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EVALUATION OF FAILED CRANE CHEMPUMPS USED DURING SALT WELL PUMPING

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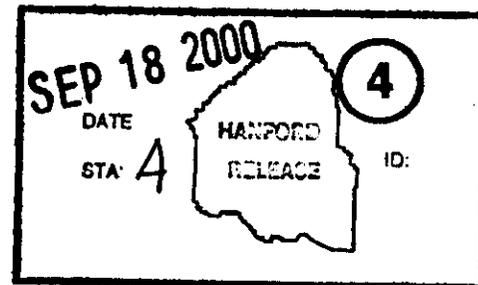
Abstract: Evaluation of failed Crane Chempumps used for saltwell pumping of single shell tank waste. Document is intended to capture recent failure mechanism associated with specific single shell tanks in S/SX, U, A and AX tank farms.

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1.0 INTRODUCTION

The Interim Stabilization Project is responsible for removing pumpable interstitial liquid from remaining single shelled tanks and transferring the waste to safer double-shelled tanks. This waste transfer is conducted by installing a saltwell pumping system within the designated single shell tank, and transferring the waste to double shelled tank using approved transfer lines. The saltwell pumping system is placed within a saltwell screen installed into the tank waste, the screen is designed to allow gravity flow of liquid into the screen and prevent solids from entering the pumping system. A foot valve consisting of a venturi jet and nozzle creates a suction, picking up waste at an equal rate as the out flow transfer rate of the saltwell system. A centrifugal pump is used to create the motive force across the eductor and drive the waste through the associated system piping and transfer lines leading to the double shelled tanks. The centrifugal pump that has typically been used in the saltwell pumping system installations is the Crane Chempump, model GA-1 ½ K with 4 ¾" impeller.

2.0 OBJECTIVE

The following evaluation is not intended to be an all inclusive analysis of the operation of a saltwell system and associated pump. This evaluation will detail some of the noted failures in specific saltwell systems and document those findings. Due to the large number of saltwell systems installed over the duration of the Stabilization Project, only those saltwell systems installed over the last two years within S, SX, U, A and AX tank farms, shall be included in this evaluation. After identification of the pump failures mechanism, recommendations shall be identified to address potential means of improving overall operational efficiency and reducing overall equipment failures.

3.0 BACKGROUND

Over the duration of the last two years, saltwell pumping systems have been installed in the following single shelled tanks: SX-104, SX-106, S-102, S-106, S-103, U-103, U-105, U-102, U-109, A-101, AX-101, SX-105 and U-106 respectively. Additional installations of similarly designed systems are planned for future tanks including S-109, SX-103 and SX-101. These tanks are not included in the operational history section of this evaluation due to limited operational data at the time this evaluation was performed and system installation status.

The first prototype saltwell system was installed on a developmental basis in single shelled tank S-111, in January 1976, Reference (1). An additional saltwell system was installed in single shelled tank BY-107, to further test and demonstrate the saltwell pumping concept, Reference (2). A final evaluation was performed on the two prototype saltwell systems following extended operation and one of the problems associated with the early pumping systems was mechanical seal leakage on the close coupled pump and motor, Reference (3). Mechanical seal leakage, caused by salt creep build up on the faces of the seal, resulted in excessive leakage within the

pump pit and high decontamination costs associated with the leaked tank waste. Reference (3) recommended the use of a "canned rotor" pump design to eliminate mechanical seal failure and subsequent leakage from the pump. The pump selected to replace the prototype model pump was the Crane Chempump, which is the same style pump currently used within the saltwell system.

The Crane Chempump is designed to recirculate the process fluid it is pumping to cool and lubricate the internal bearings of the canned pump and motor. The principles of using this recirculation loop and subsequent modifications to the original design have contributed to the increased number of pump failures and accelerated pump failure rate. The recirculation line consists of a 1/4" stainless steel tube running from the pump discharge plenum to the rear bearing housing. The differential pressure drives the amount of recirculation flow through the pump. The standard Crane Chempump utilizes a discharge filter to restrict the passage of solids through the pump recirculation line and subsequently the rear bearing, rotor/stator passage and front bearing. The original bearing material selected for previous installations is believed to have been carbon graphite.

Due to recirculation line plugging, caused by the contribution of total solids within tank waste and also crystallization of tank waste within the system caused by cooling, the recirculation line filter was removed from the Crane Chempump. Upon the removal of the recirculation line filter the bearing material was changed from the softer carbon graphite to a harder ceramic material. The ceramic material was selected to help breakup the solids passing through the recirculation line before entering the rotor/stator lining area of the motor to reduce wear associated with solid particles. The manufacturers recirculation line was modified on site, at a later date, to include an air operated valve and a clean water connection to flush the recirculation line, as evidence of pluggage was noted. Operational and administrative controls limit the clean water flush of the pump recirculation line while the system is not in operation.

Based on projected higher volumes of pumpable liquid in tanks A-101 and AX-101, the saltwell systems for A-101 and AX-101 contained a different styled foot valve and different pump than the typical saltwell system. The foot valve was of a less restrictive design with slightly larger sized orifice diameters, designed to increase transfer rates from 5 gallons per minute to 10 gallons per minute. The pump was changed from a Crane Chempump model GA- 1 1/2 K with 4 3/4" impeller to a GB-3K with a 5 1/2" impeller. The larger impeller provided an increase in differential pressure from 35 psig to 50 psig. The additional differential pressure allowed the return suction pressure to the pump from the eductor to be boosted, and therefore obtain higher transfer rates. The model GB-3K and GA- 1 1/2 K models are identical with the following exceptions; the impeller is 3/4" larger in diameter, motor is 3KW versus 1 1/2 KW and recommended recirculation flow is 2 gpm versus 1 1/2 gpm. The larger motor is associated with turning the larger impeller at the same revolutions per minute and the higher recirculation flow is related to the increase in differential pressure across the pump. This results in a higher heat load and the need for additional pump/motor cooling.

4.0 EVALUATION

The application of using the recirculated tank waste to provide bearing cooling and lubrication is a major contributor to the observed saltwell pump failures. Other contributing causes also include selected bearing material, removed circulation filter, operation of pump beyond the recommended limits of its design, configuration of saltwell pumping system piping and more complex waste characteristics than previously pumped. See Appendix A, Tank Specific Saltwell Operational History, for a detailed description of saltwell system operations for tanks SX-104, SX-106, S-102, S-106, S-103, U-103, U-105, U-102, U-109, A-101, AX-101, SX-105 and U-106.

