SELECTION OF MATERIALS FOR SAVANNAH RIVER SITE CONSOLIDATED INCINERATOR FACILITY (CIF) OFFGASS SYSTEM (U)

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ABSTRACT

This paper discusses the choice of materials for chloride containing flue gases, and quench and scrub solutions in the Consolidated Incineration Facility (CIF) (under design for Westinghouse/ Bechtel) for incineration of radioactive and hazardous waste. This facility is located at the Savannah River Site in Aiken, South Carolina.

A process need is to minimize blowdown waste. Chloride levels in the quench/scrub solutions up to 1 percent as acid or 10 percent as sodium chloride are expected. For low temperature portions of the system (up to 87°C, 190°F) polypropylene lined pipe and Derakane® 470-36 resins for FRP vessels are used. For service up to 250°F, Halar® lined carbon steel is used, and for service up 93°C (200°F) Flakeline® 103 lined carbon steel is used. For higher temperature portions of the system (up to 1000°F) Hastelloy® alloy C-22 is used.

Provisions for containment of low level radioactive gases as it affects materials selection are discussed in this article. Design of emergency quenching systems to avoid temperature excursions which could result in failure leading to hazardous emissions are presented.

Technical discussion of material thermal stabilities, aqueous corrosion data, pitting, and crevice corrosion is also given.

INTRODUCTION

A $20 million BTU/hr incineration facility is being designed for the Department of Energy (DOE) at the Savannah River Site (SRS) in South Carolina. Design is being done by Chas. T. Main, Inc., located in North Carolina. Development support for materials selection has been by Du Pont Engineering Services Division, Newark, Delaware, and by Ralph M. Parsons, Pasadena, California.

Wastes to be incinerated are generated at the SRS and include hazardous chemicals and low-level radionuclide contaminated materials. Typical incinerator feed will include organic and aqueous process liquid wastes as well as laboratory and operating wastes, with composition including

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polyvinyl chloride and phosphates. Incinerator flue gas design rate is 935 m^3/min (33,000 CFM) at 1100°C (2012°F). Average chlorides (HCl or Cl_2) are anticipated to be 16 Kg/hr (35 lb/hr) with excursions to 210 Kg/hr (460 lb/hr).

The off-gas cleanup system includes a downflow quench (co-current gas, quench liquid), a steam-hydro scrubber, cyclone separator, demister, and an exhaust gas reheater to provide dry gas for filtration through high-efficiency particulate air (HEPA) filters. The cleanup system is thus high state-of-the-art to ensure minimum release of radionuclides. The quench and scrubber liquids are recirculated to minimize blowdown waste because it will be solidified and disposed of as mixed waste. Absorbed chlorides are neutralized with sodium hydroxide. The concentration of NaCl is expected to be 10 percent in the quench solution and 2 percent in the scrubber. Adiabatic saturation temperature is 82°C (180°F) in the quench and 87°C (189°F) in the scrubber. Maximum suspended solids are estimated at 3.5 percent in the quench and 1 percent in the scrubber with particulate size below 10 microns. A blowdown filtration system is provided for high ash operating conditions so that clarified liquor can be recycled to maintain desired salt concentration.

Consideration was given in materials selection for alternate operation of the quench in the acid mode; about 1 percent HCl. For this mode of operation the scrubber solution would be at equilibrium salt concentration of 10 percent. The quench and scrubber recirculation liquid temperatures will remain approximately the same.

MATERIALS SELECTION

Hastelloy® C-22™ (or C-267)

For portions of the system with gas temperatures above 120°C (250°F) or liquids at temperatures to 100°C (212°F) and where strength properties of metal are required, Hastelloy® C-22™ was selected as the material for construction. However, in selected cases where procurement schedule problems might occur, a substitution of Hastelloy® C-276 was allowed.

Hastelloy® C-22™ is a nickel chromium alloy with 12.5 to 14.5 percent molybdenum which has better overall corrosion resistance to HCl and better resistance to pitting, crevice corrosion and stress-corrosion cracking than other nickel, chromium, molybdenum alloys available. Hastelloy® C-276 is also a high molybdenum nickel chromium alloy. The manufacturer's(1) comparative corrosion data for Hastelloy® alloys C-22™, C-276, C-4 and Cabot alloy 625 in hydrochloric acid solutions are given in Table 1.

It can be noted from the corrosion values for alloys C-22™ and C-276 that the corrosion rate varies significantly with HCl concentration and with temperature. A better appreciation for these variations can be seen on an isocorrosion diagram of alloy C-22™ from the manufacturer(1), Figure 1. There are significant variations in corrosion with both HCl concentration and temperature in the range of temperature of interest for the CIF solutions, around 82°C (180°F).

