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A FOAM PROCESS FOR APPLICATION OF DECONTAMINATION AGENTS

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ABSTRACT

This paper presents the results and observations of a study performed by the authors to parametrically evaluate the performance characteristics of a foam process for application of decontamination agents. The initial tests were established to assess foam quality. Subsequent tests determined the ability of the foam as a carrier of chemical systems, and established system operating parameters. The technique was then applied in an actual decontamination task to verify effectiveness of these established parameters and to determine decontamination reduction factors.

I. INTRODUCTION

Radioactive decontamination is the removal of radioactive material by chemical or physical methods, with the primary objective being the reduction in radiation exposure to the work force and ultimately to the general public. Decontamination can be accomplished by different means depending on how tightly the contaminate adheres to the surface and the ultimate level of decontamination desired. For loosely bonded material, vacuum cleaning may be adequate to remove it from the surface and shallow crevices For tightly bonded material or material trapped in deep, convoluted crevices, removal of a portion of the surface by chemical or physical methods may be necessary. In many cases, decontamination can be accomplished by an intermediate treatment such as water rinsing or scrubbing with soap and water; however, these simple techniques can be complicated by virtue of personnel access due to radiation fields and by control or containment of the process.

The Energy Systems Group (ESG) of Rockwell International has developed a foam process for application of decontamination agents using commercially available equipment and chemicals. Foam is produced by aspirating a foaming agent into a stream of water, mixing this with air and spraying it onto the surface to be cleaned. Decontamination agents such as, detergents and other chemicals can be added to the water to increase its cleaning power. A wet and dry vacuum cleaning system was also developed by ESG to compliment the foam cleaning process. This paper presents details of the foam process development, its apparent effectiveness and uses.

II. PROCESS DESCRIPTION

Foam cleaning consists of suspending decontamination agents in a thick, dry foam that is applied onto surfaces to be cleaned. The foam holds the decontamination agents at the surface permitting them to act on the contaminate, lifting it into the foam. The foam, with the suspended contaminate, can then be directly removed from the surface by vacuum techniques or by rinsing into other containment. Repeated application of this technique has demonstrated several orders of magnitude reduction in surface contamination. A process flow diagram is shown in Figure 1.

The foaming equipment shown in Figure 2 and diagramed in Figure 3, consists of a 208 liter (55-gal) drum to hold water with chemical additives, a water pump, a bottle for the foaming agent, a Dema Spray Foam unit, connecting hoses, pressure regulators and valves. This system requires regulated air pressure for the water pump and for aspirating the foam.

III. PROCESS EVALUATION

Studies were performed to parametrically evaluate the performance characteristics of the foam spraying equipment. Several chemical systems were tested and characterized. The initial tests were performed with no radioactivity present and no decontamination factors were measured. The objective of these tests was to determine foam quality at various operating conditions and to determine optimum equipment operating parameters. From these tests it was determined that a foam quality could be obtained that will form a light, even coating (2.5 cm-5 cm thick) with the consistency and wetness of shaving cream and that has a resident time on a vertical surface of several minutes or more.