The selected bearing material adversely affects the operation of the saltwell system in many ways. The change of bearing material to the ceramic bearing was performed at some date prior to 1991, as evidenced by spare pumps manufactured in 1991 containing the ceramic bearing. The ceramic bearing material contributed to a waste compatibility issue and an increase in bearing damage due to dry running failure. During the priming of the saltwell system the pump cavity and associated piping is filled with water. The amount of water within the recirculation line and bearing surfaces is unknown, the bearing passage may be filled with water, partially filled, or potentially dry. The heat generated by the contact of the ceramic bearing and metal rotor shaft can cause the bearings to crack, if ran dry for a period as low as a couple seconds. Another disturbing contributor to bearing failure is a chemical incompatibility issue. The changing to ceramic bearings was not properly addressed with regards to service and waste compatibility. The ceramic material used consists of 94% Aluminum Oxide. Aluminum oxide reacts unfavorably with tank waste constituents, mostly caustic solution. Recent inquiries to the Tank Farm Process Engineering group estimate a three to six month bearing life expectancy before the tank waste contributes to bearing material deterioration.

The removed recirculation line filter contributes to the total amount of solids allowed to pass through the bearing passage. The addition of the small solid particles contributes to the likelihood of recirculation restrictions and blockage and bearing wear. The recirculation filter was omitted following pluggage problems related to the filter clogging and restricting recirculation flow. The exterior design of the recirculation line contributes to potential pluggage, due to the process waste cooling in the line prior to returning to the system and contributes to bearing wear. Excessive bearing wear may allow the rotor and impeller assembly to make physical contact with other mating parts within the pump. An increase in the tolerance between the rotor assembly shaft and bearing sleeve may allow for the rotor assembly to contact the stator lining of the pump. If the stator lining is breached, process fluid could enter the motor winding cavity and short or ground out the motor. Excessive vibration was experienced at the U-105 saltwell system. This vibration, caused by excessive bearing wear is credited to the second pump failure at U-105 due to motor testing data, refer to Appendix A, U-105 Saltwell System Operation.

An additional contributor to pump failures may be the increase in overall system operating efficiencies. Previous causes for saltwell system shutdown and isolation have been greatly

reduced over the previous year. Bypassing the double contained receiver tanks (DCRT), improvements to flammable gas detection and overall system improvements made over the last two years have greatly extended periods between system shutdowns. The increase in operating efficiencies has allowed for pumps to experience in four to six months the same amount of operating hours previously observed after a year long pumping campaign. Previous saltwell pumping campaigns commenced on the tanks identified as the easier to pump with regards to waste characteristics. The last remaining tanks scheduled for saltwell pumping contain wastes with the higher temperature, specific gravity, viscosity and saturated salt concentration than the previously saltwell pumped tanks. The more demanding physical characteristics of the tank waste contribute greatly to the demand on the pump and support equipment. Prior to saltwell pumping of SX-104 in July 1998 all saltwell pumping was performed without the use of a dilution system. Of the tanks included in this evaluation only S-103 and S-106 have not relied upon a dilution system to prevent transfer line plugging.

The operation of the Crane Chempump outside the recommended limits for its application contributes to an accelerated failure rate recently associated to the saltwell pumping system. Per the manufacturers operation manual, Reference (4), the pumps existing recirculation passage is intended for use with clear fluids. If the pump is to be used for a slurry or "dirty" application, clean backflush fluid is recommended for bearing cooling and lubrication. The total amount of clean fluid required for the Crane Chempump model GA-1 ½ K is approximately 1 ½ gpm. The required volume of clean recirculation fluid makes the activity of saltwell pumping, with the existing designed Crane Chempump utilizing a clean water bearing supply, impractical. Saltwell pumping is limited to the amount of liquid inflow to the saltwell screen, which in most cases is well below the 1 ½ gpm bearing supply requirement of the Crane Chempump. The end result of using clean bearing liquid to lubricate and cool the bearings, would be to add more waste to the single shelled tanks than that being extracted, or mass dilution resulting in filling available double shell tank space with water prematurely. Extensive system modifications and Authorization Basis clarifications are required to implement a clean water supply to the bearing cavity of the saltwell system pump.

Another potential contributor to premature pump life is the physical configuration of the saltwell pumping system piping, specifically the close proximity of an elbow near the pump suction. Physical restrictions due to the small size of the existing pump pits the saltwell pumping system is designed to be installed in, resulted in the original saltwell pumping systems to be condensed into the smallest practical area. The designing of a condensed pumping system resulted in the placement of an elbow directly to the pump suction flange. This elbow contributes to inducing a turbulent flow into the pump casing and impeller eye. This turbulent flow may contribute to impeller imbalance and improper thrust balancing of the rotor assembly. A standard design practice is to allow between ten and fifteen pipe diameters spacing between the pump suction and elbow or tee. This specified distance is credited with removing suction turbulence and stabilizing flow to any pump.

The Crane Chempumps model GB-3K, used at tanks A-101 and AX-101, suffered an accelerated failure rate when compared to the previously observed failures of model GA-1 ½ K Chempumps.

The first failed Crane Chempump model GB-3K used at A-101 was recently taken apart and analyzed in a glove bag. The results of the analysis showed that there was no pluggage of the impeller or pump casing due to temperature variations. Figure 1, shows evidence of excessive wear on the front face of the rotor assembly due to contact wear with the rear face of the front bearing. Figure 2, shows the unscarred front face of a new rotor assembly for comparison. Figures 3 and 4, show the interface between the front bearing and rotor of the failed pump and a new pump. According to the manufacturer, this excessive forward thrust was the result of cavitation or a restricted recirculation flow. Cavitation is not considered to be a contributing cause due to the closed loop nature of saltwell system and known operating parameters (suction pressure between 10 psig and 40 psig) during initial A-101 saltwell pumping campaign, refer to Appendix A, A-101 Saltwell System Operation.

The initial operation of the A-101 and AX-101 saltwell systems was very positive, approximately 10 gpm outflow respectively, the overall operation of each system was well below expectations. Each system operated approximately three days before suspected rotor damage caused the systems to suffer great loss in overall performance. The rotor damage is believed to be typical of all three GB-3K pumps installed, refer to Figures 1 through 4, the exact cause of the suspected low recirculation flow may never be determined. The restricted recirculation flow is credited to solid particles restricting the overall flow within the recirculation passage. Restricted recirculation flow is the most likely cause, however the existing configuration of the saltwell system does not allow for easy modification to improve overall recirculation flow. The low recirculation flow is credited with improper thrust balance leading to bearing/rotor contact and exposure of the aluminum rotor windings to the tank waste. The aluminum rotor bars reacted with the caustic tank waste resulting in rotor degradation and reduced rotor/impeller rotation. A contributing factor to the low recirculation failure may be the extra heat generated by the larger motor. The larger pump motor in addition to a restricted recirculation flow and heat generated by the friction of front bearing and rotor, contributed sufficient heat to the recirculated process fluid to vaporize the waste within the bearing area, further degrading the thrust balance of the rotor assembly. Boiling of the recirculation fluid was noted during the A-101 pump autopsy, as evidenced by blackened deposits coating the front face and front third of the rotor assembly and pump performance.

