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BRAYTON-CYCLE HEAT-RECOVERY SYSTEM CHARACTERIZATION PROGRAM

DOE/CS/40008--T11

DE82 008646

COMPONENT TEST PLAN

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PREPARED FOR

DEPARTMENT OF ENERGY

CONTRACT NO. DE-AC03-77CS40008

ALPHA

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DISCLAIMER

1.0 STATEMENT OF PROBLEM

The critical components of the glass furnace subject to corrosion/erosion are:

1. The valve gate and the valve seat bottom and sides which can also be subject to warpage causing subsequent leakage.

2. The furnace flues (or ducting).

The Brayton System will be added to the glass furnace just downstream of the reversal valve. Hence, the inlet air to the flues will no longer be at ambient temperature but at a higher level between 800 to 1000°F. Also, the exhaust gas for the Brayton System is required to be 1500 to 1600°F at these locations. Thus, the flues and valve components will be exposed to a much higher average temperature operating with the Brayton System. The possibility of cracking of the refractory linings and warpage and scaling of the switching valve, with consequent leakage to the exhaust stream should be avoided or decreased as much as feasible because of its effect of lowering the turbine inlet temperature and thus the total system value. On the inlet side, leakage dilutes the heat added to the air (which is preheated) and reduces the expected fuel savings. Assessment of such effects and determination of potential solutions and/or improvements in these areas is the purpose of this component system analysis and testing. The following describes the materials, mechanics and operations of the two areas of concern in greater detail and the program for testing alternative approaches including test hardware, objectives, conditions and locations.

2.0 DESCRIPTION OF FLUE DUCTS

The flues joining the Brayton System to the furnace in regenerative glass furnaces are simply refractory lined tunnels serving to transport combustion gases and air to and from the reversing valve and the regenerators. Or, downstream from the reversing valve, the flues carry out the waste gases to an exhaust stack. These flues are customarily constructed of inexpensive firebrick or fireclay castable, since they perform no critical service such as containing molten glass, or providing large heat exchange surfaces. The materials employed are acceptable for temperatures up to 2000° F. Therefore, there is no required change in the basic construction of the flues for the Brayton System. On a furnace of the capacity under consideration for demonstration of the

Brayton System which is over 200 tons per day in production, the cross sectioned flue area would be 25 to 30 square feet.

Addressing the problem of air infiltration in the existing flue area, additional insulation or flue sealing would be required to improve the efficiency of the Brayton System. One method to accomplish this is to install an aluminum backed insulation to the flues after the furnace is heated up. Or, the same effect could be obtained by simply wrapping the flues in aluminum foil. However, this foil would need to be protected from physical damage by people or equipment in the vicinity of the flues.

The new ducting associated with connections from the flue to the Brayton System (turbine and/or heat exchangers) and back to the flue must be given consideration for the possibility of new construction, and therefore, characteristics of thermal expansion, heat resistance, material corrosion and erosion can be evaluated in this test program for this area.

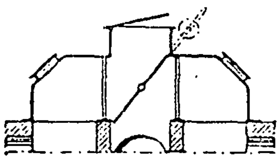
3.0 DESCRIPTION OF SWITCHING VALVE GATE AND HOUSING

The reversal valve may be of several types, some of which are depicted in Figure 1. The GCC Vernon furnace where we are conducting our materials and component tests uses a butterfly type, whereas the GCC Antioch furnace, which is elected as a possible demonstration site, uses a sliding gate type of reversal valve. In these drawings the flues to and from the furnace are shown at the lower left and right, with the air ingress from the top, and the common flue to the stack at the bottom center.