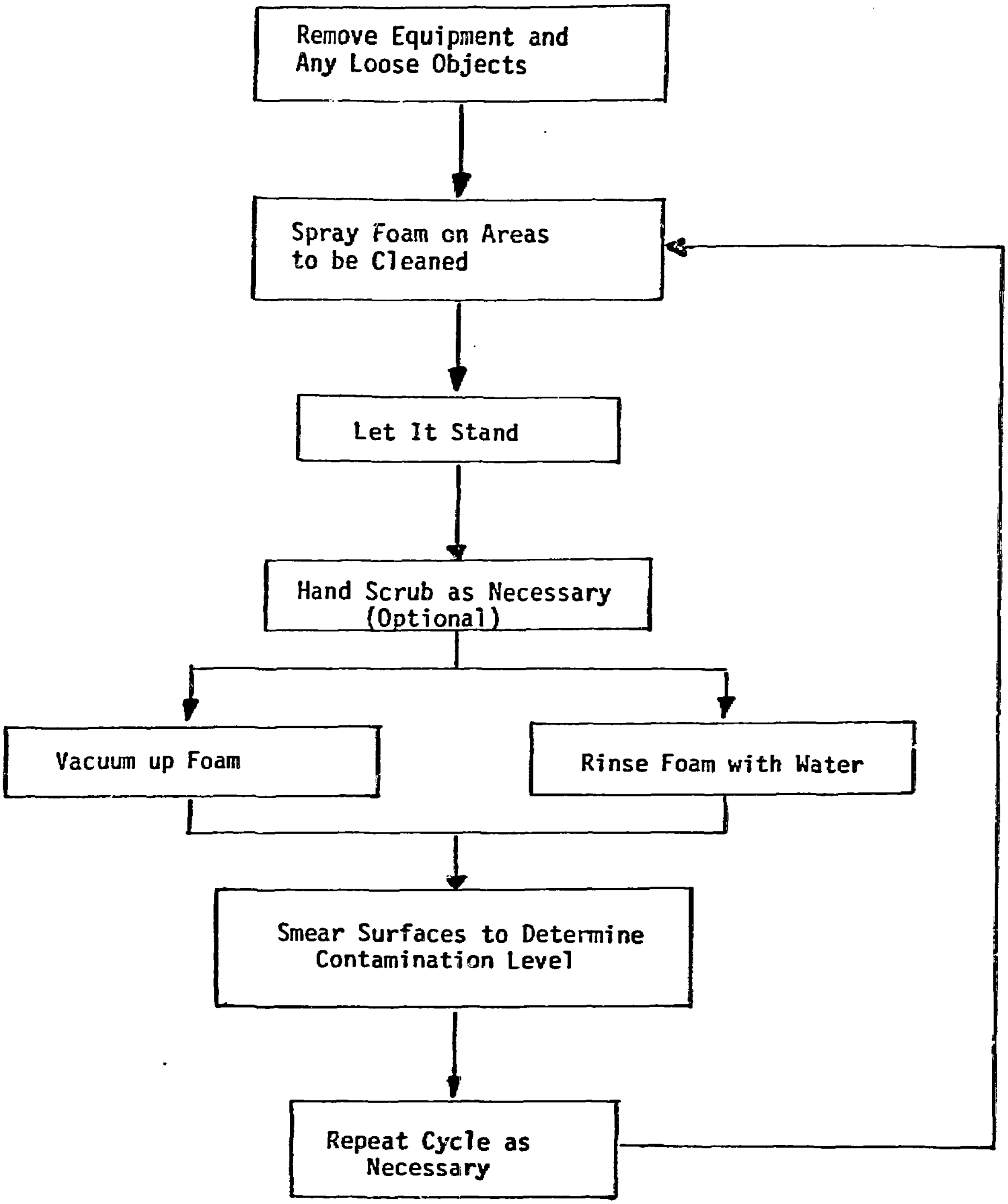