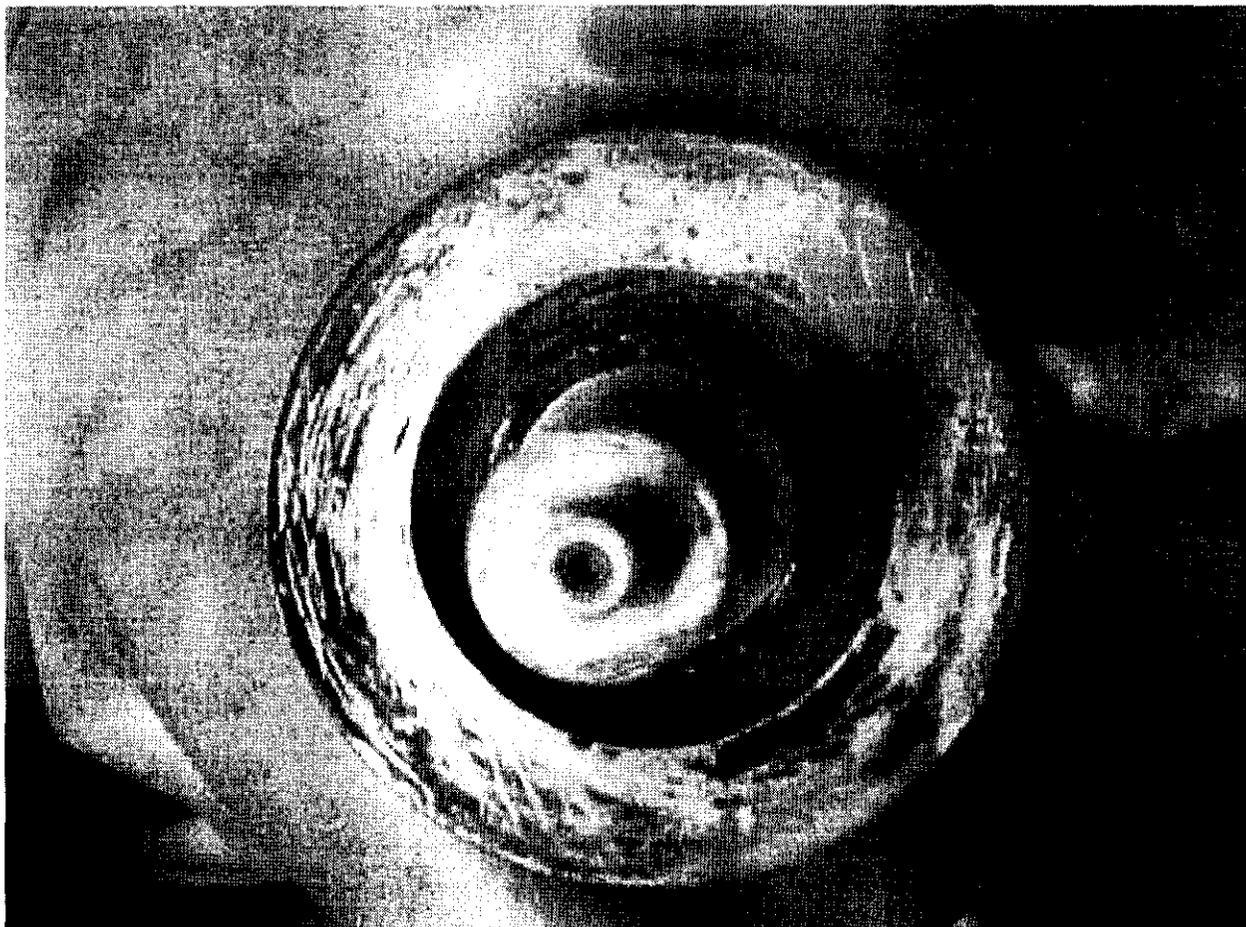


Figure 1 - Crane Chempump Front Rotor Model GB-3K

Description: Photograph shows excessive forward thrust on the rotor assembly from the Crane Chempump model GB-3K used in tank A-101. Forward thrust caused the front face of the rotor can to rub against the rear face of the front ceramic bearing. The bearing acted as a cutting tool removing protective stainless steel metal from front of rotor assembly. Removal of stainless steel exposed the front cavity of the rotors aluminum bars and end caps to caustic tank waste. Fine scratch marks on the front face of the rotor can are the result of scrapping during waste sample collection. Photograph was taken of assembly while inside glove bag used to perform pump autopsy. The blackened residue on the front half of the rotor assembly indicates excessive heat generation and likely waste boiling and vaporization.

