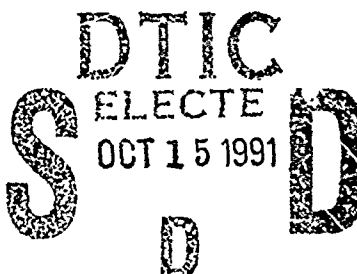


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US Army Corps of Engineers

Toxic and Hazardous
Materials Agency



Report No. CETHA-TS-CR-91033
FINAL REPORT

Evaluation of a Particulate Filtration System for an Alkaline Paint Stripper at Letterkenny Army Depot

August 1991
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During metal pretreatment operations, U.S. Army depots use a variety of chemicals that become hazardous waste when no longer useful. Alkaline paint strippers are widely used to remove paint coatings from steel parts. At Letterkenny Army Depot (LEAD) in Chambersburg, Pennsylvania, these solutions are typically disposed of every six months, generating up to 2,200 gallons of liquid waste and three 55-gallon drums of sludge. By removing this sludge continuously, it is thought that the ongoing reaction between the sludge and active paint stripper can be prevented, thereby resulting in less depletion of the active bath ingredients and an ultimate reduction in hazardous waste. As part of its pollution abatement and environmental control mission, the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) is pursuing R&D projects to assist depots in meeting the Army goal of a 50 percent reduction in hazardous waste by the end of 1992 compared with 1985 baseline levels. In one project, USATHAMA selected, installed, and					
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operated a particulate filtration system on an alkaline paint-stripping solution at LEAD. The paint-stripping tank chosen normally contains 2,500 gallons of solution, is operated at 190°-210°F, and has a pH of around 13 S.U. The solution is mostly sodium hydroxide (17.5 weight percent) and sodium gluconate (5.3 weight percent). The filtration system consisted of three bag filters in series, a 50-gpm progressing cavity pump, a control panel, automatic shutoff controls for low and high pressure, a high-pressure relief system, pressure gauges, sample valves, drain valves, and shutoff valves.

A test program was implemented to determine the effect of the filtration system on particulate removal, the rate of chemical depletion, and ultimately the reduction in hazardous waste generation. Unfortunately, during the five months that the system was in place at LEAD, a variety of mechanical problems occurred that prohibited collection of the desired data. These problems included a faulty pump weld, incompatible filter bag material, leaking flange gaskets, and failure of pressure gauges and valves due to overpressurization. These problems were addressed during the test program so that an operational system remained at the depot at the end of the project.

Despite these problems, some operational experience and data were collected. Four rounds of samples were analyzed for solids content and particle-size distribution. Two operating modes for the equipment were developed. continuous removal of suspended solids and periodic removal of settled sludge. Both monofilament and mesh filter bags were tested, and it was determined that the monofilament bags could collect a greater quantity of sludge material per weight of filter bag material, and that they could be reused, whereas the mesh bags had to be disposed of after each use.

Based on observations during the test program, the filter system should increase agitation and circulation in the paint-stripping tank (which will aid dissolution of the solid chemical used to make up a fresh solution), reduce the amount of suspended solids and sludge formation on the tank bottom, reduce sodium hydroxide usage (but not sodium gluconate usage), decrease drag-out of solids and liquid to the rinse water, increase the bath life, decrease hazardous waste, and reduce the labor required to manually remove the sludge periodically.

Recommendations presented in this report include a continuation of the test program to collect quantitative data. Other recommendations are presented regarding operation of the alkaline paint-stripping bath and the current particulate filtration system. The report also includes an engineering evaluation of the system and design and operational recommendations for future filtration systems.

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SECTION 1

INTRODUCTION

This report summarizes the results of a hazardous waste minimization test program aimed at reducing the generation of hazardous waste from alkaline paint-stripping operations. This program was conducted at Letterkenny Army Depot (LEAD) on the alkaline paint-stripping operation in Building 350. The work was sponsored by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA).

1.1 BACKGROUND

The mission of LEAD is to receive, store, maintain, and issue general supplies and ammunition in support of Department of Defense (DOD) activities. This includes the overhauling, rebuilding, and testing of wheeled and tracked combat vehicles, missile systems, fire-control systems, and associated secondary items. As part of the refurbishing process of various components and equipment, LEAD uses numerous chemical-stripping operations. In one operation, disassembled metal parts coated with metal-based paints are stripped by use of a strong alkaline paint-stripping solution. Paint removed from the metal parts remains in the bath as a sludge. Until recently, this paint sludge was removed only when the alkaline paint-stripping solution was replaced (usually after 6 months).

The accumulation of paint sludge in the alkaline paint-stripper bath is an important factor in limiting the life of the solution. The removed paint continues to react with the alkaline components in the solution and reduces the solution's cleaning and stripping capacity. Stripper solution exhaustion is evident to LEAD tank operators when rapid depletion of the stripping chemicals begins to occur and increased drag-out of solids (accumulated sludge) from the bath creates an operational problem. Drag-out of solids contributes to stripper depletion because liquid containing active ingredients will be absorbed in the solids and carried out of the bath. The drag-out of solids also contributes to contamination of the rinse water following the stripping bath. Removal

of the solids in the bath will reduce solution depletion due to solids drag-out. Solids removal may also reduce chemical usage due to elimination of the reactions with paint previously stripped from the parts.

For this project, a pressure filtration system was purchased for the continuous removal of paint sludge from the bath. Testing was conducted to evaluate the effectiveness of the pressure filtration system in removing solid material from the alkaline paint-stripper bath and to quantify the effects on the alkaline paint-stripping operations. As part of the technology review, laboratory testing was also conducted to evaluate further the potential of a centrifuge to remove particulates from the alkaline paint-stripper bath.

1.2 OBJECTIVE

The objective of this project was to reduce the overall generation of hazardous waste from alkaline paint-stripping operations by extending the life of the alkaline paint stripper solution.

1.3 TECHNICAL APPROACH

The technical approach to this project consisted of performing the following tasks:

- Characterization of the waste generated by the alkaline paint-stripping operations
- Characterization of the chemistry of the alkaline paint-stripper bath
- Survey of technologies capable of removing solids from the bath
- Selection of the most effective and economical technology to reduce stripper solution depletion
- Design, installation, and startup of the selected system
- Performance testing on the system

- Summarization of results in a final report.

A preliminary plan was developed to sample the alkaline paint-stripper bath and to characterize the solid materials generated from the alkaline paint-stripping operation (Draft Assessment Plan, Section 4.0) (ESE, 1990a). The results of the initial sampling analyses are presented in the Preliminary Waste Characterization of the Alkaline Paint Stripper Bath at Letterkenny Army Depot (Waste Characterization Report) (ESE, 1990b). The Draft Assessment Plan also outlined applicable technologies for separating solid material from the alkaline paint-stripping solution (ESE, 1990a).

The characteristics of bath chemistry were determined from information found in literature and reports compiled during the preliminary work conducted to identify the composition of the alkaline paint-stripping solution.

The information gathered and presented in the two reports identified in the preceding paragraphs was the basis for selecting a particular technology to reduce the generation of hazardous waste by prolonging the life of the alkaline paint-stripping solution. This system was designed, installed, and started operation under the direction of Environmental Science and Engineering, Inc. (ESE). The details of these tasks are presented in this report.

Upon completion of startup, performance testing was conducted. The results of the performance testing are presented in this report.

SECTION 2

ALKALINE PAINT-STRIPPING PROCESS

2.1 PROCESS DESCRIPTION

The alkaline paint stripper tank selected for filtration has a capacity of 3300 gallons of alkaline paint-stripping solution; however, the tank is normally operated with approximately 2500 gallons. The tank dimensions are 18 feet long, 4 feet wide, and 6 feet deep (Figure 1). The tank is open at the top. The level of the alkaline paint-stripping solution is normally maintained at approximately 14 inches below the top of the tank. A ventilation system around the top rear edge of the tank is used to remove any steam, fumes, or vapors generated during the paint-stripping operations.

The alkaline paint-stripping solution is made of water, sodium hydroxide, sodium gluconate, and trace compounds (Table 1). It contains 3 pounds of MIL-C-46516A (MR) (solid alkaline paint stripper) per gallon of water (U.S. Army, 1972). The viscosity of the solution is approximately 35 centipoise. Sodium hydroxide provides alkalinity and detergent action. The sodium gluconate serves to derust parts by sequestering iron (III); the oxide of iron (III) is Fe_2O_3 , or rust. Additional information on bath chemistry is presented later in Subsection 6.2. The alkaline paint stripper is analyzed by LEAD to maintain the sodium hydroxide and sodium gluconate concentrations. Although sodium hydroxide and/or sodium gluconate are added to maintain solution strength, these additions do not include the trace compounds contained in the solid alkaline paint stripper.

2.2 PROCESS OPERATION

Steel parts coated with metal-based paints and natural resin binders are stripped in the bath selected for filtration. The alkaline paint-stripping solution is not effective for removing paints with synthetic resins such as urethanes and epoxides.

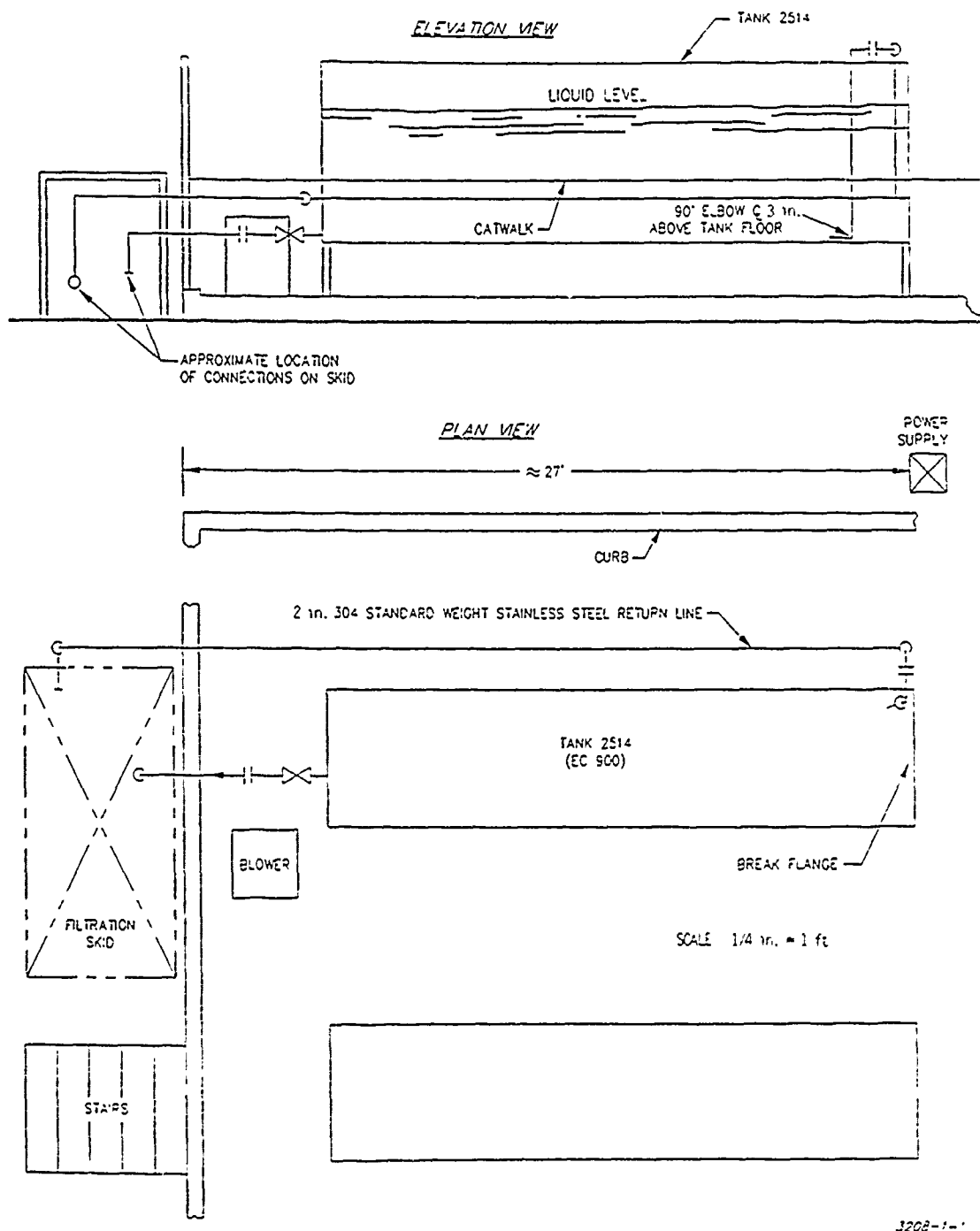


Figure 1. Schematic of Alkaline Paint-Stripping Tank.

TABLE 1. COMPOUND/ADDITIVE COMPOSITION OF CORROSION-REMOVING SOLID ALKALINE PAINT STRIPPER^a

Ingredient	Solid alkaline paint stripper composition (dry weight percent)	Concentration in fresh solution (weight percent) ^b	Rejuvenating additive (weight percent) ^c
Sodium hydroxide	66.0	17.5	-
Mineral seal oil	1.00	0.26	1.00
Fluorochemical surfactant	0.02	0.005	0.02
Sodium carbonate	1.62	0.43	5.00
Sulfonated oleic acid, sodium salt	1.25	0.33	-
Sodium gluconate	20.0	5.3	27.0
Sodium sulfate	-	-	14.78
Salt of triacetic acid ^d	6.50	1.72	7.00
Sodium alkyl sulfonate	1.00	0.26	1.00
Sodium metasilicate	0.10	0.026	0.20
Zinc silicofluoride	1.50	0.40	2.00
Methyl naphthalene sulfonate	1.00	0.26	-
Total phosphate	-	-	42.0
Ferric chloride	0.01	0.003	-

^a U.S. Army, 1972.

^b Calculated by the equation: Wt. % in solution = (3 lb/gal x dry wt %) ÷ (3 lb/gal + 8.34 lb/gal).

^c The specified rejuvenating additive is currently not added to the solution at LEAD.

^d Sodium salt of N-hydroxyethylethylenediamine triacetic acid, dihydrate.

The synthetic-resin-based paints are therefore stripped with alternate methods such as immersion in a mixture of dichloromethane (methylene chloride) and formic acid or abrasive blasting. Aluminum parts are not stripped in alkaline solutions because these solutions chemically attack such parts. The alkaline paint-stripping solution is maintained at a temperature between 190 and 210°F via steam panels that line an inside wall of the tank. A temperature controller regulates the flow of steam to maintain the operating temperature in the bath. The tank solution is agitated and mixed by air sparging through tubing positioned along the bottom of the tank.

Painted metal parts to be stripped are immersed in the bath by use of an overhead crane. Military specifications specify an immersion time of 20 to 60 minutes to remove paint and rust. Parts at LEAD may remain in the bath for a maximum of 24 hours; the actual time required for removal of the paint and rust is not available. As the alkaline paint-stripping solution breaks down the paint binder, pieces of the coating are removed from the surface of the part and either settle to the bottom as a sludge or remain suspended in solution. This sludge continues to react with the paint stripper in a saponification reaction, as shown in the following equation:



As this equation indicates, continued contact between the paint sludge and the paint stripper results in the consumption of sodium hydroxide, which ultimately reduces the cleaning and stripping capacity of the solution. In addition, buildup of sludge on the bottom of the tank creates operational problems in fitting large parts in the bath that require the entire tank depth. When the required chemical makeup and the operational problems become excessive, the bath is disposed of as hazardous waste. At this time, the sludge often must be chipped off the sides and bottom of the tank, which is a labor-intensive process. Each time the tank is emptied (about twice a

year) approximately 2,200 gallons of alkaline solution and three 55-gallon drums of sludge are disposed of.

A hot-water rinse tank is used after the stripping bath to remove the alkaline paint stripper and solids dragged out of the solution from the parts. This rinse water is treated in a wastewater treatment plant and contributes to the generation of a hazardous sludge. Increased sludge buildup in the stripping tank results in increased solids drag-out contaminating the rinse water as well as more time required to rinse parts. Treatment of the more-contaminated rinse water results in increased hazardous waste generation. Because the solids contain absorbed liquid, solids dragout will further reduce the solution's stripping capacity.

The concentrations of sodium hydroxide and sodium gluconate in the alkaline paint-stripping solution are maintained through weekly sampling of the solution by the bath operators and analyses by the LEAD laboratory. Details of the bath sampling and analysis methods are presented in the Draft Assessment Plan (ESE, 1990a). Based on historical data, the life of the alkaline paint-stripping solution is approximately 6 months.

2.3 WASTE CHARACTERISTICS

Three waste streams are generated by the alkaline paint stripper operation: the exhausted liquid alkaline stripper solution pumped from the tank, the solid sludge layer formed at the bottom of the tank, and the contaminated rinse water. A summary of the bulk properties of the stripper liquid and sludge is presented in Table 2; the rinse water was not sampled during the current project.

**TABLE 2. SUMMARY OF ANALYTICAL RESULTS FOR ALKALINE
PAINT-STRIPPING SOLUTION AT LETTERKENNY ARMY DEPOT**

Parameters	Sample type	Sample date			
		3/20/90 ^a	4/12/90 ^a	5/2/90 ^a	1/7/91 ^b
Total residue (mg/L)	Representative	727,000	668,000	525,000	636,000
Filterable residue (mg/L)	Representative	1,500	2,500	9,700	143,000
Nonfilterable residue (mg/L)	Representative	726,000	665,000	525,000	493,000
Specific gravity	Liquid	1.34	1.30	1.23	1.33
Specific gravity (sludge)	Sludge	NA ^c	1.58	1.31	1.66
Alkalinity (mg/L as CaCO ₃)	Liquid	-	-	-	-
End point pH 8.3		NA	354,000	304,000	NA
End point pH 4.5		NA	390,000	341,000	NA

^a Results presented in the Waste Characterization Report (ESE, 1990a).

^b New alkaline paint stripper bath put into service on 11/7/90.

^c NA = Not analyzed.

SECTION 3

TECHNOLOGY AND EQUIPMENT SELECTION

3.1 REVIEW OF APPLICABLE PARTICULATE REMOVAL TECHNOLOGIES

Because sludge accumulation in the bath was clearly both an operational problem and a waste disposal problem, a convenient method to remove the sludge was needed. Several technologies were considered for removal of particulate from the alkaline paint stripper bath:

- Pressure (bag) filtration
- Centrifugation
- Gravity belt filtration
- Vacuum filtration
- Hydrocyclone
- Microfiltration
- Sedimentation
- Skimmers.

Based upon the data presented in the Draft Assessment Report, discussions with vendors, and past experience at the LEAD facility, a pressure filtration system (using bag filters) was selected to collect the particulate in the alkaline paint stripper bath (ESE, 1990a). Each technology considered is discussed in the following subsections.

3.1.1 Pressure Filtration

Pressure filters are devices in which the filtering pressure is imposed by a liquid pump (Figure 2). These systems can be operated either batchwise or continuously. The filtering media are typically cartridges, screens, or filter bags. Pressure filter systems are capable of rapid filtration and enable difficult separations that would otherwise be slow. These systems are compact compared with other technologies and have a relatively low capital cost (Perry, 1973). Also, the ability to change the bag pore sizes offers flexibility in removing particles of different sizes.

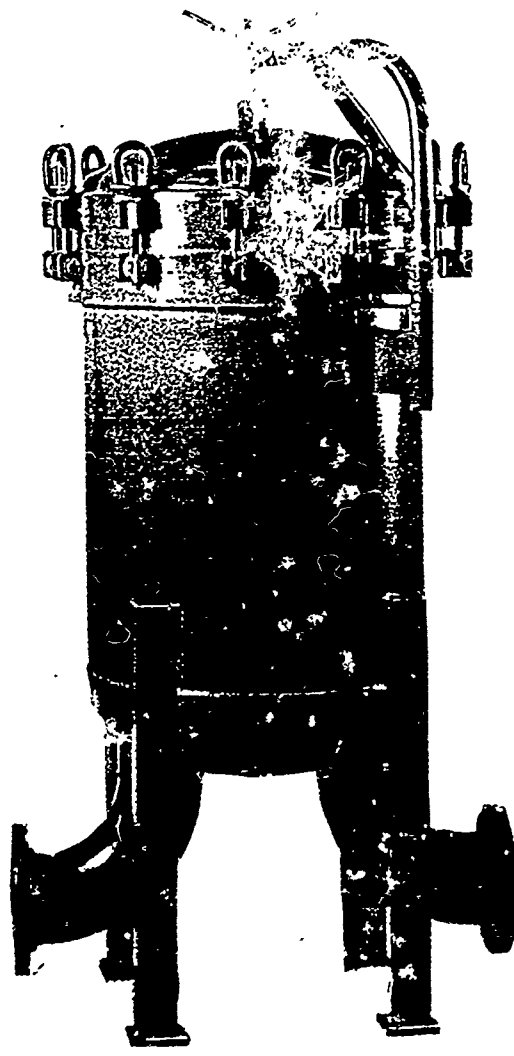


Figure 2. Illustration of a Pressure Bag Filter.

Courtesy of Strainrite, Lewiston, Maine.

3.1.2 Centrifugation

Centrifuges remove or concentrate particles of solids in a liquid by causing them to migrate radially through the fluid toward or away from the axis of rotation, depending on the density differences between particles and liquid (Figure 3). The discharge can be intermittent or continuous. Several types of centrifuge technologies are available depending upon the process requirements (Perry, 1973).

A centrifuge-based system is significantly more expensive than a pressure filtration system. Also, the high-speed rotating components result in maintenance costs higher than those for a pressure filtration system. A centrifuge is designed to collect particulate with specific characteristics (i.e., size and density) by controlling the rotational speed and throughput of liquid. Because the rotational speed and liquid throughput can only be varied in a narrow range, however, centrifugation does not have the operational flexibility of a pressure filtration system.

Based on discussions with vendors, some limited research was conducted to evaluate the applicability of a centrifuge, as discussed in Subsection 5.6.4.

3.1.3 Gravity (Hydrostatic) Filtration

In a gravity filter, the flow of the liquid across the filter media results from the hydrostatic pressure of the prefiltered liquid (Figure 4). Because this pressure is always relatively low, gravity filters are used only for relatively freely filtered materials and in cases where high flow rates are not required. Also, these units are large and require extensive floor area. These filters are simple devices with easy maintenance requirements and low initial capital costs; however, they are seldom used in process industries and are more appropriate for small pilot-scale plants (Perry, 1973).

Several years ago, a gravity belt filtration system was installed on the alkaline paint stripper bath in Building 350. This system was supposed to remove solids from the alkaline paint stripper solution. The foaming of the alkaline paint-stripping solution, which was due to the extreme detergent effect caused by sodium hydroxide and possibly soaps formed in the saponification reaction, prevented the filtration system from operating effectively. The foaming problems associated with the use of this

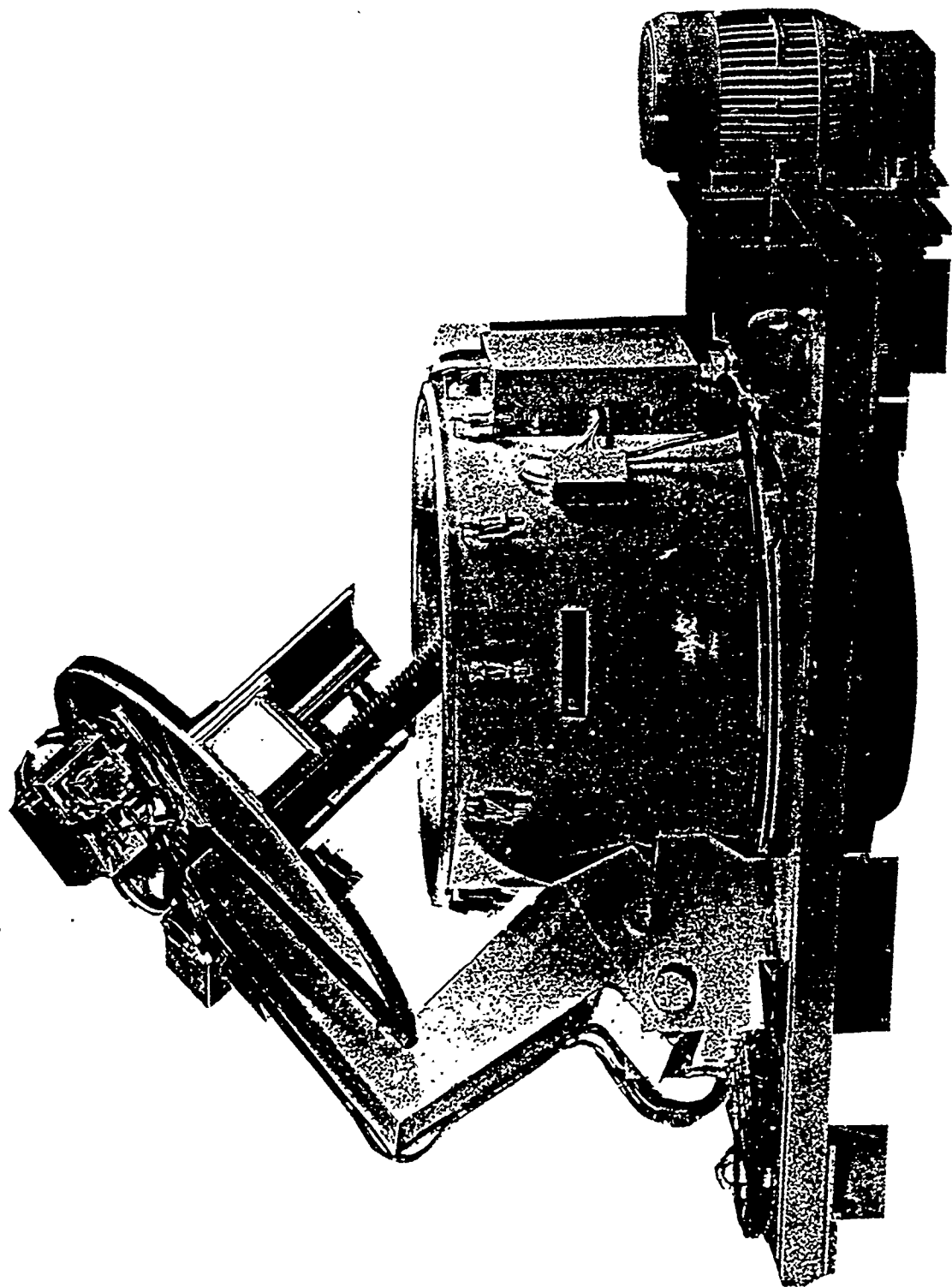


Figure 3. Illustration of a Centrifuge.

Courtesy of Robatel Inc., Pittsfield, Massachusetts

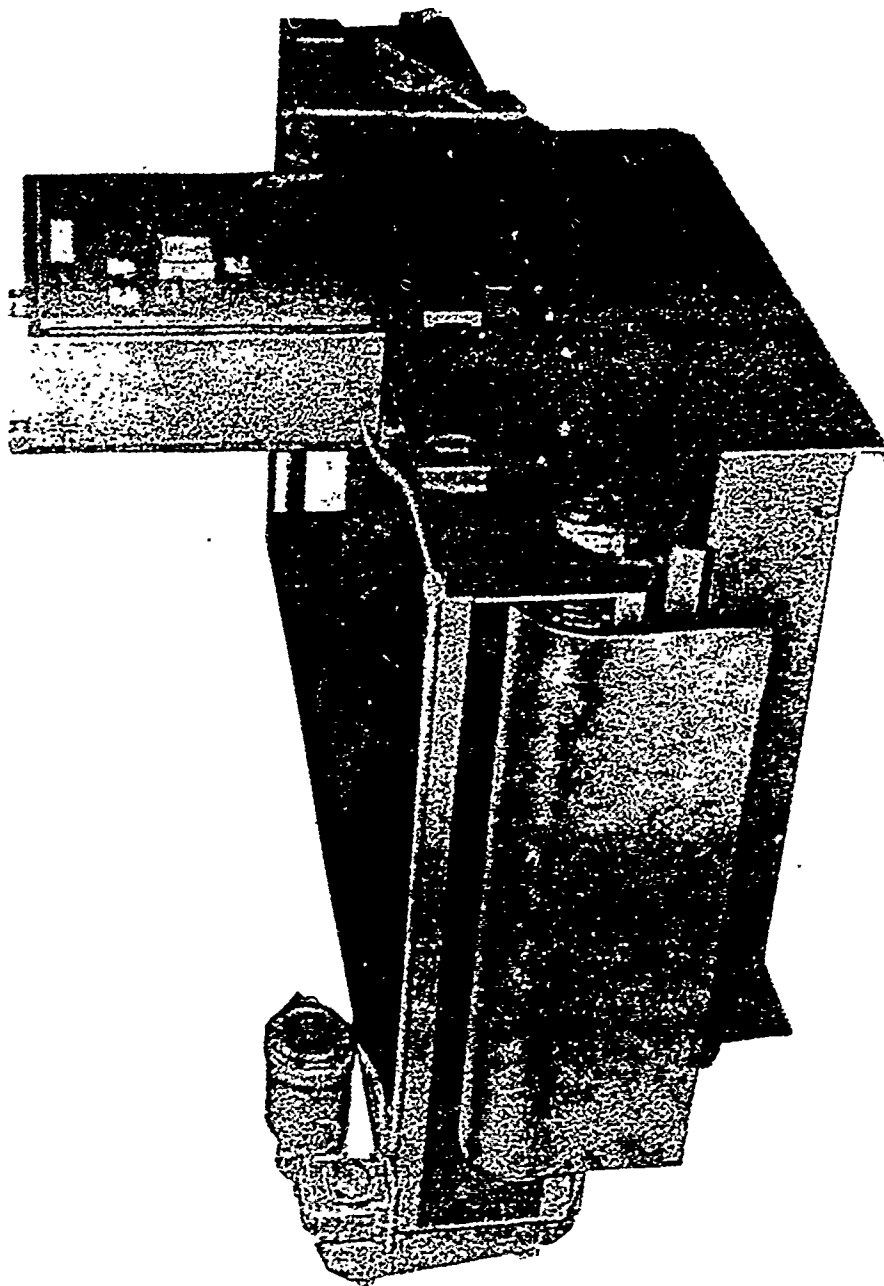


Figure 4. Illustration of a Gravity Filter.

Courtesy of Filtertech, Manlius, New York

equipment caused it to be rejected for removing solids from the alkaline paint stripper bath. The filter unit is currently used to filter honing oil, a more appropriate application of this type of filter.

