# ASME B73.1M PUMP RELIABILITY PROGRAM FORMATION; A DATA BASED APPROACH

by
**Steven J. Hrivnak**
**Senior Mechanical Engineer**
**Eastman Chemical Company**
**Kingsport, Tennessee**

*Steven J. Hrivnak is a Senior Mechanical Engineer at Eastman Chemical Company's Tennessee facility. He has a B.S. degree (Mechanical Engineering) from Virginia Polytechnic Institute and State University (1985). His responsibilities include plant and maintenance engineering working with a wide variety of rotating equipment, focusing on reliability. He also leads Eastman's machinery standards team, and the pump diagnostic team. Mr. Hrivnak has developed and taught onsite pump reliability courses and was instrumental in developing current pump, piping, baseplate, and grout standards.*

*Mr. Hrivnak is a registered Professional Engineer in the State of Tennessee. He has contributed to Process Industry Practice (PIP) by leading a task team to write the specification for "Design Of ASME B73.1 And General Purpose Pump Baseplates," RESP002, and has one U.S. Patent.*

## ABSTRACT

Data are being used to determine business decisions in this day of competitive business. In years past, many business decisions have been made without the data to support them. Today, with the use of new computer programs, maintenance engineers can use this information to focus on which equipment generates the most work orders. Analysis shows that pumps are at the top of the list for rotating equipment work orders. A pump improvement program has been initiated to reduce pump work orders, resulting in new specifications for baseplates, piping, and grouting. Proper installation and application of ASME B73.1M pumps have resulted in a significant reduction in work orders over four years on 91 pumps that were installed or reinstalled to new standards. The computerized maintenance system, reliability program implementation, standards development, and the results and conclusions of applying the reliability program to 91 ASME B73.1M pumps are reviewed.

## INTRODUCTION

Tennessee Eastman Division of Eastman Chemical Company has over 30,000 pumps. Approximately 14,000 are centrifugal type pumps with over 8,000 of the ASME B73.1M design. (Note: ASME B73.1M design pumps have also been recognized in industry as ANSI B73.1M.) In the late 1980s computerized statistical work order analysis showed that pumps ranked second in the most work orders, as shown in Table 1. The pump population migrated to homemade freestanding baseplates designed by mechanics and engineers. Decisions were made to use the free-standing design because of the lower capital costs. Valves were placed on the pump flanges to reduce product loss during maintenance. To complicate matters, straight edge alignments became normal, because it was perceived that proper alignments seldom improved results. Pump reliability became such a problem that most pumps were spared. If a spare pump was put into service, the work order to repair the primary pump became top priority with overtime approved. In some instances, some maintenance crews were forced to implement a shift work schedule to keep up with top priority pump work orders.

*Table 1. Plant Wide Work Order Pareto Chart.*

From 7-1-93 to 12-31-93
Building: All
Area: All
Equipment: (Type/Number/Problem Part):
Pareto Chart of Equipment Types - By Frequency

| Equipment Type | Frequency | Percent % |
|---|---|---|
| Pipe | 9532 | 13.91 |
| Pumps | 7862 | 11.47 |
| Tanks | 3266 | 4.77 |
| Dryers | 2173 | 3.17 |
| Conveyors | 1620 | 2.36 |

## COMPUTERIZED MAINTENANCE SYSTEM

In 1984, a computerized maintenance work order system came on line. It was called the Maintenance Management Information System (MMIS). The VAX based system allowed operations, engineering, and maintenance to enter work requests from any terminal location in the plant. The computer program contained such features as crew work management, backlog age, work order planning, priority sorting, time charging, equipment nameplate data information, problem codes, action codes, equipment history cost, and work order histories. For the first time in the plant's 70 year history, all work request histories were kept in one database.

In 1991, a work order analysis and reporting (WARP) system came on line. It gave direct statistical access to the work order histories. Employees could get pareto charts on equipment failures in an operating area, division, or the entire plant. High maintenance equipment could easily be identified. Number of work orders, hours spent on a piece of equipment, actions taken, and dollars spent, could be accessed and used to justify changes or modifications as shown in Tables 2 and 3.

*Table 2. MMIS Data Request Choice Screen.*

| WARP DATASET SUBSETTING OPTIONS | | |
|---|---|---|
| Start Date: __ __ __ (MM DD YY) | End Date: __ __ __ (MM DD YY) | (2 Years Available) |
| Building: ____ ____ ____ ____ ____ | Area: ____ ____ ____ ____ ____ | Crew: ____ <br> - Use only equipment failure records |
| Equipment: Type :____ <br> Number :____ <br> Part Number:____ | | WO Type: _ Mechanical <br> _ E&I |
| Report Title: ____ | | |

Make Selections and Press PF3 to Begin Data Search
Place curser on field and Press PF1 for Help

Having the WARP system capability was very important in providing maintenance, operations, and engineering the data needed to prioritize where maintenance improvement dollars should be spent. It also gives the data to prove that existing installation and maintenance practices produce equipment reliability problems. Poorly designed homemade free-standing baseplates cause high vibration and maintenance headaches. Similarly, air voids under grouted baseplates provide little vibration attenuation and high maintenance. Specific cost information applied to this data was used to convince management to increase money spent to improve installations.