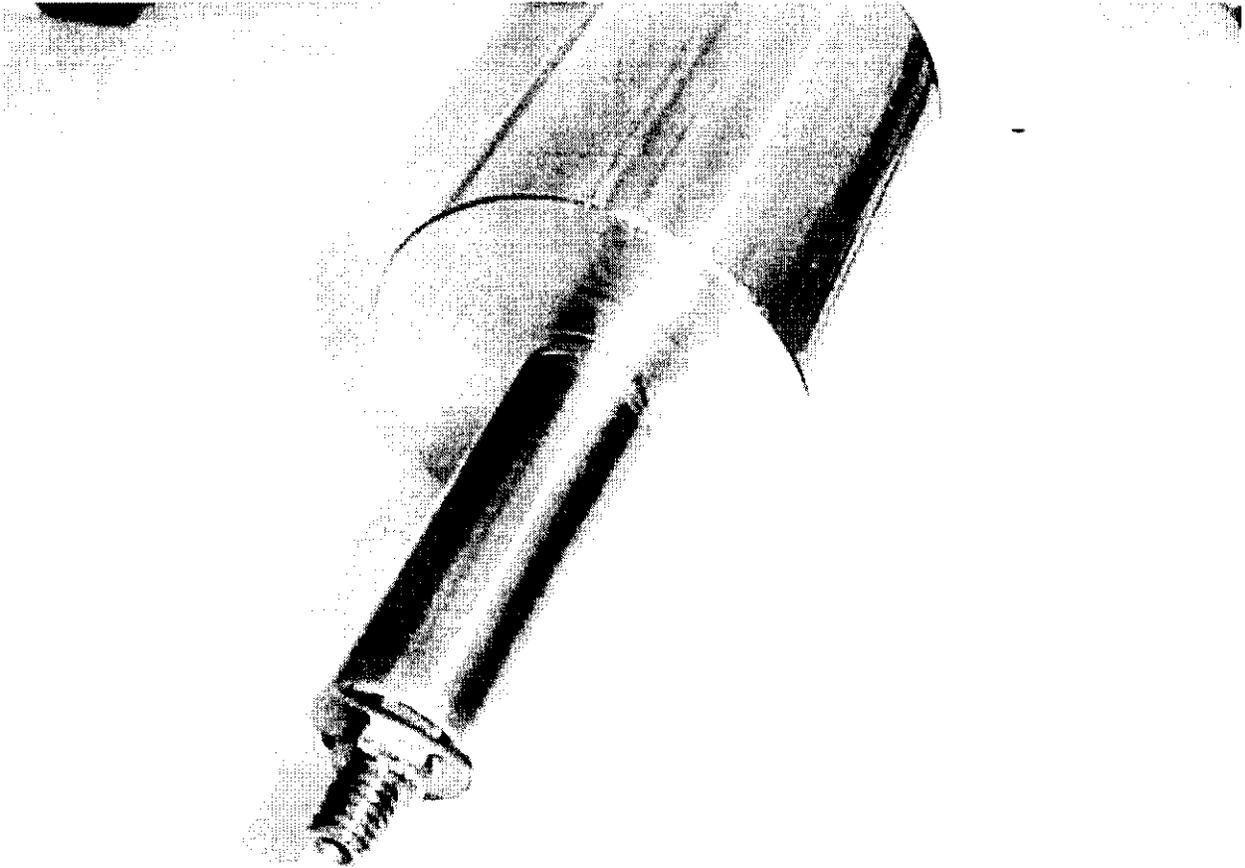


Figure 2 – New Rotor Assembly From Crane Chempump Model GA-1 ½ K

Description: Photograph shows a new rotor assembly taken from a Crane Chempump model GA-1 ½ K. Rotor assemblies for the model GA- 1 ½ K and the model GB-3K are similar in design. Note the front face of the rotor can and solid surface of stainless steel end plate.

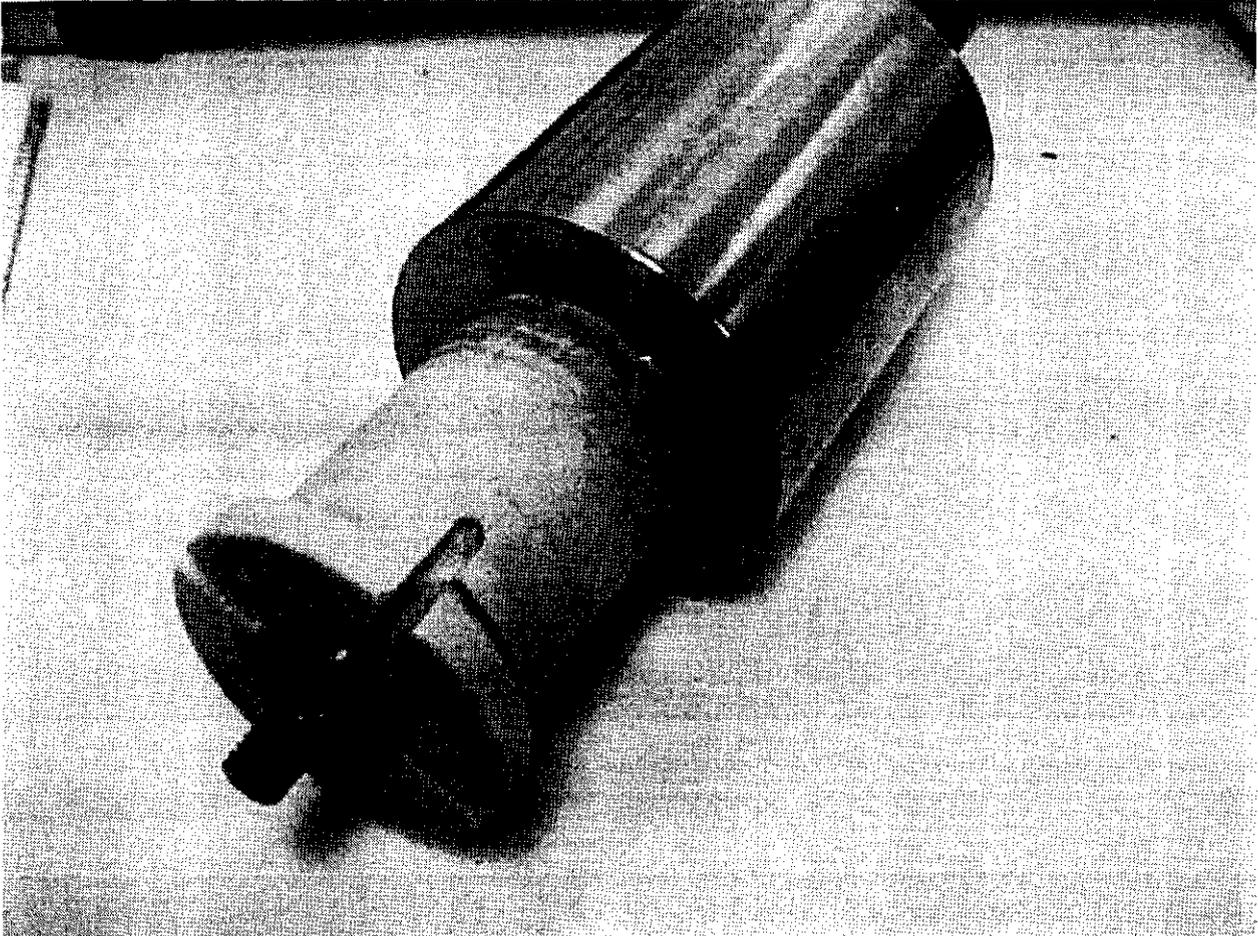


Figure 3 - Rotor/Bearing Interface

Description: Photograph shows the interface location of a new bearing and rotor assembly from a Crane Chempump model GA- 1 ½ K. The front bearing housing, which captures the front bearing is not shown for clarity. With proper thrust balance the rotor rides on a *thin wall of recirculation fluid*, which prevents bearing to rotor assembly contact.



Figure 4 – Rotor/Bearing Interface From Failed A-101 Pump

Description: Photograph shows interface between front bearing and front of rotor assembly on failed Crane Chempump model GB-3K used in tank A-101. Photograph is taken while assembly is being held in glove bag used for pump autopsy. Front bearing housing contains the front bearing, which was not removed.

