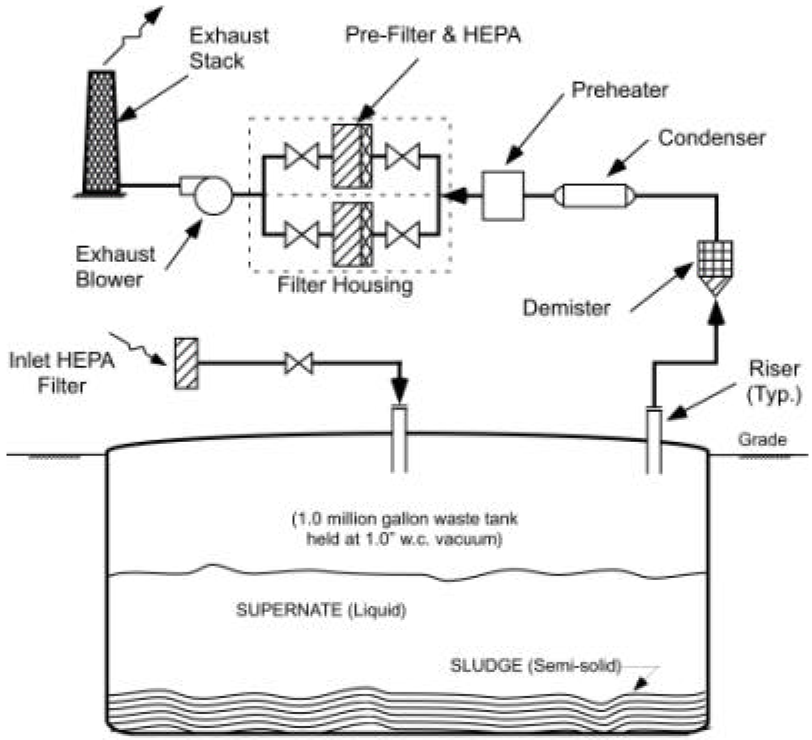


Figure 1. Typical HLW Ventilation System Flow Diagram

SRS requires that all process HEPA filters pass an in-place leak test both before being placed into service, and periodically thereafter. DOP test connectors are designed into each HEPA installation to facilitate the routine in-place DOP test per national and site standards. Both the material challenge and the filter efficiency tests conducted on the filters in this study were designed to simulate conditions found in HLW tanks at SRS.

Previous research has been conducted at other DOE sites such as Lawrence Livermore National Laboratory and Oak Ridge National Laboratory to develop an *in situ* cleanable HEPA filter with high media strength. W. Bergman, et al. conducted research on various filter media, such as steel fibers, ceramic, and sintered metal, using reverse air pulse as the *in situ* cleaning method.(2) The results of these investigations indicate that commercially available filter media could be applied to the development of an *in situ* cleanable (using reverse air pulse) HEPA filter system that would meet the performance criteria established for a conventional HEPA filter system.

In FY98 SRS started working on the theory of using high-pressure drop filter media in an *in situ* regenerative filtration system. The *in situ* cleaning of the filter media used an aqueous solution to regenerate the media to a new, clean filter status. Testing conducted in FY98 and FY99 indicated that an *in situ* cleanable filtration system is feasible for use on the HLW tanks.

A cost analysis conducted on cleanable HEPA filters showed that the *in situ* cleanable filters have the potential of being cost effective when compared to the conventional glass-fiber HEPA filters. The study estimated that the DOE complex uses an average of 11,000 filters per year at an estimated cost of $55 million. Using *in situ* cleanable HEPA filters could save the complex $42 million a year in operating cost. The study did not include costs associated with glass-fiber filter breakthrough or rupture, but these additional costs increase the cost benefit of the *in situ* cleanable filters for the complex.[2]

The DOE Tanks Focus Area and The National Energy Technology Laboratory issued a "Call for Proposals" to identify vendors conducting research in the area of *in situ* cleanable/regenerative filters or vendors interested in pursuing such technology.[3] A technical evaluation was conducted on the proposals. Based on the proposals reviewed, CeraMem Corporation, located in Waltham, Massachusetts was selected to support this research program. This project is now in its third year. In the initial phase of the program, CeraMem developed small test units (lab scale filters) that demonstrated HEPA filter performance and ability to be regenerated by backflushing. The results of this phase were reported at last year's conference.[8] This paper presents results from this past year's activities, which entailed the development and testing of full-size, prototype filters.

II. TECHNOLOGY

Figure 2 depicts the design of the CeraMem filter media and the air flow passage through the "dead-end" monolith filter. The passageway ends are plugged with ceramic cement in an "alternate, checkerboard pattern". As shown, the dirty air with particulate matter enters the filter media and the gas flow is constrained to pass through the monolith walls separating inlet and outlet passageways. The membrane coating covers the passageway walls, and the entrained particles are filtered from the air onto the surface of the microporous membrane. The clean air flows down the outlet passageways and is exhausted from the filter. Figure 3 shows a full-size prototype filter.

Below are the characteristics of the "full-size" ceramic monolith filters tested in this phase of the program:

- Monolith Membrane Support: Silicon carbide
- Membrane Coating: Glass-frit-bonded zirconium silicate
- Overall Element Dimensions: 5.66" diameter x 12" long (144 mm x 305 mm)
- Monolith Cell Size: 0.079" (2 mm)
- Monolith Cell Wall Thickness: 0.0315" (0.8 mm)
- Filtration Surface Area: 18.5 ft^2 (1.72 m^2)

Figure 4 shows photomicrographs of the silicon carbide (SiC) monolith pore structure (left) with a membrane surface coating (right), with a pore size between 0.2 – 0.5 µm. This ceramic membrane provides a relatively low-pressure drop while obtaining HEPA filter retention efficiency. Figure 5 is a photomicrograph of a cross-section view of the SiC monolith with the membrane coating.

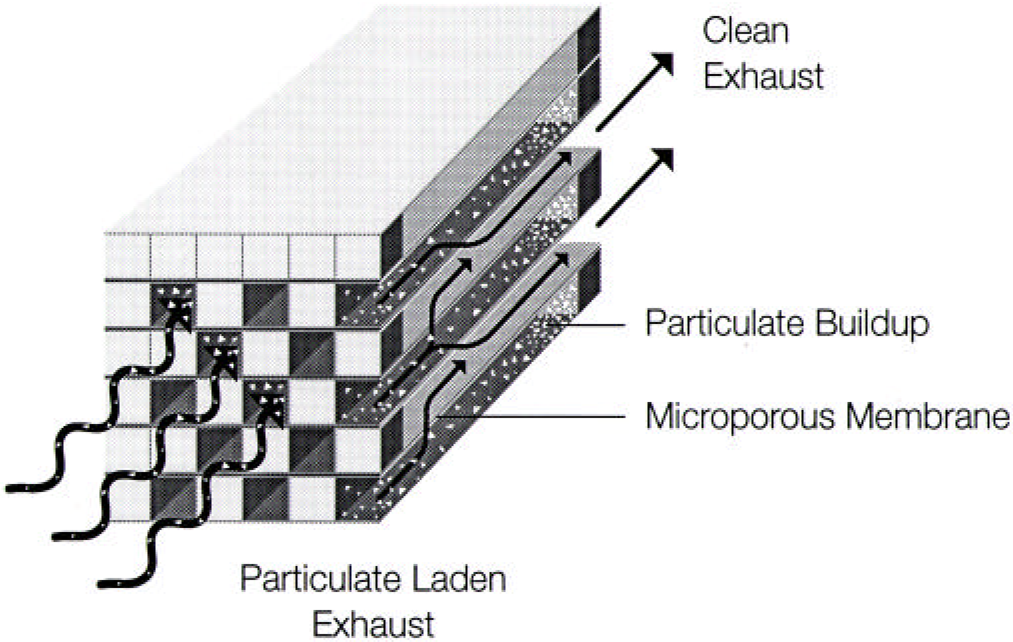


Figure 2. Airflow Pattern Through Ceramic Monolith Filter

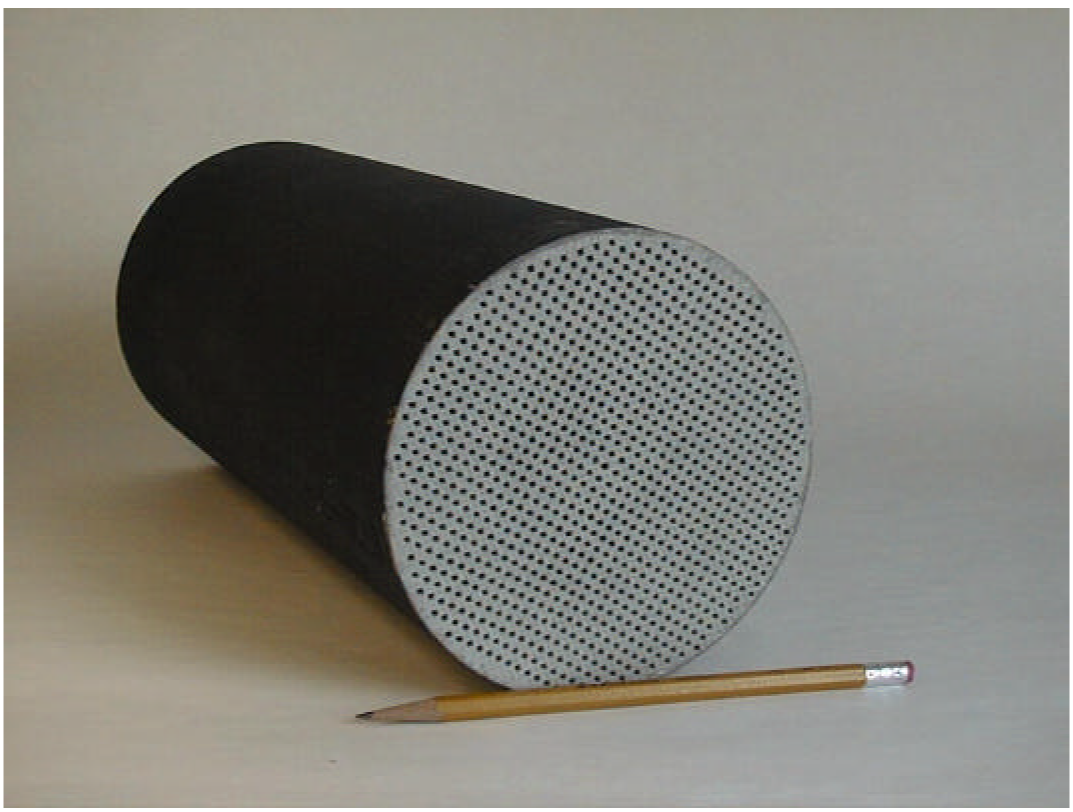


Figure 3. Photograph of Full-Size Monolith Filter (5.66" diameter x 12" length)

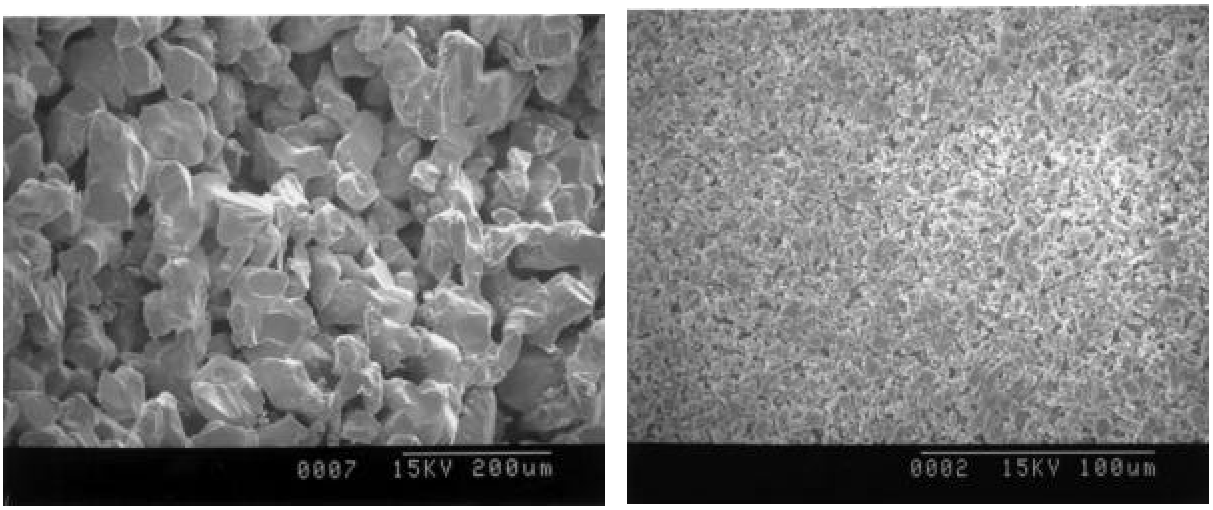


Figure 4. Surface View of Monolith Wall Pore Structure (left), and Overlying Membrane Surface Pore Structure (right)

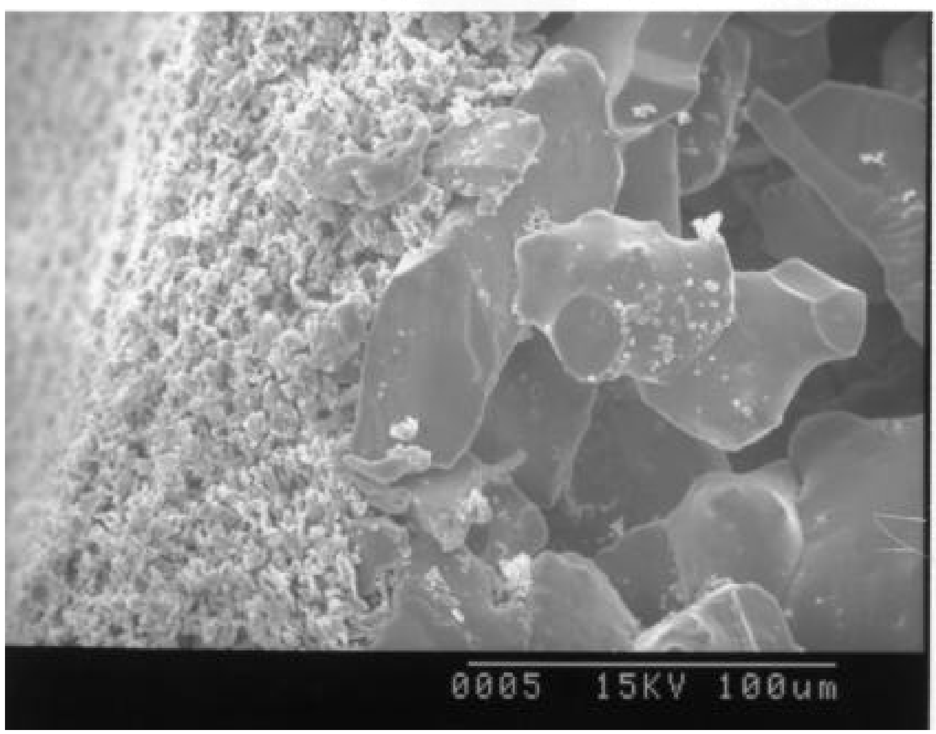


Figure 5. Cross-Sectional View of Membrane/Monolith Wall Structure

III. FULL SIZE FILTER HEPA CHALLENGE TESTS AT ORNL

Two series of filters were shipped to ATI to conduct filter efficiency tests at the Oak Ridge FTF. ATI modified their test equipment to conduct these efficiency tests in early 2001. Filters were supplied over the spring and summer of 2001 for DOP challenge tests. The second series of thirteen filters, with the preferred membrane coating, were tested under different gas flow conditions and the results are given in Tables I and II.

Table I. DOP Retention Data for Full Size Filters

Filter Serial No.	Air Flow, cfm	% Retention (Pass)	% Retention (Fail)
H-28	25	99.999	
	125	99.982	
H-29	25		98.5
	125		95.9
H-30	25		99.67
	125		93.2
H-31	25	99.999	
	125	99.986	
H-33	25		99.28
	125		96.4
H-39	25		97.6
	125		94.2
H-40	25		99.44
	125		96.8
H-41	25	99.999	
	125	99.993	
H-42	25	99.999	
	125	99.984	
H-43	25	99.999	
	125	99.989	
H-44	25	99.999	
	125	99.986	
H-46	25		99.05
	125		97.9
H-47	25	99.999	
	125	99.992	

Table II. Filter Pressure Drop at Design Flow (125 cfm)

Filter Serial No.	Pressure Drop, inches water
H-28	26.1
H-29	26.0
H-30	21.2
H-31	22.5
H-33	27.2
H-39	26.8
H-40	26.5
H-41	25.2
H-42	25.6
H-43	25.1
H-44	23.2
H-46	26.8
H-47	22.6

As can be observed in the data of Table I, seven of the thirteen filters tested passed the HEPA challenge test readily. Six failed, with quite consistent retention levels. As of the date of preparation of this paper, the filters have not yet been returned to CeraMem for examination of what appears to be a recurring defect. In any case, at this stage of making the prototype filters, the yield in excess of 50% is considered to be acceptably good.

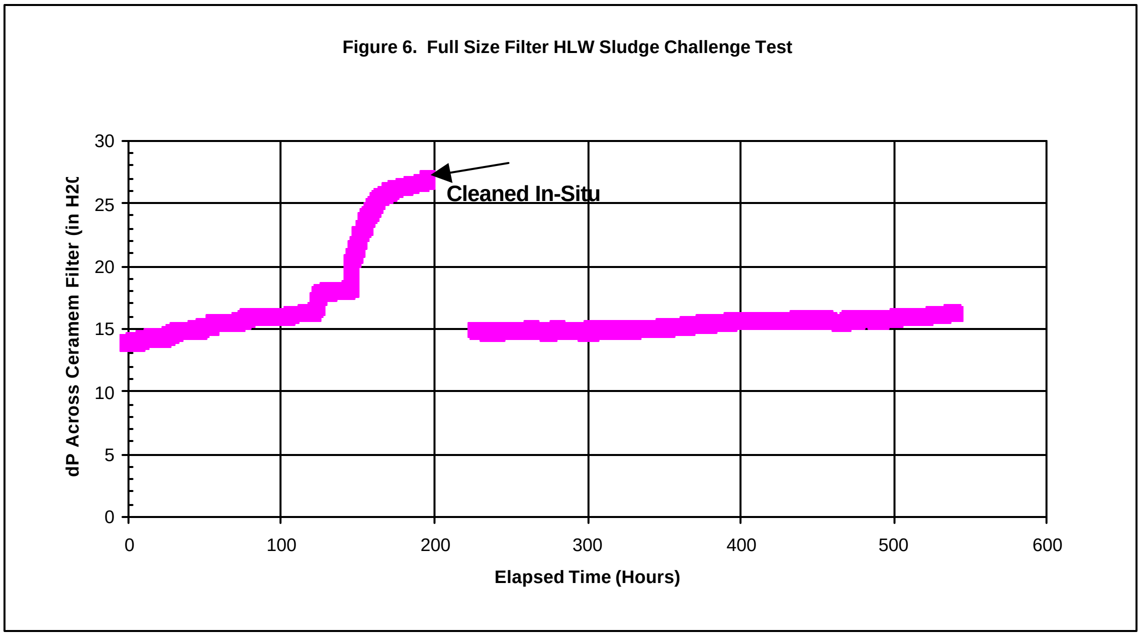
Furthermore, the pressure drop data in Table II are acceptable for a full flow system. It may be noted, however, that these pressure drop levels are substantially higher than is the pressure drop of standard, disposable, glass-fiber HEPA filter elements.

IV. PROCESS TESTS AT SRTC

Several filters have been supplied to SRTC. Initial tests with simulated waste sludge follow the test procedures described in the paper presented at last year's conference with lab-scale filter elements and are not described again here.[8] In initial tests with one filter, using moderate particulate loadings, the filter has been repeatedly plugged and backwashed successfully to recover the initial pressure drop performance.

A CeraMem filter that was subjected to such preliminary simulant testing at SRTC was re-tested by ATI at the FTF for particle retention. The results are positive in that there was little or no change in the retention capability after many *in situ* cleaning cycles. This indicates that the filter media is not deteriorating when undergoing repeated cleaning.

Data showing one filtration cycle (with accelerated plugging during the initial filtration cycle), followed by cleaning and a subsequent filtration cycle are shown in Figure 6.



V. RELATED APPLICATION AT INEEL

A set of similar, but smaller diameter, filters has been supplied to INEEL for tests. Three filters have been installed in a filter vessel and are being tested with a simulated non-radioactive calcine material to obtain results for cleaning the filters *in situ* using a reverse air pulse cleaning method. The material is very dry throughout the transfer (as well as the air used to backpulse). The filters regenerated/recovered very well *in situ* from the air backpulse method. After twenty (20) plugging/cleaning cycles, the filters regenerated to a clean filter status. The clean filter pressure drop of 10“ w.c. increased to approximately 18" w.c. before online backpulse regeneration.

VI. ALTERNATIVE FILTRATION FULL SCALE SYSTEM DEPLOYMENT

A full-scale Alternative Filtration System is planned for construction with the hot demonstration of the system being conducted at SRS. Before the hot deployment, the full-scale system will undergo cold testing at SRTC.

Figure 7 shows the filter housing containing the seven ceramic filters required to handle the total vent gas flow, of up to 800+ acfm. The filter vessel will be incorporated into the HFTA skid design previously developed by SRS, replacing the standard HEPA filter. The skid blower size will be increased to handle the increased pressure drop of the ceramic filters. The dirty air will be drawn into the bottom end of the housing and clean air will exit through the top of housing. After the filter becomes plugged with particulate or when the radioactivity from the accumulated particulate approaches area limits, the *in situ* cleaning system will be activated. The elements are cleaned *in situ* via back flushing an aqueous cleaning solution through the media, with the backflush liquid returned to the HLW tank.

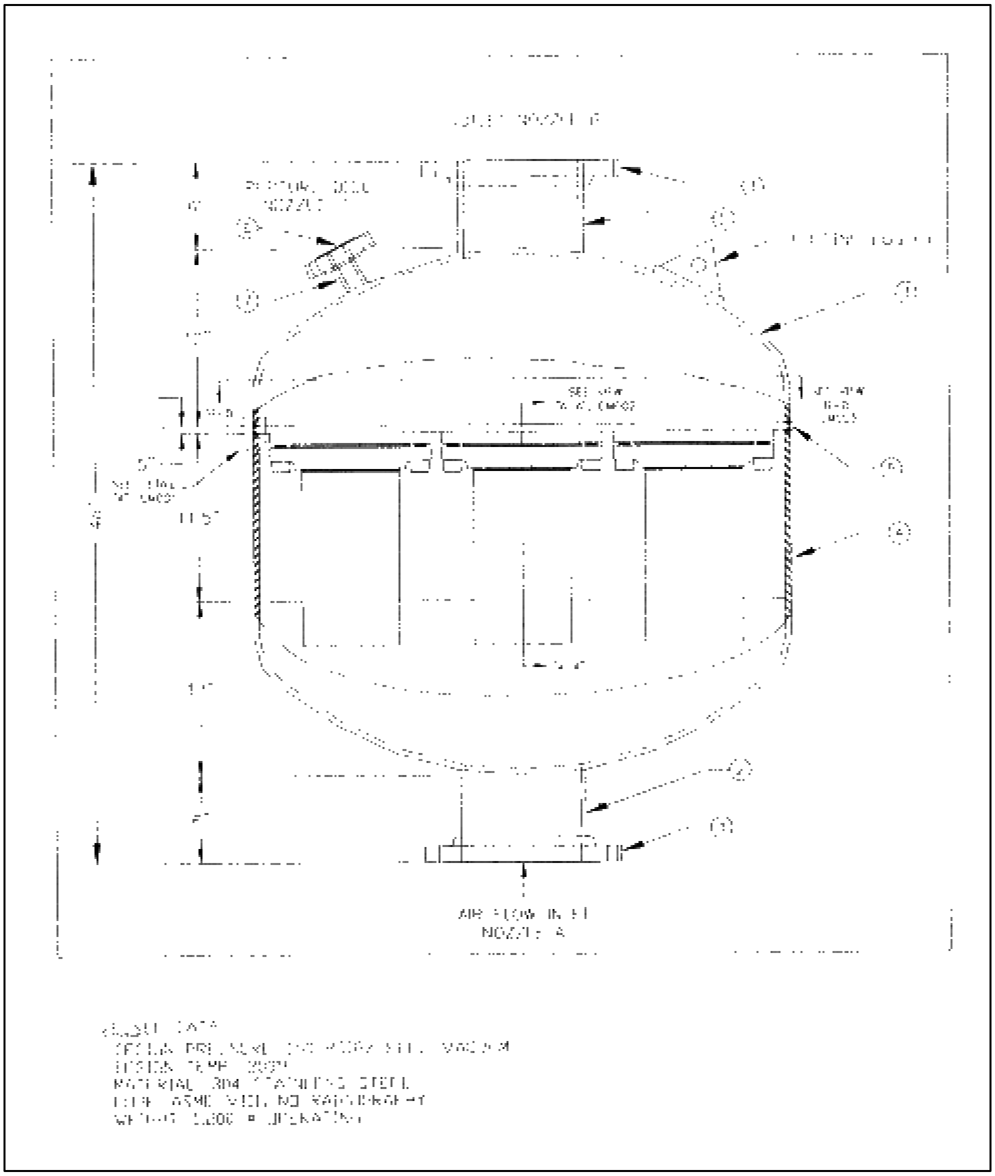


Figure 7. Filter Housing Containing Seven Filter Elements (800+ acfm)

VIII. CONCLUSIONS

Alternative media such as CeraMem ceramic membrane filters holds great promise for use as an *in situ* cleanable/regenerative HEPA filter. The proof-of-principal testing has shown that the ceramic media could be suitable as an alternative HEPA filter media. During simulated testing the filter regenerated well *in situ* with a potential for 15 years life under actual field conditions of the HLW tanks. In addition to eliminating the costs associated with disposing of and replacing disposable filters, the strong filter media also reduce the potential of a catastrophic HEPA filter failure due to rupture of the filter media.

The CeraMem ceramic membrane filter technology has been scaled up to produce full size filters. These have been shown to pass the HEPA retention test requirement in independent tests at ORNL's FTF. Process tests at SRTC show that the filter can be plugged with simulated particulate matter and regenerated by backflush cleaning. Initial test results show minimal (if any) loss of retention with repeated plugging and cleaning.

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10. Technical Task Plan, TFA Tank Waste Retrieval and Closure, "Alternatives Filtration Technologies" TTP #: SR1-8-WT-21 9/23/99
11. American Society Of Mechanical Engineers "Code On Nuclear Air And Gas Treatment" ASME AG-1 1997
12. Adamson, D.J. "Experimental Investigation Of Alternatives *In Situ* Cleanable HEPA Filters" WSRC-TR-99-000486, January, 2000
13. Laboratory Notebook, "Sintered Metal Filter Research, WSRC-NB-97-00555
14. Japuntich D. "DOP Testing: History and Perspective" Copyright 1998 3M, August 1, 1998
15. Goldsmith, R., Bishop, B, Nielsen, N, and Adamson, D., "*In Situ* Cleanable HEPA Filter for HLW Waste Tanks", Industry Partnerships for Environmental Science and Technology Conference, Morgantown, WV, October 17, 2000

VI. APPENDIX B: MONTHLY REPORTS

(Progress Reports I through IV covered Phase I.)

Progress Report IVA

William F. Haslebacher
Office of Project Management
United States Department of Energy
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Dear Mr. Haslebacher;

This letter summarizes the progress during October, 1999, in the execution of Contract No. DE-AC26-99FT40569.

Phase IIA of the project was initiated, with the following activities accomplished.

Task B.2.1.1 Full-scale RHFS Design
A purchase order for the engineering design was let to Fisher Klosterman, Inc. of Louisville, KY. A preliminary process design was prepared (by CeraMem) for presentation at a project kickoff meeting to be held in early November at SRTC.

Task B.2.1.1 Full-scale HEPA Filter Element Delivery
Work was initiated on the developed of alternative membrane chemistries for lab elements to obtain membrane coatings more chemically durable and more adherent to the silicon carbide monolith supports. It is anticipated that several lab elements will be delivered to SRTC in December for DOP tests, prior to selection of membrane chemistry for the prototype filters to be delivered at the end of February, 2000.

A purchase order was let to LiqTech A/S in Denmark to supply ten silicon carbide monolith supports in size 5.66" diameter and 12" length. Delivery by the end of this year is projected.

Dr. William Cooper was retained as a consultant to assist in project execution. Dr. Cooper worked with the undersigned for about 15 years in the membrane field and is available up to two days per week. He will be involved in both process and filter element housing design and liason with Fisher Klosterman.

A project schedule, as presently foreseen, is attached. Please feel free to get in touch with me regarding any questions about this report.

Progress Report V

Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Haslebacher:

This letter summarizes the progress during November 1999 in the execution of Contract No. DE-AC26-99FT40569.

A project kickoff meeting was held at SRS on November 11, 1999. Several changes in the program direction became apparent as a result of the discussions at this meeting. These are summarized below.

Task B.2.1.1 – Full–scale RHFS Design

On the basis of discussions at the kickoff meeting, the demonstration system design specifications were changed to require that only water, hot water, or steam be used to clean the filter to avoid any possible contact of the carbon steel HLW tanks with a corrosive fluid. Further, the system is to have two single 10” diameter by 14” long ceramic filters (one redundant) rather than two banks of four (4) parallel 5.66” diameter filters in order to afford a simpler, more reliable system.

In the kickoff meeting, it became apparent that incorporating the ceramic filters into the current SRS HEPA filter skid design was highly desirable. Because the ceramic filters can withstand liquid contact and remove entrained liquid, the reheater used to protect HEPA filters in the current skid design can be replaced by the CeraMem filters. This will facilitate the necessary approvals for a demonstration unit on an actual waste liquid tank, as the vent gas will still be passed through a final DOE-approved HEPA filter. The CeraMem filters have the additional advantage that their compactness permits their facile incorporation into the existing SRS skid design.

- ➔ CeraMem is awaiting the SRS design package for the existing HEPA filter skid so that it can make the necessary process design modifications noted above and forward the design to Fisher Klostermann (FKI). FKI will make the necessary detailed design changes to (a) replace the reheater with the CeraMem filters, and (b) increase the skid blower to accommodate the pressure drops of the ceramic filters and HEPA filters in series flow.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Lab-scale Filter Element Delivery/Testing

We have been developing alternative membrane chemistries and plan to ship several lab filters with these chemistries to SRTC for DOP testing in December. The scheduled ship date is December 10, 1999. It is our understanding that SRTC will have its contractor conduct tests shortly thereafter. Once these results are in, the membrane to be used in “full size” prototype filters will be chosen.

<u>Full-Scale Filter Production</u>

The monoliths required for testing at SRS have been extruded, will be fired in December, and should be received by CeraMem before the end of the year. Twelve (12) monoliths will be in the shipment, and this should allow an ample supply to provide more than one filter to SRTC, if desirable. It is to be noted that these filters will be 5.66” diameter x 12” long. As such, they will be reduced-size prototypes of the larger filters (10” diameter x 14” length) now planned for the demonstration system of Phase IIB.

The housing design for the 5.66” diameter prototype filters has begun, and the prototype housing delivery for filter QC testing at CeraMem in February and subsequent shipment to SRTC at the end of February is on schedule.

- Other than discussions about the washable HEPA filter project, some “off-line” discussions were held about the need for a microfiltration system for dewatering sludge in the HLW tanks prior to vitrification. We would greatly appreciate the names of contacts at DOE with whom to discuss this need.

A project schedule, as presently foreseen, is attached. Please feel free to get in touch with me regarding any questions about this report.

Progress Report VI

Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
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Dear Mr. Haslebacher:

This letter summarizes the progress during December, 1999 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

- ➔ CeraMem is awaiting the SRS design package for the existing HEPA filter skid so that it can make the necessary process design modifications noted above and forward the design to Fisher Klostermann (FKI). FKI will make the necessary detailed design changes to (a) replace the reheater with the CeraMem filters, and (b) increase the skid blower to accommodate the pressure drops of the ceramic filters and HEPA filters in series flow.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Lab-scale Filter Element Delivery/Testing

We have encountered some difficulty in preparing new membranes with exactly the properties we desire for the lab filter elements to be sent to SRTC for DOP testing. We now plan to ship in the second half of January, 2000. It is our understanding that SRTC will have its contractor conduct tests shortly thereafter. Once these results are in, the membrane to be used in "full size" prototype filters will be chosen.

Full-Scale Filter Production

The monoliths required for testing at SRS have been extruded, were fired in December at a Norton plant in Germany, and were to have been received by CeraMem before the end of the year.

➔ As part of closing of this Norton plant and moving to another facility, the monoliths have been lost. We are trying to locate them, and as a fall-back position, our Danish subcontractor (LiqTech) is extruding another set of monoliths for firing at Norton's new facility. If the first set is not found, the second set will not be received by us until mid-February, at the earliest. This would delay shipment of prototype filters to the second half of March, at the earliest.

Equipment needed for processing and testing of membrane-coated monoliths has been ordered. This consists primarily of masking and cement injection fixtures and equipment for QC filtration tests with aqueous suspensions of submicron particles.

The housing design for the 5.66" diameter prototype filters is complete, and two prototype housings have been ordered. These will be received in January. It is our intent to provide (ultimately) two filter assemblies to SRTC for tests. Current projected schedule is now at the end of March due to monolith delay.

A project schedule, as presently foreseen, is attached. Please feel free to get in touch with me regarding any questions about this report.

Progress Report VII

Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Haslebacher:

This letter summarizes the progress during January, 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

➔ CeraMem is awaiting the SRS design package for the existing HEPA filter skid so that it can make the design modifications to incorporate the washable HEPA filter element.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Lab-scale Filter Element Delivery/Testing

Eight lab scale filter elements were sent to SRTC at the end of January and were tested in early February. The results will be used (a) to calibrate CeraMem's internal QC test and (b) to select the membrane coating for the prototype filters to be delivered in Phase IIA.

Full-Scale Filter Production

The monoliths for the prototype filters (5.66" diameter x 12" length) were received at CeraMem at the end of January.

Equipment needed for processing and testing of membrane-coated monoliths has been ordered. This consists primarily of masking and cement injection fixtures and equipment for QC filtration tests with aqueous suspensions of submicron particles.

The housing design for the 5.66" diameter prototype filters is complete, and two prototype housings have been ordered. These will be modified per discussions with SRTC staff to incorporate desired connections for gas and liquids.

Current projected delivery is now at the beginning of March.

A project schedule, as presently foreseen, is attached. Please feel free to get in touch with me regarding any questions about this report.

Project Report VIII

Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Haslebacher:

This letter summarizes the progress during February, 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

CeraMem has received the SRS design package for the existing SRS HEPA filter skid (mid March). We will review it and submit to FKI for Phase IIB system design and costing. We will, per oral comment from you, size the system at 800 acfm. We should have a date for expected completion of system design and definition of what will be in the design package from FKI in early April.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Full-Scale Filter Production

The monoliths for the prototype filters (5.66" diameter x 12" length) were received at CeraMem at the end of January. Four were deemed acceptable by CeraMem for coating with membranes. Membrane coating has commenced with the first two coated. One appears close to acceptable for DOP testing, based on a correlation obtained with earlier tests with by SRTC with lab scale modules.

All components of the housing for the 5.66" diameter prototype filter will be received by CeraMem by the end of March, 2000. Tests with the prototype filter(s) to check the seals will be conducted before the end of March. If all is satisfactory, the prototype stainless steel housing and one filter will be sent to SRTC in early April. Depending on final particle retention QC tests on the filter selected, it will be provided to SRTC either as a filter for "debugging" the test system (if particle retention is unsatisfactory), or for DOP testing and process testing if our final QC results are good.

Samples of filter coupons will be sent to ATI by the end of March for DOP testing, per request of Duane Adamson.

A project schedule, as presently foreseen, is attached. Please feel free to get in touch with me regarding any questions about this report.

Progress Report IX

Mr. William Haslebacher
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Haslebacher:

This letter summarizes the progress during March, 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full–scale RHFS Design

CeraMem has received the SRS design package for the existing SRS HEPA filter skid (mid March). We have reviewed it with FKI (our proposed subcontractor for system design and fabrication) and mutually concluded that they are not a suitable subcontractor for either the engineering or fabrication of the system in accordance with the SRS Specification requirements. [Note: The Phase IIB system, as originally proposed, was to be to industrial standards, not to specifications as demanding as the SRS Specification.]

We have retained a consultant (Mr. Phil Paquette) who worked previously at CeraMem and has many years experience in project management for systems fabricated and supplied to the nuclear utility industry. These systems routinely had N-stamp shop requirements and had design and QA/QC requirements similar to SRS's. Mr. Paquette will manage the engineering design and interface with system suppliers qualified to fabricate systems to specifications similar to SRS's.

Some comments on our plans for proceeding with the demonstration system design:

1. Since the system design is now based on the SRS design package, CeraMem will prepare the system design internally as a modification to the SRS design. The modifications will be in the form of revisions to SRS's P&ID and General Arrangement Drawing. These will be provided to systems fabricators along with added component specifications for the washable HEPA filter and added system control and safety instrumentation.
2. The modified SRS design package will be submitted to the three fabricators identified by SRS as recipients of the original SRS RFQ. Mr. Paquette will contact one to three additional fabricators of equipment to similar standards. These suppliers will be requested to provide *estimates* (+/-10%) to fabricate a system to the modified SRS Specification, *with exceptions allowed.*
3. The washable HEPA filter design, recently discussed with Duane Adamson, will be capable of handling 800+ acfm and with a significant increase in filter area to minimize pressure drop. The current design approach will contain seven (7) cylindrical filters, each 5.66" diameter by 12" length. These will be housed in a single vessel of diameter <24". The total filter area will be about 130 ft^2. At 800 acfm, the filter face velocity will be about 6.2 ft/min.
4. We intend to complete the filter element/vessel design, modified SRS P&ID, and modified SRS General Arrangement Drawing and submit these to DOE by mid-May, in anticipation of a design review in mid June. This is contingent on receipt of electronic versions of the SRS drawings at CeraMem by early May.
5.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

<u>Supply of Filter Coupons to ATI</u>

Duane Adamson of SRTC has requested that filter element samples be supplied to ATI (Baltimore) for DOP testing. It appears a difference may exist between SRTC's HEPA filter QC tests and ATI's. Since the latter's equipment is used at ORNL for HEPA filter qualification, it is important that this possible discrepancy be resolved. One or more of the 1" elements previously supplied to SRTC and which passed SRTC's test will be tested at ATI. Mr. Bruce Bishop of CeraMem will join Duane Adamson on April 26 at ATI to discuss these tests.

As this trip was not included in the project budget, CeraMem will request, separately, cost coverage for the trip.

<u>Full-Scale Filter Production</u>

The monoliths for the prototype filters (5.66" diameter x 12" length) were received at CeraMem at the end of January. Four were thought to be suitable for coating with membranes. However, to date we have been unable to make filter elements at the 5.66" size that have the same performance as the 1" filter elements provided earlier. This is due to a combination of factors, including:

1. The silicon carbide monoliths received by CeraMem were fired in a different furnace at Norton's new facility in Germany, and the firing conditions were more intense than those in the furnace previously used by Norton for the 1" elements. This situation arose because Norton was moving from a plant being closed to the new location and the furnace previously used was unavailable in the time frame needed for firing monoliths for this program. The monoliths we received thus have a "coarsened" pore structure and the resulting larger pore size of the monoliths has made membrane coating difficult.

2. The 5.66" monoliths were fabricated from cemented quadrants, and the cementing process created internal defects that have required development of a new QC procedure for defect location and subsequent plugging of monolith passageways adjacent to defects. This process is not yet perfected.

3. The end cement change from epoxy (used in Phase I) to an inorganic cement has led to defects at the ends of the cemented passageways. We are working to resolve this problem and expect to have a reformulated and satisfactory inorganic cement with end seal glaze before the end of May.

In summary, we are currently limited in our ability to make 5.66" filters which can be expected to pass a HEPA filter test by the quality of monolith substrates we have on hand and until we demonstrate a suitable inorganic cement.

We believe the most sensible approach to continuing development of the prototype 5.66" filters would consist of the following:

1. Our supplier of the silicon carbide monoliths is installing a new extruder capable of extrusion of 5.66" *unitary* (i.e., not segmented) monoliths. Initial extrusions will be made during May and these should be available in June. This will coincide with Norton's bringing on-line the furnace originally used for firing of the 1" silicon carbide monoliths. Given these events, we could have substantially improved monolith substrates at CeraMem for membrane coating during July.

2. We plan to have the cement problem resolved by June.

3. On this basis, we believe it is best to defer further production of 5.66" filter elements until July. In the interim, we can supply 5.66" filter elements to SRTC for process tests with simulated waste, and intend to supply one filter in housing at the beginning of May for system shakedown tests. We do not believe these filters will pass the ATI HEPA filter test, however.