*Table 3. MMIS Pareto Chart Selection Screen.*

| PARETO CHARTS | Freq | Cost | Hours | | Freq | Cost | Hours |
|---|---|---|---|---|---|---|---|
| Building | _ | _ | _ | Area | _ | _ | _ |
| Equipment | _ | _ | _ | Part Name | _ | _ | _ |
| Equipment Number | _ | _ | _ | Priority | _ | _ | _ |
| Instrument Number | _ | _ | _ | Problem | _ | _ | _ |
| | | | | Action | _ | _ | _ |

| Tables (Freq, Cost, Hours) | | List Data | |
|---|---|---|---|
| Actions on equipment number and part | _ | By Date | _ |
| Actions on part name | _ | By Equipment Type | _ |
| Workorders on part name | _ | Mech. Description | _ |
| Workorders on equipment number | _ | By Crews | _ |

Place an X in _ to select reports - Press PF3 to run - PF1 for Help.

## RELIABILITY PROGRAM FORMATION

### *Coupling Alignment*

Because of the alarmingly high number of work orders on pumps, alignment was targeted by the Plant Maintenance Division as the solution to improve pump reliability. Management purchased computer alignment tools and taught computer alignment to maintenance mechanics in hopes of solving the pump reliability problems. The standards adopted for alignments were 0.003 in or less for vertical and horizontal offset, and 0.0005 in angular for 1800 rpm. At 3600 rpm, the standard tightens to 0.001 in or less for vertical and horizontal offset, and 0.0002 in angular. A mechanic who taught alignment and believed in its benefits, began aligning the 200 pumps in one department. That mechanic discovered many obstacles in trying to align the pumps that were associated with equipment installation (Table 4) [1].

Through this experience and others, the Plant Maintenance Division discovered that alignment alone did solve some problems, but it was not the only answer. It was, however, a piece of the puzzle. Many of the free-standing type baseplate designs could not hold alignments over time while others could.

The question was then raised, "What is the best way to install a pump?" This question started an information search on the best practices on pump installation. Engineering standards did not have answers or were years out of date. Some committed individuals in maintenance and engineering began a journey to pump reliability, but there were many obstacles to overcome.

*Table 4. Alignment Conditions Found.*

| Conditions found on first 27 pumps aligned: |
|---|
| 60% Bolt Bound |
| 11% The Motor Base Was Too High |
| 89% Were Free-Standing Design |
| 100% Had Either Pipe Or Conduit Strain |
| 100% Motors Without Alignment Jack Bolts |

### *Other Obstacles*

Many existing baseplates were either supplied by the pump vendors or designed, in house, by mechanics or engineers. The design was a "C" shaped or "Omega" shaped 1/2 in stainless bent plate. The superstructure that supported the motor, was made from bent plate, hollow tubing, c-channel, or solid blocks. Little thought was given to stiffness to maintain coupling alignment. There were no standards for the designs. On a typical inspection of a group of 30 free-standing pumps, about five pumps would be supported on only three stilts. The fourth was vibrating loosely in the air.

An analysis of the plant's ASME pump population showed that, on the average, grouted pumps with reasonable piping had one work order every 35 months (Figures 1 and 2). Freestanding baseplates with poor piping had one work order every 6.3 months (Figures 3 and 4). Some pumps had as many as 35 work orders in one year!

