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Filter Systems for IGCC Applications

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6A.2 Filter Systems for IGCC Applications

CONTRACT INFORMATION

Contract Number	DE-AC2-87MC23170
Contractor	General Electric Environmental Systems Inc. 200 North Seventh Street Lebanon, PA 17042 (717) 274-7077
Other Funding Sources	
Contractor Project Manager	Stephen Bevan
Principal Investigators	Stephen Bevan (GEESI) Robert Gieger (Pall Corporation) Nelson Sobel (Pall Corporation Dale Johnson (Dakota Gasifiation)
METC Project Manager	Justin Beeson
Period of Performance	
Schedule and Milestones	September '94 to June '95

Program Schedule

	S	O	N	D	J	F	M	A	M	J	J	A
Field Testing	—	—	—	—	—	—	—					
Sample Analysis	—	—	—	—	—	—	—	—	—			
Topical Report	—	—	—	—	—	—	—	—	—			

OBJECTIVES

The objectives of this program were to identify metallic filter medium to be utilized in the Integrated Gasification Combined Cycle process (IGCC). In IGCC processes utilizing high efficiency desulfurizing technology the traditional corrosion attack, sulphidation, is minimized so that metallic filters are viable alternatives over ceramic filters.

BACKGROUND

Hot Gas Clean Up (HGCU)

Tampa Electric Company's Polk Power Station is being developed to demonstrate Integrated Gasification Combined Cycle technology. Hot Gas Clean Up (HGCU), a new technology, is being supplied by General Electric Environmental Systems, Inc. (GEESI).

Approximately 45,000lb/hr of raw syngas will be treated in several steps in HGCU, namely initial particulate removal, chloride removal, desulfurization and barrier filtration, see Figure 1. The HGCU system will deliver clean fuel for firing in the combustion turbine.

The initial step in the HGCU system is the removal of entrained particulate by use of high efficiency cyclone separation. Downstream of the primary cyclone, a circulating fluidized bed (CFB) cyclone is employed to remove chlorides from the fuel gas. This is accomplished by injecting sodium bicarbonate into the gas entering the CFB cyclone.

The sulfur laden syngas next contacts the mixed metal oxide sorbent in the absorber vessel where, in counter current flow to the sorbent, desulfurization takes place at 900°F and 400psi. The feed to the combustion turbine is thermodynamically superior since the heat of the syngas has been retained to a high degree as compared to conventional cold gas clean up systems.

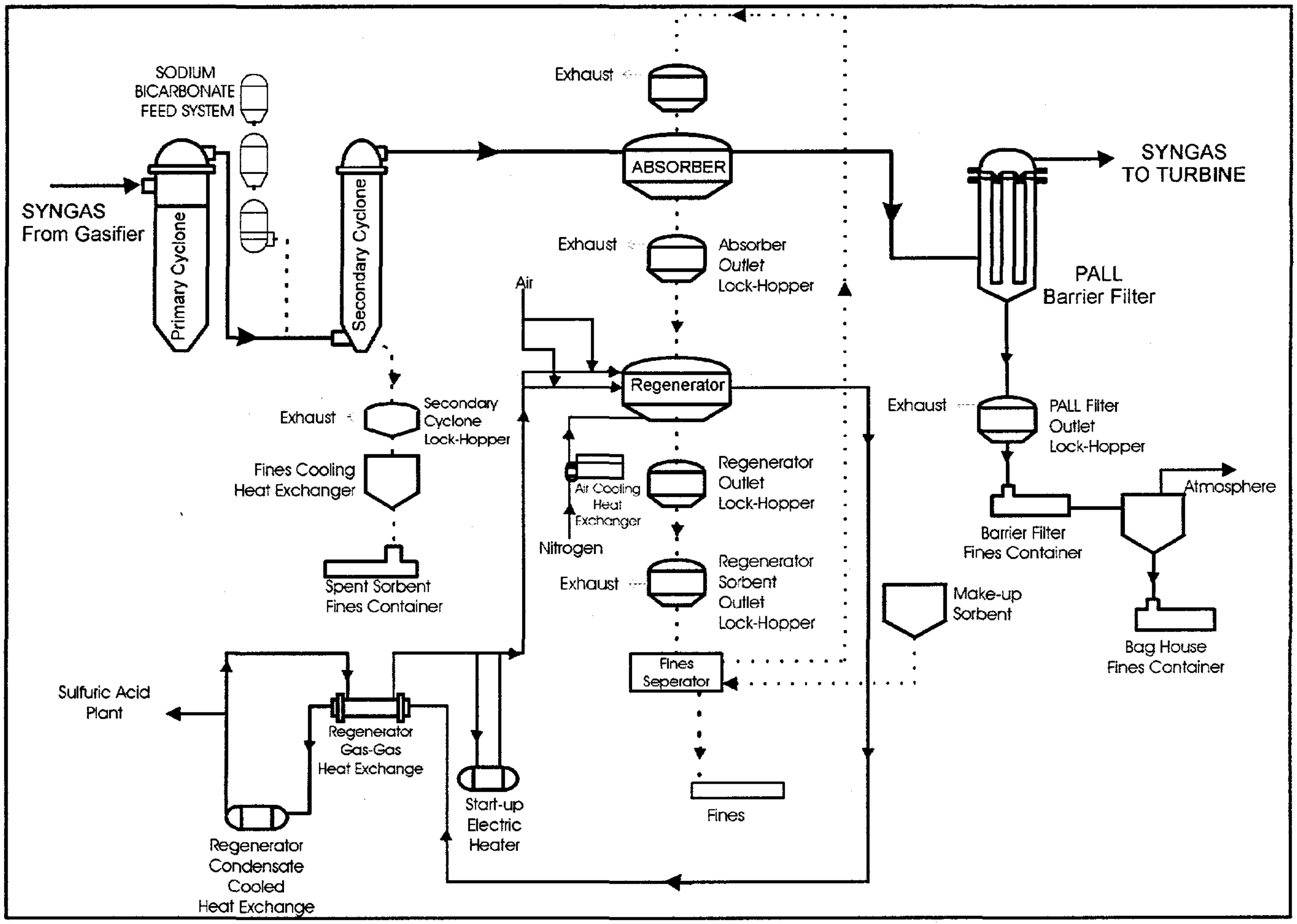


Figure 1. Simplified Hot Gas Clean Up System

The sorbent bed in the absorber acts as a granular filter, removing large particulate matter in the syngas, which is not removed in the primary or CFB cyclones. A small quantity of entrained fines, 30ppm or less, are expected in the syngas exiting the absorber. These solids are removed in a barrier filter which will capture all sorbent dust and fines. The high temperature barrier filter, employing in-situ cleaning, will reduce residual particulate by greater that 99.9% by weight. Clean syngas exiting the barrier filter is mixed with the balance of the syngas from conventional cold gas clean up system before being combusted in the combustion turbine.