Table 2 lists items which were specified for Hastelloy® C-22™ or C-276 material of construction. Schematic drawings of the quench and scrubber system are given in Figures 2 and 3. As noted in the table, the quench inlet and quench nozzles are exposed to hot gases as well as quench liquid. The quench downcomer is not expected to see high temperature because the walls are cooled on the

(1) Cabot, Wrought Products Divisions

inside by quench solution, but Hastelloy® is conservatively used in the event of temperature excursion. The quench pumps are also conservatively specified for Hastelloy® in this case to assure continued reliable operation. The scrubber housing, mixing tube, and steam and scrub liquid inlet nozzles are specified for Hastelloy® because of potential erosion from high velocity gas and liquid. A Hastelloy® wear plate on the cyclone is likewise provided because of erosion potential.

Halar Lined Carbon Steel Carbon Brick Insulation

The spray area of the quench vessel is specified for carbon brick insulation with Halar® lined carbon steel. Halar® is a fluoro- chloro-polymer with good resistance to acid or basic solutions. While the quench solution will be controlled to an acid pH to avoid formation of sodium bicarbonate from absorbed carbon dioxide, some excursions to a basic pH can be expected. For this reason, carbon brick was selected as the insulator rather than an acid brick.

Ceilcote Flakeline® 103 Lined Carbon Steel

The quench separation tank and the connecting duct between the quench vessel and the scrubber are specified to be lined with 80 mils of Ceilcote® Flakeline 103® on carbon steel. This material is used for its resistance to corrosion under acid and base submersion conditions up to 93°C (200°F). A carbon steel structure is used rather than fiberglass reinforced plastic (FRP) to assure containment of radionuclide contaminated gases in the event of a high temperature excursion due to quench system failure. To minimize the potential for quench failure, a highly reliable emergency water supply system is provided in the design. Firewater and process water with emergency power backup provide the emergency water source. This emergency system is needed since no thermal relief was provided on the incinerator. Thermal relief was avoided to preclude escape of radionuclide contaminated gases without scrubbing and HEPA filtration.

Allegheny Ludlum AL6XN

An Allegheny Ludlum stainless steel, AL6XN, consisting of approximately 20 to 22 percent chromium, 23.5 to 25.5 percent nickel, 6 to 7 percent molybdenum and 0.20 to 0.25 percent nitride hardened surface is the material of choice for the reheater housing and tubes. The AL6XN with its relatively high molybdenum content provides chloride corrosion and stress cracking and pitting resistance. The reheater uses steam coils with steam supply at 150 psig to control the gas outlet temperature to 115°C (240°F).

Polypropylene Lined Carbon Steel

Polypropylene lined carbon steel piping is specified throughout the quench and scrubber system because of the polypropylene resistance to corrosion in both acid or basic solutions up to 93°C (200°F).

Carbon Steel Insulated

Offgas duct downstream of the reheater is specified as insulated carbon steel. The neutralized offgas is heated to about 115°C (240°F) or about 28°C (50°F) above the dew point.

Carbon Steel Epoxy Coated

The offgas induced draft fans are specific as carbon steel, epoxy coated on internal surfaces. The epoxy provides an added measure of corrosion protection to the carbon steel for these fans.

Derakane® 470-36 Corrosion Liner on Fiberglass Reinforced Plastic

For vessels and equipment of the system exposed to quench and scrubber solutions or gases at temperatures up to 93°C (200°F), a structural fiberglass reinforced plastic (FRP) laminate of 380 mils with 120 mils of Derakane® corrosion liner is specified. Table 3 lists the specific items.

The vessels and tanks are to be maintained up to a few inches of water below atmospheric pressure and a plastic corrosion liner with fiberglass reinforced plastic laminate is appropriate. Derakane® 470-36 was chosen for the liner because of its resistance to either acid or basic solutions and its suitability at the design temperature. The off-gas duct and the mist eliminator, exposed to saturated gas under 93°C (200°F), were also specified for the Derakane® and fiberglass reinforced plastic. The stack, exposed to slightly lower temperature, is also specified for the Derakane® and fiberglass reinforced plastic. The scrubber and blowdown tank recirculation pumps will be purchased as manufacturer standard composite plastic pumps.