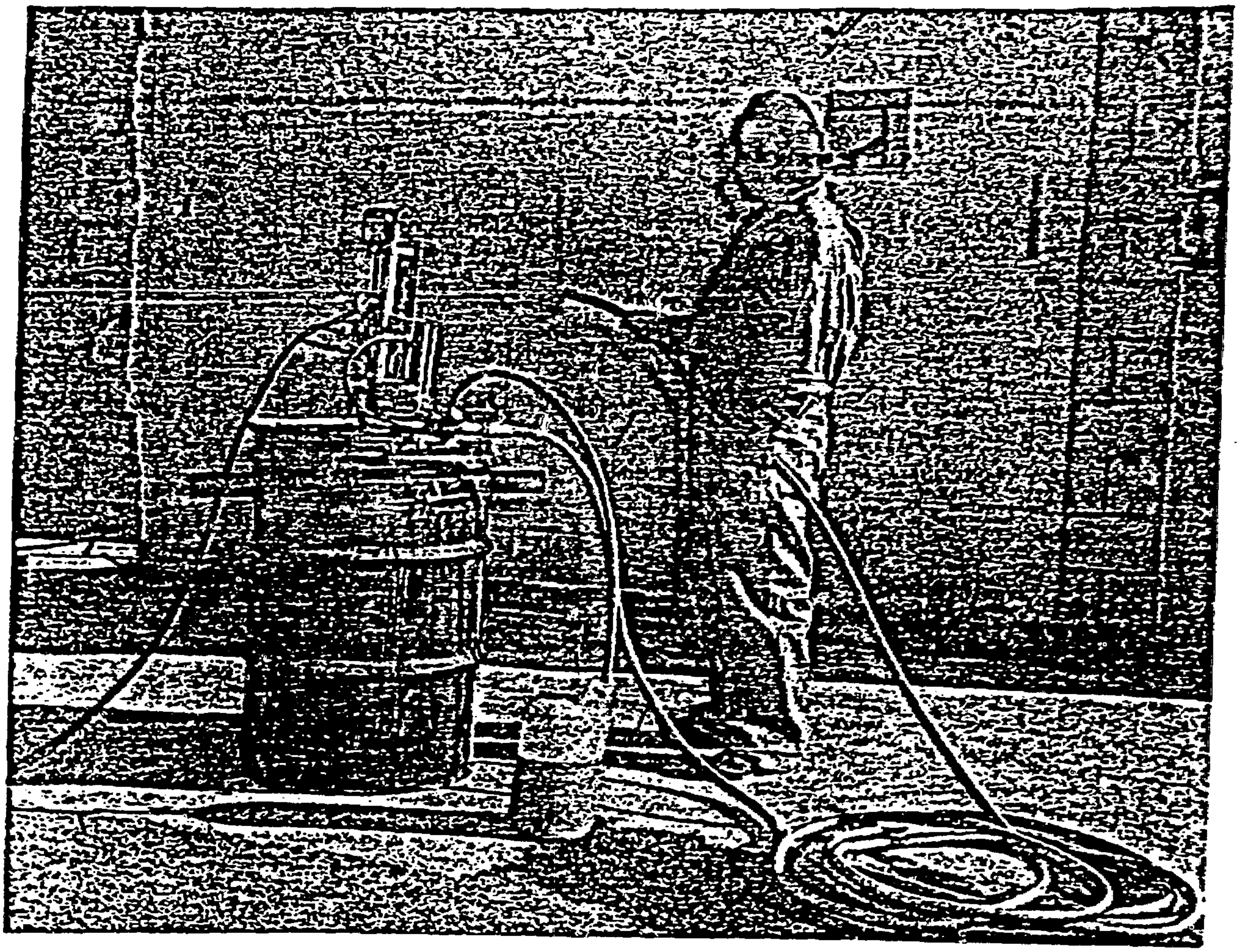