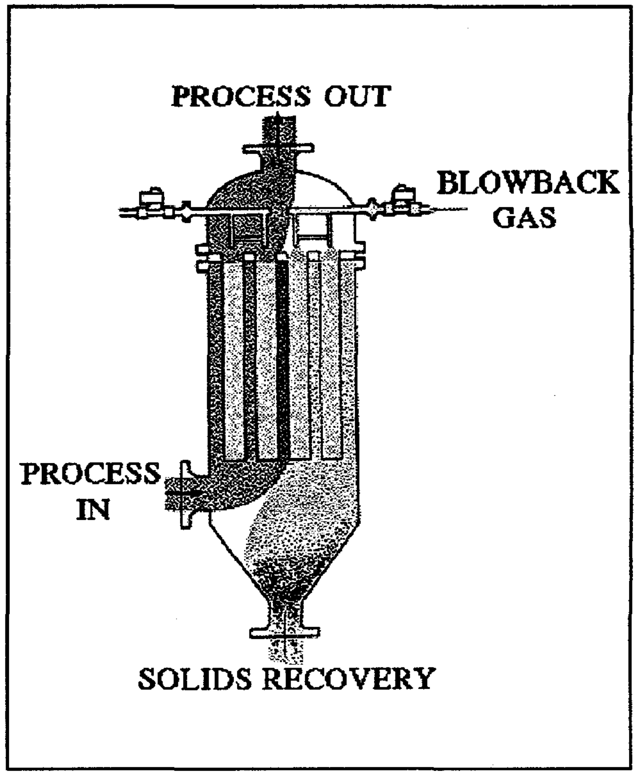


Figure 2a. Pall GSS System in Blowback Mode

Description of Hot Gas Clean Up Barrier Filtration System

The Pall Gas Solid Separation (GSS) System is a self cleaning filtration system designed to remove virtually all particulate matter from gas streams. To achieve this, filter elements constructed with high efficiency filtration medium effectively retain the gas stream solids on the filter element's outside surface. This results in the formation of a solids cake which is dislodged from the surface by initiating a momentary reverse flow, blowback, through the filter element.

For the Tampa Electric project, a GSS System using jet pulse blowback technology to clean the elements was chosen. The reverse flow through each element is created by the momentary pulsing of a high pressure jet located above each filter element. This technology has effectively been used in many applications including high temperature, high pressure service. It is an efficient method for generating a reverse flow for effective in-situ element cleaning, while minimizing blowback gas consumption.

Figures 2a, 2b and 2c show the filter elements in a housing, collecting, then discharging the solids. The cake formed on the filter element has two distinct parts; a non-permanent cake which is dislodged during the cleaning operation, and a thin, permeable, permanent cake which adheres to the filter's surface even during blowback. The permanent cake is formed after several "conditioning" cycles, and becomes a finer filter than the filter medium itself. It is the permanent cake that gives the system the ability to remove virtually all particles including ones smaller than filter medium's removal capability.

The heart of the system is the filter medium used to collect the particles on the filter surface. The medium's filtration efficiency, uniformity,

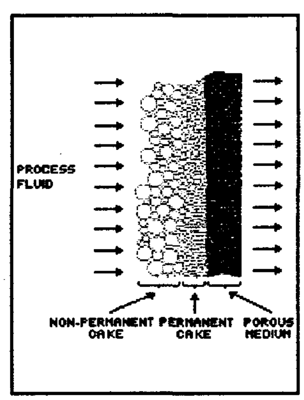


Figure 2b. Cake Formation

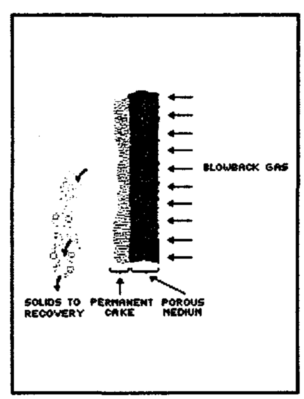


Figure 2c. Permanent Cake

permeability, voids volume, and surface characteristics are all important to establishing a permeable permanent cake. Pall produces a wide range of proprietary filter media, both metallic and non-metallic, that can be used in the GSS Systems. In-house laboratory blowback tests, using representative full scale system particulate, were used to confirm the medium selection for this project.

Figure 3 depicts the main components of the GSS System, which includes:

- Filter vessels designed to the ASME pressure vessel code.
- Tubesheet assembly to mount the filter elements and blowback gas distribution manifolds.
- Fast response valves to control the blowback gas flow.
- Gas receiver to store high pressure gas for the blowback pulse.
- Instrumentation and controls to monitor system operation.
- Miscellaneous valves and components.