Table 1. Comparative Corrosion Data for Hastelloy® Alloys in Hydrochloric Acid

Hydrochloric Acid (Wt Percent)	Temp	Average Corrosion Rate (Mils Per Year)			
		C-22™	C-276	C-4	625
1	Boiling	3	10	36	1
1.5	Boiling	11	29	64	353
2	90°C (194°F)	Nil	1	31	Nil
2	Boiling	61	51	85	557
3	90°C (194°F)	< 1	12	34	72
3	Boiling	84	70	44	296
10	Boiling	400	288	228	642

Table 2. System Components of Hastelloy® C-22™ or C-276 (As Noted)

Component	Description	Service
Quench Inlet	Quench entry	Hot gases, about 120°C (250°F) or quench liquid(1) at 82°C (180°F)
Quench Nozzle	Stellite face nozzles, of C-276	Hot gases and quench liquid
Quench Downcomer	Extension of quench vessel into quench separation vessel	Quench liquid on two sides
Quench Pumps	Recirculating pumps	Quench liquid
Scrubber Inlet Damper kiln pressure	Damper for rotary with mist carryover control	Cooled gas, 82°C (180°F)
Scrubber Housing, Mixing Tube and Nozzles	Steam driven scrubber liquid	High velocity gases and scrub liquid.(2) Steam at 225 psig, 160°C (320°F) after expansion, and scrubber liquid at 87°C (189°F)
Cyclone Separator Plate	Wear plate at cyclone inlet	High velocity gases and wear scrubber liquid

(1) Quench liquid composition 10% NaCl, with pH 3 - 8, or in alternate operating mode 1% HCl.
(2) Scrub liquid composition 1.8% NaCl, with pH 7 - 9, or in alternate operating mode 10% NaCl.

Table 3. System Components with 120 Mils Derakane® 470-36 Corrosion Liner and 380 Mils Structural Laminate

Component	Description	Service
Quench Recirculation Vessel	Quench drain collection tank	Quench vessel solution at 82°C (180°F), 10% NaCl, pH less than 8 (or 1% HCl if in acid quench operation)
Scrubber Recirculation Vessel	Scrubber cyclone drain collection tank	Scrubber solution at 87°C (189°F), 2% NaCl, pH greater than 7
Blowdown Vessels	Blowdown waste from quench, scrubber system	Quench solution at 82°C (180°F), 10% NaCl, pH less than 8 or pH equal 13 after neutralization for pumping to disposal transport.
Filter Feed Tank	Hold tank for quench solution to be recycled after filtration	Quench solution at 82°C (180°F), 2 to 10% NaCl, pH less than 8
Cyclone Separator	Cyclone at exit of steam, hydro scrubber	Scrubber solution at 87°C (189°F); 2% NaCl, pH greater than 7
Offgas Duct	Duct downstream of cyclone separator to mist eliminator	Saturated off-gas at 87°C (189°F), HCl 6 ppm with infrequent excursions to 80 ppm, liquid carryover composition 2% NaCl
Mist Eliminator	Mist eliminator down steam of cyclone separator	Saturated off-gas at 87°C (189°F), HCl 6 ppm with infrequent excursions to 80 ppm, liquid carryover composition 2% NaCl
Stack	One hundred fifty foot stack exhausting combined process and ventilation gases	Saturated process and ventilation gases at about 65°C (150°F)
Pumps (except quench)	Scrubber recirculation and blowdown hold tank pumps	Scrubber and quench solutions up to 10% HCl at 87°C (189°)