We recognize this is a significant slip in schedule, and are discussing the impact with Duane Adamson at SRTC. A project schedule without revision is attached. Once discussions are held with SRTC and DOE personnel about schedule, this will be revised accordingly.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report X

Mr. William Haslebacher
Office of Project Management
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P.O. Box 880
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Dear Mr. Haslebacher:

This letter summarizes the progress during April, 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

We will complete the filter element/vessel design, modified SRS P&ID, and modified SRS General Arrangement Drawing and submit these to DOE before the end of May, in anticipation of the design review in mid June.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Supply of Filter Coupons to ATI

Duane Adamson of SRTC and Bruce Bishop of CeraMem were at ATI (Baltimore) on April 26th for DOP testing of two lab filter elements previously tested at SRTC. One element passed and the second came close to passing. This demonstrated that a ceramic membrane-coated filter can be produced which can be validated as a HEPA filter.

Full-Scale Filter Production

The monoliths for the prototype filters (5.66" diameter x 12" length) were received at CeraMem at the end of January. Four were thought to be suitable for coating with membranes. However, to date we have been unable to make filter elements at the 5.66" size that have the same performance as the 1" filter elements provided earlier, as discussed in last month's report.

Our ability to make these larger filters, of the size to be used in the final HEPA filter assembly, now appears to require using 5.66"-diameter *unitary* (i.e., not segmented) monoliths. Based on a meeting in Waltham in May with Per Stobbe of LiqTech (Denmark), the supplier of the monoliths, the earliest we will receive a new set of pieces is at the beginning of August. Thus, the earliest we could reasonably supply full sizes filters for HEPA certification tests is at the end of August.

As this presents a serious time limitation for releasing Phase IIB funds based on full size elements passing a HEPA test, we will submit separately our suggestions on how best to proceed with the project.

Regardless, we did supply a segmented 5.66" filter element in a single element housing to SRTC for evaluation, even though we do not think this unit will pass a HEPA test.

A project schedule is appended, but requires revision pending clarification of program tasks. At the planned design review at SRTC in June, Bruce Bishop will be prepared to discuss a realistic schedule for us to produce prototype filter elements based on unitary 5.66" x 12" long silicon carbide monoliths as well as a schedule for fabrication of a filter vessel with seven filters, an assembly sized to filter 800 ACFM vent gas flow.

Also, independently of this report, we will be requesting a no-cost extension through the end of September, 2000.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XI

Mr. William Haslebacher
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Morgantown, WV 26507-0880

Dear Mr. Haslebacher:

This letter summarizes the progress during May, 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

The Full Scale RHFS preliminary design was completed in May and sent to DOE in three parts as a Draft Design Report:

Part I: Filter element/filter assembly design (design of ceramic filter subsystem)

Part II: Modified SRS P&ID (shows incorporation of filter assembly into current SRS HEPA filter skid P&ID)

Part III: Modified SRS General Arrangement Drawing (shows incorporation of filter assembly into current SDRS HEPA filter skid layout drawing)

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Our ability to make these larger filters, of the size to be used in the final HEPA filter assembly, will require using 5.66”-diameter *unitary* (i.e., not segmented) monoliths. Based on a meeting in Waltham in May with Per Stobbe of LiqTech (Denmark), the supplier of the monoliths, the earliest we will receive a new set of pieces is at the beginning of August. Thus, the earliest we could reasonably supply full sizes filters for HEPA certification tests is at the end of August.

A project schedule is appended, but requires revision pending clarification of program tasks. At the planned design review at SRTC on June 14th, Bruce Bishop will be prepared to discuss a realistic schedule for us to produce prototype filter elements based on unitary 5.66” x 12” long silicon carbide monoliths as well as a schedule for fabrication of a filter vessel with seven filters, an assembly sized to filter 800 ACFM vent gas flow. Finally, Bruce will be able to discuss how much of this can be done with remaining Phase IIA project funds.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XII

Mr. William Haslebacher
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Haslebacher:

This letter summarizes the progress during June, 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

The Full Scale RHFS preliminary design was reviewed in a design review held at SRTC on June 14th. Present from CeraMem were Dr. Bruce Bishop and Phil Paquette.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

A proposed project modification providing for delivery of 12 full size filters by October, 2000 first to ATI for DOP testing and subsequently to SRTC for process testing has been submitted to DOE. It is our expectation that this will be approved. Tests at SRTC will be followed at the end of the year on a decision about proceeding to Phase IIB of the project.

The schedule from the last monthly report is appended. This would be superseded by the new schedule in the proposed modification, if approved.

A no-cost extension through the end of year 2000 has been approved for the project.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XIII

Mr. Jagdish L. Malhotra
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
Mailstop: E06
P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during July, 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

The Full Scale RHFS preliminary design was reviewed in a design review held at SRTC on June 14th. Present from CeraMem were Dr. Bruce Bishop and Phil Paquette. A series of questions/comments raised at that meeting will be responded to next month.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

A proposed project modification providing for delivery of 12 full size filters by October, 2000 first to ATI for DOP testing and subsequently to SRTC for process testing has been submitted to DOE. It is our expectation that this will be approved. Tests at SRTC will be followed at the end of the year on a decision about proceeding to Phase IIB of the project.

During July, we received ten new full size "unitary" monoliths from our supplier, LiqTech of Lyngby, Denmark. We have begun our QC testing of these.

Continuing membrane development has led to the discovery that the filter retention is determined (affected) primarily by a few residual defects at the end faces of the filters. We have successfully developed a "caulking" procedure to heal these defects. Based on this finding and solution, we are hopeful we will meet the DOP HEPA test requirements for both lab modules and full size modules to be supplied to ATI.

The schedule from the last monthly report is appended. This would be superseded by the new schedule in the proposed modification, if approved.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XIV

Mr. Jagdish L. Malhotra
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
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Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during August 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

The Full Scale RHFS preliminary design was reviewed in a design review held at SRTC on June 14th. Present from CeraMem were Dr. Bruce Bishop and Phil Paquette. A series of questions/comments raised at that meeting will be responded to in September.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

A proposed project modification providing for delivery of 8-12 full size filters by October, 2000 first to ATI for DOP testing and subsequently to SRTC for process testing has been submitted to DOE. It is our expectation that this will be approved. Tests at SRTC will be followed at the end of the year on a decision about proceeding to Phase IIB of the project. As of this date, the modification is being finalized by DOE's Contracting Officer.

Continuing membrane development has led to the discovery that the filter retention is determined (affected) primarily by a few residual defects at the end faces of the filters. We have successfully developed a "caulking" procedure to heal these defects. More samples of membranes have been sent to ATI and some passed the DOP HEPA filter test.

During July, we received ten new full size "unitary" monoliths from our supplier, LiqTech of Lyngby, Denmark. Four of these have been coated and will be subjected to CeraMem in-house QC tests with the hope of having at least two which will be sent to ORNL for DOP challenge testing.

ASME Project Review
We have prepared a presentation for this early-September review and will participate on September 11th and 12th. The schedule from the last monthly report is appended. This will be superseded by the new schedule in the proposed modification, once approved.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XV

Mr. Jagdish L. Malhotra
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
Mailstop: E06
P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during September 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

The Full Scale RHFS preliminary design will be modified during the next two months, and questions/comments raised at the June design review meeting will be responded to as part of a final design review anticipated to take place toward the end of the year.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Substantial effort has been expended to make full size prototype filters (5.66" diameter by 12" length). As of the date of this report, two filter elements have been prepared which meet the internal CeraMem retention test and are thought to be capable of meeting the DOP HEPA filter test criterion.

The prototype filter housing previously sent to SRTC will be returned to CeraMem, providing two housings for use in testing of full size filter elements. It is our intention to ship two filter assemblies which will pass the ATI DOP test to ATI at ORNL. This should be done by the end of October, for tests beginning in early November.

In addition, if we have additional filter elements believed to have adequate retention in our QC tests to pass the DOP test, these will be supplied separately to ATI.

A training session for filter insertion into the housings will be held for Mr. Dave Crosby of ATI in Baltimore around the first of November.

It is anticipated that DOP testing at ORNL will take place in the first half of November with filters shipped subsequently to Duane Adamson at SRTC for simulated process tests.

Site Visit
Mr. Duane Adamson will make a site visit with the undersigned to the silicon carbide monolith fabrication facilities in Denmark and Germany. This trip will occur the third week in October.

No-Cost Extension
At the last project telephone conference, it was suggested and agreed that a no-cost project extension be requested. The suggested extension time was for six months. Such a request will be made before the end of the month.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XVI

Mr. Jagdish L. Malhotra
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
Mailstop: E06
P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during October 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full–scale RHFS Design

The Full Scale RHFS preliminary design is being modified, and questions/comments raised at the June design review meeting will be responded to as part of a final design review anticipated to take place in the first quarter of 2001.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Five full size filters have been shipped to ATI at ORNL for DOP tests along with two housings. Test results for these filters follow on the next page. These retention results are for CeraMem's liquid filtration test with a monodisperse silica suspension. A graph showing the correlation between this QC test and prior aerosol challenge tests with lab size modules is also included. Based on these results, we are hopeful that at least two to three of the filters will pass the DOP challenge test.

A training session for filter insertion into the housings was held for Mr. Dave Crosby of ATI in Baltimore at the beginning of November.

It is anticipated that DOP testing at ORNL will take place in the first half of December with filters shipped subsequently to Duane Adamson at SRTC for simulated process tests.

No-Cost Extension
At the last project telephone conference, it was suggested and agreed that a no-cost project extension be requested. The suggested extension time was for six months. It is our understanding that such a request will be initiated by DOE.

Please feel free to get in touch with me regarding any questions about this report.

Test Results for Filters sent to ORNL

Filter #	**Passage of 1.5µm silica**	**Pressure drop at 6 ft/min**
7	0.6 %	19 "wc
9	2.4 %	11 "wc
10	0.9 %	10 "wc
13	1.6 %	13 "wc
14	0.5 %	12 "wc

Progress Report XVII

Mr. Jagdish L. Malhotra
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
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P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during November 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

The Full Scale RHFS preliminary design is being modified, and questions/comments raised at the June design review meeting will be responded to as part of a final design review anticipated to take place in the first quarter of 2001.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Five full size filters have been shipped to ATI at ORNL for DOP tests along with two housings. It is anticipated that DOP testing at ORNL will take place in the first half of January with filters shipped subsequently to Duane Adamson at SRTC for simulated process tests.

No-Cost Extension
A no-cost project extension for six months, through June 2001, will be requested to allow for project delays.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XVIII

Mr. Jagdish L. Malhotra
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
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Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during December 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

The Full Scale RHFS preliminary design is being modified, and questions/comments raised at the June design review meeting will be responded to as part of a final design review anticipated to take place in the first quarter of 2001. At present, the redesign focuses on the filter vessel housing, and this will be completed in January.

A related activity is the development of an Acceptance Test Plan. This has been initiated and an outline will be completed in January.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Five full size filters have been shipped to ATI at ORNL for DOP tests along with two housings. It is anticipated that DOP testing at ORNL will take place in the first half of January with filters shipped subsequently to Duane Adamson at SRTC for simulated process tests.

No-Cost Extension
A no-cost project extension for six months, through June 2001, has been granted.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XIX

Mr. Jagdish L. Malhotra
Office of Project Management
United States Department of Energy
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Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during December 2000 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1 – Full –scale RHFS Design

The Full Scale RHFS preliminary design is being modified, and questions/comments raised at the June design review meeting will be responded to as part of a final design review anticipated to take place in the first quarter of 2001. At present, the redesign focuses on the filter vessel housing, and this will be completed in January.

A related activity is the development of an Acceptance Test Plan. This has been initiated and an outline will be completed in January.

Task B.2.1.2 – Full-scale HEPA Filter Element Delivery

Five full size filters have been shipped to ATI at ORNL for DOP tests along with two housings. It is anticipated that DOP testing at ORNL will take place in the first half of January with filters shipped subsequently to Duane Adamson at SRTC for simulated process tests.

No-Cost Extension
A no-cost project extension for six months, through June 2001, has been granted.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XX

Mr. Jagdish L. Malhotra
Office of Project Management
United States Department of Energy
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Dear Mr. Malhotra:

This letter summarizes the progress during February, 2001 in the execution of Contract No. DE-AC26-99FT40569.

The test results from ATI's tests during January/February are appended. These have been discussed with DOE personnel, separately. Briefly, two of the five filters fell very slightly below the HEPA test standard (did not pass). The other filters deviated more from the standard. Further, the previous correlation between the CeraMem aqueous silica QC retention test and the ATI DOP test did not fit the test data well. We had expected better performance of the filters than that obtained. ATI will repeat some of the tests during March to determine if their test results could have had any error. CeraMem will also evaluate its test procedure during this period.

A proposal for a project modification was prepared and submitted during February. As you know, this proposed modification is currently under review.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XXI

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Dear Mr. Malhotra:

This letter summarizes the progress during March, 2001 in the execution of Contract No. DE-AC26-99FT40569.

The proposal for a project modification prepared and submitted during February was approved by DOE, and we are now proceeding with the work as efficaciously as possible. The sections below, and accompanying schedule, have been modified to reflect the remaining work on the program. This includes unfinished tasks from earlier periods and the tasks included in the modification. Also, the schedule has been modified to reflect the time needed for the current work to be performed during calendar year 2001. This schedule needs to be reviewed with DOE staff to assure the work is completed to meet the project schedule requirements of DOE.

Task B.2.1.1. Full-Scale RHFS Design

A revised filter vessel design is scheduled to be completed at the end of March and will be provided with the next monthly report. We will begin the design modifications to the full scale RHFS in May, completing the modifications arising from last year's design review in June. A cost for the system will then be developed, interactively, by HiLine Engineering & Fabrication (Richmond, WA) during June and July. This design activity will be reported/reviewed during a final design review at SRS in early August.

Task B.2.1.2. Full –Scale HEPA Filter Element Delivery to ATI/SRTC
This task will entail the production of two sets of filter elements. A first set will use the remaining monolith supports at CeraMem. These will be coated with membranes and tested during May. This will be followed by DOP tests by ATI at ORNL during early June and shipment to SRTC at the end of June. These filters will serve as the filter samples for process tests by Duane Adamson at SRTC.

A second larger set of filters will be produced from a new batch of monoliths to be fabricated by LiqTech Aps (Denmark). Due to the time required to produce the monoliths, these will not be available as finished filters until mid-summer. About 20 filters will be produced and sent to ORNL for DOP testing. The purpose of producing these filters is to demonstrate reproducibility of full-scale ceramic filters that can pass the HEPA challenge test.

Additional stainless steel housings and boot seals will be procured to support the testing and supply of full-scale filters, as shown in the schedule.

Task B.2.1.4. Acceptance Test Plan of Full-Scale RHFS

We have been slowing developing a draft Test Plan. A draft of this will be finalized in May and sent to DOE for review and comment.

Other

Other activities are as indicated in the revised schedule and should be self-explanatory.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XXII

Mr. Jagdish L. Malhotra
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
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P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during April, 2001 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1. Full-Scale RHFS Design

A revised filter vessel design was completed at the end of March and has gone through an internal design review, leading to some changes being made. This was done in April and will be reviewed in the site visit planned for Duane Adamson and you on May 24, 2001.

We have begun the design modifications to the full scale RHFS. At your site visit in May, we will discuss, and presumably settle, the design package that will be needed for the SRS Design Review to be scheduled in August. We have begun providing preliminary system design detail to HiLine Engineering & Fabrication (Richmond, WA), who will prepare a system quotation.

All of this design activity will be reviewed during your visit to insure that we have the necessary information prepared for the final design review at SRS in August.

Task B.2.1.2. Full –Scale HEPA Filter Element Delivery to ATI/SRTC
This task will entail the production of two sets of filter elements. A first set will use the remaining monolith supports at CeraMem. These will be coated with membranes and tested during May. This will be followed by DOP tests by ATI at ORNL during early June and shipment to SRTC at the end of June. These filters will serve as the filter samples for process tests by Duane Adamson at SRTC. [As of the date of this report, the schedule for shipment of this set of filters is for the first week in June.]

A second larger set of filters will be produced from a new batch of monoliths to be fabricated by LiqTech Aps (Denmark). Due to the time required to produce the monoliths, these will not be available as finished filters until mid-summer. About 20 filters will be produced and sent to ORNL for DOP testing. The purpose of producing these filters is to demonstrate reproducibility of full-scale ceramic filters that can pass the HEPA challenge test. [As of the date of this report, the monoliths required to make the filters have been received at CeraMem.]

In April, we treated two of the earlier full size filters which failed the DOP test at ORNL by a caulking procedure. These were retested by ATI, and did not pass again. The results are given below. However, on receipt of the filters from ATI after the retest, it is clear they were damaged, either during installation or removal. As it is unclear when this damage occurred, the retest results are, unfortunately, suspect.

	Filter #9 (Caulking “A”)		Filter #10 (Caulking “B”)	
	1.st test	2.nd test	1.st test	2.nd test
Air flow pressure drop @ 6 ft/min	18.8	18.8	15.4	13.8
Silica retention (1.5 µm particles)	98.8%	99.0%	99.1	99.9%
DOP retention (0.3 µm aerosol)	99.92%	99.92%	99.87%	99.93%

The schedule quoted by our supplier to make the two additional stainless steel housings has proven to be excessively long. Since NaCl aerosol challenge tests are not being performed at the University of North Dakota, as originally planned, and CeraMem now does not need a housing in Waltham for filter testing, this procurement has been deferred. The necessary new boot seals to support the production and testing of a large number of filters have been ordered.

Task B.2.1.4. Acceptance Test Plan of Full-Scale RHFS

We have been slowing developing a draft Acceptance Test Plan. An outline of this has been prepared for discussion with Duane during you visit in May. Following this discussion, the test plan will be sent to DOE for formal review and comment.

Other

Other activities are as indicated in the revised schedule (same as in last month's report) and should be self-explanatory.

☞As the current schedule extends beyond the contract termination date of the end of June, we will need a new "no cost extension" through the end of September.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XXIII

Mr. Jagdish L. Malhorta
Office of Project Management
United States Department of Energy
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Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during May, 2001 in the execution of Contract No. DE-AC26-99FT40569.

A detailed Project Review was held at CeraMem on May 24, 2001, attended by Duane Adamson and you. Based on this meeting you are fully current on project status.

Task B.2.1.1. Full-Scale RHFS Design

A revised filter vessel design has been completed and is appended.

The design modifications to the full scale RHFS are underway. At your site visit in May, we discussed the design package that will be needed for the SRS Design Review to be scheduled in August. We have begun providing preliminary system design detail to HiLine Engineering & Fabrication (Richmond, WA), who will prepare a system quotation.

Task B.2.1.2. Full –Scale HEPA Filter Element Delivery to ATI/SRTC

This task entails the production of two sets of filter elements. A first set is based on the use of some remaining monolith supports at CeraMem. These were coated with membranes and preliminary tests began at CeraMem during May. This will be followed by DOP tests by ATI at ORNL during June and shipment to SRTC thereafter. These filters are intended to serve as the filter samples for process tests by Duane Adamson at SRTC. [These filters were shipped on June 14 and will be at ORNL on June 15.]

A second larger set of filters will be produced from a new batch of monoliths in July and August. About 20 filters will be produced and sent to ORNL for DOP testing. The purpose of producing these filters is to demonstrate reproducibility of full-scale ceramic filters that can pass the HEPA challenge test. [As of the date of this report, the monoliths required to make the filters have been received at CeraMem.]

Task B.2.1.4. Acceptance Test Plan of Full-Scale RHFS

We discussed during your visit the contents of a draft Acceptance Test Plan we are currently preparing. We intend to provide this as part of the RHFS Design Package to be submitted to DOE during the second half of July.

Other

Other activities are as indicated in the revised schedule (same as in last month's report) and should be self-explanatory.

☞As the current schedule extends beyond the contract termination date of the end of June, we will need a new "no cost extension" through the end of September. [We have requested this in a letter to Mary Gabriele as of June 14.]

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XXIV

Mr. Jagdish L. Malhorta
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
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Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during June, 2001 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1. Full-Scale RHFS Design

A revised filter vessel design was completed and submitted to you last month.

As of the date of this report, the design package is essentially complete. After a final internal review, this should be forwarded to you (as well as Mike Terry and Duane Adamson), by the end of this month (July).

Task B.2.1.2. Full –Scale HEPA Filter Element Delivery to ATI/SRTC
During June and early July, three experimental activities were undertaken. These are summarized below.

Caulking and Re-Testing of Full Size Filters. Two of the initial lot of full-scale filters tested by ATI at ORNL earlier in the year were returned to CeraMem. These were "caulked" by filtering a dilute suspension of ceramic fines, dried and fired to bond the caulking fines. The filters were then retested at CeraMem in our liquid filtration test and subsequently by ATI at ORNL. The results are given below:

	Filter #9		Filter #10	
	1st test	2nd test	1st test	2nd test
Air flow pressure drop, inches water @ 6 ft/min	18.8	18.8	15.4	13.8
Silica retention (1.5 μm particles)	98.8%	99.0%	99.1	99.9%
DOP retention (0.3 μm aerosol)	99.92%	99.92%	99.87%	99.93%

The results indicated that caulking appeared to heal minor defects, with filter #10 approaching HEPA filter performance. Based on these results, a first set of full-scale filters were made, caulked and shipped to ORNL.

First Set of Full-Scale Filters Tested at ORNL

The results were mixed. First, the good results are that two filters passed the DOP test with >99.97% retention (Filters #H25 and H20). The other, heavily-caulked filters, with high pressure drop, showed very poor DOP retention, even though these showed very high retention in CeraMem's aqueous silica particle retention test. Also, a full-scale filter that Duane Adamson has been testing at SRTC (Filter #7) with plugging and washing was retested by ATI at ORNL and showed negligible change in DOP retention, a very promising result indicative of good membrane durability.

We explain these results in the following manner. CeraMem's silica retention test is a measure of steric rejection of 1.5μm particles, and very high retention (e.g., >99.9%) is a measure of few, if any, pores or defects in the membrane of this size or larger. The DOP test is a measure both of steric and diffusional aerosol capture. For the heavily caulked filters, we believe a low permeability membrane was formed with a few submicron cracks. Thus, during the DOP test, high flow through these cracks led to high DOP passage – even though the steric capture for 1.5 μm silica particles was very high.

From these results, we concluded that a somewhat different path to membrane application was desired. Results of tests conducted in June are described below.

Laboratory-Scale Modules and Test Results

The above results led us to conclude that application of multiple coats should address the problems encountered to date. Accordingly, during June several laboratory modules were prepared with the old membrane application means and using multiple coats. The lab-scale filters were prepared and tested in duplicate. Testing included the silica retention test at CeraMem and the DOP test at ATI in Baltimore. As we are now reviewing the results for potential patentability, they will not be disclosed fully in this report. However, the most important result is that we have now made laboratory scale filters (in duplicate and without caulking) which have shown the test results below. These are far and away the best filters we have ever made.

Pressure Drop:	24" water at 10 ft/min filter face velocity
DOP Passage (ATI test):	99.9999% & 99.9998%

Production of Next Sets of Full-Scale Filters

Based on these results, we are now producing (as of the date of this report) a lot of eight filters. We expect to ship these to ATI by July 27 for DOP tests at ORNL. We will then make one more lot of eight filters for shipment by mid-August. We expect to ship a final lot of eight filters by the end of August.

<u>Task B.2.1.4. Acceptance Test Plan of Full-Scale RHFS</u>

The draft Acceptance Test Plan we are currently preparing will be submitted shortly included in the draft Full-Scale RHFS Design Package.

Please feel free to get in touch with me regarding any questions about this report.

Progress Report XXV

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Dear Mr. Malhotra:

This letter summarizes the progress during July, 2001 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1. Full-Scale RHFS Design

The preliminary Full-Scale RHFS Design was submitted during this reporting period. A preliminary design review has been scheduled at SRTC for September 19, 2001.

Task B.2.1.2. Full –Scale HEPA Filter Element Delivery to ATI/SRTC
A lot of seven filters has been shipped to ATI at ORNL. These will be tested in August. A second lot of eight filters is being produced, and will be shipped during August, also. Once we have DOP test results on these, we will then make one more lot of eight filters for shipment anticipated to be during September.

Several lab scale modules with silicon carbide membranes were produced and shipped to ATI (Baltimore) for HEPA filter tests. These filters had very high retention, but also high pressure drop. This is related to making the membrane coating with too fine a pore size. We anticipate one more iteration to make the silicon carbide membranes at this scale. ATI's results are shown in the attached table.

Task B.2.1.4. Acceptance Test Plan of Full-Scale RHFS

The draft Acceptance Test Plan was included in the draft preliminary Full-Scale RHFS Design Package.

Last month's schedule is appended without modification pending a decision by DOE about a project no-cost time extension.

Lab Scale SiC Membrane Filters Tested at ATI (August, 2001)

Sample Number	% DOP-Retention	Pressure drop, in. wc @ 6ft/min
1	99.996	>36
2	99.931	28.15
3	99.88	30.35
4	99.9905	>36
5	99.996	>36
6	99.9945	>36

Note: Pressure drop >36 inches wc was not measurable by ATI's manometer
Pressure drop will be measured at CeraMem on filter return.

Progress Report XXVI

Mr. Jagdish L. Malhorta
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Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during August, 2001 in the execution of Contract No. DE-AC26-99FT40569.

<u>Task B.2.1.1. Full-Scale RHFS Design</u>

The preliminary Full-Scale RHFS Design was submitted during the previous reporting period. An addendum with corrections was also submitted, and is appended.

A preliminary design review was scheduled at SRTC for September 19, 2001, but postponed. A date, probably in the November time frame, is being arranged by Duane Adamson at SRTC.

Task B.2.1.2. Full –Scale HEPA Filter Element Delivery to ATI/SRTC
Fifteen filters have been shipped to ATI at ORNL and tested. Results were submitted separately to the Project Team. These are appended. In general, 7 of 13 filters tested passed, all with retention well exceeding the HEPA DOP retention standard. Six failed, with consistent results. These will be examined on return to CeraMem to try to identify any "consistent defect". Two filters were damaged on the ends due to improper packing at CeraMem prior to shipment.

Based on these results, we conclude that we can repeatedly make filters to pass the HEPA challenge test. We would expect yield to increase as we gain more experience. Given this conclusion and the fact that the project is current "over budget", we do not anticipate producing any more filters for ATI tests at ORNL.

<u>Task B.2.1.4. Acceptance Test Plan of Full-Scale RHFS</u>

The draft Acceptance Test Plan was included in the draft preliminary Full-Scale RHFS Design Package.

A new schedule is appended including a six-month no-cost extension. Please feel free to get in touch with me regarding any questions about this report.

Progress Report XXVII

Mr. Jagdish L. Malhorta
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
Mailstop: E06
P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during September, 2001 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1. Full-Scale RHFS Design

The design review was scheduled at SRTC for September 19, 2001, but postponed. A date, probably in the November time frame, is being arranged by Duane Adamson at SRTC.

Task B.2.1.2. Full –Scale HEPA Filter Element Delivery to ATI/SRTC
A total of twenty-one full-scale filters were shipped to ATI for DOP tests. Results for the second lot of 15 were included in last month's report.

Task B.2.1.4. Acceptance Test Plan of Full-Scale RHFS

The draft Acceptance Test Plan was included in the draft preliminary Full-Scale RHFS Design Package.

A new schedule is appended including a six-month no-cost extension.

Effective this month, Bruce Bishop at CeraMem will be assuming the primary program management responsibility for CeraMem.

Please feel free to get in touch with me regarding any questions about this report or our ongoing activities.

Progress Report XXVIII

Mr. Jagdish L. Malhorta
Office of Project Management
United States Department of Energy
Federal Energy Technical Center
3610 Collins Ferry Road
Mailstop: E06
P.O. Box 880
Morgantown, WV 26507-0880

Dear Mr. Malhotra:

This letter summarizes the progress during October, November and December 2001 in the execution of Contract No. DE-AC26-99FT40569.

Task B.2.1.1. Full-Scale RHFS Design

A design review was held at the Savannah River site on December 12, 2001. Attendees for CeraMem Corporation were Phil Paquette and the undersigned.

The current schedule is appended. Further work on the project is being held in abeyance pending feed back from DOE on project continuation.

Please feel free to get in touch with me regarding any questions about this report or our ongoing activities.

VII. APPENDIX C: ALTERNATE HEPA FILTER DESIGN BOOK

Design Report (Task B.2.1.1)

Alternate High-Efficiency Particulate Air (HEPA) Filtration System

Submitted to the U. S. Department of Energy

Under Contract DE-AC26-99FT40569

Submitted by

CeraMem Corporation
12 Clematis Avenue
Waltham, MA 02453

Revision 1
November 9, 2002

TABLE OF CONTENTS

I. INTRODUCTION TO ALTERNATE HEPA FILTER SYSTEM DESIGN BOOK

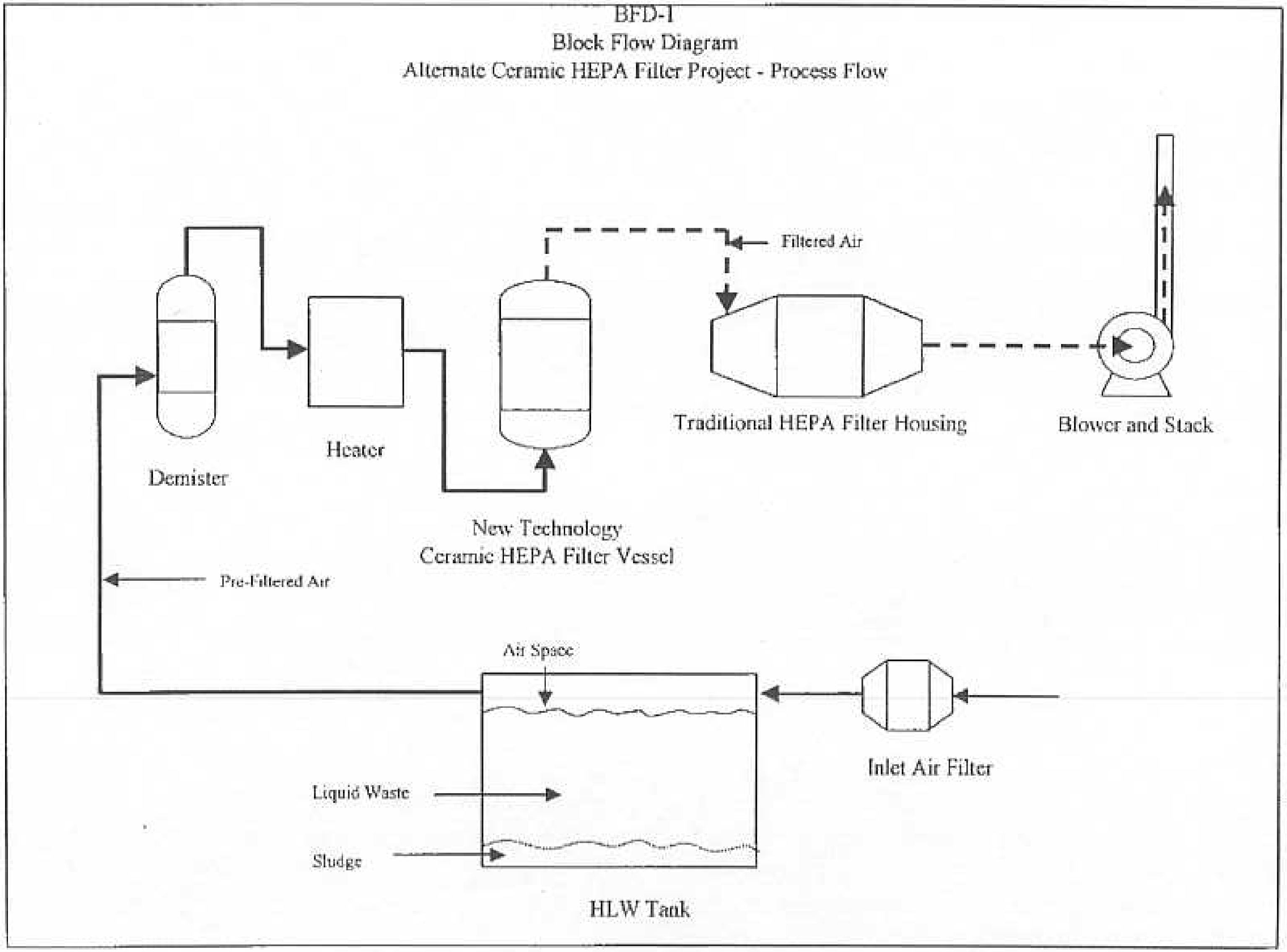
This Design Book contains the front-end design concept documents for the proposed new technology ceramic HEPA filter system. This new, in situ cleanable, ceramic filter technology provides an alternative to the existing traditional, disposable HEPA filters utilized on HLW tanks at the Savannah River Site (SRS). The design approach undertaken involves a two step process: 1) integrating the new technology ceramic HEPA filters into the existing SRS HEPA filter skid design; and 2) modifying several existing components to accommodate the new operating conditions. The design intent is to comply with all the applicable requirements of the lead SRS Specification G-SPP-H-00022. This Design Book, intended as a supplement to the SRS specification, provides sufficient detailed design information on the new technology ceramic HEPA filters and vessel. This integration will necessitate a few modifications to the existing design, which are also identified and described briefly in this Design Book. Refer to the following Block Flow Diagram, BFD-1.

Description of Integrated New Technology Components:

1. The new ceramic HEPA filters, housed in a new CM Filter Vessel is integrated into the existing SRS HEPA filter system process between the existing reheater and existing HEPA filter.
2. New instrumentation is included around the CM Filter Vessel to allow for temperature, vacuum, pressure drop and flow information and control as well as an additional DOP test port.
3. Cleaning system piping for delivery and drainage of cleaning fluids is incorporated on the skid servicing the CM Filter Vessel.
4. Provisions for attaching a clean in place (CIP) skid next to the main filter skid are included. The detailed design of the CIP skid would be formulated during the final design phase, based on cleaning test results obtained by SRTC.

Description of Major Process Design Modifications:

1. Process line size between the existing reheater and existing HEPA filter is reduced to 8" to facilitate physical installation of the CM Filter Vessel within the existing skid layout.
2. The existing blower will be replaced with a new blower with a higher vacuum capacity at the desired rated flow rates of between 800 and 1100 acfm. Current design utilizes a blower selection capable of delivering 1125 acfm and –47.5" wc vacuum at blower suction. It is anticipated that continued filter development will reduce the blower suction requirements to below this level. The New York Blower Company has provided consultation, sizing and selection of this new blower.
3. The process scheme allows operation of the two HEPA filters in series (at up to –47.5" wc combined pressure drop) or only the existing HEPA filter (at up to –11.5" wc pressure drop). This is achieved by removing the new HEPA filter vessel and replacing it with an 8" pipe spool piece. The selected system blower is provided with a two-speed motor (1750 rpm and 3500 rpm speeds) to allow for these operating modes. This flexibility is provided to allow the system to operate without the CM Filter Vessel in the unlikely event this may be needed.


BFD-1
Block Flow Diagram
Alternate Ceramic HEPA Filter Project - Process Flow
Filtered Air
Demister
Heater
New Technology
Ceramic HEPA Filter Vessel
Traditional HEPA Filter Housing
Blower and Stack
Pre-Filtered Air
Air Space
Liquid Waste
Sludge
HLW Tank
Inlet Air Filter

4. The existing HEPA filter housing will require upgrading to a new reinforced housing to allow operation at the new negative pressure of –60"wc, lower than the current rating of the HEPA filter specified by SRS. The Flanders Filter/CSC Company has confirmed this as a special but achievable design condition for this application.

Normal and Backup Operating Modes:

Normal operation of the HLW tank filtering system would be with the ceramic HEPA filters in series with the traditional HEPA filters and a blower operating at a speed of 3500 rpm for high vacuum capacity. An important design feature of the system is to allow continued filtration of the HLW tank in the unlikely event of a problem with the ceramic filters. The CM Filter Vessel would be removed at the 8" inlet/outlet piping flanges and replaced with an 8" pre-fabricated pipe spool. The blower would be switched to low speed (1750 rpm) and low vacuum operation, and the system is returned to on line filtering with the traditional HEPA filter performing as per the original design.

II. DESCRIPTION OF CERAMIC HEPA FILTERS AND HEPA FILTER VESSEL

Refer to Filter and Vessel Drawings CM001, 002, 003 and 004.

The ceramic HEPA filter consists of seven (7) filter elements in individual stainless cans, contained in a stainless steel filter vessel. The filter elements are ceramic-membrane-coated silicon carbide monoliths, plugged in a dead-end flow configuration. This configuration has been explained in the program proposal and other documentation and will not be repeated here.

Each filter element uses a "unitary" silicon carbide monolith of dimensions 5.66" diameter and 12" length. The filtration area per filter element is approx. 18.5 ft^2, for a total area in the assembly of about 130 ft^2. At a rated gas flow of 800 ACFM, the filter face velocity will be about 6.2 ft/min. and at an initial clean operating gas flow of 1125 ACFM the filter face velocity will be about 8.7 ft./min.

Each filter is inserted in a stainless can fabricated of 6" SCH 10S pipe with an inside diameter of 6.357" and a wall thickness of 0.134". The top (outlet) of the can has a standard 6" 150# ANSI flange for mounting to a mating studding outlet on the tube sheet located within the filter vessel.

An EPDM boot seal sits on the top (outlet end) of the filter element and is held in place with a retaining ring. The boot seal centers and seals the filter while the retaining ring contains and compresses the boot seal. A snap-ring then holds this assembly in place.

The bottom (inlet end) of the can also has an identical EPDM boot seal and retaining ring. A washer style can ring is tack welded (at final assembly) to the bottom inside edge of the can. This serves to hold the retaining ring, compress and contain the boot seal as in the top seal. This assembly method also accommodates any slight (+/-1/16") deviations in the length of each filter as it is canned.

The small gap between the filter element and the can is filled with an *in situ* vulcanized rubber seal to eliminate any liquid collection in this area. Note that this elastomer is not intended to form a primary seal, but is used only to eliminate dead space.

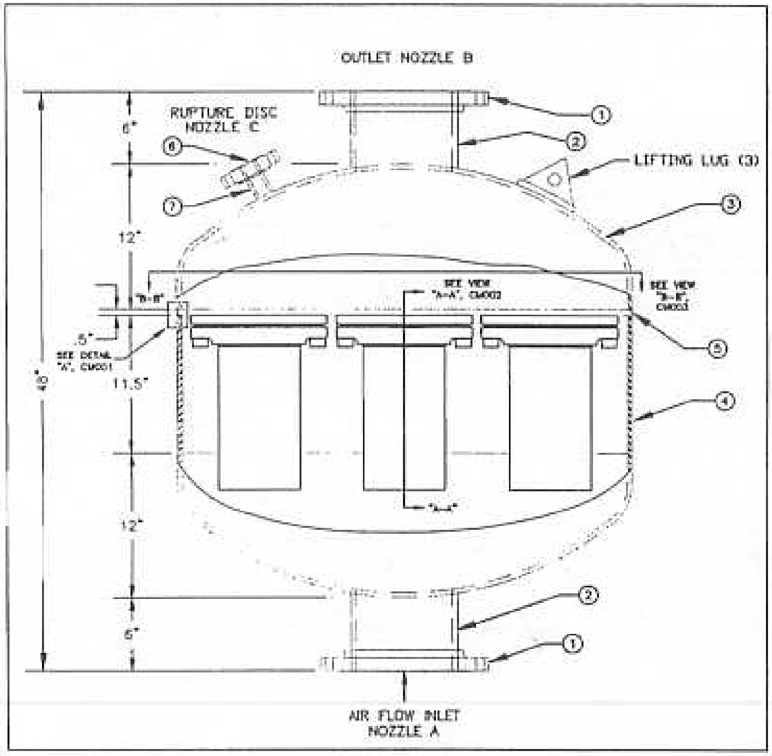
Each flanged can is attached to the tube sheet via a drilled and tapped (non-penetrating) studding outlet. The only hole that exists in the tube sheet is the filter opening hole for clean gas passage. An EPDM gasket is used to form the final gas tight and liquid tight seal needed for proper filter operation. The seven filter elements are bolted onto the tube sheet in a closely packed hexagonal array. The tube sheet is welded into the vessel between the top head and shell course joint in the filter vessel forming clean and dirty air plenums above and below the tube sheet, respectively.

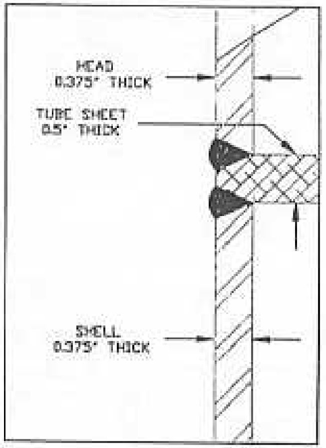
The vessel is designed and fabricated to ASME Section VIII at 150 psig and full vacuum and measures 36" inside diameter by 48" overall length. The inlet and outlet nozzles are standard 8" 150# ANSI flanges to mate with existing piping. The upper and lower heads are ASME elliptical style. The internal surfaces of the vessel will be power tool cleaned to provide an appropriate internal surface for operation. All vessel materials of construction, other than the ceramic filter elements and EPDM seals, are 304 stainless steel.

