234-5 BANK TANK CIRCULATION STUDIES

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INTRODUCTION

In plutonium process systems, critical mass considerations impose restrictions upon equipment geometry and arrangement necessitating changes from normal chemical processing practice. In the Plutonium Reclamation Facility a critically-safe geometry of the processing vessels, combined with economical utilization of building space, has resulted in manifolded, vertical tanks for blending, receiving, holding, etc. Because of the radioactivity and dollar value of the process solutions all tanks, lines, associated pumps and valves are welded wherever possible and are designed to be leakproof. The pumps attached to the bottom-outlet manifolds of the tanks are of seal-less or canned motor type. The extremely short life of these pumps (considerably below that expected even in severe abrasive and corrosive service) prompted a series of studies using glass tanks containing process solutions which, except for the associated radioactivity, duplicate plant process streams. This report presents the results of these studies.

SUMMARY

Circulation, blending and reaction characteristics of simulated process streams in glass duplicates of the 234-5 Bank Tanks TK-17, TK-27, and TK-37 revealed circulation patterns which result in intermittent cavitation within the canned motor transfer pumps. This cavitation, combined with the unavoidable corrosion and abrasion, rapidly destroys the pumps.

The circulation patterns, under varying liquid levels as encountered in plant operation, cause single and dual phase transfer of the organic-aqueous solutions to process columns at different times which results in flooding and erratic extraction efficiencies.

Reduction of cavitation and elimination of mixed phase transfer has been demonstrated by means of parallel controllable orifices in the external circulation lines. Elimination of cavitation, and uniformity of mixing in the four separate vessels comprising the bank-tank assembly, have also been demonstrated by means of changes in the inlet and outlet manifolds. The reduction of cavitation can be accomplished by changes in the system components remotely located from the tanks proper, i.e., in piping located in hoods. Complete elimination of cavitation and uniformity requires alteration of the tank headers and, while more desirable, also entails appreciable cost.

DESCRIPTION OF EQUIPMENT

The test systems are essentially "see-through" models of the existing bank tanks of the Plutonium Reclamation Facility. Three different configurations were studied. One of these was a glass model of TK-27 or standard 15 gallon capacity receiver vessel. Another was a glass model of the CAX Pump vessel, TK-37 and the third reproduced, in glass, the CAF Pump tank or storage vessel TK-17. The various basic configurations are shown in Figures 1, 2 and 3. In each case four tanks of 5-inch diameter Pyrex pipe were interconnected at the tops and at the bottoms by distributor manifolds. The bottom or outlet manifold was connected to the suction side of a canned motor pump. The discharge from the pump was returned through the top distributor to the tanks, providing a closed circuit. A bleed-off line downstream of the pump permitted controlled withdrawal of the solutions at rates simulating process transfer to the columns. The withdrawn solution was collected in a 200 liter stainless steel tank which was equipped with a pump and controls for returning the liquids to the bank tanks or disposing of them to a sewer as desired. This 200 liter vessel served as a feed make-up tank during startup of the systems.

In addition to the duplicated systems shown in the first three figures new distributor and collection manifolds were provided as shown in Figure 4. These were designed to establish equal resistance paths for fluid transfer and to eliminate aspiration and line friction effects on the liquid distribution between the four vessels in the bank assembly.

All instrumentation, feed and vent lines were reconstructed to permit precise reproduction of plant problems. Modifications to the basic tank loop were made during the progress of the runs. A short-circuiting line was installed to allow recirculation of the liquid through the pump. This line was attached to the main discharge line between the point where column feed was diverted and the location of the orifice ahead of the distribution manifold on the high pressure side and the pump inlet on the low pressure side. Subsequent alterations provided a bifurcated discharge line with different sized orifices and control valves in each leg.

OPERATION

Several tests were made with each of the different configurations. Initial circulation behavior was determined while using a 2.5 molar solution of nitric acid with sufficient aluminum nitrate to provide a specific gravity

of 1.2. Secondary tests were conducted with this aqueous solution blended with an organic phase of 20% tri-butyl phosphate in carbon tetrachloride. The final studies in each case employed acidified ferrous sulfamate-sodium nitrite solutions to establish effects of heavy gas evolution.