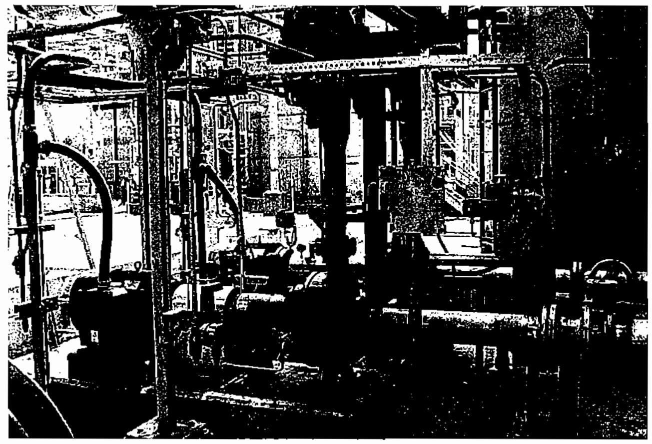

*Figure 1. Grouted Installation with Good Piping.*

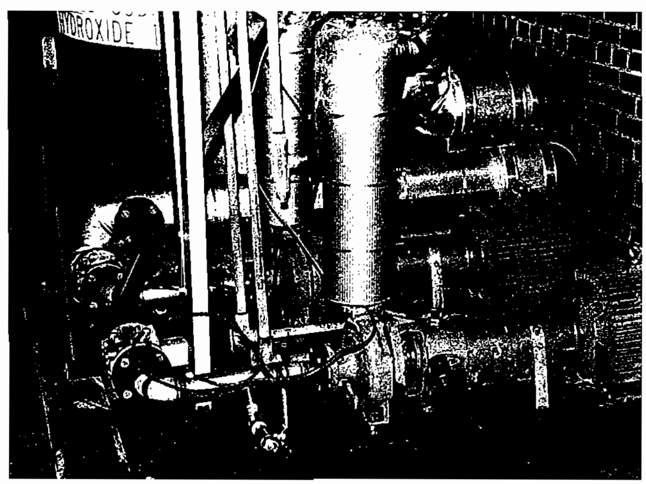

*Figure 2. Grouted Installation with Good Piping.*

Three situations around the plant have paved the way for changes to existing practices:

- It was discovered that the coupling alignment would move 0.010 in with existing free-standing baseplate designs if a stilt was loosened. This information was shown to management who then became interested in a solution to maintain alignments.
- A civil engineer raised concerns about the continuous repair of corroded floors underneath free-standing baseplates.
- Rotating equipment engineers noticed that vibration data was high on many ASME pumps. They obtained approval from the same management to fund a test to install several pumps correctly.

This management "buy-in" in one department, allowed a trial pump installation of a select group of pumps to see if correct installation would make a difference. To do this, several areas besides alignment needed to be addressed:

- Baseplate Design
- Piping Design
- Grout Placement

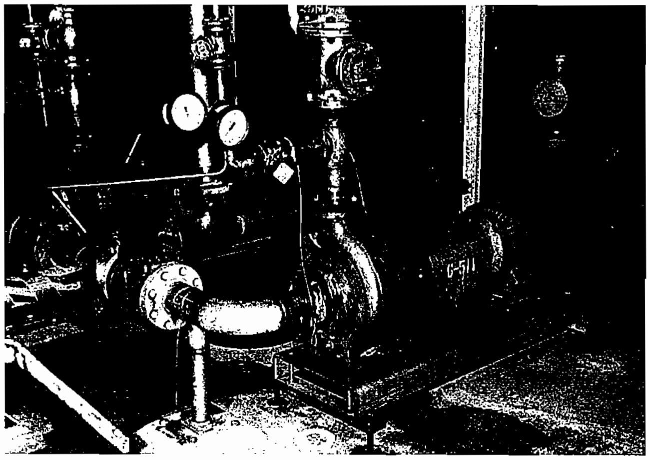

*Figure 3. Free-Standing Installation with Poor Piping.*

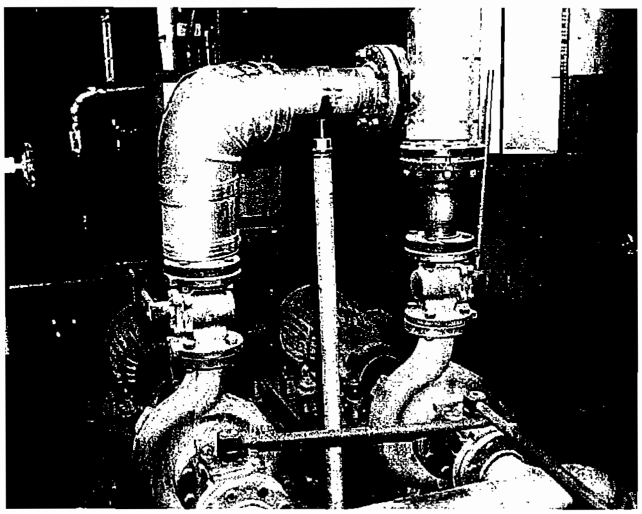

*Figure 4. Free-Standing Installation with Poor Piping.*

*Design of Baseplates*

The information search on the correct way to install pumps yielded some best practices on baseplate design for improved reliability. A team was organized to standardize baseplate designs and to apply the best practices. Certain fundamental rules were found to be overlooked when examining existing baseplate designs. The foundation mass ratio, the weight of the foundation in comparison to the weight of the machine, driver, baseplate, and the liquid or material in the machine, must be of a certain value in order to minimize vibration. For rotary equipment such as pumps, this ratio should be three to one. For reciprocating equipment, this mass ratio should be five to one. Free-standing pump designs cannot meet this requirement. Therefore efforts were focused only on grouted baseplate designs. A set of five drawings were eventually developed showing all pump and motor combinations for ASME B73.1M type pumps. The drawings contained the following design points:

- The baseplate shall be fitted with one 4.0 in grout fill hole uniformly distributed for every 10 $ft^2$ of baseplate surface and/or per subdivided section or raised welded cavity.
- Vent holes 1/2 in in diameter shall be provided for each bulkhead compartment at all corners, high points, and perimeter edges of the bulkhead. Perimeter vent holes in the baseplate shall be on 18 in centers maximum spacing. Any angle or "C" channel added for stiffness will require vent holes on both sides.
- Vertical jacking screws 1/2 in diameter minimum shall be provided around the baseplate perimeter 3.0 in from each anchor bolt location to facilitate alignment of the baseplate in the vertical direction.
- Machined mounting surfaces for the equipment and driver shall have horizontal jack screw positioning bolts 3/8 in diameter minimum.
- All welding on the baseplate shall be completed prior to machining equipment and driver mounting surfaces.
- Machined mounting surface shall be coplanar to 0.002 in.
- Machined mounting surfaces shall extend two (2.0) in beyond pump and driver feet on all sides with a 125 micro in $R_a$ finish. When machining a bent plate as a mounting surface, maximum material removal not to exceed 1/16 in.
- Provide 1/8 in minimum shim adjustment under driver feet for alignment.
- If a spacer coupling is to be used to couple the equipment to its driver, add an additional 1/4 in axial clearance to the spacer length in the baseplate design.
- Anchor bolt holes shall be 1/4 in larger on the diameter than the anchor bolts.
- Tapped equipment bolt holes in the baseplate should be of sufficient depth to allow for plenty of thread engagement. On a 1/2 in thick or smaller baseplates, weld 1/2 in or 3/4 in thick square plates under or on top of the baseplate to increase the thickness before drilling, tapping, and machining. Tapped depth shall be one and one half fastener diameter.
- All bulkhead cross bracing on the underside of the baseplate shall have a 2.0 in by 6.0 in opening to allow for grout flow from bulkhead to bulkhead.
- All corners of baseplate flanges shall be radiused a minimum of 1.0 in. All surfaces which will be in contact with the grout shall be rounded to eliminate stress risers.
- Angle, channel, or stud anchors shall be welded to the bottom surface to act as a shear key in the grout.
- Gussets shall be welded inside the driver superstructure to increase stiffness and vibration damping.

Most of the above baseplate design points can be found in the soon to be published Process Industry Practice RESP002.

*Pipe Standards*

During the same time, the baseplate standard was being developed, an ASME B73.1M pump piping standard was being created. Proper piping costs no more than improper piping. Before the new standards were written, existing practices put valves on the suction and discharge flanges or elbows directly on the pump. Many times the pump casing was the only pipe support within 20 ft of the pump. On one new installation where the pipe was out of alignment on both the suction and discharge flanges of a 6×4-10 pump by about 1/2 in, the pipes could still be easily bolted to the pump. The pipe was disconnected and the pump was aligned to class one tolerances. Then the pipe was reconnected and the alignment was rechecked. The horizontal offset moved from 0.003 in to 0.025 in. The pump was being twisted. The frightening realization was then discovered that even though the pump was twisted, the motor could be moved enough to get the class one alignment. The piping was reworked the correct way and the pump operated for two years without a failure.

Simple rules, which have been in existence for years, were typically ignored. Proper piping will minimize shaft, casing, and baseplate deflections, as well as cavitation, which will increase seal, bearing, and coupling life. A pump piping standard was written to use the best practices. The purpose of the standard was to minimize piping and nozzle loading, and provide uniform flow into the impeller eye. The standard combined available information on best practices and contained the following:

*Piping Design (Figure 5)*

•Discharge and suction lines shall be straight for a minimum of eight pipe diameters or 18 in, which ever is greater, in the runs adjacent to the pump flanges. (This minimizes the possibility of cavitation and smoothes out the flow entering the impeller.) The pump suction line shall be constructed to provide a spool section for strainer removal.