During normal filtering operations the vessel will operate between atmospheric and 50"wc vacuum. This differential will also exist across the tube sheet with the outlet clean plenum being lower. The maximum capability of the blower and other vacuum limiting controls will keep this level from exceeding 50"wc vacuum. During cleaning in place the vessel will experience a higher pressure from air and water cleaning fluids injected from the clean side discharge piping and into the clean plenum to back wash the dirty filter elements. These pressure sources are normally regulated to 10 psig with a relief protection devices set to limit pressures to 15 psig maximum. In the unlikely event that these devices fail, a vessel rupture disk, set at 20 psig, is provided directly on the vessel's clean side for ultimate vessel tube sheet over pressure protection.

The filter vessel is to be designed, fabricated and tested in accordance with the requirements of SRS Specification G-SPP-H-00022.

BILL OF MATERIALS					
ITEM	QTY.	SIZE	DESCRIPTION	MAT'L	NOTES
1	2	8"	150# R.F. SLIP-ON FLANGE	304SS	-
2	2	8"	SCH 10S PIPE	304SS	-
3	2	36" ID	ASME ELLIPTICAL HEAD (0.375" THICK)	304SS	-
4	1	36" ID	ROLLED PLATE/SHELL (0.375" THICK)	304SS	-
5	1	-	TUBESHEET ASSEMBLY W/7 CANS ATTACHED VIA FLANGES REFER TO CM002, CM003, & CM004	304SS	-
6	1	1 1/2"	150 # R.F. SLIP-ON FLANGE	304SS	-
7	1	1 1/2"	SCH 10S PIPE	304SS	





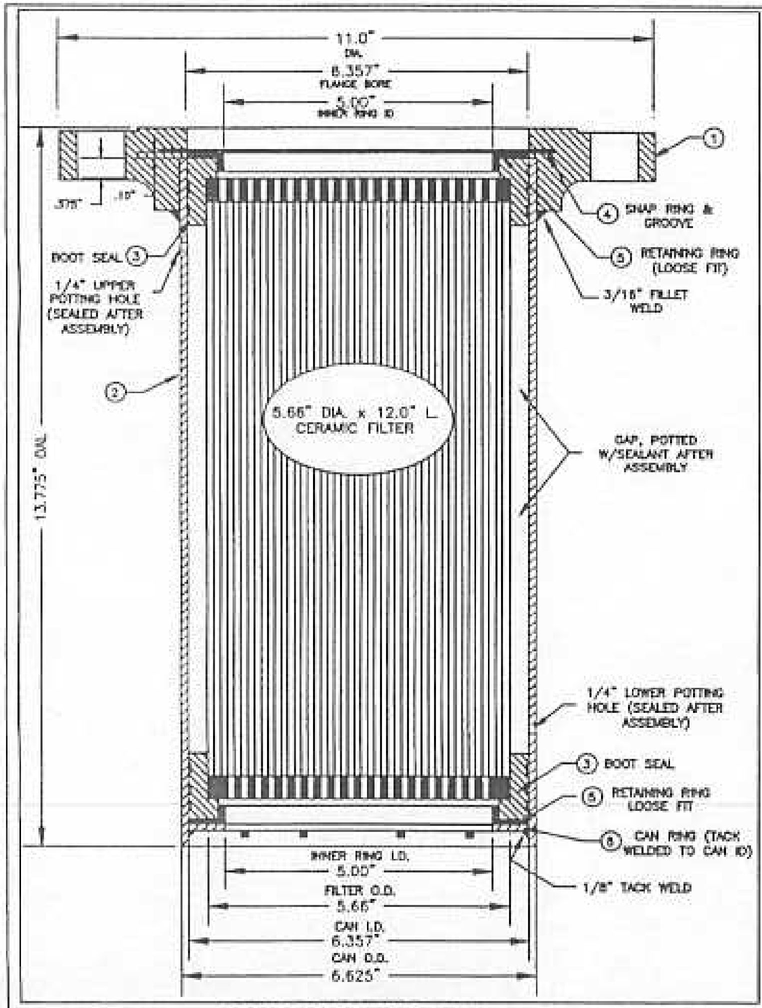
TUBE SHEET WELD
DETAIL "A"

VESSEL DATA:
DESIGN PRESSURE: 150 PSIG/ FULL VACUUM
DESIGN TEMP.: 200°F
MATERIAL: 304 STAINLESS STEEL
CODE: ASME VIII; NO RADIOGRAPHY
WEIGHT: 1,200 # OPERATING

REV	DATE	DESCRIPTION	APP.
1	5/21/01	REVISED VESSEL DESIGN	
0	5/7/00	ISSUED FOR DESIGN REVIEW	

CERAMEM CORP.
WSRC H & V TANK VENT SKID
ALT. HEPA FILTER VESSEL

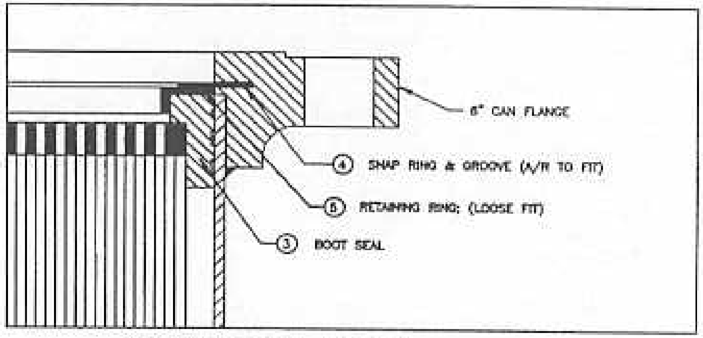
SCALE:	DRWN. BY	DATE	DWG. NO.	REV.
NONE	TAH	5/7/00	CM001	1



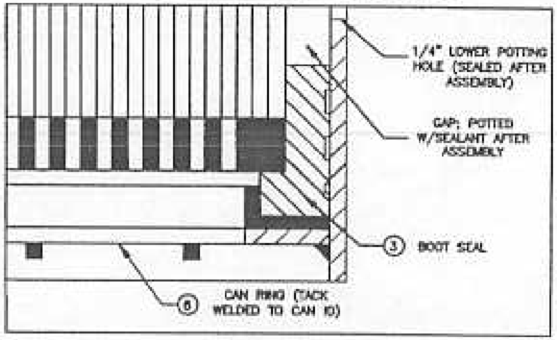
CROSS SECTION THROUGH FILTER CAN
VIEW "A-A"

BILL OF MATERIALS					
ITEM	QTY.	SIZE	DESCRIPTION	MAT'L	NOTES
1	1	6'	150# SWRF FLANGE	304SS	-
2	1	6'	SCH 10S PIPE 6.625' O.D x 0.134' THICK	304SS	LENGTH A/R
3	2	-	BOOT SEAL	EPDM	SEE DWG. 00126
4	1	A/R	SNAP RING	304SS	SIZED & GROOVE CUT TO FIT
5	2	-	RETAINING RING; 6.36' O.D x 5.00' I.D.	304SS	SEE DWG. BW022
6	1	-	CAN RING; 5.00' I.D. x 0.125' THICK	304SS	CUT O.D. TO FIT CAN I.D.

UPPER SEAL DETAIL



LOWER SEAL DETAIL



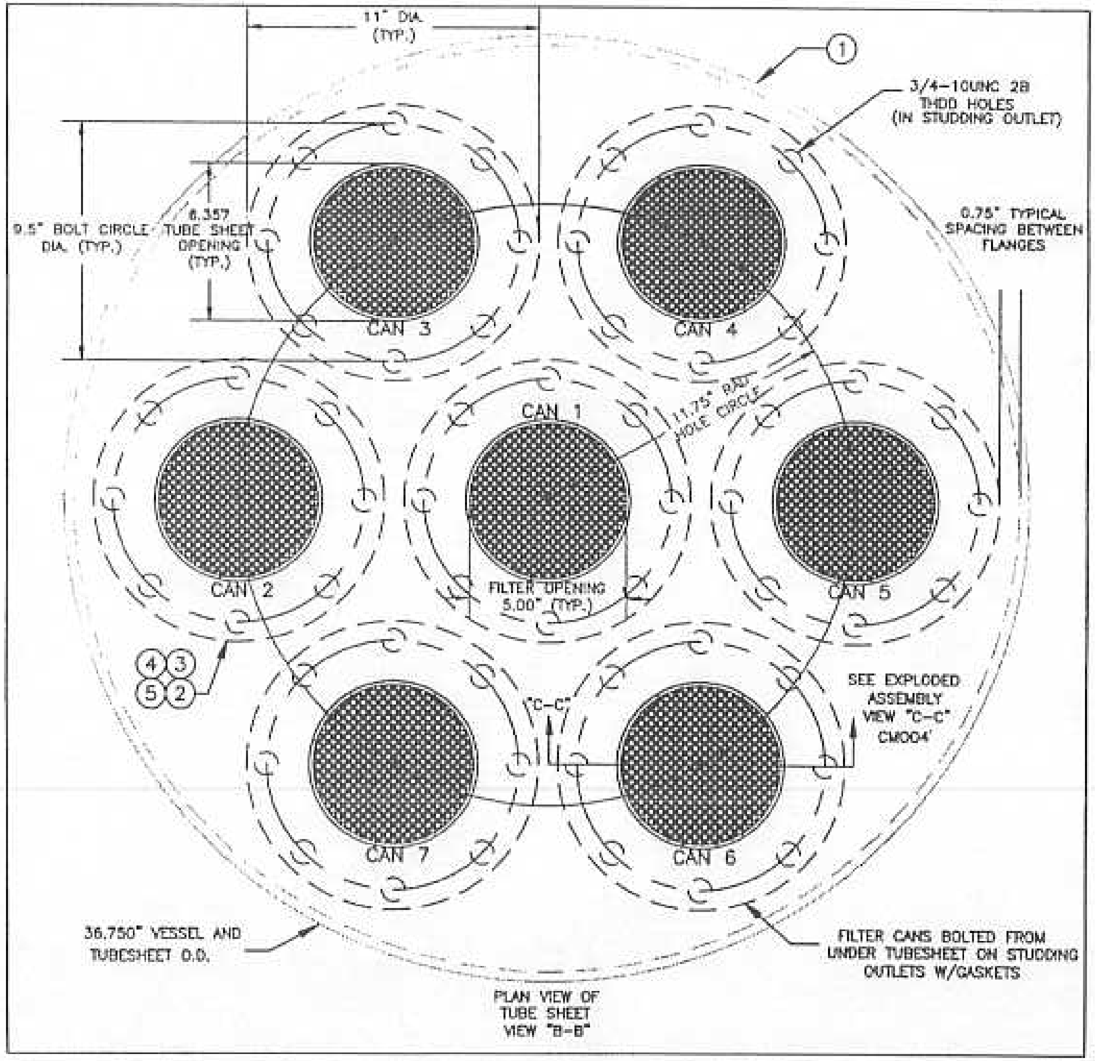
REV	DATE	DESCRIPTION	APP.
1	5/21/01	REVISED VESSEL DESIGN	
0	5/7/00	ISSUED FOR DESIGN REVIEW	

CERAMEM CORP.

WSRC H & V TANK VENT SKID

FILTER CAN

SCALE:	DRWN. BY	DATE	DWG. NO.	REV.
NONE	TAH	5/7/00	CM002	1



BILL OF MATERIALS					
ITEM	QTY.	SIZE	DESCRIPTION	MAT'L	NOTES
1	1	-	TUBE SHEET; 36.75" DIA x .500" THK	304SS	HOLES CUT PER LAYOUT
2	7	6"	FILTER CANS W/150# ATTACHMENT FLANGE	-	SEE DWG CM002
3	7	6"	GASKETS; 1/8" THK	EPDM	
4	56	3/4"	3/4"-10UNC 2A SOCKET HEAD CAP SCREWS; 1 3/4" LG.	SS	7 SETS
5	7	6"	STUDDING OUTLET, 3/4" THK TO MATCH 150# FLANGE, 11" OD x 6.357" 1/16" RF, 3/4"-10 UNC 2B TAPPED THRU THREADS	304SS	SEE DWG. CM004

REV	DATE	DESCRIPTION	APP.
1	5/21/01	REVISED VESSEL DESIGN	
0	5/7/00	ISSUED FOR DESIGN REVIEW	

CERAMEM CORP.

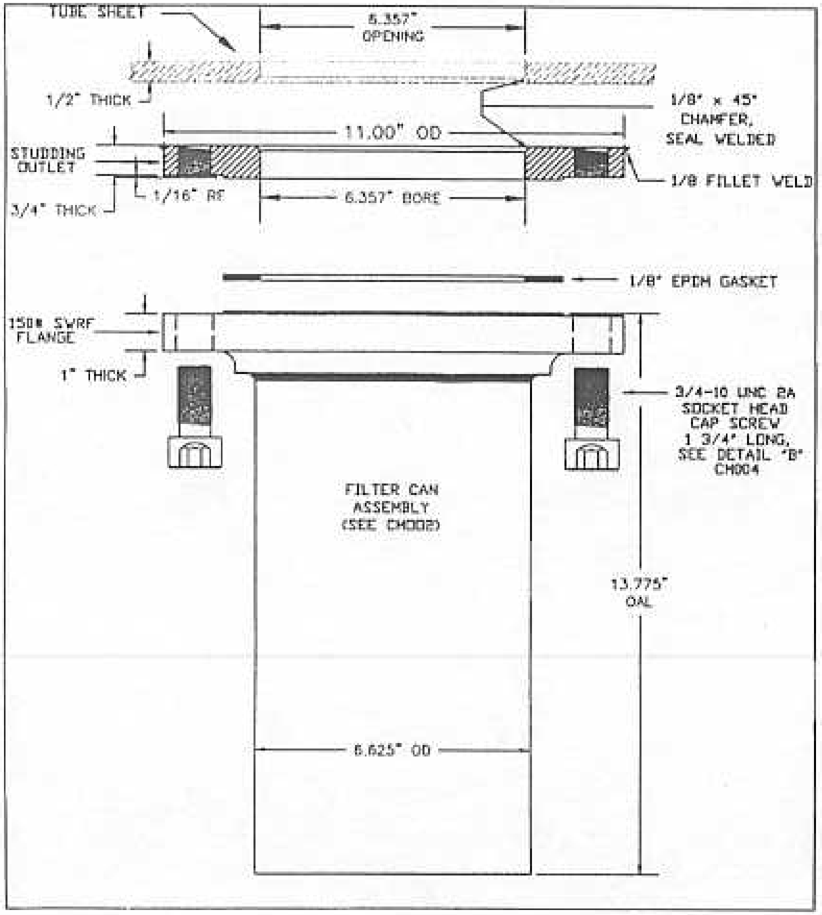
WSRC H & V TANK VENT SKID

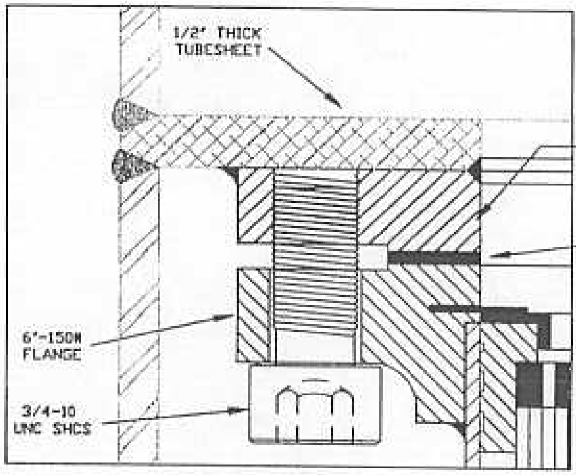
VESSEL TUBESHEET LAYOUT

SCALE:	DRWN. BY	DATE	DWG. NO.	REV.
NONE	TAH	5/7/00	CM003	1

BILL OF MATERIALS					
ITEM	QTY.	SIZE	DESCRIPTION	MAT'L	NOTES

EXPLODED ASSEMBLY OF
TUBESHEET-STUDDING
OUTLET-FLANGED CAN
VIEW "C-C"





BOLTING DETAIL "B"

REV	DATE	DESCRIPTION	APP.
0	5/21/01	REVISED VESSEL DESIGN	

CERAMEM CORP.
WSRC H & V TANK VENT SKID
EXPLODED ASSEMBLY

SCALE	DRWN. BY	DATE	DWG. NO.	REV.
NONE	TAH	5/21/01	CM004	0

III. DESCRIPTION OF ALTERNATE HEPA FILTER SYSTEM AND P&ID

Refer to the Piping & Instrumentation Diagram CM-PI-700. (Located in pocket at end)

Description of Major Process Design Changes

1. The new ceramic HEPA filters, housed in a new CM Filter Vessel are installed into the existing SRS HEPA filter system process between the existing reheater and existing HEPA filter.
2. Process line size between the existing reheater and existing HEPA filter is reduced to 8" to facilitate physical installation of the CM Filter Vessel within the existing skid layout.
3. The existing blower is replaced with a new blower with a higher vacuum capacity at the desired rated flow rates of between 800 and 1100 acfm. Current design utilizes a blower selection capable of delivering 1125 acfm and –47.5" wc vacuum at blower suction. It is anticipated that continued filter development will reduce the blower suction requirements to below this level. The New York Blower Company has provided consultation, sizing and selection of this new blower.
4. The process scheme allows operation of the two HEPA filters in series (at up to –47.5" wc combined pressure drop) or only the existing HEPA filter (at up to –11.5" wc pressure drop). This is achieved by removing the new HEPA filter vessel and replacing it with an 8" pipe spool piece. The selected system blower is provided with a two-speed motor (1750 rpm and 3500 rpm speeds) to allow for these operating modes. This flexibility is provided to allow the system to operate without the CM Filter Vessel in the unlikely event this may be needed.
5. The existing HEPA filter housing will require upgrading to a new reinforced housing to allow operation at the new negative pressure of –60"wc, lower than the current rating of the HEPA filter specified by SRS. The Flanders Filter/CSC Company has confirmed this as a special but achievable design condition for this application.

Description of Ceramic HEPA Filter System and P&ID

This description begins at the discharge of the reheater, where line size is reduced to 8". At the planned flow rates this reduction leads to a negligible increase in pressure drop in the system piping. The ceramic filters and vessel are more fully described in the "Filter and Vessel Descriptions and Drawings" document. Prior to gas flow entering the CM Filter Vessel, a new inlet DOP test connection is provided. The outlet DOP test connection is the existing "inlet" DOP connection for the existing HEPA filter.

The CM Filter Vessel is connected in series with the existing HEPA filter, with two 8" butterfly isolation valves in the inlet and outlet piping. The vessel itself has a mandatory pressure safety element (PSE) to satisfy the ASME pressure vessel code requirement. CeraMem would use a rupture disk located on the clean side of the tube sheet in the vessel. The rupture disk would be set well above the maximum envisioned operating pressure, which will be that of the water and air used for back flush cleaning. Currently, it is anticipated that 10 psig water and air services will be used for back flushing the filter elements to the HLW tank. The rupture disk on the vessel clean side would be set at a 20 psi differential to protect the vessel tube sheet.

[Note: The proposed *in situ* cleaning sequence is discussed further below.]

The CM Filter Vessel and its attendant piping will be insulated and heat traced, as necessary and similarly to the other components in the system, to avoid moisture condensation during operation.

Differential pressure instrumentation on the CM Filter Vessel is similar to that of the existing HEPA filter. Local instrumentation includes a low-pressure differential switch (PDSL), a high-pressure differential switch (PDSH) and a pressure differential indicator (PDI). The PDSL and PDSH have local control panel readout alarms and interlocks to the system blower for shutdown in case of low or high differential pressure. High differential pressure could arise in the event of plugged or inadequately cleaned ceramic filter elements. Low differential pressure could arise in the unlikely event of gross internal mechanical failure of a filter element or CM Filter Vessel tubesheet. Either of these conditions will lead to alarm and system shutdown.

At the discharge of the CM Filter Vessel additional new instrumentation is provided. First is a local temperature indicator (TI) with thermowell (TW). Next is a flow element (FE) with flow transmitter (FT). CeraMem proposes using a calibrated pitot tube connected to a differential pressure transmitter. The gas flow is indicated at the local panel (FI). In case of low flow, an alarm is initiated (FAL). This condition would occur if the ceramic filter elements were plugged or fouled. This is a companion safety feature to the high differential pressure PDSH for the CM Filter Vessel. In case of high flow, an alarm is also initiated (FAH). This condition would occur if the ceramic filter elements or tube sheet were breached. This is a companion safety feature to the low differential pressure PDSL for the CM Filter Vessel. The next new instrumentation is a pressure transmitter (PT) that is tied to a low-pressure alarm (PAL) at the local panel. This instrumentation provides absolute protection against pulling a negative pressure on the existing HEPA filter below the negative pressure rating of the filter housing. This PAL, if activated shuts down the system blower and thus the entire system.

CeraMem believes these safeties protect against any possible system malfunction that could lead to release of radioactivity, assuming the existing HEPA filter is adequately protected. Specifically, CeraMem has considered the following upset conditions that could lead to mechanical failure of the existing HEPA filter:

1. Plugging or fouling of the ceramic filter elements, which could lead to implosion of the existing HEPA filter vessel
2. Mechanical failure within the CM Filter Vessel, which could lead to high flow and high differential pressure across the existing HEPA filter. Note: Several safeties are provided to protect the existing HEPA filter in this instance: PDSL across the CM Filter Vessel, FAH in the system, and the existing PDSH instrumentation on the existing HEPA filter.

The new blower will have a 20 HP, two-speed motor allowing operation at 1750 rpm and 3500 rpm. A suitable blower has been selected and described with relevant system and blower performance curves in the "System Pressure Drop and Blower Calculations" document. At 1750 rpm, flows of about 500 to 750 acfm can be achieved at about –11.5"wc vacuum at blower suction. At 3500 rpm, flows of about 800-1125 acfm can be achieved at about –47.5"wc vacuum at blower suction. As mentioned earlier, this 20 HP blower represents the maximum expected size to overcome filter pressure drop conditions. Optimization of filter pressure drop characteristics is expected to reduce this power requirement. Power draw is shown on the curves at the various possible operating points (Appendix B). Standard motor overload protection would be employed as well as manufacturer's recommended features.

When the system is operated with only the existing HEPA filter, 1750 rpm operation would be selected manually. This could occur during ceramic filter element off-skid cleaning or replacement. At normal operation with the ceramic HEPA filters, 3500 rpm blower speed would be selected.

In situ cleaning would be achieved by the following sequence of steps, expected to be initiated when the pressure drop across the CM Filter Vessel increases from an initial, clean filter value of about 35"wc (current filter design) to a fouled value of about 45"wc. Improvements in filter design are expected to reduce this high-pressure drop characteristic.

1. The system blower would be stopped and the CM Filter Vessel would be isolated.
2. The upper portion of the CM Filter Vessel will be filled with water or a cleaning solution, using the line shown. Water pressure delivered to the CM Filter Vessel is controlled by a pressure control valve (PCV). During filling with water, the CM Filter Vessel bottom discharge valve is kept closed. Air contained in the upper portion of the CM Filter Vessel is displaced manually through the purge line shown until water in the sight glass (SG) is observed, when the purge line valve is closed. The discharge from this purge line is returned through a separate drain line/header to the HLW tank. At this point in the cleaning process, the upper portion of the CM Filter Vessel is water flooded.

   The piping design will be located and sloped such that all excess water can be air purged or drained to the HLW tank and cannot enter the air purge lines or become trapped in dead legs or pockets.
3. The CM Filter Vessel bottom discharge line is opened and water pressure is maintained across the CM Filter Vessel tube sheet. The flush is back to the HLW tank. Once flushing is complete, which can be determined by time or liquid flow rate, for example, the water flush is stopped.
4. Pressurized, filtered air is introduced on the clean side of the CM Filter Vessel tube sheet to displace water in the system to the HLW tank.
5. For final drying of the ceramic filter elements, a warm air purge is anticipated.
6. After drying, the cleaned ceramic filter elements in the CM Filter Vessel can be brought back on line by restarting the blower.

The current design concept for the clean-in-place (CIP) system is to utilize a separate, portable skid. This skid will contain two 100 gallon solution tanks and a10 gpm pump for mixing and delivering the appropriate cleaning solutions to the CM Filter Vessel on the main filtration skid. Solutions will not be returned to the CIP skid but will be discharged from the CM Filter Vessel into the HLW tank. Air purging, heating, and control equipment will also be contained on the CIP skid. The main filtration skid is designed to include the supply and interconnecting cleaning piping with all service connections located on one side of the skid for direct hookup to the CIP skid. Each main filtration skid can have it's own dedicated CIP skid or one or more portable CIP skids can be utilized. The results of ongoing filter cleaning tests will be used to determine the final configuration of the CIP skid.

IV. DESCRIPTION OF ALTERNATIVE HEPA FILTER SYSTEM SKID LAYOUT ARRANGEMENT

Refer to the General Arrangement Drawings CM-GA-800.

The new ceramic HEPA filters, housed in a new CM Filter Vessel, are installed onto the existing SRS HEPA filter system skid immediately following the existing reheater. The vertical mounting of the CM Filter Vessel keeps the filter tubesheet horizontal and allows for up-flow filtering and down flow washing/cleaning through the filters. This will facilitate drainage and cleaning and also eliminates pockets or dead spots. The block valves located before and after the CM Filter Vessel allow for isolation during cleaning. No CM Filter Vessel bypass is included as this is considered to be a potential leakage path for unfiltered air. The location of the CM Filter Vessel is such that removal via forklift is possible from the side after breaking the two major process piping flanges and removing the small diameter piping. The CM Filter Vessel and its attendant piping will be insulated and heat traced, as necessary and similarly to the other components in the system, to avoid moisture condensation during operation.

The incorporation of the filter cleaning piping routed on the skid out to the far side allows for connection to the clean-in-place (CIP) skid. The drain (and rupture disk) piping is brought to the near side to allow direct routing back to the HLW tank.

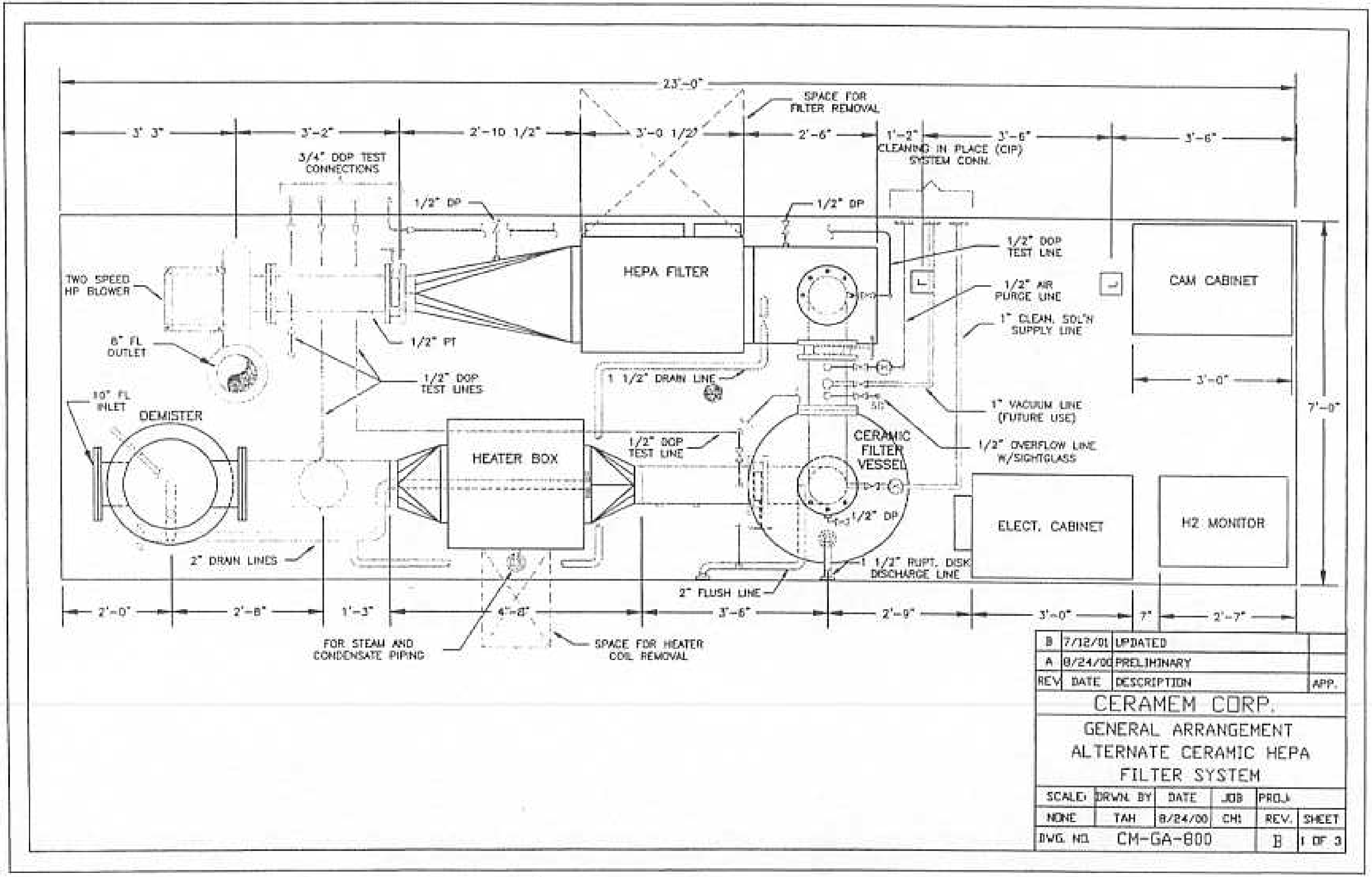
The current design concept is to utilize a separate, portable clean-in-place (CIP) skid system. The main filtration skid is designed to include the supply and interconnecting cleaning piping as shown with all service connections located on the far side of the skid for direct hookup to the portable CIP skid. Each main filtration skid can have it's own dedicated CIP skid or one or more portable CIP skids can be utilized.

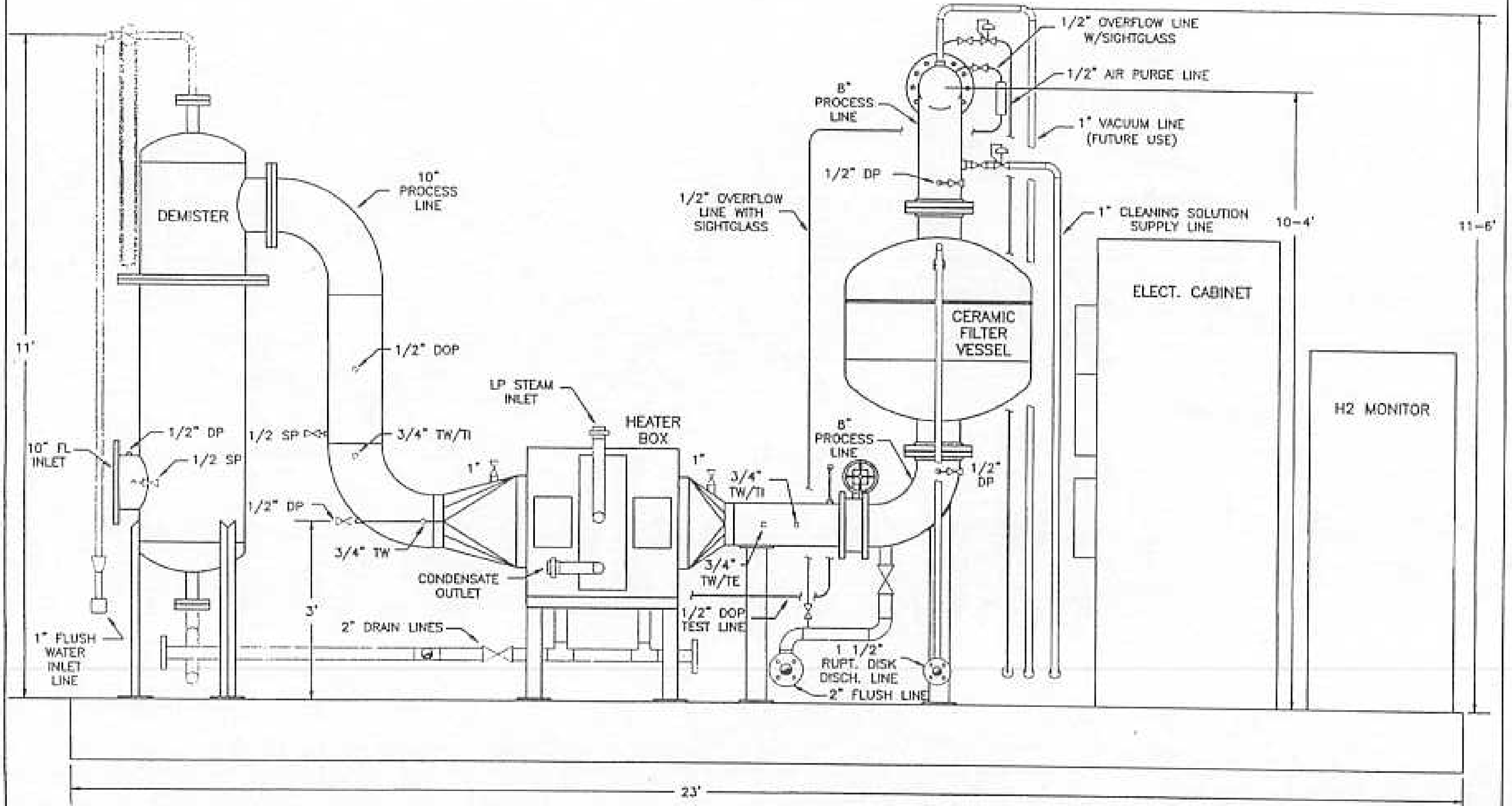
The instrumentation, electrical control and monitoring cabinet end of the skid is unchanged except to incorporate the additional instruments.

The DOP connections, including the added one, are routed to the far side and grouped together.

Access through the middle of the skid is still maintained by the arrangement of the up-and-over routing of the process piping. Process line size between the existing reheater, to the existing HEPA filter, and into the blower suction is reduced to 8" to facilitate physical installation of the CM Filter Vessel within the existing skid layout.

The space occupied by the new larger capacity blower will increase slightly in that area.


23'-0"
SPACE FOR FILTER REMOVAL
3' 3"
3'-2"
2'-10 1/2"
3'-0 1/2"
2'-6"
1'-2"
3'-6"
3'-6"
CLEANING IN PLACE (CIP) SYSTEM CONN.
3/4" DOP TEST CONNECTIONS
1/2" DP
1/2" DP
1/2" DOP TEST LINE
HEPA FILTER
CAM CABINET
TWO SPEED HP BLOWER
1/2" AIR PURGE LINE
1" CLEAN. SOL'N SUPPLY LINE
6" FL OUTLET
1/2" PT
1/2" DOP TEST LINES
1 1/2" DRAIN LINE
3'-0"
10" FL INLET
DEMISTER
1" VACUUM LINE (FUTURE USE)
7'-0"
1/2" DOP TEST LINE
CERAMIC FILTER VESSEL
1/2" OVERFLOW LINE W/SIGHTGLASS
HEATER BOX
ELECT. CABINET
H2 MONITOR
1/2" DP
2" DRAIN LINES
1 1/2" RUPT. DISK DISCHARGE LINE
2" FLUSH LINE
2'-0"
2'-8"
1'-3"
4'-8"
3'-6"
2'-9"
3'-0"
7"
2'-7"
FOR STEAM AND CONDENSATE PIPING
SPACE FOR HEATER COIL REMOVAL
B 7/12/01 UPDATED
A 8/24/00 PRELIMINARY
REV DATE DESCRIPTION APP.
CERAMEM CORP.
GENERAL ARRANGEMENT
ALTERNATE CERAMIC HEPA
FILTER SYSTEM
SCALE: NONE
DRWN. BY TAH
DATE 8/24/00
JOB CH1
PROJ.
REV. B
SHEET 1 OF 3
DWG. NO. CM-GA-800



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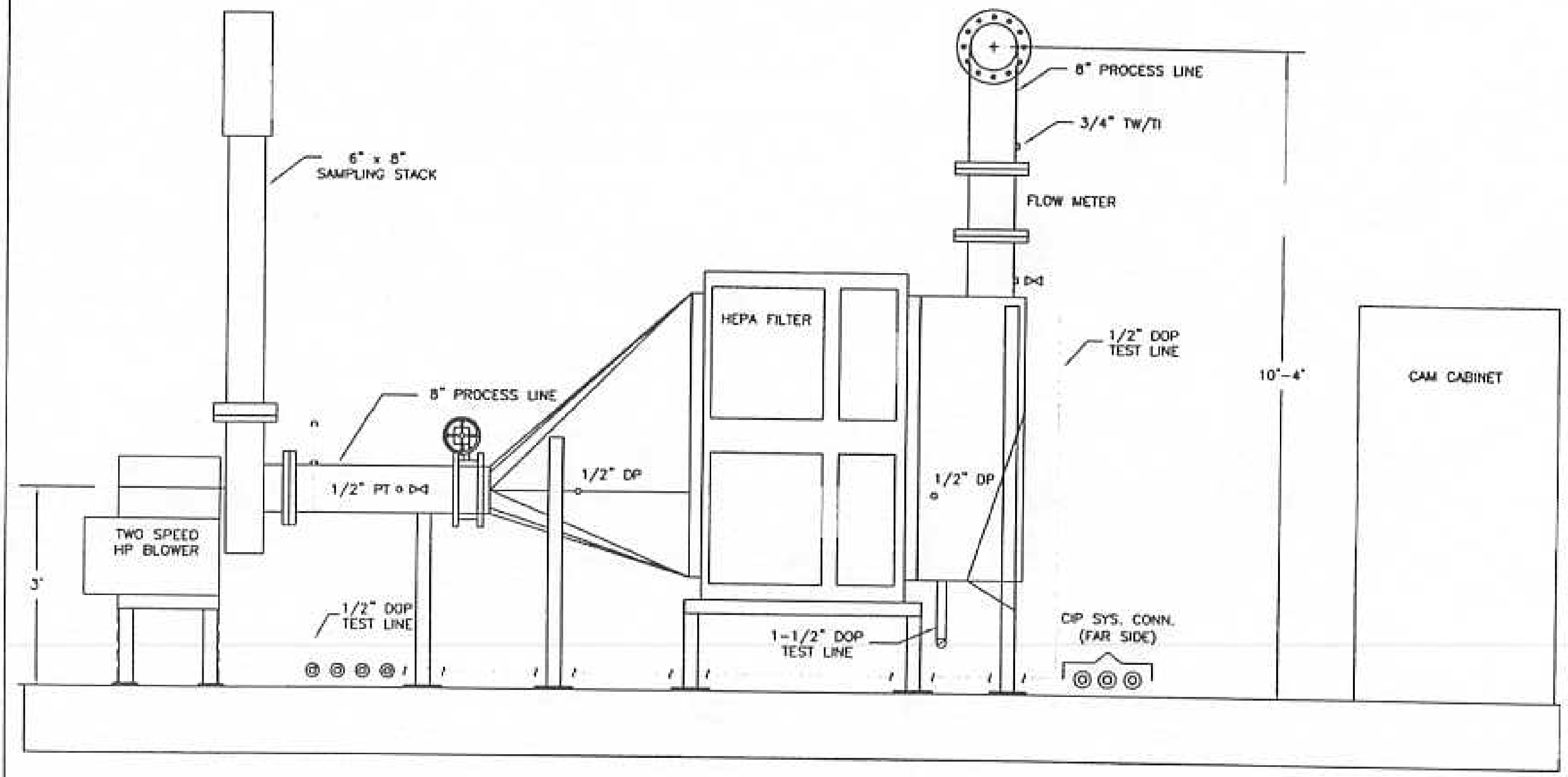
NONE	TAH	7/12/01	CMI	REV.	SHEET
DWG. NO.	CM-GA-B00			B	2 OF 3



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NONE	TAH	7/12/01	CMI	REV.	SHEET
DWG. NO.	CM-GA-800			B	3 OF 3

V. DRAFT ACCEPTANCE TEST PLAN

Overview:

Specification and Standard Hierarchy, Existing Disposable Filter Technology.

The main lead SRS document G-SPP-H-00022 (SPEC022) identifies all the Owner's major system and component requirements in a "plan & spec" format for design, assembly, fabrication, inspection, testing, documentation and delivery of the H&V Tank Skid. This main system SPEC022 references another SRS document M-SPP-G-00243 (SPEC243) for the Owner's detailed and specific design, materials, construction and testing requirements for conventional, glass fiber, disposable type HEPA filters. Also incorporated by reference is the ANSI/ASME Standard N509, which covers the industry's complementary design, materials, assembly, fabrication, inspection, and testing, documentation and delivery requirements for nuclear air cleaning units and components. Both the main SPEC022 and the N509 Standard incorporate by reference, another industry companion standard, ANSI/ASME Standard N510. This standard covers the basis and requirements for developing post-delivery testing programs (excluding acceptance criteria) for installed nuclear air treatment systems. It should be noted that the document ASME AG-1 is referenced in several places and represents the evolution of the two standards N509 and N510 into an ASME Code document. Both now exist concurrently, presumably until the AG-1 document is complete, issued and accepted.

Acceptance Testing Defined.