3.1.4 Vacuum Filtration

A vacuum filtration system operates in a manner similar to that of the gravity filtration system; however, the flow of liquid across the filter media results from the hydrostatic plus the vacuum pressure created on the "clean" side of the filter (Figure 5). This system is also appropriate for use with relatively freely filtered materials.

A vacuum belt filtration system was investigated and rejected for this application because of its high capital and operating costs compared with the pressure filtration system and the relatively large size of the system (Perry, 1973). This system would also be subject to foaming problems similar to those that occurred with the gravity belt filter. Overall, vacuum belt filtration systems are more difficult to operate than are pressure filtration systems.

3.1.5 Hydrocyclone

A hydrocyclone is a wet classifier suitable for collecting large, regular-shaped particulate (Figure 6). The hydrocyclone has had only limited success in separating finer irregular-shaped particulate such as that generated in the alkaline paint stripper bath. Also, the concentrated effluent stream of solid material will contain significant quantities of alkaline paint stripper solution. Therefore, an additional separation device (e.g., a filter press or a gravity filter) would have to be used with this equipment. Because of these limitations, a hydrocyclone was rejected for application on the alkaline paint stripper bath.

3.1.6 Microfiltration

Microfiltration is a membrane filtration technology that operates in the batch mode (Figure 7). In this process, a quantity of the alkaline paint stripper solution is removed from the bath. This quantity is slowly cleaned as it is forced through a

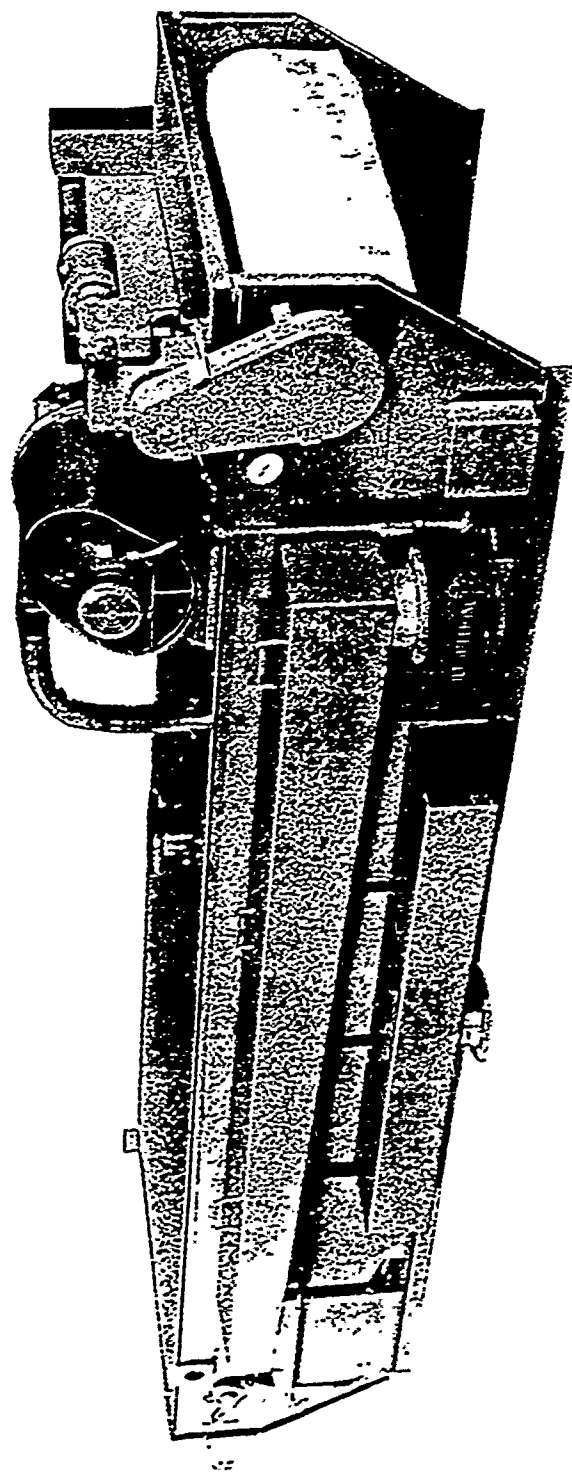


Figure 5. Illustration of a Vacuum Filter.
Courtesy of Filtertech, Manlius, New York

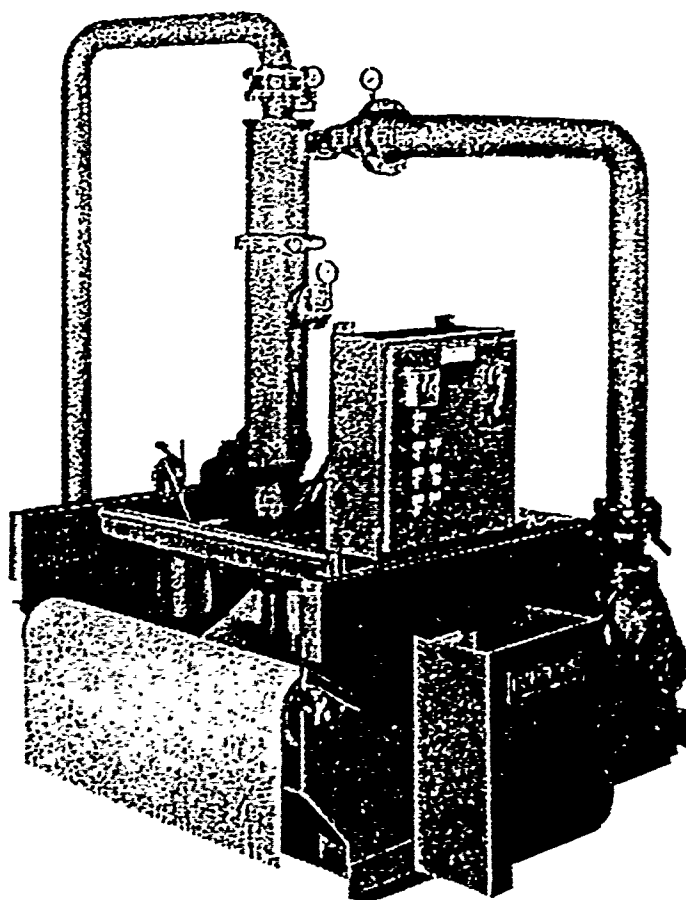


Figure 6. Illustration of a Hydroclone.

Courtesy of Filtertech, Manlius, New York

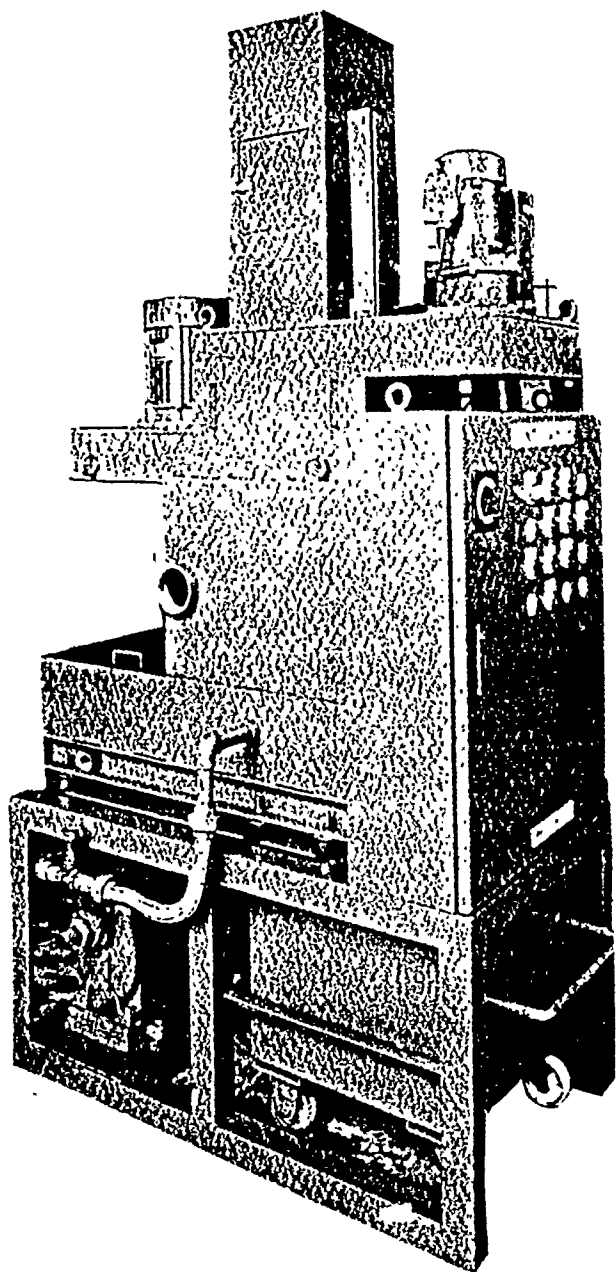


Figure 7. Illustration of a Microfilter.

Courtesy of Bazell Associates, Inc., Walnut Creek, California
representing Toto Separator Industries, Co., Ltd., Tokyo, Japan

membrane. The remaining material is a liquid stream containing the alkaline paint stripper solids. As with the hydrocyclone, an additional device (e.g., a filter press) would be required with this system to make the final separation of the concentrated solids/liquid stream. This system contains several components and requires a large amount of room. Also, the durability of the membrane element is somewhat variable and, in some applications, may require frequent element replacement. Because of the high pH of the alkaline paint stripper solution, identifying a suitable membrane could be difficult. Because of these limitations, this technology was rejected for use on the alkaline paint stripper bath.

3.1.7 Sedimentation

The sedimentation process uses a settling tank or chamber to remove particulates from the liquids. The particulates settle out of the liquid as a result of differences in density. Sedimentation is a slow process that requires a moderate-sized chamber. This process is incapable of collecting fine particulates such as those generated in the alkaline paint stripper bath. Also, after the material has settled, it still must be separated from the liquid solution (e.g., by a filter press). This system contains several components and requires a large amount of room. Because of these limitations, this technology was rejected for use on the alkaline paint stripper bath.

3.1.8 Skimmers

A skimmer is appropriate for removal of solids that collect on the top of the alkaline paint stripper bath (Figure 8). Solids on the surface of the alkaline paint stripper bath are not a significant problem compared with the sludge layer on the bottom of the tank. Given the density of the solids that make up the sludge, attempting to float these solids through the use of some type of dissolved air flotation (DAF) technology is not likely to be successful. Therefore, this technology would not solve the problem.

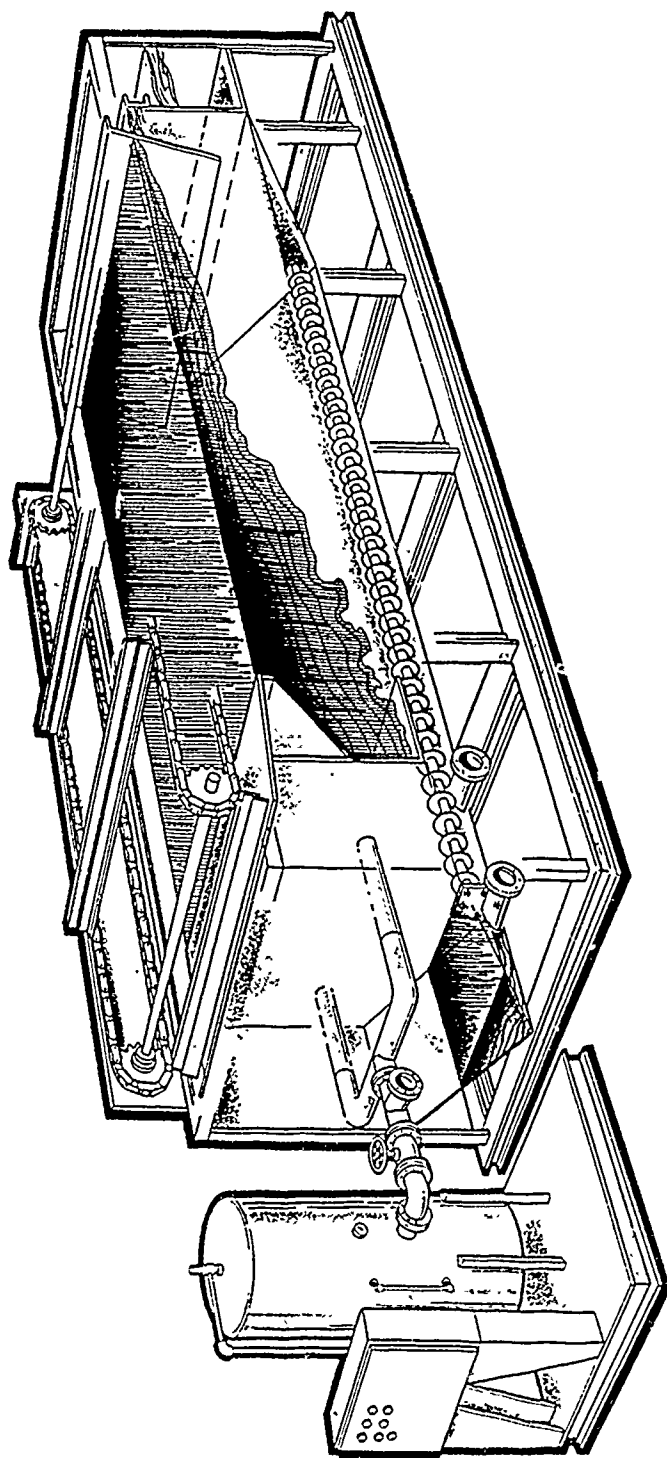


Figure 8. Illustration of a Skimmer.

Courtesy of Great Lakes Environmental, Addison, Illinois

3.2 REVIEW OF APPLICABLE PUMPING TECHNOLOGIES

Regardless of the separation technology selected, it was necessary to move the solution from the bath to the treatment equipment and back again. The following types of pumps were evaluated for circulating the alkaline paint-stripping solution through the pressure filtration system:

- Progressing cavity pumps
- Centrifugal pumps
- Diaphragm pumps

Because of the potentially high solids loading in the alkaline paint-stripping solution and the physical characteristics of the paint solids, a progressing cavity pump was selected to move the alkaline paint-stripping solution through the pressure filters.

3.2.1 Progressing Cavity Pump

A progressing cavity pump is a positive-displacement pump capable of conveying fluids with a wide range of characteristics (Figure 9). The key components of the pump are the rotor and the stator. The rotor is a single external helix with a round cross section. The stator is a double internal helix. As the rotor turns within the stator, cavities are formed that progress from the suction to the discharge end of the pump (Figure 10).

This pump is well suited for pumping liquids with high solids content and/or high viscosities. A progressing cavity pump is capable of passing solid fluids (e.g., sand) as well as larger pieces (e.g., 1/4-in. spheres). Because the pump operates at relatively low speed and low shear, it minimizes the further breakdown of paint pieces that are removed from the stripped parts. A progressing cavity pump can produce high discharge pressures even at moderate flow rates.

3.2.2 Centrifugal Pump

A centrifugal pump is the most widely used pump for the transfer of liquids (Figure 11). This pump comprises an impeller rotating within a casing. The impeller consists of several blades, either open or shrouded, mounted on a shaft that projects

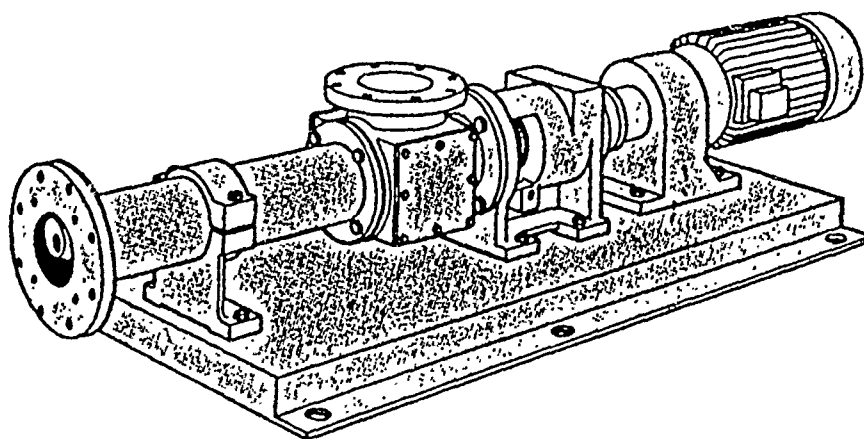


Figure 9. Illustration of a Progressing Cavity Pump.

Courtesy of Robbins & Myers, Inc., Springfield, Ohio

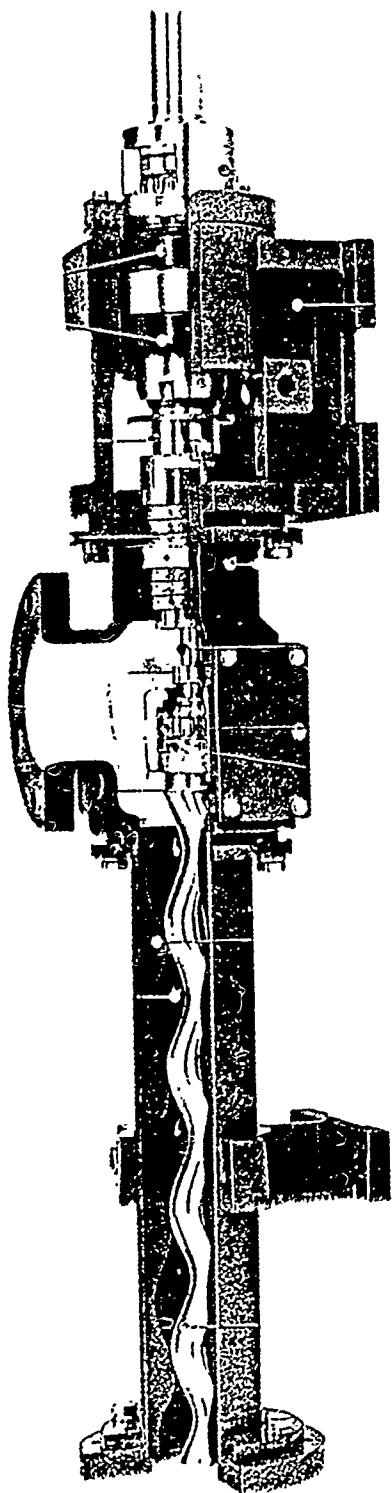


Figure 10a. Cutaway view of a progressing cavity pump.



Figure 10b. How the progressing cavity pump works. As the rotor rotates, the liquid is transported down the pump shaft.

Courtesy of Robbins & Myers, Inc., Springfield, Ohio

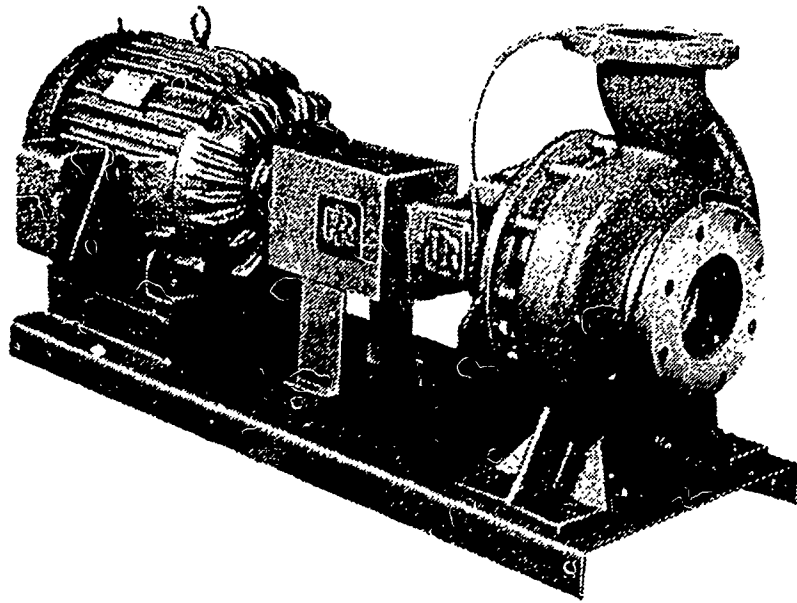


Figure 11. Illustration of a Centrifugal Pump.

Courtesy of the Ingersoll-Rand Company, Allentown, Pennsylvania

out to the casing. The casing, a chamber in which the impeller rotates, includes inlet and outlet connections for the liquid being pumped. A centrifugal pump was rejected for this application because of the high sheer nature of the equipment and the operational limitation in liquids with high solids content. A centrifugal pump is capable of passing a liquid containing fine solids. The filtration suction line from the LEAD alkaline paint stripper tank, however, may pass a high-solids-content stream (Subsection 5.3.2) and metal parts from the paint-stripping process, and either of these materials could cause pump clogging or excessive rotor blade erosion. Also, the sheer generated by the pump would break up the soft stripped paint pieces.

3.2.3 Diaphragm Pump

A diaphragm pump, a type of reciprocating pump (Figure 12), is typically air-driven. Diaphragm pumps differ from standard reciprocating pumps in that the reciprocating driving member is a flexible diaphragm fabricated of metal, rubber, or plastic. The advantage of using a diaphragm is that all packing and seals are not exposed to the pumping liquid. Because of their slow speed and large valves, these pumps can transfer delicate materials when degradation of the suspended solids is undesirable. A major consideration in the application of diaphragm pumps is that diaphragm failure will eventually occur, and the consequences of a failure must be designed into the system (Perry, 1973). Depending on the type and amount of solids, the particulate in the liquid may interfere with the inlet and outlet check valves that are required for operation of the pump. The result would be either no flow or reduced flow through the pump.

Although this pump is recommended for use with high solids, it is very inefficient and noisy. Also, it is inappropriate for the pressure and flow rates required for this application. Therefore, a diaphragm pump was rejected for this use.

3.3 DESIGN AND INSTALLATION OF THE FILTRATION SYSTEM

Based on the selected filtration and pump technologies, a pressure filtration system was designed. The system was designed to be assembled on its shipping

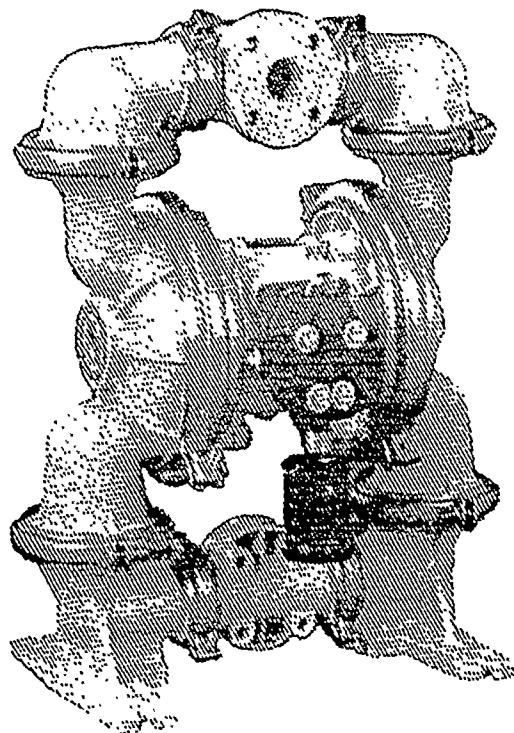


Figure 12. Illustration of a Diaphragm Pump.

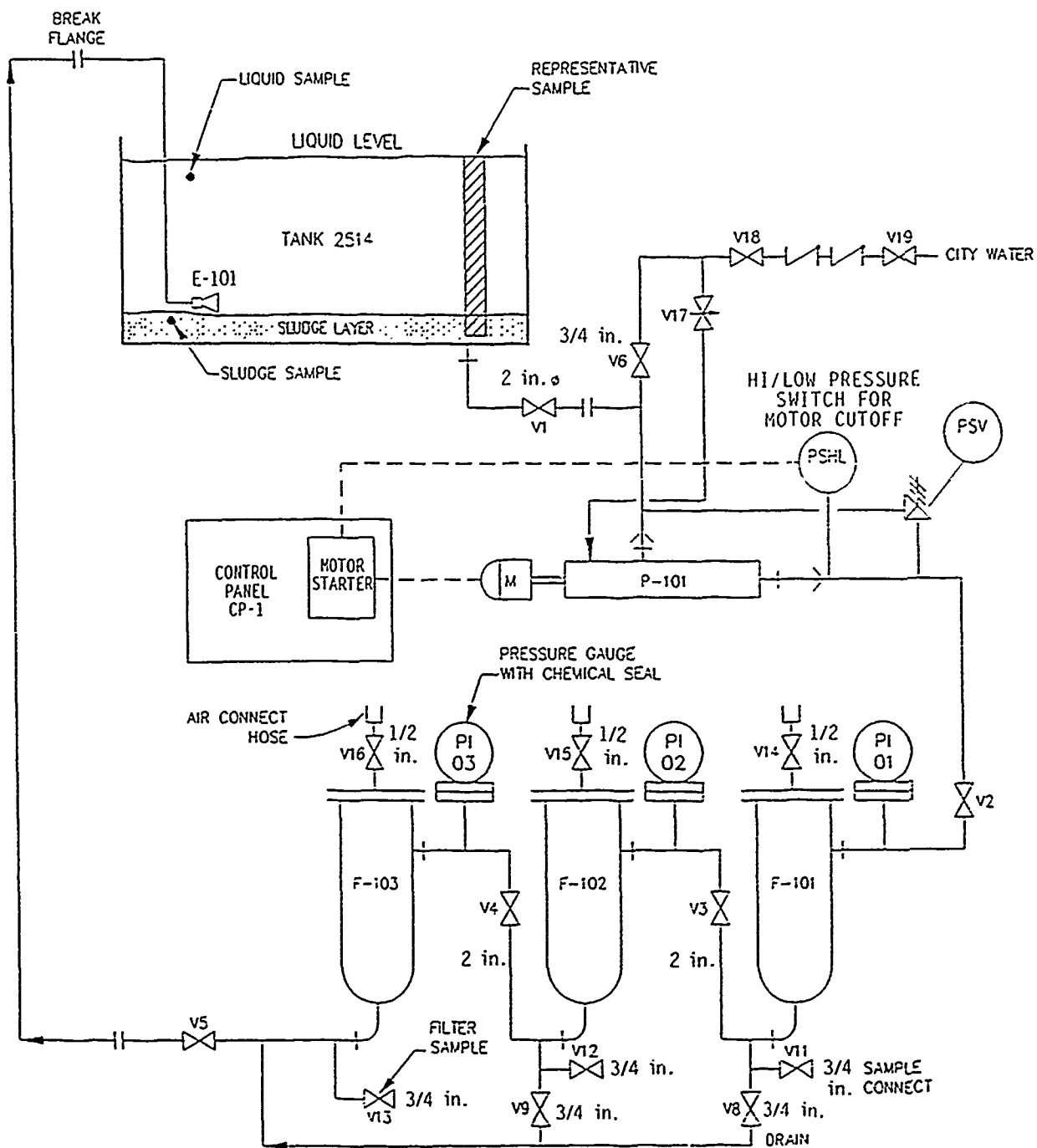
Courtesy of Warren Rupp-Houdaille, Inc.,
Mansfield, Ohio

and installation platform (a skid) and located close to the alkaline paint stripper tank (see Figure 1). Figure 13 presents a process sketch of the alkaline filtration system, and Table 3 provides a summary of the filtration system components. The maximum design pressure of the system is 150 psig. The alkaline paint stripping solution is pumped from one end of the tank, through the filtration system, and then returned to the opposite end of the tank. The return pipe extends to within 3 inches of the bottom of the tank. At this point, there is a 90-degree elbow at the end of the pipe which discharges parallel to the tank bottom. Photographs of the alkaline paint stripper bath and particulate filtration system are presented in Appendix A.

A progressing cavity pump (Roper Model 73312NNC) was selected to transport the sludge/alkaline paint stripping solution through the filtration system (see Appendix B). This pump was designed to transport 50 gallons per minute at a maximum total system pressure drop of 125 psi. The pumping rate was selected to clean the tank effectively of suspended particulate in approximately one shift (8 hours). This design criterion was based on the general guidance from filter system manufacturers that a given volume of liquid pumped through a filter 6 to 8 times would be essentially clean. The pump controls were designed to shut down in case of high pressure (due to plugging of the filtration system downstream of the pump) or low pressure (empty tank or plugging upstream of the pump). The high-pressure cutoff switch shuts the pump off at 100 psig. A high-pressure bypass valve was included to provide a backup to prevent overpressurization of the particulate filtration system. This valve opens at 130 psig.

The filtration process consists of three filtration units in series (Strain Rite Model UF1-180) (see Appendix B). All of the filter housings are fitted with bag filters. Bags of various mesh sizes were purchased for application in the particulate filtration system. Bag sizes at LEAD include 400, 200, 100, 50, 25, 5, and 1 μm . These bags can be used in various combinations to change the overall degree of filtration as conditions in the bath change.

A mixing eductor (Ketema Model 268) was installed on the particulate filtration system return line to provide agitation of the alkaline paint-stripping solution. An



J205-12

Figure 13. Process Sketch for the Alkaline Paint Stripping Solution Particulate Filtration System with the High Pressure Bypass.