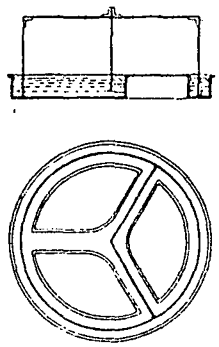
Reversal valves are usually operated at 20 minute to half hour intervals. At longer periods, temperature changes in the furnace become undesirably great because of the lowering of preheat temperatures resulting from the discharge of heat from the checkers (regenerator on gas side). Temperature variations could be reduced by more frequent reversals but that would cause a correspondingly more frequent reversal heat loss, since at each reversal, the furnace is without fire for some time (up to 40 secs.) and its temperature, accordingly, falls. The reversal procedure with natural gas or fuel oil is to, first, shut off the on one side of the furnace; air is then reversed and, lastly, the fuel supply to the other side is turned on. The time involved in reversing is from 10 to 40 seconds, attempting to make the changeover as quickly as possible so that the firing pause is brief and temperature drop in the furnace melt tank is correspondingly small. Generally, reversing valves are exposed to waste-gas temperatures

FIG. 1

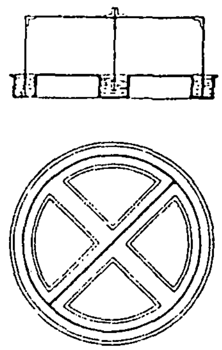
REVERSAL VALVES



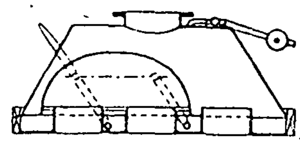
Reversing Clapper for Air



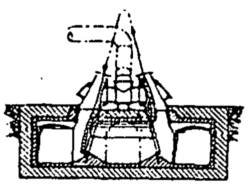
Three-section Reversal Drum



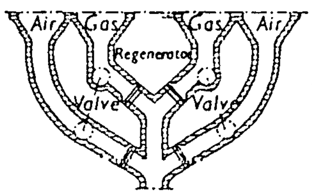
Four-section Reversal Drum



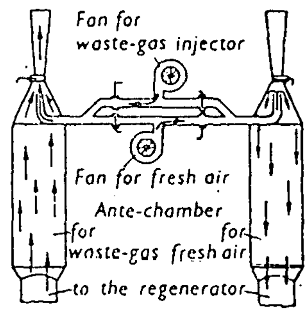
Forter Valve



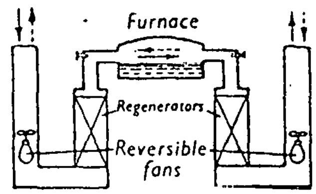
Damper Reversal.
'Blawknox' System



Reversal with Dampers and Valves



Morgan-Isley Reversing System



Reversal with Alternating Blowing and Suction of 750^{o}F to 1000^{o}F and are, therefore, made of cast iron or some alloy conditioned to withstand corrosion and warping at these temperatures. In some cases, water cooling is applied to dampers, particularly for large furnaces. The main reversal mechanism is usually metal-to-metal contact which is not meant to be perfectly gas tight. As the metals are exposed to corrosive gases at temperatures of 1000^{o}F to 1600^{o}F (the higher based on the Brayton System), these valves tend to form scale on their surfaces, further preventing tight sealing. In the case of baths containing sulphate, or of fuels with high sulphur content, the waste gases contain a fair amount of SO_2 and sulphurous deposits also accumulate on strongly cooled metal surfaces with a corrosive effect which may further degrade sealing.

4.0 BRAYTON SYSTEM ENVIRONMENT SUMMARY AND POTENTIAL TEST MATERIALS

The components are subject to operating with the Brayton System cyclic temperature changes with a range between 1100^{o}F to 1650^{o}F. The atmosphere is oxidizing. The composition of the effluent gas in terms of particle size volume fraction and composition are given in Table 1-1 from Report 80-16900, dated March 19, 1980, prepared by Garrett-AiResearch, under DOE Contract No. EC-77-C-03-1557.

The crux of the problem is to specify materials systems for the components which will protect them against the environment stated above. It may be noted that the corrosion/erosion aspect is associated with the Na_2SO_4, which is the major component representing 63% by weight of the particulate concentration, and HCl, which is 15.8 ppm weight in the vapor phase. In addition, there is 10.2 percent by weight of SiO_2 particles which contribute to the erosion problem. Each of the components is now examined individually for potential test materials.