The initial circulation tests involved starting with different liquid levels to observe differential draw-down within the tanks, relative agitation effects among the four tanks, emulsification tendencies (air/liquid), cavitation tendencies and differential temperature between tank contents and pump discharge. Flow rates from 10 liters per hour to 40 liters per hour through the bleed-off line to the feed tank were used to simulate column feed rates of the production plant. Orifices of from 1/8-inch diameter to 1/2-inch diameter were installed in the line to the distributor manifold at the top of the tanks to determine effects of plugged orifices and corrosion-abrasion enlarged orifices above the nominal 5/16-inch diameter orifices installed in the existing plant.

The initial tests were repeated using a two phase mixture of carbon tetrachloride-TBP and nitric acid-aluminum nitrate solutions in various ratios; 10%, 30% and 50% organic in aqueous solutions were tested.

Final studies in each series utilized a 0.2 molar solution of ferrous sulfamate mixed with 1 molar sodium nitrite in the tanks to determine pumpability of the gassing liquid.

RESULTS

1. TK-27 Tests

Unmodified TK-27 calibration runs with water as the test fluid showed that unequal distribution was obtained at essentially all flow rates. With the pump discharging or recirculating 13 gal/min only a trickle was observed entering the fourth or last tank in the series. At a flow of about 8.5 gal/min no flow was seen into this tank and only a trickle entered the third tank. At 4.6 gal/min both of these tanks received no fluid and a trickle entered tank 2. In all cases, the bulk of the circulation was confined to the first tank of the bank. With unrestricted flow (no orifice in line) the difference in liquid levels in the various tanks was at a maximum; tanks 3 and 4 were completely full, the level in tank 2 was about 4 inches higher than starting level and tank 1 was completely empty. With orifices of different sizes and with valves installed for further flow control it was possible to maintain almost any desired combination of levels.

The water was replaced with nitric acid-aluminum nitrate mixture and levels established at different flow rates were obtained. These are tabulated in Table 1. As indicated, air was drawn through the bottom of tank 1 after being entrapped in the solution and caused cavitation even before the maximum head differential was obtained.

The use of organic-aqueous mixtures illustrated even more vividly the undesirable effects obtained. The differential was pronounced as before and cavitation resulted also, but in addition it was seen that poor mixing resulted in the last three tanks. When 20% by volume of organic phase was present in the starting mixture, about 95% of this was found to be recirculating through the first tank within 5 minutes. The total flow was restricted by a 5/16-inch diameter orifice, giving a circulation rate of about 15 gal/min. A flow of approximately 26 gal/min or that which would be obtained from a 3/8-inch diameter orifice was required for adequate mixing in all tanks.

With acidified ferrous sulfamate-sodium nitrite mixtures, blended in the tanks, the gas evolution rate was sufficient to completely fill all tanks with foam and "air bind" the circulation pump. Digestion times of about one hour were needed to allow resumption of pumping. Prior to this the pump could not establish or maintain prime.

Installation of a by-pass line or recirculation path around the pump permitted a more uniform and single phase transfer from the bank tanks to the receiver or columns. Basically it proved to be effective in reducing the in-tank mixing and permitted disengagement of the organic and aqueous phases to occur while recirculating sufficient liquid to cool the pump. A better method establishing this control was later developed by using a bifurcated discharge line with different sized orifices in each leg. One of the orifices (1/4-inch diameter) remained open at all times. The second (3/8-inch hole) was valved off during transfer periods to permit disengagement of the organic phase from the aqueous phase in the tanks and opened during mixing periods. The variation in recirculated flow to the tanks resulting from the use of this system was from about 11 gal/min to 37 gal/min.

Final testing, using redesigned distributor and outlet manifolds, demonstrated that cavitation could be eliminated completely and that uniformity of mixing was possible at any flow rate. The distribution

header provided constant overflow weirs to each tank and the outlet manifold established uniform resistance paths from the tanks to the inlet of the pump.