Standard N509 defines an **acceptance test** as a field test made upon completion of fabrication, receipt and installation of an installed component, air-cleaning unit or system to verify that it meets the requirements specified. This test is distinguished from two other tests: (1) a performance test or (shop) production test, made on an individual item or lot of product to verify its performance in accordance with specified requirements; and (2) a qualification test which is generally made on a (shop) prototype or production lot sample to establish the suitability of a component or item for a given application. A post acceptance surveillance test is also used and defined as an in-place (field) leak test and visual inspection performed periodically to establish the current condition of a nuclear air treatment system and its components.

Applicability to New Regenerable Technology Filters and Related Ducts and Housings.

The major change to this project, and its defining specs and standards, is the substitution of CeraMem's novel, regenerable, ceramic HEPA filter for the traditional, disposable media HEPA filter. The information, discussion, requirements and criteria presented herein are therefore limited to these, new technology HEPA filters and any directly related ducts, piping, frames, tube sheets, vessels and housings. The testing plans for the remaining standard system process components (i.e. blower, heater, moisture separator, etc.) would be identical since their basic designs are unaffected by filter technology (with the exception of size and capacity changes).

Acceptance Testing and Criteria, New Regenerable Filter Technology.

Table AT-1 provides proposed acceptance testing for the new ceramic HEPA filter system. The final acceptance criteria will be developed during detailed design and provided by CeraMem. As noted earlier in 1.0, Standard N510 states its scope covers post-delivery testing of installed systems and that Standard N509 scope covers pre-delivery testing of individual components.

	Test	General Purpose of Test	Proposed Acceptance Test - Criteria Provided by Designer/Engineer		N509 References.	N509 Pre-Delivery Shop Test Req'ts	Spec H-00022 Pre-Delivery Shop Test Req'ts
			SHOP Test	**Criteria**			
	P&ID Walkdown	to verify all components are installed per the design	physically walk down all components and devices to compare with P&ID and other drawings to verify installation is complete and in accordance with design	no discrepancies, all must be resolved before proceeding			
			SHOP Test	**Criteria**			
	Electrical Continuity Test	to verify all wiring is correct and in accordance with drawings	conduct standard electrical continuity check of all wiring	no wiring errors, all discrepancies must be corrected before proceeding			
			SHOP Test	**Criteria**			
	System Functional Test	to verify all components are in working, functioning order	operate all devices either manually or automatically; stroke all valves, bump all motors, test all alarms and safeties	all devices must function as intended, all discrepancies must be corrected prior to proceeding			
N510 Section	per N510	per N510	**SHOP Test**	**Criteria**			
6.2.1	Duct/Piping and Housing/Vessel Structural Capability Test	to verify no unacceptable distortion at certain upset conditions	1) isolate the inlet system up to the ceramic filter inlet (test entire system if isolation is not practical) and evacuate to -4"wc and examine all equipment and ducts for distortion or breach of boundary;	at 1.25 x max. operating vacuum: no visible distortion, safeties function	4.2 design parameters	per para 5.10.8.2 same shop acceptance test req'd	per para 4.2.2.2 same shop acceptance test req'd
			2) isolate ceramic filter vessel at inlet valve and evacuate downstream side to -60"wc, observe lo P trip and examine filter housings for distrotion or breach of boundary.	at 1.25 x max. operating vacuum: no visible distortion, safeties function			
	N510	per N510	**SHOP Test**	**Criteria**			
6.2.2	Duct/Piping and Housing/Vessel Leak Test	to verify external leakage from vessel is below acceptance criteria for normal operation	1) evacuate the entire system to -3.5"wc and examine all equipment and ducts for leakage	method and acceptable leak per N510 at 1.15 x max. operating vacuum	4.2 design parameters, 4.6.4 leak test pressures, 4.14 pressuure boundary leakage	per para 5.6.5.4 same shop acceptance test req'd	per para 4.2.2.2 same shop acceptance test req'd, also per ANSI B31.3 Code shop piping leak test req'd
			2) isolate ceramic filter vessel at inlet valve and evacuate downstream side to -55"wc and examine equipment for leakage	method and acceptable leakage per N510 at 1.15 x max. operating vacuum			

	Test	General Purpose of Test	Proposed Acceptance Test - Criteria Provided by Designer/Engineer		N509 References	N509 Pre-Delivery Shop Test Req'ts	Spec H-00022 Pre-Delivery Shop Test Req'ts
		to verify external leakage from vessel is below acceptance criteria for cleaning cycle operation	3) isolate the ceramic filter vessel from inlet valve to outlet valve and pressurize to 23 psig and examine all equipment and ducts for leakage	method and acceptable leak per N510 at 1.15 x max. cleaning pressure	4.2 design parameters, 4.6.4 leak test pressures, 4.14 pressure boundary leakage	per para 5.6.5.4 same shop acceptance test req'd	per para 4.2.2.2 same shop acceptance test req'd, also per ANSI B31.3 Code shop piping leak test req'd
	N510-Optional	per N510	**SHOP Test**	**Criteria**			
7.1	*Mounting Frame/Tubesheet Pressure Leak Test*	*to verify leakage across frame/tubesheet is below acceptance criteria*	*performed during ceramic filter manufacutring assembly process; filter can and tube sheet seals wil lbe tested as an integral assembly with filter, due to mounting techniques and seal design this test requires further definition at detailed design.*	*method and acceptable leakage TBD*	*5.6.5.3 defines critical frames (tubesheet) to be tested, 4.6.4 leak test pressures, 4.14 pressuure boundary leakage*	*per para 5.6.5.3 same shop acceptance test req'd*	*per para 4.2.2.2 same shop acceptance test req'd*
		per N510	**SHOP Test**	**Criteria**			
8.1	AirFlow Capacity and Distribution	to verify under act'l field conditions, design flows at min/max HEPA dP, and verify airflow uniformity at HEPA	1) operate completed system by running fan at 3500 rpm and observing clean filter operating flow and pressure pts.; vary flow with damper to simulate dirty filter loading flow conditions. Flow distribution within the vessel is not an issue with the ceramic filter.	design operating pt. is - 47.5"wc at between 800 and 1125 acfm flow, compare to system curve	4.2 design parameters, 4.14 pressuure boundary leakage	per para 5.6.5.5 same shop acceptance test req'd	
			FIELD Test	**Criteria**			
			2) operate completed system by running fan at 3500 rpm and observing clean filter operating flow and pressure pts.; load filter with simulated waste stream and observe flow and dP conditions	TBD by SRS and CM			
	N510	per N510	**FIELD Test**				
9.1	Air-Aerosol Mixing Uniformity	prerequisite to Sect. 10 tests, to verify challenge gas is uniform at HEPA	to verify challenge gas is introduced to provide uniform mixing approaching HEPA filter. May not be possible due to the closed, sealed construction of the ceramic filter vessel (filters are not field removable).	TBD by SRS and CM	4.2 design parameters	per para 5.6.5.6 same shop acceptance test req'd	
	N510	per N510	**FIELD Test**				
10.1	In-Place HEPA Leak Test	to determine HEPA performance via in-place DOP penetration tests	to field verify max. allowable penetration in final installed configuration.	TBD by SRS and CM	4.2 design parameters		
	N510	per N510	**FIELD Test**				
14.1	Air Heater Performance Test	to verify air heater meets performance specs	to field verify temperature rise at design airflow rate by operating steam heater with varying air flows.	TBD by SRS and CM	4.2 design parameters, 5.5 air flow/velocity		
			FIELD Test				
	CIP System Performance Test	to insure system delivers flows and pressures required to clean filters	hook up and operate each service and verify results per established procedure (TBD)	TBD by SRS and CM	4.2 design parameters		

Further, the main SPEC022 states in paragraph 4.2.2.2 that: "The Supplier shall perform acceptance testing as described in Standard N509 in accordance with the procedures of Standard N510 for the duct and filter housing assembly." This is interpreted to mean that a pre-delivery initial "acceptance" test is required in the supplier's shop using the acceptance test procedures and criteria to verify assembly, structural capability, leak tightness and functionality. Further field "acceptance" testing is then required to verify shop tests and to further demonstrate performance on air-aerosol (DOP) mixing and removal are anticipated and included in the plan. Table AT-1 reflects this interpretation between SHOP and FIELD "acceptance" tests. This plan and Table AT-1 further delineates "acceptance" to exclude any performance guarantee and any simulated or actual waste testing as part of the acceptance criteria or process. Any post-delivery, post "acceptance" of the installed system, will be performed by the Owner at SRS discretion and in accordance with all the applicable requirements and criteria of Standard N510 and any additional requirements established for this purpose. CeraMem will support any further testing of this nature beyond its "acceptance" test plan commitment if desired by SRS.

Insuring a successful acceptance test starts with successfully making ceramic filters. This section outlines the in-process, quality control and acceptance test practices and procedures for the ceramic filters used in this alternative HEPA filter system. The block flow diagrams provided show the three major elements of the in-process and acceptance test procedures and practices employed and planned for this project. These include:

In-Process Tests for the HEPA Filter Elements (through "Filter Canning")

Shop Fabrication Tests of the Assembled Alternative HEPA Filter Vessel

Shop and Field Acceptance Tests (including tests at SRTC)

Flow Charts FC-1 and FC-2 provide the manufacturing and testing sequence currently planned by CeraMem for the ceramic HEPA filter elements and the filter-vessel assembly, respectively. This in-process "acceptance testing" of the ceramic filters as they progress through the manufacture and assembly process into cans, onto the tube sheet and ultimately into the vessel, will ensure that the final acceptance testing of the system in accordance with Table AT-1 will be successful.

In-Process Manufacturing and Tests for the HEPA Filter Elements through Canning, FC-1

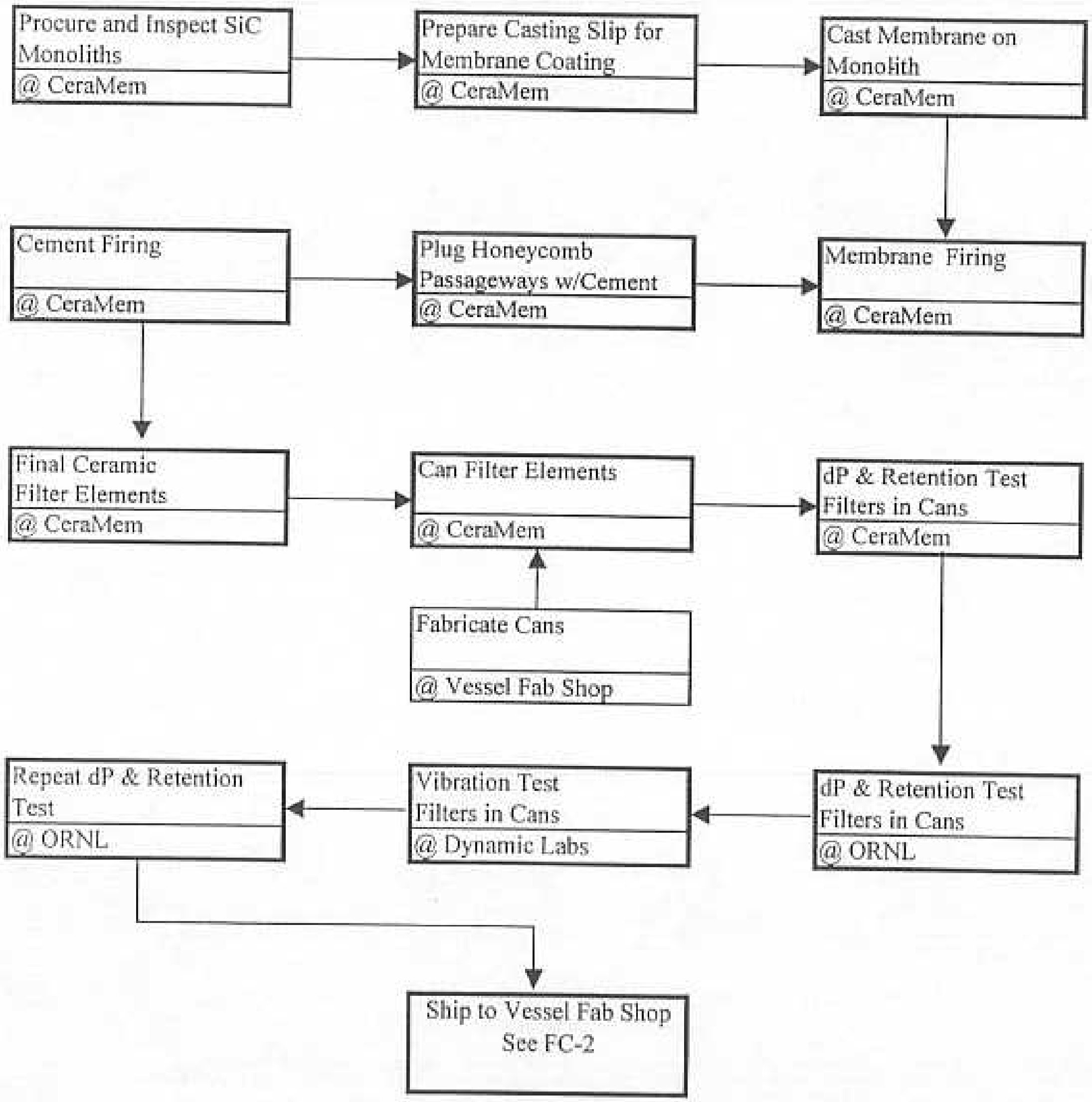
CeraMem's in-house HEPA filter process and product quality control procedures require the following steps be taken to manufacture quality ceramic filter elements:

Procure and Inspect Silicon Carbide (SiC) Monoliths

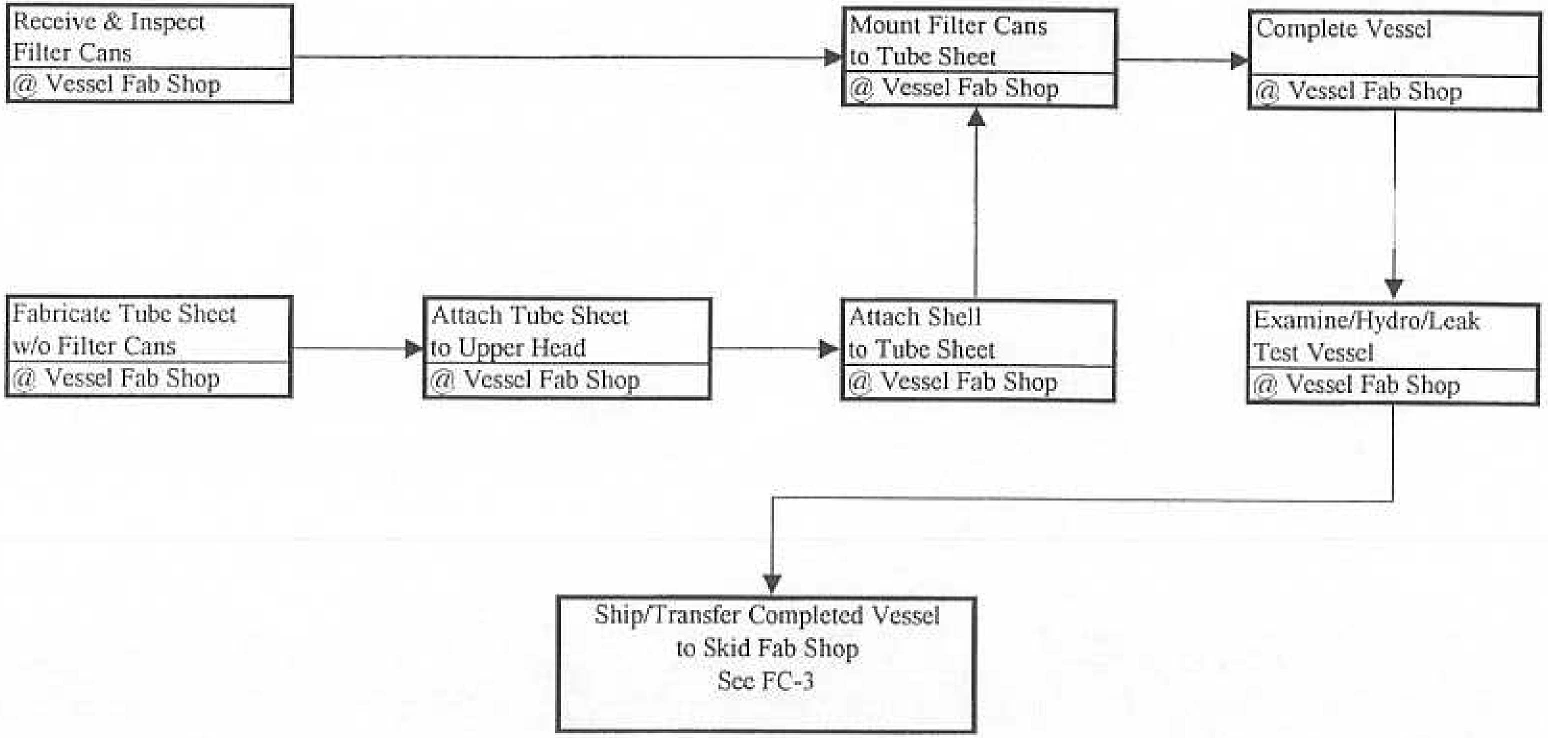
Monoliths are procured based on a specification and are subsequently inspected to that specification upon receipt. The inspection includes dimensional measurements, a non-destructive internal defect test, and material properties evaluations. The dimensional measurements include length, diameter, out-of-roundness, honeycomb passageway size, and passageway wall thickness. The defect test consists of pouring a nominal 40-micron diameter graphite powder into every other passageway in the monolith. A mask is used to get the graphite into the correct passageways. If the graphite leaks into one of the adjacent cells then that passageway is defective and is marked as such. No more than one defective cell is allowed. Materials properties that are measured include strength and pore size.

Flow Chart FC-1

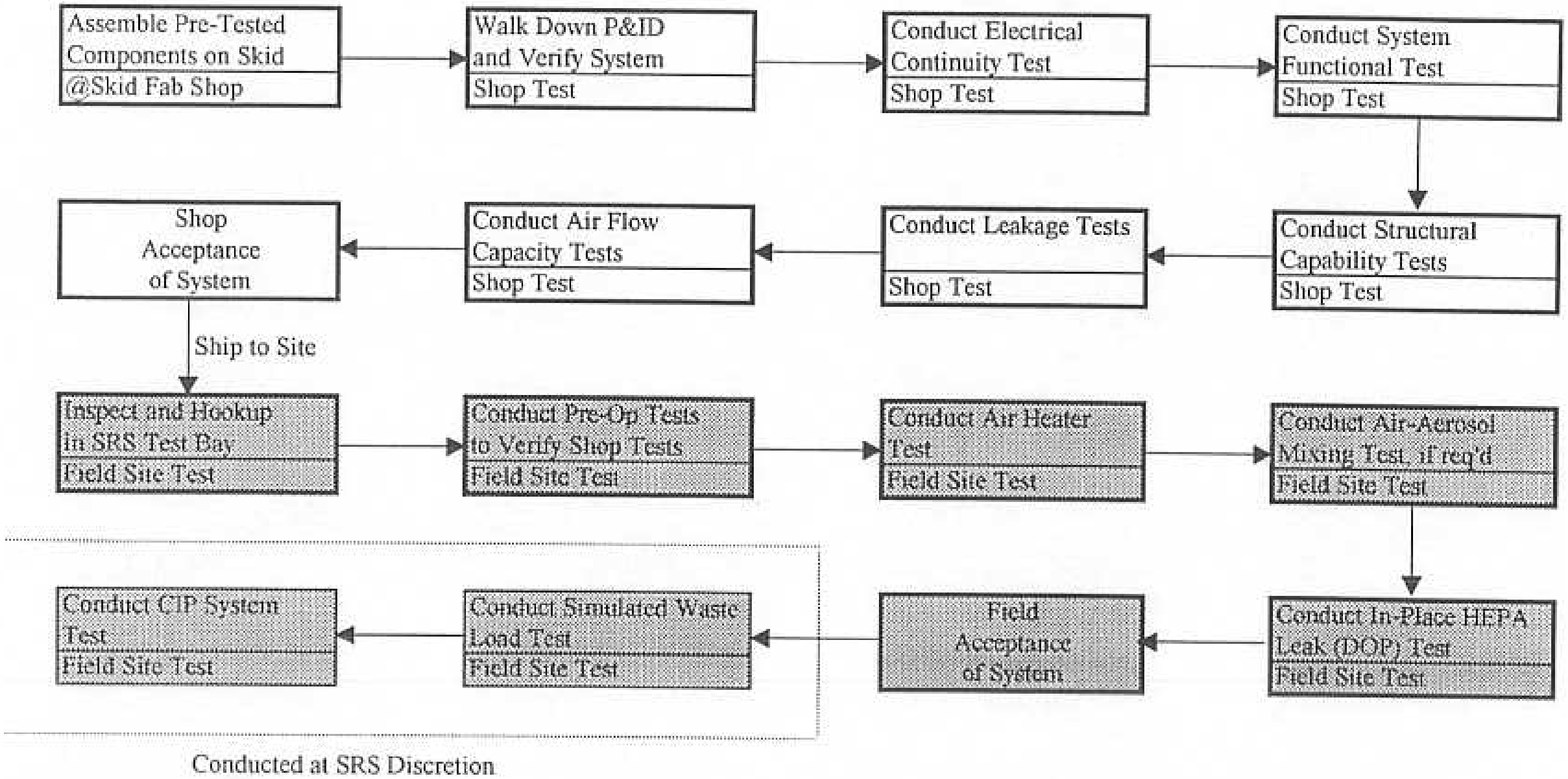
In-Process Filter Manufacturing and Testing for the HEPA Filter Elements



Flow Chart FC-2
Ceramic Filter Vessel Manufacturing and Test Sequence Flow Chart
Alternate Ceramic HEPA Filter Project



Flow Chart FC-3
Ceramic Filter Skid Testing Sequence Flow Chart
Alternate Ceramic HEPA Filter Project



Prepare Casting Slip for Membrane Coating

Each batch of casting slip is checked for viscosity, specific gravity, and pH in order to ensure proper slip preparation.

Cast Membrane on Monolith Honeycomb

Both visual and quantitative measures are made to ensure proper coating of the membrane on the monolith. After coating, the membrane is checked visually to ensure correct and uniform coating of each passageway. In addition, the mass uptake of the membrane coating is measured to track uniformity from part to part.

Membrane Firing

For each lot of membrane filters, the firing profile is recorded both by computer data logging and by the use of pyrometric cones. Review of the time-temperature profile as well as the shape of the pyrometric cones after firing ensures that the filters have been properly fired. Any deviations from the correct firing profile can be detected. In addition, the filters themselves are visually evaluated and the mass after firing measured to ensure good quality membrane coatings were prepared.

Plug the Honeycomb Passageways with Cement to Prepare Dead-ended Filters

The cement for plugging channels is prepared and visually inspected to ensure the proper consistency. The passageways are plugged using similar masking technology as in the graphite test. Once both sides of the honeycomb monolith are plugged, the plugs are checked to ensure no light can be seen through the passageways and the length of the plugs is checked to ensure proper depth penetration into the passageways. Plugging of defective cells detected earlier is accomplished at this time.

Cement Firing

Similar to membrane firing.

Fabricate Cans and Can Filter Elements

The filter cans (housings) are procured and fabricated according to the engineering drawings as part of the CM Filter Vessel procurement process. Inspections of components are performed upon receipt. After installation of a filter into a can, the end seals are inspected to look for any indication of seal or housing damage.

Differential Pressure and Retention Test Filters in Cans (at CeraMem)

Each filter assembly is tested for pressure drop as a function of air-flow face velocity and retention quality. The gas flow pressure drop must be less than 40" wc at 10 ft/min face velocity in order to meet acceptance criteria. Retention is measured by flowing a known volume of turbid SiO_2 suspension through the filter. The suspension consists of water and 1.5-micron SiO_2 particles at a concentration equivalent to 800 normal turbidity units (NTU). The filter must have at least 99% retention of SiO_2 based on turbidity before it is shipped for aerosol testing. Excess SiO_2 is flushed out of the filter before shipping.

Differential Pressure and Retention Test Filters in Cans (at ORNL)

Filters will be tested by AIR TECHNIQUES International (ATI), which operates the Oak Ridge Filter Test Facility for DOE to test HEPA filter elements for pressure drop and DOP retention. Only filters that demonstrate, in ATI tests, retention of >99.97% at rated flow and 20% of rated flow will be accepted for inclusion in the HEPA filter system. Further, a final maximum pressure drop (to be determined in current filter tests) at rated flow will be set as a pass/fail criterion.

Vibration Test Filters in Cans

Each of the canned filters will be shipped to a vibration-testing laboratory that will conduct a transportation-vibration test to simulate rough conditions during shipment and handling. This test will be conducted in accordance with MIL STD 810E, test method 514.4, category 1. After consultation with Dynamic Labs of Phoenix regarding the performance of an initial "rough handling" test per AG-1, they have provided a proposal and proposed this method as a substitute to the AG-1 requirement. It was suggested that the "rough handling" test was an older test performed using an out-dated machine that is not readily available to laboratories. Dynamic Labs will provide a test procedure, a filter visual inspection and a test report.

Repeat Differential Pressure and Retention Test Filters in Cans (at ORNL)

Following the vibration test, a repeat performance test will be conducted by ATI to insure that no damage was sustained in the vibration testing.

Shop Fabrication and Tests of the Assembled Alternative HEPA Filter Vessel, FC-2

Receive and Inspect Filter Cans

Upon receipt at the vessel fabrication shop, a visual inspection of the filters in cans will be conducted prior to proceeding.

Fabricate Tube Sheet w/o Filter Cans

The tube sheet will be fabricated to the engineering drawings and dimensionally inspected.

Attach Tube Sheet to Upper Head

The upper head of the vessel will be assembled per the engineering drawings and the tube sheet will be welded to this assembly along the outer circumference.

Attach Shell to Tube Sheet

The upper head with the tube sheet attached (welded) will then be attached to the shell section of the vessel per the engineering drawings. The second circumferential weld will then be completed at the tube sheet section. This two-step, two-weld process allows for welding near the ceramic filter seals to be conducted without the filters and seals being exposed to high detrimental heat during welding.

Mount Filter Cans to Tube Sheet

The pre-tested filters in cans will be attached (bolted) to the studding outlets on the tube sheet. No tube sheet penetration holes are used for bolting in this design. This assembly process prevents heat from welding the tube sheet from reaching the seal area of the cans and tube sheet.

The gasketed joints are inspected visually prior to closing in the vessel. An appropriate leakage test for this gasketed joint will be developed during the detailed design phase.

Complete Vessel

The vessel will be completed per the engineering drawings thus sealing the ceramic filters within the vessel.

Examine/Hydro/Leak Test Vessel

The completed vessel will be inspected, examinations, hydrotested and leak tested as required by the procurement specifications to insure the vessel meets the code and specification requirements.

Shop Fabrication Tests of the Assembled Alternative HEPA Filter Skid and Final Field Acceptance Test, FC-3

Walkdown P&ID and Verify System

Following completion of the assembly operations, the HEPA filter skid in it's entirety will be walked down to visually verify all components, lines, connections, instruments, valves, parts and pieces are installed in accordance with the P&ID. A Punch List will be generated and all discrepancies will be corrected or resolved before proceeding. An "as-built" P&ID will be generated and approved.

Conduct Electrical Continuity Test

All wiring will be inspected for completeness, markings and routing per the electrical drawings. All terminations will be inspected for tightness and security. "As-built" wiring drawings will be generated and approved. An electrical continuity test will be performed and documented on all permanent skid wiring as well as any temporary test wiring hookups. Any failures or discrepancies will be corrected prior to proceeding.

Conduct System Functional Test

Each component on the skid will be operated to demonstrate that it functions when receiving it's motivating signal whether manual or automatic. Some simulations may be required to artificially drive certain components to perform their function such as instrument trips. This will include motor rotations, valve stroking, instrument signals and trips. Any item that cannot be functionally checked during this phase will be checked at the beginning of an appropriate subsequent test. A Check List will be developed and all tests results will be recorded. Any non-functioning items will be corrected prior to proceeding.

Conduct Structural Capability Test

A two step structural capability test will be performed to verify the structural integrity of the system. No visible distortion is permitted, structural weaknesses discovered must be corrected prior to proceeding. The low vacuum inlet side will be tested first, followed by the higher vacuum outlet side. Test pressures will be 1.25 times maximum operating vacuum in the section. A Test Report will be generated.

Conduct Leakage Test

A two step leakage test will be performed to verify the leak tightness of the system. Leak test method and quantitative leakage criteria will be developed in the detailed design phase. Any leakage from locations above the criteria will be corrected prior to proceeding. The low vacuum inlet side will be tested first, followed by the higher vacuum outlet side. Test pressures will be 1.15 times maximum operating vacuum in the section. A portion of the system will see positive pressures while in the cleaning mode. These sections will also be pressure tested and verified. A Test Report will be generated.

Conduct Air Flow Capacity Test

This final shop test will involve operating the entire system with the blower operating at 3500 rpm. The actual system clean filter resistance and blower performance curves will be compared to the detailed design curves for operation at various flow and vacuum conditions. The steam air reheater will not be tested for performance in the shop, see reheater test below. A Test Procedure with acceptable flows, vacuums and pressure drops will be developed during the detailed design phase. The CM Filter Vessel will be removed and replaced with the replacement spool piece and a 1750 rpm flow vs. vacuum test will also be conducted.

Shop Acceptance of System

Acceptance of the satisfactory performance of the mechanical and electrical functioning of the Alternative HEPA Filter Skid prior to shipment from the site of manufacture it will be deemed "shop accepted". On this basis, the following procedures are envisioned to take place at SRTC.

Field Acceptance of System

Following receipt and any re-assembly of the HEPA filter skid, DOE will install it at the test facility at SRTC in accordance with CeraMem's interface drawings. It is anticipated that system checkout tests will be conducted by SRTC to assure satisfactory mechanical and electrical performance of the system. This testing will duplicate, to the extent DOE deems necessary, the Shop Acceptance Tests. In addition, the steam air reheater will be tested to verify performance in accordance with design.

Once the system shows satisfactory mechanical and electrical operation, an aerosol challenge test will be performed using the SRS site aerosol challenge test. This will be either a DOP or poly(alpha olefin) aerosol challenge test. The filter system will be deemed to have passed the Field Acceptance Test if it shows >99.97% retention of the challenge aerosol at an ambient air flow of 500-800 ACFM.

Demonstration of the system to meet this HEPA filter retention standard at rated flow and pressure drop will constitute Final Acceptance of the HEPA filter system.

Appendix A

Alternative HEPA Filter Vessel Specifications

Procurement Specification

for the

Alternate Ceramic HEPA Filter Vessel

at
Savannah River Site (SRS)
H&V Tank Vent Skid Project
by
Westinghouse Savannah River Company (WSRC)

CeraMem Corporation Document

Rev:	Date:	Issued For:	Prepared By:	Approved By:
0	6/5/01	Internal Review and Approval	Phillip D. Paquette	
1	7/23/01	Client Design Review	Phillip D. Paquette	

Table of Contents

1.1 GENERAL

1.1.1. This specification describes the requirements for design, materials and fabrication of an all stainless steel filter vessel, tube sheet and cans for housing and mounting ceramic filters.

1.1.2. The attached Data Sheet and reference Drawings together define the specific requirements for the stainless steel vessel, tube sheet and ceramic filter cans.

1.1.3. The filter vessel is intended for outdoor, unsheltered service at:

1.1.3.1. 0 F to 120 F,

1.1.3.2. 100% RH,

1.1.3.3. 325 ft above sea level.

1.1.3.4. with a low level of radiation in the immediate environs and with radioactive particulate in the fluid air stream being filtered.

1.1.4. The function of the filter vessel with its horizontal tube sheet is to hold ceramic filters in a vertical up flow filtering position which creates a dirty air plenum beneath the filters and a clean air plenum above the filters.

1.1.5. The filter vessel design also provides for in-place cleaning of the filter elements by back flushing with water, caustic cleaning solution and air from the clean side plenum through the filters and into the dirty plenum.

1.2. SCOPE

1.2.1. Scope of Work Included.

1.2.1.1. Design and fabricate the stainless steel vessel per the ASME Code Section VIII. Fabricator shall perform all Code Calculations required to confirm or revise the Buyers design based on economics and ease of fabrication subject to Buyer's approval.

1.2.1.2. Design and fabricate the tube sheet and studding outlet mounting arrangement including attachment gaskets and socket head cap screws. Fabricator shall optimize design of the tube sheet-studding outlet arrangement based on economics and ease of fabrication subject to Buyer's approval.

1.2.1.3. Design and fabricate seven stainless steel filter cans with all snap and retaining rings. Filters and filter seals are excluded.

1.2.1.4. Select, supply and install a rupture disk assembly based on the criteria contained herein.

1.2.2. Exclusions.

1.2.2.1. Buyer will supply ceramic filters, boot seals, potting materials and labor to can filters.

1.2.2.2. Insulation and heat tracing will be provided by Others

1.2.2.3. External piping supports, gaskets and hardware for external piping connections will be provided by Others.

1.3. RELATED DOCUMENTS

1.3.1. WSRC and SRS Standard Procurement Specification G-SPP-H-00022 for the H&V Skid, Rev 0, 9/15/99.

1.3.2. ANSI N509 Nuclear Power Plant Air Cleaning Units and Components, 1980

1.3.3. CeraMem Corporation Document – Filter and Vessel Description and Drawings.

1.4. CODE REQUIREMENTS

1.4.1. Vessels shall be designed constructed in accordance with this specification and the requirements of the ASME Boiler & Pressure Vessel Code, Section VIII, Division 1, and stamped with the ASME "U" symbol and registered with the National Board.

1.4.2. Vessels shall comply with the requirements of South Carolina where the vessel will ultimately be installed.

1.4.3. All welding procedures and welding operators shall be certified in accordance with ASME Code, Section IX.

1.4.4. Nondestructive examination procedures shall conform to the requirements of ASME Code, Section V.

1.5. SUBMITTALS

1.5.1. Fabricator shall submit to Buyer: Vessel Drawings, Code, Tube Sheet, Over Pressure Calculations, Welding, Fabrication and Test Procedures and Other Documents as required herein for review and approval prior to fabrication or use.

1.6. DESIGN AND FABRICATION

1.6.1. Vessel

1.6.1.1. The vessel shall be designed in accordance with the attached Filter Vessel Data Sheet.

1.6.1.2. The vessel shall be designed to operate in the normal air filtering up flow mode followed by periodic in-place down flow cleaning with water, caustic solution and air as the cleaning fluids.

1.6.1.3. The vessel heads shall be ASME elliptical with an OAH specified and of a seamless design.

1.6.2. Tube sheet

1.6.2.1. The Fabricator shall perform a tube sheet analysis and an optimization of the tube sheet design and fabrication based on the Drawings and the following requirements and submit to Buyer for review and approval. The tube sheet design shall sustain the following loads while maintaining leak tightness and having no permanent detrimental deformation.

1.6.2.2. filter can dead weight,

1.6.2.3. pressure differential of 50"wc vacuum encountered during normal filtration from dirty (high) to clean (low) side plenums,

1.6.2.4. pressure differential of 20 psi encountered during cleaning from clean (high) to dirty (low) side plenums.

1.6.2.5. The tube sheet shall incorporate a drilled and tapped tube sheet or a studding outlet (no through holes for bolting) as shown on the Drawings. The ½" thick tube sheet shown on the Drawings is an estimate and is to be confirmed on adjusted based on Fabricator's analysis. The tube sheet design may be incorporate stiffener or braces to achieve objectives

1.6.2.6. The tube sheet shall be welded integral with the top head-to-shell course circumferential weld as shown on the Drawings.

1.6.3. Nozzles

1.6.3.1. Nozzles shall be designed and reinforced as required by Code and shall not project beyond the inside of the shell or head.

1.6.4. Handholes and Manways

1.6.4.1. Handholes and manways are not preferred, but if required by Code shall be minimized and equipped with a flanged cover and hinge if necessary and an o-ring seal designed such that no crevices are formed when the cover is closed.

1.6.5. Vessel Lugs and Supports

1.6.5.1. Three lifting lugs shall be attached to the top head. Design shall allow for initial lifting and subsequent removal with a single hook lifting device. Lugs shall be stainless steel.

1.6.5.2. Vessel shall be provided with three pipe style support legs, designed to support the full vessel weight and for bolting to a skid with a foot pad. Legs shall be stainless steel.

1.6.6. Overpressure Protection

1.6.6.1. Fabricator shall perform an over pressure analysis based on the following paragraphs and submit to Buyer for review and approval.

1.6.6.2. The vessel operates on the suction side of a blower at between atmospheric and various vacuum conditions. The vessel is designed for full vacuum (407"wc vacuum) with a worst case maximum vacuum of 50"wc possible from the blower. System instruments will also limit vacuum levels in the vessel. No additional vacuum protection is required or provided.

1.6.6.3. The vessel is over-designed for an internal pressure of 150 psig. During in place cleaning with air and water injected from the clean side plenum, pressures of 10 psig are expected. Each service will provide relief protection to limit pressures from exceeding 15 psig. In the unlikely event that these devices fail, the vessel clean side plenum shall be equipped with a flanged 20 psi rupture disk sized based on the following conditions:

1.6.6.3.1. air to the clean side plenum at 20 psig and 20 scfm.

1.6.6.3.2. water to the clean side plenum at 20 psig and 10 gpm.

1.6.6.3.3. An external fire analysis shall also be performed to determine if this condition governs. The vessel is assumed to be isolated with no flow, and containing ambient air at atmospheric pressure. The ceramic filters will withstand high heat (2000 F) but the elastomeric seals shall be assumed to fail and connect the clean and dirty side plenums (no tube sheet differential) in this circumstance.

1.6.6.4. A 1 ½" flanged nozzle (resized if necessary) on the clean side plenum has been allowed for this over pressure device. Fabricator to provide flanged rupture disk assembly.

1.6.6.5. External piping from the rupture disk outlet will be provided by Others.

1.6.7. Welding

1.6.7.1. All internal welds shall be ground flush and finished consistent with the surface finish shown in the Data Sheet.

1.6.7.2. Since the filter elements must be canned and attached to the tube sheet prior to final vessel assembly, the sequence of welding and the heat from welding must be controlled to avoid melting or distorting the elastomeric seals within the filter cans. Fabricator shall develop an assembly sequence and heat control procedure and <u>submit to Buyer for review and approval</u>.

1.6.8. Materials

1.6.8.1. Vessel shell, heads, tubesheet, nozzles and all other metals in contact with the process fluids shall be constructed of stainless steel materials as indicated in the Data Sheet and Drawings.

1.6.8.2. Items welded to the vessel shall be the same material as the vessel.

1.6.9. All elastomeric gaskets, o-rings and other seals shall be EPDM. No other sealing material is approved.

1.6.10. Miscellaneous

1.6.11. Fabricator shall provide a grounding lug located on a support leg. The lug material of construction shall be identical to the support.

1.6.12. Vessel "external surface finish" requirements pertain only to exposed vessel surfaces. Reference to "interior surface finish" on the Data Sheet indicates the interior of the vessel, nozzle necks, and all potential fluid wetted parts and appurtenances. Fabrication shall be done in an area where only stainless steel is fabricated and with tools that have not been used on carbon steel.

1.7. INSPECTION AND TESTING

1.7.1. The Buyer reserves the right to notify Fabricator and inspect the vessel during fabrication.

1.7.2. The Buyer shall be notified Fabricator prior to conducting testing to allow for witnessing by Buyer.

1.7.3. In process NDE requirements shall be determined and performed in accordance with Sections VIII, V, IX, Division 1 of the ASME Code

1.7.4. Pressure testing shall be done in accordance with Section VIII, Division 1 of the ASME Code. Pneumatic testing is preferred due to the nature of the ceramic filters and the design of the vessel. If hydrotesting is performed, consultation with Buyer is required to ensure that the installed ceramic filters are not damaged or compromised during testing. Fabricator shall develop a HyrdoTesting Procedure and submit to Buyer for review and approval.

1.7.5. Helium leak testing is required on all vessel internal to external welds and all internal plenum to plenum tube sheet sealing welds. Fabricator shall develop a Helium Leak Test Procedure (and sequence) for either in-process or final assembly tests and submit to Buyer for review and approval.

FILTER VESSEL DATA SHEET				Sheet 1 of 1	Rev. #	1
Name:	Ceramic HEPA Filter Vessel	#: n/a	Prep by:	pdp	Date:	7/23/01
Project:	SRS Alternate HEPA Filter Project	#: CM1	App by:		Date:	
Service:	Amb. Radioactive Air Filtration		Issued For:	Review and Approval		

CERAMIC FILTER DATA

	Units	Minimum	Normal Operating	Maximum	Comments/Remarks/Notes
Filter Size	in		5.66 dia X 12 long		
Filter Area	sf		18.5		
Filter Qty			7		
Total Filter Area	sq. ft.		129.5		
Fluid			air		
Flow rate	acfm	250	900	1125	
Face Velocity	fpm	1.93	6.95	8.69	
Pressure Drop	"wc	9.7	34.7	43.4	based on 5 "/fpm face velocity
Temperature	deg F	0	90	120	
Humidity	%RH	0	90	100	

GENERAL VESSEL CONSTRUCTION

Vertical	x	Cylindrical	x	**Top Head**	x	**Bottom Head**	x	Insulated		Jacketed	
Horizontal		Flat Sided		Flat Cover		Bottom Cone		**Legs**	x	Saddles	

VESSEL DESIGN DATA

			Notes
Design Pressure	150 psig and Full Vacuum		
Design Temperature	200 deg F		
Vessel Diameter	36" ID		
OA Vessel Length	48"		
Shell Thickness	.375"		see Note 2.
Head Thickness	.375" top	.375" bottom	see Note 2.
Head Type	ASME Elliptical, 12" OAH		
Corrosion Allowance	None		
Mat'l of Construction	304SS		
Int'l Surface Finish	SSPC, SP3 Power Tool Clean		
Ext'l Surface Finish	mill finish		

ACCESSORIES

1 Rupture Disk.
3 Lift Lugs, top mtd.
3 Pipe Legs, side mtd.

TUBESHEET

Filters flanged and supported vertically from a horizontal tubesheet drilled and and tapped (studding outlet) design creating two plenums, clean and dirty 304 SS, see Note 3.

