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ABSTRACT

Criteria are presented for a horizontal cocurrent spray nozzle scrubbing system designed to remove fluorine and hydrogen fluoride from the 3000 cfm of ventilation air passing through the Volatility Pilot Plant located in cells 1 and 2, Bldg. 3019. A reduction of fluorine concentration from 1520 to < 2 ppm during a total release of 68 lbs, and a reduction of hydrogen fluoride concentration from 4090 to < 1 ppm during a total release of 200 lbs, will adequately protect the Fiberglas media filters. Six scrubbing stages each containing four nozzle-throat spray units are needed with a 5-10% aqueous caustic potash recycle system pumping at a maximum rate of ~ 180 gal/min, with a range per nozzle from 3-7 gal/min. The scrubber will be 4 ft x 4 ft x ~ 25 ft, containing a deentrainment section of baffles and demister. The associated ventilation system hardware, services, and instrumentation requirements are given.

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1.0 INTRODUCTION

This report presents design criteria developed for a gas scrubbing system to remove fluorides from ventilation air from cells 1 and 2 of Bldg. 3019. The Volatility Pilot Plant, presently housed in these cells, was built for uranium recovery studies of irradiated Zr-U nuclear submarine fuels. Ventilation gas containing unscheduled fluorine, hydrogen fluoride and/or uranium hexafluoride releases from the process would attack and could damage the building ventilation system "absolute" Fiberglass filters liberating radioactivity to the atmosphere via the stack. To prevent this, a horizontal cocurrent spray chamber scrubber design using caustic (KOH) solution as the removal agent was selected because it best satisfies all the requirements: is simple and economical to fabricate, is a well-proven method, should require relatively low maintenance, causes practically no pressure drop and requires only a few simple operation procedures. The experience, experimental data and scrubber design developed at ANL (ref 1 and 2) for a similar Chemical Engineering Division installation was utilized.

Basic process and equipment information was used to determine potential fluoride releases and then the necessary scrubber system requirements for assured absolute filter protection. Then design criteria for the scrubber and caustic handling equipment was worked out in detail. However, equipment locations, service requirements, piping, supporting equipment such as ducts and accessories, and instrumentation will have to be developed from basic process data presented herein plus engineering studies based on conditions at the site selected adjacent to Bldg. 3019.

Fluorine recovery from stack gases by limestone bed absorption was studied by TVA personnel, and limestone bed absorption of various halogens and halides was investigated at ANL (ref 1). Mineral wool fibers used for fluorides absorption from flue gases were investigated by Silverman (ref 4), who also developed the Wet-cell washer (ref 6). The horizontal spray tower for halogens, carbon dioxide and aerosol removal was developed at ANL (ref 2).

2.0 SUMMARY

The unscheduled release of fluorine and hydrogen fluoride during VPP processing could result in cell ventilation concentrations of 1520 and 4090 ppm, respectively. Normal releases diluted with 3000 cfm of air are usually undetectable quantities, but fluorine discharged from a poorly operating vessel off-gas scrubber could result in concentrations up to 4 ppm in the cell ventilation gas stream. Reduction to 2 and 1 ppm for fluorine and hydrogen fluoride, respectively, will be adequate to protect the "absolute" Fiberglass filters during the release of 68 lbs fluorine, 200 lbs hydrogen fluoride and 10 lbs uranium hexafluoride. Hydrolysis of uranium hexafluoride produces hydrogen fluoride, which attacks the filter; otherwise, the uranium salts do not present recovery problems in the ventilation system.

The 6 stage cocurrent spray scrubber designed to produce 6.6 transfer units based on ANL data (ref 1 and 2) will contain 4 spray systems per stage. Schutte-Koerting spray nozzles (No. 622C) directing a hollow cone spray through the No. S4935-J1 throat pieces creates an efficient gas-liquid contact area for mass transfer of the fluorides. Baffles and a demister eliminate spray from the discharge gas. A 750-gallon recycle solution charge of a 10% potassium hydroxide feeds the spray nozzles by a pumping system. Liquid drains back from the scrubber by gravity flow. A 10% side stream is filtered to prevent solids buildup in the recycle liquid. Stainless steel will be the material of construction for components in contact with the liquid phase. Suitable substitutes are available.