The Filter housing is a 42 inch diameter externally insulated vessel, designed for 440 psig and 1000°F. The vessel's material of construction is 347 SStl and the tubesheet is 310 SStl. The system design considers many factors to ensure that performance specifications are met with reliable operating equipment. Among these factors is filter element construction, element support structure within the vessel, sealing mechanisms, ancillary equipment selection, etc. Heated blowback gas is used to avoid potential condensation and the associated corrosion that could occur within the filter vessel. If ceramic candles are used, heating the blowback gas precludes premature mechanical

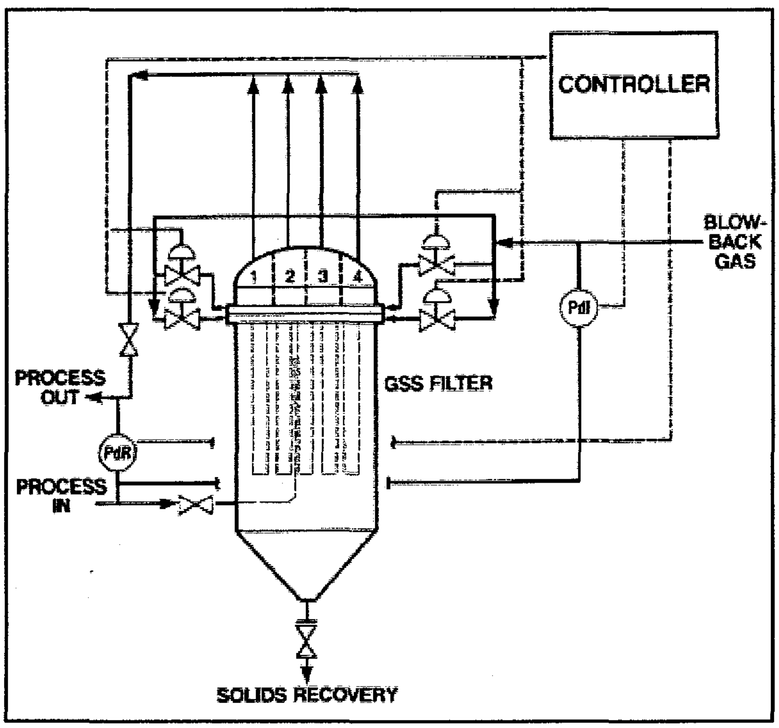


Figure 3. The Components of a Pall GSS Blowback System

failure caused by thermal cycling with ambient temperature blowback gas.

To increase system reliablilty, a fail safe fuse is included in the design. In essence, the fuse is a coarse grade, strong non-blowback filter element that is located at the outlet of each primary element. In the unlikely event of a primary element failure, the fuse will rapidly plug with particles, effectively removing the damaged element from service and preventing solids bypass. The loss of one element has a negligible effect on system performance, and under normal operation, the fuse gives very low resistance to flow and has no effect on filter blowback performance.

Filter Media

For the Tampa Electric Project, two types of filter medium were considered; Vitropore™ silicon carbide and PSS® porous metal medium elements. Ceramic candles have traditionally been used in IGCC application because of their known corrosion resistance to the process conditions. The base material for Vitropore candles is silicon carbide grit which is bonded together with a proprietary sodium aluminosilicate bond system. The candle, shown in Figure 4, has a 10 mm thick coarse grit body for strength, and a thin outer membrane coating for filtration.

Although having excellent corrosion resistance, service problems have been reported with ceramic candles in this application due to element brittleness and sealing mechanisms. Since the GSS system is located downstream of chloride and sulfur removal equipment, it opens up the potential for using PSS metal medium elements. If metal media can withstand the reduced chloride and sulfur levels in the gas stream, the mechanical problems associated with ceramic candles would be solved. In addition, metal media filters typically results in lower cost filtration systems. A porous metal element assembly is shown in Figure 5.

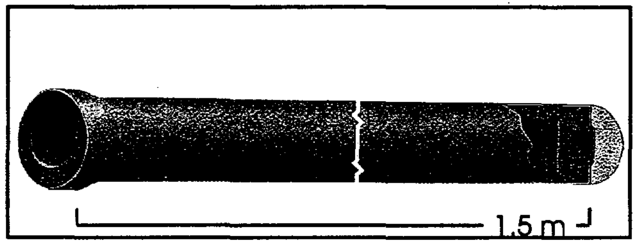


Figure 4.Vitropore Silicon Carbide Element

With regard to filter media corrosion, it should be noted that PSS medium is made from relatively small particles of the base material and sinter bonds produce material with about 45-60% void volume depending on the product. Since there

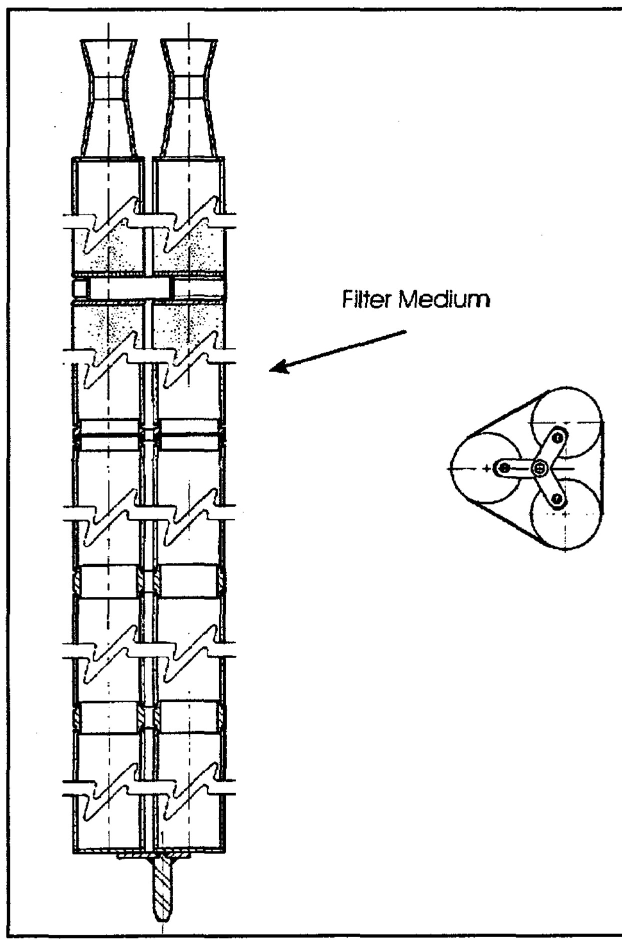


Figure 5. Pall PSS Element Triad Assembly

is an extremely high surface area within the medium pore structure, and the cross section of the bonds are small, corrosion rates need to be applied to the bond cross section and not to the overall medium thickness. As such, typical corrosion evaluations made for solid materials do not necessarily apply to filter media.

