

RADWASTE INCINERATOR SCRUBBER MATERIALS TEST PROGRAM

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ABSTRACT

Extensive testing was performed on various materials of construction for wet scrubbers used on radwaste incinerators. Long term immersion tests provided the most conclusive results of the corrosion resistance of the alloys in two different concentrations of sodium chloride solutions.

BACKGROUND

The volume reduction of dry active waste generated by nuclear power plants can economically reduce utilities' radwaste problems. Koch Process Systems offers a controlled air incinerator system for use on nuclear power plant waste. The dry active waste can contain significant quantities (up to 50% by weight) of polyvinyl chloride (PVC), neoprene, sulfur bearing rubber compounds, and other acid bearing materials. When these wastes are burned in an incineration system the products of combustion include acid gases such as HCl and SO₂.

In the Koch system, the acid gases are cooled and neutralized in a series of process components consisting of a quench column, high energy venturi scrubber and packed column. A sodium hydroxide based scrubbing liquid is used to neutralize the acid gases. Thus, sodium chloride and sodium sulfite sulfate are formed in the scrubbing liquid. Because the scrub solution liquid is recycled after filtration, the concentration of these salts continuously builds up. In order to prevent plugging of the scrubbing components, a liquid stream must be discharged from the loop, thus maintaining an equilibrium concentration of salts at a safe level. This stream is commonly referred to as a blowdown stream.

Since the blowdown stream can contain radioactive materials, the liquid must be processed in the plant's radwaste equipment. As can be seen from Fig. 1, the flow rate of this liquid blowdown stream will vary depending on the concentration of salt present in the stream and the PVC content of the dry active waste being fed to the incinerator. Since it is desirable to minimize the quantity of liquid radwaste to be processed, and the concentration of PVC in the feed is fixed, it is advantageous to increase the concentration of salts in the blowdown stream to as high a concentration as possible. However, certain factors, such as solubility and corrosiveness limit the operating point.

In the design of the Koch VR-System 350, the choices of materials of construction for the wet scrubbing system depended on their corrosion resistance at the operating conditions. The objective of this program was to determine the corrosion resistance of various materials at relatively high salt concentrations.

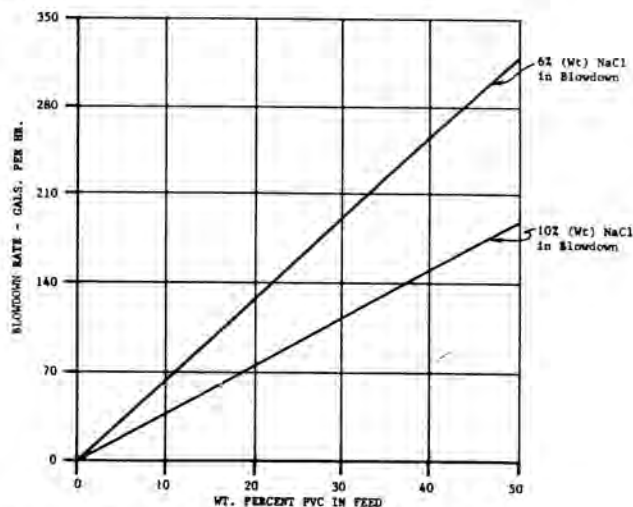


Fig. 1. Percent PVC vs. Blowdown Rate for VR-System 350.

WET SCRUBBING SYSTEM

The Koch System VR-350 utilizes a controlled air incinerator to burn radioactive waste. In the process, a hot flue gas containing acid gases and a small amount of particulate is produced. After the hot (2200°F) gas discharges from the incinerator, it enters the wet scrubbing system, the first component of which is the quench column. This column consists of a spray tower which utilizes an overflow weir to maintain a wetted wall. This prevents overheating of the quench column shell material. Multiple redundant sprays are used to ensure that the gas is cooled to approximately 170°F.

The high energy venturi scrubber, used to remove particulates, consists of converging and diverging cones with a variable throat valve between the cones. Liquid is injected just upstream of the valve. In the throat of the venturi the liquid and gas are accelerated to high velocities. Due to the extreme turbulence in the throat, the liquid droplets are shattered into small droplets which contact any particulates present in the gas stream and capture them. The high energy venturi will sustain a pressure drop of more than 50 inches of water column, thus ensuring greater than 99% removal of particulate present in the flue gas. Gas from the venturi scrubber goes to the packed column.