4.1 Valve Gate and Housing

The principal problem comes about from the corrosion of high temperature alloys by Na_2SO_4. Furthermore, erosion greatly accentuates the corrosive effect, as shown in Figure 2 attached hereto. A potential solution would be to keep the temperature of the components above 1700^{o}F, which would prevent the condensation of Na_2SO_4, and the resulting corrosive attack. Unfortunately, this is not a practical solution in this instance.

The common high temperature alloys are Hastelloy X, Rene 41, Haynes-188, IN 671, IN 738, IN 739, which are in approximate order of increasing use temperature. However, some of the better alloys, such as IN 739, are only available

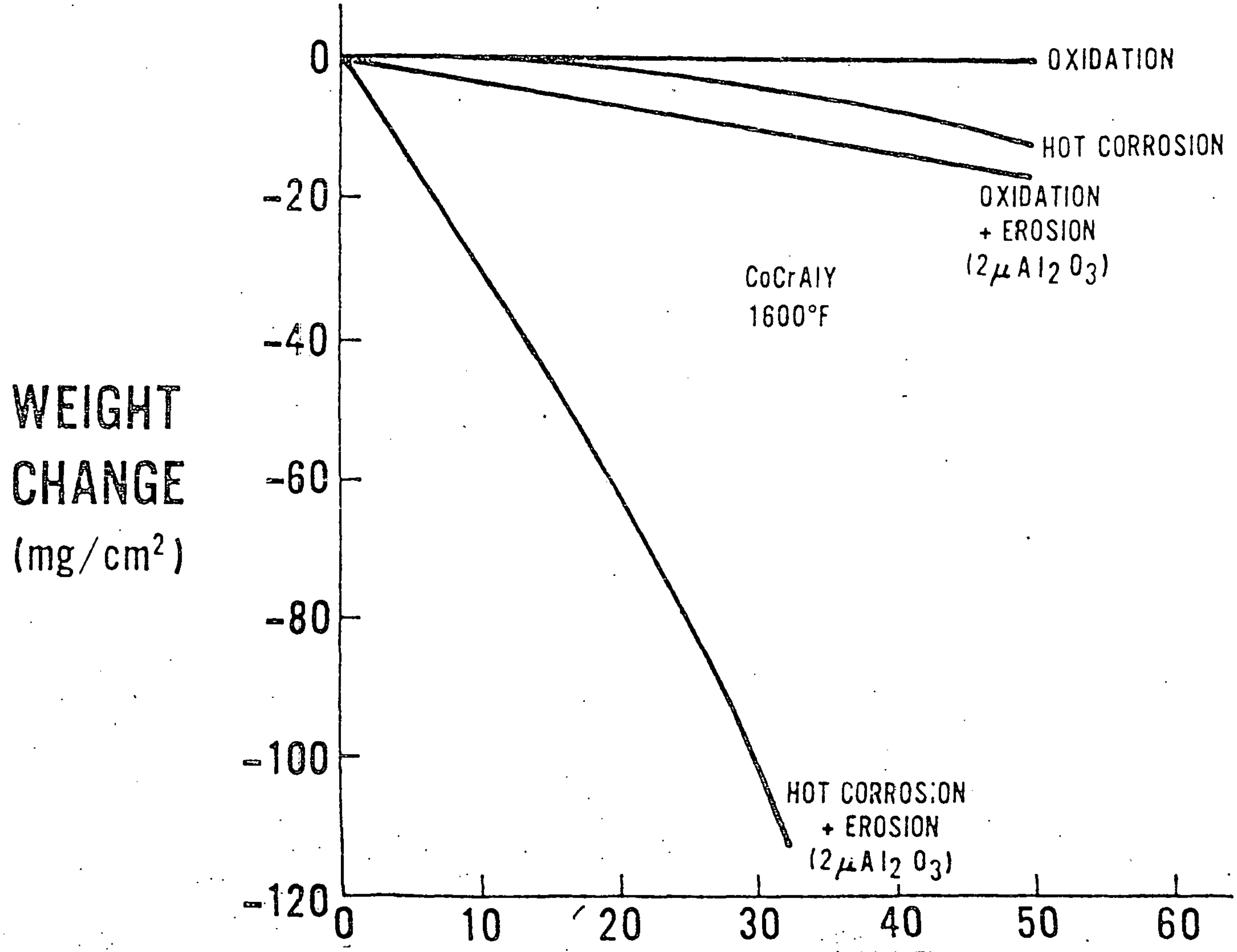
TABLE 1-1

BASELINE SIMULATED EFFLUENT GAS

Particulate concentration in gas stream:	200 ppm
Particulate	
Size, microns	Percentage
Larger than 30	<1
30 to 10.7	1.7 to 3.4
10.7 to 3.1	4.3 to 8.6
3.1 to 0.3	94 to 86
Smaller than 0.3	<1
Particulate concentration in solid mixture	
Constituent	Weight, percent
SiO_2	10.2
Al_2O_3	8.3
Na_2SO_4	63.0
K_2SO_4	3.6
CaC	0.6
MgO	2.0
Fe_2O_3	1.5
Cr_2O_3	0.6
As_2O_5	5.0
B_2O_3	5.0
Vapors	
Constituent	Parts per Million, by wt in gas stream
HCl	15.8
HF	1.5

FIGURE 2

EFFECTS OF EROSION ON OXIDATION AND HOT CORROSION



in cast form and the others will not be able to withstand the corrosion/erosion thermal cyclic environment. Therefore, a potential solution is to make the components out of a wrought high temperature alloy and plasma spray a corrosion/ erosion resistant coating or even two coating layers. Such sprayed coatings are being used on Diesel engine valves and seats by Transamerica, Di Lavalle Diesel Power Generator Company. The coatings in this case is a Ni-Al (Metco) spray base coat 2-3 mils in thickness followed by 8-10 mils thickness of a Magnesium Zirocorate coating for erosion resistance. Alternate erosion resistance layers may be SiC or ZrO_2.