5.0 CONCLUSION

Recent saltwell system pump failures can be attributed to problems caused by the recirculation fluid design, bearing material, saltwell system piping configuration and application of the Crane Chempumps. The Crane Chempump recirculation flow is not designed for a slurry application. A clean fluid supply is recommended for applications consisting of slurry or "dirty" fluids, typical of tank farm waste. The selected bearing material, Alox – Aluminum Oxide, contributes to early pump failure associated with chemical incompatibility with tank waste and dry running damage. Removal of the recirculation filter, due to previous plugging, allows larger particles to enter the bearing passage and rotor/stator lining contributing to restricted recirculation flow. Induced turbulent flow into the pump suction contributes to sustained periods of upset pump flow.

Despite the numerous contributing causes to failures associated with the Crane Chempump, it is however, the available pump that the existing saltwell system was designed around. Any modification to the existing system may adversely affect the schedule of deployment of the remaining saltwell systems. The existing schedule is built around an assumed properly designed and functioning saltwell pumping system and associated equipment. A major cost and schedule undertaking would be required to redesign the saltwell system.

The use of the Crane Chempump, in its current application is not ideal. However, the Interim Stabilization Program currently and historically has been able to operate the saltwell system with great success. Millions of gallons of single shell tank waste has successfully been transferred to double shelled tanks using the existing pump and technology. If the Stabilization program is able to accept the risk (cost, dose and schedule) of unscheduled pump replacements, then the existing Crane Chempump design should be capable of completing the saltwell pumping of future single shell tanks. A saltwell system operating at normal parameters currently consumes less than two pumps per a saltwell pumping campaign. The accelerated failures of Crane Chempump model GB-3K in the A-101 and AX-101 saltwell systems are an exception. The exact cause of the contributors to the excessive forward thrust can only be theorized based on the operating information, discussion with pump manufacturer and engineering judgment.

6.0 RECOMMENDATION

The primary recommendation is to replace the existing Crane Chempump with a similar designed centrifugal pump utilizing a clean fluid for bearing lubrication and cooling, which meets necessary system requirements, see Reference (5) and (6). The higher anticipated operating efficiencies of the newly selected pump should provide the A-101 and AX-101 saltwell system the necessary pump performance to remove the expected high volume of pumpable liquid.

Until a new pump application can be implemented, the bulleted items below contain recommendations for improving the operation and life expectancy of the Crane Chempump currently used for saltwell pumping.

- Maintain existing pump configuration, accepting pump replacements until new system can be implemented.
- Replace existing Aluminum Oxide bearings with Silicon Carbide bearings.
- Heat trace and insulate recirculation line to prevent solidification within.
- Closely monitor bearing temperature as indication of restricted recirculation flow.
- Improve temperature sensitivity reading on rear bearing housing.
- Improve saltwell system piping configuration to increase distance of suction elbow to pump inlet.
- Do not install additional GB-3K pumps until failure mechanism is fully understood.

The remaining Crane Chempumps within the Stabilization Program recently had the bearing material changed from Aluminum Oxide to Silicon Carbide on August 11, 2000, per work package WS-00-508. Pump bearings installed in the SX-105 and U-106 systems were not changed due to schedule impact regarding saltwell system startup. Silicon carbide bearings eliminate the chemical compatibility issue associated with the bearing material, but do not eliminate the potential cracking concern due to brittle material, or abrasive cutting potential due to material hardness.

Installed Crane Chempumps for U-102, U-105, U-109, A-101, AX-101 and SX-105 incorporated the addition of heat trace and insulation on the recirculation line, as will all remaining Crane Chempump installations.

Additional improvements to the rear bearing temperature indication should be pursued. Currently the monitored rear bearing temperature is a combination of pump pit ambient temperature and rear bearing housing temperature, this combination results in a lower indicated temperature than actual bearing temperature.

Bench testing of the existing saltwell piping configuration is being performed to evaluate the effects of the distance between the pump suction and first elbow. If results of this testing indicate that pump life may be extended by modifying the piping configuration, future saltwell systems will incorporate a straightening of the suction piping for existing and future pump applications. The S-109 saltwell pumping system shall incorporate an extended suction piping arrangement to help eliminate turbulent flow introduction into the pump. If the life expectancy of the Crane Chempump within the existing saltwell pumping system can be extended by the previously stated recommendations, then installation of the existing saltwell pump and system may be justified for installation into single shelled tanks with a shorter anticipated pumping duration.

7.0 REFERENCES

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Appendix A

Tank Specific Saltwell Operational History

The following contain brief system descriptions and include operational history for the identified saltwell pumping systems. Systems are listed in chronological order starting with SX-104 and proceeding through SX-106, S-102, S-106, S-103, U-103, U-105, U-102, U-109, A-101, AX-101, SX-105 and U-106.

SX-104 Saltwell System

The SX-104 saltwell system utilized a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 7/23/98 and operated successfully until 7/25/99, pumping approximately 117,000 gallons of waste. The saltwell system was isolated due to pump failure. The failure mechanism of this pump was a leaking pump casing gasket. The front pump casing gasket for this pump was EPDM, future pumps changed gasket material specification from EPDM to spiral wound gaskets to improve leak tightness. With the exception of the spray leak from the pump casing, all indications were that the pump was operating satisfactorily. Tank SX-104 has subsequently been declared stabilized.

SX-106 Saltwell System

The SX-106 saltwell system utilized a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 10/7/98 and operated successfully until 12/21/99, pumping approximately 147,000 gallons of waste. The saltwell system operated satisfactorily during the pumping campaign with one exception. The saltwell did not operate well at the high transfer rates, exceeding 2 gpm. System operating parameters suggested that a large solid particle was being lifted into the foot valve and interfering with the fluid flow between the venturi jet and nozzle. The SX-106 saltwell system was lifted and blocked up approximately eight inches to verify this situation. Following elevation of the saltwell system, transfer rate performance was elevated to the maximum designed discharge rate of 4 gpm. Tank SX-106 has subsequently been declared stabilized.

