ACOUSTIC AND TURBULENT AGGLOMERATION OF SODIUM AEROSOLS

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ABSTRACT

Design of a wet cell washer and test system for air cleaning of sodium fire aerosols is described.

The test aerosol was produced by continuous burning of metallic sodium in a 90 m³ chamber to maintain a concentration of 1.14±0.05 g/m³ for as long as 65 minutes. The sodium fire aerosol was drawn through the wet cell washer test loop at a constant flow rate of 9 m³/min. The wet cell washer consisted of two cells in series, the first, two off-set layers of perforated metal screen, and the second, a 4" thick filter stage packed with curly glass fibers 35 µm in diameter. The wet cells were washed by solid cone water spray at 16.7 lpm at 30 psig. Sodium removal efficiencies ranged from 87 to 94%. Curly glass fibers were found to deteriorate after a six hour exposure to sodium aerosols.

EXPERIMENTAL APPARATUS

1. Scrubber System

Figure 1, is diagram of an experimental wet cell washer being used to clean high concentration sodium aerosols. It consists of three fiber cells in series. The first two are wetted and the third is dry to act as a mist eliminator. Each of the three cabinets has a support frame sealed to the scrubber unit at a 45 degree angle to provide more filter face area in the 12"x12" scrubber cross section. Cell face area measures 12"x15" and may be up to 4" thick. Cells composed of fibers can be packed to various densities and thicknesses. Alternatively the upstream cell may be a double off-set perforated metal Neva-clog screen sealed directly to the support frame. This Neva-clog screen consists of two stainless steel plates which have 1/16 inch holes covering the surface in aligned rows and columns. The two plates are joined together so that the corresponding holes on each plate are off centered. Thus, flow through the plates must bend and this is a cause of interception and impaction of sodium aerosol particles on the plates. Physical characteristics of the Neva-clog screen are as follows:

screen size	10 3/4"x14"x1/8"
hole diameter	1/16"
hole density	59.61 holes/in. ²
total area of holes	27.52 in. ²
total area of screen	150 in. ²
solidity =	$\frac{\text{total area} - \text{open area}}{\text{total area}} = (0.817)$

Each wet cell is provided with a Spraying Systems type 3/8 HH27W nozzle. The nozzle produces a wide angle round spray that covers the cell face and penetrates the cell. The spray washes insoluble aerosol deposits off the face of the filter or through the pack. Water is retained by an outlet at the bottom of each cabinet and can be recirculated. The final stage mist eliminator

FIGURE 1. WET CELL WASHER

removes entrained water droplets and produces a dry downstream airstream that can be sampled easily for analytical purposes.

The sodium entering the wet cell washer is humidified with the aid of two Spraying Systems 1/4 J cells to provide one second retention time prior to entry into the wet cell washer. An upstream sampling station is located between the 90 m³ aerosol generation chamber and the prehumidification nozzles. A downstream centrifugal blower draws the aerosol from the chamber through the humidification section and the scrubber unit. A Venturi meter located downstream of the scrubber unit measures gas flow and U-tube manometers are used to measure pressure drop across the wet cells.

2. Aerosol Generation

In the 90 m³ aerosol generation chamber sodium is burned continuously in a heated steel pot to produce a dense sodium oxide aerosol for test purposes. Several open 5 cm diameter ports in one chamber wall provide chamber cross ventilation to mix and dilute the aerosol before it is drawn out through a 25 cm port to the prehumidification section upstream of the scrubber unit at a rate of 9 m³/min. Another 5 cm port located at mid-chamber height is used to sample the chamber aerosol concentration. Chamber aerosol concentrations agreed stoichiometrically with sodium concentrations sampled upstream of the scrubber unit. Therefore there is little loss of aerosol in the ductwork leading from the aerosol chamber to the scrubber unit.

A feed chute, 5 cm in diameter and 1.2 meters long, slants 45 degrees from the outside of the chamber to the sodium burning pot to provide a means for continually adding sodium metal from outside the chamber. Heater controls and thermocouples monitor the operating conditions of the sodium burning pot. Compressed air may be directed onto the surface of the pool fire in the burning pot to enhance burning rates by providing additional oxygen and turbulent mixing to obtain higher aerosol concentrations (>1.0 g/m³).

3. Aerosol Sampling Procedures

Simultaneous samples were collected isokinetically up and downstream of the washer unit on all glass absolute filter paper (MSA 1106-B) and analyzed for sodium content by atomic absorption spectrophotometry. Because the filter paper contains some leachable sodium content, a sodium blank must be determined and subtracted from the total sample value. Filter background ranged from 200 to 600 mg of sodium and produced less than 0.5% correction.

Open faced filter samples were taken at 18.4 lpm for 2 to 3 minutes at mid-chamber height in the burn chamber to monitor aerosol mass concentration during the time period of each sodium burn. A design goal for each sodium burn is to maintain in the chamber the desired sodium aerosol concentration, 1 to 10 g/m³, to within ±20% of the mean for a two hour period. This simulates

to some degree a prolonged sodium fume evolution that would occur within a reactor containment vessel following certain types of sodium releases.