Figure 1

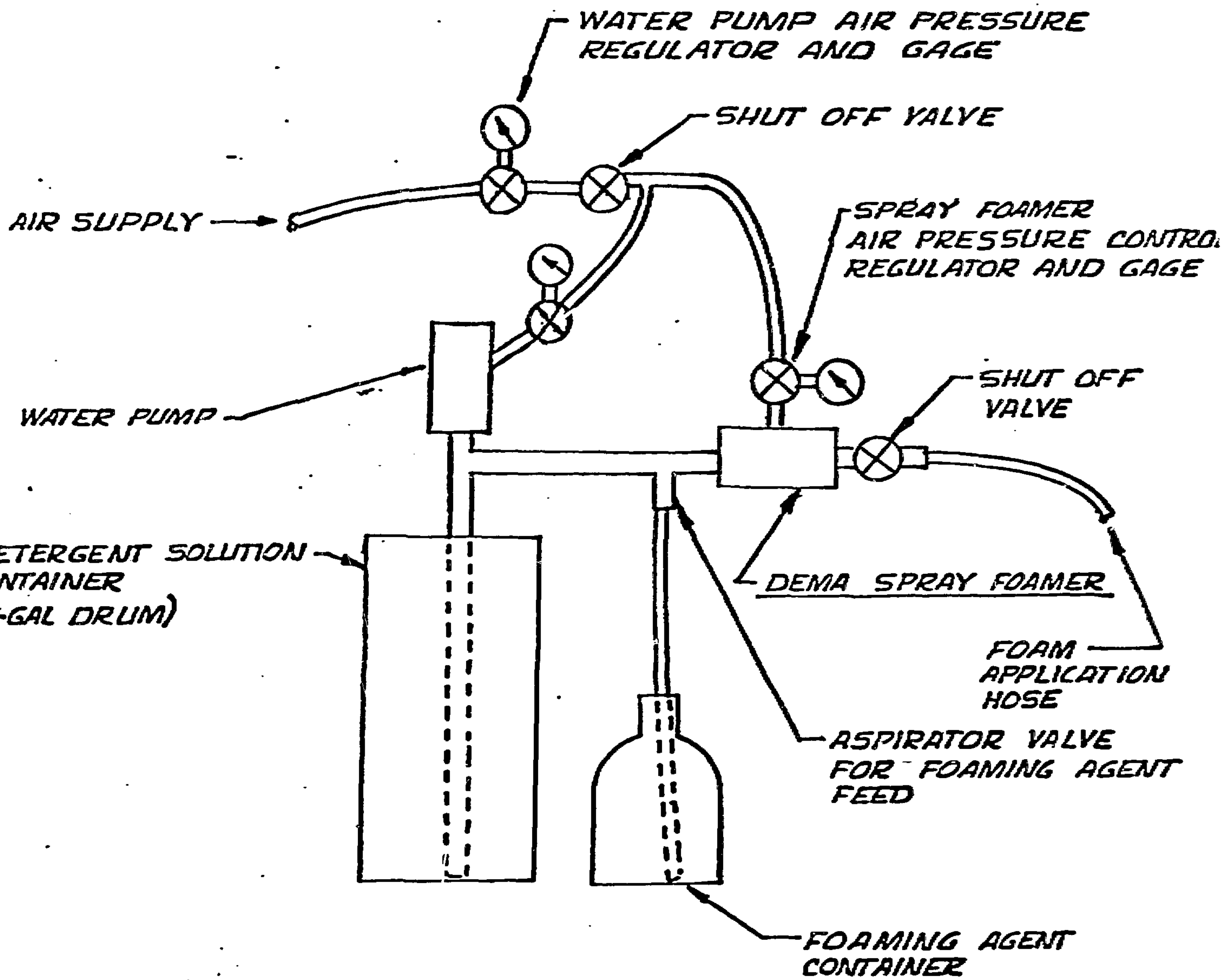
FOAMING PROCESS FLOW DIAGRAM

FIGURE 2



THE FOAM SPRAYING EQUIPMENT

FIGURE 3



FOAM SPRAYING EQUIPMENT

After the optimum parameters for operation of the foaming equipment were determined and tested with decontamination agents, effectiveness of the system was evaluated in actual decontamination operations at the Rockwell International Hot Laboratory (RIHL) and during obsolete nuclear facility decommissioning. Decontamination effectiveness on painted surfaces inside a hot cell at the RIHL was determined to be 63 to 92%. The foam process effectiveness on unpainted carbon steel surfaces was determined to be 75 to 90%.

A. Foam Quality Evaluations

The foam quality evaluations were performed using the equipment listed in Table I and the chemicals listed in Table II. The equipment and chemicals used in the development of this process were predominately Turco Products. Other chemicals have been successfully employed in the practical application of this process.

The first foam consistency tests were conducted with water and Turco foaming agent 5865. (Turco 5865 was used as the foaming agent in all the tests reported here.) The air pressures to the water pump and spray foamer were varied over the ranges 14-70 Kg/cm^2 to 7-65 Kg/cm^2 respectively. The open end of a 7.6 m hose was held horizontally about 1.4 m above an asphalt surface, and the foam was ejected from it. The foam quality and ejection distances obtained are shown in Table III. The conditions giving the best quality foams were repeated using a .5 m hose; the results are shown in Table IV. The best quality foam obtained as judged by the operator was with 56 Kg/cm^2 water pump air pressure and 42 Kg/cm^2 spray foamer air pressure. The aspirator needle valve was closed and then reopened to several different settings. The foam quality was evaluated and the foaming agent consumption measured. The results are shown on Table V.

Several detergents, at different concentration levels were added to the water in the 200 liter drum. Foam quality tests were then made at three different aspirator needle valve positions. In two cases, the solution was heated to 60°C. The results shown in Table VI, indicated that Turco Product 4512-A and Alkaline Rust Remover can produce an acceptable foam at room temperature, 56 Kg/cm^2 pump and 42 Kg/cm^2 spray foamer air pressures, with the needle valve open 1-1/2 to 4 turns. At 60°C only Turco Product 4512A was tested and 50-100 cc/l water produced acceptable foams.

A mixture containing 50 cc of Alkaline Rust Remover in one liter of water was heated to 60°C. It was aspirated with Turco Product 5865 and sprayed on a 3 m x 3 m vertical painted block wall that had been warmed by the sun. The needle valve was opened 2-1/2 turns and 56 Kg/cm^2 water pump and 42 Kg/cm^2 spray foamer air pressures were used. The 3 m x 3 m wall was covered with foam in less than two minutes and 7.7 liters of the liquid were consumed. The foam adhered to the wall satisfactorily and softened the pain. Much of the paint was removed when the wall was rinsed with a water spray from a garden hose.