Iron aluminide materials have shown very good resistance to sulfidation, and are potentially viable candidates for future projects. Samples of non-commercially available medium were exposed in this test for purposes of gathering information. Pall has recently been awarded funding under a DOE PRDA for the development of iron aluminide medium. This product is expected to be very beneficial for IGCC applications, especially with high sulfur containing gases.

When the filter system design was started, the medium selection, Vitropore SiC ceramic, or PSS metal, was not finalized. To meet the overall project schedule, as well as to provide flexibility for future media developments, the system is designed to have interchangeable filter elements. All components in the system are designed to accommodate any of the filters that would be used.

PROJECT DESCRIPTION

Process Simulation

Filter Media Evaluation Program at Dakota Gasification Company. The filter media test system was developed by Dakota Gasification Co, Pall Corporation and GEESI to test several media samples simultaneously under process conditions which closely resemble conditions experienced in the HGCU system. The H_2S content, moisture content and operating temperature were of particular importance. Table 1 shows the expected conditions of the HGCU system and the filter test system process set points.

The purified syngas exiting the rectisol system was chosen as the primary feedstock due to the similarities in composition and the lack of undesirable contaminants. The rectisol syngas is cool, dry and essentially sulfur free. Therefore, the filter test system required the addition of steam and H_2S to achieve the appropriate composition and an electric heater was utilized to achieve the desired temperature.

Table 1. HGCU and Test Systems Process Set Points

Parameter	HGCU System	Test System
H_2O	12 -18%	18%
H_2	30%	52%
N_2	8%	0.1%
CO	35%	15%
CO_2	12%	1%
CH_4	0.2%	13%
H_2S	30 - 50ppm	30ppm
Temperature	800 - 1000°F	900°F
Pressure	300 - 400psig	300psig

Figure 6 is the simplified configuration of Dakota Gasification Company's filter system. Syngas and steam are metered and combined at the inlet of the electric heater. The heater and filter system are protected from overheating or insufficient steam flow with an interlock system. H_2S is metered and introduced at the discharge of the electric heater. The H_2S spiked hot gas is then introduced into the filter housing, which holds up to 30 test elements. The effluent from the filter housing is discharged to the flare system.

The filter test system was designed to safely

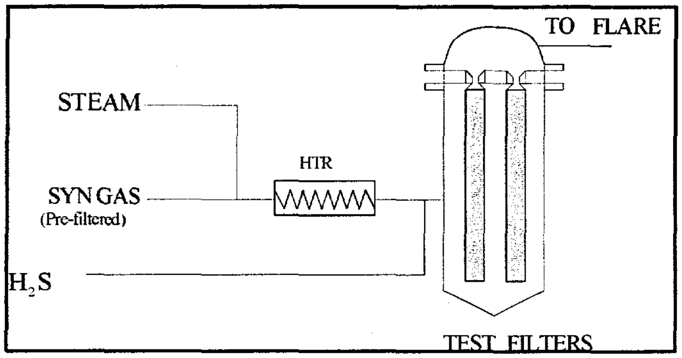


Figure 6. Simplified Diagram of Simulated Test System

perform the filter media evaluation at the desired test condition. The system was manually controlled and monitored. Dakota Gasification Company provided 24hr monitoring of the test system.

EXPOSURE TEST METHOD

To obtain flow-through media test, 4" test elements were constructed from various alloys and supplied to General Electric Environmental Systems, Inc. by Pall Corp. The total test duration was for 153 days with elements being removed at 12, 26, 71 and 153 day intervals.

The test gas flows from the housing inlet, through the filter medium of each element, to the housing outlet. Flow distribution is controlled within the housing with orifices to ensure that each element sees adequate flow.

Test elements constructed from six alloys were supplied for exposure tests, see the list below:

PSS 310SC (modified 310S alloy),
PSS 310SC heat treated,
PSS 310SC-high Cr,
PSS 310SC-high Cr heat treated,
PSS Hastelloy X,
PSS Hastelloy X heat treated,

After exposure, the elements were thoroughly cleaned using DI water and alcohol. The threaded fitting was wire brushed to remove any residual anti-seize compound.

The samples were then subjected to the following analyses: **Weight Change**, the exposure samples were weighed prior to and after testing to monitor changes in weight of the samples(all weight loss was attributed to the medium); **Air Flow Permeability Test**, a constant gas flow (28scfm/ft^2) is applied to the exposure sample. The sample represents a restriction to gas flow and the differential pressure is a measure of the sample's permeability at the given air flow; **Bubble-Point Test**, the sample is immersed in a test liquid which wets and saturates the filter pore structure. Gas pressure is applied to one side of the porous medium so that the wetting fluid is displaced by the gas. The gas pressure is slowly increased until the first steady stream of gas bubbles is observed from a point on the sample's surface; **Ductility**, was performed by compressing ring samples until an initial crack was observed. The percent change in outer diameter was calculated and is an indicator of ductility; **Tensile Strength**, tensile strength on samples was performed using a MTS 810 Material Testing System. **Chemical Analysis**, chemical analysis was performed with the following equipment:

- Oxygen and nitrogen: LECO TC-136.
- Carbon and sulfur: LECO CS-344

Samples of 0.1g were digested in acid and analyzed via a Beckman DCP Spectrophotometer; **Visual Examination**, samples were viewed utilizing a scanning electron microscope to detect fines entrained in the filter medium; **Microstructural Examination**, representative samples of exposed medium were epoxy impregnated, placed in a metallographic mount and polished. The samples were viewed and photographed in both the as-polished and etched condition.

TEST RESULTS

Type 310SC SStl performed the best of all alloys exposed based on the data collected. The following sections outline these results.