Ducts and accessories will be required to convey gases from the cells to the scrubber and from there to the main duct. Argonne data (ref 2) upon which this unit was designed requires a ΔP of 0.2 in. water at 2500 cfm. The entire system with ducts control accessories, and scrubber will be designed for a minimum flow of 3000 cfm at 2 in. water ΔP .

Instrumentation will be required to control the recycle solution and demineralized water "make-up" systems. Fluoride detectors before and after the scrubbing will detect process leaks and scrubber effectiveness.

Limestone beds, slag filters and solid absorbents in general were investigated, but were found to be inferior and unsatisfactory for fluoride use (ref 1, 3, and 4). Charcoal beds are also unsuitable because they do not effectively remove fluorine in the concentration ranges expected (ref 5). Liquid scrubbers such as Wet-cell washers and packed towers have pressure drop limitations and present radioactive solids handling problems, making them unsuitable (ref 1 and 6).

3.0 SURVEY OF FLUORINE AND HYDROGEN FLUORIDE DISPOSAL METHODS

Fluorine and hydrogen fluoride removal from ventilation gases suggests solid absorbents; ideal because no operations would be required except infrequent solids removal after an unscheduled fluoride release. However, the following reasons show why solid absorbents are impractical. First, the removal mechanism is a chemical reaction at the surface. The limestone bed is an example. This material reacted efficiently with hydrogen fluoride until 50% of the bed was exhausted (1/8-to 1/4-inch particles of oolitic limestone), but was found inefficient for fluorine--81.3% efficiency for 0.09% of the bed, then 57.8% for the next 0.061% of the bed, with rapid loss of efficiency before 1% of the bed reacted (ref 1). Obviously, an impervious coating is rapidly formed. The reaction of mineral wool filters (slag) with fluoride vapors produces a similar result; 91% efficiency dropping off rapidly to 19% with increased ΔP from 2.3 to 6.0 in. water (ref 4). Increased pressure drop commonly occurs as the solid reacts with the halide. The degree usually being a function of reaction efficiency. This increased pressure drop could conceivably become prohibitive when assured flow of ventilation gas is needed (in the event of a sudden release of fluorine).

Decreasing particle size (increasing surface area) increases efficiency at the expense of greatly increased pressure drop which quickly becomes prohibitive. Also, smaller size packings tend to act as efficient filters for atmospheric dust and radioactive particles, making these devices more sensitive to plugging. Handling large quantities of potentially radioactive solids eliminates solid absorbent systems from consideration but the ΔP and massive equipment requirements for VPP service are also important factors.

Next, liquid-gas absorption systems were investigated. Obviously, the first liquid considered was water. It is an excellent hydrogen fluoride absorbent but unsatisfactory for fluorine. An intermediate compound OF_2 , which reacts much slower than fluorine is sometimes formed (ref 7 and 8). The fluorine reaction with water is unpredictable and on occasions produces violent explosions (ref 8). However, early work at the ORGDP indicated fluorine-nitrogen mixtures with less than 16% fluorine would not explode when mixed with water (ref 9). Explosive limits of air-fluorine mixtures with water are not known. An accelerated corrosion rate (which is unsatisfactory) of Monel when exposed to aerated dilute hydrofluoric acid (ref 10) and the additional requirement of neutralization equipment before disposal of acid to the radiochemical liquid waste system are the reasons why water was eliminated from consideration. The other liquid choices best suited for fluorine removal are the hydroxides. Potassium and sodium have both been used successfully. Potassium hydroxide is superior for two reasons: (1) potassium fluoride and the carbonate formed by carbon dioxide absorption are very soluble, but sodium fluoride is only slightly soluble and the precipitate erodes pumps, plugs spray nozzles, etc. (ref 11); (2) the OF_2 formed in the presence of sodium reacts slowly (ref 12). Apparently, OF_2 and F_2 both react fast with potassium hydroxide solution (ref 1). However, when enough holdup time is built into the equipment and the sodium hydroxide concentration is kept above 2%, the OF_2 is quantitatively reacted. A method using lime to regenerate caustic and remove the fluoride as solid calcium fluoride is the basis of a commercial process for fluorine and volatile fluorides removal (ref 13). This process is economically feasible only because large quantities of caustic are required, and the more expensive potassium salt justifies the cost of the increased capital equipment expenditure. In the VPP situation only an insignificantly small amount of potassium salt would be consumed in the unlikely event of an unscheduled release. Successful use of the potassium salt over a 5-year period at Argonne attests its reliability (ref 1 and 2). Other advantages of potassium hydroxide solution are: (1) it can be sent to the existing radiochemical waste system without any treatment; (2) it can be handled in stainless steel equipment which is easy to decontaminate.