TABLE 3. SUMMARY OF PARTICULATE FILTRATION SYSTEM COMPONENTS

Equipment No.	Description	Purpose
CP-1	Control panel	Provides housing for the electrical components, including hi/low pressure warning lights, cutoff switch, and cutoff relays.
E-101	Eductor	Increases agitation by converting potential energy (pressure) to kinetic energy (velocity).
F-101	Filter Housing No. 1	Performs first level of filtration.
F-102	Filter Housing No. 2	Performs second level of filtration.
F-103	Filter Housing No. 3	Performs third level of filtration.
P-101	Progressing cavity pump	Prime mover of the alkaline paint stripper solution. Provides pressure to overcome pressure resistance of filters and venturi jet on the return line.
PI-01	Pressure gauge before F-101	Measures pressure before F-101.
PI-02	Pressure gauge before F-102	Measures pressure before F-102.
PI-03	Pressure gauge before F-103	Measures pressure before F-103.
PSHL	High/low pressure switch	Turns off motor in case of low or high pressure.
PSV	Pressure relief valve	Prevents overpressure conditions in the particulate filtration system.
V1	2-in. ball shutoff valve	Isolates the particulate filtration system from the bath suction line.
V2	2-in. ball shutoff valve	Isolates F-101 and throttles flow into the particulate filtration system.
V3	2-in. ball shutoff valve	Isolates F-102 and throttles flow through F-102 and F-103.
V4	2-in. ball shutoff valve	Isolates F-103 and throttles flow into F-103.
V5	2-in. ball shutoff valve	Isolates the particulate filtration system from the bath return line.
V6	3/4-in. ball shutoff valve	Fresh water particulate filtration system flush line.
V8	3/4-in. ball bypass valve	Bypasses solution around F-102 and F-103 for draining housing.
V9	3/4-in. ball bypass valve	Bypasses solution around F-103 for draining housing.
V11	3/4-in. ball sample valve	Allows collection of samples after F-101.
V12	3/4-in. ball sample valve	Allows collection of samples after F-102.
V13	3/4-in. ball sample valve	Allows collection of samples after F-103.
V14	1/2-in. ball vent valve	Used to connect air line to clear F-101 of liquid to change filter bags.
V15	1/2-in. ball vent valve	Used to connect air line to clear F-102 of liquid to change filter bags.
V16	1/2-in. ball vent valve	Used to connect air line to clear F-103 of liquid to change filter bags.
V17	3/4-in. needle shutoff valve	Controls fresh water flush rate into the pump packing.
V18	3/4-in. ball shutoff valve	Controls fresh water supplied to the particulate filtration system
V19	3/4-in. gate shutoff valve	LEAD valve to control fresh water to the particulate filtration system

eductor consists of a fixed orifice and a venturi. The potential energy (pressure) of the return liquid stream is converted to kinetic energy (velocity) across the fixed orifice. The result is a high-velocity liquid stream, and the overall effect is that the volume of the stream leaving the diverging cone of the nozzle is four times that of the liquid being pumped. The eductor increases the filtration system pressure drop by 20 to 25 psig. This arrangement provides significant agitation in the alkaline paint-stripper tank, which helps move the paint sludge toward the filtration system suction pipe (see Figure 1).

Additional equipment on the particulate filtration system includes a control panel, pressure gauges, sample valves, drain valves, and shutoff valves (see Figure 13). The filtration system safety features include a high-pressure relief valve and the automatic pressure shutoffs discussed earlier.

Based on the selection of the major system components, a preliminary design of the particulate filtration system was completed. Based on this design, vendors were contacted to procure, build, and deliver the proposed system. The specifications of this system are presented in Request for Quotation and Specifications for an Alkaline Stripping Solution Filtration System (ESE, 1990c). A summary of the vendor specifications is presented in Appendix B (ESE, 1990d). Of the qualified responding vendors, APT, Inc. (Annapolis Junction, Maryland) was selected to build, test, and deliver the system to LEAD. PELEC, Inc. (Chambersburg, Pennsylvania) was selected to install the system.

SECTION 4

FIELD TESTING PROGRAM

The particulate filtration system represents the first use of pressure bag filtration on the alkaline paint stripper bath in Building 350. To evaluate the effectiveness of the particulate filtration system, a field testing program was initiated. The details of the testing methodologies are presented in the Test Plan (ESE, 1990f).

This testing was performed to verify that the particulates in the alkaline paint stripper bath were removed by the filtration system and to determine if particulate removal reduced the amount of hazardous waste generated by the alkaline paint-stripping operation. Data gathered from this study were used to make recommendations on methods to improve filtration, to propose improvements in system design, operation, and performance, and to identify other ways to minimize the generation of hazardous waste.

In addition to the field testing of the pressure bag filtration system, a sample of the alkaline paint stripper bath was collected for centrifugation. The test results were then reviewed to evaluate the potential for removing the particulate generated in the bath by centrifugation.

4.1 DATA COLLECTION

Several aspects of the alkaline paint stripper bath and particulate filtration system were recorded during the field testing program, including operations monitoring results, in-house test results, and results of analysis of alkaline paint stripper bath samples.

Operations monitoring consisted of recording the following information:

- Parts placed into the alkaline paint stripper bath (as required)
- Chemicals added to the alkaline paint stripper bath (weekly)
- Alkaline paint stripper bath temperature (daily)
- Standard testing performed by the in-house laboratory (weekly)
- Replacement frequency of bag filters (weekly or as required)
- Qualitative description of used filter bags during replacement

- Reading of all filter pressure gauges (each shift).

The standard tests performed by the in-house laboratory include:

- Specific gravity
- Titration for alkalinity
- Titration for sodium gluconate.

The filtration system was to begin continuous operation on a fresh alkaline paint-stripping solution. After approximately 1 week of operation, sampling would be started to evaluate the effect of the particulate filtration system.

The filtration system actually began operating 63 days after a fresh alkaline paint-stripping solution had been prepared. By this time, the alkaline paint-stripping solution had turned brown and a thick sludge layer had collected on the bottom of the bath. The layer was barely detectable in the end of the tank where the filtration system return line is located and a few inches thick on the opposite end (near the particulate filtration suction line). Only one round of samples was collected when the filtration system was ready to begin operation. This included sampling the bath before operation of the particulate filtration system was begun to establish the baseline level of particulate in the bath. This would not have been necessary if the particulate filtration system had been operational and the Test Plan had been initiated with a fresh alkaline paint-stripping solution.

Three types of samples were collected from the alkaline paint stripper bath:

- Representative fraction
- Liquid fraction
- Sludge fraction.

These sampling locations are presented in Figure 13.

The representative fraction samples were collected by using a coliwasa sampling column. The coliwasa was opened before being lowered into the bath to just above the bottom of the tank. The coliwasa was then sealed and withdrawn. The sample was transferred to a glass container.

A bailer was used to collect the liquid fraction aliquot. The bailer was lowered into the tank until the top was just above the surface of the liquid. The bailer was then withdrawn, and the sample was poured into a large glass container.

For collection of the sludge fraction aliquot, a sealed colliwasa was lowered into the solution to just above the bottom of the tank. The colliwasa was then unsealed, allowed to fill, sealed, and withdrawn. The sample was transferred to a large container.

4.2 ANALYSES OF SAMPLES

4.2.1 Analytical Parameters

The alkaline paint stripper bath was sampled and analyzed for the following characteristics:

- Solids content
- Settling time
- Specific gravity
- Alkalinity
- Particle size distribution.

All analytical methods were conducted according to the procedures contained in standard reference sources (ASTM, 1989; Standard Methods for Examination of Water and Wastewater, 1990; Bernholm, 1990). Specifics of the methodologies are discussed in the Test Plan (ESE, 1990f). The type and number of samples collected per sample round are summarized in Table 4. These analyses are similar to the analyses conducted during the preliminary testing of the alkaline paint stripper bath described in the Draft Assessment Plan (ESE, 1990a).

4.2.2 Sampling Schedule

The Test Plan proposed that sampling be conducted one week after operation of the filtration system and a fresh alkaline paint-stripping solution were begun, and then every other week for three sampling rounds. This schedule was later modified because of mechanical problems that occurred during the installation and initial startup

**TABLE 4. ANALYSES CONDUCTED ON THE ALKALINE
PAINT-STRIPPING SOLUTION SAMPLES**

Parameter	No. of samples per episode	Sample aliquot	Method
Total residue	2	Representative Liquid/Solid	EPA 160.3 ^a
Total filterable residue	2	Representative Liquid/Solid	EPA 160.1 ^a
Total nonfilterable residue	2	Representative Liquid/Solid	EPA 160.2 ^a
Specific gravity	1	Liquid Fraction	ASTM E868-82, Section 9.9 ^b
Bulk density	1	Concentrated Solid Fraction	ASTM E868-82 Section 9.9 ^b
Alkalinity titration (pH 8.3 and 4.5)	1	Liquid Fraction	EPA 310.1 ^a
Particle size and distribution	2	Concentrated Solid Fraction	Coulter Counter ^c

^a Standard Methods for the Examination of Water and Wastewater, 1985.

^b ASTM, 1989.

^c Coulter Electronics Application Laboratory Standard Methods, undated.

of the filtration system. Because of these mechanical problems, the test program was delayed and eventually implemented on a stripping solution that had been used to process parts for 63 days. These developments resulted in a revised sampling frequency being proposed. The revised sampling schedule included:

- An initial sampling round to establish baseline conditions of the alkaline paint-stripping solution
- Three sampling rounds at 2-week intervals.

The initial sampling round was collected before operation of the particulate filtration system was begun. Three additional sample rounds were to be collected to evaluate the effect of the filtration system on the alkaline paint-stripping operation. Because sufficient operation time was not achieved during the test phase, these additional samples were not collected.

4.2.3 Quality Control/Assurance

Most of the analyses conducted under the Test Plan are simple and do not require extensive quality control. Sampling quality control was established through careful collection of the samples from the alkaline paint stripper bath and the particulate filtration system and a chain-of-custody system.

Laboratory quality control was established through purchase of standardized solutions and calibration of particle-size-determination equipment involving spheres of known diameters. Quantitative limits of the laboratory results are presented in Appendix C.

4.3 SAMPLING HEALTH AND SAFETY PROCEDURES

Health and safety procedures for LEAD personnel who monitored the alkaline paint-stripping operation are presented in the depot's Health and Safety Plan (LEAD, 1986). Health and safety procedures for ESE and its contractors are presented in the "Accident Prevention Safety Program Plan for Evaluating the Alkaline Paint Stripper and Particulate Filtration System at Letterkenny Army Depot" (ESE, 1990e). Copies of the

Health and Safety Plans were provided to USATHAMA, LEAD, and the system installation vendor for review and ready reference.

SECTION 5

IMPLEMENTATION OF THE TEST PLAN

Initially, the field testing program was to be implemented immediately after installation of the pressure filtration system. During the startup of the filtration system, however, several mechanical problems developed. As a result, insufficient quantitative data were obtained during the test phase from which to draw conclusions concerning the precise effectiveness of the particulate filtration system. Characterization of the alkaline paint-stripping solution was limited to a single round of laboratory samples obtained from the alkaline paint stripper bath before operation of the filtration system. These results were to provide a baseline for comparison with additional samples after the filtration system was in operation. Because of insufficient filtration system operation time, additional samples were not justified.

Also because of the insufficient operation time of the filtration system, in-house laboratory data were not collected. Some operational monitoring data were collected, however, the amount was too limited to be useful.

Data were collected on the mass of materials removed from the bath with different filter bag configurations and operating scenarios. The experience gained by ESE and LEAD personnel during the startup, shakedown, and operational phases was used to confirm and modify, where necessary, operational methods and materials of construction.

Results of centrifuging a sample of the alkaline paint-stripping solution are presented herein. These data were used for further evaluation of the effectiveness of the centrifugation system. Additional information pertaining to the bath chemistry is presented in this chapter. This information, together with the discussion on bath chemistry presented in the Waste Characterization Report (ESE, 1990b), was used to predict the effects of the particulate filtration system on the alkaline paint-stripping solution.

Installation and operation of the filtration system occurred in essentially five phases, as described in Table 5. Each phase is characterized by a set of activities, time period, and specific events beginning and ending each phase. Because of the mechanical problems encountered in the first four phases, few quantitative data on the system characteristics were obtained by the end of the project schedule. Table 6 summarizes (by phase) the mechanical problems encountered and the actions that were taken to rectify these problems. The remainder of this section presents a brief history of the project, the problems encountered, and the solutions to these problems.

TABLE 5. DEFINITION OF PROJECT PHASES

Phase No.	Phase name	Date	Event beginning phase	Event ending phase
1	Installation	Nov. 5-28, 1990	Skid delivery	Return and installation of repaired pump
2	Startup	Nov. 30-Dec. 7, 1990	Completion of installation	Problems with filter bag material and O rings
3	Operational shakedown	Jan. 7-11, 1991	Replacement of filter bags and O rings	Operation of system turned over to LEAD
4	LEAD initial operational phase	Jan. 14-23, 1991	Operation of system turned over to LEAD	Shut down to determine cause of gasket and equipment failure
5	LEAD continuing operational phase	March 20, 1991 - Ongoing	Replacement of pressure gauges, valves, and gaskets; installation of eductor and high-pressure relief valve; mixing of fresh solution	Ongoing

TABLE 6. PROBLEMS ENCOUNTERED DURING IMPLEMENTATION OF TEST PLAN FOR FILTRATION OF ALKALINE PAINT-STRIPPING SOLUTION

Phase	Equipment/ system item	Problem encountered	Solution
1	Tank lining	Asbestos used as insulation.	Removed by LEAD personnel before installation.
1	Pump	Faulty weld.	Repaired by manufacturer.
2	Filter bags	Polyester bag material specified by manufacturer's literature disintegrated.	Replaced by nylon filter bags.
2	Filter bags	Replacement nylon bags had been sewn using polyester thread, which disintegrated.	Bags were stapled temporarily, then replaced by nylon bags sewn with nylon thread.
2	O rings on filter basket	Failed at seam.	Replaced by molded (no seam) O rings in Phase 3; upgraded to Teflon in Phase 5.
2	Pump	Motor and gear reducer couplings went out of alignment.	Skid was leveled and pump was realigned.
3	Sludge layer	Significant sludge layer had accumulated on the tank bottom after 63 days of use.	Manual raking procedure was developed.
3	Rack on tank bottom	Interfered with raking process.	Removed temporarily.
3	Filter basket	Failed at seam because of over-pressurization.	Replaced; high-pressure relief valve installed.
3-4	Pressure gauges	Failure due to overpressurization.	Replaced, high-pressure relief valve installed.
3-4	Valves	Failure of two valve seals due to overpressurization.	Valve seals were replaced; high-pressure relief valve was installed.
3-4	High-pressure cutoff controls	10-second delay allowed sufficient pressure to damage parts.	High-pressure relief valve and backup system installed in Phase 5.
3-4	Tank agitation	Tank agitation and return velocity of filtered solution were insufficient to transport sludge to suction inlet.	Installed eductor.
4	Filter housing bolt	Corrosion occurred because bolt was cadmium-plated carbon steel rather than the specified stainless steel.	Replaced by LEAD.
4	Flange gasket	Leak from chemical attack although neoprene material was specified by manufacturer.	Upgraded to Teflon and replaced.

(continued)

TABLE 6 (continued)

Phase	Equipment/ system item	Problem encountered	Solution
5	Solution mixing	During mixing of a new solution, powder dissolved very slowly.	Filtration unit was used to provide additional turbulence.
5	Pump	Coupling was slipping	Replaced coupling
5	Pressure gauges	Malfunction; pressure reading too low	LEAD plans to replace with flange-mounted gauges to prevent solids buildup

5.1 PARTICULATE FILTRATION SYSTEM INSTALLATION

Installation of the particulate filtration system began with the delivery of the skid-mounted system to LEAD. Completion of the skid installation was delayed, however, by several complications. One day prior to shipping the completed system, the manufacturer discovered a faulty weld in the progressing cavity pump housing. Nevertheless, because the installation contractor had made all the necessary arrangements to start work, the unit was shipped to LEAD so that part of the installation could be completed.

The particulate filtration skid arrived at LEAD on November 5, 1990. The alkaline paint stripper tank had been emptied and cleaned in preparation for installation of the filter skid. As shown in Figure 13, the filtration system was placed next to Tank 2514, the alkaline paint stripper bath. The location of the filtration skid in relation to the alkaline paint stripper tank is shown in Figure 1. A small amount of asbestos insulation had to be removed from the tank by LEAD personnel to install the suction pipe through the tank wall. The piping and electrical installation was completed on November 7, 1990. When the piping between the filtration system and the alkaline paint stripper bath and electrical work between the filtration skid and the LEAD electrical supply were completed, the progressing cavity pump was removed and shipped out for repair.

The repaired pump was returned to LEAD on November 28, 1990. The installation contractor completed the skid installation by connecting the system and the

pump packing flush-water line. The assembled filtration system was leak-tested and briefly run on clean water, and monitoring logs from the Test Plan were supplied to LEAD personnel (see Section 4.1.2 of the Test Plan) (ESE, 1990a).

5.2 STARTUP OF THE PARTICULATE FILTRATION SYSTEM

On November 30, 1990, the filtration system began operation on the alkaline paint-stripping solution. The filtration system was first operated in the following filter bag configuration: a 50- μ m bag in filter housing F-101, a 5- μ m bag in filter housing F-102, and a 1- μ m bag in filter housing F-103. When the system was operated in this configuration, the 5- μ m bag blinded within 5 minutes, and the 50- μ m bag contained some material, including large paint pieces and sand.

A second filter bag configuration was attempted as follows: a 200- μ m bag in filter housing F-101, a 100- μ m bag in filter housing F-102, and a 50- μ m bag in filter housing F-103. The polyester bag material disintegrated before the bags were blinded (after approximately 20 minutes). The system was then shut down for repair before any further data could be gathered.

Based on further discussions with filter bag manufacturers, nylon bags were determined to be suitable for this service. The appropriate size nylon bags were ordered to continue the test program. When the nylon filter bags arrived and were installed, the filtration system was returned to service. The replacement nylon filter bags were not affected by the alkaline paint-stripping solution. Unfortunately, an error by the manufacturer resulted in the use of polyester thread to sew the filter bags. As a result, the bags opened up along the seams after a few minutes of service. These filter bags were temporarily repaired by stapling the seam together and were replaced in a later phase with nylon bags sewed with nylon thread.

Also during this test phase, the motor and gear reducer couplings on the pump went out of alignment because of either loose pump and drive mounting bolts or improper shaft alignment. The system was repaired by leveling the filtration skid and realigning the pump shaft and gear reducer couplings. The pipe between the pump

(P-101) and filter housing F-101 was inspected for metallic objects (i.e., small fuel lines, nuts, or bolts that are sometimes found in the bath). Nothing was found during the inspection of the process pipe section.

An additional problem resulted from all the neoprene O rings on the filter basket and in the filter housing groove failing at the welded or glued seam. The O rings were replaced with molded (no seam) neoprene O rings in Phase 3 and then upgraded to Teflon in Phase 5.

The filtration system was shut down at the end of the startup phase to await the arrival of the replacement filter bags and O rings.

5.3 OPERATIONAL SHAKEDOWN OF THE PARTICULATE FILTRATION SYSTEM

After receipt of the replacement filter bags and O rings, the filtration system was returned to service on January 7, 1991, to begin Phase 3 of the project, operational shakedown. During a week of operation, the system was frequently operated 24 hours a day. Because of the mechanical problems that occurred during the first two phases, the stripping solution had been used for 63 days to strip paint from parts without removal of the paint from the bath. During this period, a sludge layer had formed at the bottom of the alkaline paint stripper tank. Operation of the filtration system alone had little effect on this bottom sludge layer (i.e., moving it along the tank bottom); therefore, methods for filtering this sludge were also developed. The following subsections summarize the experience gained during the filtering of the alkaline paint-stripping solution and the sludge layer.

5.3.1 Filtration of the Alkaline Paint-Stripping Solution

Initially, a 50- μ m filter bag was used to filter the alkaline paint-stripping solution. After a total of 48 hours of operation, no increase in pressure drop had occurred in the filtration system. Examination of the 50- μ m filter bag indicated some minor accumulation of filter cake. During additional operating time, the following filter bags were used to filter the alkaline paint-stripping solution. a 400- μ m bag in filter housing

F-101, a 100- μm bag in F-102, and a 50- μm bag in F-103. During the operation of the filter system while equipped with these filter bags, no significant increase was noted in the system pressure drop. Examination of the filters indicated some minor accumulation of solids in each of the three filter bags. This accumulation was indicated by bag discoloration and loose solid materials.

5.3.2 Filtration of the Sludge Layer

During the test phase, agitation of the alkaline paint-stripping solution from the filtration system return line was not sufficient to transport the large volume of heavy sludge along the entire tank bottom because of the high density of the sludge material. Very little bottom sludge was noticed on the side of the tank where the return line was placed, however. Therefore, greater turbulence from the return line would be required to produce adequate particle suspension.

A simple procedure was devised to move the sludge layer manually to be closer to the filtration system suction line. This was done with a rake provided by LEAD tank operators. Basket support grates located on the bottom of the bath complicated the raking of the sludge. This problem was solved by temporarily removing the grates from the bath. Raking was started at the end of the tank where the particulate filtration system return line is located. The sludge was moved closer to the particulate filtration system suction line by pulling the sludge material with the rake. The sludge was raked to the end of the tank where the particulate filtration system suction line is located and then directly into the suction line.

Raking the sludge layer toward the particulate filtration suction line proved to be very effective. Tests were conducted to determine the performance of various filter bag combinations while receiving the sludge solids raked into the filtration system. Initial tests were performed with a single 50- μm (mesh) filter bag (while the other filter housings were left empty). The 50- μm bags were blinded almost immediately after the raking started and did not collect a significant cake. Because these bags were not reusable, they had to be disposed of. Based on separate tests with 50- μm (mesh), 100- μm (mesh) and 400- μm (monofilament) bags, the performance of the 400- μm bags

was superior because these monofilament bags could be emptied and reused numerous times. Additional permutations of filter bags were attempted, as shown in the following:

- F-101 = 400 μ m, F-102 = 50 μ m, F-103 = empty
- F-101 = 400 μ m, F-102 = 100 μ m, F-103 = 50 μ m
- F-101 = 400 μ m, F-102 = 400 μ m, F-103 = empty

When used for removal of sludge, multiple bags in series did not significantly improve sludge collection capacity. During this testing period, 200- μ m bags were not available.

The overall process for collecting the sludge layer in the alkaline paint stripper bath included the following steps:

- Installing a 400- μ m filter bag into filter housing F-101 (see Test Plan, Appendix A).
- Starting the particulate filtration system and observing the pressure gauge on filter housing F-101 (PI-01) for 2 minutes.
- Raking the bottom of the alkaline paint stripper bath so as to move the sludge layer directly into the suction line of the particulate filtration system.

The most efficient procedure involved using three 400- μ m filter bags. One bag was placed in a filter housing (the other filter housings remained empty). After this bag became blinded, it was removed and set aside to allow the liquid to drain from the filter cake. The contents of the filter bag consisted of small paint pieces, sand, and a thick sludge material. A layer of sludge up to 10 inches deep formed at the bottom of the filter bag, and a filter cake of between 1/4 and 1/2 in. formed on the side of the filter bag. The monofilament filter bag cleanout proved to be quite easy.

A second 400- μ m bag was placed in the filter housing, and the filtration operation was restarted. After the second 400- μ m bag became blinded, it was removed and set aside to drain and the third filter bag was placed in the filter housing. After the filtration system was restarted, the first filter bag was emptied of solids and prepared for reuse in the filtration system when the third filter bag became blinded.

Each time the filter bag was emptied, approximately 5 to 15 pounds of sludge was removed from the paint-stripping bath. It is clear that only a few bags would be required to remove and dispose of a significant amount of sludge from the bath.

During this test phase, between 250 and 300 pounds of sludge was removed from the tank by raking, which is equivalent to half of a 55-gallon drum. This amount of material was removed within 12 hours. A relative measure of the significance of collecting this quantity of material is evident by noting that cleanout of the bath after 6 months of operation produces approximately 3 drums of sludge.

5.3.3 Development of Operating Modes

Based on the preceding information, two operation modes were developed. In the first mode, the system was used to filter the alkaline paint-stripping solution. The system would be operated for the greater portion of the time in this mode. In the second mode, the system can be used to filter the sludge that accumulates on the bottom of the alkaline paint stripper bath. This mode will only be required if a sludge layer accumulates in the alkaline paint-stripping tanks. Each operating mode is described here.

Mode 1. Continuous Removal of Suspended Solids

With new bags in each filter housing, the filtration system is started every Monday during the first shift. For filtration of the paint-stripping solution, adequate performance without excessive downtime was demonstrated by using the following filter bags: a 400- μ m bag (monofilament) in filter housing F-101, a 200- μ m bag (monofilament) in filter housing F-102, and a 50- μ m bag (mesh) in filter housing F-103. It is expected that the filter bags will require replacement midway through the week. The particulate filtration system is operated during the first and second shifts (16 hours per day). When not in use, the pump should be shut down and valves V1 and V5 should be closed (see Figure 13).

Mode 2. Periodic Removal of Settled Sludge

If a sludge layer accumulates in the alkaline paint-stripping tank, the 200- μm and 50- μm filter bags used in Mode 1 should be removed (the 400- μm filter bag should remain in filter housing F-101). The bottom of the bath must be raked to transport the heavy sludge into the filtration system suction line. When the 400- μm bag becomes blinded, it should be removed from the filter housing and emptied. Blinding of filter bags is indicated by a high pressure drop, which will lead to automatic shutdown of the pump. The bag should then be placed back into the filter housing and the sludge raking process repeated. The sludge raking process should continue until the bath is put back into production or the sludge layer is cleared from the tank.

5.4 LEAD INITIAL OPERATIONAL PHASE

After completion of the startup and operational shakedown phases, LEAD personnel began to operate the particulate filtration system. The filter system was operated with the following filter bag configuration: a 400- μm bag in filter housing F-101, a 200- μm bag in filter housing F-102, and a 50- μm bag in filter housing F-103. Since entering the operation phase, the filtration system has not been operated to remove sludge from the alkaline paint stripper bath.

Several problems occurred during this operational phase. First, corrosion on a filter housing bolt made it difficult to open the housing lid and eventually caused the threads to become stripped. The bolt was made of cadmium-plated carbon steel, rather than the stainless steel that had been specified. The bolt was replaced by LEAD personnel, and the system was returned to operation. Second, a neoprene flange gasket developed a leak during the system operation. In addition, all pressure gauges and two valves (V8 and V12) failed because of system overpressurization. The pump controls include a 10-second delay between sensing a high- or low-pressure condition and shutting off the pump; this design allows startup of the system without the pump shutting off because of low pressure. Apparently, this delay was sufficient time for equipment damage to occur. The system was shut down to

determine if the flange had leaked as a result of mechanical failure (from over-pressurization) or chemical attack by the alkaline paint-stripping solution. The system was also shut down so that a high-pressure relief system could be installed.

According to the supplier of the filtration system, the original flange gaskets were neoprene. Nearly all of these gaskets exhibited varying degrees of degradation, such as swelling and perforation of the gasket. Although neoprene should have worked in this service, it was decided to upgrade all gasket materials to Teflon. In Phase 3 (operational shakedown) the original O rings in the filter housings were replaced with molded neoprene ones and used for a period of time before being replaced with Teflon units in Phase 5. When the neoprene rings were removed, they showed no signs of chemical attack. Although no additional data were gathered to support this conclusion, it is believed that the original flange gaskets were probably buna-N rather than neoprene. Buna-N would not be expected to last in this service.

All pressure gauges were returned to the manufacturer, who indicated that all of the pressure gauges had been exposed to pressures above their rated capacity. This probably occurred as a result of closing a valve during operation of the pump. The gauges were eventually replaced by the manufacturer and reinstalled during Phase 5.

Two of the 3/4-in. sample/bypass valves failed to seal completely when closed. These valves were disassembled and inspected. Based on discussions with the valve manufacturer, the valves had been exposed to pressures above the rated capacity. The valve packing was replaced in the leaking valves, and extra valve packing kits were ordered and delivered to LEAD during Phase 5.

5.5 LEAD CONTINUING OPERATIONAL PHASE

During the final phase of this project, the filtration system was repaired and modified, and then left on site for ongoing use in LEAD operations. The phase began with the repair of the pressure gauges, valve packing, and flange gaskets that had been damaged by overpressurization. An eductor was installed on the return line to increase agitation in the paint-stripping tank so the sludge would move toward the

suction line of the filtration system. A backup high-pressure relief valve was installed to ensure that overpressure conditions would not recur (see Figure 13) even if the system were operated incorrectly.

At the beginning of the phase, the paint-stripping solution was replaced with a fresh bath. During the mixing of this solution, it was discovered that the powder dissolves very slowly. The progressing cavity pump was used to circulate the solution through the filtration system to help mix the powder. Initially, the filtration system was operated with the filter baskets but without the bags in place; all three baskets were filled quickly with sodium hydroxide pellets. The system was then operated without the baskets to help dissolve the powder.

The project ended within a week after these repairs were made, and the project schedule did not allow for additional characterization of the bath or monitoring of the desired impact of particulate removal. The system remains in place for continuing use by LEAD; except for continuing malfunctions of the pressure gauges, depot engineers have indicated that the system is operating properly. LEAD plans to replace the pressure gauges with a different design.

5.6 COLLECTION OF TEST DATA

This section presents a summary of the quantitative data collected during the testing phase of the project. The data include laboratory analysis of samples collected from the alkaline paint stripper bath, on-site settling tests conducted by ESE personnel, centrifugation analysis results of alkaline paint stripper bath samples, and measurements of the quantity of material collected by the filter bags. In-house LEAD laboratory results were not collected for this report.

A limited quantity of operations monitoring data were collected by LEAD operators and ESE. These data are presented in Appendix D.

5.6.1 Alkaline Paint Stripper Solution - Laboratory Analyses

One round of sampling was obtained during the operational shakedown phase. The samples were collected on January 5, 1991. The alkaline paint stripper bath was

sampled per the methods outlined in Section 6.0 of the Test Plan (see Table 3) (ESE, 1990f). Samples of the alkaline paint-stripping solution that was returned from the particulate filtration system were not collected during this round. This sampling round was used to establish the baseline condition of the unfiltered bath inasmuch as the bath was already in use. These results were to be compared with results of samples collected after the filtration process had operated long enough to clean the alkaline paint-stripping solution of solids. The results of the baseline analysis are as follows:

- Liquid sample
 - Specific gravity 1.33
 - Alkalinity (as pH) 13.2
- Representative sample
 - Total filterable residue 143,000 mg/L
 - Total nonfilterable residue 493,000 mg/L
 - Total residue 636,000 mg/L
- Concentration solids sample
 - Specific gravity (liquid layer) 1.41
 - Specific gravity (sludge layer) 1.66

The information provided by the laboratories is presented in Appendix C. A summary of all sampling data collected from the alkaline paint stripping operation was presented earlier in Table 2. Particle-size-distribution tests were also conducted. The results of these tests and a summary of previous data collected are presented in Figures 14 and 15. The results supplied by Coulter Laboratories are presented in Appendix C.

The mean particle diameter for the population data ranged from 1.29 to 1.91 μm , while the median particle diameter ranged from 1.19 to 1.67 μm , depending on the sampling episode. Greater than 90 percent of the number of particles were in the 0.84 to 1.13 μm range.

The volume data indicate that the mean particle volume was that of a particle with a 44 to 97 μm diameter, while half the volume of particles was due to those with diameters greater than 59 to 108 μm . Greater than 90 percent of the volume was attributable to particles with diameters greater than 3.8 to 33 μm .