S-102 Saltwell System

The S-102 saltwell system utilized a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 3/18/99 and has operated sporadically during the pumping campaign. To date the pumping system has transferred approximately 56,000 gallons of waste. Initial system operating parameters indicated that a restriction was present within the foot valve. Disassemble of the remaining supply of foot valves for cleaning and inspection, revealed the likely cause. Four of the twelve foot valves contained a fine steel mesh screen on the inlet piping chamber to the jet. It is believed a screen was present within the S-102 foot valve. The restriction eventually solidified to the point that high temperature water and elevated pressures could not clear the restriction. The entire saltwell pump leg assemblies, including new foot valve, were replaced the week of 7/14/99, and the system was returned to service with satisfactorily operating parameters. System operated until 11/16/99 when the pump failed due to suspected bearing failure. A

replacement pump was installed on 2/19/00 and operated until 3/23/00 when indications of rotor or impeller failure occurred, this pump also ran with a restricted recirculation flow for a duration of time as indicated by high bearing temperatures. Pump did not produce any differential pressure when energized, amperage draw was below normal, no stator failure was indicated, pump rotation was assumed due to vibration felt through above grade valve handles. No detailed autopsy was performed on S-102 pump #2. Following the autopsy of the first U-109 pump a similar failure mechanism is assumed, see U-109 saltwell system description. The second replacement pump was returned to service on 5/25/00 and operated for approximately two weeks before system operating parameters indicated a potential blockage within the suction piping near the foot valve. System was shutdown when initial signs of performance deterioration were noted, in an attempt to save the newly installed pump. Troubleshooting has determined a blockage exists in the foot valve region of piping, possibly the result of cold fingering. Cold fingering is the process where localized waste is cooled below its freezing temperature due to nearby contact with steel piping at lower temperatures. At the date of this evaluation no clear path forward has been established for returning S-102 to operational status.

S-106 Saltwell System

The S-106 saltwell system utilized a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 4/16/99 and operated successfully until 1/5/00, pumping approximately 106,000 gallons of waste. The saltwell system operated satisfactorily during the pumping campaign. The pump was shutdown due to high rear bearing temperature, indicating a restricted recirculation flow and possible bearing damage. Tank S-106 has subsequently been declared stabilized.

S-103 Saltwell System

The S-103 saltwell system utilized a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 6/4/99 and operated successfully until 1/4/00, pumping approximately 23,000 gallons of waste. The saltwell system operated satisfactorily during the pumping campaign. The saltwell system was shutdown due to the failure of transfer line SN-219, between S-103 pump pit and S-A valve pit. Tank S-103 has subsequently been declared stabilized.

U-103 Saltwell System

The U-103 saltwell system utilized a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 9/26/99 and operated successfully until 5/11/00, pumping approximately 98,000 gallons of waste. The saltwell system operated satisfactorily during the pumping campaign. The pump was shutdown due to high rear bearing temperature, indicating a restricted recirculation flow and possible bearing damage. Tank U-103 has subsequently been declared stabilized.

U-105 Saltwell System

The U-105 saltwell system utilized a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 12/11/99 and operated successfully until 3/7/00, when pump bearing failure occurred. The initial pump experienced excessive vibration during the final days of operation, which indicated a failed front or rear bearing. On 4/11/00 a replacement Chempump was installed into the system and operated until 7/13/00. Total waste pumped is approximately 87,000 gallons of waste. The second pump also experienced excessive vibration during the final days of pumping. The second pump exhibited signs of a failed stator winding when electrical checks were performed. The subsequent bearing damage and excessive vibration allowed the rotor to penetrate the stator lining, exposing the stator winding to tank waste. Tank U-105 is undergoing review for declaration of stabilization.

U-102 Saltwell System

The U-102 saltwell system utilizes a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 1/20/00 and operated successfully until 5/29/00, when pump bearing failure occurred. On 6/8/00 a replacement Chempump was installed into the system and is currently still operating at time of this evaluation. Total waste pumped to date is approximately 51,000 gallons of waste. A pump autopsy of the first pump was performed and the pump showed signs of rotor assembly wear caused by contact of the front face of the rotor assembly with the rear face of the front bearing. Excessive shaft wear was also observed on the rotor assembly front and rear shafts. The pump manufacturer suggests this wear is evidence of excessive forward thrust caused by restricted recirculation flow or cavitation. Figures 5 and 6 show signs of the wear noted while taking pump apart. Megger testing was conducted on pump stator and results were found to be normal.

U-109 Saltwell System

The U-109 saltwell system utilizes a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 3/11/00 and operated successfully until 6/12/00, when pump failure occurred. The original pump exhibited signs of a failed rotor or impeller. On 7/4/00 a replacement Chempump was installed into the system and is currently still operating at time of this evaluation. Total waste pumped to date is approximately 51,000 gallons of waste. A pump autopsy of the first pump was performed and the pump showed signs of rotor assembly wear caused by contact of the front face of the rotor assembly with the rear face of the front bearing. Excessive shaft wear was also observed on the rotor assembly front and rear shafts. The pump manufacturer suggests this wear is evidence of excessive forward thrust caused by restricted recirculation flow or cavitation. The resulting sheared impeller shaft was the result of a pump restart following recirculation line flushing. The flushing pushed the rotor assembly and impeller forward into the pump casing, and start up torque caused the shaft to break due to a bound impeller. Figure 7 shows signs of the wear noted while taking pump apart. Megger testing results performed on stator were normal.