Weight Change

Figure 7 shows that the exposure to the environment has negligible effects on weight gain for 310SC SStl alloy.

Air Flow Permeability Test

The 310SC samples showed small changes in air flow vs. delta P. This is primarily due to the element capturing particles in the gas stream. There was an average increase of ~10% after in-house cleaning using DI water and alcohol.

Bubble-Point Test

Results from bubble-point testing show slight increases in bubble-point values. There was an average increase of ~ 3%. Some values fell within acceptable specifications used in QC process.

Ductility

The 310SC samples tested retained an average of 65% of their original ductility. Experience has shown that ~25% is an acceptable

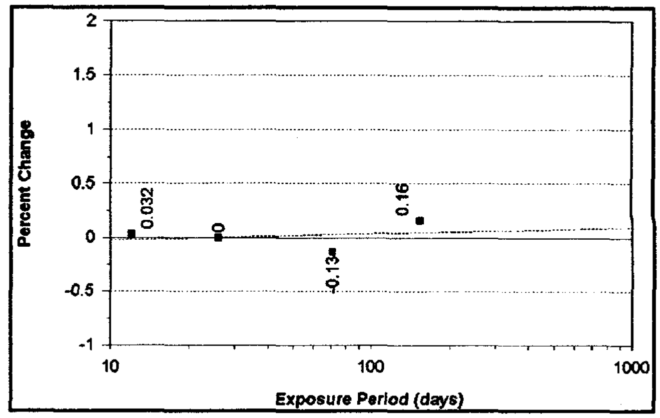


Figure 7. Percent Weight Change

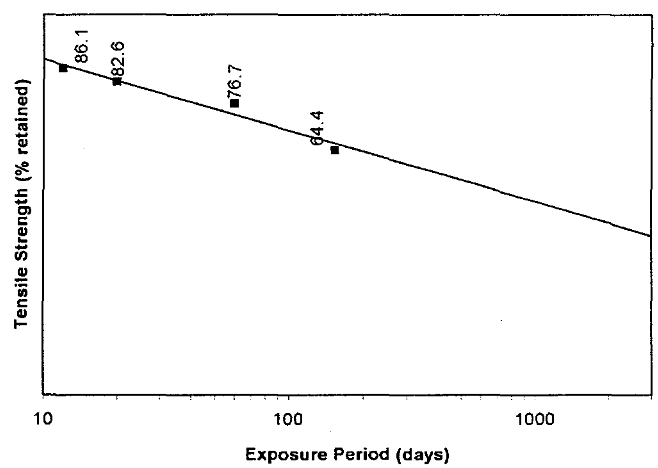
minimum value.

Tensile Strength.

Figure 8 shows the tensile strength data for the samples. All but one sample retained tensile strength within allowable manufacturing ranges. The last sample returned was <5% out of manufacturing range. Overall, it does not appear as if tensile strength was adversely affected due to exposure.

Chemical Analysis.

The results from chemical analyses show negligible increases/decreases for all elements tested. All samples show an increasing carbon pick up with increasing exposure time. The chemical composition of the gas at Dakota Gasification Co.



has a substantially higher methane content when compared to Tampa Electric Co. conditions, see Table 1. The carburizing component of TECO's environment is carbon monoxide and carbon dioxide. Methane is a stronger carburizing agent. It is expected that a carbon pick up will be less at Polk Station than at Dakota Gasification Co.

Visual Examination.

Exposed and unexposed samples were viewed for medium pore plugging. Photographs 1a and 1b are at low magnification (300X) and photographs 2a and 2b are at high magnification (1000X). It is evident that the pores of the medium are essentially free of fines entrainment. At the high magnification, the surface of the medium appears very similar to the unexposed state.

Microstructural Examination

Results of the analysis performed on representative samples of the medium show an even distribution of irregularly shaped particles and voids typical of sintered powder materials. The as-polished sample revealed a structure similar to unexposed material, see photographs 3a and 3b

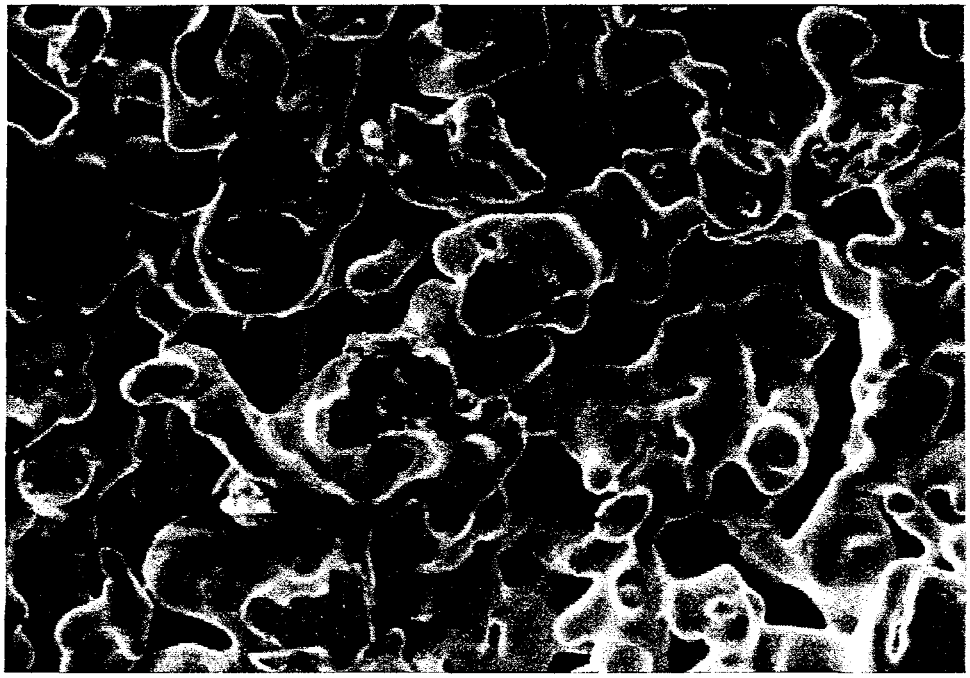
Etching revealed a microstructure typical for 300 series stainless steel, see photographs 4a and 4b. Inspection for intergranular corrosion followed ASTM procedure A262-86. Results revealed no difference in structure between the new and exposed sample.