The packed column consists of a tower which contains approximately 10 feet of high efficiency Koch Flexipac® packing. Scrub solution liquid is introduced to the top of the column, while the flue gas containing the acid gases enters below the packing and flows upward countercurrent to the scrub solution liquid. The Flexipac® packing provides the necessary mass transfer area for the neutralization of the acid gases by the caustic solution. Downstream of the wet scrubbing components are HEPA filters and a charcoal adsorption bed for the removal of iodine. To protect against poisoning of the charcoal bed by SO₂, the removal efficiency in the packed column for SO₂ and HCl must be extremely high.

In order to meet nuclear power plant standards, the wet scrubbing components should be constructed of metal rather than plastic or fiberglass. This is particularly true for the quench column and high energy venturi because of the potential for high temperature excursions at the vessel walls. Furthermore, in order to ensure that Regulatory Guide 1.143 is met, the materials should be ASTM quality and welded using ASME code certified welders and procedures.

The recirculating scrub solution drains from the base of the packed column and is filtered, cooled, pH adjusted and then returned to the wet scrubbing components. The pH is maintained at a minimum level of 8 at the packed column discharge to minimize potential corrosion. The pH must then be increased to neutralize the acid gases. However, too high an increase will result in CO₂ absorption, thereby increasing the consumption of sodium hydroxide. The scrub solution liquid is maintained at a maximum temperature of 170°F. It is saturated with oxygen due to the excess oxygen present in the flue gas coming from the incinerator. This is the environment that the wet scrubbing components must survive: high chloride and sulfate concentrations, of pH of approximately 8, aeration and a temperature of 170°F.

INITIAL TESTING PROGRAM

Koch Process Systems was awarded a contract in September, 1981, to commercialize the Los Alamos controlled air incinerator system. In executing this contract we identified that the materials of construction (FRP) in the Los Alamos system were not adequate for nuclear power plant use. During our commercialization contract, an initial testing program was established to screen some potential materials of construction for the wet scrubbing components.

Three different tests were undertaken to determine the corrosion resistance of several materials:

- a one month immersion test in test solutions
- an accelerated electrochemical test
- immersion of samples in the Los Alamos system during fission product testing.

The first set of immersion tests was conducted at Arthur D. Little, Inc. and was done using a modification of the ASTM G48-76 procedure. The procedure calls for ferric chloride to be used but in our modification we utilized 6% and 10% solutions of sodium chloride each containing 3% of sodium sulfate. The materials listed in Table I were tested in the solutions shown. Each sample was a 1 inch by 2 inch coupon with a weld in the middle. Teflon washers were applied to both sides of the sample to provide crevices to detect possible crevice corrosion.

TABLE I

Short Term Immersion Test Samples

Alloy	
Hastelloy G ³	Each alloy immersed in each solution
Hastelloy C ₂₇₆ ³	
Incoloy 825 ⁴	
Inconel 625 ⁴	
Titanium (Gr 1)	

Test Solutions Salt Concentrations	1	2	3
NaCl	3.5%	6.0%	10.0%
Na ₂ SO ₄	3.0%	3.0%	3.0%

The samples were suspended by nylon line and immersed in two liter flasks for a one month period. The solutions were maintained at 170°F, air was bubbled through the solutions to maintain oxygen saturation and the pH of the stream was maintained at 8 ± 0.5. The solution pH and level were monitored daily and corrections were made as required. Because of the relatively high vapor pressure of water at 170°F, condensers were mounted on each flask and water vapor from the flask was condensed and returned. Please refer to Fig. 2 for a sketch of the test setup.

CORROSION CELL

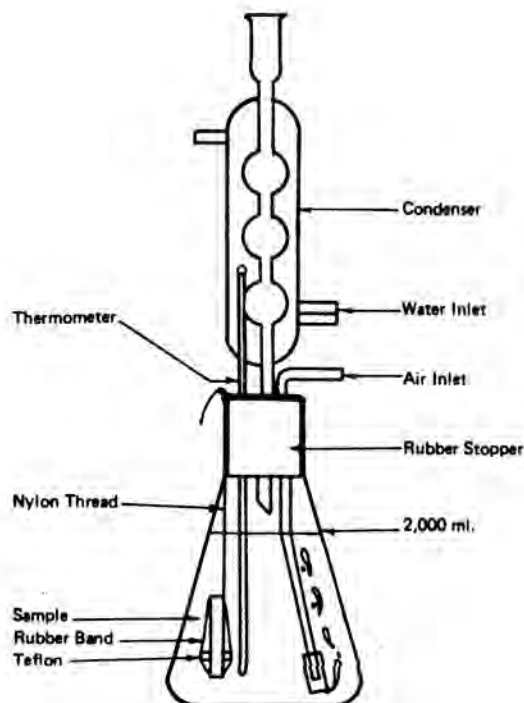


Fig. 2. Drawing of corrosion cell used for ASTM Test G48-76.