EXPERIMENTAL RESULTS AND DISCUSSION

Different sodium addition rates were made to the pool fire to maintain a constant aerosol concentration for more than a one hour period. In Figure 2, results of Scrubber Run #16 are presented. A sodium addition rate of 85 g every 2 minutes with an air addition rate of 16.5 lpm onto the surface of the pool fire were utilized. This produced an aerosol concentration to the scrubber unit of $1.14 \text{ g/m}^3 \pm 0.05 \text{ g/m}^3$ for a 65 minute period. Sodium collection efficiencies for this run ranged from 87.0% to 90.1%. A perforated metal screen, Neva-clog, was used for the first wet stage and a 10.2 cm thick curly glass fiber filter for the second wet stage. The curly glass fiber filter had the following characteristics:

fiber diameter	35 micrometers
cell thickness	10.2 cm
packing density	16.02 kg/m^3
fiber orientation	random
cell size	12"x15"x4"

Wash water nozzle flow rates for each wet cell were 16.7 lpm (4.4 gpm) at 30 psig nozzle pressure.

Difficulties occurred during several scrubber tests because the electrical heating elements used on the burn pot were damaged from caustic that formed on the surface and from heat stress during the pool fire. The heat stress results from the fact that during a pool fire the temperature of the liquid can rise to the boiling point (877.5°C) and because liquid sodium has a high thermal conductivity it transfers heat rapidly to the burn pot walls where the heating elements are imbeded. When temperature of the heating elements exceeds their maximum operating temperature (820°C) the reduced internal resistance causes excessive current drain and overloading of protecting fuses. With the heating elements off solidifying of the liquid in the burn pot occurs and eventually the solids build up to a point where the burning surface is considerably reduced and burning stops.

Future scrubber tests will use a natural gas fired Meker type burner to heat the burn pot. This is expected to eliminate the inconsistent heating rates caused by failure of the electric heaters. The general effect that heater failures have on the concentration level can be seen in Figures 3 and 4. As the burn pot cooled off, the sodium burning rate decreased and the concentration level slowly dropped (Figure 3). Increasing sodium addition rates had little effect on aerosol generation rate and could not raise the

FIGURE 2. SCRUBBER RUN #16

FIGURE 3. SCRUBBER RUN #13

FIGURE 4. SCRUBBER RUN #14

concentration level to its original level (Figure 4).

Noticeable damage to the curly glass fibers used in the wet cells was observed after several sodium aerosol scrubber runs. This was not unexpected as strong sodium hydroxide does dissolve glass slowly. Nevertheless, the glass packing was used because it had been used for prior studies and it was expected to last a sufficient length of time for the scrubber tests. Resistant materials could of course be substituted for a production unit. Also, the force of the water sprays on the face of the cells had worn thin spots in the filter such that sodium deposits could be observed on the downstream side of these spots and along the edges of the filter. When this occurred the filters were rinsed with distilled water and repacked. To improve sodium collection efficiency, the upstream wet cell was replaced with a Neva-clog metal screen and for the downstream wet cell, the spray nozzle orientation was changed to improve filter face spray coverage. Repositioning the nozzle perpendicular and back away from the center of the filter until the entire surface area was washed was an improvement upon the original positioning parallel to air flow which poorly washed the edges of the filter.

When using the double perforated metal impingement screen, Neva-clog, upstream during Scrubber Run #13 (Figure 3) sodium collection efficiency was as high as 93.5% with a wash water spray of 16.2 lpm (4.3 gpm at 28 psig). Sodium aerosol concentration in the burn chamber was 1.48 g/m³ during this run. Pressure drop across the metal screen at a gas flow rate of 9 m³/min. was constant at 3.5" w.g., whereas pressure drop across the downstream curly glass filter increased from 1.6" to 1.8" w.g. during the tests.

In later runs, pressure drop across the metal screen remained constant at 3.5" w.g., but the downstream curly glass fiber filter increased to 2.1" w.g. and sodium collection efficiencies fell to 89-90% and on inspection it was seen that the curly glass filter in the second cell had shallow spots across the filter surface and a build up of sodium deposits on the downstream side. The curly glass fibers had been discolored by rust from the water nozzle lines and a lot of unidentifiable small solids could be seen to have imbeded on the upstream side of the filter. These foreign solids could have caused the permanent increase in pressure drop as it is believed that all sodium deposits on the filter had been rinsed out in between scrubber runs. The decrease in sodium collection efficiency from Scrubber Run #13 (93.5% high) Figure 4 to Scrubber Run #16 (87.0% low) Figure 2 is due to the physical breakdown of the filter packing in the downstream curly glass wet cell. For these tests the filters were exposed to sodium for approximately 6 hours. To improve collection efficiency new filter media will be sought that can withstand these water pressures.

FUTURE WORK

A natural gas burner will replace the unreliable electrical heaters for heating the sodium burning pot to provide a constant evolution of sodium aerosols. Because the curly glass fiber

packings are deteriorating under the caustic conditions in the scrubber unit, new cell packings will be evaluated for resistance to sodium attack. Statistically designed experiments will be devised to determine effects of cell packing densities, filter face velocities, and cell thickness on sodium removal in the wet cell washer.