CONCLUSIONS

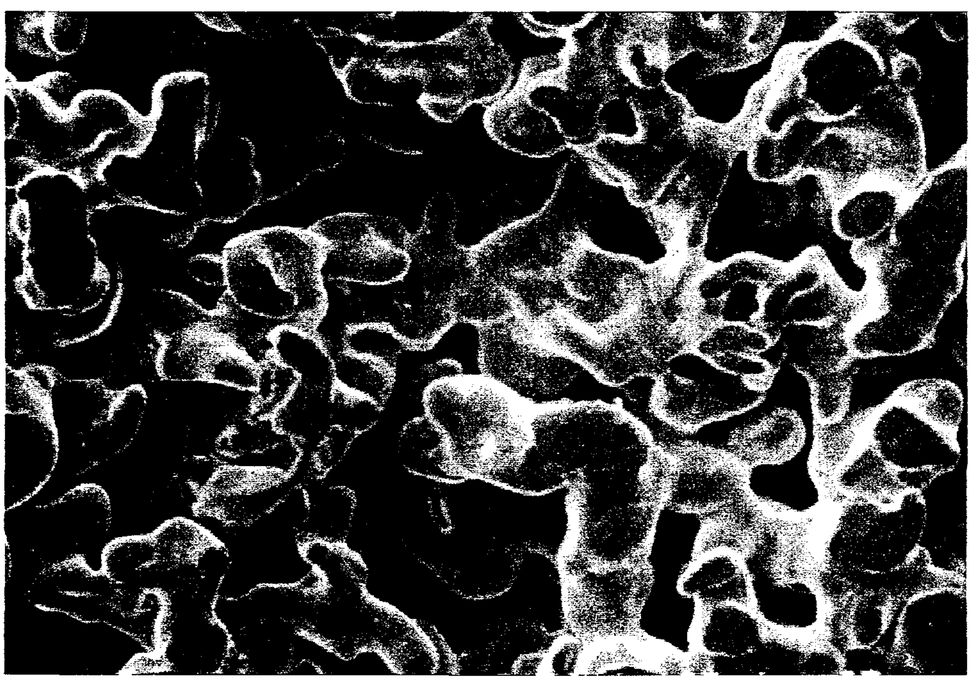
In the IGCC processes utilizing high efficiency chloride removal and desulfurizing technology the traditional corrosion attack, sulfidation, is minimized so that metallic filters are viable alternatives. Metallic filters offer better mechanical properties (ductility, less prone to shock/vibration crack propagation) and a more secure sealing mechanism (ease of welding).

Pilot Scale exposure tests, utilizing 4" high x 2.375" diameter metallic filter elements of various metal alloys, were performed at Dakota Gasification Company. The filters were exposed for various time intervals (12, 26, 71 and 153 days) at 900°F and 30ppm H_2S process equivalent. The returned samples were analyzed for performance properties (air flow vs. differential pressure and bubble point testing), mechanical properties (tensile strength, ductility and weight change) and chemical/structural properties (chemical composition, electron microscopy and microstructure).

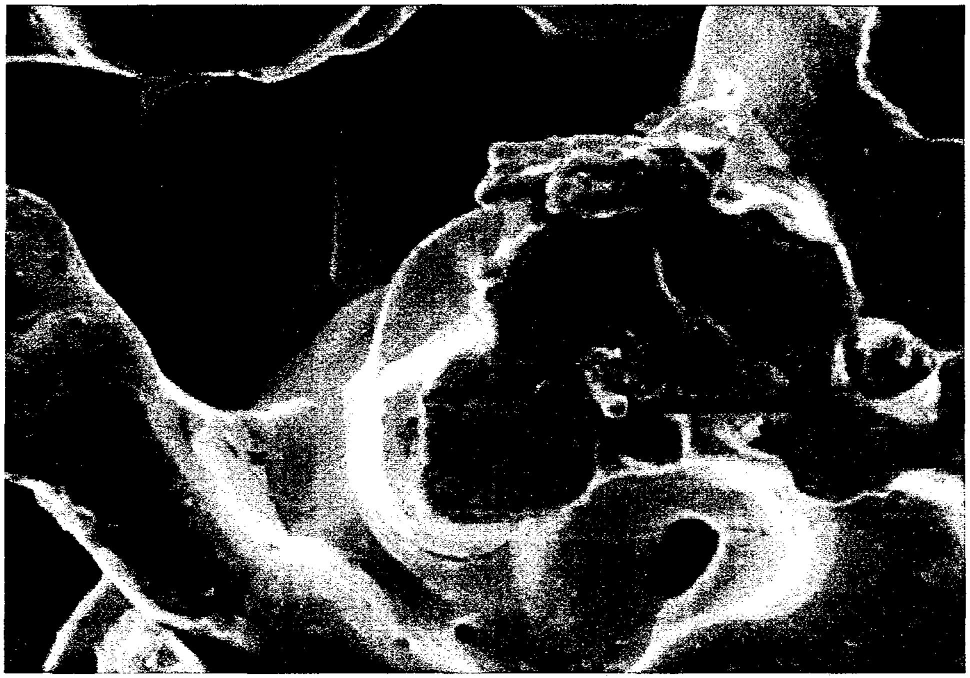
Results from the investigation demonstrate that filter elements of PSS medium Type 310SC stainless steel showed good resistance to corrosion. It is concluded that a Pall Gas Solids Separation System utilizing metallic filter elements is a viable option and will be used in the GEESI Hot Gas Clean Up system.