Sixteen cc of Foam-Go No. 2 per liter were added to the water in the vacuum cleaner. The ability of the vacuum cleaner to pick up and liquify the foam was then evaluated. The 200 liter vacuum cleaner drum held the foam produced from 5.7 liters of liquid and its 120 liter catch drum held foam from 11 liters of liquid.

TABLE I

FOAM PROCESS EQUIPMENT

1. Turco Barrel Pump, Model 432 BSST (4 1/2:1 ratio)
2. Turco Barrel Pump, Model 452 BSST (10:1 ratio)
3. Goodall coupled hose (15 m with swivel one end)
4. Turco stainless steel spray pole, Model 671-WS w/tips
5. Dema Spray foam air foamer, Model 293
6. Absolute filter vacuum cleaner
7. Absolute filter vacuum cleaner catch drum
8. Glas-Col Apparatus Co. Barrel heater, Model DH-112-C, 6000 Watts

TABLE II

FOAM PROCESS CHEMICALS

1. Turco Foaming agent, 5865: A foaming agent consisting of sulfonated detergents blended with synthetic wetting agents and containing coupling agents.
2. Turco product, Decon 4324: Mildly alkaline detergent cleaning powder.
3. Turco product, Decon 4512-A: Inhibited liquid phosphoric acid.
4. Turco product Alkaline Rust Remover: A mixture of sodium hydroxide, chelating agents (gluconates) with wetting agents and inhibitors.
5. Turco product Foam-Go No. 2: A silicon anti-foaming agent emulsified in water.
6. Turco product Decon 4521: Inhibited acidic powder containing oxalate, citrate and ammonium ions, as well as inhibitors, surfactant and a foam suppressant.

TABLE III

SPRAY FOAMER AIR PRESSURE (Kg/cm^2)	Water Pump Air Pressure Kg/cm^2: 14	28	42	56	70
10	Soapy Water (No Foam) Drizzled out of hose	Soapy Water (No Foam) Drizzled out of hose	Soapy Water (No Foam) Drizzled out of hose	Soapy Water (No Foam) Drizzled out of hose	Soapy Water (No Foam) Drizzled out of hose
10.5	Soapy Water (No Foam) .6 m Travel	Soapy Water (No Foam) 1.2 m Travel	Soapy Water (No Foam) 1.2 m Travel	Soapy Water (No Foam) 1.2 m Travel	Soapy Water (No Foam) 1.2 m Travel
14	Very Wet Running Foam 1.8 m Travel	Soapy Water + Some Foam 1.8 m Travel	Soapy Water + Some Foam 1.8 m Travel	Soapy Water (No Foam) 1.8 m Travel	Soapy Water (No foam) 1.8 m Travel
17.5	Very Wet Running Foam 2.7 m Travel	Soapy Water + Some Foam 3 m Travel	Soapy Water + Some Foam 3 m Travel	Soapy Water + Some Foam 3 m Travel	Soapy Water - Some Foam 3 m Travel
21	Foam (No Run) 4.6 m Travel	Very Wet Foam (Slight Run) 3.6 m Travel	Very Wet Foam (Slight run) 3.6 m Travel	Runny Foam 3.6 m Travel	Runny Foam 3.6 m Travel
24.5	Dry Foam (No Run) 4.6 m Travel	Wet Foam (No Run) 5.5 m Travel	Wet Foam (No Run) 5.5 m Travel	Very Wet Foam (Runs) 4.6 m Travel	Very Wet Foam (Runs) 4.6 m Travel
28	Extra Dry (Foam) 4.6 m Travel	Foam (No Run) 5.5 m Travel	Foam (No Run) 5.5 m Travel	Wet Foam (No Run) 4.6 m Travel	Wet Foam (No Run) 4.6 m Travel
31.5	Very Dry Foam (Exits hose erratically) 4.6 m Travel	Dry Foam 5.5 m Travel	Dry Foam 4.6 m Travel	Foam 5.5 m Travel	Foam 5.5 m Travel
35		Dry Foam 5.5 m Travel	Dry Foam 4.6 m Travel	Dry Foam 6.1 m Travel	Dry Foam 6.1 m Travel
38.5		Dry Foam 6.1 m Travel	Dry Foam 6.1 m Travel	Extra Dry Foam 6.7 m Travel	Extra Dry Foam 6.7 m Travel
42		Dry Foam 6.4 m Travel	Extra Dry Foam 6.7 m Travel	Very Dry Foam 7.3 m Travel	Very Dry Foam 7.3 m Travel