Several types of contacting equipment for liquid-gas absorption are available. Two stand out, the spray column and the Wet-cell washer. The Wet-cell washer is a modified horizontal spray contactor with Saran (Dynel has also been used) fiber beds located under the sprays and contained so that cocurrently gas and liquid contact each other in a bed, usually about 4 in. deep (ref 6). These pads (or beds), fabricated from 44 to 178 micron fibers, (a single size for a given pad) produce very efficient contact of the phases by virtue of the relatively large surface area presented. These units are undoubtedly excellent contactors, but the following features make them undesirable, if not unsatisfactory, for VPP purposes.

1. A minimum ΔP of 5 in. water is required to satisfy design requirements, while spray towers operate at essentially zero ΔP . Any device requiring more than about 2 in. water ΔP will necessitate additional blower equipment, plus a much more complex and expensive system.

2. The beds act as filters plugging with atmospheric dust, radioactive particles, and other solids formed in or introduced into the system.

3. The manual handling required to replace and dispose of radioactive beds is a hazardous and expensive operation, especially compared to draining a spray tower to the radiochemical waste drain.

4. The compatibility of fluorine with Saran and Dynel (the two fibers available) in the dry condition is unknown, a condition that could result from operational error. The rapid chemical reaction of fluorine with most unfluorinated organic materials is well known. Probably, these materials would decompose on contact with fluorine. In any event, a testing program would be required before they could be used at the VPP.

5. A Wet-cell washer installation with all the necessary supporting equipment and facilities would undoubtedly cost more than the simple spray system scrubber.

6. Performance data for fluorine absorption in Wet-cell washers, satisfactory for design purposes, is unavailable.

The horizontal cocurrent spray scrubber discussed in detail elsewhere in this report needs no further explanation here.

Packed columns and countercurrent flow devices are not required for this service, and since they would only create complications, increase cost and ΔP , they were not considered further.

Charcoal beds for fluorine disposal backed by a limestone bed for hydrogen fluoride was first thought of as a possible removal method, but the data (ref 5) indicated that fluorine removal at concentrations below 0.4% (4000 ppm) was very poor in these beds. Therefore, since these units would have to be backed with a caustic scrubber their use was not applicable.

4.0 "ABSOLUTE FILTER" PROTECTION REQUIREMENTS

The "absolute" and pre-filter "roughing" units are fabricated from all-glass filter media. The high efficiency air filter units (absolute) now in service are American Air Filter Company type F (ref 14). Guaranteed efficiency is 99.97% on 0.3 micron-size particle. The label or seal of the Underwriters Laboratories, Inc. is evidence of inspection by procedure UF 586 (ref 15). Roughing filters are American Air Filter Company, Airmat Deep Bed, Pocket Type, model A units (ref 14). Each of five pockets is packed with one 25 FG and one 50 FG, filterdown media mats. The average efficiency for atmospheric dust using the U. S. Bureau of Standards test methods is 90 to 95% as reported by the manufacturer.

Data to calculate "absolute" filter damage by fluorine and/or hydrogen fluoride attack in terms of throughputs of radioactive material is not available. Neither is "break through" (loss of pressure drop over the unit) data in terms of attack by these agents known. While these data would be desirable, they are not worth the effort required to obtain them because a caustic scrubber system is definitely required, and the additional cost to design a unit for 99.9% efficiency vs 98% efficiency is small by comparison with any development program involving radioactive material releases through "absolute" filters. Therefore, to assure minimum filter damage and consequently a negligible release of radioactivity to the stack, the permissible concentration of fluorine in the cell ventilation gas after scrubbing was set at 2 parts per million (steady state condition) and the hydrogen fluoride concentrations less than 1 ppm at all times.