2. Tanks TK-17 and TK-37

Operation of glass models of TK-17 and TK-37 served to confirm results obtained in the test with the shorter vessels and in addition permitted quantification of the differential draw-down obtained during operation. It was observed that under full tank conditions and with unrestricted recirculation rates the differential draw-down was about six feet between the first and last tanks in the bank. Since instrumentation in plant tanks is located in the last tank it is clearly possible to show the six feet of liquid in the system and actually be cavitating because of air inclusion from the first empty vessel. This differential was reduced to about 2 feet when a 3/8-inch orifice (minimum size for adequate mixing) was installed.

3. Ferrous Sulfamate-Sodium Nitrite Addition

A period of unpumped mixing was found to be advisable during the blending or reaction stage of ferrous sulfamate and sodium nitrite. If the solutions are allowed to react for approximately 15 minutes following the addition of reactants the pump can generally be started without cavitation. A 20-minute waiting period allowed safe operation of the pump every time.

Solution Temperatures

No differential temperatures greater than 4°C were noted at any time between the bulk tank temperatures and the pump discharge.

4. Emulsification

Little tendency to form stable emulsions was found when 3/8-inch or larger orifices were installed and when the liquid levels were maintained to prevent cavitation. The mixing was complete and gave a fairly fine "fish egg" blend of organic and aqueous phases with a disengagement time of less than one minute. However, when the system was allowed to cavitate and pump discharge was impaired, abraded carbon from the pump bearings became evident and the emulsion endured beyond 15 minutes after cessation of pumping.

CONCLUSIONS

The original bank tank configuration and method of operation contribute to premature pump failure, process irregularities and operating difficulties.

1. Immediate Mechanical Alterations

Installation of a dual orifice system in a bifurcated recirculation line between the pump discharge and the tank entry will result in improvement. One 1/4-inch diameter orifice will permit adequate fluid flow through the canned motor pump to provide cooling and lubrication and at the same time will allow sufficient disengagement between organic and aqueous phases for single phase transfer to the columns. A 3/8-inch diameter orifice arranged in a leg parallel to the smaller orifice can be controlled by means of a valve. When open, the combined flow of the 1/4- and 3/8-inch orifices will provide adequate mixing in all four of the bank tank sections.

2. Immediate Operating Modifications

Transfer of the mixed process fluids should be made in single phase fashion by use of the dual orifice system in order to prevent or reduce the possibility of flooding in the columns.

During the ferrous sulfamate-sodium nitrite reduction procedure the gas liberation rate will interfere with pump operation even if the redesigned manifolding method is employed. Therefore, during a period of not less than 15 minutes following blending of the reactants it is not advisable to run the pump-motor. At the expiration of this time it is again possible to attain full liquid flow, even though some gas evolution is evident.

3. Long Range Mechanical Alterations

Installation of redesigned inlet distribution manifolds and outlet manifolds will promote even greater equipment life by eliminating cavitation as a contributing factor in shortened pump life. Process improvements should also result from the more uniform mixing.

Table 1

Tank Levels at Various Flow Rates, 234-5 Bank Tank TK-27

2.5M nitric acid-aluminum nitrate
specific gravity 1.2

<u>Overall Flow Rate gpm</u>	<u>Tank 1</u>	<u>Tank 2</u>	<u>Tank 3</u>	<u>Tank 4</u>
3.0	+ 0.75	- 0.5	- 0.5	- 0.5
12.5	- 2.0	0	- 0.25	+ 0.5
15.4	- 4.0	- 0.5	- 1.0	- 0.75
17.5	- 7.0	- 1.25	+ 2.0	- 0.25
21.5	-11.0	- 1.5	+ 4.75	+ 5.0
25.0	-13.5	- 1.5	+ 6.0	+ 7.0
31.0	-19.0	- 2.0	+10.0	+11.0
37.5	-25.5*	- 0.5	Full	Full
42.0	Empty	+ 4.0	Full	Full

* Cavitation developing, air being drawn through vortex.

Arrangement TK-27

Arrangement TK-17

FIGURE 2

Arrangement TK-37

FIGURE 3

NOTE: DISTANCES A TO E, B TO E, C TO E AND D TO E
ARE EQUAL.
DISTANCE H IS IDENTICAL FOR ALL TANKS.

FIGURE 4

MODIFIED DISTRIBUTION AND OUTLET MANIFOLDS
PLUTONIUM RECLAMATION FACILITY BANK TANKS