FOAM QUALITY EVALUATION WITH 7.6 METER HOSE

TABLE IV

Spray Foamer Air Pressure (Kg/cm^2) \ Water Pump Air Pressure Kg/cm^2	28	42	56	70
38.5	Extra Dry Foam 5.5 m Travel	Extra Dry Foam 4.6 m Travel	Extra Dry Foam 6.1 m Travel	Extra Dry Foam 6.1 m Travel
42	Very Dry Foam 5.5 m Travel	Very Dry Foam 6.1 m Travel	Very Dry Foam 6.1 m Travel	Very Dry Foam 6.1 m Travel
65		Very Dry Foam (Exits hose erratically) 6.1 m Travel	Very Dry Foam (Exits hose erratically) 6.1 m Travel	Very Dry Foam (Exits hose erratically) 6.1 m Travel

FOAM QUALITY EVALUATION WITH 15 METER HOSE

TABLE V

Aspirator Needle Valve Position \ Water Pump Air Pressure Kg/cm^2	28	42	56	Spray Foamer Air Pressure (psi)
Open 1 Turn			Dry Foam 7.6 m Travel Consumption: 62.5 cc/l H_2O	60
Open 2 Turns	Semi Dry Foam Consumption: 125 cc/l H_2O	Semi Dry Foam 156 cc/l H_2O	Semi Dry Foam 125 cc/l H_2O	40
Open 2 Turns	Extra Dry Foam Consumption: 94 cc/l H_2O	Extra Dry Foam 117 cc/l H_2O	Extra Dry Foam 141 cc/l H_2O	55
Open 4 Turns			Extra Dry Foam 4.9 m Travel Consumption: 164 cc/l H_2O	60

FOAM QUALITY EVALUATION AND FOAMING AGENT CONSUMPTION

TABLE VI

EVALUATION OF DETERGENT ADDITIVES*

Detergent	cc/l H_2O	Temp.	Aspirator Needle Valve Position (Turns)	Foam Quality	Travel Meters
Turco Product 4324	31	Ambient	1	Erratic Wet Slush	3.7
			2½	Erratic Very Wet Slush	4.6
			4	Erratic Wet Foam	5.5
	62	Ambient	1	Erratic Soapy Water	4.6
			2½	Erratic Mush Foam	4.6
			4	Erratic Runny Foam	5.2
Turco Product 4512-A	100	Ambient	1	Dry Foam	6.1
			2½	Extra Dry Foam	6.1
			4	Extra Dry Foam	6.1
	47	60°C	1	Semi-dry Foam	6.4
			2½	Dry Foam	5.5
			4	Extra Dry Foam	5.5
	100	60°C	1	Semi-dry Foam	5.5
			2½	Dry Foam	4.9
			4	Extra Dry Foam	
Turco Product Alkaline Rust Remover	47	Ambient	1	Semi-dry Foam	6.7
			2½	Dry Foam	6.1
			4	Extra Dry Foam	5.5
	94	Ambient	1	Watery Slush	1.5
			2½	Very Wet Runny Foam	2.4
			4	Erratic Dry Foam	4.6

* All tests were conducted with 56 Kg/cm^2 water pump air pressure, 42 Kg/cm^2 spray foamer air pressure and with Turco foaming agent 5865 in the foaming agent container.

B. Decontamination of Cell 3 at Rockwell International Hot Laboratory

After the optimum parameters for operation of the foaming process equipment were determined, the painted surfaces in Cell 3 at the RIHL was cleaned to evaluate the effectiveness of the system in an actual decontamination operation.

Initially, all removable equipment, false flooring and support stands were taken out of the cell and all loose material was picked up. Then a baseline survey of the radioactivity in cell was performed. The results of this and subsequent surveys are shown in Table VII.

The foam process equipment was set up in the RIHL operating gallery and the foam delivery hose was inserted into Cell 3 through a standard equipment feed-thru in the front face of the cell. The hose operator, an assistant, and a backup man were fully suited and equipped with supplied air. A support man stood by on the clean side of the service gallery change line and the equipment operator was in the operating gallery (see Figure 4).