NOZZLE DESCRIPTION

#	Size	Type	Purpose
A	8"	150# SO RF ANSI	Inlet Flow
B	8"	150# SO RF ANSI	Outlet Flow
C	1.5"	150# SO RF ANSI	Over Pressure RD

EXAMINATION, TESTING

Type	Yes	No	Comments/Remarks/Notes
Hydrostatic	x		Pneumatic preferred
Air Leak		x	
Helium Leak	x		
Radiography			see Note 2
Other NDE			see Note 2

WEIGHTS

Normal Operating	1200#	Tubesheet	230#	Ceramic Filter, ea.	12#	Canned Filter, ea	42#

NOTES

1. See Vessel Drawings CM001, 002, 003, 004
2. Final Design and Code Calculations performed by Fabricator, approved by Buyer
3. Filter holding tubesheet design to be finalized and optimized by Fabricator, approved by Buyer
4. Filter cans built by Fabricator; filter canning to be performed by Buyer
5. Filters supplied by Buyer

Preliminary Calculations (8 pages)

PRELIMINARY VESSEL CALCULATION
PRESSURE/THICKNESS DESIGN CALCULATION
CYLINDRICAL SECTION OF VESSEL

CeraMem Ceramic Filter Vessel for H&V Tank Vent Filter

Basic Data

Mat'l	SA 240-304	Sa	17800	Table UHA-23	
Td	200 F	Ejt	0.7	Table UW-12	no x-ray
Po	150 psig	Sy	30000	Table UHA-23	
L	36 in	Su	75000	Table UHA-23	
Di	36 in	Emod	2.80E+07		

UG-27 Thickness Calc., Normal Design, ***Internal Pressure***

Di	36 in
Ri	18 in
P	225 psi
Sa	17800 Table UHA-23
Ejt	0.7 Table UW-12

Circ. Stress (long jt)
t= PR/(SE-.6P) **0.329** in. Select "t" **3/8** in. / 0.375 in.

Long. Stress (circ jt)
t= PR/(2SE+.4P) 0.162 in.

UG-28 (c)(1)Normal Design , ***Vacuum Capability***

Deformation Prevention Design, Pd

	Di	36 in.				
	L	36 in		1 L/D<5		
Check	Select "t"	0.328 in.	@12.5%	reduction for mfg tolerance		
	Do	36.75 in.				
			From Fig.5-UGO-28.0	Man. App.	From Fig.5-UHA-28.1	304 SS
D/t>10	Do/t	112	A=	→	B=	
L/D<5	L/Do	0.980	0.00125		9000	Emod= 2.80E+07

Eq. 1	Pa=	4B/3(Do/t)	**107.1** psi, vacuum	w/B from chart
Eq. 2	Pa=	2AE/3(Do/t)	208.3 psi, vacuum	B value off chart

PRELIMINARY VESSEL CALCULATION
PRESSURE/THICKNESS DESIGN CALCULATION
ELLIPTICAL HEAD OF VESSEL

CeraMem Ceramic Filter Vessel for H&V Tank Vent Filter

Basic Data

Mat'l	SA 240-304	Sa	17800	Table UHA-23	
Td	200 F	Ejt	0.7	Table UW-12	no x-ray
Po	150 psig	Sy	30000	Table UHA-23	
		Su	75000	Table UHA-23	
Di	36 in	Emod	2.80E+07		

UG-32 (d) Thickness Calc., Normal Design, ***Internal Pressure***

Di	36 in	IDD=	9	in
P	225 psi	OAH=	12	in
Sa	17800 Table UHA-23	see head sketch		
Ejt	0.7 Table UW-12			

Elliptical (2:1) Head

t= PDi/(2SE-.2P) **0.326** in Select "t" **3/8** in. 0.375 in.

UG-33 (d) Normal Design, ***Full Vacuum Calc.***

Rupture Prevention Design, Pr

	Di	36 in.			
	Ko	0.9 in	From Table UG-33.1 @ 2:1		
Check	Select "t"	0.328 in.	@12.5% reduction for mfg tolerance		
	Ro	33.075	Ro/t=	100.8	Ro=KoxDo
	Do	36.75 in.			

A= .125/Ro/t A= 0.0012401 ⟶ From Fig.5-UHA-28.1

B= 9000 Emod= 2.80E+07

Eq. 1	Pa=	B/Ro/t	**89.3** psi, vacuum	w/B from chart
Eq. 2	Pa=	.0625E/(Ro/t)2	172.2 psi, vacuum	B value off chart

Basic Data
Code: B31.3

Mat'l	A312 TP304	*Pipe*		S	20000	Table A-1	
Td	200 F			E	0.8	Table A-1B, EFW single butt	
Pd	150 psi			Y	0.4	Table 304.1.1	

Find the pipe wall "t" that will withstand design pressure, "Pd", from the inside

304.1.2 *Straight Pipe Under Internal Pressure*

Do	8.625 in	for 8" Pipe
P	150 psi	
S	20000 psi	
E	0.8	
Y	0.4	

t= PD/2(SE+PY) 0.040 in. min req'd

D/6= 1.438

is t less than D/6 ?? yes

pick 0.148 in. SCH10S x 87.5%= 0.130 in.. min actual
OK

304.1.3

UG-28 (c)(1)Normal Design , ***Vacuum Capability***

Deformation Prevention Design, Pd

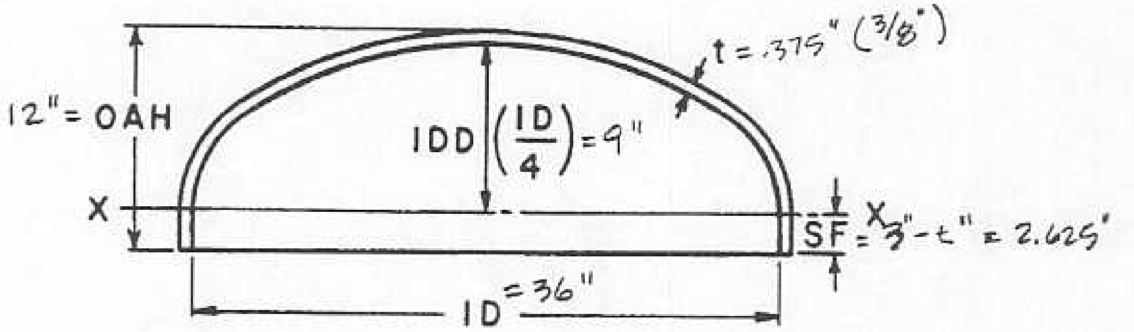
	Di	8.329 in.		
	L	6 in	0.7203746 L/D<5	
Check	Select "t"	0.130 in.	@12.5%	reduction for mfg tolerance
	Do	8.625 in.		

			From Man. App. Fig.5-UGO-28.0	From Fig.5-UHA-28.1 304 SS	
D/t>10	Do/t	67	A=	B=	
L/D<5	L/Do	0.696	0.004	12000	Emod= 2.80E+07

Eq. 1	Pa=	4B/3(Do/t)	**240.2** psi, vacuum	w/B from chart
Eq. 2	Pa=	2AE/3(Do/t)	1121.1 psi, vacuum	B value off chart

SECTION 8—ASME ELLIPTICAL—2:1 RATIO

12/19/00
Page 4



INFORMATION REQUIRED ON INQUIRIES AND ORDERS

Quantity

Grade of steel

Diameter (OD or ID)—Note General Section 1, page 3.

t (minimum or nominal)

SF } Specify the more important dimen-
OAH } sion, as both cannot be maintained.

Special tolerances

Machine work, gas cutting, etc.

NOTES

Standard, commonly furnished diameters are shown in the tables; all intermediate diameters between 24 and 198 in., however, are readily available from our regular equipment.

Consult us on requirements for heavier gages than are shown in the tables.

The maximum SF shown in the tables can, in some cases, be exceeded, although it is recommended that they be ordered as short as possible. Consult us on your requirements.

Blank diameters and corresponding weights are based on an SF of 2 in. or actual rolled thickness, whichever is greater. For heads having dimensions other than shown, refer to the blank diameter formula, page 6.

List prices are based on an SF not exceeding the Standard SF shown. For heads having an SF in excess of those standards, add, for each ½-in. or fraction thereof in excess, 5 per cent of the list price.

For intermediate diameters and heavier gages, list price for the next larger diameter or heavier gage applies.

Volumes are measured between the plane X-X and the concave side of the dish. The cylinder volume of the SF is not included.

For Nominal ID, refer to page 3.

In most instances where the resulting blank diameter is greater than 152½ in., the head will be furnished with a center weld seam. A blank diameter which is greater than 152½ in. but does not exceed 198 in. will be priced using the one piece pricing method. Blank diameters exceeding 198 in. will be priced in accordance with Pamphlet B, Special Pricing Procedure for Two-piece Heads.

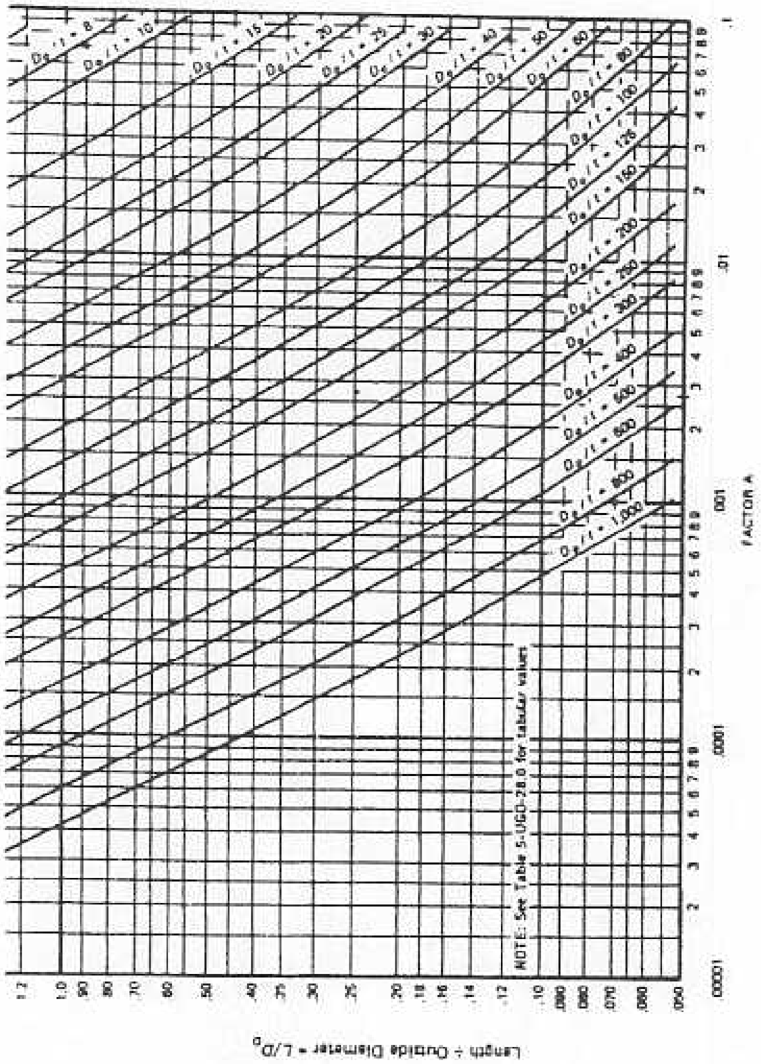
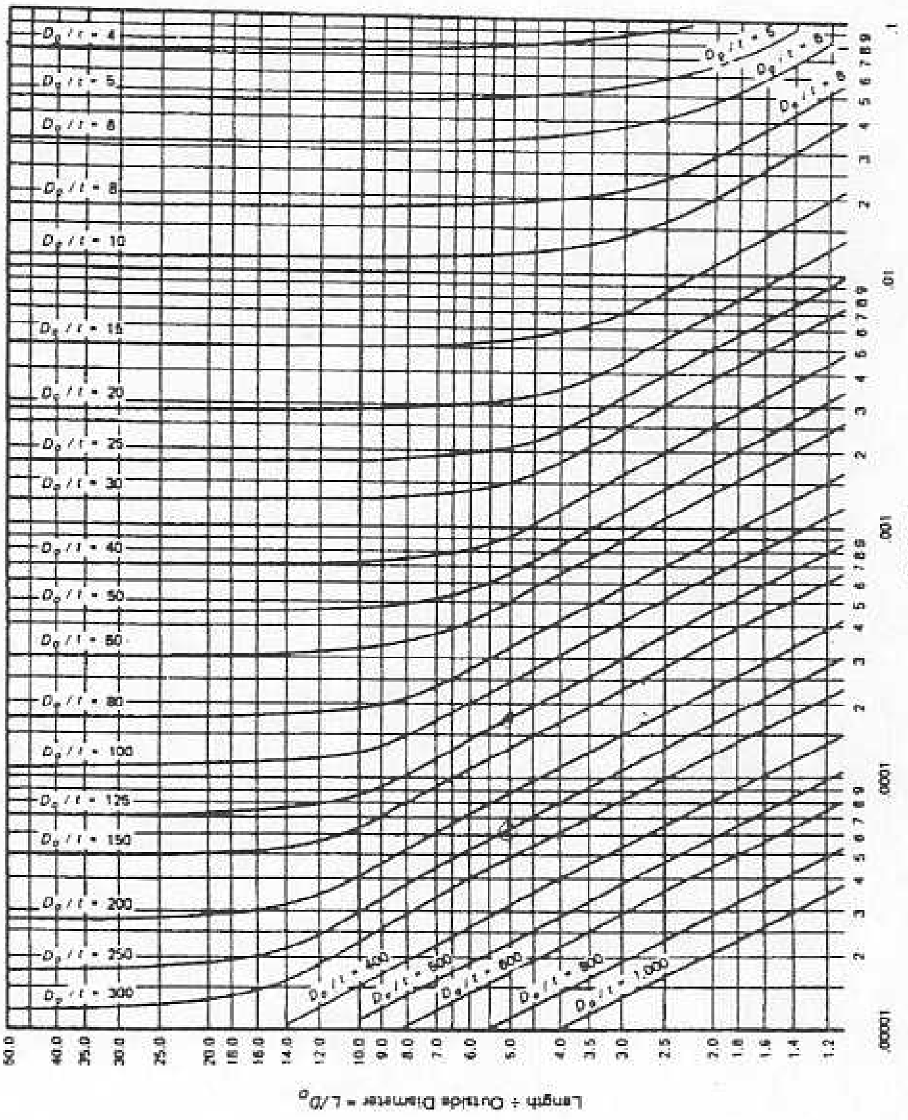


FIG. 5-UGO-28.0 GEOMETRIC CHART FOR CYLINDRICAL VESSELS UNDER EXTERNAL OR COMPRESSIVE LOADINGS (FOR ALL MATERIALS)


D_o/t = 4
D_o/t = 5
D_o/t = 6
D_o/t = 8
D_o/t = 10
D_o/t = 15
D_o/t = 20
D_o/t = 25
D_o/t = 30
D_o/t = 40
D_o/t = 50
D_o/t = 60
D_o/t = 80
D_o/t = 100
D_o/t = 125
D_o/t = 150
D_o/t = 200
D_o/t = 250
D_o/t = 300
D_o/t = 400
D_o/t = 500
D_o/t = 600
D_o/t = 800
D_o/t = 1,000
FACTOR A
.00001
.0001
.001
.01
.1
50.0 40.0 35.0 30.0 25.0 20.0 18.0 16.0 14.0 12.0 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.5 3.0 2.5 2.0 1.8 1.6 1.4 1.2
Length ÷ Outside Diameter = L/D_o

Page 7

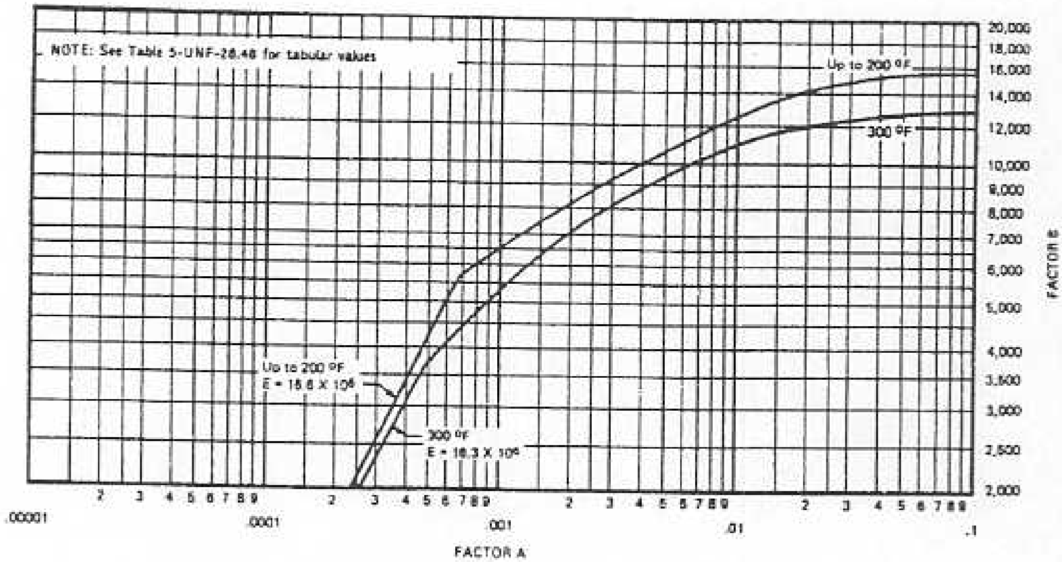


FIG. 5-UNF-28.48 CHART FOR DETERMINING SHELL THICKNESS OF CYLINDRICAL AND SPHERICAL COMPONENTS UNDER EXTERNAL PRESSURE WHEN CONSTRUCTED OF SB-75 AND SB-111 LIGHT DRAWN SEAMLESS COPPER TUBES, ALLOYS C10200, C12000, C12200, AND C14200

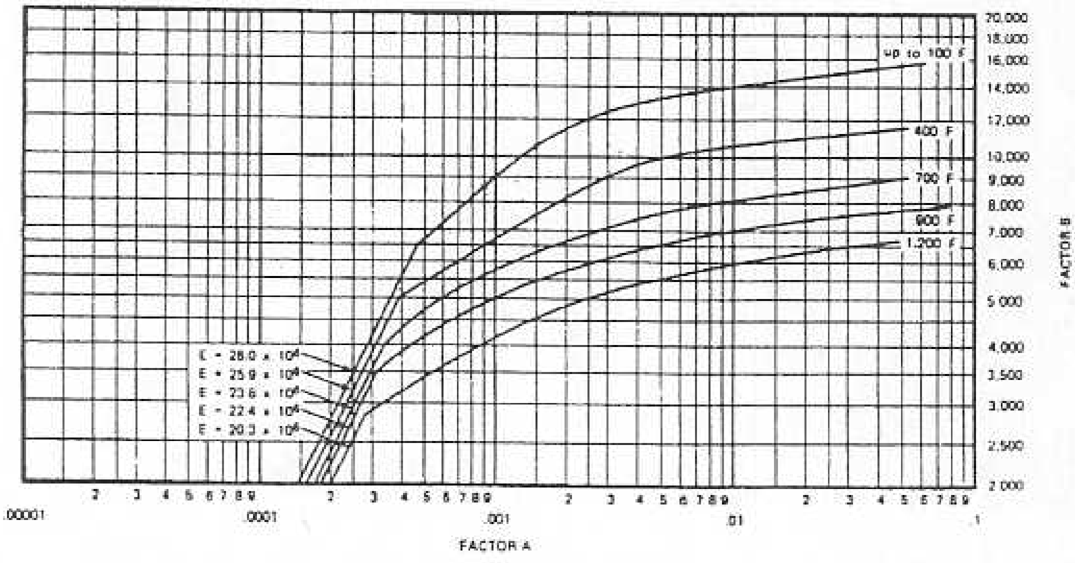


FIG. 5-UHA-28.1 CHART FOR DETERMINING SHELL THICKNESS OF CYLINDRICAL AND SPHERICAL VESSELS UNDER EXTERNAL PRESSURE WHEN CONSTRUCTED OF AUSTENITIC STEEL (18Cr-8Ni, TYPE 304) [NOTE (8)]

36" DIA. VESSEL WEIGHT ESTIMATE - **1,200#**

1 - 8" SORF FLANGES - 28# from catalog
6" - 8" SCH 10S PIPE - 9# from catalog
.375" - 36" ASME EL. HD - A = (24")² × 3.14 = 1808 sq in × .375"
= 678 cu in
= 190# (@ .28#/cu in)

.375" - 36" SHELL ROLL UP = C = 2 × 3.14 × 18" = 113"
A = C × L = 113 × 12" = 1356 sq in
= 508 cu in
= 142#

.5" × 36" TUBESHEET = A = (18")² × 3.14
= 1017 sq in
A_H = (2.5")² × 3.14 × 7
= 137 sq in
} 1017 - 137
= 880 sq in
= 440 cu in
= 123#

2	nozzles @	35"	= 70#
2	heads @	190#	= 380#
1	shell @	142#	= 142#
1	tubesheet @	123#	= 123#
7	studding outlets @	15#	105
3	lifting lugs @	10#	= 30#
1	1½" noz/flange @	15#	= 15#

865# → 900# VESSEL w/o FILTER & CANS

7 FILTER CANS @
6" FL - 17#
6" SCH PIPE - 9.5#
} ≈ 30# w/o FILTER × 7 = 210#
12# / FILTER (KN email 12/19/00)
42# w/FILTER × 7 = 294# → 300#

Appendix B

Alternative HEPA Filter System Pressure Drop Calculations and Blower Specification

System Pressure Drop
and
Blower Calculations

for the

Alternate Ceramic HEPA Filter Concept

Savannah River Site (SRS)
H&V Tank Vent Skid Project
Westinghouse Savannah River Company (WSRC)

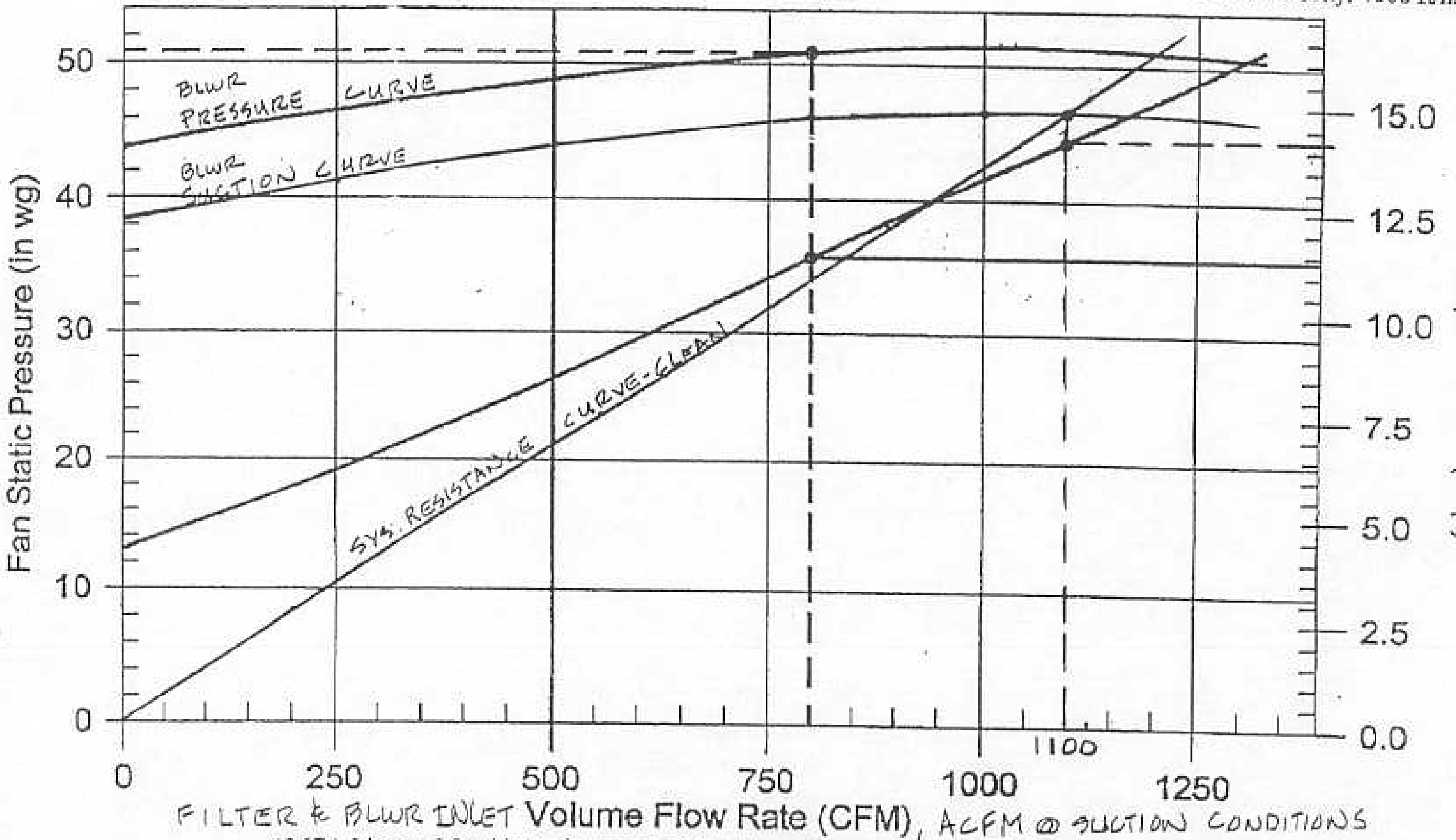
System and Blower Curves
(4 pages)

The New York Blower Company

Fan-to-Size
Volume Flow Rate: 800 CFM
Fan Static Press.: 50.8 in wg
Speed: 3500 rpm
Power: 11.4 bhp

Pressure Blower
2606 Aluminum
Arr.: 4

Temp.: 90 Deg F
Altitude: 325 ft
Density: 0.0714 lb/ft3
Outlet Velocity: 4000 ft/min



AMCA Licensed for Air Performance without Appurtenances. Power (bhp) excludes drives.

[v1.50.0010-R – May, 1999] Date Printed: 05/29/2001

Your Sales Representative:
L.J. Fiorello Corporation
Phone: (508) 765-0266

6/2/01
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2606

The New York Blower Company

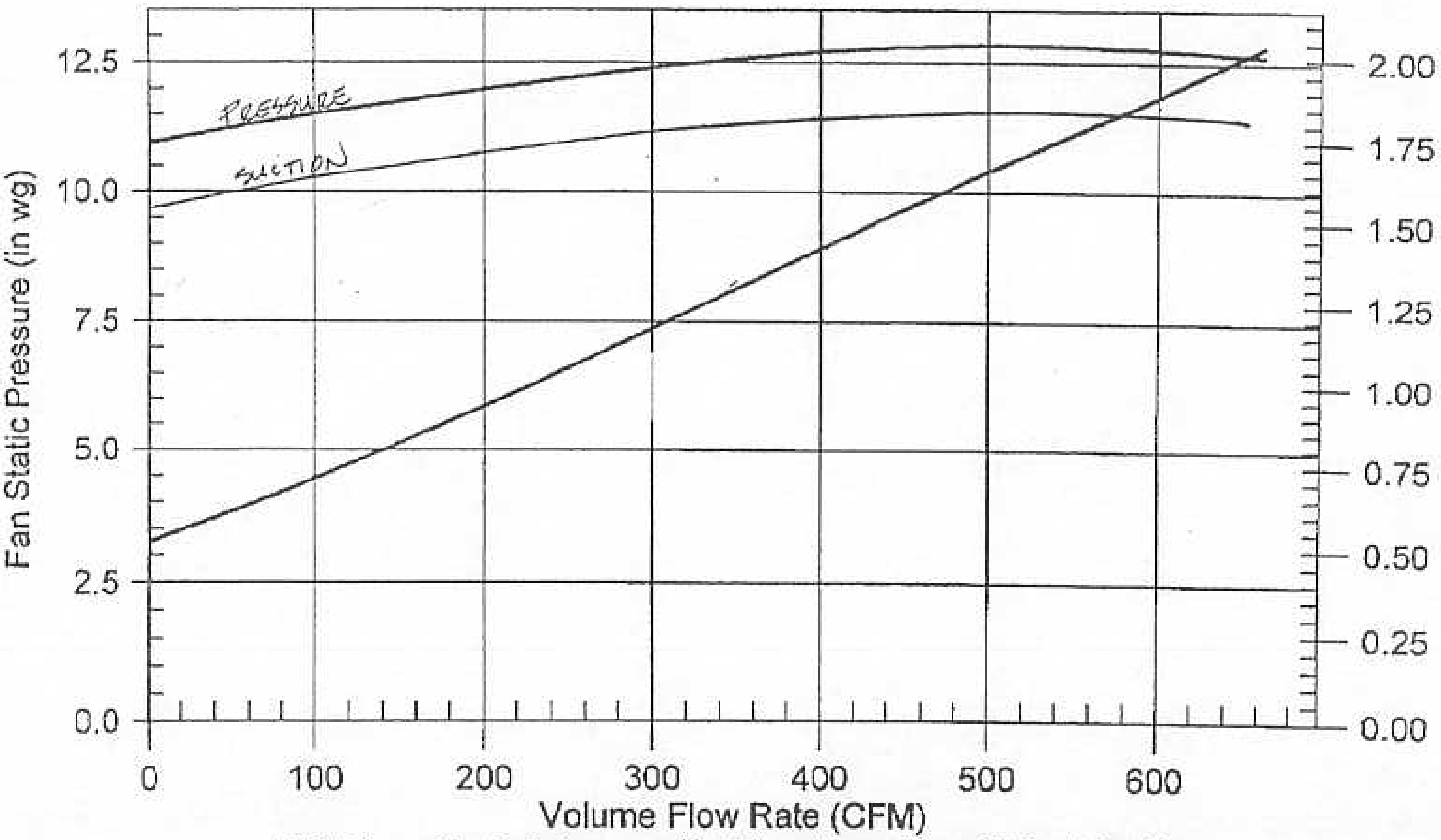
Fan-to-Size

Pressure Blower
2606 Aluminum
Arr.: 4

REDUCED SPEED

Speed: 1750 rpm

Temp.: 90 Deg F
Altitude: 325 ft
Density: 0.0714 lb/ft3



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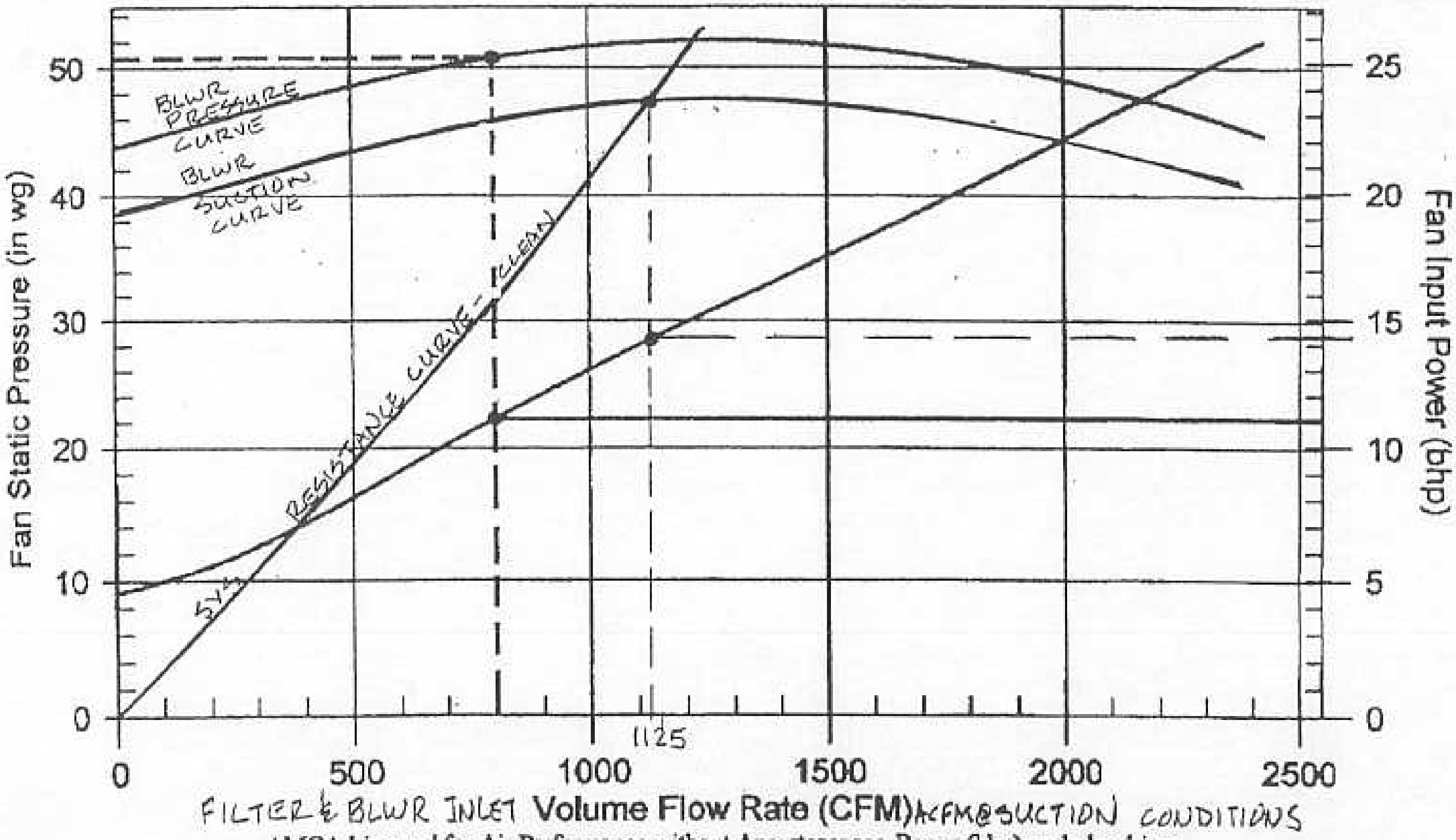
2608

The New York Blower Company

Fan-to-Size
Volume Flow Rate: 800 CFM
Fan Static Press.: 50.8 in wg
Speed: 3500 rpm
Power: 11.0 bhp

Pressure Blower
2608 Aluminum
Arr.: 4

Temp.: 90 Deg F
Altitude: 325 ft
Density: 0.0714 lb/ft3
Outlet Velocity: 2286 ft/min



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2608

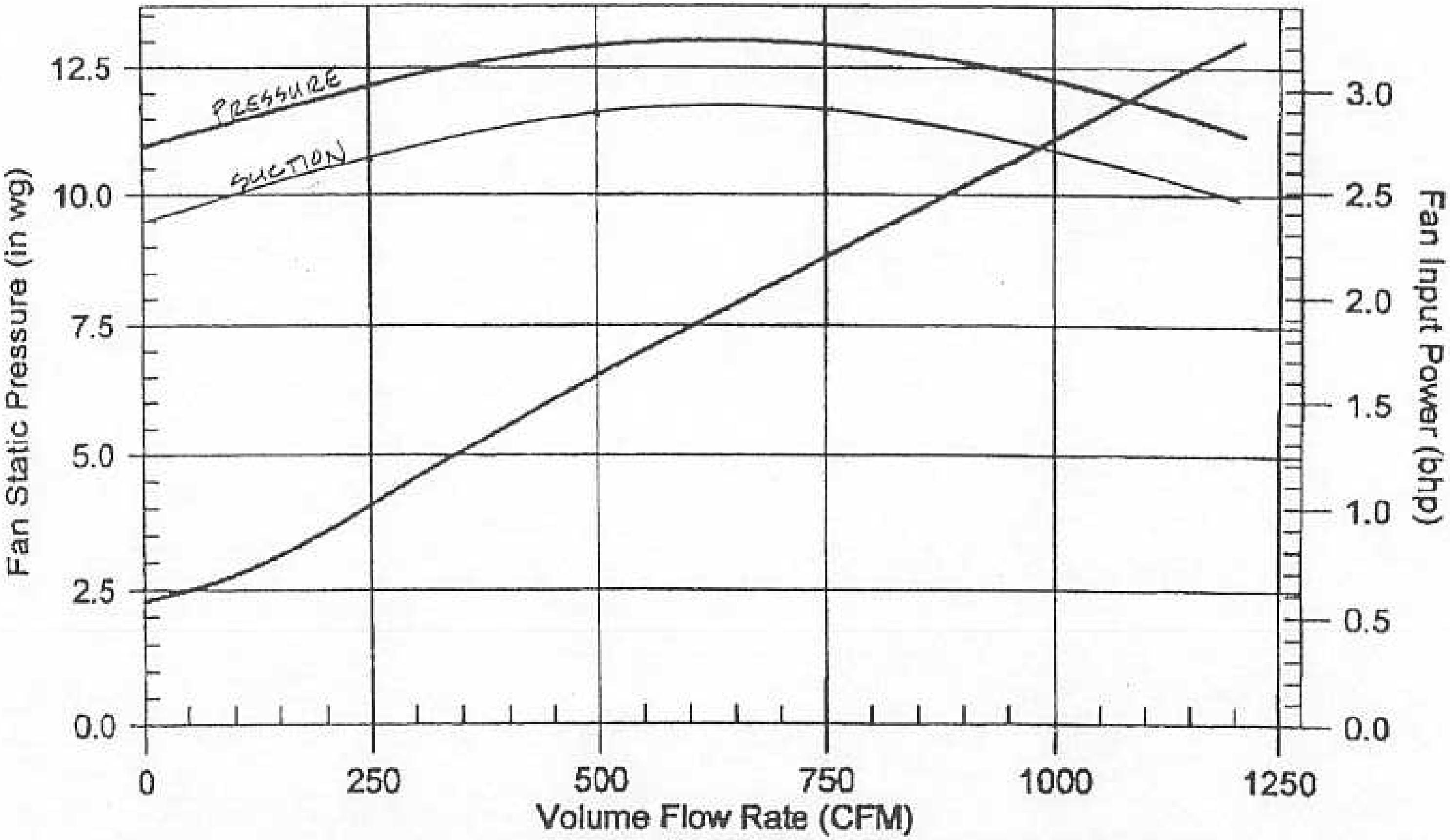
The New York Blower Company

Fan-to-Size

Pressure Blower
2608A Aluminum
Arr.: 4

@ REDUCED SPEED
Speed: 1750 rpm

Temp.: 90 Deg F
Altitude: 325 ft
Density: 0.0714 lb/ft3



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05/29/2001 12:12 15087650328 LJ FIORELLO PAGE 07
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Vendor Blower Selection and Curves
7 pages

L.J. FIORELLO CORPORATION
495 Main Street / Post Office Box 67, Southbridge, Massachusetts 01550
Email address: ljfcobrian@myexcel.com

FAX

Date: 5-29-01
Number of pages including cover sheet: 7

To:
Attn: Phil Paquette
Phone:
Fax:
Ref: New York Blower

From: Brian K. Dauphin
Phone: (508) 765-0266
Fax: (508) 765-0328

REMARKS: ☐ Urgent ☒ For your review ☐ Reply ASAP ☐ Please comment

Phil,

Please see the attached fan curves. The curves reflect pressure only and must be corrected for suction. In this case, there is a 5 – 6" static pressure difference for rarification (10-12%). Therefore, the maximum suction you will see is about 45" wg. Please call if you have any questions.

Thank You,

Brian

If you have any questions or need further assistance, please feel free to contact us.