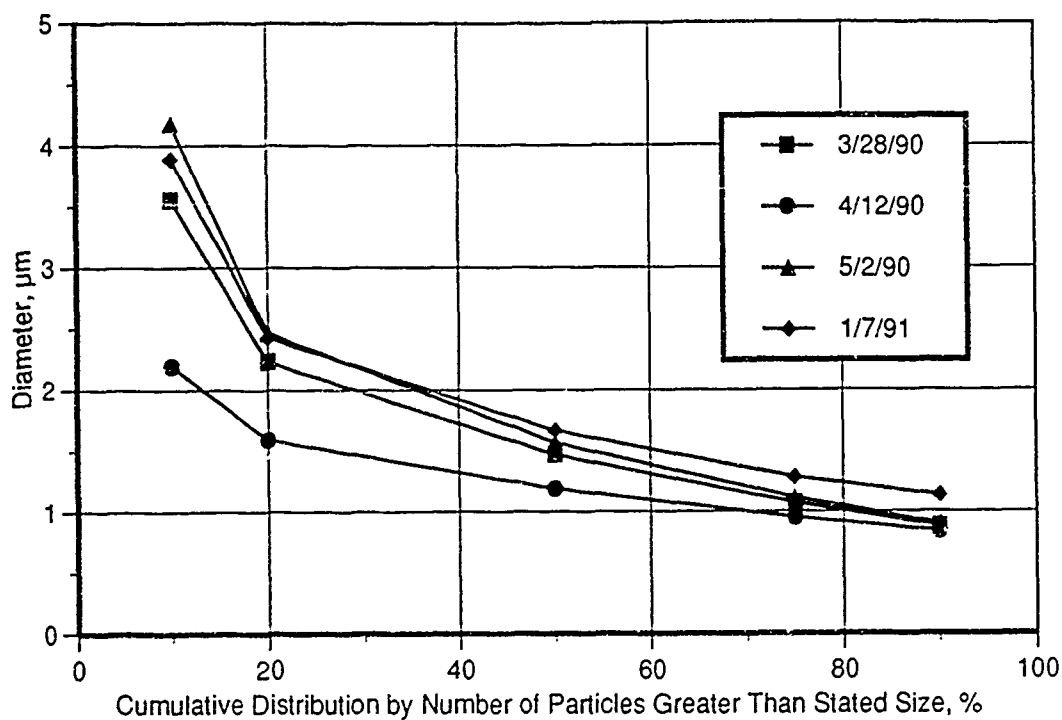


Figure 14. Distribution of Population Data.

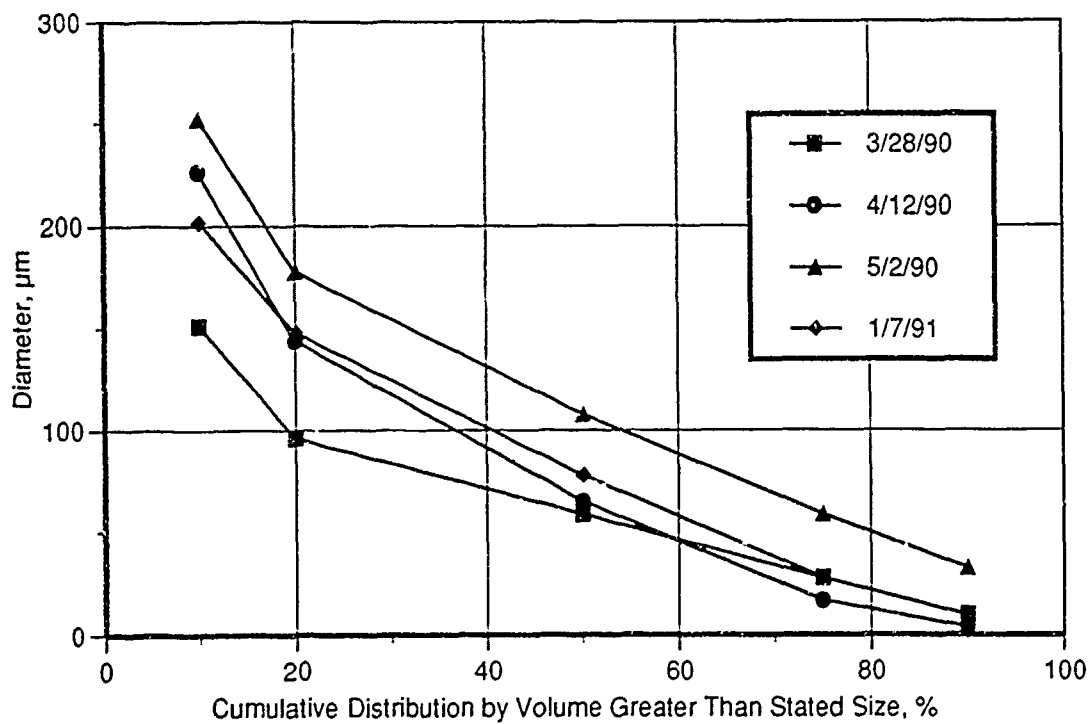


Figure 15. Distribution of Volume Data.

These data show that a filter bag mesh size on the order of 50 to 100 μm would remove a majority of the volume of particles that eventually constitute the sludge. A smaller mesh size, on the order of 1 μm , would be required to remove a majority of the particles. Because these analyses were performed on a sludge sample, these data apply to particles that eventually form the sludge on the tank bottom, the data do not describe the requirements for removing dissolved solids or solids that remain suspended in solution.

5.6.2 Settling Test

Through the combined effects of the sampling equipment and the sampling method, very little solid material was collected for the settling test. The sampled alkaline paint-stripping solution was cloudy and brown and a thin layer of fine solids had collected at the bottom of the graduated cylinder. Also, a thin oily layer appeared on top of the alkaline paint-stripping solution. Each layer was less than 1 mm thick, and the layers occurred within 1 minute after the test was begun.

5.6.3 Filter Bag Collection Efficiency

Several filter bags were used in the testing and operating phases of the filtration system. A sample of these bags was analyzed to estimate the quantity of solid material removed from the bath. Upon blinding, some types of filter bags must be disposed of, whereas others may be reused. Bag disposal increases the quantity of hazardous waste generated by the process.

A convenient method of expressing the filter bag collection efficiency is in terms of pounds of solids removed from the bath per pound of filter bag material ($\text{lb}_s/\text{lb}_{bm}$) that must be disposed of as waste. During the test program, it was noted that mesh bags had to be disposed of upon blinding, whereas monofilament bags could be emptied and reused.

Several blinded mesh bags of differing sizes were analyzed to determine their solids removal efficiency. The quantity of solid material in each bag was determined by weighing both a blinded bag and an unused bag of the same micrometer rating.

With this methodology, mesh filter bags were capable of collecting between 1.0 and 3.6 lb_s/lb_{bm} when used to filter the alkaline paint-stripping solution, whereas monofilament bags were capable of collecting approximately 5.3 lb_s/lb_{bm}. Monofilament bags were capable of collecting greater than 74 lb_s/lb_{bm} when used to filter the sludge layer. Also, the monofilament bags could be emptied and reused.

Based on observations made while the system was operated with monofilament bags, the filter bags were used more than 20 times without requiring replacement. Because the original bags used during the testing phase were still usable at the end of testing, the operational life of these bags could not be determined.

5.6.4 Centrifugation Testing

A liquid fraction from the alkaline paint stripper bath was obtained to evaluate the potential of centrifugation for removing the particulate generated. This testing was performed by a centrifuge equipment vendor using their standard procedures and equipment (Centrico, Inc., Northvale, New Jersey).

The results of the centrifugation test were inconclusive. Differences were noted between the solids content of the sample compared with laboratory results obtained during the preliminary waste characterization. This deviation is probably due to the methods used to collect the samples. The sample submitted for centrifugation was collected at the surface of the alkaline paint stripper bath. Because of the high density of the solids compared with that of the solution, the particles quickly settled to the bottom of the bath. The test results (presented in Appendix C) indicated there was very little solid material in the sample. After centrifugation, an oily layer was noted at the top of the sample. The vendor indicated some concern about possible erosion of their equipment due to the presence of sand and gritty material in the stripping solution.

SECTION 6

EVALUATION

During the installation and operation of the particulate filtration system on the alkaline paint stripper, several observations were made pertaining to the equipment and materials used in the construction of the system. These observations are summarized in this section. Based on the operational experience gained on the filtration system, information pertaining to the maintenance of the system is also presented.

This section also includes the results of the research conducted on bath chemistry, which was conducted to predict the effect of the filtration system on the alkaline paint stripper operation. Based on this information and the experience gained during the operation of the filtration system, additional testing is proposed. Specifics of this additional testing are presented herein.

6.1 SYSTEM COMPONENTS

A summary of the equipment components associated with the particulate filtration system was presented in Table 3. Specific discussions pertaining to these components are presented in the following subsections.

6.1.1 Control Panel

The control panel has provided adequate service to date; however, because of the operation of the progressing cavity pump during unstable conditions (large air pockets in the filter housing that must be vented) and the placement of the control panel on the filtration skid, control panel vibrations are noticeable at times. LEAD may consider adding braces to the control panel to control these vibrations, even though they are not expected to cause any operational problems.

6.1.2 Filter Bags

Several problems developed pertaining to the filter bag materials of construction. A product bulletin recommended polyester bags for this application, however,

these bags were not capable of providing adequate service under the combination of temperature and chemical conditions. A bag would begin to disintegrate after 15 to 20 minutes of services. Only 5- μ m polyester filter bags, which blinded within 5 minutes, could be effectively evaluated in the filtration system.

The manufacturer of the filter bags was contacted to discuss the materials compatibility problems. Based on additional information provided by the manufacturer, nylon was determined to be a more appropriate material for the bags.

The replacement nylon filter bags were not affected by the alkaline paint-stripping solution; however, the polyester thread used to sew the filter bags was, and the bags opened up along the seam after a few minutes of service. When nylon bags sewn with nylon thread were obtained, no problems occurred. Future orders of the filter bags should specify both the bag and thread materials. Consideration should also be given to the compatibility of chemicals other than sodium hydroxide with the filter bag and thread materials.

6.1.3 Filter Housings/Baskets

Originally, welded O rings were supplied with the filter housings. All of the original O rings on the filter baskets and in the filter housing groove failed at the welded seam. This problem was solved by replacing the welded O rings (with seams) with molded O rings (no seams). No problems have been encountered with the molded O rings. During the upgrading of the flange gaskets, all of the O rings were changed over to Teflon.

During the startup phase, the welded seam of a filter basket screen opened up 3 or 4 in. during the filtering of the sludge layer of the alkaline paint-stripping solution. This was caused by an overpressure condition that resulted from starting the filtration system with a blinded filter in one filter housing. The overpressure condition occurred during startup, before the 10-second high-pressure control switch time delay had expired. This incident demonstrated the need for a backup high-pressure relief valve (which was later installed). The damaged filter basket was repaired and returned to service. No filter basket problems have since occurred, and the repaired basket has

provided adequate service. Nevertheless, a spare filter basket was purchased for LEAD.

When the filtration system entered the LEAD operational mode (Phase 4), problems occurred with the bolts used to secure the lids of the filter housings. The bolt material of construction was cadmium-plated carbon steel, which was inadequate for this service. As the cadmium plating wore off the threads, the carbon steel bolts corroded when they came in contact with the strong alkaline solution. This problem was solved by replacing the stripped bolts with stainless steel bolts (as specified in the Filtration System RFQ). Since the repairs, no problems have been recorded.

6.1.4 High/Low-Pressure Cutoff Valve

The high/low-pressure cutoff switch performed as designed. During operation of the filtration system, however, it was noted that an overpressure condition could occur before the 10-s time delay had expired. This time delay had been built into the control system to allow starting the equipment without the pump shutting off immediately because of low pressure. This problem was solved by installing a pressure relief valve. This valve provided a backup system in case of a control switch failure and to prevent the occurrence of overpressure conditions before the 10-s time delay of the high-pressure cutoff switch expires.

6.1.5 Pressure Gauges

All of the original pressure gauges developed problems and had to be repaired. The first (PI-01) and third (PI-03) gauges developed significant gauge reading offsets. The second pressure gauge (PI-02) began leaking silicone oil and would not function. These gauges were disassembled and inspected. The first and third pressure gauges had been overpressured and were replaced. The cause of this overpressure was eliminated by installing a backup high-pressure relief valve. The second pressure gauge (on filter housing F-102) had been tampered with or damaged. A small amount of silicone oil was leaking from the threaded connection between the pressure gauge

and the diaphragm seal. The gauge was removed and repaired by reestablishing the seal isolating the pressure gauge from the alkaline paint-stripping solution.

At the end of this project, LEAD engineers indicated that the pressure gauges were malfunctioning and that the pressure readings appeared too low. LEAD has suggested that solids may be building up on the diaphragms of the gauges. Depot engineers plan to specify flange-mounted gauges to solve this problem.

6.1.6 Pressure Relief System

Because of the overpressure problems that occurred during the shakedown and operational phases of this project, a backup high-pressure relief system was installed. This system consists of a spring-loaded pressure relief valve located at the pump discharge. If the pressure exceeds the 130-psig setting of the valve, the valve will open and return some or all of the pump discharge back to the pump suction. This will immediately eliminate the high-pressure condition. The valve automatically closes after the high pressure is dissipated. The high/low-pressure cutoff valve is designed to shut down the pump at a pressure of 100 psig. Therefore, after the pressure relief system decreases the pressure to below 130 psig, the pump will be shut down after the 10-s time delay expires if the cause of the increased pressure has not disappeared. This design allows the temporary reduction of pressure to avoid equipment damage, while still shutting off the pump to notify the equipment operator of a malfunction that can then be identified and corrected. The pressure relief system is also effective in controlling short-duration pressure surges without causing the system to shut down. This system is also useful as an emergency backup in the event that the pressure gauge for the high-pressure cutoff valve malfunctions.

During operation of the filtration system, the pressure relief system has performed as expected; however, during pressure testing of the filtration system (to test for system leaks), the relief valve leaks slightly through the packing house when a high pressure is applied to the valve discharge, which never occurs during its operation. This is not considered a problem and will not affect the performance of the filtration system or the high-pressure relief valve.

6.1.7 Process Piping/Flange Gaskets

No process piping problems were noted during operation of the filtration system. During installation of the high-pressure relief valve, however, the pump suction piping was examined, and a significant buildup of sludge had occurred in the pipe section between the filtration system suction line in the tank and the suction valve (V1). This resulted from the system sitting idle while the bath solids settled in the pipeline. Although this is not expected to happen when the filtration system is operating, this pipe should be suspected if unexplained low-flow problems occur.

Neoprene flange gaskets were initially used on the particulate filtration system. During the LEAD initial operational phase of this project, a flange gasket developed a leak. Examination of several neoprene gaskets indicated that they had been subjected to severe chemical attack. The neoprene gaskets were replaced with Teflon gaskets, although a review of the materials compatibility indicated that both Teflon and neoprene are recommended for this service. No problems have been observed since the Teflon gaskets were installed. As discussed earlier, there is speculation that the original gaskets may not have been neoprene.

6.1.8 Progressing Cavity Pump

Problems developed with the progressing cavity pump before its delivery to LEAD. A weld on the pump leaked, and the pump had to be returned to the manufacturer for repair. This proved to be a manufacturing defect, and it is not expected to be a recurring problem.

Since the pump was repaired, it has demonstrated its ability to circulate the alkaline paint-stripping solution and sludge mixture. The pump flow rate was determined by using a nonintrusive flowmeter (based on sound waves). Measurements indicated this flow varies between 48 and 54 gallons per minute at a pressure up to the high-pressure shutoff point of 100 psig. The pump was also shown to be capable of pumping the concentrated sludge with no problems.

During the test program, several operational characteristics of the pump were noted. Vibrations generated by the pump during the startup phase of the project

caused the pump shaft to become out of alignment. This problem was due to either loose pump and drive mounting bolts or improper shaft alignment of the pump. The problem was aggravated by the lack of a flat surface where the skid was located. This problem eventually caused the pump drive couplings to "slip." To prevent this problem from recurring, the skid was leveled and the pump shaft was realigned. Since this realignment, no problems have occurred. It was also found that venting trapped air from the filter housings significantly reduced the vibration of the system.

During realignment of the gear reducer coupling, the grease seal on the pump shaft was found to be damaged. This probably occurred when the pump was being repaired. No problems occurred when the system was run without the seal; however, the seal should be replaced by the system manufacturer or LEAD.

A potential operational problem was identified during the weekly shutdown and cleaning of the progressing pump if the pump is left unattended. After the pump is operated for an extended time, a layer of sludge will collect between the pump rotor and stator. This is a normal occurrence inasmuch as the system may pump a high-sludge liquid stream. If the system is not scheduled to operate for more than a day, this sludge probably should be purged from the pump. During the shakedown phase, a procedure was developed to address this issue. Jogging the pump for 5 seconds while the fresh-water line valve (V8) is open and the suction line cutoff valve (V1) is closed effectively purges the sludge from the pump. Once the sludge has been removed, fresh water will flow freely into the first filter housing (F-101) even with the pump off. This flow can be observed by removing the filter housing cover and viewing the inlet line (while the pump is off). LEAD engineers noted, however, that in Phase 5 of the project, despite a long shutdown and the accumulation of a large amount of undissolved reagent in the pump, the pump was started and operated without problems.

6.1.9 Valves

The sample valve after filter housing F-102 (V12) was observed to be leaking alkaline paint-stripping solution. Also, the bypass valve after filter housing F-101 (V8)

had begun to leak. Both valves were disassembled and examined. Apparently, these valves had been subject to overpressure. No materials compatibility problems were evident. The valve seals were replaced and the valves reassembled. No other valve problems have been noted.

6.2 BATH CHEMISTRY

Information was collected to define the chemistry of the paint-stripping process. The information was collected from the open literature and from work conducted to determine the original alkaline paint stripper composition (Spencer, 1962; Kolene Corporation, undated; Durney, 1982).

One of the objectives of the Test Plan was to observe and correlate any changes in the bath chemistry associated with the use of the particulate filtration system. Specifically, the amounts of sodium hydroxide, sodium gluconate, and water added to the bath were to be measured during the test program.

The concentrations of sodium hydroxide and sodium gluconate and the solution-specific gravity are measured weekly by the LEAD laboratory. Each of these parameters has a target value that was established in the original specifications and by operating experience. The results of these tests are used to determine the amount of any of these materials that must be added to the bath to stay within the acceptable range. Currently, trace alkaline paint-stripping chemicals are not monitored.

Although it was not demonstrated during testing, a decrease in the amount of sodium hydroxide added to the bath should be noted. As discussed in Section 2.2, during paint removal the sodium hydroxide reacts with the paint binders in a typical saponification reaction (ESE, 1990a). As this occurs, the sodium hydroxide is consumed in the reaction.

During testing, sizable (1/4 in. to >1 in. across) pieces of paint coating were found to be mixed in with the sludge that was removed from the filter bags. This indicated that the paint coating was removed from the parts in relatively large pieces and subsequently sank to the bottom of the alkaline paint stripper bath. Because the

coating was still in the solution, it continued to react and consume the sodium hydroxide.

The filtration system has the ability to remove the pieces of paint coating from the bath before they react to fine particles; therefore, less sodium hydroxide should have to be added to the bath. The mechanical problems with the filtration system prevented quantitative results from being obtained.

The other bath parameter that was to be tracked during system testing was the quantity of sodium gluconate added to the bath. Based on a report supplied by LEAD personnel, operation of the particulate filtration system is not expected to cause a significant reduction in the amount of sodium gluconate added to the bath. Based on the data presented in the Army report (see Appendix E), sodium gluconate is thermally unstable and decomposes with time. The report provided a correlation between the rate of decomposition and temperature. As shown in Figure 4 of Appendix E, the decomposition of sodium gluconate increased significantly as the temperature approached the boiling point of the solution. No plan existed to change the bath temperature during the filtration testing; therefore, the consumption of sodium gluconate was not expected to change significantly as a result of removing the paint sludge from the bath.

This same report examined the effect of temperature on the corrosion-removing performance of various formulations. Table 7 of Appendix E summarizes the results of this work. The table indicates that the solution temperature has a strong influence on corrosion removal. Therefore, lowering the bath temperature to reduce the depletion of sodium gluconate may be at the expense of effective corrosion removal.

In addition to the major alkaline paint stripper components (sodium hydroxide and sodium gluconate), several trace compounds are included in the solid alkaline paint stripper. These trace compounds play a significant role in controlling the bath chemistry. No baseline analyses were performed to characterize the decomposition of these trace alkaline paint stripper chemicals. A summary of the trace compounds included in the solid alkaline paint stripper, the purpose, and the recommended solution concentration are included in the Draft Assessment Report, Appendix B (ESE,

1990a). Currently, LEAD adds only sodium hydroxide and sodium gluconate to rejuvenate the bath. Two rejuvenating additives are available that contain sodium hydroxide and trace compounds (Type I - Corrosion Removing Compound) or sodium gluconate and trace compounds (Type II - Rejuvenating Additive) (ESE, 1990a). These additive mixtures may be preferred as a means of resupplying trace compounds to the alkaline paint stripper bath.

The filtration system is expected to have the added benefit of decreasing the amount of chemicals used in the bath. Both the LEAD operators and engineers are aware that a significant quantity of chemicals added to the bath do not go into solution; however, the amounts have never been quantified. Because of lack of agitation, the solid alkaline stripper sinks to the bottom of the tank and becomes part of the sludge layer. This happens during initial makeup of the solution and when material is added over the life of the bath. During the makeup of the last fresh bath, the filtration system was used (without filter bags in the housings) to dissolve the chemical solids more rapidly and completely. Overall, this will lead to more effective use of the chemicals added and a reduction in the amount of chemicals added to keep the measured bath parameters at the same level. When Tooele Army Depot replaced its solid paint stripper with a stripper packaged in a liquid form, personnel noted an increase in tank life, perhaps in part due to less undissolved reagent. Reducing undissolved solids by better mixing may also extend tank life.

6.3 MAINTENANCE OF THE PARTICULATE FILTRATION SYSTEM BY LEAD

Several components on the particulate filtration system will require routine maintenance. The lubricant in the progressive cavity pump gear reducer should be replaced when the system is repaired. Afterwards, the gear reducer lubricant should be checked every 2,000 hours of operation (or every 6 months). The gear reducer lubricant should be replaced once a year. The pump bearings should be lubricated every 5,000 to 10,000 hours of operation. The Operations and Maintenance Manual provided with the filtration system should be consulted for additional routine

maintenance (APT, Inc., 1990). All other system components should receive routine maintenance in accordance with LEAD standard procedures. The pump manufacturer should be contacted to establish some level of support through the factory or nearest representative.

In addition to the routine scheduled maintenance, LEAD personnel should regularly inspect the equipment for leaks or malfunctioning equipment. This includes flange gaskets, pump packing, and filter housing O rings. The valves should be pressure-tested weekly to prevent leaks.

6.4 EXPECTED RESULTS, PERFORMANCE, AND BENEFITS

Based on the research conducted to date, the following performance objectives and benefits are expected from operating the particulate filtration system on the alkaline paint stripper bath. The system will reduce or eliminate the formation of a sludge layer in the alkaline paint-stripping tank. Because sludge layer thickness is one of the parameters used to decide when to replace the paint-stripping solution, this should extend the bath life. Removal of the sludge layer and stripped paint should also have an effect on the bath chemistry. Information on bath chemistry presented in Section 6.2, however, suggests that sodium gluconate additions may not decrease with the use of the filtration system, but filtration may reduce sodium hydroxide depletion. Reducing the amount of solids drag-out on the parts will reduce carryout of absorbed liquid, reduce rinse time, and reduce contamination of rinse water. The tank operators have reported that since the filtration system has been operating, parts drag out significantly less solids and require much less rinse time.

The most noticeable effect on reduction in waste disposal will be the ability to remove the sludge without emptying the bath. The goal will be to dispose of six barrels of sludge per year while replenishing only the active ingredients in the solution. An additional benefit is the reduction in manpower traditionally needed to remove the sludge and the elimination of the hazards associated with going inside the tank.

The turbulence created by the system will help dissolve the alkaline paint stripper powder. LEAD personnel have noted that the tank turbulence and flow through the filtration unit is sufficient to reduce material floating on the solution's surface.

Also, with the application of the reusable monofilament nylon filter bags instead of mesh bags, fewer filter bags must be disposed of. None of the monofilament bags have been disposed of because of blinding; therefore the filter bags will not add to the volume of waste from the operation.

6.5 ADDITIONAL PERFORMANCE TESTING OF THE PARTICULATE FILTRATION SYSTEM

Because of mechanical problems with the particulate filtration system, performance testing was not completed. During startup and shakedown, the filtration system was demonstrated as being effective in the removal of particulates from the bath; however, a quantitative measure of this effectiveness could not be obtained. Therefore, additional testing should be conducted to determine the following:

- Change in the alkaline paint-stripping solution chemical usage and solution bath life when operating the filtration system
- Most effective filter bag combination to collect particulate from the alkaline paint-stripping solution
- Most efficient filter bag to collect the particulate in the sludge layer
- Effective life of the monofilament bags
- Effectiveness of monofilament bags below 200 μm .

The effectiveness of the particulate filtration system should be measured by its ability to reduce/eliminate a sludge layer at the bottom of the tank and to effect a reduction in the chemical additions (e.g., sodium hydroxide and sodium gluconate). Additional research should be conducted to select the most efficient filter bags to operate the filtration system. The most efficient bags will be capable of removing a

large quantity of material without requiring frequent replacement or cleaning. This research should include using only reusable monofilament filter bags. Testing should also be conducted to quantify the waste collected from the alkaline paint stripper bath by the quantity of waste generated by the filtration system (i.e., blinded filter bags).

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Based on the results presented in Section 5 and the technical evaluation in Section 6, several conclusions can be drawn concerning the alkaline paint-stripping and filtration operations. Of the solid-liquid separation technologies evaluated, the pressure bag filter was determined to be the best choice, based on efficiency, cost, and operational simplicity, for removing the particulates generated in the alkaline paint stripper bath. Application of other particulate removal technologies was rejected because of technical limitations, size, or expense. Supplementary results obtained on centrifuging the alkaline paint-stripping solution and the nature of the paint-stripping operation eliminated the centrifuge option.

Based on the data collected and the observations made during the testing phase of the project, the pressure filtration system is capable of removing the solids from the alkaline paint stripper bath. Therefore, this system achieved one of the objectives of the project.

Mechanical problems that developed before and after installation of the filtration system prohibited obtaining quantitative results to prove that the system would extend the life of the alkaline paint stripper bath or reduce the sodium hydroxide usage.

Based on research previously conducted by the Army during the development of the alkaline paint-stripping operation, there is evidence indicating that the particulate filtration system will not significantly decrease the usage of sodium gluconate. Sodium gluconate decomposition is most strongly influenced by the bath temperature. The bath temperature should be kept as low as possible and still strip the paint and corrosion from the parts in the process. The bath should not be heated when no production is scheduled.

A review of the alkaline paint stripper bath chemistry and LEAD chemical addition procedures indicated that trace chemicals required for the stripping operation

were not added to the bath. Methods should be developed to measure the solution concentration of some trace compounds.

7.2 RECOMMENDATIONS

The recommendations presented herein are based on the data collected and observations made during the testing and operational phases of this project. They pertain to alkaline paint stripper bath operations, particulate filtration system operations, and the design and operation of future filtration systems.

Also presented are recommendations pertaining to additional testing of the existing system. The additional testing will provide quantitative evidence of the performance of the filtration system and identify which filter bags or filter bag combinations remove the greatest quantity of solids from the paint stripper bath without frequent bag changes.

7.2.1 Alkaline Paint Stripper System Operation

The particulate filtration system was designed to operate without continuous monitoring or requiring modifications in tank operation. Several alkaline paint-stripping operational practices, however, were noted to increase the efficiency of the filtration process and the life of the paint-stripping solution.

Based on on-site observations and discussions with the tank operators and supervisors, elevating the grates above the bottom of the bath is recommended as a means of increasing the turbulence generated by the return line of the filtration system. The grates should be elevated by welding legs to the bottom of the grates to allow increased flow across the bottom of the paint-stripping tank. The greater turbulence at the bottom of the tank should increase suspension of the sludge layer. It is recommended that additional operations be conducted to quantify the effect of increased turbulence on the sludge layer.

Starting the filtration process with a clean bath will allow the filtration system to remove the particulates from the bath as they are generated. Methods were developed during this project, however, to remove sludge accumulated over a period

of time. These methods would allow reclamation of a contaminated bath so that there is no need to dispose of a bath for the sole purpose of beginning operation of the filtration system on a fresh solution.

The paint stripper sludge layer should be measured on a weekly basis. If a sludge layer develops, the recommended sludge-raking procedures should be used to remove this material.

Based on a review of reports summarizing the original quantitative work and a review of LEAD operating parameters, changes in the chemical addition procedures are recommended. Currently, only sodium hydroxide and sodium gluconate are added to rejuvenate the alkaline paint stripper bath. LEAD should consider returning to the addition of the chemical additives recommended by the paint stripper vendor. These additives contain either sodium hydroxide or sodium gluconate and the trace compounds required for optimal bath operation.

7.2.2 Particulate Filtration System Operation

Based on the operational experience gained during the test phase, the following operational practices are recommended.

When a fresh alkaline paint stripper solution bath is made, the filtration system should be operating (without filter bags). The filtration system will increase bath turbulence, which increases the dissolution of the solid stripper.

The filtration process should be started with a clean bath to prevent or reduce sludge buildup. The alkaline paint-stripping solution should be filtered during the first and second shifts Monday through Friday (see Subsection 5.3.3). At the end of the second shift on Fridays and on the days preceding holidays, the filtration system should be shut down and cleaned. If a sludge layer begins to form on the bottom of the alkaline paint stripper tank, weekly raking should be conducted (see Subsection 5.3.2).

For filtering the alkaline paint-stripping solution, the following filter bag train is recommended:

- F-101 = 400 μm , F-102 = 100 μm , F-103 = 50 μm

If the amount of material in the filter bags decreases, the micrometer rating of the bags should be reduced to capture the smaller particles. This should be done in steps, and at least a week should be allowed between a change in the micrometer ratings of the bags. If a sludge layer forms in the bath, it should be removed on a weekly basis by the techniques discussed in Subsections 5.3.2 and 5.3.3. The sludge layer should be filtered through a single 400- μm filter in filter housing F-101.

It is recommended that nylon filter bags sewn with nylon thread be used to collect the particulate from the alkaline paint-stripping solution. This must be explicitly stated when ordering replacement bags. All bags should be monofilament rather than mesh. Although monofilament nylon bags of small micrometer rating are significantly more expensive than mesh nylon bags, the potential for their reuse may make this application economical.

Filter bags should be changed when the pressure drop of the system exceeds 100 psi or the high-pressure alarm sounds.