The first decontamination experiment cleaned the south and rear wall of Cell 3. Fifty cubic centimeters of Alkaline Rust Remover were added per liter of water. Turco foaming agent 5865 was used in the foaming agent container. The water pump air pressure was 56 Kg/cm^2, the spray foamer air pressure was 42 Kg/cm^2 and the aspirator needle was opened 2½ turns. Seventy-six liters of solution were consumed in this first foam process experiment.

The foam was rinsed off within 15 minutes using a high pressure water pump with an 0.1 millimeter hole in the tip of the wand. About 200 liters of hot water were used to rinse the foam from the cell.

The cell was smeared to determine progress. The results shown in Table VII indicate a 92% reduction in the average contamination level of the south wall and 63% on the rear.

For the second foam decontamination experiment, the north wall and the floor were cleaned. One hundred cc of Turco Product Decon 4512-A were added per liter of water. The foam and rinse parameters were the same as for the first foam decon operation.

After rinsing, the cell was again smeared to determine progress. The results indicated a contamination reduction of 85% for the north wall and 75% for the floor.

C. Decontamination of Unpainted Carbon Steel

An unpainted carbon steel service vault contaminated with mixed fission products was used in another experiment to determine the effectiveness of the foam decontamination process.

The results of this experiment is given in Table VIII. Surface #1 was decontaminated first using Turco 4521 in water (62 cc/l) heated to 52°C. The foam was removed using the absolute filtered vacuum system. Smear results indicated a contamination reduction of 49%. A second application to surface #1 was made using Turco 4512-A in water (62 cc/l) heated to 52°C. A water rinse

TABLE VII

DECONTAMINATION OF PAINTED SURFACES

Location	Average Count Rate of Smears from Each Location (d/m/20 cm^2)		
	Initial	Experiment #1	Experiment #2
North Wall	170,300	---	27,700
South Wall	474,400	36,700	---
Rear Wall	278,100	103,600	---
Floor	1,197,000	---	300,500

<u>Contamination Reduction Factors (Rf)</u>

	Experiment #1	Experiment #2
North Wall	---	Rf 6.2 (84%)
South Wall	Rf 12.9 (92%)	---
Rear Wall	Rf 2.7 (63%)	---
Floor	---	Rf 4.0 (75%)