The New York Blower Company

Fan-to-Size
Fan Selection Data

Project:	
Location:	
Contact:	

8" Inlet
6" outlet

Fan Design

Product:	Pressure Blower	Arrangement:	4
Size/Model:	2606	Drive type:	Direct
Wheel Type:	Aluminum		
Wheel Material:	Aluminum		
Wheel Width:	100.0 %	Wheel Diameter:	100.0 %

All Pressure

Operating Conditions

Volume Flow Rate:	800 CFM	Fan Speed:	3500 rpm
Fan Static Pressure:	50.8 in wg	Fan Input Power:	11.4 bhp
Outlet Velocity:	4000 ft/min		
Altitude (above mean sea level):	325 ft	Operating Temperature:	90 Deg F
Operating Inlet Airstream Density:	0.0714 lb/ft3		
Static Efficiency:	56.28%	Mechanical Efficiency:	57.33%
Maximum Operating Temperature:	90 Deg F	Maximum Safe Operating Speed:	3800 rpm

Operating Conditions at 70 Deg F

Volume Flow Rate:	800 CFM	Fan Speed:	3500 rpm
Fan Static Pressure:	52.7 in wg	Fan Input Power:	11.8 bhp
Density at Altitude (325 ft) :	0.0741 lb/ft3	Max. Safe Speed at 70 Deg F:	3800 rpm

Sound Power Level Ratings Levels expressed in dB (power levels reference 10^{-12} watts)

Center Frequency (Hz):	63	125	250	500	1000	2000	4000	8000	
Octave Bands:	1	2	3	4	5	6	7	8	Overall
Total Fan Power Levels*:	87.	94.	101.	104.	102.	96.	92.	82.	107.9
Inlet Power Levels**:	84.	91.	98.	101.	99.	93.	89.	79.	104.9
Outlet Power Levels**:	84.	91.	98.	101.	99.	93.	89.	79.	104.9

*As corrected for point of operation (location on fan curve)
**Unsilenced Inlet and Outlet power ratings are 3 dB lower than total fan power levels under the assumption that "half" of the sound power can be attributed to each opening. Silenced power ratings include this 3 dB reduction as well as the silencer attentuation.

Estimated Sound Pressure Levels Levels expressed in dB (pressure levels reference $2x10^{-4}$ microbar)

Directivity/Reflection Factor (Q) is 4, quarter-spherical radiation; Distance is 5 ft.; A-weighting is in use.

The estimated sound pressure level outside the fan due to an open inlet OR outlet is 94.3 dBA at 5.0 feet. The estimated sound pressure level outside the fan when BOTH inlet and outlet are ducted is 82.3 dBA at 5.0 feet (Housing Radiated Noise).

Your Representative:
L.J. Fiorello Corporation
PO Box 67
Southbridge, MA 01550-0067
Phone: (508) 765-0266
Fax: (508) 765-0328
E-Mail: ljfcorp@myexcel.com

The The New York Blower Company certifies that the Pressure Blower fan is licensed to bear the AMCA Air Performance Seal. The ratings shown are based on tests and procedures performed in accordance with AMCA Publication 211 and comply with the requirements of the AMCA Certified Ratings program.

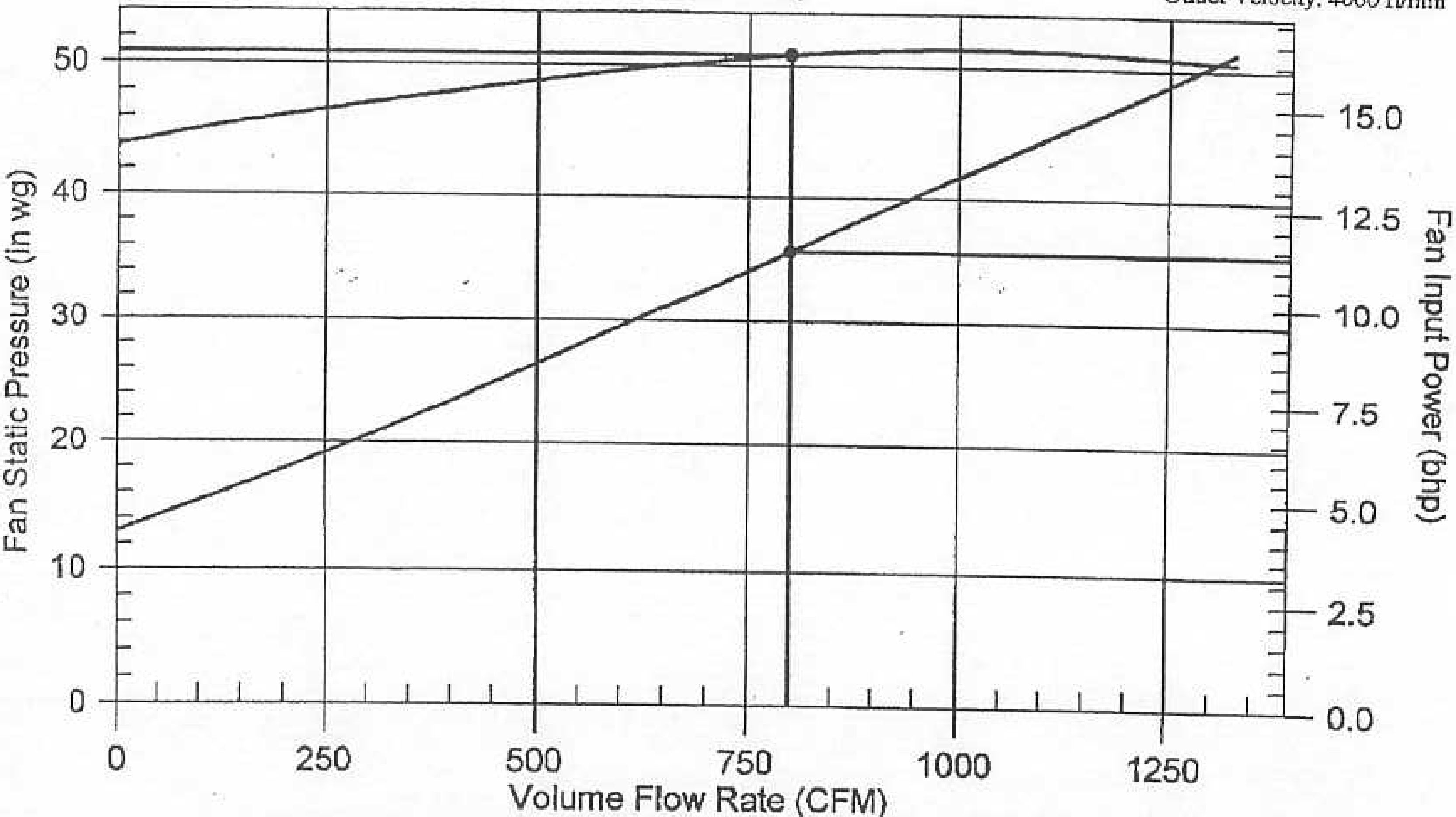
AMCA Licensed for Air Performance without Appurtenances. Power (bhp) excludes drives.

The New York Blower Company

Pressure Blower
2606 Aluminum
Arr.: 4

Fan-to-Size
Volume Flow Rate: 800 CFM
Fan Static Press.: 50.8 in wg (all pressure)
Speed: 3500 rpm
Power: 11.4 bhp

Temp.: 90 Deg F
Altitude: 325 ft
Density: 0.0714 lb/ft3
Outlet Velocity: 4000 ft/min



AMCA Licensed for Air Performance without Appurtenances. Power (bhp) excludes drives.

[v1.50.0010-R – May, 1999] Date Printed: 05/29/2001

Your Sales Representative:
L.J. Fiorello Corporation
Phone: (508) 765-0266

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05/29/2001 12:12 15087650328 LJ FIORELLO PAGE 03
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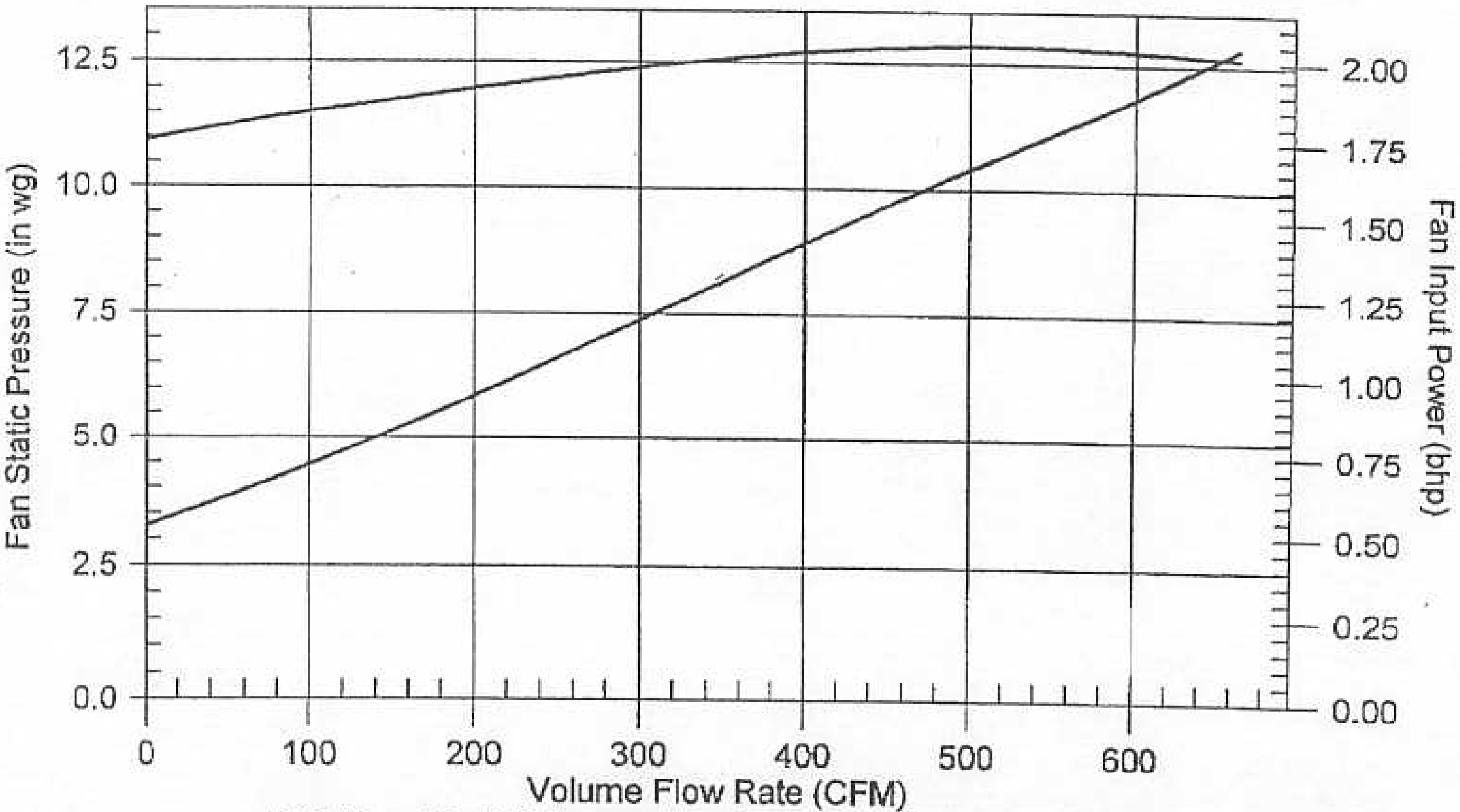
The New York Blower Company

Fan-to-Size

Pressure Blower
2606 Aluminum
Arr.: 4

Speed: 1750 rpm

Temp.: 90 Deg F
Altitude: 325 ft
Density: 0.0714 lb/ft3



AMCA Licensed for Air Performance without Appurtenances. Power (bhp) excludes drives.

[v1.50.0010-R -- May, 1999] Date Printed: 05/29/2001

Your Sales Representative:
L.J. Fiorello Corporation
Phone: (508) 765-0266

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05/29/2001 12:12 15087650326 LJ FIORELLO PAGE 04

The New York Blower Company
Fan-to-Size
Fan Selection Data

Project:	
Location:	
Contact:	

8" Inlet
8" outlet

Fan Design

Product:	Pressure Blower	Arrangement:	4
Size/Model:	2606	Drive type:	Direct
Wheel Type:	Aluminum		
Wheel Material:	Aluminum		
Wheel Width:	100.0 %	Wheel Diameter:	100.0 %

All pressure

Operating Conditions

Volume Flow Rate:	800 CFM	Fan Speed:	3500 rpm
Fan Static Pressure:	50.8 in wg	Fan Input Power:	11.0 bhp
Outlet Velocity:	2286 ft/min		
Altitude (above mean sea level):	325 ft	Operating Temperature:	90 Deg F
Operating Inlet Airstream Density:	0.0714 lb/ft3		
Static Efficiency:	57.79%	Mechanical Efficiency:	58.15%
Maximum Operating Temperature:	90 Deg F	Maximum Safe Operating Speed:	3800 rpm

Operating Conditions at 70 Deg F

Volume Flow Rate:	800 CFM	Fan Speed:	3500 rpm
Fan Static Pressure:	52.7 in wg	Fan Input Power:	11.4 bhp
Density at Altitude (325 ft) :	0.0741 lb/ft3	Max. Safe Speed at 70 Deg F:	3800 rpm

Sound Power Level Ratings
Levels expressed in dB (power levels reference 10^{-12} watts)

Center Frequency (Hz):	63	125	250	500	1000	2000	4000	8000	
Octave Bands:	1	2	3	4	5	6	7	8	Overall
Total Fan Power Levels*:	88.	95.	98.	99.	97.	93.	89.	83.	104.2
Inlet Power Levels**:	85.	92.	95.	96.	94.	90.	86.	80.	101.2
Outlet Power Levels**:	85.	92.	95.	96.	94.	90.	86.	80.	101.2

*As corrected for point of operation (location on fan curve)

**Unsilenced Inlet and Outlet power ratings are 3 dB lower than total fan power levels under the assumption that "half" of the sound power can be attributed to each opening. Silenced power ratings include this 3 dB reduction as well as the silencer attenuation.

Estimated Sound Pressure Levels
Levels expressed in dB (pressure levels reference $2x10^{-4}$ microbar)

Directivity/Reflection Factor (Q) is 4, quarter-spherical radiation; Distance is 5 ft.; A-weighting is in use.

The estimated sound pressure level outside the fan due to an open inlet OR outlet is 80.8 dBA at 5.0 feet. The estimated sound pressure level outside the fan when BOTH inlet and outlet are ducted is 78.0 dBA at 5.0 feet (Housing Radiated Noise).

Your Representative:
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PO Box 67
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The The New York Blower Company certifies that the Pressure Blower fan is licensed to bear the AMCA Air Performance Seal. The ratings shown are based on tests and procedures performed in accordance with AMCA Publication 211 and comply with the requirements of the AMCA Certified Ratings program.

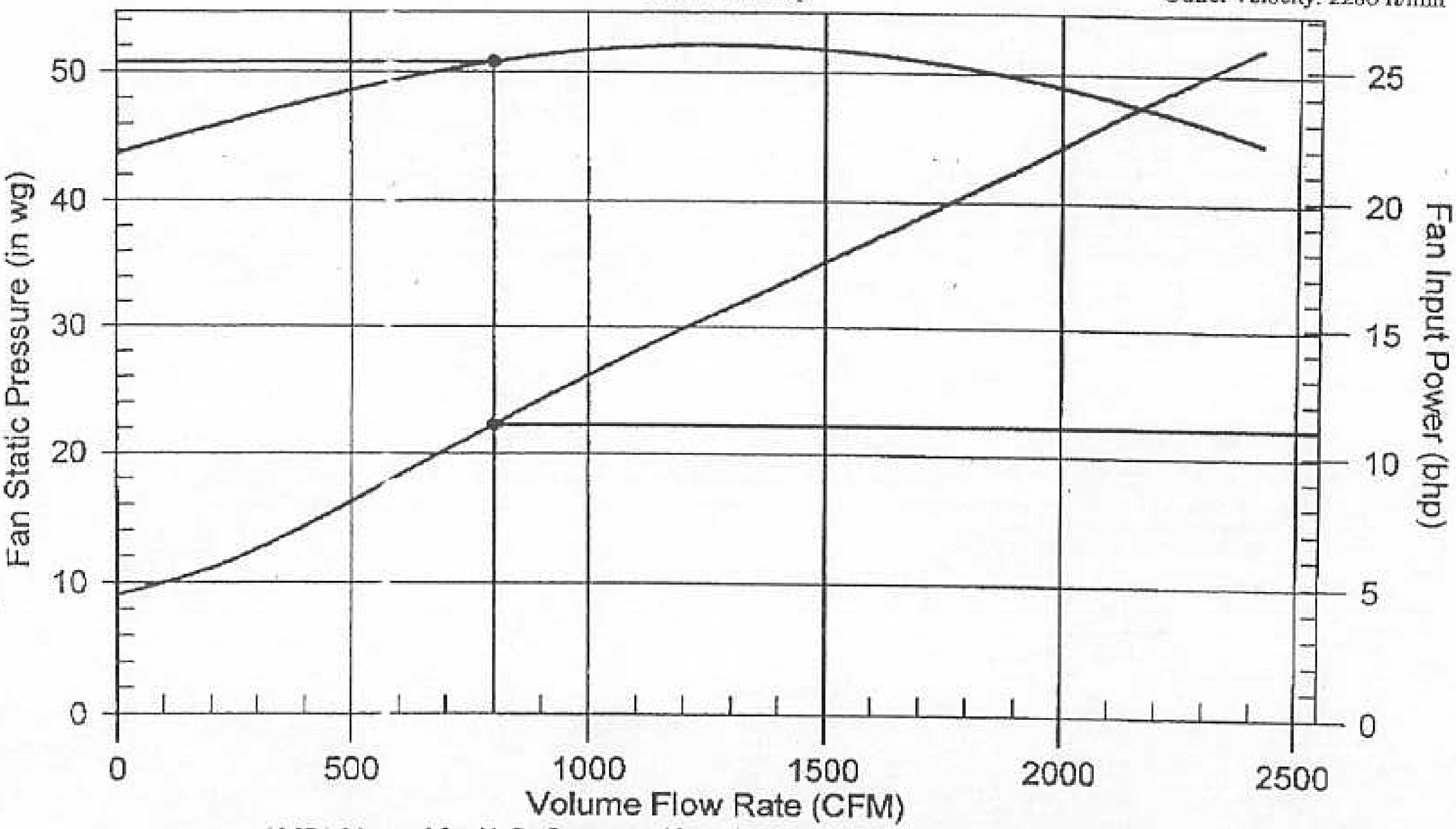
AMCA Licensed for Air Performance without Appurtenances. Power (bhp) excludes drives.

The New York Blower Company

Fan-to-Size
Volume Flow Rate: 800 CFM
Fan Static Press.: 50.8 in wg (pressure)
Speed: 3500 rpm
Power: 11.0 bhp

Pressure Blower
2608 Aluminum
Arr.: 4

Temp.: 90 Deg F
Altitude: 325 ft
Density: 0.0714 lb/ft3
Outlet Velocity: 2286 ft/min



AMCA Licensed for Air Performance without Appurtenances. Power (bhp) excludes drives.

[v1.50.0010-R -- May, 1999] Date Printed: 05/29/2001

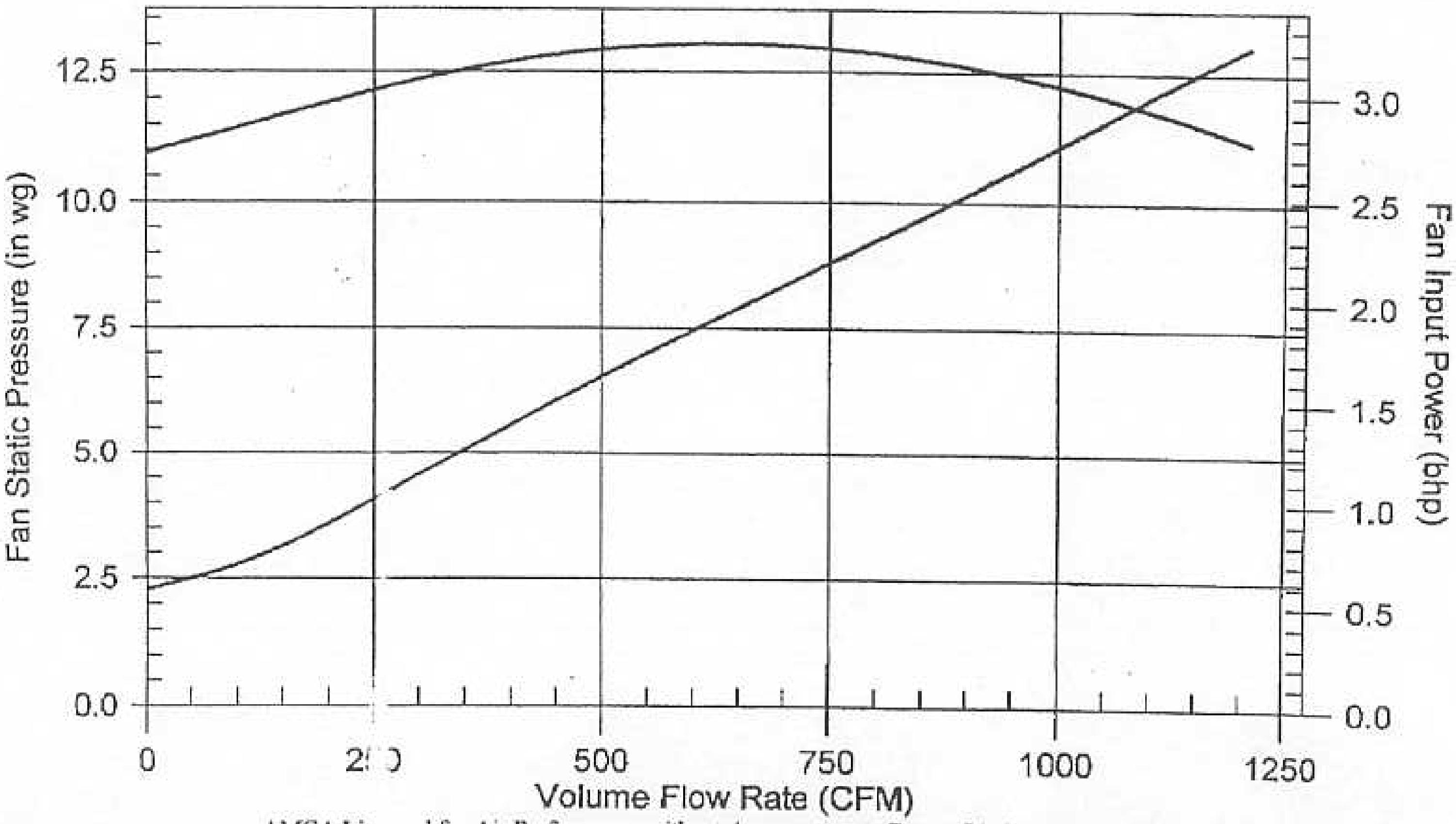
Your Sales Representative:
L.J. Fiorello Corporation
Phone: (508) 765-0266

The New York Blower Company
Fan-to-Size

Pressure Blower
2608A Aluminum
Arr.: 4

Speed: 1750 rpm

Temp.: 90 Deg F
Altitude: 325 ft
Density: 0.0714 lb/ft3



AMCA Licensed for Air Performance without Appurtenances. Power (bhp) excludes drives.

[v1.50.0010-R -- May, 1999] Date Printed: 05/29/2001

Your Sales Representative:
L.J. Fiorello Corporation
Phone: (508) 765-0266

System Pressure Drop Calculations
5 pages

Alternate Ceramic HEPA Filter
System dP Calculations

AIR PIPE/TUBE dP CALCS

Enter Pipe/Tube Size 8in SCH10S

ID 8.33 *in*
0.69 *ft*
Area 54.47 *sq.in.*
0.378 *sq. ft.*
d5 40107.45 *in5*

Altitude at location
325 *ft*
0.98 *Palt-correct*
from Barometric Chart

Calc. Atmos. Pres. 14.41 *psi*

Calc @ Actual Inlet Conditions

Enter Inlet Vol. Flow 200 *acfm*
Enter Temp 90 *F*
Enter Inlet Pressure 0.00 *psig*
Calc. Inlet Density 0.071 *#/cf* *using T and Alt corrections*
Enter Viscosity 0.019 *cp from A-5 Chart*
Calc. Mass Flow 850 *#/hr*
200.0 *cf/min*

Calc @ Standard

Calc. Vol. Flow 193 *scfm* 0.96 *Tcorrect*
Calc. Mass Flow 867 *#/hr* 1.00 *Pcorrect*

Calc New @ Downstream Blower Inlet Conditions

Calc. Vol. Flow 225 *acfm*
Enter Temp 90 *F* 1.04 *Tcorrect*
Enter Pressure -1.6 *psig* 1.12 *Pcorrect*
Calc. Density 0.064 *#/cf*
Calc. Mass Flow 867 *#/hr*
Calc. Exit Velocity 595 *fpm*

Calc Reynolds No. 3.39E+04 =6.31*W/du

Pick friction factor 0.0240 *f from A-25 Chart*

Calc Pressure Drop
=.000336(f/rho)(W^2/d^5)

@ Inlet Conditions	@ Downstream Conditions	@ Average Conditions
0.00 psi/100'	0.00 psi/100'	0.00 psi/100'
0.06 in WC/100'	0.06 in WC/100'	0.06 in WC/100'
		0.0006 in WC/ft

Total Piping L	199	ft			
Total Piping dP	0.12	"WC	Enter	Unit dP's	
Demister dP	0.15	"WC	0.075	"WC per 100cfm	
Heater dP	0.01	"WC	0.005	"WC per 100cfm	
HEPA dP	0.26	"WC	0.13	"WC per 100cfm	
CM Filter dP	**8.65**	**"WC**	5	**"WC/fpm**	
Total System	9.19	"WC			

Alternate Ceramic HEPA Filter
System dP Calculations

AIR PIPE/TUBE dP CALCS

Enter Pipe/Tube Size	8in SCH10S		**Altitude at location**		
ID	8.33	*in*	325	*ft*	
	0.69	*ft*	0.98	*Palt-correct*	
Area	54.47	*sq.in.*	*from Barometric Chart*		
	0.378	*sq. ft.*			
d5	40107.45	*in5*			
Calc. Atmos. Pres.	14.41	*psi*			
Calc @ Actual Inlet Conditions					
Enter Inlet Vol. Flow	500	*acfm*			
Enter Temp	90	*F*			
Enter Inlet Pressure	0.00	*psig*			
Calc. Inlet Density	0.071	*#/cf*	*using T and Alt corrections*		
Enter Viscosity	0.019	*cp from A-5 Chart*			
Calc. Mass Flow	2125	*#/hr*			
	500.0	*cf/min*			
Calc @ Standard					
Calc. Vol. Flow	482	*scfm*	0.96	*Tcorrect*	
Calc. Mass Flow	2168	*#/hr*	1.00	*Pcorrect*	
Calc New @ Downstream Blower Inlet Conditions					
Calc. Vol. Flow	562	*acfm*			
Enter Temp	90	*F*	1.04	*Tcorrect*	
Enter Pressure	-1.6	*psig*	1.12	*Pcorrect*	
Calc. Density	0.064	*#/cf*			
Calc. Mass Flow	2168	*#/hr*			
Calc. Exit Velocity	1487	*fpm*			
Calc Reynolds No.	8.47E+04	=6.31*W/du			
Pick friction factor	0.0190	*f from A-25 Chart*			

Calc Pressure Drop =.000336(f/rho)(W^2/d^5)	@ Inlet Conditions	@ Downstream Conditions	@ Average Conditions
	0.01 psi/100'	0.01 psi/100'	0.01 psi/100'
	0.28 in WC/100'	0.31 in WC/100'	0.29 in WC/100'
			0.0029 in WC/ft

Total Piping L	199	ft			
Total Piping dP	0.59	"WC	Enter	Unit dP's	
Demister dP	0.375	"WC	0.075	"WC per 100cfm	
Heater dP	0.025	"WC	0.005	"WC per 100cfm	
HEPA dP	0.65	"WC	0.13	"WC per 100cfm	
CM Filter dP	**21.63**	**"WC**	5	**"WC/fpm**	
Total System	23.27	"WC			

Alternate Ceramic HEPA Filter
System dP Calculations

AIR PIPE/TUBE dP CALCS

Enter Pipe/Tube Size	8in SCH10S		**Altitude at location**	
ID	8.33	*in*	325	*ft*
	0.69	*ft*	0.98	*Palt-correct*
Area	54.47	*sq.in.*	*from Barometric Chart*	
	0.378	*sq. ft.*		
d5	40107.45	*in5*		
Calc. Atmos. Pres.	14.41	*psi*		

Calc @ Actual Inlet Conditions

Enter Inlet Vol. Flow	800	*acfm*	
Enter Temp	90	*F*	
Enter Inlet Pressure	0.00	*psig*	
Calc. Inlet Density	0.071	*#/cf*	*using T and Alt corrections*
Enter Viscosity	0.019	*cp from A-5 Chart*	
Calc. Mass Flow	3400	*#/hr*	
	800.0	*cf/min*	

Calc @ Standard

Calc. Vol. Flow	771	*scfm*	0.96	*Tcorrect*
Calc. Mass Flow	3469	*#/hr*	1.00	*Pcorrect*

Calc New @ Downstream Blower Inlet Conditions

Calc. Vol. Flow	900	*acfm*		
Enter Temp	90	*F*	1.04	*Tcorrect*
Enter Pressure	-1.6	*psig*	1.12	*Pcorrect*
Calc. Density	0.064	*#/cf*		
Calc. Mass Flow	3469	*#/hr*		
Calc. Exit Velocity	2379	*fpm*		

Calc Reynolds No. 1.36E+05 =6.31*W/du

Pick friction factor 0.0180 *f from A-25 Chart*

Calc Pressure Drop	@ Inlet Conditions	@ Downstream Conditions	@ Average Conditions
=.000336(f/rho)(W^2/d^5)	0.02 psi/100'	0.03 psi/100'	0.03 psi/100'
	0.68 in WC/100'	0.75 in WC/100'	0.71 in WC/100'
			0.0071 in WC/ft

Total Piping L	199	ft			
Total Piping dP	1.42	"WC	Enter	Unit dP's	
Demister dP	0.6	"WC	0.075	"WC per 100cfm	
Heater dP	0.04	"WC	0.005	"WC per 100cfm	
HEPA dP	1.04	"WC	0.13	"WC per 100cfm	
CM Filter dP	**34.61**	**"WC**	5	**"WC/fpm**	
Total System	37.71	"WC			

Alternate Ceramic HEPA Filter
System dP Calculations

5/29/01

AIR PIPE/TUBE dP CALCS

Enter Pipe/Tube Size 8in SCH10S

ID 8.33 *in*

0.69 *ft*

Area 54.47 *sq.in.*

0.378 *sq. ft.*

d5 40107.45 *in5*

Altitude at location

325 *ft*

0.98 *Palt-correct*

from Barometric Chart

Calc. Atmos. Pres. 14.41 *psi*

Calc @ Actual Inlet Conditions

Enter Inlet Vol. Flow 1000 *acfm*

Enter Temp 90 *F*

Enter Inlet Pressure 0.00 *psig*

Calc. Inlet Density 0.071 *#/cf* *using T and Alt corrections*

Enter Viscosity 0.019 *cp from A-5 Chart*

Calc. Mass Flow 4250 *#/hr*

1000.0 *cf/min*

Calc @ Standard

Calc. Vol. Flow 964 *scfm* 0.96 *Tcorrect*

Calc. Mass Flow 4336 *#/hr* 1.00 *Pcorrect*

Calc New @ Downstream Blower Inlet Conditions

Calc. Vol. Flow 1125 *acfm*

Enter Temp 90 *F* 1.04 *Tcorrect*

Enter Pressure -1.6 *psig* 1.12 *Pcorrect*

Calc. Density 0.064 *#/cf*

Calc. Mass Flow 4336 *#/hr*

Calc. Exit Velocity 2974 *fpm*

Calc Reynolds No. 1.69E+05 =6.31*W/du

Pick friction factor 0.0170 *f from A-25 Chart*

Calc Pressure Drop
=.000336(f/rho)(W^2/d^5)

	@ Inlet Conditions	@ Downstream Conditions	@ Average Conditions
	0.04 psi/100'	0.04 psi/100'	0.04 psi/100'
	1.00 in WC/100'	1.10 in WC/100'	1.05 in WC/100'
			0.0105 in WC/ft

Total Piping L	199	ft			
Total Piping dP	2.10	"WC	Enter	Unit dP's	
Demister dP	0.75	"WC	0.075	"WC per 100cfm	
Heater dP	0.05	"WC	0.005	"WC per 100cfm	
HEPA dP	1.3	"WC	0.13	"WC per 100cfm	
CM Filter dP	**43.27**	**"WC**	5	**"WC/fpm**	
Total System	**47.46**	"WC			

Alternate Ceramic HEPA Filter
System dP Calculations

No.	Node	Element	Size/Qty	L	TL	Pres. Drop	
				ft	ft	psi	
1	Skid Inlet Noz.						
		Demister				**0.75**	per 1000acfm
2	Demister Out Noz.						
		Piping	**10"**	**3**	3	0.00	
	(2 els)	Fittings	**2**	16	32	0.00	
		Valves	**0**	35	0	0.00	
3	Heater Inlet Noz.						
		Heater				**0.05**	per 1000acfm
4	Heater Out Noz.						
		Piping	**8"**	**2**	2	0.00	
	(1 el, 1 tee)	Fittings	2	14	28	0.00	
		Valves	1	27	27	0.00	
5	CM Filter Inlet Noz.						
		CM Filter					
6	CM Filter Out Noz.						
		Piping	**8"**	**6**	6	0.00	
	(2 els, 1 tee)	Fittings	3	14	42	0.00	
		Valves	1	27	27	0.00	
7	HEPA Inlet Noz.						
		HEPA				1.3	per 1000acfm
8	HEPA Out Noz.						
		Piping	**8"**	**5**	5	0.00	
		Fittings	0	14	0	0.00	
		Valves	1	27	27	0.00	
9	Blower Suction Inlet						
	Total Equivalent Length				199	ft	

Reference Tables and Charts
(4 pages)

Barometric pressure chart and table

Hastings, MI-based Viatec Inc.'s Dale Keeler, engineering manager, gives the following equations derived from curve fit computer programs that use the data in Table 1:

Barometric pressure, (1)

$$\text{in Hg} = 29.921 - 0.001078 \times Z + 1.44559 \times 10^{-8} \times Z^2 \quad (1)$$

$$\text{Boiling point of water, °F} = 212 - 0.0018298 \times Z \quad (2)$$

where:

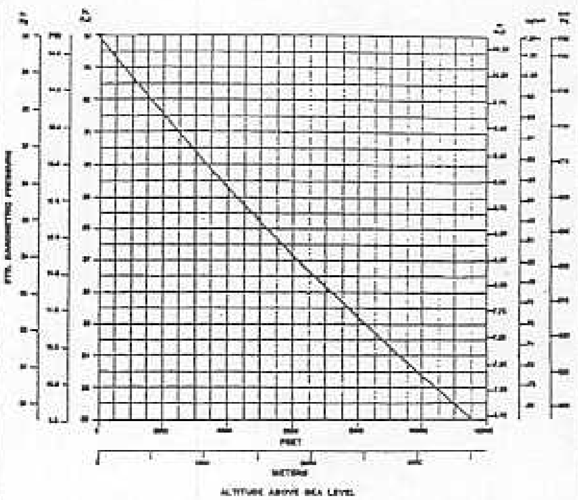
Z = altitude in feet (from -1,000 to 10,000 ft).

■ To receive information on ordering *Engineering Data Book, Second Edition*—Hydraulic Institute, Parsippany, NJ. CIRCLE 260

■ To receive a free "Barometric Pressure Formulas" white paper—Viatec Inc., Hastings, MI. CIRCLE 261

■ To receive the "SMACNA Bookstore 1996-1997" publications catalog—Sheet Metal and Air Conditioning Contractors National Association Inc. (SMACNA), Chantilly, VA. CIRCLE 205

By Brayton O. Paul, P.E., Senior Technical Editor.



Right: Effect of altitude on barometric pressure. Source: *Engineering Data Book, Second Edition*, Hydraulic Institute, Parsippany, NJ.

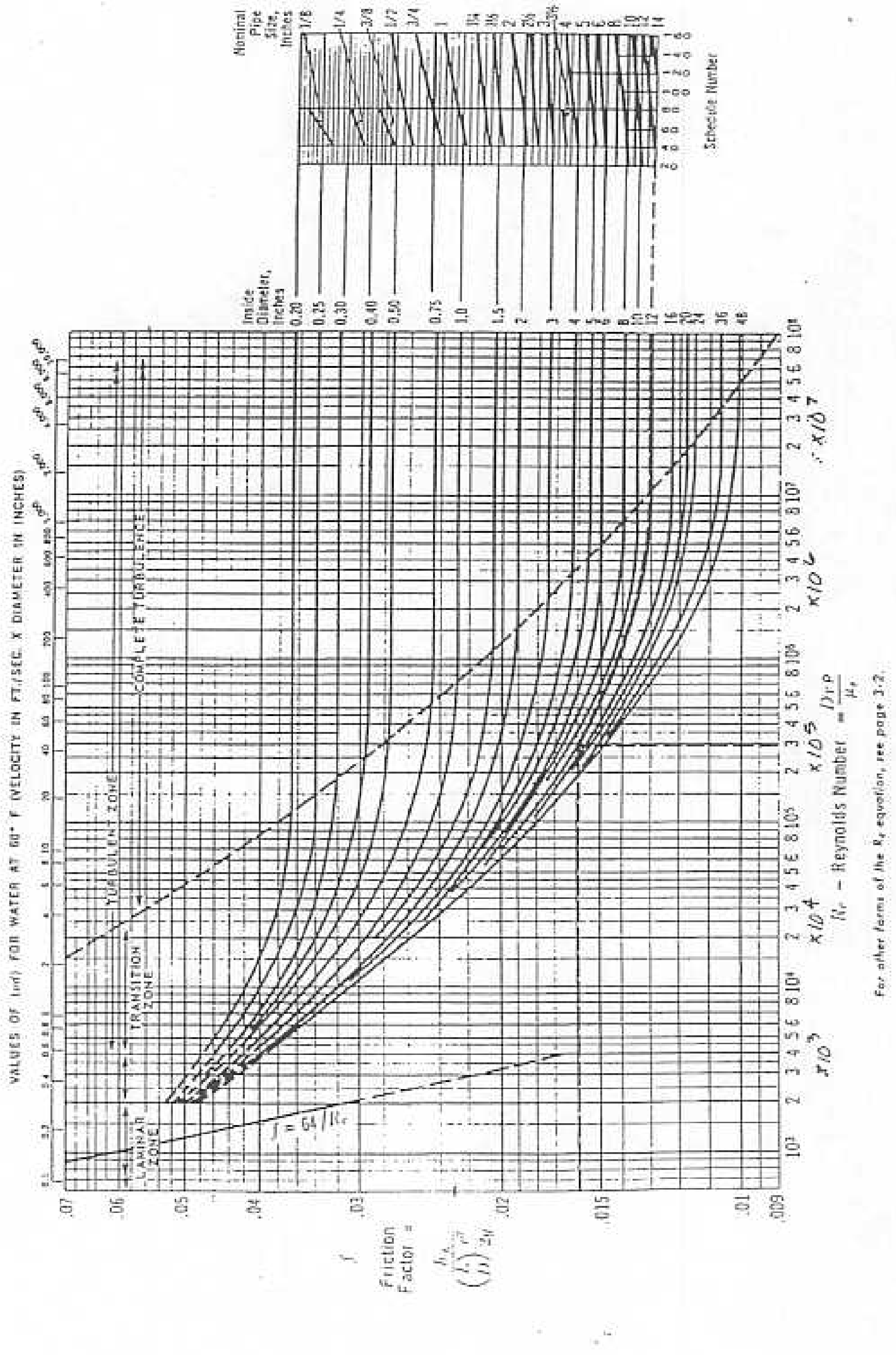
TABLE 1. AIR DENSITY CORRECTION FACTORS (U.S. UNITS).

			Sea level										
Altitude, ft	-1,000	-500	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
Barometer, in Hg	31.02	30.47	29.921	28.86	27.82	26.82	25.84	24.90	23.98	23.09	22.22	21.39	20.58
in water	422.5	415.0	407.5	392.8	378.6	365.0	351.7	338.9	326.4	314.3	302.1	291.1	280.1
ft water	35.2	34.7	34.0	32.8	31.6	30.5	29.4	28.3	27.3	26.2	25.2	24.3	23.4
psi	15.2	15.0	14.7	14.2	13.7	13.2	12.7	12.2	11.8	11.3	10.9	10.5	10.1
Boiling point, °F	213.8	212.9	212.0	210.2	208.4	206.5	204.7	202.9	201.0	199.2	197.4	195.5	193.7
Air temperature, °F													
-40			1.26	1.22	1.17	1.13	1.09	1.05	1.01	0.97	0.93	0.90	0.87
0			1.15	1.11	1.07	1.03	0.99	0.95	0.91	0.89	0.85	0.82	0.79
40			1.06	1.02	0.99	0.95	0.92	0.88	0.85	0.82	0.79	0.76	0.73
70			1.00	0.96	0.93	0.89	0.86	0.83	0.80	0.77	0.74	0.71	0.69
100			0.95	0.92	0.88	0.85	0.81	0.78	0.75	0.73	0.70	0.68	0.65
150			0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.67	0.65	0.62	0.60
200			0.80	0.77	0.74	0.71	0.69	0.66	0.64	0.62	0.60	0.57	0.55
250			0.75	0.72	0.70	0.67	0.64	0.62	0.60	0.58	0.56	0.53	0.51
300			0.70	0.67	0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.50	0.48
350			0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.51	0.49	0.47	0.45
400			0.62	0.60	0.57	0.55	0.53	0.51	0.49	0.48	0.46	0.44	0.42
450			0.58	0.56	0.54	0.52	0.50	0.48	0.46	0.45	0.43	0.42	0.40
500			0.55	0.53	0.51	0.49	0.47	0.45	0.44	0.43	0.41	0.39	0.38
550			0.53	0.51	0.49	0.47	0.45	0.44	0.42	0.41	0.39	0.38	0.36
600			0.50	0.48	0.46	0.45	0.43	0.41	0.40	0.39	0.37	0.35	0.34
700			0.46	0.44	0.43	0.41	0.39	0.38	0.37	0.35	0.34	0.33	0.32
800			0.42	0.40	0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30	0.29
900			0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30	0.29	0.28	0.27
1,000			0.36	0.35	0.33	0.32	0.31	0.30	0.29	0.28	0.27	0.26	0.25

(Apply correction factor to standard air density, sea level, 70°F = 0.075 lb/cu ft at 29.92 in Hg)

Source: Adapted from "HVAC Systems Duct Design," published by the Sheet Metal and Air Conditioning Contractors National Association Inc. (SMACNA), Chantilly, VA, and "Goulds Pump Manual GPM6," Goulds Pumps Inc., Seneca Falls, NY, used with permission.