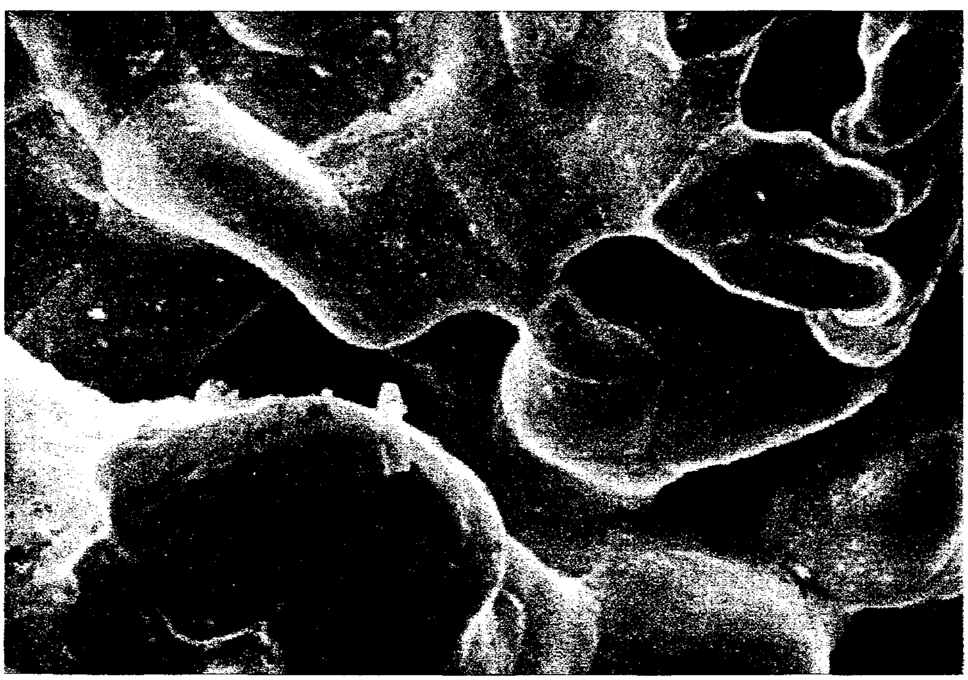
Photograph a. Unexposed 310SC media open pore structure (300X).



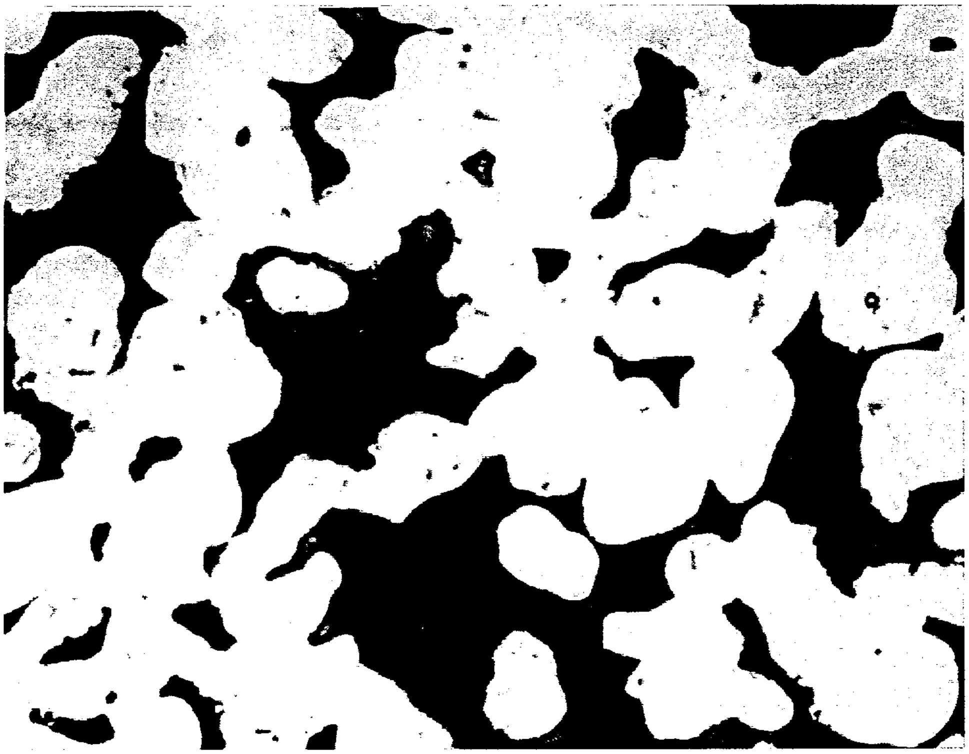
Photograph 1b. Exposed 310SC media open pore structure (153 days, 300X).



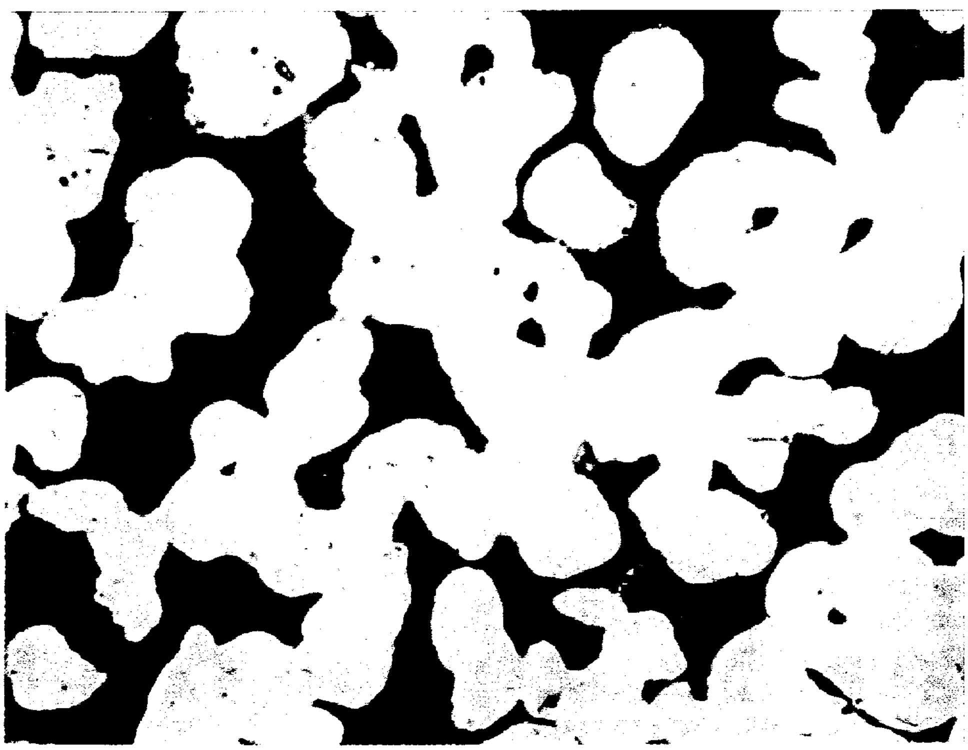
Photograph 2a. Unexposed 310SC media open pore structure (1000X)