A regular maintenance program should be developed to service the particulate filtration system. The basis for this program was discussed in Section 6.3.

7.2.3 Design and Operational Recommendations for Future Particulate Filtration Systems

The design presented earlier in Section 3.2 with the proposed modification should serve as the basis of future designs. Figure 16 presents a process sketch of the proposed future particulate filtration systems for alkaline paint strippers. Sample valves need not be installed on future systems. These valves were installed only to collect samples to evaluate the performance of the filtration system during the test.

The 3/4-in. bypass piping should be enlarged to 2-in. piping. During the test program, it would have been convenient if a single filter housing could have been bypassed with the rest of the system remaining operational. It is also recommended that an additional bypass valve be moved onto the skid. The valve located after filter housing F-103 (see Valve V5 on Figure 13) should be moved (see Valve V5 on Figure 16).

The pressure gauges should be relocated on the piping. The present location leaves the gauges vulnerable to being struck while opening the filter housing or loosening the filter housing bolts. The pressure gauges should be placed horizontally on the vertical section of the pipe between the pipe and the filter housing (see Figure 17).

Additional support braces should also be installed on future systems to reduce vibration. Braces should be placed on the pipe before the first filter housing to the base on the filter skid. This last modification was added to the system at LEAD during the final phase of the work, and it significantly reduced the vibration.

7.2.4 Proposed Sampling Data Collection Techniques for the Existing System

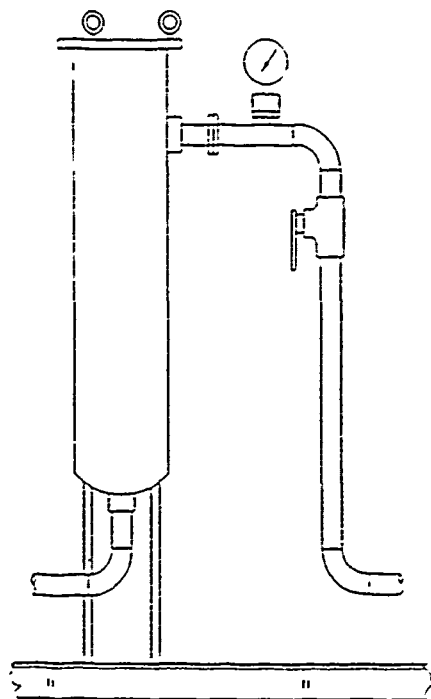
Changes should be made in the sampling techniques presented in Section 5.2 of the Test Plan. A long-handled ladle could be used to collect liquid samples. The representative samples and sludge samples should be discontinued because there will be no significant sludge layer to sample, and the large increase in the level of turbulence makes any stratification in the bath unlikely. A method of measuring the presence and depth of a sludge layer should be developed, however.

7.2.5 Additional Testing

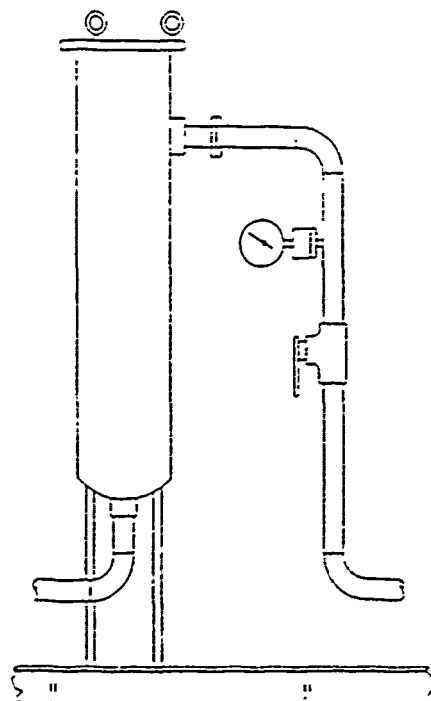
Because of the mechanical problems encountered during the test program, few quantitative data were obtained for evaluating the effect of the filtration system on the paint stripper characteristics and hazardous waste generation. A test program should be implemented that follows the procedures outlined in the Test Plan revised according to the experiences obtained during this project.

Chemical usage and bath life can be determined by evaluating the results of in-house laboratory analyses. These data can be compared with chemical usage and bath life data collected from past operations (without the filtration system).

The particle size distribution and total filterable solids should be determined before and after filtration of the alkaline paint-stripping solution with 400- μm , 200- μm ,



EXISTING CONFIGURATION



PROPOSED CONFIGURATION

3222-1-3

Figure 17. Proposed Change of Pressure Gauge Location on the Particulate Filtration System.

100- μ m, and 50- μ m filter bags. These measurements will help to specify a more efficient filter bag train.

Also, additional data should be collected to estimate the mass of bath waste collected per additional waste generated from the filtration process (i.e., disposal of filter bags). Additional research should be conducted to determine the operational life of the monofilament filter bags.

Long-term monitoring of the paint-stripping solution should be conducted to determine the filtration system's effect on the characteristics of the paint-stripping solution and to verify that the ultimate desired benefit of hazardous waste reduction is achieved.

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APPENDIX A

**PHOTOGRAPHS OF THE PARTICULATE FILTRATION
SYSTEM INSTALLED ON THE ALKALINE PAINT
STRIPPER AT LEAD**

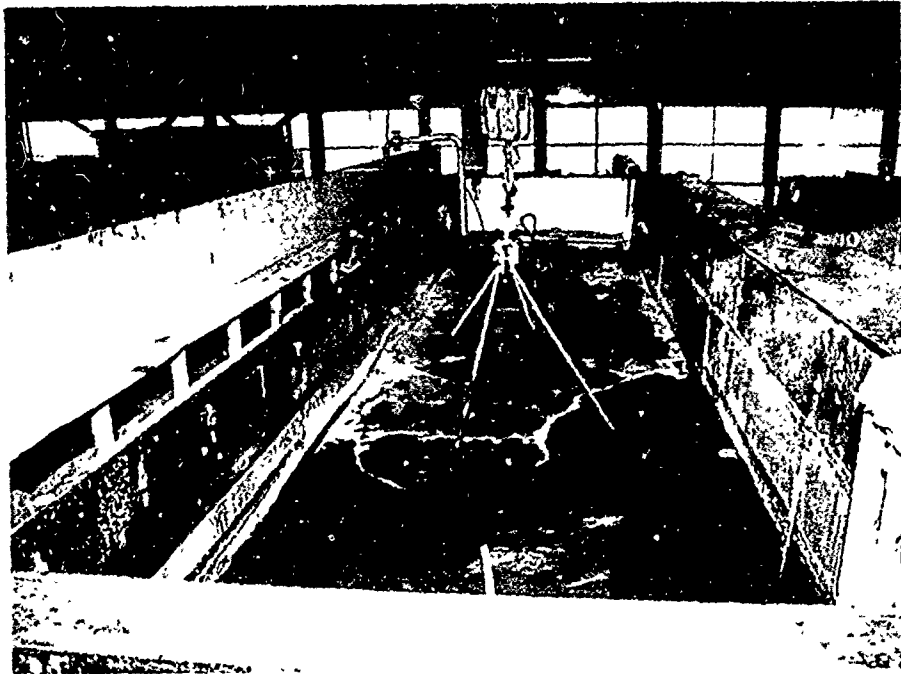


Figure A-1. Alkaline paint stripper bath. Note the particulate filtration system return line at other end of tank.

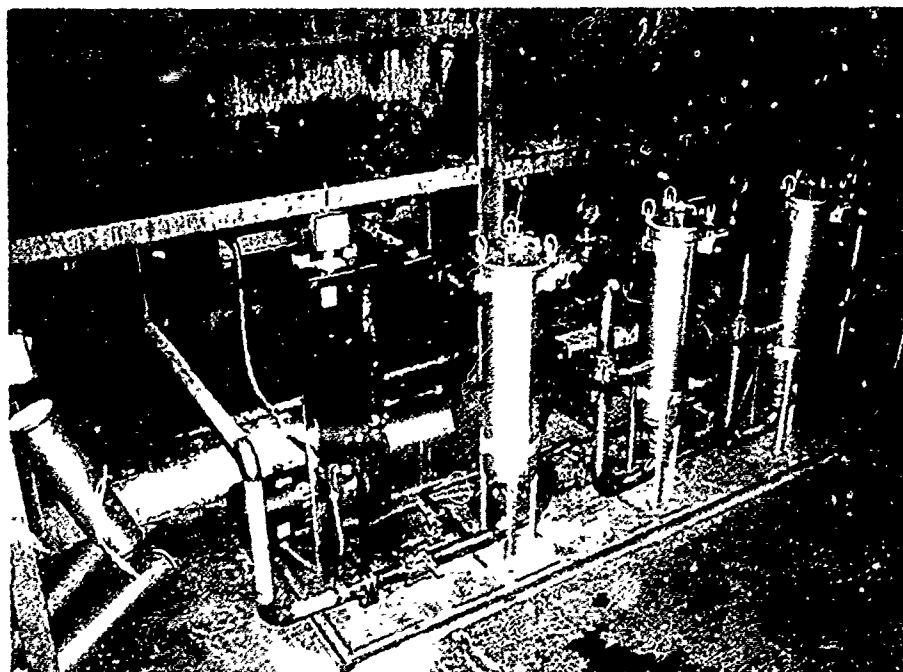


Figure A-2. Particulate filtration system.

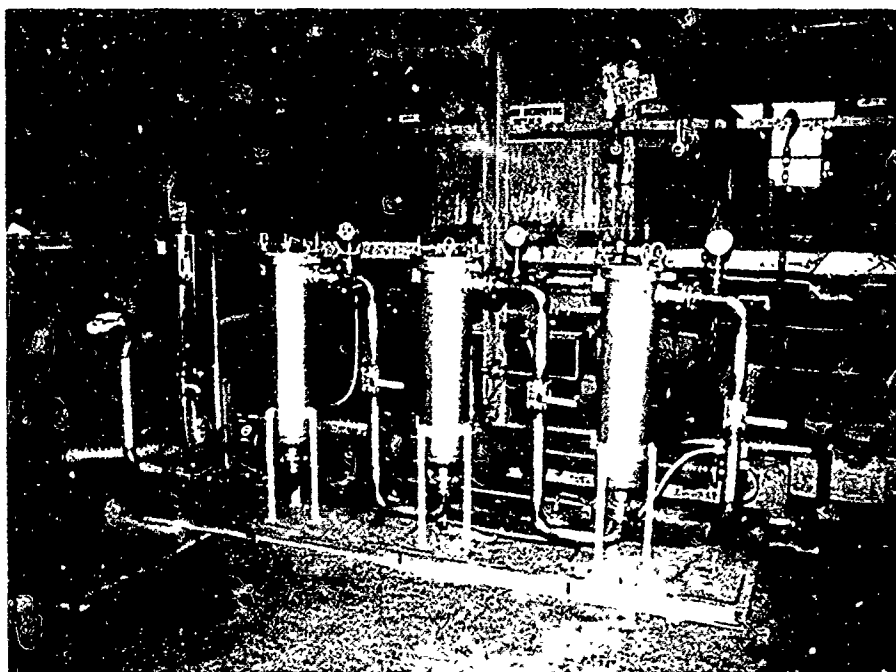


Figure A-3. Particulate filtration system and alkaline paint stripper bath.

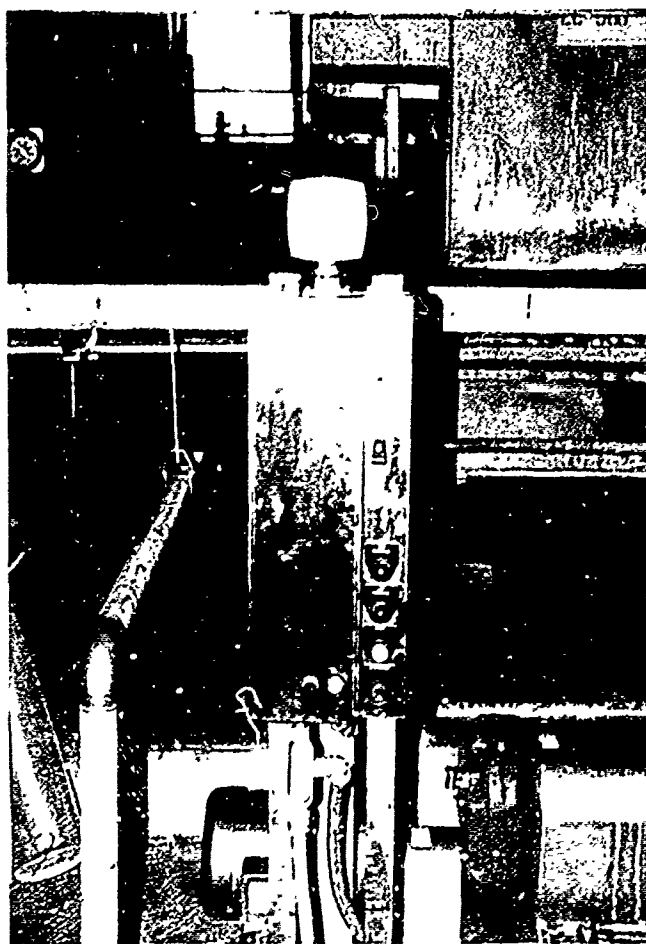


Figure A-4. Particulate filtration system control panel.

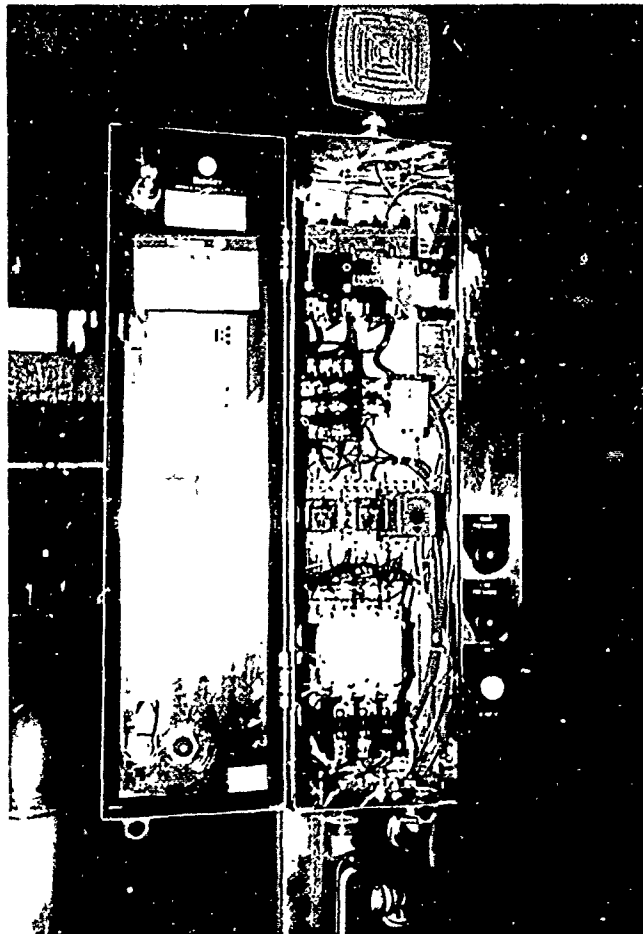


Figure A-5. Contents of the control panel.

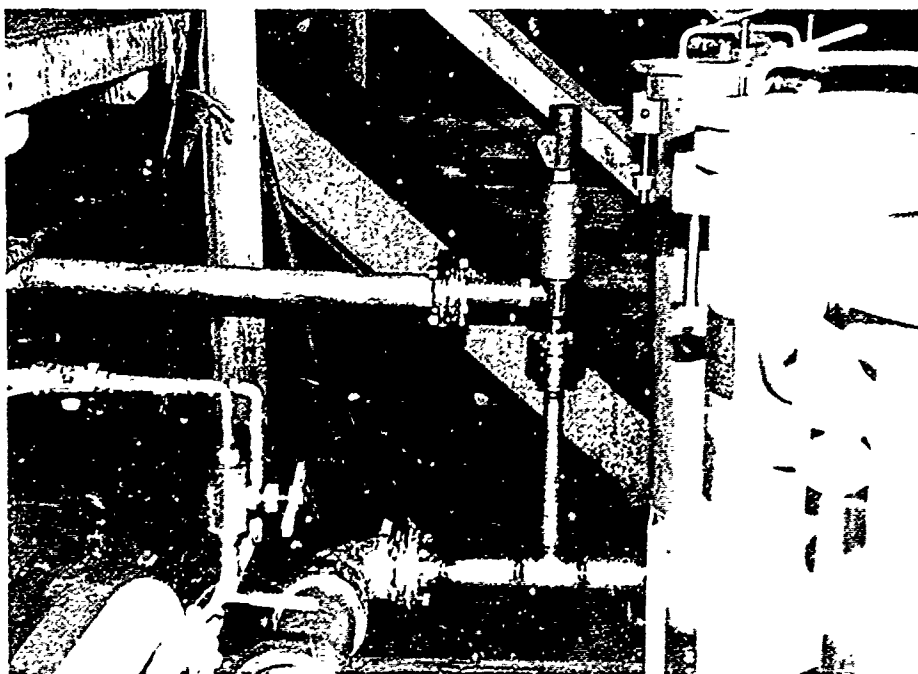


Figure A-6. Close-up of the high pressure relief valve.



Figure A-7. Particulate filtration system suction line with screen installed.



Figure A-8. Close-up of the particulate filtration system suction line without the screen.



Figure A-9. Particulate filtration return line with eductor.

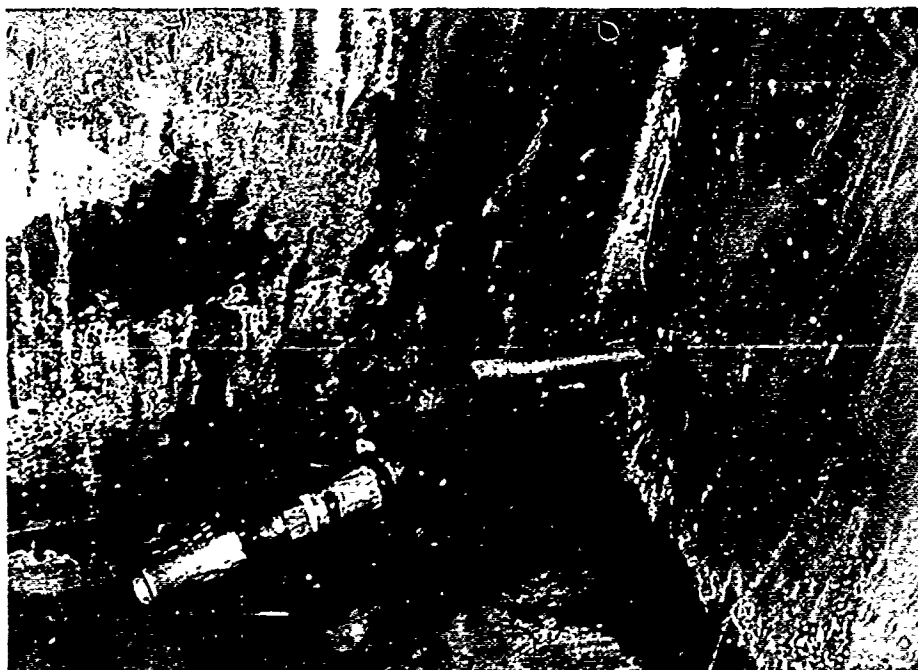


Figure A-10. Close-up of the eductor used to agitate the alkaline paint stripper solution.

APPENDIX B

**QUOTATIONS AND JUSTIFICATION
OF SELECTED VENDORS**



Environmental
Science &
Engineering, Inc.

MEMORANDUM

TO: Jeff Davis, PEI DATE: 9/19/90
cc: Lou Billelo, ESE
FROM: Jack Dunne, ESE
SUBJECT: FINAL QUOTATIONS AND RECOMMENDATIONS ON THE ALKALINE
STRIPPER PARTICULATE FILTRATION SYSTEM

This memorandum pertains to the final review and recommendation of the system vendor to construct the alkaline paint stripper bath particulate filtration system. Based upon a review of the quotations presented in Attachment #1, ESE recommends that APT be awarded the contract to construct the filter skid.

A summary of APT's proposed system is presented below:

Three (3) Strain Rite UF10180 304 ASME Code Bag Filters arranged in series with a three stage Roper progressive cavity pump. Each filter will have one bag (No. 2 type bag), installed. The bags will be 50 μ m, 5 μ m, and 1 μ m respectively.

The equipment will be mounted on a 304 stainless steel frame and include all stainless steel valves, flanges, mating flanges, gages, and diaphragm seals shown on the "Revision 1" process sketch. The frame size will be 4' wide X 10' long. There will be a NEMA 4X control panel which will include a motor starter, disconnects, start and stop push bottoms, HOA switch, and lights to indicate high and low system pressure. One day of training at APT Incorporated is included.

The price for this system is \$25,357 FOB Letterkenny Army Depot (LEAD), Pennsylvania. Delivery time is 5-6 weeks after receipt of purchase order.

Selection of APT is made based on the following criteria:

- lowest price
- shortest delivery time
- preferred filter basket design

- ship on company truck (better coordination with installation contractor)
- 3-stage progressive cavity pump

The remaining components are competitive with the other vendors (i.e. recognized brands). ESE prefers the wire mesh basket design rather than a perforated basket in the filter housing because there is more surface area available for filtration. Since APT will deliver the equipment with a company owned truck, APT can coordinate with the selected installation contractor and Letterkenny Army Depot to deliver the equipment to the facility.

ESE recommends that the number of additional filter bags to operate the system be determined and purchased separately from the manufacturer. This will allow LEAD to avoid the system vendor mark-up.

If you have any questions pertaining to the technical evaluation of the equipment or ESE's recommendation, please contact me.

Comparison of Vendor Quotes
for
Skid

Item	APT (Vendor 1)	Vendor 2	Vendor 3	Vendor 4
Materials of Construction	SS	Fiberglass	CS	CS
Paint/Coating	Not Required	Not Applicable	Red Oxide Primer, Industrial Enamel or Coal Tar Epoxy Enamel (see Option #6)	MAB Rust-o-lastic
Skid Dimensions (length, width, height), in feet	9'6"x4'x5'	8'x4'x6'	8'-10"x4'x5'	8'x4'x5'
Lifting Lugs (Yes/No)	No	No	Yes	Yes
Anchor Bolt Holes (Yes/No)	Yes	No	Yes	Yes
Spill Lip (Yes/No)	No	No	Option (see option #4)	Yes (around pump)
Open/Solid Skid Base (Open/Solid)	Partially Open	Open	Solid	Open Ended Bent Steel
Notes: • Provided drawing of shape of skid.				

Comparison of Vendor Quotes
for
System Specifics

Item	APT (Vendor 1)	Vendor 2	Vendor 3	Vendor 4
Assembled Equipment and Skid (Weight), lbs	2,200	1,800 estimated empty	3,200 estimated	2,000
Equipment Arrangement Sketch Showing Piping, Pump, Filter and Motor Starter (Yes/No)	Arrange in Any Method	Yes (upon placement of purchase order)	Yes	Yes ("CAD" print in 4 weeks)
Crating (Yes/No)	Not Required	Yes	No	Yes
Delivery Time, weeks	8	12 - 14	8 - 10	8 - 10
Period of Guarantee	1 year	1 year	1 year	1 year after start (18 months including shipping and storage)
Shop Testing	Hydrostatic, Flow and Functional	Operational and Functional	Hydrostatic	Hydrostatic
O & M Literature	--	Yes	3 sets	4 sets
Start-up/Training (Yes/No)	Yes (1 day at APT)	No	No (\$500/day trip)	Yes (one day)
Quote Analysis, Fair Pricing	--	Yes		Yes (as fair as possible)
Shipping Cost	APT truck, no cost	\$410	\$375	\$250

Comparison of Vendor Quotes for Pumps

Item	APT (Vendor 1)	Vendor 2	Vendor 3	Vendor 4
Pump/Motor Arrangement	..	In-Line Gear Motor	In-line gear motor	Gear Box Drive
Pump Body Material Construction	316 SS	316 SS	SS	316 SS
Pump Manufacturer	Moyno Model 2E012G1 2-Stage w/Gear Drive	Moyno Model 2E012G1 2-Stage w/Gear Drive	Moyno Model 2E012G1 2-Stage w/Gear Drive	Moyno Model 2E012G1 2-Stage w/Gear Drive
Pump Seal Method and Material	Packed	Packed	Packed	Packed
Pump Rotor Material of Construction	316 SS	316 SS	SS	316 SS
Pump Stator Material of Construction	EPDM	EPDM	EPDM	EPDM
Drive (gear/direct/hell)	Separate Gear Receiver	Eurodrive Gear Motor	Direct Gear Motor	Gear
Pump Flanged Inlet/Outlet	Yes	..	Yes: 4"	4x4 flanged
Pump Speed, rpm	460	462	450	350
Motor Manufacturer	Marathon	Eurodrive	Pump Vendor Choice	Balder or Marathon
Motor Voltage	460 V	230/460 V, 3 phase	3-phase, 60 Hz, 230/460 V	230/460 V
Motor Horsepower (hp)	7.5	5	7.5	7.5
Type of Motor (TEFC/Drip Proof)	TEFC	TEFC	TEFC	TEFC
Motor Speed, rpm	3,500	1,725	1,700	1,750
Notes: • 1 overjaw Coupling				

Comparison of Vendor Quotes for Valves/Piping

Item		APT (Vendor 1)	Vendor 2	Vendor 3	Vendor 4
2" Process Valves	Valve Type	3 piece	3 piece, SS, Full Port, 800 lb wgt	Ball Valve, Socket Weld, 3 piece	Ball
	Manufacturer	FlowTech	NIBCO #K595-56R-66	AVCO	Jamesbury
	Seal and Seat Materials	PTFE Seal Seats, PTFE w 15% Glass Fiber	Reinforced TEF with 316 SS Trim	Teflon	Teflon
	Connection (welded or flanged)	Welded	Welded	Welded	Welded
	Materials	SS	SS	316 SS	316 SS
1/2" Sample/ Drain/Vent Valves	Valve Type	3 piece	3 piece, SS, Full Port, 800 lb wgt	Ball Valve, Socket Weld, 3 piece	Ball
	Manufacturer	FlowTech	NIBCO #K595-56R-66	AVCO	Jamesbury
	Seal and Seat Materials	PTFE Seal Seats, PTFE w 15% Glass Fiber	Reinforced TEF with 316 SS Trim	Teflon	Teflon
	Connection (welded or flanged)	Welded	Welded	Welded	Welded
	Materials	SS	SS	316 SS	316 SS
Sample/Drain/Vent Valve Open Connections (threaded/flanged/socket)	Welded				
	Yes				
	Yes (socket weld)				
Suction Line 2" Valve, Llave		Yes	Yes	Yes	Yes

Comparison of Vendor Quotes
for
Valves/Piping
(Continued)

Item	APT (Vendor 1)	Vendor 2	Vendor 3	Vendor 4
Pump Reducer Flanges	--	Yes	Yes	Yes
Pipe Flange Gasket Materials	As Required	Viton	Non-Asbestos	Non-Asbestos
Pipe Materials/Schedule	304 SS Pipe and Frame, Schedule 40	304 SS, Schedule 40	304L SS, 2" Schedule 40, 1/2" Schedule 80	SS
Notes: * Includes safety relief valve.				

Comparison of Vendor Quotes
for
Electrical/Instruments

Item	APT (Vendor 1)	Vendor 2	Vendor 3	Vendor 4
Motor Starter Manufacturer	Westinghouse	Furnas	Westinghouse or (GE)	Westinghouse
Motor Starter Disconnect, Located on Skid	Yes	Yes	Yes	Yes
Manufacturer of Pump Push Button	--	Furnas	Westinghouse or (GE)	Westinghouse
Hi/Low Pressure Switch Manufacturer	Ashcroft GPDN4GGB25	United Electric	United Electric with Diaphragm Seal	Westinghouse
Hi/Low Pressure Switch Set Points	-- (Variable)	10 - 110 psi	10 - 125 psi (10 falling, 125 rising)	Variable-Field Adjustable
Prewired Motor/Push Button/Pressure Switch	--	Yes	Yes	Yes
Time Delay for Pump Start	Yes	Yes (0 - 155)	Yes (minimum run timer)	No
Description of Lights/Alarms	Run, under/over pressure	Hi/Low Pressure Alarm with Shut Down	--	None
Enclosure Class (i.e., NEMA 4)	NEMA 4X	NEMA 4X	NEMA 4	NEMA 4
Manufacturer	Ashcroft	U.S. Gage	Solfrunt/Ametek	Ashcroft/WIKA
Model #	Type 1009	4 1/2" Series 1980	550L w/RB Diaphragm Seal	Liquid Quart Filled with Diaphragm Seal
Type	Seal Type 100	4 1/2" Diameter Filled with SS Diaphragm Seal	4 1/2" Diameter Filled with SS Diaphragm Seal	Liquid Filled Barrier Gauge
Connection, (welded/flanged/threaded)	Threaded	1/4 MNPT Threaded	1/4" Threaded	Threaded
Pressure Range	0 - 200 psi	0 - 200 psi	0 - 200 psi	0 - 200 psi

Comparison of Vendor Quotes
for
Filters

Item	APT (Vendor 1)	Vendor 2	Vendor 3	Vendor 4
Filter/Basket/Bags Manufacturer	UP Strain Rite UF 1-180	UP Strain Rite UF 1-180	Rosedale 820-2F-3-150C-ST513	American Felz and Filter Company
Materials of Construction	304 SS	304 SS	304 Ss	316 SS
Housing Size	11=56", D=8%"	8%-OD, 33 1/2" High	8 - 30	7"x17"
In/Out Arrangement	Side In, Bottom Out	2" SS Flange	Topside In, Bottom Elbow Out	2" 150 lb Flange
Vent Connections	Yes	Yes (1/4")	Yes	Yes
Flanged Connections	Yes (2")	Yes	Yes	Yes
Gasket Materials	--	Neoprene	Teflon Encapsulated	Viton
Method of Filter Housing Support (i.e., Legs)	Legs	Legs (adj.)	Legs	Legs (adj.)
Method to Close Filter Housing	Flat Lid, o-ring	Swing bolts	Eye nut	wing nuts
Bag Materials	Polyester	Polyester	Polyester Felt	Polyester
Replacement Bags (quantity for each filter)	10	1	2 (100 with option)	50
Optional Cost	50 µm: \$6/bag 5 µm: \$8/bag 1 µm: \$12/bag	\$3.48	50 µm: \$3.59/bag 5 µm: \$3.59/bag 1 µm: \$3.95/bag	\$3.50 each per 50 bags
Basket Type and Mesh	304 SS	304 SS	304 SS Perforated SS (9/64 Diameter Holes)	316 SS
Code	ASME	ASME	ASME	ASME with stamp

APPENDIX C

**LABORATORY RESULTS OF SAMPLING OF
THE ALKALINE PAINT STRIPPER BATH**

22

Lancaster Laboratories

INCORPORATED

2510 Hamilton Road, Cincinnati, OH 45246-4098 (513) 651-4200

IT Environmental Programs, Inc.
11499 Chester Road
Cincinnati, OH 45246-4098

LTI Sample No. WU-1620398

Date Reported 1/29/91
Date Submitted 1/11/91
Discard Date 2/ 6/91
Collected 1/ 7/91 by JM
Time Collected 1615
P.O. 6287-3769-4-B
Rel.