Friction Factors for Clean Commercial Steel and Wrought Iron Pipe[18]



Problem: Determine the friction factor for 12-inch Schedule 40 pipe at a flow having a Reynolds number of 300,000.

Solution: The friction factor (f) equals 0.016.

Resistances of Elbows, Tees and Bends—Table I

(Resistance in equivalent pipe length, ft)

Nominal Pipe Size, In	90° Elbows*: Short Radius, R = 1.0	90° Elbows*: Long Radius, R = 1.50	90° Bends*: R = 5.0	90° Bends*: R = 10.0	Tee: Flow-Through Branch	Tee: Flow Through
1½	4.5	3	2.5	4	8	3
2	5.25	3.5	3	5	11	3.5
2½	6	4	3.5	6	13	4
3	7.5	5	4	7.5	16	5
4	10.5	7	5.5	10	22	7
6	15	10	8.5	15	30	10
8	21	14	11	20	40	14
10	24	16	14	25	50	16
12	32	21	16	30	60	21
14	33	22	19	33	65	22
16	39	26	21	35	75	26
18	44	29	24	42	85	29
20	49	32	27	50	100	32
24	57	38	32	60	120	38

*For 45° elbows and bends, estimate 50% of tabulated values.
For 180° returns, double the tabulated values.

velocity as a volumetric flowrate, Q, gpm, we substitute $D = d/12$, and $v = 0.408(Q/d^2)$ into Eq. (13). These substitutions now yield:

$$\Delta P = 0.000216 f L \rho (Q^2/d^5) \quad (14)$$

where ΔP is pressure drop, psi; f is friction factor; L is pipe length, ft; ρ is density lb/ft^3; Q is volumetric flowrate, gpm; and d is pipe diameter, in. Note that density and volumetric flowrate must be expressed at the flowing temperature.

If we want to express the pressure drop as the customary loss per 100 ft of pipe, we substitute $L = 100$ ft in Eq. (14), and get:

$$\Delta P_{100} = 0.0216 f \rho (Q^2/d^5), \text{ psi/100 ft} \quad (15)$$

Eq. (15) can be expressed in terms of specific gravity, S, by substituting $\rho = 62.37S$:

$$\Delta P_{100} = 1.35 f S (Q^2/d^5), \text{ psi/100 ft} \quad (16)$$

[Note that in establishing Eq. (16) the density of water, 62.37 lb/ft^3, is at 60°F. Hence, the specific gravity, S, in Eq. (16) must be the density of the liquid at flowing temperature compared to the density of water at 60°F.]

Eq. (15) and (16) are the most convenient for calculating unit losses in liquid lines. Values of d^5 are listed in manufacturers' catalogs.

Example 1—What is the pressure drop per 100 ft in a 6-in Schedule 40 (I.D. = 6.065 in, d^5 = 8,206 in^5) line for kerosene? Liquid conditions are: flowrate, Q_{60} = 900 gpm; density, ρ_{60} = 51 lb/ft^3; and temperature, t = 321°F.

Resistances to Flow for Various Types of Valves—Table II

(Resistance in equivalent pipe length, ft)

Nominal Pipe Size, In	Gate Fully Open	Globe,* Fully Open, Bevel or Plug Seat: 90°	Globe: 60°	Globe: 45°	Check: Swing	Check: Ball	Straight-Through Cock†	Three-Way Cock‡: Straight-Through Flows	Three-Way Cock‡: Flow-Through Branch	Butterfly, Fully Open
1½	1.75	46	23	18	17	20	2.5	6	20	6
2	2.25	60	30	24	22	25	3.5	7.5	24	8
2½	2.75	70	35	30	27	30	4	9	30	10
3	3.5	95	45	31	35	38	5	12	36	12
4	4.5	120	60	43	45	50	6.5	15	48	15
6	[illegible]	175	86	[illegible]	[illegible]	75	10	22	70	23
8	9	230	125	95	90	100	13	30	95	27
10	[illegible]	260	150	130	125	130	16	38	120	35
12	[illegible]	320	170	145	140	150	19			42
14	[illegible]	383	190	160	155	170	25			45
16	[illegible]	425	[illegible]	[illegible]	170	190	22			50
18	[illegible]	460	250	[illegible]	180	215	24			58
20	23	520	[illegible]	240	[illegible]	240	27			64
24	32	[illegible]	[illegible]	[illegible]	[illegible]	295	33			79

*[illegible]
†[illegible]
‡[illegible]

Viscosity of Gases and Vapors

The curves for hydrocarbon vapors and natural gases in the chart at the upper right are taken from Maxwell[13]; the curves for all other gases (except helium[32]) in the chart are based upon Sutherland's formula, as follows:

$$\mu = \mu_0 \left(\frac{0.555\,T_0 + C}{0.555\,T + C}\right)\left(\frac{T}{T_0}\right)^{3/2}$$

where:

μ = viscosity, in centipoise at temperature T.

μ_0 = viscosity, in centipoise at temperature T_0.

T = absolute temperature, in degrees Rankine (460 + deg. F) for which viscosity is desired.

T_0 = absolute temperature, in degrees Rankine, for which viscosity is known.

C = Sutherland's constant.

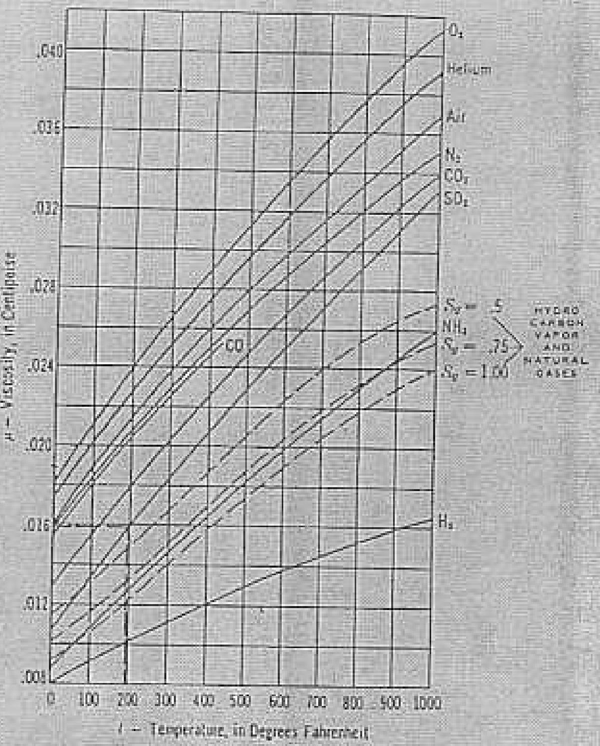
Note: The variation of viscosity with pressure is small for most gases. For gases given on this page, the correction of viscosity for pressure is less than 10 per cent for pressures up to 500 pounds per square inch.

Fluid	Approximate Values of "C"
O_2	127
Air	120
N_2	111
CO_2	240
CO	118
SO_2	416
NH_3	370
H_2	72

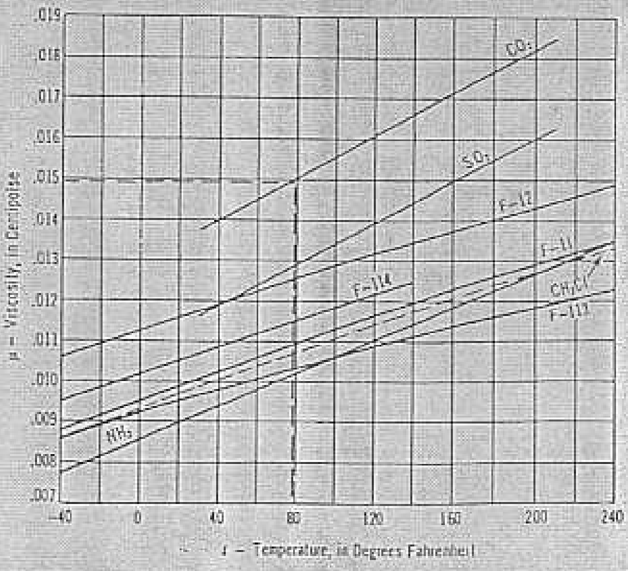
Upper chart example: The viscosity of sulphur dioxide gas (SO_2) at 200 F is 0.016 centipoise.

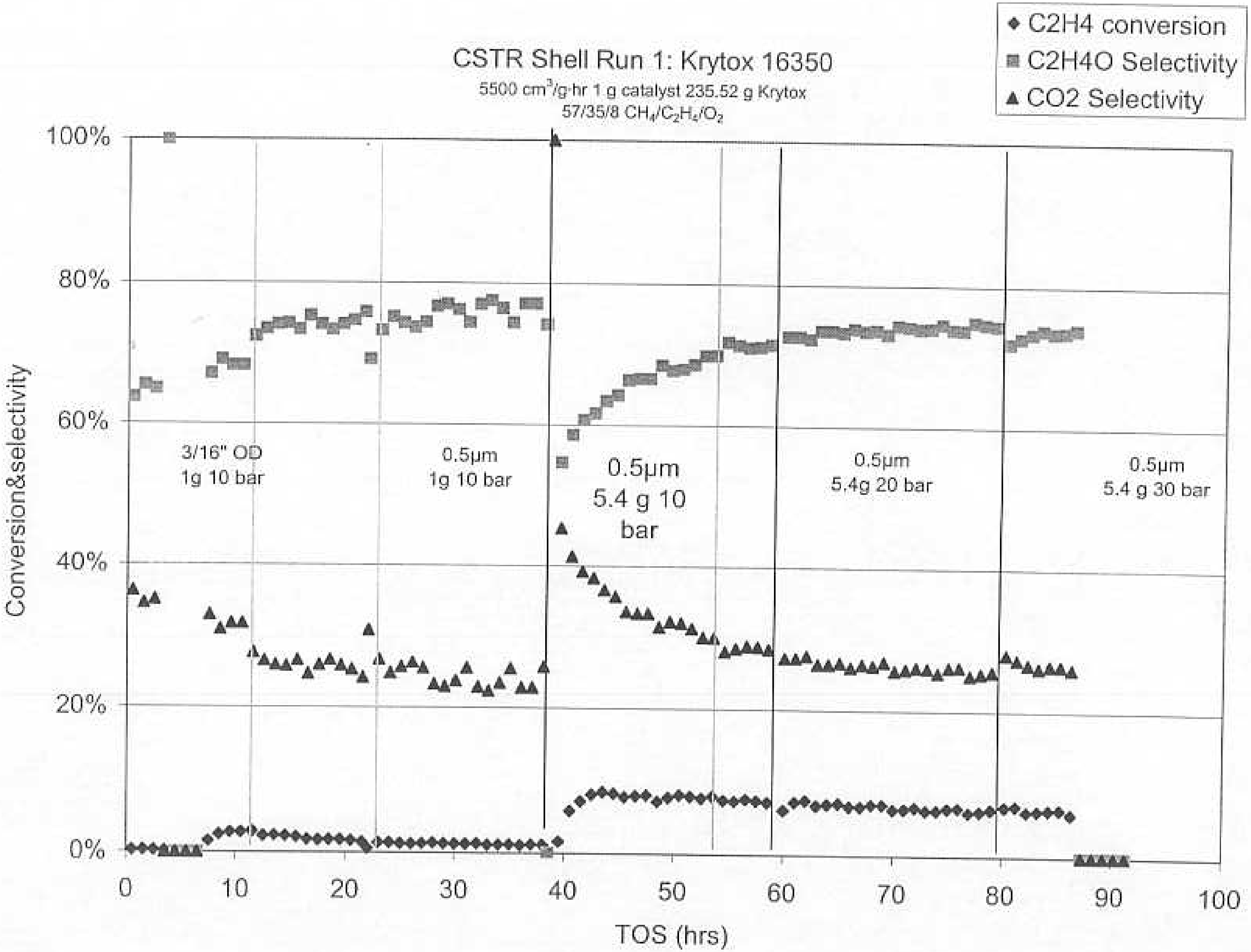
Lower chart example: The viscosity of carbon dioxide gas (CO_2) at about 80 F is 0.015 centipoise.

Viscosity of Various Gases*



Viscosity of Refrigerant Vapors[11]
(saturated and superheated vapors)




CSTR Shell Run 1: Krytox 16350
5500 cm³/g·hr 1 g catalyst 235.52 g Krytox
57/35/8 CH4/C2H4/O2
C2H4 conversion
C2H4O Selectivity
CO2 Selectivity
Conversion&selectivity
100%
80%
60%
40%
20%
0%
3/16" OD
1g 10 bar
0.5µm
1g 10 bar
0.5µm
5.4 g 10
bar
0.5µm
5.4g 20 bar
0.5µm
5.4 g 30 bar
0
10
20
30
40
50
60
70
80
90
100
TOS (hrs)

Data Summary

CSTR Sell Run 1	CSTR-700 RPM
Experiment Reference:	NB#136PG#22
Date:	8/2/02
Catalyst:	Shell Catalyst 43-53µm
Catalyst pretreatment:	none
Catalyst Mass (grams):	As Indicated
Krytox 16350 - Lot 16	235.3200

TOS Range	**11.5-21.5**		**23-38**		**54.5-58.5**		**60-79**	
sparger	3/16" OD		.5µm		.5µm		.5µm	
Catalyst Loading (g)	0.999		0.999		5.3996		5.3996	
Reaction Conditions	Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
Dilluant	CH_4		CH_4		CH_4		CH_4	
Promoter	None		None		None		None	
External Temperature (°C)	304.7	1.5	N/A	N/A	295.8	3.9	304.2	0.8
Internal Temperatue (°C)	198.8	1.24	N/A	N/A	198.3	1.73	198.9	0.90
Pressure (psig)	136.5	1.15	134.9	3.65	133.3	2.79	285.9	3.70
GHSV (cm^3/h·g)	5512.55		5512.55		1019.90		1019.90	
Effluent Conditions								
EO Flow (µmol/s)	0.35	0.07	0.21	0.02	1.27	0.03	1.18	0.06
EO Mole Fraction	0.01	0.00	0.003	0.00	0.02	0.00	0.02	0.00
EO Partial Pressure (psia)	0.63	0.06	0.47	0.04	2.83	0.05	5.33	0.61
Conversion and Selectivity								
Ethylene Conversion	1.96%	0.42%	1.19%	0.09%	7.42%	0.16%	6.70%	0.40%
Oxygen Conversion	11.92%	2.29%	9.31%	0.97%	42.04%	1.08%	37.11%	3.68%
EO Selectivity	74.13%	0.96%	75.62%	1.46%	71.47%	0.32%	73.83%	0.68%
CO_2 Selectivity	25.87%	0.96%	24.38%	1.46%	28.53%	0.32%	26.17%	0.68%
Shell Selectivities								
S1	74%	1.0%	76%	1.5%	71%	0.3%	74%	0.7%
S2	74%	1.0%	76%	1.5%	71%	0.3%	74%	0.7%
S3	68%	2.8%	62%	2.6%	70%	0.6%	71%	2.6%
S4	64%	5.1%	48%	5.2%	68%	1.1%	69%	4.9%
S5	82%	3.6%	90%	1.0%	75%	1.1%	78%	2.3%
S6	74%	1.0%	76%	1.5%	71%	0.3%	74%	0.7%
Deactivation								
Normalized Rate (day^{-1})	-0.987		-0.295		-0.145		-0.161	

VIII: APPENDIX D: QUESTIONS/ANSWERS AFTER JUNE 2000 DESIGN REVIEW

CeraMem's Responses to June 14, 2000 Design Review Comments

1. What gasket material will be used?

EPDM

2. Use welded vs. bolted joint for can to tube sheet attachment.

At this time, we prefer to use the gasketed design since this has been shown to work well at ORNL. We believe this should be acceptable to SRS because (1) gasketed joints are used elsewhere, e.g., HEPA filter flanges, and (2) the gasketed joints are entirely internal to the filter vessel. Furthermore, the number of mechanical joints at the tube sheet has been significantly reduced by utilizing a studding outlet design on the filter can flange, with non-penetrating bolt holes in the vessel tube sheet. While we believe welding the filter cans to the tube sheet is feasible, this would require development and testing.

3. Weld the entire vessel together.

CeraMem has redesigned the vessel and eliminated the large body flange previously employed.

4. A flow meter exists in the stack.

The existing flow meter can be utilized assuming it can be instrumented to perform the necessary functions of the system design. This will be determined in the detailed design phase.

5. What are the manufacturing tolerances of filter elements?

Filter cans and seals between the filter elements and cans take into consideration the tolerances of the ceramic filter elements. The tolerance in filter diameter is 5.66 +/- 0.079", and tolerance in length is 12" +/- 0.050".

6. What is the failure rate in manufacturing and in operation?

CeraMem is still developing the filter manufacturing process. The initial product yield in the first production run was slightly above 50%. CeraMem anticipates that once a fully developed manufacturing process is place, these filters will be made at yields above 90%.

The failure rate of filters in operation is unknown at this time. It will be highly dependent upon the actual processing conditions and can only be determined through in-field use. Fifteen-year life is considered a reasonable expectation.

7. Eliminate bypass around CM Filter.

Done.

8. What is the estimated cleaning volume.

The volume of the upper filter vessel plenum and flush lines is estimated at about 45 gallons. If two volumes of cleaning/flush water were used, about 90 gallons of water would be used in each cleaning. However, this depends on the cleaning cycle requirements under development at SRTC.

9. What is the weight of the unit? Add lifting lugs.

CeraMem estimates the weight of the vessel at approximately 1200 pounds. This includes the weight of seven filter cans at 42 pounds each. Lifting lugs are included in the current design.

10. Explore other cleaning mechanisms such as use of steam.

Development of cleaning techniques is to be done by SRTC. We can design the system to incorporate steam or other *in situ* techniques, if found desirable by SRTC.

11. What codes and standards are you designing and constructing the HEPA Filter Unit?

CeraMem's ceramic filter unit will be built based on the existing Tank 11 H&V Skid design as defined in SRS Specification G-SPP-H-00022 and referenced standard ASME N509. The additions and modifications will be made in accordance with these specifications, codes and standards. The new filter vessel will conform to ASME VIII and could be stamped or not (designed only) depending on WSRC requirements. The ductwork, piping and other mechanical and electrical features would conform to the appropriate existing specifications as well.

CeraMem's ceramic, cleanable filter itself is uniquely different in design, construction and performance from the traditional, disposable, glass fiber filters currently in use and for which SRS's Specification M-SPP-G-00243 and referenced standard ASME N510 are written. Therefore, CeraMem intends to review and interpret the appropriate specification and standard sections and requirements in order to provide both intended and meaningful design features and test results for it's unique ceramic HEPA filter.

12. In your design and construction of the HEPA Filter Unit, are you following ANSI/ASME AG-1 (formerly ANSI/ASME N-509 & N-510)? Ultimately the HEPA Filter Unit has to be constructed in accordance with ANSI/ASME AG-1 (Design & construction formerly N-509 the inspections and testing N-510).

With regard to AG-1, CeraMem understands that AG-1 represents the evolution of the two industry standards N509 and N510 into actual ASME Code documents. As such, and if required, this code will be followed when it supercedes the standards. Certain exceptions arise from the differences between the glass fiber HEPA filter and CeraMem's unique ceramic HEPA filter. As discussed above, other than the filter elements and process parameters related to these (e.g. pressure drop), the design will conform to the existing WSRC specifications.

13. Material that will be selected for O.D. Skin covering of the filter media is of concern. If material fails, liquid will get into the dead space. This O.D. surface should be a ceramic solid surface.

The skin of the filter could potentially be sealed with a commercially available silicate based glaze. Chemical and mechanical durability of the coating would have to be evaluated were this approach taken. Instead, we intend to fill the dead space with suitable vulcanized EPDM potting compound.

14. Recommend vacuum pump discharge line to be routed to stack in place of waste tank.

The vacuum drying technique has been abandoned in the current design. This line will now be used to supply heated air for filter element drying.

15. Consider using cement seal at filter can interface top and bottom. Note: Channel plugs are cement seal → need standard change?

While ceramic-metal seals might be possible, we see this as a significant development program, unnecessary since the EPDM seal should be long-lived in radioactive service. A flexible seal at this position allows for differences in coefficients of thermal expansion between the ceramic filter and the metal can. It also accommodates dimensional tolerances for the can and filter elements. Finally, it places the elements under a slight compressive load. These factors minimize mechanical stresses on the filter, providing the most reliable design.

16. What is structural integrity of ceramic, how much force/impact to crack/fracture?

The compressive strength of the monoliths is about 5800 psi while the flexural strength (i.e. modulus of rupture) ranges from 300 to 4350 psi depending on direction. CeraMem has no problems handling the parts during filter fabrication and would not anticipate any mechanical problems of the filter assemblies during installation.

During operation, the largest stresses are during water back flushing. The monolith, based on CeraMem's experience with liquid filtration, can readily support more than 100 psi for filter flushing.

17. The efficiency of the filters need to be evaluated on a range of ambient outdoor temperatures (say 0°-120°F) as we will use this system in an outdoors environment subject to these conditions.

The testing program recently completed at ORNL has not incorporated measurement of DOP retention other than at ambient conditions. Filter mechanical stability is not an issue. We expect aerosol capture efficiency would vary with temperature similarly to any HEPA filter, since capture mechanisms are essentially the same. CeraMem would propose testing the filter in the field at SRTC after it has been qualified at room temperature. Note that the current design incorporates a traditional HEPA filter as a backup filter.

18. Plan on a lifting eye for crane to hook on to remove. Will piping above preclude removal by crane?

Lifting lugs will be designed and located during the detailed design once the most appropriate removal scheme is determined. The flanged piping arrangement is intended to allow an up-and-out removal procedure using side access via a fork truck or davit/crane arrangement.

19. What are effects on filter as far as expansion/contraction is concerned due to outside temperatures (ambient)? Will it crack?

Using the temperature range of 0°F to 120°F, the differential change in the length between the filter element and the stainless steel mounting can will be approximately 0.0056" in contraction (metal can shorter relative to filter element) at low temperature and 0.0043" in expansion (metal can longer relative to filter element) at high temperature. Assuming the compressive modulus of the elastomer to be about 10,000 psi, the additional stress on the monolith at low temperature will be about 150 psi. At high temperature, the stress will be reduced. Based on similar seal types, CeraMem would estimate that it would take about 180 psi to seal the gasket. After applying additional compression to compensate for compression set of the elastomer (0.010" of compression) and loss of compression at higher temperature (115 psi), the initial gasket stress would be about 560 psi. When the additional compression at lower temperature is added, the maximum stress on the gasket (and hence the filter element) would be about 700 psi. This is significantly less than the 5800 psi compressive strength of the monolith. Therefore, the filter element should not crack due to thermal transients.

20. Do you have an "erosion" type effect on the filter media depending upon the number of times you flush it (if we flush a lot, will it still last 15 years)?

The membrane coating is fired to a high temperature after coating in order to bond the particles in the coating to each other and to the support surface. Hence, CeraMem would not anticipate any significant erosion of the filter media due to back flushing.

21. If you don't air dry, will contaminants "wick" through the filter media?

If the filter is wetted, the pores will fill. This is no different than for the Mott metal filters or the traditional fiberglass HEPA filters. It is not clear if this liquid would be reentrained as an aerosol on the clean side of the filter. Wetting of the filter would be manifested in a rapidly increasing pressure drop, which is an alarm/shutdown condition.

22. Operating procedure for either the Mott or CeraMem System should include closing the trap on the demister before back pulsing the filter with air.

The drain piping arrangement now incorporates this change.

23. Filters should be bubble point tested to determine the pressure necessary to pull water through the membrane. If it is significantly above the pressure generated by the vacuum pump, then soluble radioactive cesium will not be pulled through.

Wettability of the filter depends on the surface tension of the liquid. It is not clear that a bubble point test with pure water would reflect wettability with an actual aerosol. Further, as for traditional HEPA filters, a significant factor in achieving HEPA filter performance is diffusional capture of the aerosols. Thus, the wetting and wicking of entrained water is best addressed by staying above the dew point, and depending on increase in pressure drop to lead to an alarm/shutdown sequence in case of reheater failure.

24. Filter element validation should occur after the filters are canned. This does not apply to Phase IIA testing of filter elements by ATI.

As described in the Draft Acceptance Test Plan, various tests will be performed on the filters, including tests of individual filters in cans and the final assembled filter vessel.

25. In general, the SRS review panel preferred to have the conventional HEPA filter downstream of the blower but saw no reason for CeraMem to change the system design. The general consensus was that we should assume that the ceramic HEPA filters would work. Also, it was pointed out that glass fiber HEPA filter vessels (Flanders) are made with 1 psi flanges and can be made with 3 psi flanges so having the conventional HEPA filter between the ceramic HEPA filter vessel and the blower should not be problem.

CeraMem's design leaves the conventional HEPA between the ceramic HEPA and the blower.

26. CeraMem needs to anticipate water condensing on the dirty side of the filters even if the gas pretreatment train is in place. Therefore, a condensate drain line with an isolation valve for cleaning is required. This second drain line can be branched off to a collection tank for acidic wash water if acid is used on the skid.

The CeraMem design includes cleaning piping that can be utilized for this purpose.

IX. APPENDIX E. ASME REPORT

TECHNICAL PEER REVIEW REPORT

REPORT OF THE REVIEW PANEL

ALTERNATIVE CERAMIC HIGH EFFICIENCY PARTICULATE AIR FILTRATION SYSTEM

Members of the Review Panel:

James W. Dickey
Frederick S. Jeselsohn
Francis J. Patti
Richard D. Porco, Chair
Bernard J. Scheiner
Henry Shaw

SEPTEMBER 11-15, 2000
RICHLAND, WA

ASME International

(Report Submitted: September 20, 2000)

INTRODUCTION

Based on a request from the Office of Science and Technology (OST), Office of Environmental Management, U.S. Department of Energy (DOE), a Review Panel (RP) was established to peer review the "Alternative Ceramic High Efficiency Particulate Air Filtration System". The RP received reading materials provided by project managers (1-14). The Project Summary and the Review Criteria were prepared by the Technical Secretary of the RP and approved by the DOE project managers. The RP met on September 11-15, 2000 in Richland, WA. At the beginning of the meeting, the RP was introduced to the American Society of Mechanical Engineers (ASME) peer review process and the DOE's desire for a non-conflicted and independent peer review. The Project Team presented its findings in about three hours, and the RP had an executive session. On September 11, 2000, a discussion was held to give the RP the opportunity to ask clarifying questions. Subsequently, the RP prepared its Report of the Review Panel.

PROJECT SUMMARY

The objective of this project is to develop alternative filtration technologies for use on high-level radioactive liquid waste tanks. The new ceramic filters must have High Efficiency Particulate Air (HEPA) efficiency performance, and be regenerated or cleaned in situ. Additionally, the system should prevent the passage of moisture through the filter because cesium is relatively soluble in water. Each of the 1.3 million-gallon tanks on the site is equipped with an exhaust ventilation system to provide tank ventilation and to maintain the tank contents at approximately 1-in. water gauge vacuum, to prevent the release of radioactive material into the environment. These systems include conventional, disposable, glass-fiber, HEPA filters that require frequent replacement and disposal. The routine replacements are often caused by structural weakening or accelerated filter loading due to the moist-operating environment. The current ventilation systems include demisters, condensers, and reheaters to reduce the possibility of carryover of cesium dissolved in the moist ventilation air. The end-user may choose to leave the demisters, condensers, and reheaters as part of the ventilation system, but a system that does not require these components is preferred. In conjunction with the National Energy Technology Laboratory, CeraMem—a commercial vendor—is under contract to develop alternative filter technologies. A ceramic monolith filter is evaluated for full-scale development and hot demonstration on a waste tank at Savannah River Site (SRS).

The ceramic monolith filter consists of seven filter elements in individual stainless sleeves contained in a stainless steel filter vessel. The filter elements are ceramic-membrane-coated silicon carbide monoliths plugged in a dead-end flow configuration. Each filter element uses a "unitary" silicon carbide monolith of 5.66" diameter and 12" length. Each filter is inserted into a stainless tubing sleeve of 6" outer diameter and 0.065" wall thickness. The bottom of the sleeves has a stainless washer welded to the bottom as a retaining ring. The small gap between the filter element and the sleeve is filled with an *in situ* vulcanized rubber seal to eliminate liquid collection in this area. The elastomer is not intended to form a primary seal, but it is used to eliminate dead space. The top of the sleeve is flanged for mounting to a tube sheet located between the filter vessel flanges. The seven filter elements are bolted to the tube sheet in a closely-packed hexagonal array.

The laboratory-scale filters were tested to determine the feasibility of regenerating or washing them in situ with a liquid after becoming plugged with simulated High Level Waste (HLW) sludge, simulated HLW salt, and simulated atmospheric dust (South Carolina road dust). The filters were tested in a hostile environment where they would plug rapidly in order to maximize the number of filter cleaning cycles that would occur in a specified period of time. Cleaning solutions included water, mild nitric acid, and caustic solutions.

Parallel with the SRS testing efforts, CeraMem has been developing conceptual and full-scale designs for moisture-tolerant, washable (regenerable) HEPA filter systems for initial cold demonstration at Savannah River Technology Center (SRTC) facilities and—if the testing is successful—hot deployment on an operating tank at SRS.

PEER REVIEW CRITERIA

The RP was asked to assess the project based on the following review criteria:

1. Does the test approach employed at the SRTC test facility adequately evaluate the efficiency of the filter media and the effectiveness of the cleaning approach?
2. Will the proposed full-scale testing system adequately simulate the conditions that the filter system is expected to encounter in field service?
3. Do the media and systems conform to the "intent" of the directives "DOE HEPA Filter Test Program" (DOE-STD-3022-98) and "Specification For HEPA Filters Used by DOE Contractors" (DOE-STD-3020-97)?
4. Can the media meet the leak test requirement of "Standard Practice for Evaluation of Air Assay Media by the Monodisperse DOP (Dioctyl Phthalate) Smoke Test" (ASTM D2986-95a)?
5. Can the media meet the requirement of the "Code on Nuclear Air and Gas Treatment" (ASME AG-1-1997)? If not, does it meet the intent of the requirement?
6. Are the filter systems that are proposed for full-scale development viable?
7. The results of testing suggest that pressure drops associated with the proposed media exceed the prescribed limit for true HEPA classification. Is the Project Team's assumption that this can be approved for use under the intent of the above-mentioned standards reasonable? Has the Project Team considered alternatives for pursuing approval for use?
8. Do the documents provided address the mandatory requirements—and those expected to be required—under a normal technology development activity?
9. Has the Project Team published articles resulting from this project in peer-reviewed journals?
10. Based on the technical merit of this project, should it be continued?

FINDINGS OF THE RP

The findings of the RP with respect to the review criteria are as follows:

1. The SRTC test facility did not establish a base-line for testing the efficiency of the filter. Some tests were performed for a dead-ended membrane filter with silicon carbide support coated with glass-frit-bonded zirconium silicate and alumina; however, no tests were performed by SRTC for the dead-ended monolithic filter with silicon carbide support coated with microporous silicon carbide membrane that is currently selected for deployment. Similarly, the cleaning method has been changed for Phase II. Therefore, no baseline was established to assess the effectiveness of the

cleaning approach.

2. The proposed full-scale testing system will adequately simulate the conditions that the filter system is expected to encounter in field service if the effluent of the tank selected for Phase II demonstration bounds the expected conditions of service.
3. The media and systems do not conform to the "intent" of the directives "DOE HEPA Filter Test Program" (DOE-STD-3022-98) and "Specification For HEPA Filters Used by DOE Contractors" (DOE-STD-3020-97) because the filter has not been sufficiently developed to establish the parameters that require control in the design, manufacturing, testing, and installation of the filter and system.
4. The media can meet the leak test requirement of “Standard Practice for Evaluation of Air Assay Media by the Monodisperse DOP (Dioctyl Phthalate) Smoke Test” (ASTM D2986-95a).
5. The media cannot meet the requirements of the "Code on Nuclear Air and Gas Treatment" (ASME AG-1-1997) because these requirements do not include ceramic HEPA filters. The media could meet the intent of these requirements if valid test methods and base-line conditions are established to meet the intent of the qualification and performance testing of ASME AG-1-1997.
6. The filter systems proposed for full-scale development are viable if findings 1-5, 12, and 15 are adequately addressed.
7. The test results suggest that pressure drops associated with the proposed media exceed the prescribed limit for true HEPA classification. The Project Team's assumption that this can be approved for use under the intent of the above-mentioned standards is reasonable.
8. The documents provided do not address the mandatory requirements—and those expected to be required—under a normal technology development activity because the data presented are incomplete due to the changes in the directions of development of the filters.
9. The Project Team has not published articles resulting from this project in peer-reviewed journals.
10. This project should be continued provided that the recommendations of the RP are adequately addressed.

In addition, the RP has the following findings:

11. A HEPA filter, by definition, must be 99.97% efficient on thermally generated particles with a mean diameter of 0.3 μm. The filters tested in this program were tested with particles with the mean diameter equal to approximately 0.7 μm to determine leak efficiency, not performance efficiency. Therefore, these results cannot be used to fulfill the requirements of the HEPA filter definition. Filter media (i.e., not filters) have been tested by ATI for performance efficiency. Some filter media met the HEPA filter definition criteria; however, complete filters have not been tested.
12. Accelerated durability tests have not been planned or conducted to determine media life-time under bounded conditions of expected service. A return to the initial pressure drop is not sufficient evidence to demonstrate that the performance of the filter has not changed.
13. The Project Team has severe timing constraints to address the above findings before deployment. Although the exploratory research performed by the Project Team is of commendable quality, the RP feels that baseline testing is the necessary next step before deployment.
14. A code section FI, Metal Filters (which also includes ceramic filters), is currently “in the course of preparation” to be included in ASME AG-1. It may be beneficial to the Project Team if members interface with the ASME Subgroup FI.
15. The seals for the ceramic filters are not defined.

CeraMem Corporation; (May 30) 2000.
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BIOGRAPHICAL SUMMARIES OF THE MEMBERS OF THE RP

James W. Dickey is a consultant with expertise in: transportation; the storage and processing of spent reactor fuel; and environmental compliance management. He has evaluated a plutonium facility for re-start after a shutdown for safety concerns; provided engineering and design support for the decontamination and removal of contaminated ventilation systems for a nuclear fuel processing facility; as well as provided guidance and reviewed plans for compliance requirements with the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency for the decommissioning of a research reactor. James Dickey has been a consultant to the DOE, coordinating data acquisition and preparing the first Baseline Environmental Management Report to Congress—which addressed the cost and scheduling for clean-up of the Savannah River Site (SRS); System Engineering manager for High Level Waste (HLW) at the SRS; providing expert advice on all technical and safety aspects associated with HLW engineering systems; project manger on two major SRS projects involved in the separation of uranium isotopes using advanced technology, and uranium oxide fuel fabrication; Technical Authority on DOE Orders 6430.1A, "General Design Criteria"; "Project Management" for HLW facilities and projects, providing coordination and technical direction to division staff in the oversight of contractor engineering activities; and Branch Chief for the Liquid Waste Division, as program/project manager for radioactive liquid waste storage, transfer, treatment, and disposal. James Dickey also served as a supervisor in Nuclear Field Engineering and an Engineer and Supervisory Engineer in the Nuclear Fluid Systems and Mechanical Division. His various job responsibilites have included: evaluation and approval of safety analysis reports; processing hazards analysis; engineering calculations; start-up test plans; test results; and special procedures. He was also responsible for: the operation of high level waste tank farms; evaporators; in-tank precipitation facility; extended sludge processing facility; effluent treatment facility; new waste transfer facility; the waste removal from storage tanks; replacement of HLW evaporators, and various facility upgrade projects, such as upgrading waste tank ventilation systems to the latest nuclear criteria. James Dickey was the Deputy Director of DOE's New Production Reactor (NPR) Project Management Office (where he participated/directed/coordinated activities in all aspects of the NPR project) and, the Project Engineering Division of SRS (where he was involved in projects ranging in size from $10 million to $250 million). James Dickey also certified the official readiness of all nuclear fluid systems and mechanical equipment for start-up testing and operation of a reactor plant; participated in 7 reactor plant start-ups after 100% refueling, and 11 reactor plant start-ups after extended maintenance and overhaul outages; and reviewed and approved shipyard facility design and modifications for facilities in which nuclear work was accomplished. He also designed nuclear support systems and developed operating and test procedures; designed and constructed reactor plant fluid system decontamination systems and equipment; and prepared operating procedures. James Dickey studied Chemical Engineering at both undergraduate and graduate levels at Texas A&I University. He is a registered professional engineer.

Frederick S. Jeselsohn is currently an independent consultant. He has previously worked for various companies including: Reeco, Inc. & Reeco-Dürr as a Fume Incinerator designer—designing the largest unit ever built; Ray Engineers International, Inc.,—consulting engineers—as Chief Civil/Structural Engineer; Research-Cottrell as a designer and consultant for air pollution control equipment; C F Braun & Co., as High-Temperature High-Pressure Vessel Specialist; The Air Preheater Company as Project Engineer for Heat Exchangers and Air Pollution Control Equipment; and Baldwin-Lima-Hamilton Corporation—heavy equipment manufacturers and fabricators—as Project Manager and Manager of the Stress Analysis Department. He is a specialist in the design of high pressure/high temperature vessels. Frederick Jeselsohn has over 30 years experience in the field of engineering and consulting. He has supervised the design of projects for: industrial and commercial installations; designed and specified equipment for petrochemical plants; designed vessels and vessel repairs, structures, and marine installations; designed high pressure/high temperature electrostatic precipitators; high voltage transformers; testing machines; mechanical cyclone collectors; and heat exchangers, as well as designed and estimated fabric filters and fume incineration equipment for utility and industrial applications. He has also been responsible for the design, fabrication, and erection of precipitators, including: ducts, supports, foundations, stacks and details, specifications, transformers and controls. Frederick Jeselsohn has been a member of The American Society of Mechanical Engineers for over 25 years and is the author or coauthor of numerous publications on precipitators. He received a Bachelor of Science in Civil Engineering from the University of Alabama, a Master of Science Degree from Newark College of Engineering, and completed the Electronic Certificate Course at the New Jersey Institute of Technology. Frederick Jeselsohn is a Licensed Professional Engineer in New York and New Jersey.

Francis J. Patti is currently an independent consultant with expertise in the fields of Civil Engineering and Nuclear Engineering. His architect engineer experience covers a wide range of technical and management areas—particularly, the nuclear area. He has been involved in nine major nuclear power projects, working with hot cell facilities; research reactors; radwaste facilities; and decommissioning projects. His experience includes both analytical work and systems designs. Francis Patti reviewed, evaluated, or was involved with: providing welding engineering support at construction sites; air modeling, permitting, hazardous waste issues; waste water treatment systems for power plants; emergency plans; procedures; safety analysis; tritium systems upgrade engineering; and piping verification work. Previously, Francis Patti was involved with various studies including: the decommissioning of Brookhaven Graphite Research Reactor; evaluation of containment liner under post LOCA conditions; the conversion of a nearly complete Russian nuclear power plant to coal firing; plutonium disposition; advanced liquid metal reactor; pressurized water reactor; modular high temperature gas reactor; NASA Plum Brook research reactor; Hoffman LaRoche/Medi-Physics Accelerator; Tritium Recovery Facility; Radwaste Facilities; the Savannah River Site and Three Mile Island, Unit 2—where he was on-site engineering manager for plant modifications during the initial recovery program following the accident of March 28, 1979. He had technical responsibility for safety on the Chemical Agent BZ Demilitarization Facility. During these various studies, he provided technical overviews on: fuel fabrication; process and instrument diagrams; component specifications; subcompartment analysis; pipe break and safe shutdown analysis; system design descriptions; safety evaluations; radiation shielding issues; decommissioning studies; volume reduction solidification facilities; filtered containment vent systems;and tritium target fabrication and recovery. He was responsible for the conceptual design report and detailed engineering for decommissioning three-100,000 gallon Radwaste Tanks, High Flux Beam Reactor reports for remote control room building and automated vent valve; detailed engineering of Vehicle Radiation Monitor; and a work plan for closure of landfills. At Brookhaven National Laboratory, he was project leader for a major modification to the medical research reactor. Francis Patti is an active member of the American Society of Civil Engineers and the American Nuclear Society. He is the author or coauthor of 18 technical papers. He holds a Bachelor of Science in Civil Engineering from Drexel University and a Master of Science in Civil Engineering from the Massachusetts Institute of Technology. He also has a diploma in Nuclear Science and Engineering from the International School of Nuclear Science and Engineering as well as a Master of Science and Professional Degrees in Nuclear Engineering from Columbia University. Francis Patti is a registered professional engineer in New York.