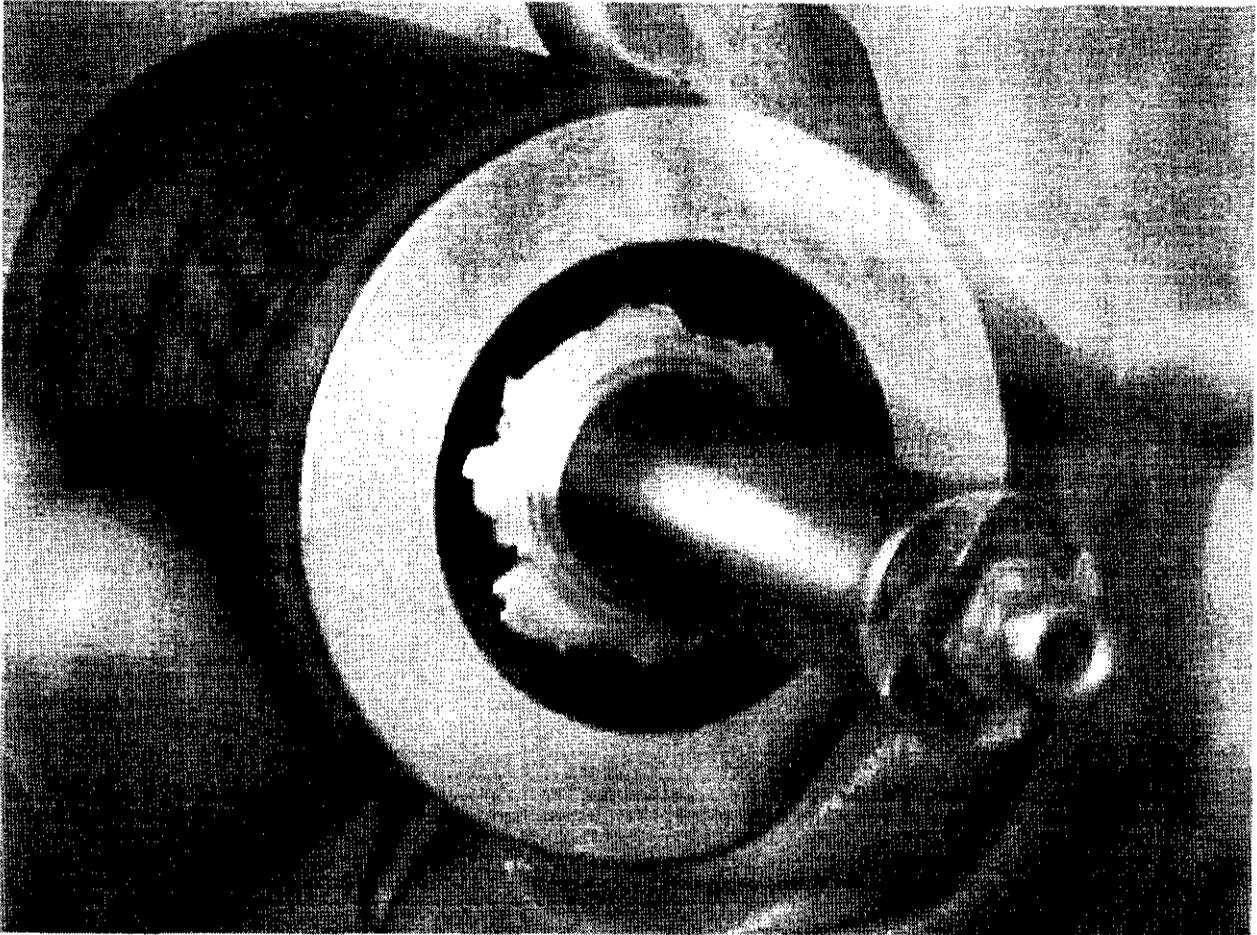


Figure 5 -- Crane Chempump Front Rotor Assembly GA-1 ½ K (U-102)

Description: Photograph of front face of rotor assembly of Crane Chempump GA-1 ½ K from U-102, shows wear caused by contact with rear face of front bearing. Pump operated for approximately 1400 hours. Front shaft shows signs of significant wear, reducing overall cross sectional diameter of shaft.

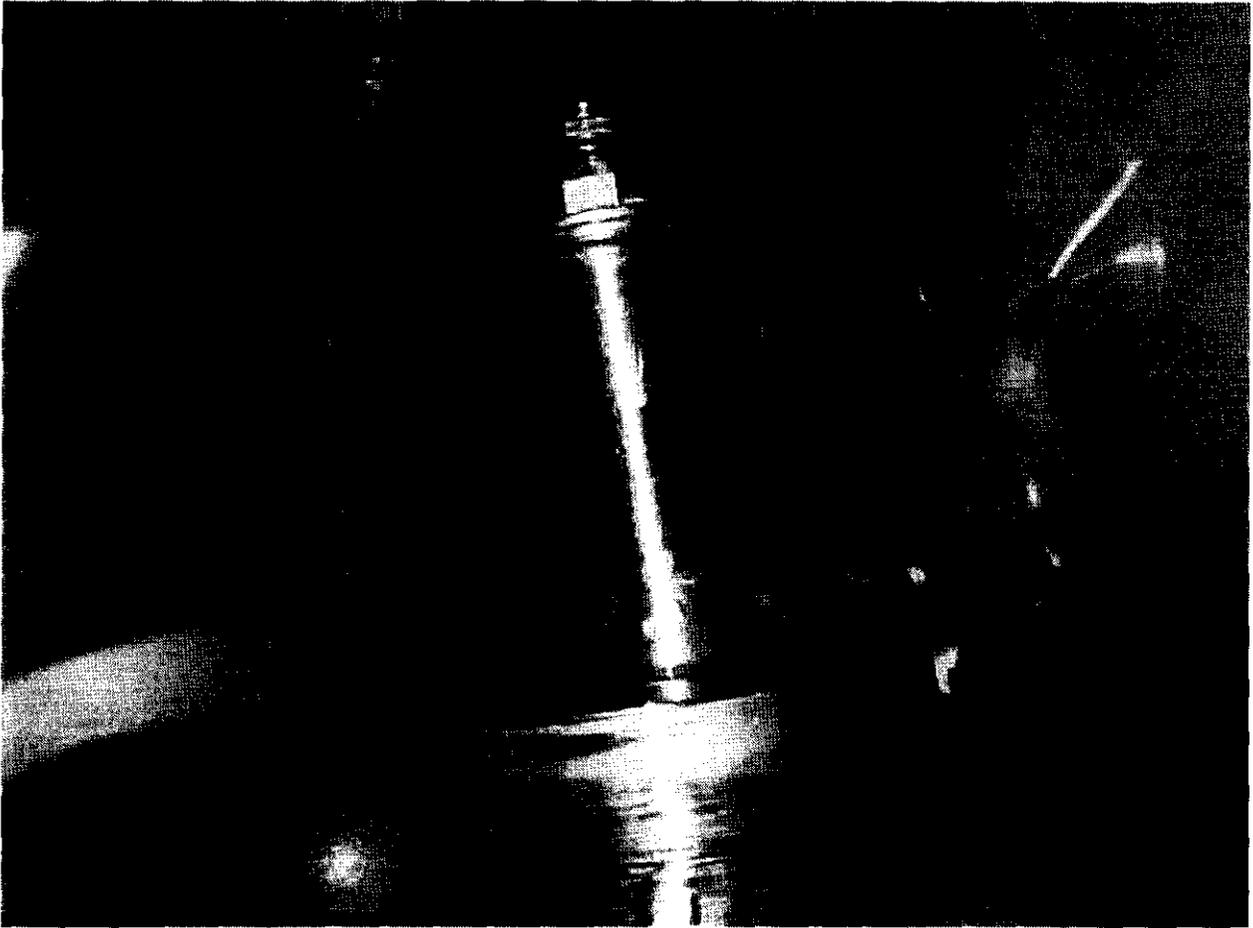


Figure 6 - Crane Chempump Front Rotor Assembly GA-1 ½ K (U-102)

Description: Photograph shows front shaft of rotor assembly from GA-1 ½ K Crane Chempump used in service at U-102. Pump operated for approximately 1400 hours. Front shaft shows signs of significant wear, reducing overall cross sectional diameter of shaft. Increased spacing between shaft and bearing sleeve results in an eccentric rotation pattern of the rotor assembly and impeller.