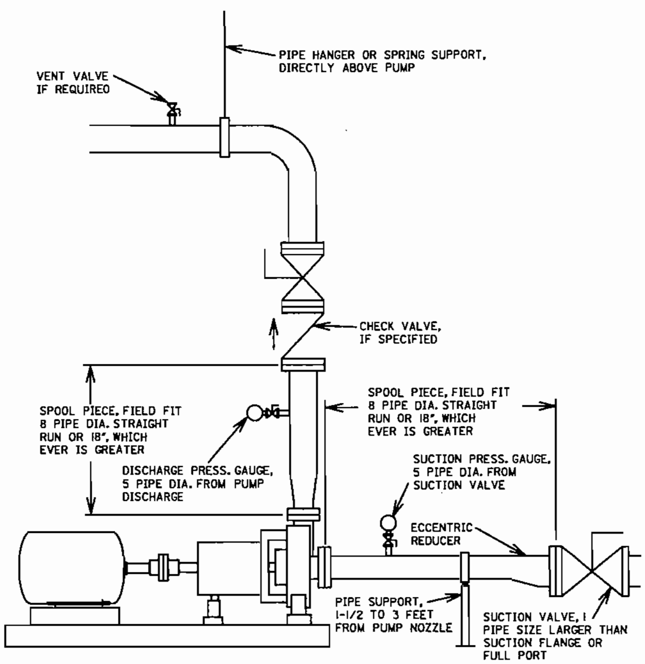


*Figure 5. Pipe Installation Diagram.*

• Discharge valves shall be located directly after the required straight run. Suction valves shall be located directly before the straight run. Suction valve port area shall be equal to or greater than the suction line area. Suction piping shall be sized for 5.0 ft/sec (bulk velocity) or less. Hot condensate service and service for other liquids within 10°F of the boiling point at suction pressure shall be sized for 2.0 ft/sec or less.

• Reducers in the horizontal suction lines shall be eccentric and located directly after the suction valve. If the liquid is within 20°F of boiling, place the eccentric reducer at the suction flange of the pump.

• Lateral suction piping shall be supported and guided no closer than 1.5 ft to a maximum of 3.0 ft from flanges. Vertical discharge piping shall be supported from above using spring hangers. Hangers shall be sized so that there are minimal vertical loads on the pump nozzle in the cold condition. Piping shall be guided to help prevent transfer of piping moments to pump nozzles. All pump loads shall be below those determined by the pump manufacturer and verified by calculations for both hot and cold service. Exceptions: Support design may differ from above description if acceptable loading is verified by calculations and approved by the appropriate engineer. Special care should be exercised in support design in lines with fast acting and shock inducing check valves.

*Installation*

• Install piping to within the eight pipe diameters of the pump. Grout the pump baseplate and align the motor using the reverse indicator method to within 0.002 in TIR. Bolt the suction and discharge stub ends and flanges with gaskets to the pump, using four bolts. The spool pieces connected to the pump shall be field fabricated; field-fit and tack weld the piping to the stub ends, and then match-mark the flanges. Finally, remove the spool piece and final weld the piping to the stub ends.

• For reference purposes, the following installation guidelines shall apply:

  • If the flanges cannot be aligned by hand (not hand tools) for the insertion of the bolts, the spool piece will be reworked.

  • If a set of flange faces are not parallel to each other to within 1/32 in across the length of the faces, the spool piece(s) will be reworked (Figure 6).

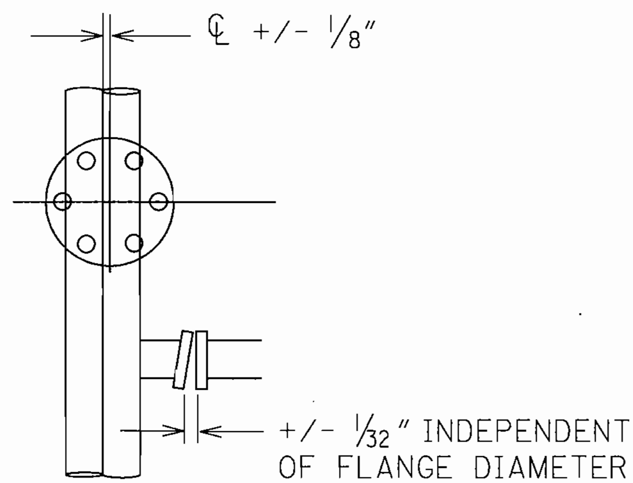


*Figure 6. Piping Flange Tolerance.*

  • If the spool piece, which should be eight pipe diameters or greater in length, is more than +/- 1/8 in of true length, the spool piece will be reworked (Figure 7).

  • The pump shaft deflection shall be checked using face and rim method during flange bolt tightening. Coupling alignment must remain within 0.002 TIR.

*Miscellaneous*

• Baseplates

  • Baseplates shall be grouted and not free-standing.

• Strainer

  • For new pump installations, a strainer shall be installed to trap foreign material. The strainer should be removed and cleaned every 8.0 hr until it no longer traps material. It should then be removed from the piping. A spool piece should be installed for easy removal of the strainer.