Richard D. Porco is currently Vice President of Power and Thermal Products at Ellis and Watts International, Inc.. He has over 30 years experience in engineering, design, and development of products and systems for the nuclear, military, and environmental facilities throughout the world. He was a member of the industry response team at Three Mile Island. Previously, Richard Porco worked as Senior Director of Engineering and Sales, as well as Director of Engineering with Ellis and Watts. He was responsible for the engineering; design; research; and development of products and systems for the nuclear, military, medical, pharmaceutical, and environmental markets. He developed and executed difficult business plans to establish Ellis and Watts as the dominant supplier of safety-related heating, ventilation, and air-conditioning equipment in the domestic and international markets. Prior to this, Richard Porco worked for various companies and served in various positions including: President of RDP Consulting Services; Manager of Chemical Filtration Products for Donaldson Co., Inc.; Manager of Engineering, and Assistant Manager of Nuclear Filter Systems for Mine Safety Appliances Co., Filter Products Div.; Systems Supervising Engineer for Struthers Wells Corporation; and Project Engineer for M.S.A. Research Corp., Division of Mine Safety Appliances Co. While serving in these positions, his job responsibilities included: providing design, fabrication, and testing expertise to the nuclear, military, pharmaceutical, and air filtration industries; chemical filtration products; development of the catalytic destruct system for volatile organic chemical removal (including ethylene oxide); engineering and development of all products for the Filter Products Division—including High Efficiency Particulate Air Filters, carbon adsorption and catalytic oxidation; filters; fans; dampers; seismic analysis; instrumentation and controls; heaters; and cooling coils; system design of the Closed Loop Dump Heat Exchangers for the Liquid Metal Fast Breeder Reactor Program; and responsibility for the design and overall job completion of systems and components conforming to the American Society of Mechanical Engineers (ASME) Code and nuclear specifications. He is a member of several professional societies and committees including: the Institute of Environmental Sciences; The American Nuclear Society; and the ASME, and he received a Certificate of Achievement Award and a Certificate of Appreciation Award from the ASME. He is Chair of the ASME Committee on Nuclear Air and Gas Treatment which is responsible for the ASME Code AG-1. Richard Porco teaches an ASME/ISNATT short course on Nuclear Air Cleaning Standards, and holds a patent for a Bacteria Control System for Ultrasonic Humidifier. He is the author or coauthor of six articles or technical papers. Richard Porco holds a Bachelor Degree in Chemical Engineering from the University of Dayton, and he has taken postgraduate courses from Penn State University.

Bernard J. Scheiner is President of BCD Technology and serves as part of the Graduate Faculty at the University of Alabama. He served as both Chairman of the American Filtration and Separations (AFS) Society, and Technical Editor of its Fluid/Particle Separation Journal, and serves on the Board of Directors of AFS. In the past he served as Chairman of the Mineral Processing Division of the Society for Mining, Metallurgy, and Exploration, where he also served on the Board of Directors. Bernard Scheiner received international recognition for research in the field of liquid-solid separation which included the developing of a new dewatering technology (that is being evaluated in the crush stone industry by large scale testing), and defining the mechanism of the flocculation sequence. Bernard Scheiner has authored or coauthored 160 technical papers, which includes 40 Bureau of Mines reports; editor of 12 books including: Advances in Filtration and Separation Technology, Vol. 5, Separation Problems and the Environment; Advances in Filtration and Separation Technology, Vol. 10; Pollution Prevention for Process Engineers; and Water and Wastewater Filtration. In addition he has published 120 outside publications—conference proceedings and review articles—and holds 18 patents. Bernard Scheiner has been granted the Distinguished Service Award by the U.S. Department of Interior; the Wells Shoemaker Award; the Frank Tiller Technical Award—both given by the American Filtration and Separation Society; the Robert H. Richards Award—given by the American Institute of Mining, Metallurgical, and Petroleum Engineers; and The Mill Man of the Year Award from the Mineral Processing Division for Mining, Metallurgy, and Exploration. Bernard J. Scheiner holds a B.S. degree and a Ph.D. in Chemistry, both from the University of Nevada at Reno.

Henry Shaw is currently retired as Professor in the Department of Chemical Engineering, Chemistry, and Environmental Science at the New Jersey Institute of Technology (NJIT), where he directed an initiative to establish the Emissions Reduction Research Center—an NSF Industry/University cooperative Research Center for Pollution Prevention Technology—with Massachusetts Institute of Technology, the Ohio State

University, and Pennsylvania State. He is conducting research in the areas of: catalytic oxidation; scrubbing of acid rain precursors; packed and fluidized bed adsorption of acidic gases; control of soot/NO_x in Diesel engines; and sustainable green manufacturing of Department of Defense energetic materials. Previously, Henry Shaw worked for Exxon Research and Engineering Co., where he advanced from researcher to Area Manager in charge of obtaining and implementing internally and externally funded research and development (R&D) contracts in pollution control and energy conservation (greenhouse effect, low-NO_x turbines, solar applications, and cogeneration), as well as fossil fuel technologies (jet fuels from shale and coal oils, Fischer-Tropsch catalysts, pressurized fluid bed combustion). Prior to this Henry Shaw worked as a Nuclear Chemical Engineer for both Mobil Oil Company and Babcock & Wilcox Company, doing R&D in the areas of nuclear radiation induced activation of catalysts and reactions; chemical process design and development; nuclear fuel processing; re-processing; and waste treatment. Henry Shaw's professional activities include: Advisory Board for the *Journal of Clean Products and Processes*; Editorial Board of *Environmental Progress*; and Past Chair of the American Institute of Chemical Engineers Environmental Division. He contributed to three National Research Council Committees including Alternate Chemical Demilitarization Technologies, Future of Chemical Engineering, and the DOE Chemistry Program. He served as Chairman of the Engineering Foundation Board, and Chairman of the Oak Ridge National Laboratory Advisory Board for the Chemical Technology Division. Henry Shaw has received a number of awards, such as the Lawrence K. Cecil Award in Environmental Chemical Engineering; AT&T Industrial Ecology Faculty Fellow; Frank Dittman Excellence Award; and he was elected Fellow of the American Institute of Chemical Engineers. He holds four patents, and is the author or co-author of over 75 peer-reviewed publications. Henry Shaw holds a Bachelor's degree in Chemical Engineering from City College of New York; a M.S. degree in Chemical Engineering from NJIT; a MBA in Management; and a Ph.D. in Physical Chemistry from Rutgers University.

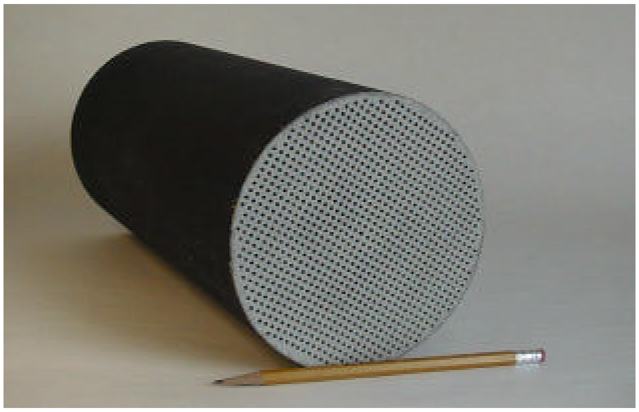
X. APPENDIX F. DRAFT TECHNOLOGY SAFETY DATA SHEET REPORT

International Union of Operating Engineers
National Hazmat Program

Human Factors Assessment Report

Alternative HEPA Filtration CeraMem Ceramic HEPA Filter

DOE Technology Management System #: 2091



Report Issued: August 2002

OENHP # 2001-11 Version A

International Union of Operating Engineers National Hazmat Program
International Environmental Technology and Training Center

Human Factors Assessment Report

Frank Hanley, General President

The OENHP would like to thank the following team members for their participation in this assessment and for the professional expertise they provided:
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Alternative HEPA Filtration CeraMem Ceramic HEPA Filter
OENHP # 2001-11 Version A

Table of Contents

1.0 EXECUTIVE SUMMARY

The Operating Engineers National HAZMAT Program (OENHP) assessment team conducted a human factors assessment on December 12, 2001 at the Department of Energy (DOE) Savannah River Site (SRS), Research Campus. The human factors assessment took place during a full-scale design review of the ceramic High Efficiency Particulate Air (HEPA) filter developed by CereMem Corporation.

The DOE maintains about 300 High Level Waste (HLW) tanks at its various sites around the United States. The vent gas from the HLW tanks is filtered through disposable glass fiber HEPA filters. Replacement of the used filters generates both a waste disposal problem and a problem of operator exposure during filter replacement.

The CereMem filtration system removes sub-micron particles from a tank venting air system. The CeraMem filter is housed above ground using an existing SRS skid system. A vacuum pump draws the air from the top of the tank through one of the filter sets. The dirty air with particulate matter travels via pipe to a demister and through a heater before entering the filter media. The entrained particles are filtered from the air by a micro-porous membrane. The clean air flows down clean channels and is exhausted from the filter. Conventional HEPA filters are in place behind the CeraMem filter and serve as a back up or failsafe system. Projected replacement of the CeraMem filters is every 15 years.

The Alternative HEPA Filter will be compared to disposable glass fiber HEPA filters, currently the baseline technology being used on HLW tank ventilation systems. The glass filters are subject to a shortened life span due to deterioration from condensation. Deterioration requires replacement of the filters, thus, creating worker exposure to the HLW and a waste disposal problem. The standard HEPA filters used at DOE facilities can be damaged by fire, potentially releasing radioactive particles to the environment. As a result of the OENHP assessment, the team recommended that the developer and users should create and implement a hazard communication program identifying all the known chemicals and contaminants in use or in the vicinity. Hazardous substances should be identified and Material Safety Data Sheets (MSDS) provided when necessary. The team also recommended the user develops and implement a comprehensive training program for material handling of hazardous substances and working with powered industrial trucks in a hazardous environment. Finally, the team recommended the development of standard operating procedures (SOPs) focusing on start-up and shutdown, both routine and emergency.

2.0 INTRODUCTION

2.1 OENHP Safety and Health Assessment

OENHP human factors assessment personnel included Chip Booth, M.S., Safety Professional; John Kovach, M.S., Safety Professional; Jeana Harrison, Industrial Hygienist; and Mary Jenison, M.S., ASP, Safety Professional from the DOE Office of Science and Technology. The assessment took place during a full-scale design review at the DOE Savannah River Site, Research Campus, 227 Gateway Dr., Aiken, SC 29803.

2.2 Technology Description and Operation

The *Specification for HEPA Filters Used by DOE Contractors,* DOE-STD-3020-97 defines HEPA filters as: "A throwaway, extended media, dry type filter with a rigid casing enclosing the full depth of the pleats. The filter shall exhibit a minimum efficiency of 99.97 percent when tested at an aerosol of 0.3 micrometers diameter".[1]

HLW tanks, located outdoors throughout the DOE complex, are equipped with a ventilation system to maintain the tank contents at negative pressure in order to prevent the release of radioactive material to the environment. These systems are outfitted with conventional disposable glass-fiber HEPA filters. CeraMem developed a ceramic monolith HEPA filter, in situ cleanable; to replace the conventional glass filters. The new technology ceramic HEPA filter is integrated into the existing SRS HEPA filter skid design.

The ceramic HEPA filter consists of seven (7) filter elements in individual stainless cans, contained in a stainless steel filter vessel. The filter elements are ceramic-membrane-coated (cordierite) silicon carbide (SiC) monoliths, 5.66-inch diameter and 12 inches in length, plugged in a dead-end flow configuration.

Each filter is inserted in a stainless steel can fabricated of 6 inch SCH 10S pipe with an inside diameter of 6.357 inches and a wall thickness of 0.134 inches. The top (outlet) of the can has a standard 6 inch 150# American National Standards Institute (ANSI) flange for mounting to a mating outlet on the tube sheet located within the filter vessel. The top and bottom of the filter elements have an Ethylene-Propylene-Diene-Monomer (EDPM) boot seal and is held in place with a retaining ring.

Each flanged can is attached to the tube sheet via a drilled and taped studded outlet. The only hole that exists in the tube sheet is the filter opening hole for clean gas passage. An EDPM gasket is used to form the final gas tight and liquid tight seal needed for proper filter operation. The seven filter elements are bolted onto the tube sheet in a closely packed hexagonal array. The tube sheet is welded into the vessel between the top head and shell course joint in the filter vessel forming clean and dirty air plenums above and below the tube sheet, respectively.

The vessel is designed and fabricated to American Society of Mechanical Engineers (ASME) Section VIII at 150 pounds per square inch gauge (psig) and full vacuum and measures 36 inches inside diameter by 48 inches overall length. The inlet and outlet nozzles are standard 8 inch 150# ANSI flanges to mate with existing piping.

All vessel materials of construction, other than the ceramic filter elements and the EDPM seals, are 304 stainless steel.

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[1] US Department of Energy, DOE Standard, *Specification For HEPA Filters Used By DOE Contractors,* DOE-STD-3020-97, January 1997.

During normal filtering operations, the vessel will operate between atmospheric and 50 inch water column (wc) vacuum. During in situ cleaning, the vessel will experience pressure sources that are normally regulated to 10 psig with relief protection devices to limit pressures to 15 psig. A vessel rupture disk, set at 20 psig, is provided on the vessel's clean side for ultimate vessel over pressure protection. Filter vessel weight including the seven filter cans is approximately 1200 lbs. Filter face velocity is approximately six ft/min.

The CeraMem filtration system removes submicron particles from a tank venting air system. The CeraMem filter is housed above ground utilizing an existing SRS skid system. A vacuum pump draws the air from the top of the tank through one of the filter sets. The dirty air with particulate matter travels via pipe to a demister and through a heater before entering the filter media. The entrained particles are filtered from the air by a microporous membrane. The clean air flows down clean channels and is exhausted from the filter. Conventional HEPA filters are in place behind the CeraMem filter and serve as a back up or failsafe system.

The filters become partially plugged by particles they filter out. The proper cleaning procedure is presently being developed. When the differential pressure across the filter reaches a specified level, the dirty filter is cleaned, in situ, by filling both the feed side and downstream side of the filter with nitric acid percent. The acid is drained into a holding tank and the filter is filled completely with filtered water from the clean side. The water is displaced with air into the waste storage tank. The filter is dried by flowing dry instrument air from the clean side, through the filter, into the headspace of the tank being vented. The acidic wastes are neutralized with sodium hydroxide, concentrations between 5 – 10 percent are currently being tested, and pumped into the tank being vented. In refining the cleaning procedure, a water only cleaning protocol may be realized.

The system is convertible to standard SRS design by removal of the ceramic filter vessel followed by minor modifications to the existing system to allow for the installation of a traditional HEPA filter. It is projected that the CeraMem filters will be replaced every 15 years.

3.0 METHODOLOGY

3.1 Methodology for Assessment of Safety Issues

The team completed a What-if Analysis. The What-if Analysis is a well-established tool designed to identify potential causes and consequences associated with a piece of equipment or process. During a What-if Analysis, a multi-disciplined team brainstorms about what would happen if an operator took a particular action (or failed to do so) as well as what the consequences would be if each piece of the equipment failed. The team then determines if there is a safeguard in place to deal with the consequence and makes a recommendation if that safeguard is missing or inadequate. The What-if Analysis is particularly valuable in that it identifies human error as well as component malfunctions. Using information from the What-if Analysis and the design review, the OENHP created a Technology Safety Data Sheet (TSDS). This innovative tool, based on the concept of the MSDS, is being developed for DOE technologies. The TSDS contains a broad summary of safety and health information about the technology in a format that is friendly for workers and useful to project engineers and safety professionals. See Section 6.0 for completed safety analyses.

4.0 RESULTS AND DISCUSSION

4.1 Safety Issues

4.1.1 Chemical Exposure

The ceramic HEPA filter and filter vessel will rely on several chemical agents during operation. Nitric acid will possibly be used during the cleaning process. Nitric acid is a strong oxidizer and a corrosive. After the cleaning process, the nitric acid will be neutralized using sodium hydroxide. Sodium hydroxide is also corrosive and irritating to the eyes, skin, and mucus membranes.

During development, and possibly onsite, users will perform a di-octyl phthalate (DOP) test to measure the filter's efficiency. A DOP test is defined as a measure of the efficiency of a filter for the production of ultra-pure air based on the concentration of 0.3 µm di-octyl phthalate aerosol particles that penetrate a filter at a predetermined flow. Expressed as a percentage of retention, 99.97% DOP retention indicates a HEPA filter grade as defined by ASTM D2986-71. (See Figure 4.1.1) Di-octyl phthalate is harmful if swallowed or inhaled. It causes irritation to the skin, eyes, and respiratory tract. It affects the central nervous system, liver, reproductive system, gastrointestinal tract, and is possibly a carcinogen.

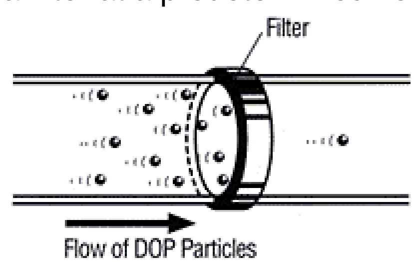

Figure 4.1.1: An example of a DOP test.

Finally, the operators working on or around the HLW tanks may be exposed to the contents of the tanks.

4.1.2 Material Handling

Material handling during set-up and deactivation/decommissioning will be an issue. Users will be required to safely place the skid and filter vessel in place during set-up and deactivation. The skid and filter vessel are mentioned separately here because they may be independently moved or moved as a unit. The skid supports the filter vessel and may be described as a working platform built around the filter vessel. During deactivation and decommissioning, the components will be contaminated and users will be transporting and storing hazardous materials. At this stage of development, both nitric acid and sodium hydroxide are necessary for the operation of the ceramic filter.

The nitric acid is necessary as a cleaning solution and the sodium hydroxide as a neutralizing agent. Both of these will have to be stored properly before they are introduced into the system. Nitric acid will require tightly closed containers housed in a cool, dry, well-ventilated area away from incompatible substances. Nitric acid brought

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into contact with reactive materials such as aluminum may result in the generation of flammable hydrogen gas. Sodium hydroxide storage will require a cool, dry, well-ventilated space away from strong acids, metals, flammable liquids, and organic halogens.

4.1.3 Moving Vehicles

During set-up and dismantlement, users will be required to move either the skid or the filter vessel separately or both as a unit. This will require the use of forklifts, small cranes, and large trucks. In addition to the traditional hazards associated with moving vehicles such as struck by or caught between, operators will be forced to perform some, if not all their tasks while wearing personal protective equipment (PPE). Depending on the level of PPE, operators may lose manual dexterity, may have restricted vision, and be more susceptible to heat stress.

4.1.4 Emergency Shutdown

Uncontrolled release of HLW may result during emergency shutdown. The alternative HEPA filtration system depends on several different systems during operation including condensers and pumps. One component's failure, or all the components being shutdown at the same time may have consequences that should be identified.

4.2 Baseline Comparison

The baseline the Ceramic HEPA Filter will be compared to is the glass fiber HEPA filter currently being used on HLW tank ventilation systems. The glass filters are subject to a shortened life span due to their deterioration from condensation. Deterioration requires replacement of the filters, thus, creating worker exposure to the HLW during replacement and a waste disposal problem. Current HEPA filters, because of their materials of construction, can easily be damaged or destroyed by heat: exposure of the filter medium to temperatures of 700-750 degrees F for only five minutes can significantly reduce filter efficiency. Fires in defense nuclear facilities can reach several thousand degrees.[2]

Temperature, humidity, moisture, and other factors associated with the HLW tanks do not affect the Alternative HEPA Filters. The developers anticipate a long service life of at least 15 years.

5.0 RECOMMENDATIONS

1. Develop and implement an effective hazard communication program. The basis of the hazard communication program should be a site-specific hazard analysis cataloguing all known hazards the users may be exposed to. This will include MSDSs for nitric acid and sodium hydroxide. The contents of the HLW tanks should be identified. The proper controls for each contaminant should be applied

[2] Defense Nuclear Facilities Safety Board. (1999, May). HEPA Filters Used in the Department of Energy's Hazardous Facilities. Technical Report 23. 2-4.

using the hierarchy of controls, engineering controls, administrative controls, and PPE.

2. Develop and implement an effective material handling training program. Users should be trained on the hazards associated with working in a hazardous environment as defined by the Occupational Safety and Health Administration (OSHA) in 29 CFR § 1910.120. Additionally, users should be trained with regard to use and storage of hazardous substances.
3. Develop and implement an effective powered industrial truck training program. Users should be trained on traditional hazards associated with powered industrial truck use as well as hazards created while working in a hazardous environment as defined by 29 CFR § 1910.120. Powered industrial truck training requirements may be found in 29 CFR § 1910.178.
4. Develop and implement SOPs outlining both routine and emergency shutdown procedures. Because of the characteristics of the HLW, anticipation of all scenarios is necessary to ensure the safety of the surrounding environment and workers. Both routine and emergency shutdown, as well as system failures, should be anticipated and planned for through SOPs.

6.0 APPENDIX

6.1 Acronym List

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASP	Associate Safety Professional
ASTM	American Society for Testing and Materials
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
dBA	Decibels in A-weighted scale
DOE	Department of Energy
DOP	di-octyl phthalate
EDPM	Ethylene-Propylene-Diene-Monomer
F	Fahrenheit
FMEA	Failure Mode Effects Analysis
ft	feet
HEPA	High Efficiency Particulate Air
HLW	High Level Waste

lbs	Pounds
mg/m^3	milligram per cubic meter
min	Minute
mm	Millimeter
MS	Master of Science
MSDS	Material Safety Data Sheet
OENHP	Operating Engineers National Hazmat Program
OSHA	Occupational Safety and Health Administration
PAO	Poly Alpha Olefin
PEL	Permissible Exposure Limit
PPE	Personal protective equipment
ppm	parts per million
psig	Pounds per square inch gauge
rpm	Revolutions per minute
SCH	Schedule
SiC	Silicon Carbide
SOP	Standard Operating Procedures
SRS	Savannah River Site
STD	Standard
TSDS	Technology Safety Data Sheet
wc	water column

6.2 What-if Analysis

What-if Analysis Alternative HEPA Filtration CeraMem Ceramic HEPA Filter (OENHP # 2001-11 Version A)

What-if…	Consequence/Hazard	Recommendations
…the filter element is plugged or fouled? … ceramic filter elements are inadequately cleaned?	High differential pressure resulting in compromise of the HEPA filter vessel or failure of the HEPA filters.	• Install sensors and alarms. • Shutdown the system following standard operating procedures. • Develop HEPA failure procedures to be followed in the event the HEPA filter system fails.
…there is a mechanical failure within the CeraMem filter vessel?	High flow and high differential pressure across the existing HEPA filter resulting in HEPA failure.	• Install sensors and alarms. • Shutdown the system following standard operating procedures. • Develop HEPA failure procedures to be followed in the event the HEPA filter system fails.
…the filter element fails to perform or the CeraMem filter vessel tubesheet fails?	Low differential pressure. Low differential pressure will cause the CeraMem filter to fail.	• Install sensors and alarms. • Shutdown the system following standard operating procedures. • Continue to use the traditional HEPA filters as a backup until the new HEPA filters are proven to be effective.
…there is an external fire?	Ceramic filters will withstand high heat (2000 F), but the elastomeric seals may fail and connect the clean and dirty side plenums.	• Install sensors and alarms. • Shutdown the system following standard operating procedures. • Back flush and dry the filters. Perform a standard in-place leak test using a disperse aerosol to determine if filters are damaged. If filters are damaged, replace the vessel.
… the elastomeric seals are damaged due to age, degradation, or another cause?	Elastomeric seals fail and connect the clean and dirty side plenums.	• Install sensors and alarms. • Shutdown the system following standard operating procedures. • Back flush and dry the filters. Perform a standard in-place leak test using a disperse aerosol to determine if filters are damaged. If filters are damaged, replace the vessel.

What-if Analysis
Alternative HEPA Filtration CeraMem Ceramic HEPA Filter
(OENHP # 2001-11 Version A)

What-if…	Consequence/Hazard	Recommendations
…there is an undiagnosed problem with CeraMem filter?	Continued filtration of the HLW tank utilizing the CeraMem filter is not possible.	• Remove CeraMem filter vessel at the 8" inlet/outlet piping flanges and replace with an 8" pre-fabricated pipe spool. • Switch blower to low speed (1750 rpm) and low vacuum operation and return system to on line filtering with the traditional HEPA filter performing according to the original design.
… the DOP test uses di-octyl phthalate as chemical agent in test?	Harmful if swallowed or inhaled. Causes irritation to skin, eyes and respiratory tract. Affects the central nervous system, liver, reproductive system and gastrointestinal tract. Possible cancer hazard. Possible adverse reproductive effects.	• Without compromising the integrity of the test, consider using an alternate chemical if possible. One possibility is poly alpha olefin (PAO).

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Technology Safety Data Sheet
Alternative HEPA Filtration CeraMem Ceramic HEPA Filter
(OENHP # 2001-11 Version A)

Section 1: Technology Identity

Technology Name(s):		**Emergency Contact:**
Ceramic HEPA Filter		Robert L. Goldsmith (781) 899-4495
Manufacturer's Name and Address:		**Information Contact:**
CeraMem Corporation Waltham, MA		Duane J. Adamson SRTC 803-725-5307 duane.adamson@srs.gov
Date Prepared:	**TMS Number:**	**Prepared By:**
1/20/02	TMS # 2091	Chip Booth, MS, (304) 253-8674 Mary M. Jenison, MS; John J. Kovach, MS; Jeana Harrison

Section 2: Technology Diagrams

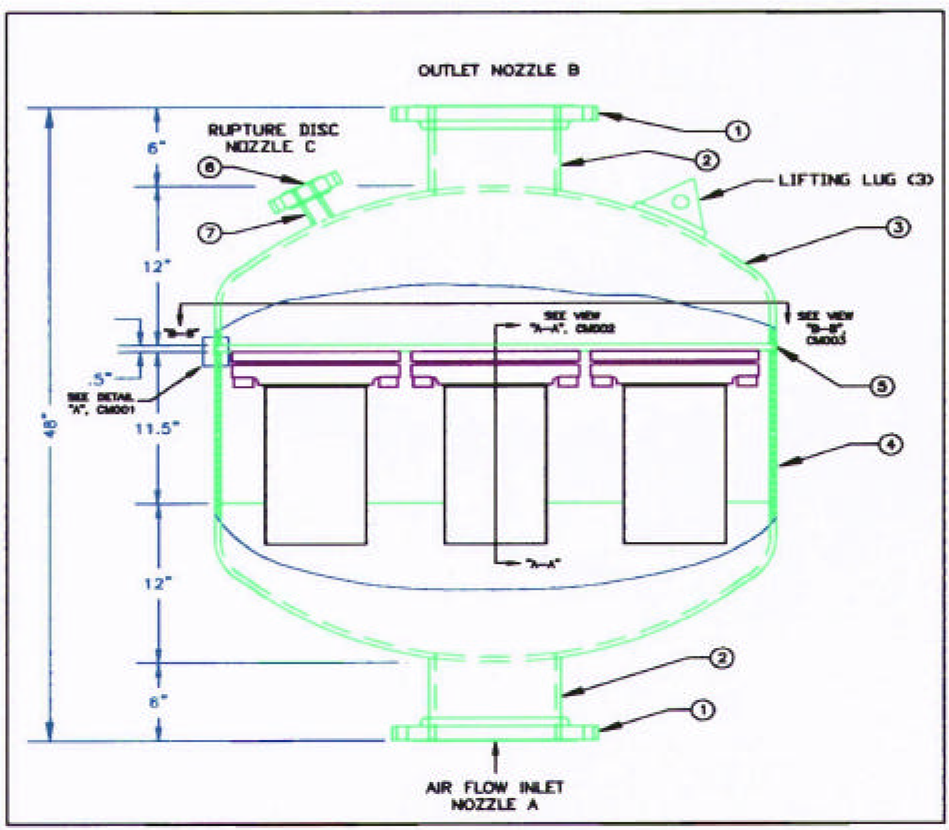

Figure 1: Schematic of CeraMem HEPA filter elements with stainless steel filter vessel.

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Section 3: Technology Description

The CeraMem alternative high efficiency particulate air (HEPA) filter is a ceramic HEPA filter; developed to replace conventional glass filters. Unlike the older filters, which must be thrown away when clogged, the CeraMem unit can be cleaned in place and reused. The new ceramic HEPA filters are designed to be integrated into the existing Savannah River Site (SRS) HEPA filter skid design.

The ceramic HEPA filter consists of seven (7) filter elements in individual stainless cans, contained in a stainless steel filter vessel. Each flanged can is attached to the tube sheet via a drilled and tapped studded outlet. The only hole that exists in the tube sheet is the filter opening hole for clean gas passage. The seven filter elements are bolted onto the tube sheet in a closely packed hexagonal array. The tube sheet is welded into the vessel between the top head and shell course joint in the filter vessel forming clean and dirty air plenums above and below the tube sheet, respectively. Filter vessel weight including the seven filter cans is approximately 1200 lbs.

The CeraMem filter is housed above ground utilizing an existing SRS skid system. A vacuum pump draws the air from the top of the tank through one of the filter sets. The dirty air with particulate matter travels via pipe to a demister followed by a heater before entering the filter media. The entrained particles are filtered from the air by a microporous membrane. The clean air flows down clean channels and is exhausted from the filter. Conventional HEPA filters are in place behind the CeraMem filter and serve as a back up or failsafe system.

The filters become partially plugged by particles they filter out. The proper cleaning procedure is presently being developed. When the differential pressure across the filter reaches a specified level, the dirty filter is cleaned, in place, by filling both the feed side and downstream side of the filter with nitric acid (10 percent). The acid is drained into a holding tank and the filter is filled completely with filtered water from the clean side. The water is displaced with air into the waste storage tank. The filter is dried by flowing dry instrument air from the clean side, through the filter, into the headspace of the tank being vented. The acidic wastes are neutralized with sodium hydroxide (concentrations between 5 – 10 percent currently being tested) and pumped into the tank being vented. In refining the cleaning procedure, a water only cleaning protocol may be realized.

Section 4: Safety Hazards

Hazard Category:

4 -	Could result in death or permanent total disability
3 -	Could result in permanent partial disability or injuries or occupational illness that may result in hospitalization of at least three persons
2 -	Could result in injury or occupational illness resulting in one or more lost work days
1 -	Could result in injury or illness not resulting in a lost work day
N/A -	Is not applicable to this technology and poses no appreciable risk

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A. Buried Utilities, Drums, and Tanks	Hazard Rating: N/A
Buried tanks are present under the filters; personnel will not be required to access them.	

B. Chemical (Reactive, Corrosive, Pyrophoric, etc)	Hazard Rating: 2
• Nitric acid, used in the cleaning process, is a strong oxidizer and a corrosive. Consult MSDS for a listing of incompatibles, handling, and disposal information. • Sodium hydroxide, used to neutralize the nitric acid from the cleaning process, may be corrosive and irritating to eyes, skin, and mucous membranes. Consult MSDS for a listing of incompatibles, handling, and disposal information.	

C. Confined Space	Hazard Rating: N/A
No confined spaces associated with the CeraMem filter.	

D. Electrical	Hazard Rating: 2
The CeraMem filter itself does not require electricity to operate but the equipment it is coupled with will. Assure proper grounding of all equipment. Compliance with applicable electrical standards and codes and lockout/tagout procedures must be followed to assure the safety of personnel.	

E. Ergonomic	Hazard Rating: 1
There may be some ergonomic concerns as the filter is on a platform and some parts of the apparatus are almost 12 feet high. The level of hazard should be determined when the technology is deployed.	

F. Explosives	Hazard Rating: N/A
The CeraMem filter does not pose an explosion threat in and of itself.	

G. Fire Protection	Hazard Rating: 1
• The CeraMem filter does not pose a fire threat in and of itself. • If nitric acid is used as a cleaning agent, care must be taken to ensure safe handling and storage, as nitric acid is a strong oxidizer. Store in a tightly closed container. Contact with reactive metals (e.g. aluminum) may result in the generation of flammable hydrogen gas. Eliminate all ignition sources, no smoking, flares, sparks, or flames in immediate area. • If di-octyl phthalate is used as the chemical agent in the DOP test, a slight fire hazard exists. Keep in a tightly closed container, stored in a cool, dry, ventilated area. Eliminate all ignition sources, no smoking, flares, sparks or flames in immediate area.	

H. Gas Cylinders	Hazard Rating: N/A
No compressed gas cylinders are used in the CeraMem filter system.	

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I. Ladders/Platforms	Hazard Rating: 1

- The skid, as currently envisioned, is 1-2 ft. above the ground.
- The filter and associated apparatus are assembled on the skid and are 11.6 ft in height.
- Level of hazard should be evaluated when the technology is deployed.

J. Lockout/Tagout	Hazard Rating: 2

The CeraMem filter itself does not require electricity to be used but the equipment it is coupled with will. Assure proper grounding of all equipment. Compliance with applicable electrical standards and codes and lockout/tagout procedures must be followed to assure the safety of personnel.

K. Mechanical Hazards	Hazard Rating: 1

The filter itself does not have any mechanical parts. Components necessary for the operation of the Alternative HEPA Filter may pose a hazard during maintenance, setup, and dismantlement.

L. Moving Vehicles	Hazard Rating: 2

Personnel exposure to heavy moving equipment (semi-tractor trailers, cranes, and forklifts) will be experienced during set-up, change of filters, and dismantlement.

M. Overhead Hazards	Hazard Rating: 3

Unloading and loading of technology may require a crane or use of a forklift. Proper precautions indicated.

N. Pressure Hazards	Hazard Rating: N/A

- During normal filtering operation the vessel will operate between atmospheric and 50" wc. The maximum capability of the blower and other vacuum limiting controls will keep this level from exceeding 50" wc vacuum.
- During cleaning the vessel will experience a pressure from air and cleaning fluids injected from the clean side discharge piping and into the clean plenum to back wash the dirty plenum. These pressure sources are normally regulated to 10 psig with relief protection devices set to limit pressures to 15 psig maximum. A vessel rupture disk set at 20 psig provides vessel over pressure protection. In the event of rupture, the release of vessel contents is vented/piped back to the HLW tank.
- No pressure hazards evident at this time.

O. Slips/Trips/Falls	Hazard Rating: 1

- The CeraMem filter does not pose a slip/trip/fall hazard in and of itself. As always, caution is advised when performing work in an environment where vehicles, hoses, electrical wires/lines, and fluids may produce hazards.
- Sodium hydroxide solutions, used in the cleaning process, are slippery to the touch. May produce hazardous slippery conditions if spilled on floors.

P. Suspended Loads	Hazard Rating: 3
This is not part of this technology during operation. This hazard may be present during set up/dismantlement and change of filters. All applicable standards and precautions must be followed for the type of equipment used.	
Q. Trenching/Excavation	**Hazard Rating: N/A**
Not part of this technology.	

Section 5: Health Hazards

A. Inhalation	Hazard Rating: 2
• The nitric acid used in cleaning may pose an inhalation hazard. May cause irritation of the respiratory tract with burning pain in the nose and throat, coughing, wheezing, and shortness of breath. Use adequate general or local exhaust ventilation to keep airborne concentrations below the OSHA Permissible Exposure Limit (PEL) of 2 parts per million (ppm). • The sodium hydroxide used in cleaning may pose an inhalation hazard. May be corrosive and irritating to the mucous membranes. Use adequate general or local exhaust ventilation to keep airborne concentrations below the PEL (5 mg/m^3). • If di-octyl phthalate is used as the chemical agent in the DOP test, the low vapor pressure of this material essentially eliminates inhalation hazards unless the material is heated or misted. Inhalation of mists can cause nausea and is irritating to the respiratory tract. Use adequate general or local exhaust ventilation to keep airborne concentrations below the PEL (5 mg/m^3).	
B. Skin Absorption	**Hazard Rating: 2**
• The nitric acid used in cleaning may cause skin irritation and/or burns. Burns to the eyes with possible permanent damage. • Sodium hydroxide used in cleaning may cause skin and eye irritation. • If di-octyl phthalate is used as the chemical agent in the DOP test, slight skin irritation may occur from prolonged skin contact. Low levels may be absorbed through the skin.	
C. Noise	**Hazard Rating: N/A**
• The CeraMem filter itself does not present a noise hazard. • Based on the current system, the estimated sound pressure level based on current levels outside the fan when both the inlet and outlet are ducted is 78.0 dBA at 5.0 feet. Estimated noise level is below 85dB, the OSHA limit requiring a hearing conservation program, but should be evaluated when the technology is deployed.	
D. Heat Stress/Cold Stress	**Hazard Rating: N/A**

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The technology does not create a heat stress hazard when in operation. PPE will be required to work on or around the Alternative HEPA filtration system and will compound any heat stress hazards due to the ambient temperature.

E. Ergonomics	**Hazard Rating: N/A**

Operation of the Alternate HEPA Filtration system does not seem to pose ergonomic hazards. Evaluation of the support components and set-up, maintenance, and dismantlement should be done when the technology is deployed.

F. Ionizing Radiation	**Hazard Rating: 3**

- Ionizing radiation is not used or generated by the CeraMem filter.
- Ionizing radiation is filtered by the technology as a function of the technology.
- A failure of the gaskets could release radiation.

G. Non-ionizing Radiation	**Hazard Rating: N/A**

Non-ionizing radiation is not used or generated by the CeraMem filter.

H. Biological Hazards	**Hazard Rating: N/A**

Biological hazards are not created by the CeraMem filter.

I. Other	**Hazard Rating: N/A**

None

Section 6: Phase Analysis

A. Construction/Start-up

The set-up or start-up phase presents several hazards including:

- Pinch points
- Struck by hazards
- Overhead hazards
- Slips/trips/falls
- Muscular/back injury
- Exposure to HLW

B. Operation

The CeraMem filter is designed to perform its function in place without operator interaction. Any hazards that exist should be the result of system components that support the CeraMem filter such as:

- Electrical hazard that result from improper grounding or electrical failure of the pumps, condensers, or heaters.
- Material handling hazards associated with nitric acid and sodium hydroxide.

C. Maintenance (Emergency and Routine)

- The developer anticipates cleaning of the filters will be done on a semi- annual basis and that replacement of the filters will not be necessary for 15 years.
- Cleaning and replacement procedures have not been finalized at this time. Further evaluation will be necessary at the time of deployment taking into consideration site-specific hazards such as radiation and the contents of the HLW tanks.

D. Shutdown (Emergency and Routine)

Standard operation procedures should be developed for both routine and emergency shutdown to prevent the release of HLW. HEPA failure procedures should be included in the SOPs in place in the event the system fails or has to be shut down in the event of an emergency.

E. Decontamination/Decommissioning

- Properly handling the filter vessel will be a necessity when removing and replacing the existing filter vessel or the entire skid.
- Proper handling, storage, and disposal will be required when working with the spent filter vessel or any components.

Section 7: Worker Protection Measures

A. Exposure Monitoring

- Monitoring for site-specific hazards will be required when working on or around the High Level Waste tanks including personal radiation monitoring.
- Noise monitoring may be required around the system's components especially the pumps.

B. Worker Training

The following should be covered:
- Technology-specific training emphasizing standard operating procedures
- Radiation Training, Rad Worker I & II
- Material Handling with emphasis on hazardous materials, handling contaminated components, and working in hazardous environments
- Personal Protective Equipment use
- HAZWOPER 29 CFR § 1910.120

C. Medical Surveillance

Site-specific hazards may require medical monitoring. Specific requirements for personal radiation monitoring need to be reviewed at each site.

D. Engineering Controls

There are not engineering recommendations at this time. Evaluation of the system during and after deployment may identify a need for engineering controls for the CeraMem filter, the filter skid, or the support components.

E. Administrative Controls

- CeraMem operating procedures
- CeraMem maintenance and cleaning procedures

F. Personal Protective Equipment

- Hard hat
- Eye protection
- Gloves
- Work boots
- Chemical and/or radiation suits based on site characterization and hazard identification
- Hearing protection will be determined based on monitoring conducted in the future on an operational system
- Respiratory protection based on site characterization and hazard assessment.

Section 8: Emergency Preparedness

Failure of the Alternative HEPA Filtration system may result in a need for emergency response. The type of response and level of preparedness will be determined by the contents of the High Level Waste tanks.

Section 9: Comments, Lessons Learned, and Special Considerations

This Technology Safety Data Sheet has been prepared as result of a design review. Further consideration and evaluation will be required as the technology is developed and inevitably changes. Furthermore, some hazards may not be fully evaluated without a complete system, examples being noise and ergonomics. This sheet should be updated as new information becomes available.