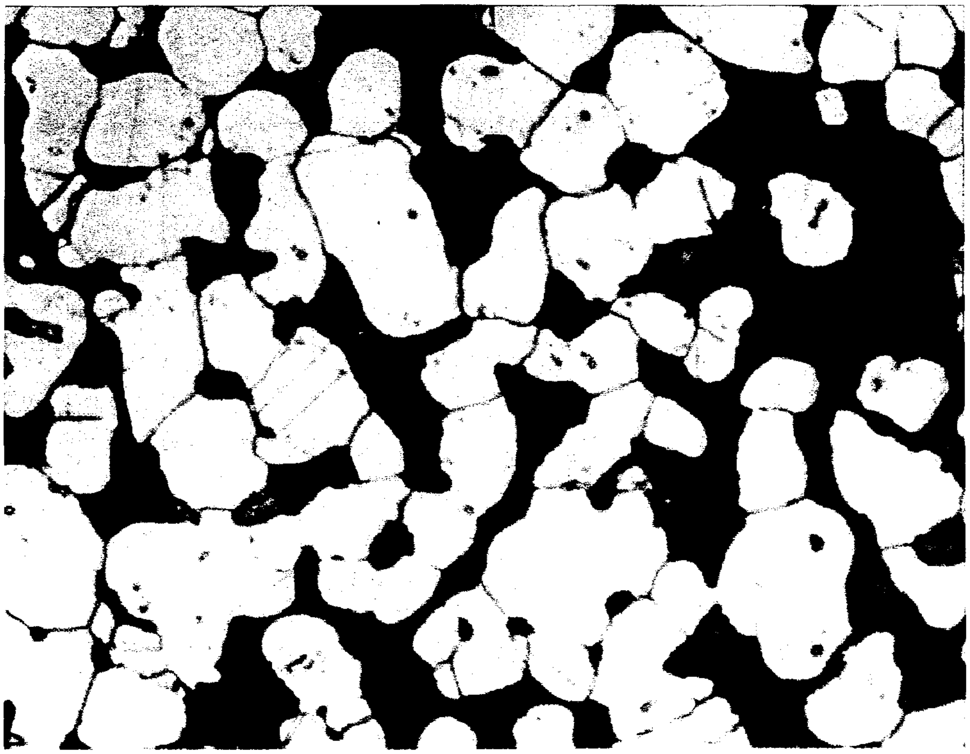
Photograph 2b. Exposed 310SC media open pore structure (153 days, 1000X)



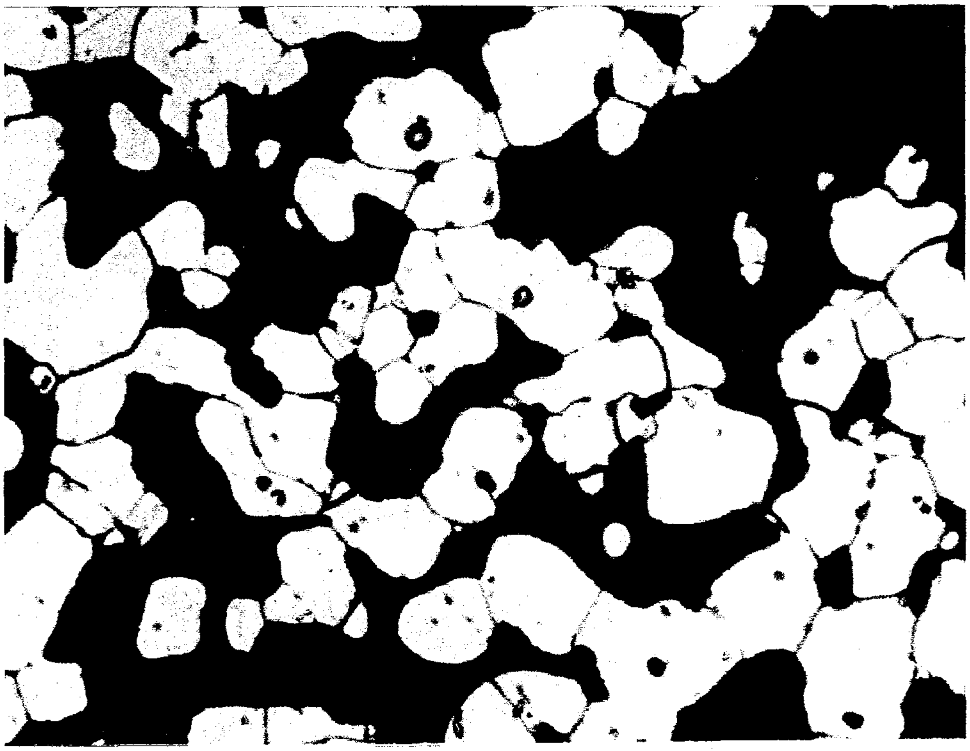
Photograph 3a. Photomicrograph of unexposed 310SC in the polished condition (400X)



Photograph 3b. Photomicrograph of exposed 310SC in the polished condition (153 days, 400X)



Photograph 4a. Photomicrograph of unexposed 310SC in the etched condition (400X)



Photograph 4b. Photomicrograph of exposed 310SC in the etched condition (153 days, 400X)