• Pressure Gauges

  • Pressure gauges or taps for pressure gauges shall be installed. (Pressure gauges can be used to trouble shoot pump problems).

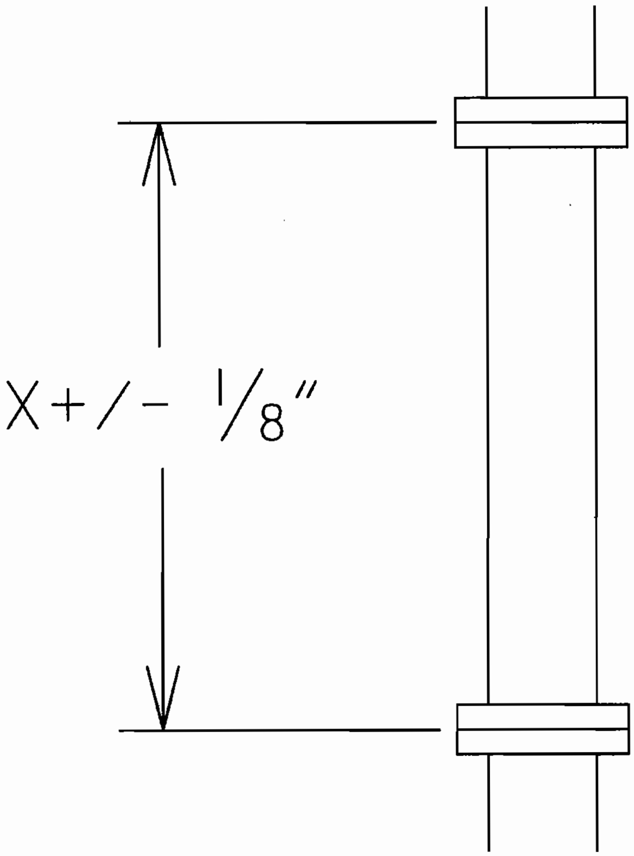


*Figure 7. Piping Length Tolerance.*

*Grout Standards*

As the result of some excellent onsite grout training where mechanical engineers, civil engineers, mechanics, installers, and engineering contractors were all invited to learn, at the expense of the Rotating Equipment Team, representatives from each group teamed up to write a new grout standard. The specification provides requirements for cementitious, epoxy, and corrosion resistant grouting of rotating and reciprocating equipment baseplates to concrete slabs or raised foundations. The theory behind following these procedures was to minimize equipment vibration and alignment problems and increase bearing, seal, and coupling life. The specification contained the following:

*Slab or Foundation Preparation and Protection*

• After concrete has been properly cured, and obtains its design strength, typically 28 days, scarify existing slab or foundation surface that will come in contact with the grout using a small chipping hammer to expose aggregate (1.0 in minimum depth). High pressure air clean chipped area to remove all dust and grit.

• Slab or Foundation Protection–The cleaned scarified surface of the foundation shall be protected from water, oil, and dust, contamination, etc. The preferred method is to place the grout directly against the clean foundation.

• For epoxy grouts, if the time interval between cleaning and grout placement is sufficient for the contamination of the prepared area by water and oil, the scarified area may be coated with the grout manufacturer's recommended primer approximately 3.0 to 5.0 mils thick. Under no circumstances will a generic epoxy paint be used. If the prepared area becomes contaminated, clean before grout placement.

• The prepared area for epoxy or corrosion resistant grouts shall be kept dry. Epoxy grout will not bond properly to damp or uncured concrete.

• For cementitious grouts, the prepared area should be wetted prior to grout placement per manufacturer's recommendation.

• The prepared area shall be kept within the manufacturers temperature limits. The area is to be shaded from direct summer sun light 24 hr before pour and 48 hr after pour.

*Anchor Bolt Sleeves*

• Clean out any foreign material in the anchor bolt sleeve if used, and fill with a non-bonding urethane foam.

*Grout Thickness and Flow Lengths*

• In the absence of information from the grout manufacturer, minimum thickness of grout shall be 1.0 in with a maximum grout flow length of 1.0 ft. For each additional foot of grout flow length, the foundation to baseplate clearance should be increased by 1/2 in. The maximum allowable grout flow length shall be 5.0 ft.

• The maximum grout thickness shall be per the manufacturer's written instructions and recommendations.

*Reinforcing Steel*

• In cementitious and polymer grout pours 4.0 in and greater, concrete reinforcing steel shall be provided in accordance with ACI 318-89 Section 7.12 requirements for temperature and shrinkage. Reinforcing steel shall conform to ASTM A615, Grade 60 and shall be fabricated and placed in accordance with ACI 301 and Specification 03001, unless otherwise specified on the construction drawings. Consult the manufacturer for reinforcing in epoxy grouts.