Figure 1. Resistance to Hydrochloric Acid

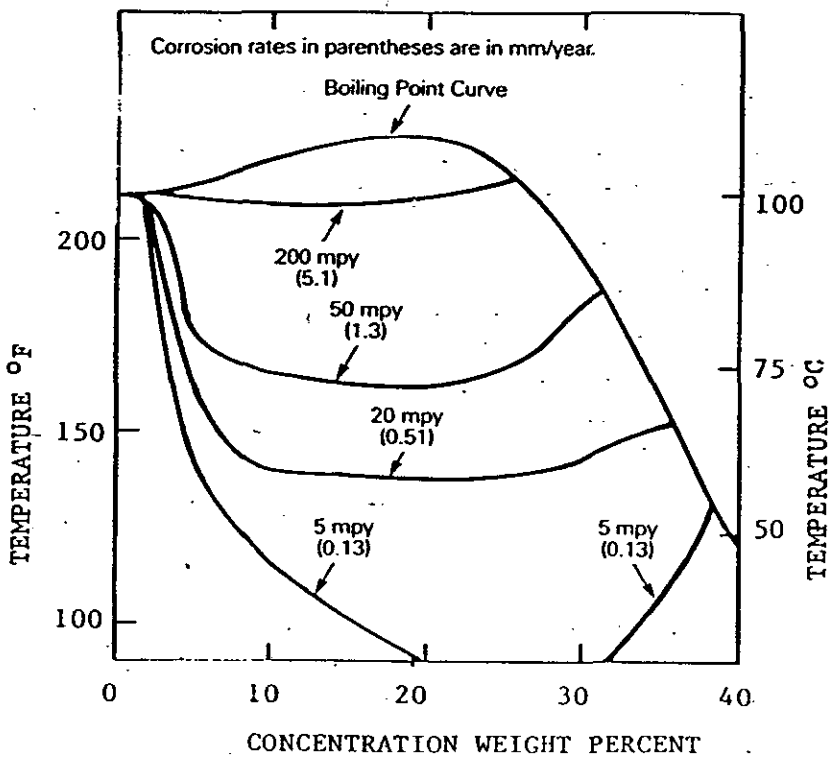

Figure 2. Quench System Flow Diagram

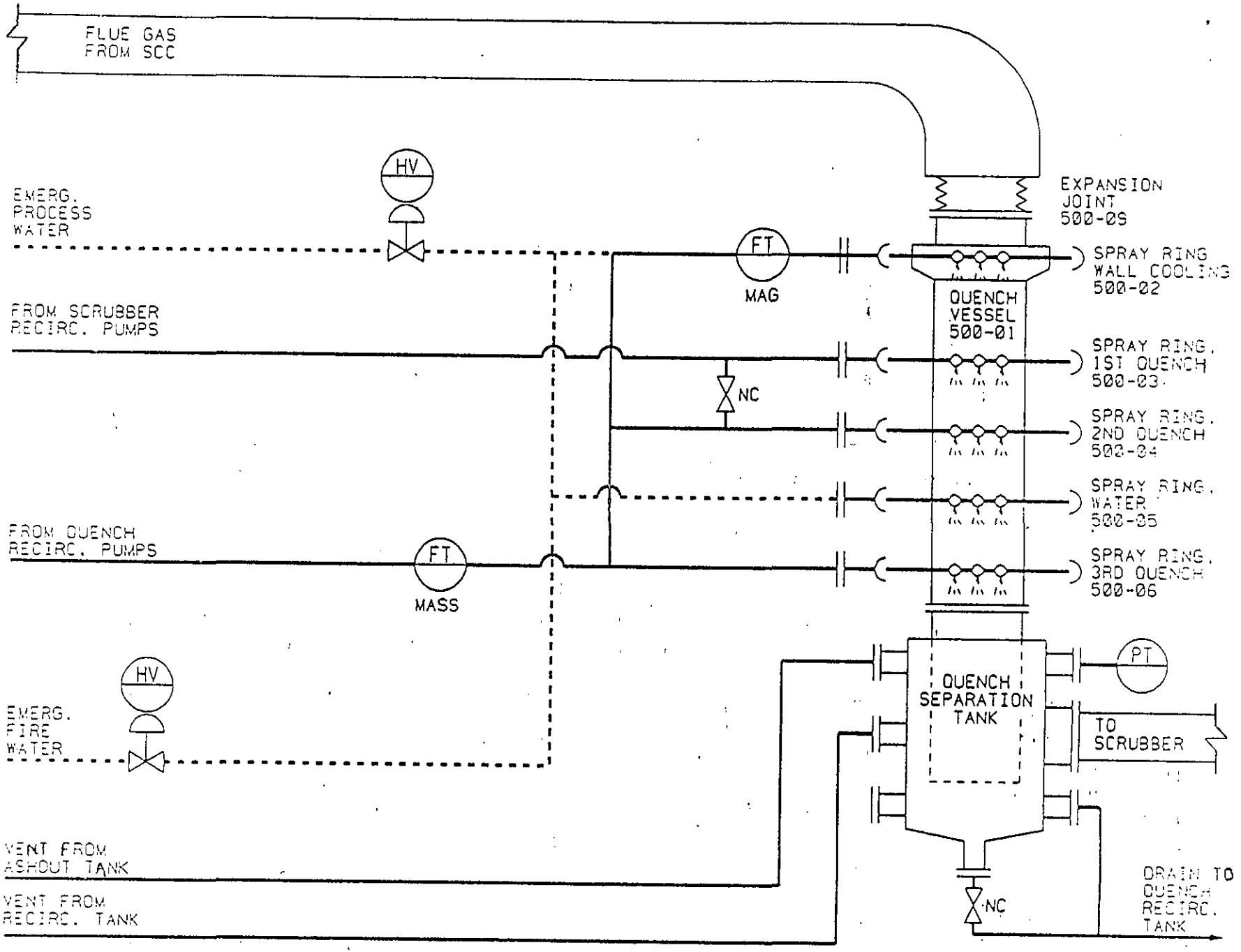

Figure 3. Scrubber Operation Flow Diagram