Another potential corrosion resistant coating has the composition Co-29r-6 Al-1Y which has been recently developed by J. R. Rairden, General Electric Corporate Research and Development Laboratories, P.O. Box 8, Schenectady, New York 12301, Telephone: (578) 385-2211. Potential vendors for plasma spraying are:

Howmet Corporation, Whitehall, MI 49641,
Attention: Lou Dardi

Garrett-AiResearch, Phoenix, Arizona
Attention: T. E. Strangman

To investigate advanced components we plan to procure coupons of high temperature alloys, have them plasma sprayed with various combinations of metalic and ceramic layers and test them at various temperatures in the environmental test setup. Vendor for high temperature alloys is:

Sun Metal Source Corporation, P.O. Box 3757,
Santa Monica, California 90403
Attention: Nanci Folska

In addition to investigating these potential advanced component materials, Alpha will evaluate the cast alloy that will be used for the new GCC switching valve at their Antioch plant. The manufacturer, Blaw-Knox has warranted this switching appliance to operate up to 2000°F which is in compliance with the Brayton cycle material requirements, disregarding any air leakage concerns which are a function of the system's design (metal-on-metal) and erosion and corrosion effects over time. We have obtained a metal sample of this alloy from the manufacturer which will be formed to a gate design for the test switching valve. This gate will be subject to cyclic temperatures and gases like those in a full scale furnace operating with a Brayton system. This test condition will allow us to evaluate erosion, corrosion, warpage and scaling for this alloy as well as others in a good test simulation environment.

4.2 Ducting

As previously described, for an existing furnace with typical fire clay ducting no radical changes are recommended with the exception of providing some sort of covering (such as foils) to reduce air leakage to a minimum. The new ducting connecting the existing flues to the Brayton turbine/heat exchanger system does provide the opportunity to select designs and materials that optimize the operational conditions and reduce any potential corrosion or erosion problems to a minimum.