*Baseplate Preparation*

This section contains information that shall be completed before grout mixing begins.

• *Grout Holes*–Verify that the baseplate has a grout fill hole of adequate size and location to permit proper placement of the grout. If the baseplate does not already have a grout hole, cut a 4 in diameter grout hole in the center of each cavity.

• *Air Relief Holes*–Verify that the baseplate has 1/2 in diameter grout vents located in the corners of each cavity where air may be trapped. If each baseplate cavity does not already have 1/2 in diameter grout vents, drill 1/2 in diameter holes every 18 in. Place vent holes on both sides of any angle or "C" channel added for stiffening. This will allow air to escape while the grout is being poured and avoid air pockets.

• *Baseplate Edges*–Remove all sharp edges of the baseplate (chamfering from 1/4 in to 1/2 in) that will be in contact with the grout. The radius of all corners shall be 1.0 in minimum. This will prevent crack propagation in the grout.

• *Jack Screws*–Verify that the baseplate has jack screws for leveling adjacent to each anchor bolt. If the baseplate does not have holes for jack screws, drill and tap a 1/2 in-13 UNC or larger hole 3.0 in away from each anchor bolt hole.

• *Cleaning of Baseplate*–Clean and dry the underside of the baseplate, to remove dirt, oil, and other contamination.

• *Sandblasting*–When using epoxy grouts, the underside of the baseplate shall be sandblasted to white metal and a 3.0 mil anchor profile minimum (soda ash and bead blasting are unacceptable) to remove rust and scale. The preferred method is to have the bare metal of the baseplate in contact with the grout. However, in the interest of corrosion prevention, if the time interval between cleaning and grout placement is sufficient for the formation of rust, the bare metal may be coated with the grout manufacturer's recommended primer. Under no circumstances will a generic epoxy paint be applied to metal surfaces to be set in epoxy grout. A rust-free, bare metal surface is the preferred alternative that is simple, safe, and yields structurally superior results.

*Installation Of Baseplate (Figure 8)*

• Place 2.0 in diameter by 3/8 in thick stainless steel pieces with sharp corners removed on the scarified concrete under the jack screw locations. Level the baseplate using the jack screws against the 3/8 in thick pieces. The preferred method is to level the baseplate without the equipment. If the equipment must be mounted while leveling, pregrout the 3/8 in thick pieces to stop movement under the increased load. Level the machined area of the baseplate to within manufacturers specifications. If manufacturers specifications are unavailable, use the following parameters (Table 5). Hold the baseplate in position against the jack screws with the anchor bolts.

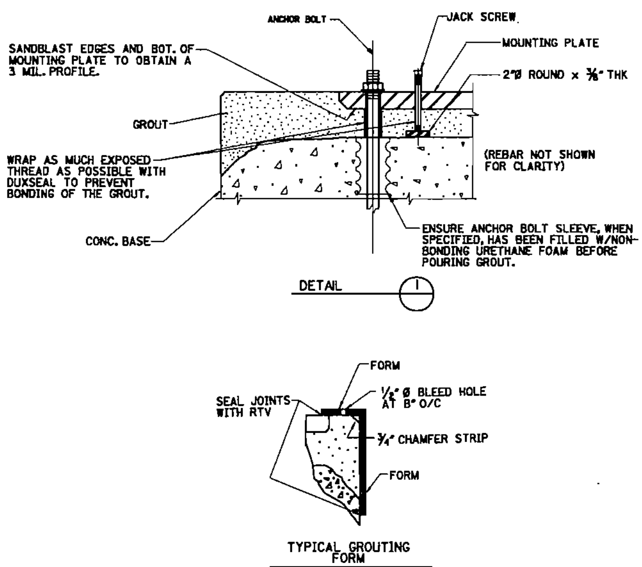


*Figure 8. Typical Grouting Details.*

*Table 5. Machinery Leveling Tolerance.*

| TYPE OF EQUIPMENT | LEVELING REQUIREMENTS OF FOOT PADS |
|---|---|
| ANSI Pumps 3600 rpm and less, Positive Displacement and Reciprocating Pumps with horsepower's below 100. | Use a standard bubble level. A maximum elevation variation across the length of the baseplate of 0.010 inch is expected. |
| API Pumps | .002 inch per foot of length of the baseplate or less. |
| Turbo Machinery, and Reciprocating Equipment above 100 horsepower. | .0005 inch per foot of length. Use Machinery Analysis in Plant Engineering to assist leveling the baseplate. The mounting surfaces should be coplanar within 0.002 inch. |

• *Anchor Bolt and Jack Screw Preparation*–Prior to pouring grout, wrap the baseplate leveling jack screws and anchor bolts with putty to prevent the grout from adhering. Coat equipment fastener bolts and coupling guard bolts with antiseize and install all the way into the baseplate to keep grout from clogging the threaded bolt holes and adhering to the bolts. (If grout adheres to anchor bolts, proper torquing may break them. If grout adheres to leveling jack screws, they cannot be removed after grout cures. Grout is designed to support equipment weight and absorb vibration; leveling screws are not.)