Letterkenny-Filtration System #7 Liq Frac Sample

ANALYSIS	RESULT AS RECEIVED	LIMIT OF QUANTITATION	LAB CODE
pH	13.2	0.01	020000700

1 COPY TO IT Environmental Programs, Inc. ATTN: Mr. Jeff Davis
1 COPY TO Environ. Science & Engineering ATTN: Mr. Jack Dunne

The American Association for
Laboratory Accreditation
Chemical, Biological & Environmental
Fields of Testing



Member American Council of
Independent Laboratories, Inc.



Questions? Contact Environmental
Client Services at (717) 656-2301
126 06130 0.00 000700

See Reverse Side For Explanation
Of Symbols And Abbreviations And
Our Standard Terms And Conditions

Respectfully Submitted
Lancaster Laboratories, Inc.
Reviewed and Approved by:

Bethany A. Ebling, B.S.
Group Leader, Water Quality

ELI Sample No. ~~WW-1620396~~
 Date Reported 1/29/91
 Date Submitted 1/11/91
 Discard Date 2/ 6/91
 Collected 1/ 7/91 by JM
 Time Collected 1615
 P.O. 6287-3769-4-B
 Rel.

LIMIT OF
QUANTITATION LAB CODE
 144301000

RESULT
AS RECEIVED

see below

This sample consisted of two phases. The specific gravity of the phases is as follows: upper phase - 1.41

is as follows: upper phase - 1.41

lower phase - 1.66 g/cc (solid)

1 COPY TO IT Environmental Programs, Inc. ATTN: Mr. Jeff Davis
1 COPY TO Environ. Science & Engineering ATTN: Mr. Jack Dunne

Questions? Contact Environmental
Client Services at (717) 656-2301
126 06130 0.00 001000

Respectfully Submitted
Lancaster Laboratories, Inc.
Reviewed and Approved by:

Bethany A. Ebling, B.S.
Group Leader, Water Quality

The American Association for
Laboratory Accreditation
Chemical, Biological & Environmental
Fields of Testing



Member American Council of
Independent Laboratories, Inc.



See Reverse Side For Explanation
Of Symbols And Abbreviations And
Our Standard Terms And Conditions

Lancaster Laboratories

INCORPORATED

06-52-06
12-15-78

IT Environmental Programs, Inc.
11499 Chester Road
Cincinnati, OH 45246-4098

LI- Sample No. - WW-1620397
Date Reported 1/29/91
Date Submitted 1/11/91
Discard Date 2/ 6/91
Collected 1/ 7/91 by JM
Time Collected 1615
P.O. 6287-3769-4-B
Rel.

Letterkenny-Filtration System #6 Liq Frac Sample

ANALYSIS	RESULT	LIMIT OF	LAB CODE
Specific Gravity/Bulk Density	AS RECEIVED 1.33	QUANTITATION 0.01	144301000

By this method specific gravity only applies to liquids and is reported without units. Solids or semisolids, having air spaces present in the bulk sample, are determined as bulk density in g/cc units.

1 COPY TO IT Environmental Programs, Inc. ATTN: Mr. Jeff Davis
1 COPY TO Environ. Science & Engineering ATTN: Mr. Jack Dunne

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126 06130 0.00 001000

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Respectfully Submitted
Lancaster Laboratories, Inc.
Reviewed and Approved by:

Bethany A. Ebling, B.S.
Group Leader, Water Quality

Lancaster Laboratories

INCORPORATED

IT Environmental Programs, Inc.
11499 Chester Road
Cincinnati, OH 45246-4098

LLI Sample No. WW-1620375

Date Reported 1/29/91
Date Submitted 1/11/91
Discard Date 2/ 6/91
Collected 1/ 7/91 by JM
Time Collected 1615
P.O. 6287-3769-4-B
Rel.

Letterkenny-Filtration System #1 Represent Sample

ANALYSIS	RESULT AS RECEIVED	LIMIT OF QUANTITATION	LAB CODE
Total Solids	636,000. mg/l	100.	020301200
This sample was analyzed past the 7 day hold time for total solids.			
Total Dissolved Solids	493,000. mg/l	100.	021201500
This sample was analyzed past the 7 day hold time for total dissolved solids.			

1 COPY TO IT Environmental Programs, Inc. ATTN: Mr. Jeff Davis
1 COPY TO Environ. Science & Engineering ATTN: Mr. Jack Dunne

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Chemical, Biological & Environmental
Fields of Testing



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Independent Laboratories, Inc.

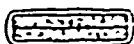


Questions? Contact Environmental
Client Services at (717) 656-2301
126 06130 0.00 002700

See Reverse Side For Explanation
Of Symbols And Abbreviations And
Our Standard Terms And Conditions

Respectfully Submitted
Lancaster Laboratories, Inc.
Reviewed and Approved by:

Bethany A. Ebling, B.S.
Group Leader, Water Quality



CENTRICO, INC.



December 27, 1990

Environmental Science & Engineering, Inc.
555 Bridgeport Avenue
Shelton, CT 06484

Attention: Mr. Jack Dunne

Ref.: Letterkenny Army Depot
Our Project # 1-3522

Dear Mr. Dunne:

Enclosed please find the results from the spin test conducted on the two samples submitted to us from Letterkenny Army Depot's caustic bath solution.

The following procedure was used when testing the samples. The contents of each bottle were agitated and broken apart. 125 cc's from each bottle were then poured into a beaker, which was subsequently heated to 190°F. Test tubes containing 10 cc's of the heated solution were then placed into a centrifuge, developing 1700 g's at the tip of the test tube, and spun for three minutes.

Test results:

Top Sample

Light Phase: 3% pourable brown colored oil phase and 1% beige colored pourable emulsion phase.
Heavy Phase: 95.7% slightly turbid aqueous caustic, with deep yellow tint.
Solids Phase: 0.3% gray colored settleable solids. Very low compaction, very fine solids, possibly erosive, but unable to confirm, due to low volume.

Bottom Sample

Light Phase: 6% Pourable opaque brown colored oil.
2% Beige colored pourable emulsion.
Heavy Phase: 91.7% Turbid caustic with deep dirty yellow tint.
Solids Phase: 0.3%. Gray colored settleable solids with very low compaction. May be erosive, but grittiness was undetectable, due to low volume level.

The results of the samples that we have obtained from you, do not seem to correlate with those results that were initially published in the packet that was submitted to us on the 14th of June 1990. The static settling tests that were conducted indicated a solids level of 60 - 105 ml. Even allowing for the compaction generated in a spinning centrifuge, the results obtained in our samples were drastically different from results obtained in March thru May. Based upon our results, this application is better suited for a 3 phase disc type separator centrifuge.

In a disc style separator, one or both of the liquid phases may be discharged under pressure, while the solids are intermittently ejected in the bowl periphery. The specific gravity of your heavy phase and solids would require a reduced bowl speed as a safety precaution. As with a decanter style centrifuge, the presence of sand or gritty material and subsequent possibility of erosiveness due to these materials, is still of major concern.

Please review the information enclosed with your people, and any concerned parties at Letterkenny Army Depot. I would appreciate your response and comments regarding the disparity between sampling results. Should you have further questions concerning the enclosed, please feel free to contact the undersigned.

Regards,

CENTRICO, INC.



Tom Kelman
Process Specialist

TK:ga



February 22, 1991

Mr. Jeff Davis
P.E.I. ASSOCIATES INC.
11499 Chester Road
Cincinnati, OH 45246

Dear Mr. Davis,

The particle size analysis of your 2 samples of Slurry have been completed using the COULTER³ MULTISIZER. The actual analytical conditions used are shown on the top pages of the computer printouts. The summary of the test results are as follows:

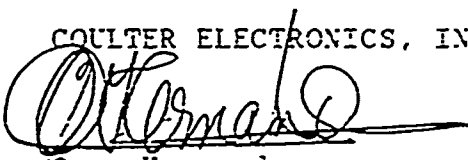
<u>SAMPLE I.D.</u>	<u>VOLUME DATA</u>			<u>POPULATION DATA</u>		
	<u>MEAN</u>	<u>MEDIAN</u>	<u>MODE</u>	<u>MEAN</u>	<u>MEDIAN</u>	<u>MODE</u>
2A	61.95	74.27	299.4	1.697	1.495	1.088
4A	58.09	77.92	189.4	1.907	1.672	1.089

Enclosed please find the computerized data printouts for the 2 samples submitted.

Should you desire any further information, please feel free to contact Hanu R. Batchu, our Lab Manager, or myself at (800) 327-6531, ext. 4306 or 4314.

Sincerely,

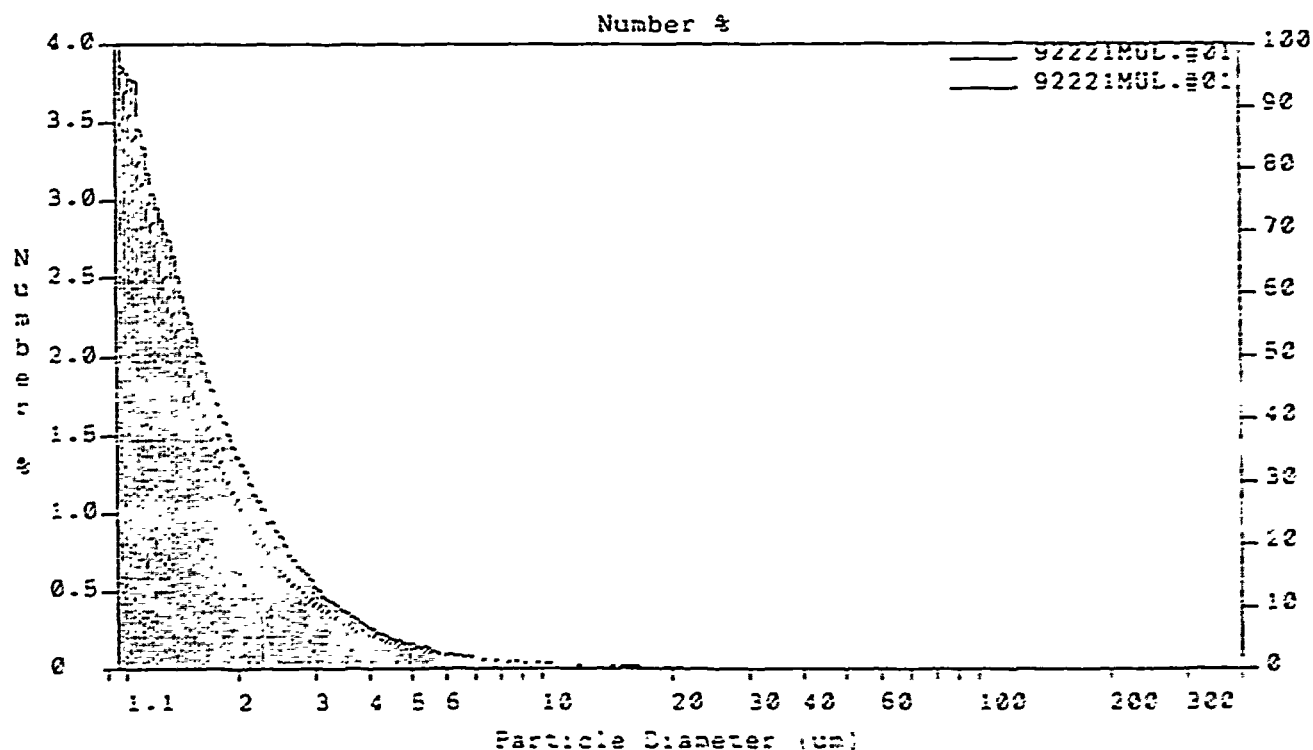
COULTER ELECTRONICS, INC.

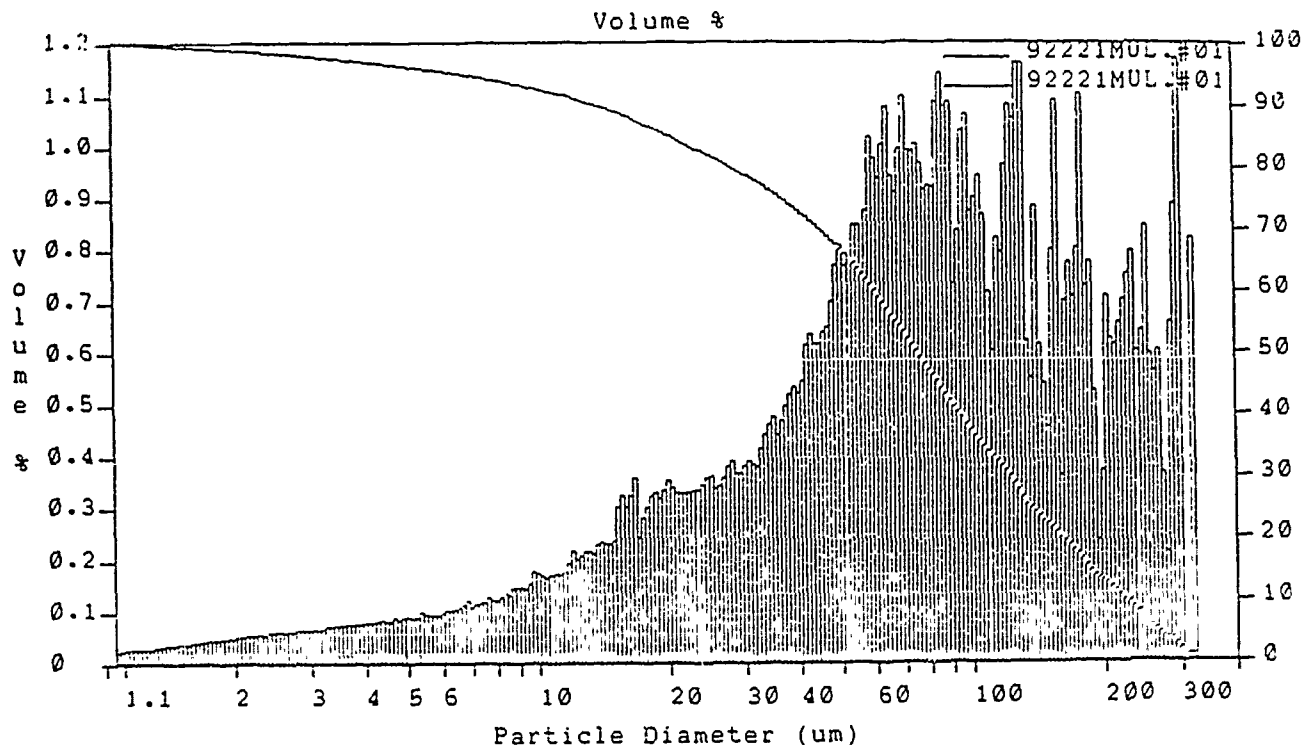

Omar Hernandez
Chemist

OH/mev
Enclosure

92221MUL.#01

Filename: 92221MUL.#01 Sample Number: 130
Group ID: 92221560
Sample ID: 2A
Comments: E.S. & E INC. 560 140 & 50 UM TUBES OVERLAPPED
Operator: OH
Electrolyte: ISOTONII
Dispersant: NONE
Aperture Size: 560 um 92221560.#01
140 um 92221140.#01
50 um 9222150.#01
Channels 256 Variable 1: 0.000000
Variable 2: 0.000000
Acquired at: 17:13 Thu Feb 21 1991





Number Statistics (Geometric)

92221MUL.#01

Calculations from 1.05 um to 323.79 um

Number	11.64*10 ⁶	Coinc. Corrected:	1	
Mean:	1.697 um	95% Conf. Limits:	1.697-1.698	um
Median:	1.495 um	Std. Dev.:	0.453	
Mean/Median Ratio:	1.136	Variance:	0.206	
Mode:	1.088 um	Coef. Var.:	85.71 %	
		Skewness:	1.982e+000	Right skewed
		Kurtosis:	6.108e+000	Leptokurtic

% >	10.00	25.00	50.00	75.00	90.00
Size um	3.014	2.043	1.495	1.225	1.116

Volume Statistics (Geometric)

92221MUL.#01

Calculations from 1.05 um to 323.79 um

Volume	1.348*10 ⁹ um ³	Coinc. Corrected:	1	
Mean:	61.95 um	95% Conf. Limits:	61.95-61.96	um
Median:	74.27 um	Std. Dev.:	1.104	
Mean/Median Ratio:	0.834	Variance:	1.219	
Mode:	299.4 um	Coef. Var.:	26.76 %	
		Skewness:	-1.017e+000	Left skewed
		Kurtosis:	9.832e-001	Leptokurtic

% >	10.00	25.00	50.00	75.00	90.00
Size um	222.8	134.5	74.27	36.47	13.64

92221MUL.#01

Channels	Particle Diameter um	Diff Number %	Cum Number %	Diff Volume %	Cum Volume %
1	1.05	3.69	100.00	0.02	100.00
2	1.08	3.82	96.31	0.02	99.98
3	1.10	3.82	92.49	0.02	99.96
4	1.12	3.78	88.68	0.03	99.93
5	1.15	3.77	84.90	0.03	99.91
6	1.18	3.45	81.13	0.03	99.88
7	1.20	3.33	77.68	0.03	99.86
8	1.23	3.17	74.34	0.03	99.83
9	1.26	3.04	71.17	0.03	99.80
10	1.29	2.95	68.14	0.03	99.77
11	1.32	2.87	65.18	0.03	99.74
12	1.35	2.79	62.31	0.03	99.71
13	1.38	2.74	59.53	0.03	99.68
14	1.41	2.64	56.79	0.03	99.65
15	1.44	2.50	54.15	0.03	99.61
16	1.47	2.38	51.65	0.04	99.58
17	1.50	2.28	49.27	0.04	99.54
18	1.54	2.21	46.99	0.04	99.51
19	1.57	2.12	44.78	0.04	99.47
20	1.61	2.01	42.66	0.04	99.43
21	1.65	1.96	40.65	0.04	99.39
22	1.69	1.85	38.69	0.04	99.35
23	1.72	1.79	36.85	0.04	99.31
24	1.75	1.70	35.06	0.04	99.27
25	1.80	1.62	33.36	0.04	99.22
26	1.84	1.53	31.74	0.05	99.18
27	1.88	1.50	30.15	0.05	99.13
28	1.92	1.43	28.65	0.05	99.08
29	1.97	1.37	27.22	0.05	99.04
30	2.01	1.31	25.86	0.05	99.00
31	2.06	1.27	24.54	0.05	98.94
32	2.11	1.19	23.27	0.05	98.89
33	2.15	1.12	22.08	0.05	98.84
34	2.20	1.08	20.96	0.05	98.78
35	2.25	1.03	19.88	0.05	98.73
36	2.31	0.94	18.85	0.05	98.67
37	2.35	0.95	17.91	0.06	98.62
38	2.41	0.86	16.96	0.06	98.56
39	2.46	0.85	16.08	0.06	98.50
40	2.52	0.80	15.23	0.06	98.45
41	2.57	0.72	14.43	0.06	98.39
42	2.63	0.70	13.71	0.06	98.33
43	2.69	0.66	13.01	0.06	98.27
44	2.75	0.64	12.35	0.06	98.21
45	2.82	0.61	11.71	0.06	98.15
46	2.88	0.57	11.10	0.06	98.09
47	2.94	0.52	10.54	0.06	98.02
48	3.01	0.50	10.02	0.06	97.96
49	3.08	0.46	9.51	0.06	97.89
50	3.15	0.45	9.05	0.07	97.83
51	3.22	0.44	8.60	0.07	97.76

92021MUL.#01

Channels	Particle Diameter	Diff Number	Cum Number	Diff Volume	Cum Volume
	um	%	%	%	%
52	3.29	0.42	8.16	0.07	97.70
53	3.37	0.40	7.75	0.07	97.63
54	3.44	0.37	7.35	0.07	97.55
55	3.52	0.35	6.98	0.07	97.48
56	3.60	0.34	6.62	0.07	97.41
57	3.68	0.32	6.29	0.07	97.34
58	3.77	0.29	5.97	0.07	97.26
59	3.85	0.26	5.68	0.07	97.19
60	3.94	0.27	5.40	0.08	97.12
61	4.03	0.25	5.13	0.08	97.04
62	4.12	0.23	4.88	0.08	96.96
63	4.21	0.22	4.65	0.08	96.89
64	4.31	0.22	4.42	0.08	96.81
65	4.41	0.20	4.21	0.08	96.73
66	4.51	0.18	4.01	0.08	96.65
67	4.61	0.19	3.83	0.09	96.57
68	4.71	0.17	3.64	0.08	96.49
69	4.82	0.16	3.48	0.09	96.40
70	4.93	0.16	3.31	0.09	96.32
71	5.04	0.15	3.16	0.09	96.23
72	5.15	0.13	3.01	0.09	96.14
73	5.27	0.14	2.86	0.10	96.06
74	5.39	0.13	2.73	0.09	95.96
75	5.51	0.12	2.59	0.09	95.86
76	5.64	0.11	2.49	0.09	95.77
77	5.76	0.10	2.38	0.09	95.68
78	5.89	0.10	2.28	0.10	95.59
79	6.03	0.10	2.18	0.10	95.50
80	6.16	0.09	2.08	0.10	95.40
81	6.30	0.09	1.99	0.10	95.30
82	6.45	0.08	1.90	0.11	95.19
83	6.59	0.08	1.82	0.11	95.09
84	6.74	0.08	1.74	0.12	94.98
85	6.89	0.07	1.65	0.11	94.86
86	7.05	0.07	1.58	0.11	94.75
87	7.21	0.07	1.52	0.12	94.64
88	7.37	0.06	1.45	0.12	94.53
89	7.54	0.06	1.39	0.13	94.41
90	7.71	0.06	1.32	0.12	94.29
91	7.88	0.05	1.27	0.12	94.16
92	8.06	0.05	1.22	0.13	94.04
93	8.24	0.05	1.17	0.13	93.92
94	8.43	0.05	1.11	0.13	93.79
95	8.62	0.05	1.07	0.14	93.65
96	8.82	0.05	1.02	0.15	93.51
97	9.02	0.04	0.98	0.14	93.37
98	9.22	0.04	0.93	0.14	93.22
99	9.43	0.04	0.89	0.15	93.08
100	9.64	0.04	0.86	0.17	92.93
101	9.86	0.04	0.81	0.17	92.78
102	10.08	0.04	0.77	0.17	92.58

92221MUL.#01

Channels	Particle Diameter um	Diff Number %	Cum Number %	Diff Volume %	Cum Volume %
103	10.31	0.03	0.74	0.10	92.41
104	10.55	0.03	0.71	0.17	92.25
105	10.79	0.03	0.68	0.17	92.08
106	11.03	0.03	0.65	0.17	91.91
107	11.28	0.03	0.62	0.18	91.74
108	11.53	0.03	0.59	0.19	91.56
109	11.80	0.03	0.57	0.22	91.37
110	12.06	0.02	0.54	0.20	91.15
111	12.34	0.02	0.52	0.21	90.95
112	12.61	0.02	0.49	0.21	90.75
113	12.90	0.02	0.47	0.21	90.53
114	13.19	0.02	0.45	0.21	90.32
115	13.49	0.02	0.43	0.23	90.11
116	13.80	0.02	0.41	0.23	89.88
117	14.11	0.02	0.39	0.23	89.65
118	14.43	0.02	0.37	0.23	89.42
119	14.75	0.02	0.36	0.24	89.19
120	15.09	0.02	0.34	0.30	88.96
121	15.43	0.02	0.32	0.32	88.66
122	15.78	0.02	0.30	0.30	88.33
123	16.14	0.02	0.29	0.32	88.03
124	16.50	0.02	0.27	0.36	87.71
125	16.87	0.01	0.25	0.24	87.36
126	17.25	0.01	0.24	0.25	87.11
127	17.65	0.01	0.23	0.30	86.82
128	18.05	0.01	0.22	0.32	86.53
129	18.45	0.01	0.21	0.33	86.21
130	18.87	0.01	0.20	0.32	85.88
131	19.30	0.01	0.19	0.33	85.57
132	19.74	0.01	0.18	0.35	85.23
133	20.18	0.01	0.17	0.34	84.88
134	20.64	0.01	0.16	0.33	84.54
135	21.11	0.01	0.15	0.32	84.21
136	21.58	0.01	0.14	0.33	83.89
137	22.07	0.01	0.14	0.32	83.56
138	22.57	0.01	0.13	0.33	83.23
139	23.08	0.01	0.12	0.32	82.90
140	23.61	0.01	0.12	0.34	82.56
141	24.14	0.01	0.11	0.36	82.22
142	24.69	0.01	0.11	0.36	81.86
143	25.25	0.00	0.10	0.33	81.50
144	25.82	0.00	0.10	0.34	81.17
145	26.40	0.00	0.09	0.36	80.83
146	27.00	0.00	0.09	0.38	80.47
147	27.61	0.00	0.08	0.37	80.09
148	28.23	0.00	0.08	0.37	79.70
149	28.87	0.00	0.08	0.37	79.33
150	29.53	0.00	0.07	0.36	78.97
151	30.20	0.00	0.07	0.38	78.59
152	30.88	0.00	0.07	0.38	78.20
153	31.58	0.00	0.06	0.38	77.81

92221MUL.#01

Channels	Particle Diameter	Diff Number	Cum Number	Diff Volume	Cum Volume
	um	%	%	%	%
154	32.29	0.00	0.06	0.41	77.44
155	33.02	0.00	0.06	0.44	77.02
156	33.77	0.00	0.06	0.46	76.58
157	34.54	0.00	0.05	0.48	76.12
158	35.32	0.00	0.05	0.44	75.64
159	36.12	0.00	0.05	0.47	75.20
160	36.93	0.00	0.05	0.50	74.73
161	37.77	0.00	0.04	0.52	74.24
162	38.62	0.00	0.04	0.53	73.72
163	39.50	0.00	0.04	0.52	73.18
164	40.39	0.00	0.04	0.55	72.66
165	41.31	0.00	0.04	0.61	72.11
166	42.24	0.00	0.04	0.64	71.50
167	43.20	0.00	0.03	0.62	70.87
168	44.18	0.00	0.03	0.62	70.25
169	45.18	0.00	0.03	0.64	69.63
170	46.20	0.00	0.03	0.65	68.99
171	47.24	0.00	0.03	0.70	68.34
172	48.31	0.00	0.03	0.77	67.64
173	49.41	0.00	0.02	0.81	66.87
174	50.52	0.00	0.02	0.77	66.06
175	51.67	0.00	0.02	0.78	65.29
176	52.84	0.00	0.02	0.85	64.51
177	54.03	0.00	0.02	0.85	63.68
178	55.25	0.00	0.02	0.79	62.81
179	56.51	0.00	0.02	0.85	62.05
180	57.79	0.00	0.02	1.02	61.17
181	59.09	0.00	0.02	0.98	60.15
182	60.43	0.00	0.01	0.94	59.17
183	61.80	0.00	0.01	1.00	58.23
184	63.20	0.00	0.01	1.08	57.23
185	64.63	0.00	0.01	0.95	56.15
186	66.09	0.00	0.01	0.91	55.20
187	67.59	0.00	0.01	1.00	54.23
188	69.12	0.00	0.01	1.13	53.29
189	70.68	0.00	0.01	0.99	52.19
190	72.28	0.00	0.01	0.99	51.20
191	73.92	0.00	0.01	1.00	50.21
192	75.59	0.00	0.01	0.97	49.21
193	77.30	0.00	0.01	0.92	48.23
194	79.05	0.00	0.01	0.92	47.32
195	80.84	0.00	0.01	0.92	46.39
196	82.67	0.00	0.01	1.09	45.47
197	84.54	0.00	0.00	1.14	44.56
198	86.45	0.00	0.00	1.05	43.64
199	88.41	0.00	0.00	1.09	42.15
200	90.41	0.00	0.00	0.77	41.07
201	92.46	0.00	0.00	0.84	40.34
202	94.55	0.00	0.00	1.03	39.50
203	96.69	0.00	0.00	1.05	38.47
204	98.88	0.00	0.00	0.85	37.41