The second test involved the samples shown in Table I and the ASTM G61-78 procedure was utilized. This test is an accelerated corrosion test in which a sample is immersed in the proper solution and a varying voltage is applied. A one cm² piece of alloy was

utilized for the testing. The procedure calls for a slow potential scan applied to the sample and the currents which result as a function as a potential are recorded. The observed current is a indication of the corrosion potential of the sample at the conditions used. Prior to running actual samples, a standardized polarization plot was generated for Hastelloy C276³. The polarization curve obtained was compared to standard curves as indicated in ASTM G61-78 and it was found that the curve obtained very closely matched results shown in the ASTM procedure. This confirms that the procedure and the equipment utilized for the test were correct. Some of the polarization curves obtained are shown in Fig. 3 and 4.

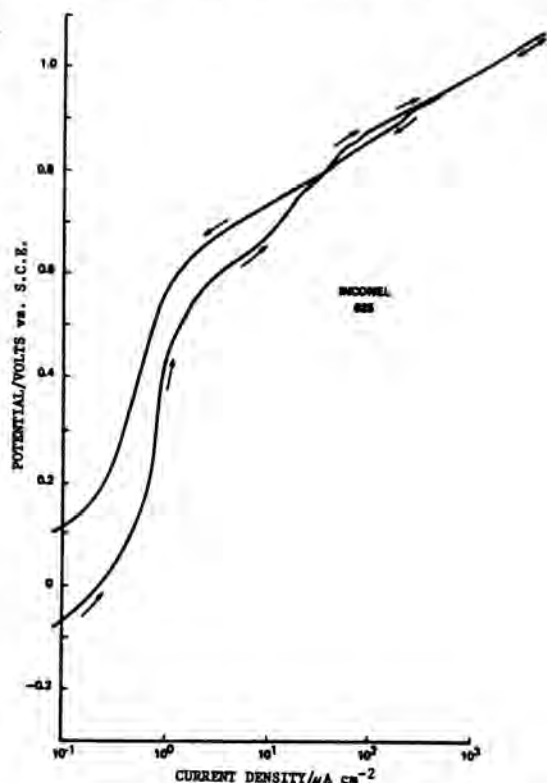


Fig. 3. Polarization plot for Inconel 625, base alloy.

The third test consisted of immersing various alloy samples in the actual scrub solution liquid in the Los Alamos controlled air incineration system while fission product testing was performed. The samples were immersed in the scrub solution filter vessel for a matter of a few days.

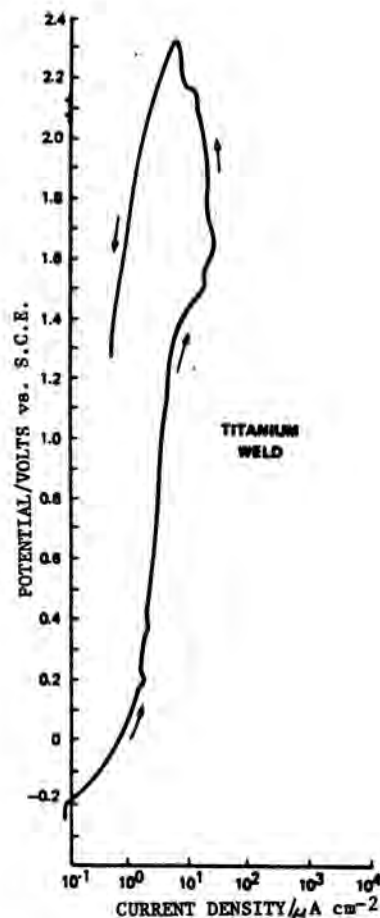


Fig. 4. Polarization plot for Titanium, weld.

LONG TERM TESTING

It was apparent after the three earlier tests were completed that insufficient and inconclusive data were generated and further testing was required. Koch then reconstructed the ADL test setup in our shops for a long term test of the matrix of alloys and solutions shown in Table II. The test conditions were identical to the first immersion test: a pH 8 of \pm a temperature of 0.5, 170°F and aeration of the solutions.