5.0 POSSIBLE FLUORIDE GAS RELEASES

5.1 Hydrogen Fluoride

No normal releases are planned. The maximum quantity of anhydrous HF in the system at any time is 200 lbs. The maximum unscheduled release of 60 lbs/hr HF vapor to the cell ventilation system could occur if the transfer line were ruptured during operation. Other HF leaks would generate vapor at lesser rates.

5.2 Fluorine

The caustic scrubbed vessel off gas can release small quantities of fluorine to the cell ventilation system. Unit Operations Section experiments indicate between 0.013 and 0.00007 cfm (ref 16). Dilution with 3000 cfm of air would produce 4 ppm fluorine concentration in the cell ventilation gas, based on the 0.013 figure. Normally only an undetectable amount will be released.

The VPP fluorine supply system shown in Fig. 1 is located outside of Bldg. 3019 at the southeast corner adjacent to cells 1 and 2. One of two storage vessels (at 60 psig pressure) feeds a 1/2-in. pipe line system containing the necessary valves and equipment items. The major portion of the pressure drop in this system would occur through the pressure regulator, the flow control valve, and the flow element in the event of an unscheduled release. Neglecting the pressure drop through the other components of the system, a maximum flow rate of about 100 standard liters per minute of fluorine is the calculated maximum flow rate that could occur with a 60 psi ΔP over the system from the trailer to the cell providing all devices were inoperable and that the line were severed in the cell.

The method of estimating this flow is shown below:

The pressure drop across the pressure regulator and the flow control valve is calculated using the Hamel-Dahl Company equation for these valves. The coefficient C_v is known to be 0.1. The pressure drop through the flow

Fig. 1. Schematic VPP-fluorine supply system.

element orifice was estimated using the data from Table 17 on pages 1-15 of Kent's Mechanical Engineer's Handbook, 11th Edition.

The Hamel-Dahl equation:
$$Q = (1360)(C_v) \sqrt{\frac{\Delta P \times P_a}{T_a \times G}} \quad \text{eq. 1}$$

where Q = the flow in cu ft/hr

C_v = the valve orifice factor (0.1)

P_a = total absolute pressure in psi

G = specific gravity, 1.3 for F_2

ΔP = differential pressure drop in psi

T_a = absolute temperature, $^{\circ}F$ (475 assumed)

Assuming a flow of 100 slm

Rearranging eq. 1

$$\Delta P = \frac{Q^2 \times 3.33 \times 10^{-4}}{(C_v)^2 \times P_a} \quad \text{eq. 2}$$

For the pressure regulator:

$$\Delta P = \frac{15.75}{(0.01)(75)} = \underline{\underline{21 \text{ psi}}}$$

For the flow control valve:

$$\Delta P = \frac{15.75}{(0.1)^2(75-21)} = \frac{15.75}{(0.01)(54)} = \underline{\underline{29.1 \text{ psi}}}$$

For the flow element orifice:

$$\Delta P = 10 \text{ psi (from Kent)}$$

Since the total of these individual pressure drops equals approximately 60 psi, the maximum flow rate for these conditions will obviously be less than 100 slm (or about 23 lbs/hr).

5.3 Uranium Hexafluoride

Uranium hexafluoride released to the cell ventilation gas quickly hydrolyzes to HF and UO_2F_2 . The white UO_2F_2 particles will settle out in the cell or be carried to the scrubber where a large portion will probably be washed out, the remainder will be caught on the filters. In the absence of sufficient water vapor for hydrolysis, the UF_6 could conceivably be carried to the scrubber where it would be removed by the caustic solution.

The maximum quantity of UF_6 in the cell during VPP processing will be 4.5 kg (~ 10 lbs) (ref 17). The maximum discharge rate of 1.5 kg/min was determined by assuming a hot cold trap rupture with the entire contents being released to the cell in one minute. This will generate hydrogen fluoride by hydrolysis at a maximum rate of 0.753 lbs/min (or ~ 45.3 lbs/hr). This rate being less than the maximum 60 lbs/hr release rate from a ruptured transfer line (Sect. 5.1) would be adequately removed.

6.0 INSTALLATION REQUIREMENTS

6.1 General

Hydrogen fluoride and fluorine removal from the cell ventilation gas discharged during VPP processing will require the following items.