Figure 7 - Crane Chempump Front Rotor Assembly GA-1 ½ K (U-109)

Description: Photograph of front face of rotor assembly of Crane Chempump GA-1 ½ K from U-102, shows wear caused by contact with rear face of front bearing. Pump operated for approximately 1400 hours. Front and rear shafts shows signs of significant wear, reducing overall cross sectional diameter of shaft. Increased spacing between shaft and bearing sleeve results in an eccentric rotation pattern of the rotor assembly and impeller. Rear face of rotor can shows signs of wear caused by contact with front face of rear bearing. Complete rotor face wear away had note yet been caused. Note impeller nut thread section is sheared off.

A-101 Saltwell System

The A-101 saltwell system utilized a Crane Chempump (Model GB-3K with 5 ½" impeller) and a retrofitted Myers foot valve (H-14-103852). The existing saltwell system was modified with a less restrictive foot valve and a slightly higher pressure pump, the modifications allowed saltwell transfer rates to increase from 5 gpm to a maximum of 10 gpm. The saltwell system was initially started on 5/6/00 and operated successfully until 5/8/00, when the system was shutdown due to a material balance discrepancy (MBD). The result of the increasing MBD issue was attributed to a leaking wall nozzle inside the wall of the A-101 pump pit. Repair of the wall nozzle was completed on 5/24/00. The saltwell system was unable to be returned to service on 5/26/00, due to foot valve pluggage issues and a poor differential pressure across the pump. Inability to prime the system was attributed to a partially blocked open check valve on the bottom of the foot valve. Subsequent flushes with hot water were able to clear the restriction from the check valve. The poor differential pressure on the pump, approximately 20 psi instead of the previous 50 psi indicated that some degree of pump failure had occurred. Review of the initial operating data indicated that system performance degradation was evident from initial startup. The A-101 system was originally throttled to run at 4 gpm with an indicated discharge pressure of 95 psig and suction pressure of 40 psi. After approximately ten hours of operation system performance parameters were reduced to 4 gpm with an indicated discharge pressure of 77 psi and suction pressure 35 psi. Following another twelve hour period of operation the system was transferring at approximately 4 gpm with a discharge pressure of 60 psi. Following saltwell system isolation for approximately three weeks to repair the wall nozzle, the pump performance deteriorated while the unit was not operated.

Following disassembly of the Crane Chempump model GB-3K on 8/11/00 and discussions with the pump manufacturer, it was revealed that extensive damage had occurred to the pumps rotor assembly. The damage to the rotor assembly was caused by excessive forward thrust and the inability of the automatic thrust balance to occur properly within the motor. The two possible causes of forward thrust are cavitation and restricted recirculation flow. Cavitation is not considered to be a credible cause due to positive suction pressure being maintained between 10 psi and 40 psi during pump operation. Restricted recirculation flow is the likely cause of the poor thrust balance. The cause of restricted recirculation flow is attributed to partial blockage of the recirculation passage by solid particles. Once the recirculation flow was restricted to below the required flow of 1 ½ to 2 gpm the thrust balancing is effected. One possible scenario based upon damage discovered during pump autopsy is that due to the low recirculation flow and extra heat caused by friction between the ceramic bearing and rotor. The process fluid passing through the pump internal recirculation passage was boiling and therefore adding vaporization to the already out of balance thrust condition. The results of the poor thrust balance are clearly seen in the attached figures, the actual cause may be indeterminate.

A second Crane Chempump Model GB-3K was installed in the A-101 system on 7/8/00, prior to the disassembly and subsequent failure identification of the original pump. The replacement pump operated in a similar fashion and was inoperable five days later. Blocked impeller vanes or suction eye was credited with the initial failure of the system based on best available

information. A parallel path to original pump disassembly included the addition of a slightly concentrated caustic solution to the A-101 saltwell system. It was thought that the caustic would dissolve any solidification within the system and return the system to previous operating parameters. The caustic additions were unsuccessful in returning the system performance. The caustic addition eventually indicated that some gas reaction occurred on the final flushing attempt, due to elevation in system pressures while pump was isolated. Discussions with the pump manufacturer revealed that the rotor within the stainless steel can contained aluminum bars and end caps. The exposure of the added caustic to the internal bars of the rotor indicate that the second pump failed in a similar fashion to the first, due to excessive forward thrust caused by likely restricted recirculation flow. Subsequent megger testing of both Crane Chempump model GB-3K used in A-101 revealed normal stator resistance readings.

To date the A-101 saltwell system pumped approximately 14,000 gallons of waste and is inoperable due to failure of the pump. An alternative pump technology is presently being pursued to continue saltwell pumping of A-101.

AX-101 Saltwell System

The AX-101 saltwell system utilized a Crane Chempump (Model GB-3K with 5 ½" impeller) and a retrofitted Myers foot valve (H-14-103852). The existing saltwell system was modified with a less restrictive foot valve and a slightly higher pressure pump, the modifications allowed saltwell transfer rates to increase from 5 gpm to a maximum of 10 gpm. The saltwell system was initially started on 7/30/00 following review of A-101 and AX-101 waste similarities. The review of waste characteristics was performed due to presumed solidification problems encountered on the A-101 saltwell system. The AX-101 saltwell system operation parameters performed in a similar fashion to the two operating sessions of the A-101 saltwell system. The AX-101 saltwell system operated for 14 days and transferred approximately 8000 gallons of waste. The majority of the pumping duration of the AX-101 campaign was performed with a deteriorated differential pressure across the pump of approximately 20 psi, indicating that rotor damage also occurred on this unit. The AX-101 saltwell system is inoperable due to failure of the pump. Subsequent megger testing of the Crane Chempump revealed normal stator resistance readings. Normal stator resistance readings were also obtained from a spare Crane Chempump model GB-3K pump. The normal readings indicate that stator winding failure is not attributed to the poor operation of the model GB-3K pumps. An alternative pump technology is presently being pursued to continue saltwell pumping of AX-101.

SX-105 Saltwell System

The SX-109 saltwell system utilizes a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 8/8/00 and is currently operating successfully on the date of this evaluation. The SX-105 saltwell system has transferred approximately 48,000 gallons of waste.

U-106 Saltwell System

The U-106 saltwell system utilizes a Crane Chempump (Model GA-1 ½ K with 4 ¾" impeller) and a retrofitted Goulds foot valve (H-14-100539). The saltwell system was initially started on 8/24/00 and is currently operating successfully on the date of this evaluation. The U-106 saltwell system has transferred approximately 29,000 gallons of waste.