TABLE VIII

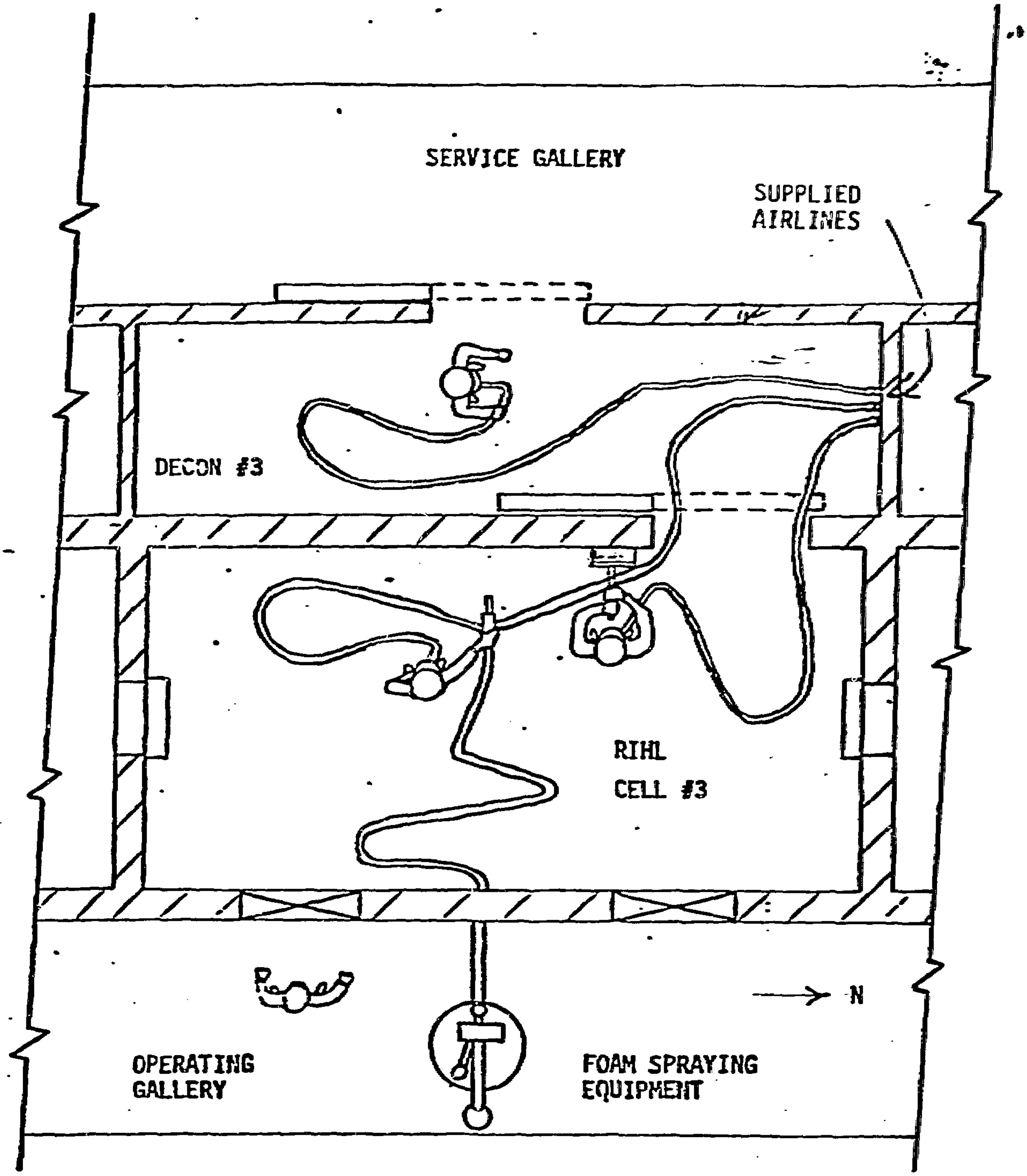
DECONTAMINATION OF UNPAINTED CARBON STEEL

Results in dpm/100 cm^2

	Baseline	Decon 1	Decon 2
Surface #1	11,697	5997	2905
Surface #2	20,454	5995	2255

Contamination Reduction Factors (Rf)			Total
Surface #1	Rf 2.0 (49%)	Rf 2.1 (52%)	Rf 4.0 (75%)
Surface #2	Rf 3.4 (71%)	Rf 2.7 (62%)	Rf 9.1 (89%)

FIGURE 4



DEPLOYMENT OF WORK CREW DURING DECONTAMINATION EXPERIMENTS was used to remove the foam from the wall surface. Smear results indicated a contamination reduction of 52% from the previous result for an overall reduction of ~75%.

Surface #2 was decontaminated using Turco 4324 in water (62 cc/l) heated to 52°C. Two applications reduced the contamination level to 71% and 62% respectively for a total of 89%. In both experiments the foam was removed by vacuum.

IV. CONCLUSIONS AND RECOMMENDATIONS

The foaming equipment and chemicals evaluated in this study are very effective in decontaminating non-porous surfaces. The operating parameters have been optimized and chemical systems that are effective have been identified.

To improve the effectiveness of the foam decontamination operations, the following should be adopted:

1. A compressor with a capacity of at least 70 Kg/cm^2 maximum pressure is recommended for sustained foaming application.

2. The anti-foaming agent should be added to the rinse water in addition to the transfer tank.

3. The foam should be vacuumed with a wet/dry vacuum cleaner before the surfaces are rinsed. This will greatly reduce the volume of liquid waste produced.

The primary advantages of foam cleaning are that it can lift contamination from the surfaces and deep crevices, it produces less liquid waste than ordinary water rinsing, it can be applied remotely and from distances of up to 6 meters from the surface to be cleaned, it does not usually damage the surface, and it is not hazardous or dangerous to use.

This process has been routinely used effectively by ESG in the decontamination of hot cells, glove boxes and obsolete nuclear facilities being decommissioned. The process is most effective when the foam is applied hot and in the decontamination of non-porous surfaces.

Potential difficulties with the process are maintaining an adequate residence time on vertical surfaces and free liquid penetration on horizontal surfaces. The chief advantages of the process are the low amounts of resulting liquid waste, ease of application, and its adaptability to a variety of chemical additives.