1. Blower capacity capable of removing 3000 cfm total air from cells 1 and 2 at about 2 in. of water ΔP .
2. A horizontal caustic spray scrubber capable of reducing hydrogen fluoride concentrations from 4090 ppm to < 1 ppm and fluorine concentrations from 1520 to < 2 ppm.
3. Auxiliary heating protection against freezing, if needed.
4. Duct work and necessary hardware.
5. Adequate instrumentation to assure protection of the "absolute" filters and for control purposes.

6.2 The System

From cells 1 and 2 a separately installed duct will carry gases to the scrubber located east of Bldg. 3019 (see Sect. 6.6). Another duct will carry the gas from the scrubber to the main building duct for filtration. Damper valves will be needed at the cells, and a control valve will be needed at the entrance point to the main building duct.

The scrubber and auxiliary equipment shown in Fig. 2 is described in other parts of this section.

Fig. 2. Cells 1 and 2 ventilation air scrubber - Building 3019.

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6.3 Horizontal Spray Scrubber

The scrubber will be a box fabricated from 14 gauge 304 stainless plate, 4 ft square and about 25 ft long, with connections at each end for ductwork (Fig. 2). Six successive sections or stages will be provided, each having a bank of four hollow cone spray nozzles (Schutte-Koerting 622C) impinging on S&K No. S4935-11 throat pieces mounted on the stage dividers. The box will rest on its side with liquid and gas flows cocurrent in the horizontal direction. Following the last stage an array of staggered baffle plates backed by a 4-in. bed of 250-micron Monel fibers will provide de-entrainment. Each stage chamber and the de-entrainment section will be equipped with Lucite viewing windows.

Calculations for mass transfer requirements based on ANL data (ref 1 and 2) are given below.

VPP - Cell Ventilation System Conditions

Gas volume flow = 3000 cfm

Maximum possible fluorine release rate = 100 slm or 3.5 scfm

Maximum possible fluorine concentration = $\frac{3.5 \times 100}{3000} = \underline{\underline{0.117 \text{ vol } \%}}$

or $\times 1.3 = \underline{\underline{0.152 \text{ wt } \%}}$

Maximum possible HF release rate = 60 lbs/hr

Maximum possible HF concentration = $\frac{60 \times 100}{14,610} = 0.409 \text{ wt } \%$

Fluorine

$$N_T = 2.3 \log \frac{C_1}{C_2} \quad (\text{see ANL-5429 for derivation and assumptions})$$

where: N_T = the number of transfer units

C_1 = the inlet fluorine concentration

C_2 = the exit fluorine concentration

Then for VPP Conditions

$$N_T = 2.3 \log \frac{1520}{2} = (2.3)(2.879)$$

$$N_T = \underline{\underline{6.61}} \text{ transfer units required}$$

From ANL Experiments (ANL-5015, Table 4)

$$N_T = 2.3 \log \frac{100}{2} \quad (\text{greater than 98\% efficiency reported})$$

$$N_T = (2.3)(1.701)$$

$$N_T = 3.91 \quad (\text{using 3 stages})$$

or N_T per stage was ~ 1.3 transfer units

Then VPP scrubber would require $6.6/1.3 = 5.1$ stages. Therefore, 6 full stages would be required for the VPP unit.

This unit would obviously remove HF inlet concentrations of 4090 ppm to less than 1 ppm because of the very high mass transfer rate for HF (ref 1).

6.4 Caustic System

A 1000-gallon stainless steel caustic recycle tank of conventional cylindrical design equipped with a submerged centrifugal pump with Graphitar bushings, capable of delivering 170 gal/min at a pressure of 60 psig, will be required.

A filter to remove 0.005-in. particles from a side stream of 750 gal/hr will be required. A cake space of 1 cu ft will be sufficient. The filter must have a backwash feature to permit cake removal by a slurry method. It should be designed for 100 psig or greater. The shell and wettable parts should be stainless steel. A Sparkler Co. filter No. 18-S-11, or equal, would be satisfactory.

Valves and piping should be stainless steel with packing materials adequate for 10% KOH service at 150°F.

A 100-gal KOH supply tank will be valved to permit drainage of 45% KOH solution by gravity flow into the recycle tank as required for neutralization of a sustained hydrogen fluoride release. This adds an additional 500 lbs of KOH which will adequately satisfy the design requirements.

The recycle tank and filter unit will be provided with bottom drains piped to the radiochemical liquid waste drains.