92221MUL.#01

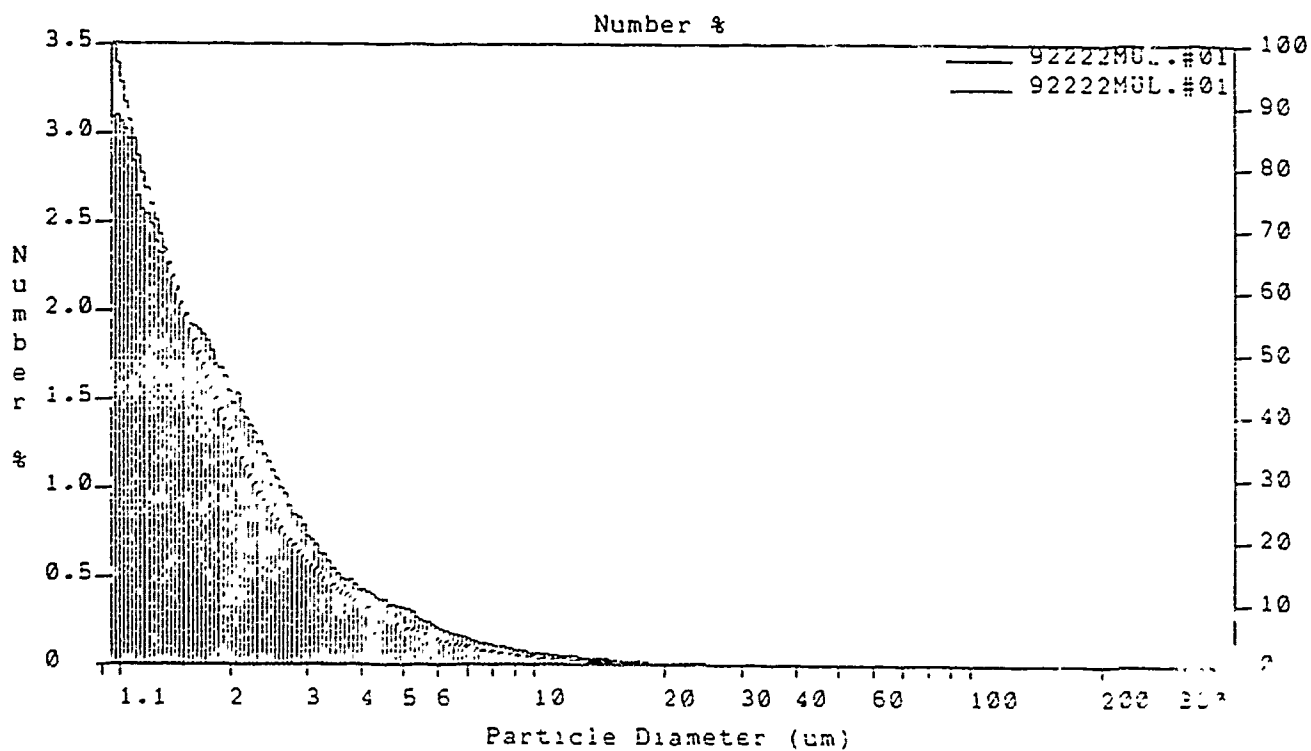
Channels	Particle Diameter	Diff Number	Cum Number	Diff Volume	Cum Volume
	um	%	%	%	%
205	101.12	0.00	0.00	0.90	36.53
206	103.41	0.00	0.00	0.94	35.63
207	105.75	0.00	0.00	0.87	34.69
208	108.14	0.00	0.00	0.72	33.82
209	110.59	0.00	0.00	0.60	33.10
210	113.09	0.00	0.00	0.82	32.50
211	115.65	0.00	0.00	0.80	31.67
212	118.27	0.00	0.00	0.97	30.88
213	120.94	0.00	0.00	1.08	29.91
214	123.68	0.00	0.00	1.06	28.83
215	126.48	0.00	0.00	1.16	27.78
216	129.34	0.00	0.00	1.16	26.61
217	132.27	0.00	0.00	0.62	25.45
218	135.26	0.00	0.00	0.55	24.63
219	138.33	0.00	0.00	0.89	24.28
220	141.48	0.00	0.00	0.51	23.40
221	144.66	0.00	0.00	0.54	22.78
222	147.93	0.00	0.00	0.45	22.24
223	151.28	0.00	0.00	0.80	21.79
224	154.70	0.00	0.00	1.09	20.99
225	158.21	0.00	0.00	0.36	19.90
226	161.79	0.00	0.00	0.70	19.54
227	165.45	0.00	0.00	0.77	18.84
228	169.18	0.00	0.00	1.71	18.05
229	173.00	0.00	0.00	0.80	17.36
230	176.94	0.00	0.00	1.10	16.53
231	180.94	0.00	0.00	0.73	15.45
232	185.04	0.00	0.00	0.78	14.72
233	189.23	0.00	0.00	0.52	13.95
234	193.51	0.00	0.00	0.24	13.42
235	197.89	0.00	0.00	0.37	13.15
236	202.37	0.00	0.00	0.71	12.82
237	206.95	0.00	0.00	0.63	12.11
238	211.63	0.00	0.00	0.61	11.48
239	216.40	0.00	0.00	7.65	10.86
240	221.32	0.00	0.00	0.70	10.21
241	226.33	0.00	0.00	0.75	9.59
242	231.45	0.00	0.00	0.80	8.75
243	236.67	0.00	0.00	0.60	7.95
244	242.08	0.00	0.00	0.64	7.35
245	247.53	0.00	0.00	0.85	6.72
246	253.17	0.00	0.00	0.50	5.87
247	258.86	0.00	0.00	0.56	5.28
248	264.72	0.00	0.00	0.60	4.71
249	270.71	0.00	0.00	0.36	4.11
250	276.84	0.00	0.00	0.21	3.75
251	287.10	0.00	0.00	0.85	3.56
252	295.51	0.00	0.00	0.59	2.88
253	296.06	0.00	0.00	1.17	1.75
254	302.76	0.00	0.00	0.30	0.82
255	309.62	0.00	0.00	0.00	0.22

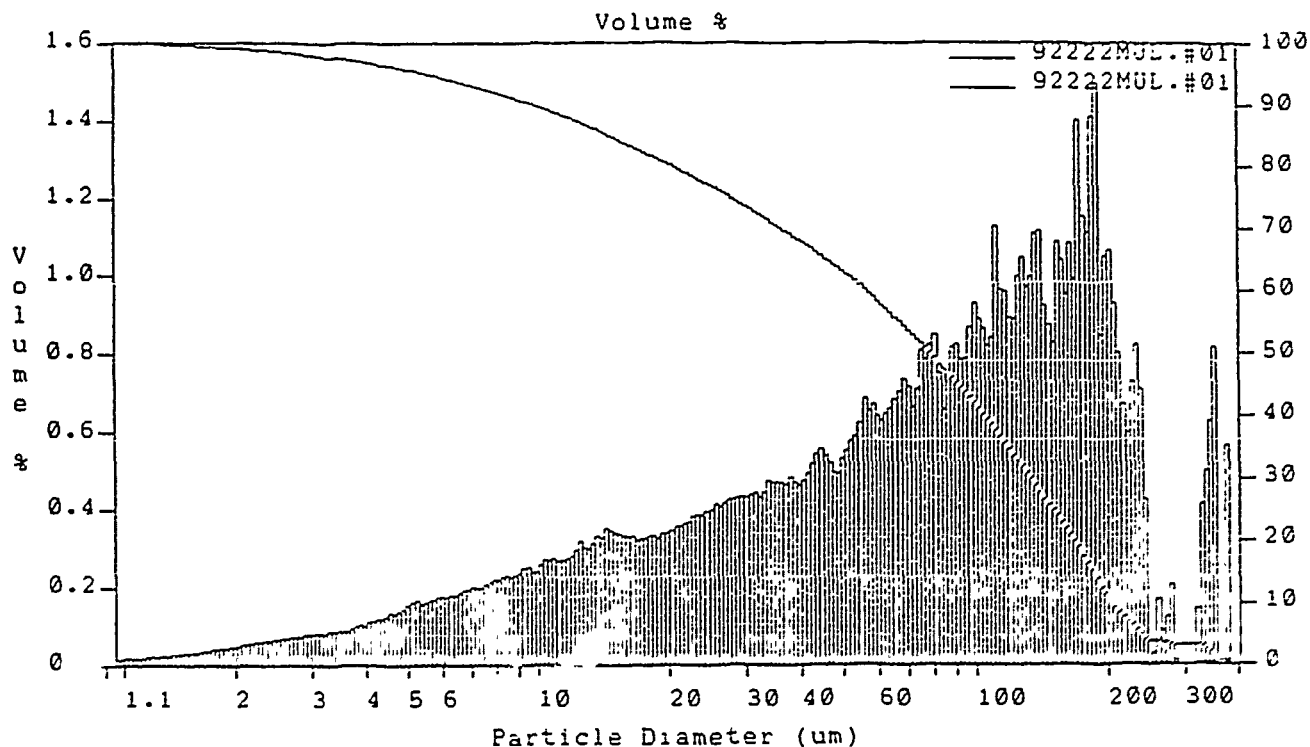
90001MUL.#01

Channels	Particle Diameter um	Diff Number %	Cum Number %	Diff Volume %	Cum Volume %
256	316.62	0.00	0.00	0.82	0.82

92222MUL.#01

Filename: 92222MUL.#01 Sample Number: 130
Group ID: 92222560
Sample ID: 4A
Comments: PEI ASSOCIATES INC 560 140 & 50 UM TUBES OVERLAPPED
Operator: OH
Electrolyte: ISOTONII
Dispersant: NONE
Aperture Size: 560 um 92222560.#01
140 um 92222140.#01
50 um 9222250.#01
Channels 256 Variable 1: 0.000000
Variable 2: 0.000000
Acquired at: 10:33 Fri Feb 22 1991





Number Statistics (Geometric)

92222MUL.#01

Calculations from 1.05 um to 382.39 um

Number	24.71*10 ⁶	Coinc. Corrected:	1
Mean:	1.907 um	95% Conf. Limits:	1.906-1.907 um
Median:	1.672 um	Std. Dev.:	0.520
Mean/Median Ratio:	1.140	Variance:	0.270
Mode:	1.089 um	Coef. Var.:	80.50 %
		Skewness:	1.492e+000 Right skewed
		Kurtosis:	2.968e+000 Leptokurtic

% >	10.00	25.00	50.00	75.00	90.00
Size um	3.894	2.431	1.672	1.285	1.134

Volume Statistics (Geometric)

92222MUL.#01

Calculations from 1.05 um to 382.39 um

Volume 3.346*10⁹ um³

Mean: 58.09 um

Median: 77.92 um

Mean/Median Ratio: 0.745

Mode: 189.4 um

Coinc. Corrected: 1

95% Conf. Limits: 58.09-58.09 um

Std. Dev.: 1.191

Variance: 1.418

Coef. Var.: 29.32 %

Skewness: -8.422e-001 Left skewed

Kurtosis: 6.528e-002 Leptokurtic

% >	10.00	25.00	50.00	75.00	90.00
Size um	202.5	148.2	77.92	27.74	9.796

52222MUL.#01

Channels	Particle Diameter um	Diff Number %	Cum Number %	Diff Volume %	Cum Volume %
1	1.05	3.08	100.00	0.01	100.00
2	1.08	3.10	96.92	0.02	99.99
3	1.10	3.06	93.82	0.02	99.97
4	1.13	3.02	90.76	0.02	99.95
5	1.15	2.97	87.74	0.02	99.94
6	1.18	2.84	84.77	0.02	99.92
7	1.21	2.65	81.93	0.02	99.90
8	1.24	2.57	79.28	0.02	99.88
9	1.26	2.54	76.71	0.02	99.86
10	1.29	2.49	74.17	0.02	99.84
11	1.32	2.39	71.68	0.02	99.82
12	1.36	2.32	69.29	0.02	99.80
13	1.39	2.32	66.97	0.02	99.77
14	1.42	2.25	64.65	0.03	99.75
15	1.45	2.19	62.40	0.03	99.72
16	1.47	2.17	60.21	0.03	99.70
17	1.52	2.04	58.09	0.03	99.67
18	1.56	1.97	56.05	0.03	99.64
19	1.59	1.92	54.07	0.03	99.61
20	1.63	1.91	52.15	0.03	99.58
21	1.67	1.80	50.25	0.04	99.55
22	1.71	1.81	48.31	0.04	99.51
23	1.75	1.83	46.50	0.04	99.47
24	1.78	1.77	44.67	0.04	99.41
25	1.83	1.69	42.90	0.04	99.39
26	1.87	1.62	41.21	0.04	99.35
27	1.91	1.62	39.53	0.05	99.31
28	1.95	1.51	37.91	0.05	99.26
29	2.00	1.47	36.36	0.05	99.22
30	2.05	1.53	34.89	0.05	99.17
31	2.10	1.41	33.36	0.05	99.11
32	2.15	1.39	31.93	0.06	99.06
33	2.20	1.35	30.54	0.06	99.01
34	2.25	1.31	29.19	0.06	98.95
35	2.30	1.25	27.87	0.06	98.89
36	2.35	1.19	26.62	0.06	98.83
37	2.41	1.14	25.43	0.06	98.77
38	2.47	1.10	24.29	0.07	98.71
39	2.52	1.05	23.20	0.07	98.64
40	2.58	1.00	22.15	0.07	98.57
41	2.64	0.95	21.15	0.07	98.50
42	2.70	0.90	20.19	0.07	98.43
43	2.77	0.85	19.28	0.07	98.36
44	2.83	0.87	18.41	0.08	98.29
45	2.90	0.79	17.60	0.08	98.21
46	2.97	0.77	16.82	0.08	98.14
47	3.03	0.71	16.09	0.08	98.06
48	3.10	0.67	15.33	0.08	97.98
49	3.16	0.67	14.71	0.08	97.90
50	3.25	0.62	14.03	0.08	97.82
51	3.33	0.59	13.40	0.09	97.73

92222MUL.#01

Channels	Particle Diameter	Diff Number	Dum Number	Diff Volume	Dum Volume
	um	%	%	%	%
52	3.40	0.54	12.87	0.00	97.65
53	3.48	0.51	12.33	0.00	97.50
54	3.57	0.48	11.82	0.00	97.47
55	3.65	0.43	11.33	0.00	97.39
56	3.73	0.40	10.85	0.10	97.29
57	3.82	0.45	10.37	0.10	97.19
58	3.91	0.41	9.92	0.10	97.00
59	4.00	0.42	9.51	0.11	96.99
60	4.09	0.41	9.00	0.11	96.89
61	4.19	0.40	8.68	0.12	96.77
62	4.29	0.37	8.25	0.12	96.66
63	4.39	0.37	7.91	0.12	96.54
64	4.49	0.37	7.54	0.13	96.42
65	4.59	0.34	7.17	0.13	96.29
66	4.70	0.73	6.83	0.14	96.15
67	4.81	0.32	6.50	0.14	96.01
68	4.92	0.32	6.15	0.15	95.87
69	5.04	0.31	5.85	0.16	95.72
70	5.15	0.30	5.55	0.16	95.56
71	5.27	0.27	5.25	0.16	95.39
72	5.40	0.25	4.95	0.16	95.24
73	5.52	0.25	4.73	0.17	95.06
74	5.65	0.23	4.43	0.17	94.91
75	5.78	0.22	4.25	0.17	94.72
76	5.92	0.21	4.02	0.17	94.57
77	6.05	0.20	3.81	0.17	94.39
78	6.20	0.18	3.62	0.18	94.22
79	6.34	0.16	3.47	0.18	94.04
80	6.48	0.17	3.26	0.18	93.86
81	6.64	0.16	3.06	0.19	93.68
82	6.79	0.15	2.93	0.19	93.48
83	6.95	0.15	2.77	0.20	93.30
84	7.11	0.14	2.62	0.20	93.10
85	7.28	0.13	2.48	0.20	92.90
86	7.45	0.12	2.33	0.20	92.70
87	7.62	0.12	2.27	0.21	92.51
88	7.80	0.11	2.11	0.22	92.32
89	7.98	0.11	2.00	0.22	92.14
90	8.17	0.10	1.86	0.22	91.95
91	8.36	0.10	1.74	0.23	91.76
92	8.55	0.09	1.63	0.23	91.57
93	8.75	0.08	1.50	0.23	91.37
94	8.96	0.08	1.52	0.23	91.14
95	9.17	0.09	1.44	0.25	90.91
96	9.38	0.05	1.36	0.25	90.68
97	9.60	0.07	1.25	0.24	90.44
98	9.82	0.06	1.21	0.24	90.21
99	10.05	0.05	1.15	0.25	89.97
100	10.28	0.05	1.04	0.27	89.73
101	10.52	0.05	1.03	0.27	89.48
102	10.77	0.05	0.97	0.27	89.24

R2222MUL.#01

Channels	Particle Diameter	Diff Number	Dim Number	Diff Volume	Dim Volume
	um	%	%	%	%
103	11.02	0.05	0.91	0.27	88.67
104	11.28	0.05	0.86	0.27	88.47
105	11.54	0.04	0.82	0.27	88.14
106	11.81	0.04	0.77	0.28	87.86
107	12.06	0.04	0.73	0.29	87.58
108	12.36	0.04	0.69	0.32	87.29
109	12.65	0.04	0.65	0.30	86.97
110	12.95	0.03	0.61	0.30	86.67
111	13.25	0.03	0.58	0.31	86.38
112	13.56	0.03	0.54	0.33	86.07
113	13.87	0.03	0.51	0.33	85.74
114	14.20	0.03	0.48	0.35	85.41
115	14.53	0.03	0.45	0.34	85.06
116	14.87	0.03	0.42	0.34	84.72
117	15.21	0.02	0.39	0.34	84.38
118	15.57	0.02	0.37	0.37	84.16
119	15.93	0.02	0.35	0.37	83.72
120	16.30	0.02	0.37	0.37	83.38
121	16.68	0.02	0.31	0.32	83.06
122	17.07	0.02	0.29	0.32	82.72
123	17.47	0.02	0.28	0.33	82.42
124	17.87	0.01	0.26	0.37	82.09
125	18.28	0.01	0.26	0.37	81.76
126	18.71	0.01	0.27	0.37	81.42
127	19.15	0.01	0.22	0.34	81.11
128	19.61	0.01	0.21	0.34	80.78
129	20.08	0.01	0.20	0.34	80.44
130	20.57	0.01	0.19	0.35	80.18
131	21.08	0.01	0.18	0.36	79.78
132	21.60	0.01	0.17	0.36	79.37
133	22.13	0.01	0.16	0.37	78.91
134	22.68	0.01	0.15	0.38	78.64
135	23.25	0.01	0.14	0.38	78.22
136	23.83	0.01	0.17	0.38	77.81
137	24.43	0.01	0.17	0.38	77.40
138	25.05	0.01	0.12	0.41	77.01
139	25.68	0.01	0.11	0.41	76.60
140	26.32	0.01	0.11	0.41	76.20
141	26.98	0.01	0.10	0.42	75.80
142	27.65	0.01	0.09	0.42	75.40
143	28.33	0.01	0.09	0.43	75.00
144	29.03	0.00	0.08	0.43	74.61
145	29.75	0.00	0.08	0.43	74.18
146	30.48	0.00	0.07	0.43	73.76
147	31.23	0.00	0.07	0.44	73.31
148	32.00	0.00	0.07	0.44	72.89
149	32.79	0.00	0.10	0.43	72.46
150	33.59	0.00	0.10	0.45	72.01
151	34.40	0.00	0.10	0.47	71.58
152	35.23	0.00	0.05	0.47	71.16
153	36.08	0.00	0.05	0.47	70.72

92222MUL.#01

Channels	Particle Diameter um	Diff Number %	Cum Number %	Diff Volume %	Cum Volume %
154	35.67	0.000	0.005	0.47	70.15
155	36.50	0.000	0.004	0.46	69.43
156	37.35	0.000	0.004	0.48	69.21
157	38.22	0.000	0.004	0.47	68.73
158	39.11	0.000	0.004	0.46	68.26
159	40.02	0.000	0.004	0.47	67.80
160	40.95	0.000	0.003	0.49	67.33
161	41.91	0.000	0.003	0.52	66.83
162	42.88	0.000	0.003	0.54	66.32
163	43.88	0.000	0.003	0.55	65.77
164	44.91	0.000	0.003	0.54	65.22
165	45.95	0.000	0.003	0.52	64.68
166	47.02	0.000	0.002	0.50	64.16
167	48.12	0.000	0.002	0.49	63.67
168	49.24	0.000	0.002	0.53	63.17
169	50.39	0.000	0.002	0.53	62.64
170	51.56	0.000	0.002	0.58	62.09
171	52.76	0.000	0.002	0.59	61.52
172	53.99	0.000	0.002	0.62	60.93
173	55.25	0.000	0.002	0.68	60.31
174	56.54	0.000	0.002	0.65	59.63
175	57.85	0.000	0.001	0.67	58.97
176	59.20	0.000	0.001	0.64	58.31
177	60.58	0.000	0.001	0.67	57.67
178	61.99	0.000	0.001	0.65	57.04
179	63.44	0.000	0.001	0.66	56.39
180	64.91	0.000	0.001	0.68	55.74
181	66.43	0.000	0.001	0.70	55.06
182	67.97	0.000	0.001	0.73	54.35
183	69.56	0.000	0.001	0.71	53.62
184	71.18	0.000	0.001	0.66	52.91
185	72.84	0.000	0.001	0.71	52.24
186	74.53	0.000	0.001	0.81	51.53
187	76.27	0.000	0.001	0.78	50.73
188	78.05	0.000	0.001	0.82	49.95
189	79.87	0.000	0.001	0.85	49.12
190	81.73	0.000	0.001	0.75	48.29
191	83.63	0.000	0.001	0.66	47.53
192	85.58	0.000	0.001	0.75	46.87
193	87.57	0.000	0.000	0.82	46.12
194	89.61	0.000	0.000	0.82	45.30
195	91.70	0.000	0.000	0.78	44.48
196	93.84	0.000	0.000	0.78	43.70
197	96.02	0.000	0.000	0.87	42.92
198	98.26	0.000	0.000	0.93	42.05
199	100.55	0.000	0.000	0.89	41.12
200	102.89	0.000	0.000	0.86	40.23
201	105.29	0.000	0.000	0.82	39.37
202	107.74	0.000	0.000	0.84	38.55
203	110.25	0.000	0.000	1.13	37.71
204	112.82	0.000	0.000	0.96	36.88

92222MUL.#01

Channels	Particle Diameter um	Diff Number %	Cum Number %	Diff Volume %	Cum Volume %
205	115.45	0.00	0.00	0.90	35.62
206	118.14	0.00	0.00	0.89	34.60
207	120.89	0.00	0.00	0.89	33.77
208	123.71	0.00	0.00	1.00	32.88
209	126.59	0.00	0.00	1.05	31.89
210	129.54	0.00	0.00	0.97	30.94
211	132.56	0.00	0.00	0.99	29.87
212	135.65	0.00	0.00	1.11	27.83
213	138.81	0.00	0.00	1.12	27.77
214	142.04	0.00	0.00	0.92	26.65
215	145.35	0.00	0.00	0.87	25.73
216	148.74	0.00	0.00	0.82	24.86
217	152.20	0.00	0.00	1.09	24.03
218	155.75	0.00	0.00	1.04	22.95
219	159.38	0.00	0.00	0.95	21.91
220	163.09	0.00	0.00	1.45	21.90
221	166.89	0.00	0.00	0.95	19.87
222	170.73	0.00	0.00	1.40	18.89
223	174.76	0.00	0.00	1.15	17.48
224	178.83	0.00	0.00	1.11	16.33
225	182.99	0.00	0.00	1.41	15.22
226	187.26	0.00	0.00	1.50	13.80
227	191.62	0.00	0.00	0.95	12.31
228	196.08	0.00	0.00	1.05	11.40
229	200.65	0.00	0.00	1.00	10.41
230	205.33	0.00	0.00	0.93	9.35
231	210.11	0.00	0.00	0.80	8.42
232	215.01	0.00	0.00	0.67	7.62
233	220.02	0.00	0.00	0.53	6.95
234	225.14	0.00	0.00	0.77	6.30
235	230.39	0.00	0.00	0.82	5.63
236	235.75	0.00	0.00	0.71	4.61
237	241.25	0.00	0.00	0.43	4.10
238	246.87	0.00	0.00	0.66	3.67
239	252.62	0.00	0.00	0.07	3.67
240	258.50	0.00	0.00	0.17	3.64
241	264.53	0.00	0.00	0.08	3.48
242	270.69	0.00	0.00	0.12	3.30
243	277.00	0.00	0.00	0.21	3.27
244	283.45	0.00	0.00	0.01	3.00
245	290.05	0.00	0.00	0.00	3.00
246	296.81	0.00	0.00	0.00	3.00
247	303.73	0.00	0.00	0.00	3.00
248	310.80	0.00	0.00	0.00	3.00
249	318.04	0.00	0.00	0.14	3.00
250	325.45	0.00	0.00	0.41	2.61
251	333.04	0.00	0.00	0.50	2.50
252	340.79	0.00	0.00	0.62	2.00
253	348.73	0.00	0.00	0.21	1.37
254	356.80	0.00	0.00	0.00	0.56
255	365.17	0.00	0.00	0.00	0.50

92222MUL.#01

Channels	Particle Diameter um	Diff Number %	Cum Number %	Diff Volume %	Cum Volume %
256	373.68	0.00	0.00	0.50	0.50

APPENDIX D
OPERATIONS MONITORING LOGS

SHIFT INFORMATION LOG

DATE	SHIFT	Pressure Gage Readings			TEMP. (°F)
		1st	2nd	3rd	
1/11/91	1st	94	—	14	—
1/11/91 12:00	1st	125	—	34	—
1/11/91 7:35	1st	127	—	40	—
1/18/91 6:15	1st	20	—	37	—
1/22/91 "	1st	40	—	40	—

Boiling
system
1/11/91

FILTER INFORMATION LOG				
DATE	FILTER NO.	DESCRIPTION OF FILTER BAG		THICKNESS OF CAKE
		Sticky	Large Particles	Thin ($< 1/8"$) Medium ($> 1/8"$ and $< 1/4"$) Thick ($> 1/4"$)
1/11/91	# 2 (100 gm)	No	YES	Pile of sledge on horizon
1/18/91	# 2 (100 gm)	No	YES	" " "
1/18/91	# 2 (100 gm)	N	YES	" " "
1/25/91	# 1, 400 gm	N	YES	" " "
1/25/91	SS (sand) 600 gm	Yes	Yes	14 bags and 2 more bags in corner

[illegible]

BATH USAGE LOG			
DATE	PART DESCRIPTION	TIME IN BATH (Minutes)	COMMENTS

APPENDIX E

**LEAD SODIUM HYDROXIDE AND SODIUM
GLUCONATE ALKALINE PAINT-STRIPPING
STUDY**

AN EVALUATION OF IMMERSION DERUST SOLUTIONS

OBJECT

The object of this project was to:

1. Determine what influences the iron sequestering power of immersion derust solutions.
2. Determine the thermal stability of immersion derust solutions.
3. Develop a performance test for comparing the derusting capability of various immersion derust solutions and Type 1 solutions conforming to MIL-C-14460, Corrosion Removing Compound, Sodium Hydroxide Base; For Electrolytic or Immersion Application.

SUMMARY

The calcium sequestering ability of caustic-gluconate solutions was found to be caustic dependent. In extremely caustic solutions gluconate does not sequester calcium ions. The iron sequestering ability of gluconate-caustic solutions was found to be dependent on the caustic content and the ability of the gluconate to sequester more than one iron (III) ion. The addition of ethylene diamine tetracetic acid (EDTA) improved the calcium sequestering power but did not affect the iron sequestering ability of caustic-gluconate solutions.

Immersion (Type 1) derust solutions were depleted of gluconate while being maintained at operating temperature (240°F). At 160°F, no thermal degradation of immersion derust solutions was evident. Thermal degradation of immersion derust solutions at 200°F was evident but to a lesser extent than that which occurred at 240°F. Little degradation of the caustic and no degradation of the EDTA was observed during the test period.

Rusted panels were placed in derust formulations for various times and at different temperatures. The amount of rust removed during the test period was determined. To achieve maximum rust removal from the corroded panels, the derust solution had to be maintained at the boiling point temperature.

CONCLUSIONS

It was concluded that:

1. Caustic-gluconate solutions could be used to sequester trivalent iron when EDTA was not present. Addition of EDTA did not improve the iron (III) sequestering power of the caustic-gluconate solution.

2. An iron (III) titration might be used to estimate the sequestering power of a derust solution.

3. Current immersion (Type 1) derusting solutions are thermally unstable. Maintaining the derust solution temperature near the boiling point for 80 hours resulted in a 50% decrease in the gluconate concentration.

4. The caustic and EDTA content are not significantly affected by lengthy exposure to operating temperatures.

5. Salt spray (ASTM-B117) rusted panels could possibly be incorporated into a rust removing performance test for immersion derust solutions.

6. Eliminating the EDTA from immersion (Type 1) derust solutions would result in significant cost savings.

RECOMMENDATIONS

It is recommended that:

1. EDTA not be used in the formulation of immersion (Type 1) derust solutions.

2. Caustic-gluconate derust solutions be heated to boiling only when work is available for processing to minimize thermal degradation of the gluconate.

3. Standard rust panels be used for performance testing of immersion (Type 1) derust solutions.

4. The immersion formulation be used to develop a cyanide-free electrolytic (Type 2) derust solution.

INTRODUCTION

The MIL-C-14460 specification requires that gluconate, EDTA and caustic be used to formulate immersion derusting solutions along with other minor constituents. The specification describes analytical procedures to be followed for acceptance-testing of these materials and states that the solution be operated at a slow rolling boil. However, the specification does not provide analysis to be conducted for the purpose of replenishing the bath during production operations.

Recently, some questions have been raised as to the efficiency of the immersion formulation in the specification. These questions included the following:

1. Why can't the immersion (Type 1) derust solution be replenished?

2. Why does the derust solution become ineffective in the absence of production operations?

3. Could the immersion specification solution be made competitive with current proprietary formulations?

4. Could a performance test be developed to evaluate the rust removing capability of immersion derust solutions?

These unanswered questions, the fact that some analytical procedures needed refinement and because the specification is up for review are all considerations which prompted this investigation.

PROCEDURE AND RESULTS

I. Sequestering Ability

Solutions containing 25 grams of sodium gluconate and varying amounts of sodium hydroxide were weighted out and placed in a 100 ml volumetric flask. The mixtures were dissolved with distilled water and the flask was filled to the mark. A five ml sample of the prepared solution was titrated with a 2.2% calcium chloride solution. Five ml of 5% sodium oxalate was added as an indicator and the titration proceeded until calcium oxalate was precipitate. The data is summarized in Table 1. Note that the calcium sequestering ability exhibits a maximum at 15%-25% sodium hydroxide.

Table 1. The affect of caustic on the calcium sequestering ability of 25% sodium gluconate.

<u>Caustic Content (% Weight)</u>	<u>ml OF Calcium used</u>	<u>Caustic Content</u>	<u>ml of Calcium</u>
0	0.05	20	30.5
2	1.3	25	30.9
5	10.6	35	0.1
10	23.8	42	0.01
15	28.4	50	0.01

This data is shown graphically in Figure 1.