A relatively simple solution for the new ducting is to make it out of stainless steel and line the inside with a suitable material which provides the corrosion/erosion resistance as well as thermal insulation to keep the energy in the flue gas. Such candidate materials are:

(1) Carbon material of low thermal conductivity known as "Grafoil". It is available in foil, felt or block form. There are two known sources:

Fibre Materials, Inc., Biddeford Industrial Park,
Biddeford, Maine 04005, (207) 282-5911

Union Carbide Corporation, Carbon Products Division,
120 South Riverside Plaza, Chicago, Illinois 60606

These materials would have to be mechanically fastened to the steel. A source is:

ZIRCAR Products, 110 North Main Street,
Florida, N.Y. 10921

Alternately, zirconia or magnesium zirconate may be attached to the inside surface of the ducting.

A test ducting has been provided in the test rig for examining the performance of these alternatives with the furnace waste gas at elevated temperatures (to $1600^{o}F$)

5.0 TEST PLAN

The materials shown in Table 5-1 have been selected as initial candidates for application for duct lining or for use in the glass furnace switching valve. They have been selected for their potential usefulness in overcoming the system problems of erosion, corrosion and cost.

TABLE 5-1
COMPONENT MATERIAL TEST CHART

Component Material to be Tested	Vendor	Test Area: 1550°F	Test Area: Switching Valve
A. Zirconia Type ZYFB-13 Insulating Board	ZIRCAR Products	X	
B. Zirconia Type ZYFB-6 Insulating Board	"	X	
C. Zirconia Type ZYC Cylinder	"	X	
D. Alumina Type AL-30 Insulating Board	"	X	
E. Alumina Type AL-30 "All Aluminum" Board	"	X	
F. Alumina Type AL-30 Insulating Cylinder	"	X	
G. Alumina Type ZAL-15 Insulating Board	"	X	
H. Alumina Type ZAL-45 Insulating Board	"	X	
I. Carbon Fiber		X	
J. Graphite Fiber		X	
K. High Nickel Alloy Used by Mfg. in Glass S/V	Blaw-Knox, Inc.		
L. Same Alloy as K in Gate Form			X
M. Graphite Gate	Circle		X
N. Indo-form 2800-Fiber Molded Cylinder	Industrial Insulation, Inc.	X	
O. Magnesium Alumina Silicate (Ceramic Fin Heat Exchanger)	GTE Sylvania	X	
P. Ceramic Coated Surface	General Electric	X	

The alumina and zirconia materials selected are available in many forms (rolls, cylinder, block) for application to the interface ducting between the furnace and a Brayton system, and can ordinarily be bonded or mechanically attached to a metallic outer shell. The samples selected for test are representative of some of the forms available. The testing will be able to evaluate resistance to spalling which would be caused by the erosive effects of the gas flowing over them as well as any corrosion in the materials.

The graphite and carbon fabrics will be bonded to metal samples for test purposes. They are designed for use as high-temperature insulation, but are normally applied by furnace designers for resistance or induction furnaces which have inert atmosphere. We may expect to encounter oxidation of the material when subjected to the furnace waste gas at the test temperatures of between 1350°F to 1550°F, but this test provides the opportunity to confirm this.

Ceramic coated samples are most promising for ducting application in terms of erosion and corrosion resistance, but the costs and methods for coating large surfaces of various forms must be further investigated and analyzed. We are working with G.E. to obtain the most feasible test samples.

The metal alloy samples that are to be tested for switching valve application are the same metal that will be used in the GCC Antioch furnace rebuild. The most critical test application is in the model switching valve where the material will be subject to the waste gas at varying temperatures up to 1550°F. Because of the design of the test switching valve, it will be possible to substitute the Blaw-Knox metal alloy gate with other gates made from coated materials at a later time.

5.1 Test Conditions and Locations

The test system is shown in Figure 5.1. The location of the test system is at the Vernon Glass Container Corporation Furance. The Switching Valve and Test Box #3 will be used to support these component material tests with the distribution of materials, as shown in Table 5-1. The materials will be inspected and their condition recorded after 30 day intervals, but should remain under test for a minimum of 90 days before removal and analysis.

FIGURE 5-1. TEST SYSTEM