The present 45% caustic makeup system used to supply solution for the VOG scrubber (FV-150) and the HF neutralizer (FV-1009) will also feed the supply tank.

Calculation of Potassium Hydroxide Requirements

Fluorine reacts with potassium hydroxide by the following reactions:

Net result

Hence, 2 moles KOH are required per mole F_2

For a total release of 68 lbs of F_2 ,

Moles of $F_2 \times 2 \times \text{mole wt KOH} = \text{lbs } 100\% \text{ KOH required}$

$$\frac{68}{38} \times 2 \times 56 = \underline{\underline{200 \text{ lbs/100\% KOH}}}$$

Hydrogen fluoride reacts with potassium hydroxide by the following reaction:

Moles of HF $\times$ mole wt KOH = lbs 100% KOH required

$$\frac{200}{20} \times 56 = \underline{\underline{560 \text{ lbs/100\% KOH}}}$$

Therefore, the unscheduled hydrogen fluoride release controls the size of caustic charge required.

The useful caustic solution range is from 5 to 10% by weight.
From Solvay Co., Bulletin #15

$$\text{lbs KOH/gal of } 10\% \text{ solution} = 0.92$$

$$\text{lbs KOH/gal of } 5\% \text{ solution} = \underline{\underline{0.46}}$$

$$\text{lbs KOH/gal available for neutralization} = 0.46$$

$$\text{Then for } \frac{560 \text{ lbs/100\%}}{0.46 \text{ lbs/gal}} \approx 1220 \text{ gal charge will be required}$$

The 5 to 10% KOH range was selected because in the work at ANL (ref 2) in this range neither the KOH concentration nor the fraction carbonated had an appreciable influence on K_G .

6.5 Services Required

Electric power, demineralized water, instrument air, plant water, and liquid radiochemical waste drain connections are the services required.

Electric power will be required primarily for the recycle pump motor. The smaller KOH supply system pump and lighting requirements will be small by comparison. The filtration and demineralized water systems may also require small amounts of power.

The ANL scrubber removed about 0.1 gal/min of water from the system. From this information it is reasonable to assume that a 10 gal/hr supply of demineralized water would be sufficient; however, a 500- to 700-gallon quantity will be required initially or to replace the recycle fluid charge when necessary. This supply will be made available by the Operations Division upon request.

Instrument air will be required for level and gravity instruments and air operated valves.

The liquid handling system could contain radioactivity, therefore, drains must be piped to a radiochemical waste system.

Plant water will be required for washing down equipment prior to maintenance. The plant water pressure may make it a more desirable source of supply than the demineralized water for removing discard solids from the filter.

6.6 Equipment Location

The scrubber and KOH handling equipment will be located above the east dock area roof and under the main ventilation duct east of Bldg. 3019. The recycle tank and pump should be located near the scrubber at a lower level to permit drainback from the scrubber by gravity flow, but not so low that pumping head is greatly increased. The filter should be located near and at tank level. Drip pans under equipment handling liquid caustic potash solution are necessary to protect personnel and facilities from this chemical.

6.7 Instrumentation Requirements

6.7.1 Caustic System. The recycle tank requires level and gravity instruments, with high-low alarms, and a solution draw-off line for sampling purposes.

A control device for automatically adding demineralized water is required. Similar operating conditions at ANL required 0.1 gal/min. A system delivering 1.0 gal/min would adequately supply demands created by operating fluctuations.

A pump discharge pressure gauge with high-low alarms located in the line after the throttling valve will be required.

6.7.2 Scrubber System. Pressure drop indication across the scrubber is required, 0 to 2 in. water range. The air flow discharge measured with a pitot tube will be recorded at the Bldg. 3019 ventilation control station when built, but will be temporarily located on the VPP panelboard in the interim period.

The inlet and exit gases from the scrubber unit will be monitored for fluorine and fluorides using the portable continuous fluoride analyzer developed at ORGDP (ref 18). These devices will be installed by the VPP operating group.

Instruments to determine the recycle liquid and the spray chamber temperatures will be required. The chamber temperature should be determined at points after the first stage and between the knockout baffles and the demister.