TABLE II

Long Term Immersion Test Samples

Alloy	% NaCl in Flask
1. Alloy 904L	6
	10
2. Hastelloy G ³	6
	10
3. Inconel 625 ⁴	6
	10
4. Hastelloy C276 ³	6
5. Incoloy 825 ⁴	6
	10
6. 316L Stainless Steel	6
7. Titanium (Gr 1)	10

A problem developed after approximately the first month and a half of testing when salt dried out on the tips of the aeration nozzles and caused loss of air flow to the flasks. This was particularly prevalent in the 10% sodium chloride solutions so instead of continuous aeration, the samples were intermittently aerated for 8 hours every 24 hours. Again, samples were monitored daily for pH and levels and were adjusted accordingly.

Triplicate samples of each alloy were initially immersed in each flask. This allowed removal of one of the samples after six months while still maintaining two samples for a full year. After six months elapsed, one of each sample was removed and sent to Arthur D. Little, Inc. for examination and weighing. The remaining two samples were left in the flasks and the test continued for another six months.

Another problem arose during the second six month period. The rubber bands used to hold the teflon washers to the samples failed, allowing the washers to fall to the bottom of the flasks. The samples had the teflon washers reattached using new rubber bands. The second set survived the second portion of the test.

RESULTS: INITIAL TESTING PROGRAM

The results of the first short term immersion test were inconclusive because no corrosion was observed on any of the samples. Either the samples were corrosion resistant or the sample test duration was too short. Some discoloration of the samples was observed and after four weeks all the samples showed a slight gain in weight. This weight gain is explained as a buildup of oxide film on the sample which actually improves the corrosion resistance of the alloy. It would be impossible to properly select the correct alloy based on the results of this first test.

The electrochemical test showed that all alloys at all concentrations were immune to corrosion except for the possible exception of Incoloy 825⁴ at a 10% sodium chloride solution concentration. This test also was not conclusive but showed that the possibility of corrosion existed. Arthur D. Little consultants recommended that further testing be completed before conclusions were drawn about the acceptability of the alloys. One interesting observation was that titanium appeared to be the most corrosion resistant material in the electrochemical testing. This result should be compared to the results of the long term immersion test presented in the following section.

The results of the Los Alamos testing were also inconclusive because of the short duration of the testing as well as the low chloride concentration of the scrub solution liquid. The Los Alamos system uses a continuous feed and bleed system, and the concentration of chlorides never approaches the 6% sodium chloride level.

LONG TERM CORROSION TESTING RESULTS

The long term corrosion testing produced some interesting results. The 316L sample was greatly corroded and showed deep pits not only in the weld area, but away from the weld area and smaller pits were distributed across the entire surface. One of the 316L samples was the only sample to lose weight which was from the loss of material due to corrosion.

Both titanium samples in the 10% sodium chloride solutions were observed to have a few pits located in the area just away from the weld. This was unexpected because the titanium looked so good during the electrochemical test.

Hastelloy G samples in the 10% solution were also observed to have pits away from the weld area. This is consistent with the six month observation in which the Hastelloy G sample that was examined showed one pit near the weld at that time. It was expected that Hastelloy G would do far better than this test showed due to its relatively high molybdenum content. The Hastelloy G samples in the 6% solution were also pitted, but to a far lesser extent than in the 10% solution. Alloy 904L samples at six months were observed to have no pits in the 6% solutions but 2 corrosion pits close to the weld area in the 10% solution. After one year, the samples in 6% solution showed no general corrosion but there was a crack at one end of the weld in one of the samples. The 904L samples in the 10% solution after one year had no deep corrosion pits but the surface was uniformly covered with very small diameter pitting. The Inconel 625, Hastelloy C276 and Incoloy 825 samples in 6% and 10% solutions were observed to have no pits, no general corrosion, and no problems after the one year test. Once the samples were rinsed with distilled water they all had the appearance of brand new material. This was somewhat of a surprise in that the Incoloy 825 showed some signs of possible corrosion during electrochemical testing. Even at the 10% sodium chloride level, the Incoloy 825 welded with the 625 filler metal showed no signs of corrosion.

CONCLUSIONS

After the completion of the multifaceted corrosion testing on a variety of materials in different sodium chloride salt solutions, it can be concluded that either Incoloy 825, Hastelloy C276 or Inconel 625 are suitable for use in incinerator wet scrubber materials used in radwaste incineration. Since there is a considerable cost difference between the Incoloy 825 and the other two alloys, Koch Process Systems believes that Incoloy 825 is the optimum material of construction for the wet scrubbing components.

REFERENCES

1. ASTM G48-76 Standard Test Method "Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by the Use of Ferric Chloride".
2. ASTM G61-78 Standard Test Method "Conducting Cyclic Potentiodynamic Polarization Methods for Localized Corrosion".
3. Trademark of Cabot Corporation.
4. Trademark of Huntington Alloys, Inc.