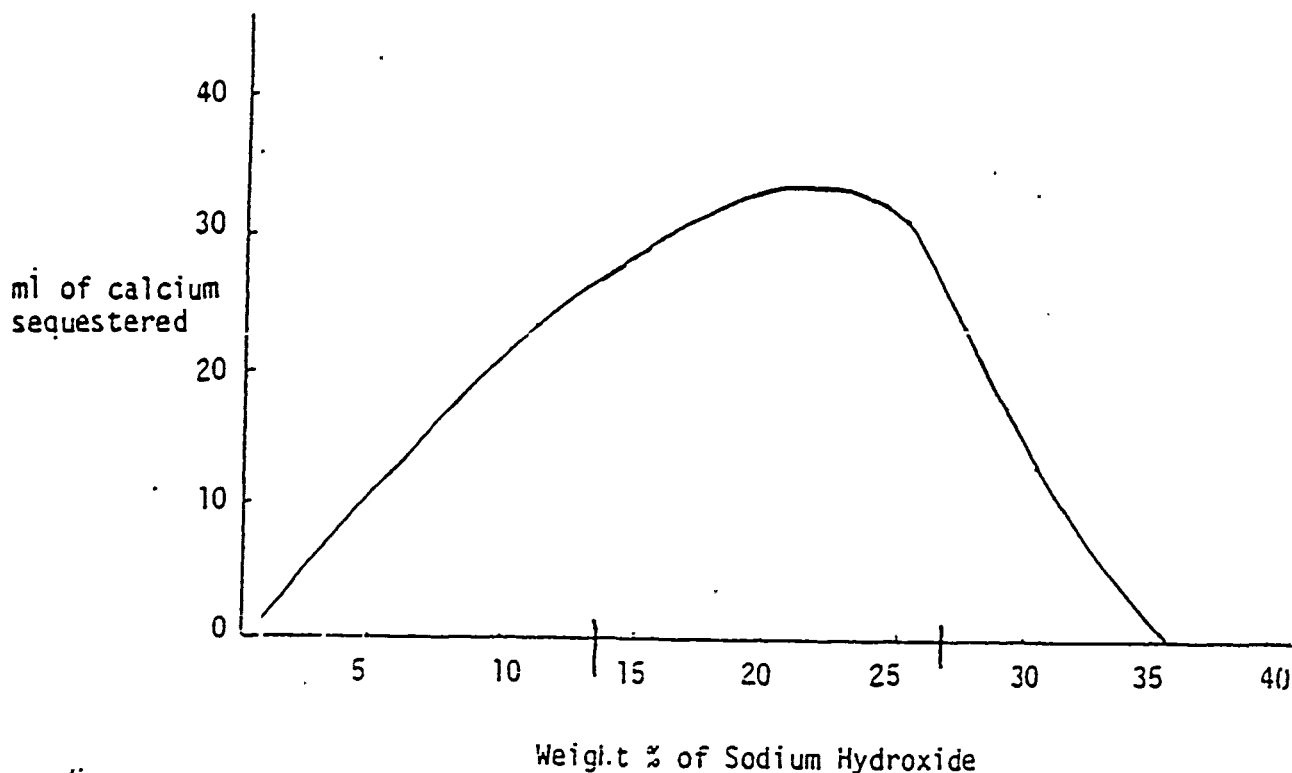


Figure 1. Affect of NaOH on the Calcium Sequestering of 25% Sodium Gluconate

The preliminary test using calcium was conducted because calcium is generally used to determine the sequestering power of many solutions. However, derust solutions must be capable of sequestering iron. A second group of solutions was prepared by dissolving 25 grams of sodium gluconate along with varying amounts of caustic in a 100 ml flask and diluting to the mark with distilled water. A one ml sample was titrated with 2.5% ferric chloride hexahydrate until a ferric hydroxide precipitate was formed. Data could not be acquired with the low caustic solutions since the ferric chloride (acid) solution neutralized the caustic that was present and no ferric hydroxide precipitate would form. Data acquired from the titrations is summarized in Table 2. Note that the iron sequestering ability of gluconate continuously increases as the caustic content increases.

Table 2. Affect of Sodium Hydroxide on the Iron (III) Sequestering Ability of 25% Sodium Gluconate

Caustic Content (% by Weight)	ml of Fe Used	Caustic Content	ml of Fe Used
0	Not enough OH	20	20.0
2	" " "	25	24.5
5	" " "	35	32.8
10	" " "	42	38.0
15	" " "	50	36.0

This data is shown graphically in Figure 2.

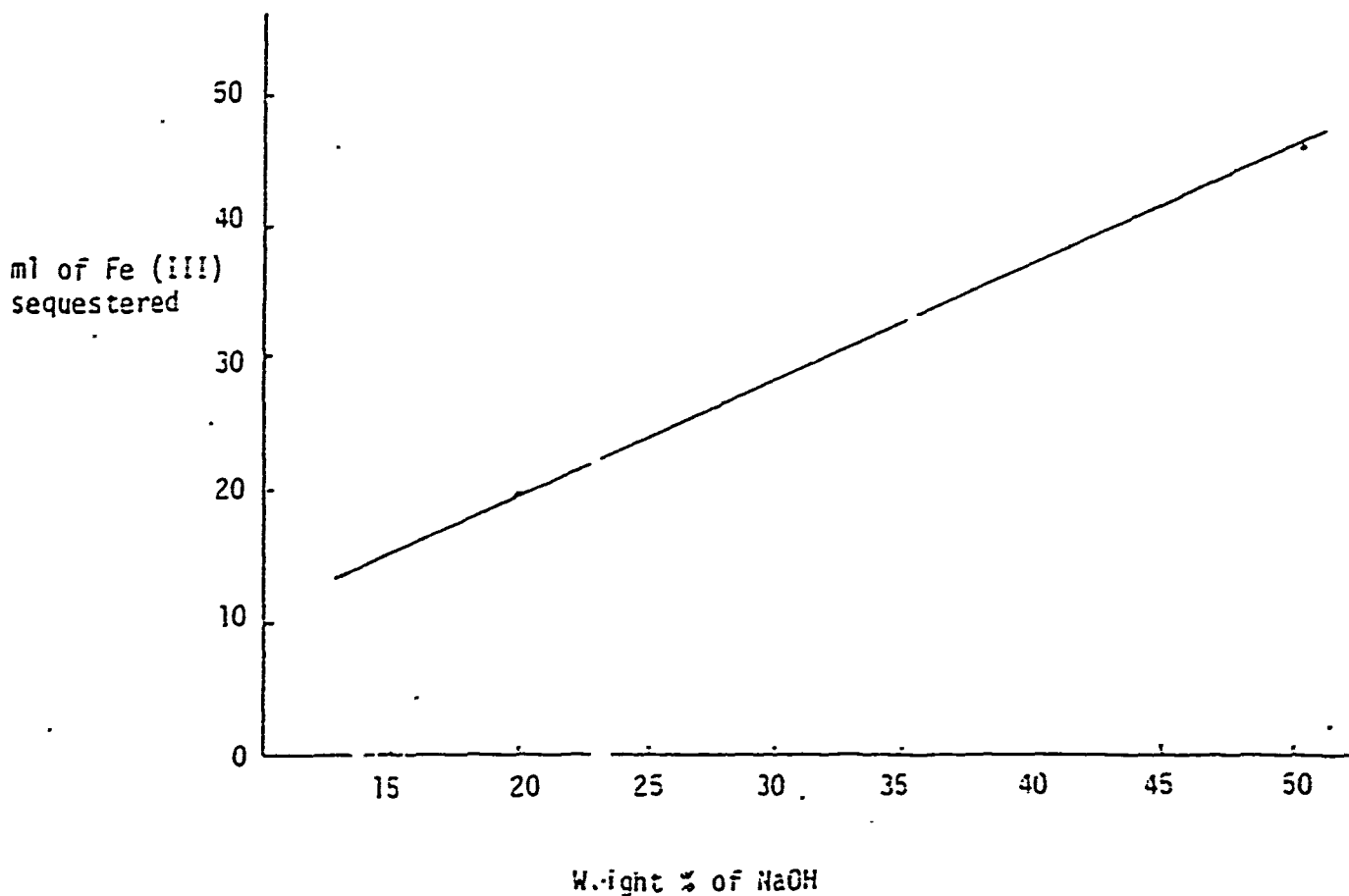


Figure 2. Affect of Sodium hydroxide on the Iron (III) Sequestering Ability of 25% Sodium Gluconate

One other caustic-gluconate variable was investigated. This time the caustic was held constant at 25 grams or 50 grams and the gluconate content was varied. Samples were prepared as previously described in a 100 ml volumetric flask. A five ml sample was titrated with 2.5% iron chloride until ferric hydroxide was precipitated. Data is summarized in Table 3.

Table 3. The Affect of 25% and 50% Sodium Hydroxide on the Iron (III) Sequestering Ability of Sodium Gluconate at Various Concentrations.

<u>50% NaOH plus</u>		<u>25% NaOH plus</u>	
<u>Na Gluconate</u>	<u>ml of Fe (III) Used</u>	<u>Na Gluconate</u>	<u>ml of Fe (III) Used</u>
5	2.8	5	16.0
10	43.2	10	21.0
15	44.0	15	22.5
20 *	45.6	20	24.0
25	47.2	25	24.5
30	49.3	30	24.7
35	46.5	35	26.5
40	44.3	40	27.0

* Ten grams of 3Na EDTA was added to this solution. The flask was heated to boiling to get the EDTA into solution. A five ml sample was titrated with iron (III) chloride solution to the ferric hydroxide end point. The titration required 41.0 ml of iron (III) solution. This indicates that EDTA does not improve the iron (III) sequestering power of the gluconate-caustic mixture.

The data in Table 3 was used to prepare Figure 3.

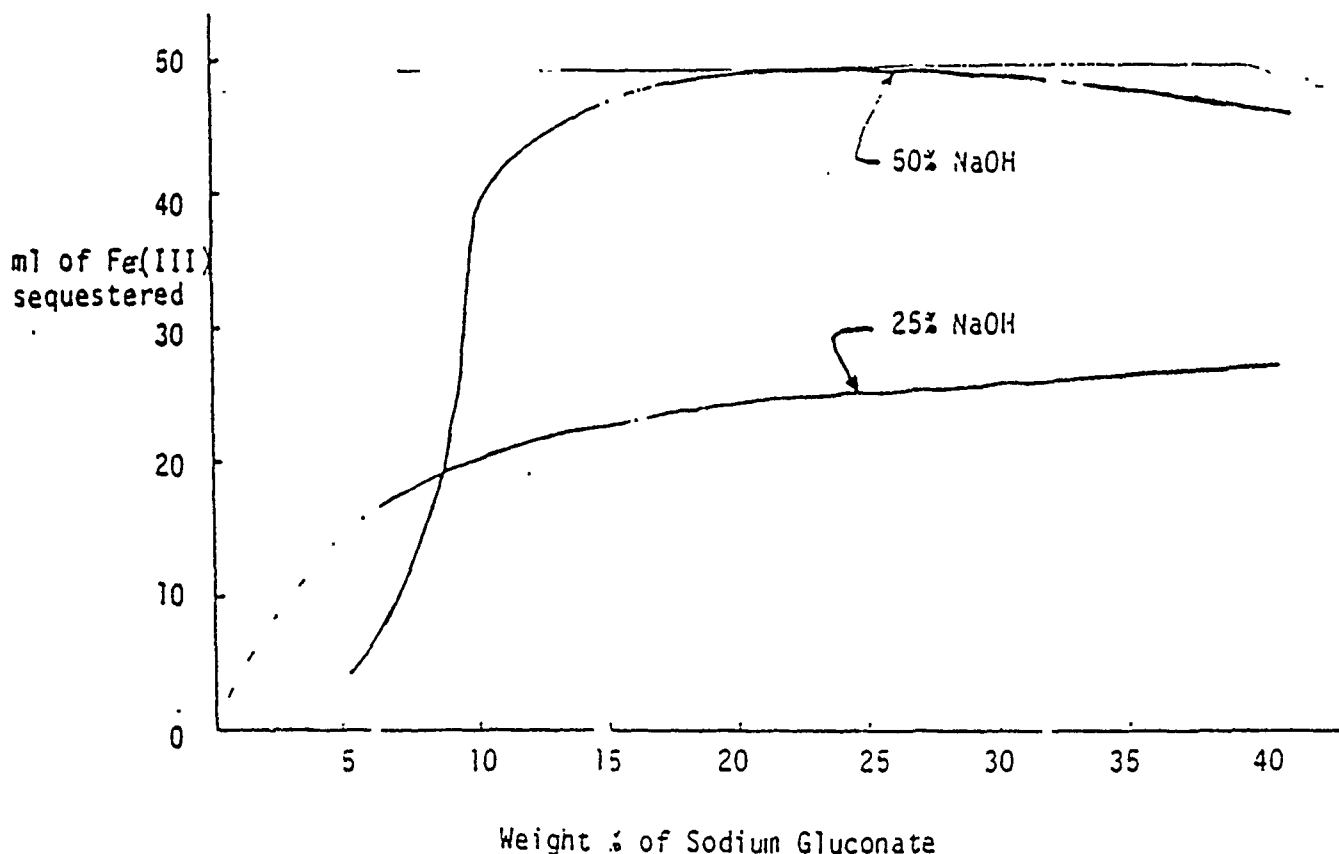


Figure 3. The Affect of Sodium Hydroxide on the Iron (III) Sequestering Ability of Various Sodium Gluconate Solutions

Some calculations were made to determine the amount of iron (III) sequestered by the 20% sodium gluconate - 50% sodium hydroxide sample. Calculations showed that under these conditions three moles of iron (III) are sequestered by one mole of sodium gluconate prior to precipitation of ferric hydroxide.

Ten grams of 3Na EDTA was dissolved in 100 of distilled water. Ten ml of 25% ferric chloride was added and a yellow colored solution resulted. Ten grams of sodium hydroxide was added and a ferric hydroxide precipitate was observed indicating EDTA does not sequester iron (III) in a 10% caustic solution.

II. Thermal Degradation

The following solution was prepared:

Sodium hydroxide 324 grams
3Na EDTA 90 grams
Sodium gluconate 186 grams
Distilled water to one liter

Four hundred ml of this stock solution was placed in a 500 ml beaker. An analysis of the compounds was performed by (1) titrating the caustic with hydrochloric acid, (2) a potentiometric titration of EDTA with calcium and (3) determining the optical rotation of the gluconate. The solution was placed in a furnace at 240°F and periodic analysis of the solution was performed. Data acquired from the analyses are summarized in Table 4.

Table 4. Values Obtained During Periodic Analysis of a Derust Solution at 240°F.

<u>Time (hours)</u>	<u>Caustic</u>	<u>Gluconate</u>	<u>EDTA</u>	<u>ml Fe (III) Sequestered</u>
0	55.4	23.6	13.2	31.5
20	56.0	19.1	13.3	33.5
40	53.3	16.3	13.2	29.5
90	48.7	12.3	12.7	12.0
44 grams of sodium gluconate added				
140	48.5	22.0	13.0	<u>33.0</u>
190	47.5	17.6	12.9	18.0

Table 4 shows that the gluconate concentration becomes significantly depleted after 90 hours of exposure to 240°F even though no rusty specimens were processed in the bath. Table 4 also shows that the gluconate concentration can be replenished by a simple addition of sodium gluconate.

Another four hundred ml sample of the stock solution was placed in a 500 ml beaker. The stock solution was analyzed using the procedures previously described and the solution was then placed in a furnace at 160°F. Periodic analyses of the solution were conducted and the results are summarized in Table 5.

Table 5. Values Obtained During Periodic Analysis of a Derust Solution at 160°F.

<u>Time (hours)</u>	<u>Caustic</u>	<u>Gluconate</u>	<u>EDTA</u>	<u>ml of Fe (III) Sequestered</u>
0	55.4	23.1	13.1	32.2
44	53.6	22.9	13.0	30.6
112	54.0	23.5	13.4	28.4
160	54.0	22.1	13.2	30.9
208	55.3	23.3	13.3	31.6
280	56.0	24.0	13.4	32.0

The data presented in Table 5 indicates that very little, if any, thermal degradation occurs at 160°F. This may be the reason why some proprietary formulations are recommended for use at 140°-160°F.

The thermal stability of two derust solutions at 200°F. One solution consisted of 400 ml of a MIL-C-14460 Type 1 compound (600 grams pr liter) and the second solution (stock solution) consisted of the following:

Sodium Hydroxide 130g
 3Na EDTA 369
 Sodium gluconate 74g
 Distilled Water up to 400 ml

Periodic analysis were conducted on the solutions and the results are shown in Table 6.

Table 6. Thermal Decomposition of the Specification Solution (A) and the Stock Solution (B).

A.

<u>Time (hours)</u>	<u>Caustic</u>	<u>Gluconate</u>	<u>EDTA</u>	<u>ml of Fe (III) Sequestered</u>
0	53.3	24.5	10.2	30.0
16	52.7	22.0	9.95	29.5
40	51.2	20.5	10.6	30.0
68	52.1	20.0	10.9	29.0
92	49.5	18.8	10.3	28.0
164	47.3	16.7	10.2	26.5

B.

0	51.6	26.5	12.5	31.0
24	53.0	24.0	12.7	31.0
48	51.2	21.0	12.4	30.0
72	51.0	18.8	12.8	29.5
144	47.7	16.2	12.5	28.0
192	49.0	16.0	12.9	27.0

Table 6 shows that at 200°F thermal degradation of the gluconate is experienced but the degradation is much less than that experienced at 240°F. Thus it would seem advantageous to start out with a minimum amount of gluconate and then replenish with gluconate as it is depleted. Also, to keep the thermal degradation to a minimum, the solution should only be heated when materials to be derusted are available. Holding the solution at operating temperatures in anticipation of periodic processing will greatly reduce the efficiency of the bath and add to the derusting costs. Thermal degradation of derust solutions at various temperatures is shown in Figure 4.

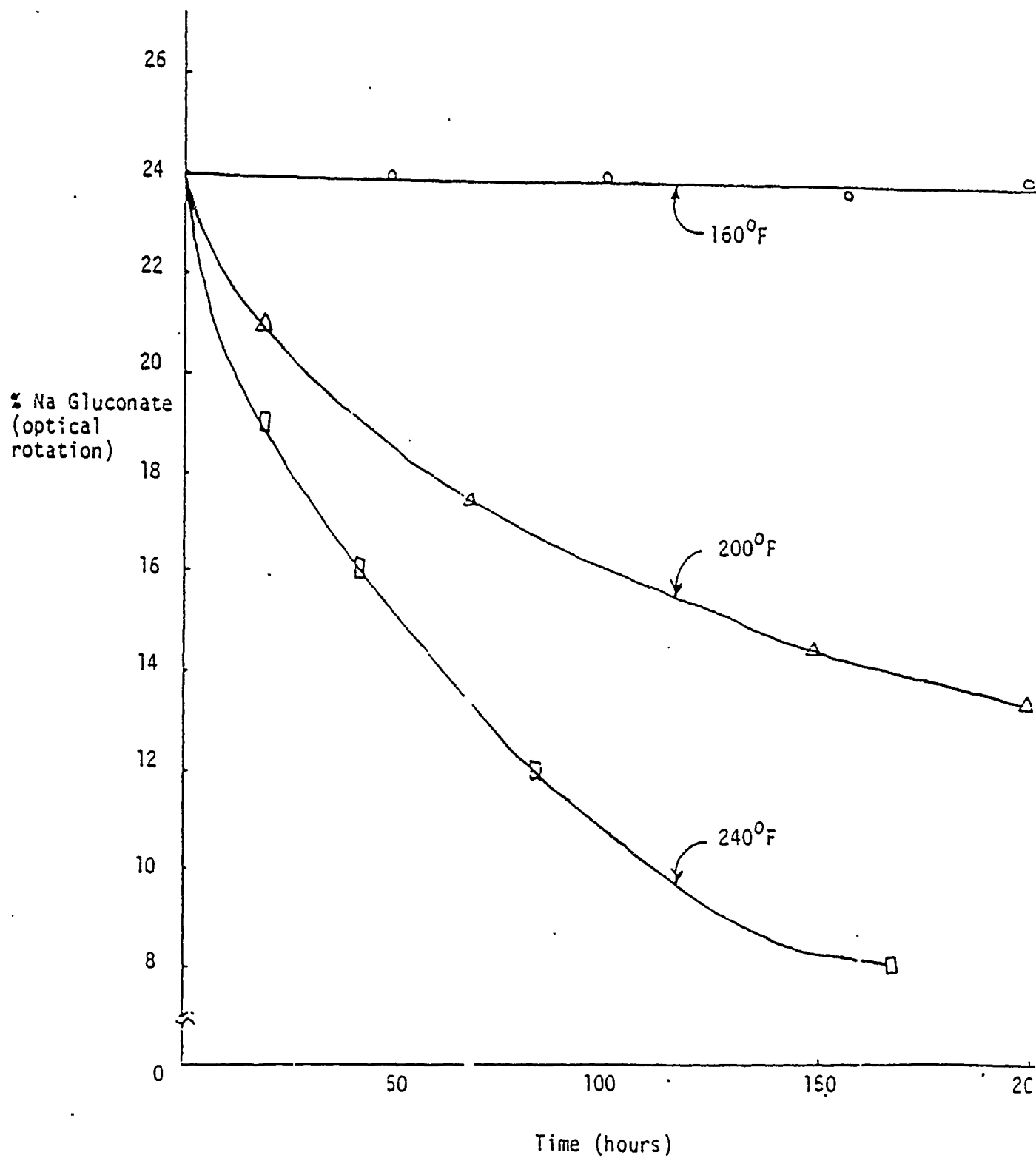


Figure 4. Thermal Stability of Sodium Gluconate in Immersion Derust Solutions.

III. Performance Testing

Panels of SAE 1020 steel, 2" x 3" x .06", were vapor degreased, blasted with 250 mesh glass beads and exposed to the 5% salt spray test (ASTM-B117) for 16 hours. The panels were rinsed with distilled water and placed in an oven at 210°F for a minimum of eight hours. The panels were removed from the oven approximately one-half hour before being weighted. They were immersed in a derust solution, water rinsed, dried and reweighted. Finally the panels were blasted clean with 250 mesh glass beads and weighted again. In this manner, the amount of rust removed by the derust solution was compared to the total amount of rust on the specimen. Various derust formulations at different temperatures were tested using this procedure. The data obtained during performance testing is summarized in Table 7.

Table 7. Performance of Derust Formulations at Various Temperatures.

<u>Derusting Solution</u>	<u>°F.</u>	<u>Immersion Time(min)</u>	<u>Removed Rust(mg)</u>	<u>Residual Rust(mg)</u>	<u>Total Rust(mg)</u>	<u>% Rust Remov Total Rust</u>
Type 1 (600 g/l)	240	10	217.9	6.6	224.5	97.0
Type 1 (300 g/l)	223	10	213.8	14.9	228.7	93.3
Exp'l Type 1 (3% 3Na EDTA)	220	10	203.1	14.8	217.9	93.2
Proprietary Type 1	215	10	197.8	25.7	223.5	88.6
Stock Solution (300 g/l)	218	10	183.9	29.6	213.5	86.4
97g NaOH 27g 3Na EDTA } 300 ml	235	10	41.9	136.9	178.8	23.5
97g NaOH	232	10	57.0	147.4	204.4	27.9
97g NaOH 56g Na Gluconate } 300 ml	234	10	178.6	2.0	180.6	99.0
100 ml T.G. NaOH 13g Na Gluconate } 350 ml	224	10	182.6	7.4	190.0	95.8
Stock (300 g/l) Air Agitated	160	60	108.9	107.2	216.1	51.9
Type 1 (300 g/l)	150	60	72.4	151.1	223.5	32.5
Exp'l Type 1 (3% 3Na EDTA)	150	60	116.1	99.1	215.2	54.0
Type 1 (600 g/l)	150	60	166.7	39.6	206.3	80.7
Proprietary Type 1	150	60	88.8	125.8	214.6	41.1
Stock Solution	150	60	115.3	122.4	237.7	48.4
Type 1 (600 g/l)	150	30	96.3	110.0	105.3	46.6
Type 1 (600 g/l)	185	30	195.6	10.9	206.5	94.5

Table 7 shows that all derust solutions are most effective at their boiling point. It also shows that salt spray furnace and oven dried specimens can be used to distinguish the ability of a solution to remove rust. Natural rust may be more difficult to remove than salt spray formed rust, but Table 7 shows that time and temperature can be altered to make a performance requirement more difficult to meet.

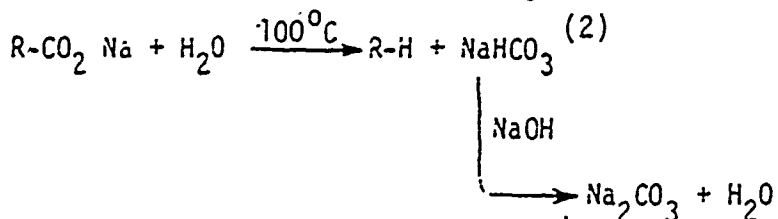
DISCUSSION

During this investigation additional reference work was conducted to learn more about the possible reactions of Type 1 compounds in an effort to explain the chemical processes which occur in derust solutions. First, the poor thermal stability of sodium gluconate in a hot caustic solution will be discussed. The following paragraph describes one of the processes which could occur.

"The complex reaction sequence promoted by the action of aqueous alkali at 35°C on reducing sugars includes isomerization, fragmentation and fragment recombination. Two kinds of products form: carbohydrates and saccharinic acids. The products of fragmentation are themselves at the oxidation level of carbohydrates and they may isomerize or recombine to form larger molecules. In addition, there are formed colored products of high molecular weight and undetermined structure." (1)

This statement applies to glucose, but the site at which these reactions occur is along the six carbon atom chain. The only difference between glucose and sodium gluconate is the functional end group. The atomic arrangement along the carbon chain is identical.

A reaction which appears in an organic text is written as follows:

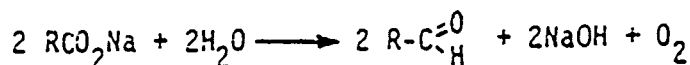


This represents a decarboxylation reaction in which a CO₂ group is removed from the gluconate and in the presence of caustic forms sodium carbonate. If the gluconate content is increased to 50% in a 30% caustic solution and heated to boiling, excessive gassing of the solution is observed. Remembering that alcohols can be oxidized to acids in the presence of an oxidant and acid, the gluconate could possibly decompose in a caustic media to produce oxygen and the corresponding aldehyde or alcohol.

(1) Journal of the American Chemical Society, 1952, page 499.

(2) Organic Chemistry by Cram and Hammond.

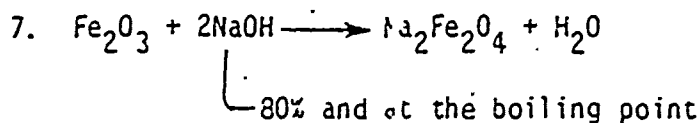
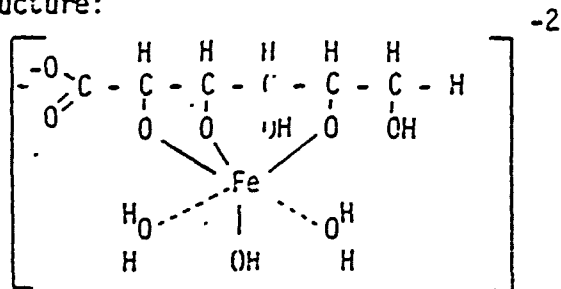
The proposed reaction would be:

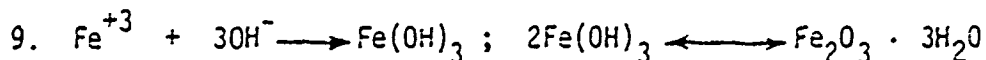
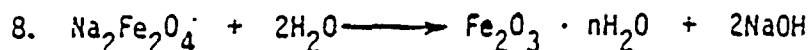


These reactions would render the optically active gluconate inactive and account for the gassing that occurs along with the depreciation in the gluconate concentration. Thus, a combination of isomerization, fragmentation, decarboxylation and deoxygenation of gluconate may be involved when sodium gluconate is present in caustic solutions.

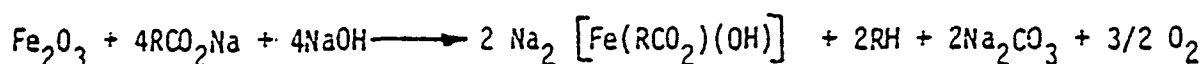
Secondly, The chemical reactions involved in the rust removal by caustic-gluconate solutions was investigated. The following are statements or reactions from various references related to the rust removing or iron sequestering capability of derust solutions.

1. For high temperature work, EDTA may be more economical due to its better thermal stability.
2. EDTA forms stable complexes with ferrous and ferric ions.
3. To some extent EDTA is relatively ineffective as a sequestering agent in the presence of high caustic soda concentrations.
4. The electron attracting tendency of iron (III) is sufficiently great so that, "induced dissociation" of the hydroxyl proton occurs on the gluconate.
5. Sodium gluconate in highly alkaline solutions can be completely dehydrogenated on the -OH groups.
6. The iron (III) complex formed with gluconate at pH 9.3 has the following structure:

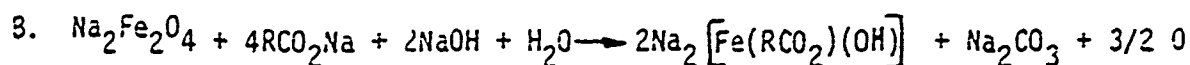




This illustrates that caustic is the ingredient which most significantly affects the dissolution of rust. The gluconate is simply there to sequester iron (III). An overall reaction for rust removal can thus be postulated assuming the complex at pH 9.3 is typical and the fact that gluconate sequesters iron (III) on a 1:1 basis.



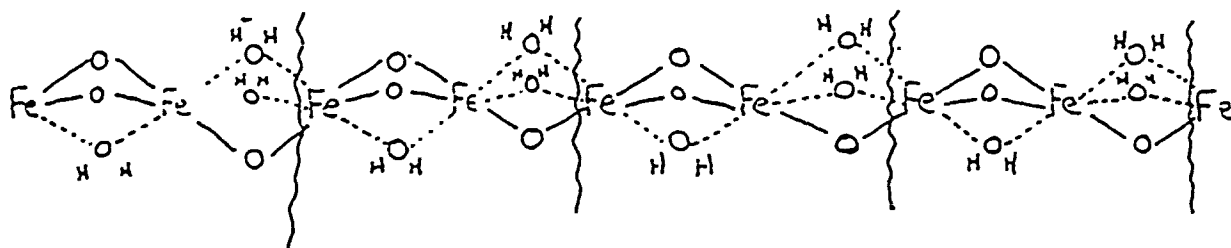
This reaction is a combination of the following reactions.



Note that all these processing reactions can be written without including EDTA into the reaction.

One other factor remains to be discussed and that is how can more than one mole of iron (III) be sequestered by one mole of gluconate. A 1967 report states that polymeric iron oxide could be formed by adding caustic to an iron (III) citrate complex. Polymers with a molecular weight of more than 1.5 million were produced.

A proposed structure for such an iron oxide polymer is shown.



The basic $\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ formulation is continually repeated. In relatively the same manner, gluconate could sequester iron (III) on a mole for mole basis until an excess of iron (III) is present. Then polymeric iron oxide could begin to form and the extent to which it would grow (and be sequestered) would depend on the structural stabilities of the polymer and the parameters under which it was growing.