7.0 TENTATIVE OUTLINE OF PROPOSED OPERATIONS

7.1 Caustic System Charging

The recycle tank will be charged initially with 750 gallons of 10% KOH solution. This will be accomplished by pumping the calculated amount (~ 167 gal) of 45% caustic through the supply tank to a previously added demineralized water charge (~ 583 gal). When the recycle solution has been prepared, the supply tank valve will be closed and a charge of 45% caustic will be held for emergency release, should it be required.

7.2 Scrubber Startup

Adequate air flow is essential to avoid scrubber overheating caused by dissipation of pumping energy released in the spray nozzles. Before starting the liquid recycle pump, damper valves should be set for 3000 cfm air flow. The spray nozzle header bank valves should be open (or previously set).

The throttle valve in the main feed line to the nozzle banks should be fully opened before pumping. Recycle tank level observation during pump startup reveals the level drop compensating for liquid holdup in the scrubber assembly and a "normal" operating level for a given flow condition. Level will vary with viscosity, temperature, caustic concentration, main ventilation duct pressure and other system variables, but mostly with liquid flow rate through the nozzles.

When recycle tank level, scrubber temperature and flow rate remain reasonably constant for fifteen minutes, filter operation is initiated as described in Section 7.3. A total flow increase of 12.5 gal/min will supply this stream.

The automatic level control device for adding demineralized water to compensate for evaporation losses and maintain the level indicated by steady state conditions is set and actuated.

7.3 Recycle Solution Filtration

After the drain and backflush valves are closed and the upstream gate valve is opened, the downstream throttle valve is adjusted to filter about 750 gal/hr of recycle solution. Filter cake removal schedules will be developed from operational experience using ΔP data. The filter will be taken off stream and the solids flushed to a radiochemical drain after monitoring.

7.4 Scrubber Operation

Normal scrubber operation requires little attention. Infrequent action required for trouble shooting purposes is described in Section 7.5. Other minor maintenance, occasional visual inspection of nozzle performance, sampling, filter cake removal and shutdown functions should be scheduled. Recycle solution sampling (frequency indicated by VPP activities) for determination of total alkalinity and fluoride ion concentration is required for control purposes. Sampling for uranium and fission product analyses is necessary before draining a spent caustic charge to the radiochemical waste system.

When the system is shut down, the demineralized water valve should be shut off to prevent an unintentional slow discharge from causing overflow of the recycle tank.

7.5 Irregularities Arising from Scrubber Operation

Several operational irregularities become known by visual inspection or by instrument alarms for the more serious ones. Operating personnel should be trained to perform the functions listed below.

1. Recycle tank high liquid level alarm sounds. The pump should not be shut off because this allows scrubber holdup liquid to drain into the recycle tank, which may cause recycle fluid overflow. Level increase is caused by the demineralized water makeup control valve and/or the caustic supply tank valve leaking. Both should be checked immediately and the trouble corrected. The demineralized water valve can be turned off temporarily until the level is brought back to normal. Excess water can be evaporated to return the system to "normal" operating level without turning off the flow to the spray nozzles, if that choice is possible, but if necessary to discontinue scrubber operation some of the liquid may have to be drained to avoid overflowing the tank.
2. Recycle tank low liquid level alarm sounds. The system should be checked for leaks, open or leaking drain valves, and demineralized water flow cutoff; then the indicated trouble should be corrected.

3. Temperature changes in scrubber and recycle solution. Slight changes of a gradual nature could be caused by changing ambient temperature conditions, process heating changes, varying air flow conditions, and perhaps drastic changes in humidity. These are not serious and no corrective action should be required. Rapid increases in temperature could result from chemical reactions or stoppage of the air flow through the scrubber. Check these things immediately. The first condition would indicate a serious process release, which should be discontinued as soon as possible. The second condition should be corrected by either starting the air flow again or shutting down the liquid flow to the scrubber.

4. Pressure changes in the nozzle feed solution on the discharge side of the pump. Loss of gauge pressure indicates electric power outage to the pump motor or pump maloperation. Slight pressure changes from the established normal for a given set of operating conditions indicates viscosity changes of the solution resulting from temperature and/or concentration changes (gain or loss of water by malfunctioning of the water makeup system). Increase in pressure indicates nozzles plugging with solids. Check indicated items and take necessary corrective action. Unplug nozzles when possible. At high liquid flow rates (6 gal/min/nozzle) several nozzles could be inoperable with no serious loss of fluoride removal efficiency.

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