*Wood Forms*

• Coat the inside of the wooden form's vertical face with one coat of form oil for cememtitious grouts or three coats of paste wax for epoxy grout (to prevent sticking). Forms should be waxed before installation, to prevent accidental application of wax to surfaces where the grout is to bond.

• Seal all form joints with silicone rubber sealant caulk to prevent the grout from leaking out.

*Grout Placement*

Grout to be mixed and placed per manufacturer's instructions. An 18 to 24 in long by 4.0 in head pipe and funnel is recommended to facilitate grout placement. Put a flange on one end and physically hold the flange down over the grout hole or build a wood bracket to hold it in place. Pour the grout through the funnel into the head pipe. (The head pressure will help the grout flow and push the air out from under the baseplate.) Before removing the head pipe, plug all grout vent holes with rubber or wood stoppers. After removal of the head pipe, plug grout fill holes with plywood. (This holds the grout in place and prevents air pockets beneath the plate.)

• Vibrators

  • DO NOT USE a vibrator on polymer concrete or epoxy grouts as it will separate the aggregate from the resin.

  • When using cementitious grout, use a high frequency vibrator to remove entrapped air bubbles.

*Curing*

• The grout shall be cured in accordance with the manufacturer's specifications. (Typically, cementitious grouts are moist cured and epoxy or corrosion resistant grouts are air cured.)

*Leveling Jack Screw Removal*

• Remove jack screws after the grout cures, degrease jack screw holes and, in noncorrosive areas, fill holes with silicone caulk. In corrosive areas, fill holes with a mix of silica powder and the resin used in the grout. If jackscrews cannot be fully removed, retract jack screws 1/2 in and saw off flush with baseplate. (This makes the baseplate rest on the grout rather than the jack screws.)

*Anchor Bolt Tightening*

After the grout has cured, tighten the anchor bolts to the applicable torque values (Table 6).

*Void Testing*

• Tap the baseplate carefully to "sound out" voids with a small ball peen hammer. A small hammer will give a better ring than larger hammers, bolt or some other metal object. The sounding procedure should be done after the grout has cured per manufacturer's cure time.

• When tapping the baseplate with the ball peen hammer, a definite ring will be heard where a void is present. The areas where the baseplate is in full contact with the grout will have a solid sound like a "lead nickel." There will be other times when the sound will not be so definite. Caution should be taken not to assume there is a void at these locations. Sometimes the cross bracing under the baseplate will give a different sound than in the center of the steel plate. Vertical gusset reinforcement near motor or driven mounts will sometimes ring as you tap the base. Do not confuse these sounds as voids. If a void is discovered, contact the design engineer for proper repair. Injection repair of voids can distort baseplate if not vented and done correctly.

*Table 6. Anchor Bolt Torque Values.*

| Bolt Diameter, in. | Bolt Area, in. | Torque, Ft-lbs |
|---|---|---|
| 0.625 | 0.226 | 60 |
| 0.750 | 0.334 | 100 |
| 0.875 | 0.462 | 180 |
| 1.000 | 0.606 | 270 |
| 1.125 | 0.763 | 390 |
| 1.250 | 0.969 | 550 |
| 1.375 | 1.160 | 720 |
| 1.500 | 1.410 | 950 |

For a more indepth look at grout installation, see the referenced paper in the "Related Papers" section at the end of this document.

## FIRST SUCCESS

Several problem pumps in two test areas were reinstalled with marginal to exceptional results. Engineering management learned of the Rotating Equipment Team's work to move away from using free-standing designs and to allow for proper piping, which was in conflict with the capital team's direction of low cost plants. The rotating equipment team was asked to produce data which supported going away from free-standing baseplate designs and to use proper piping (Table 7) [2]. The data was collected and presented. Through reinstallation of the test pumps, 9.38 failures per year per pump, were reduced to 0.88 failures per year per pump. Management gave support and commissioned the Rotating Equipment Team to convince operations and capital projects that change was in the best interest of the company. This took several years and more data to convince the entire company.

### *The Cellulose Esters Pump Reliability Program*

Some of the first pump rebuilds were conducted in the cellulose esters division. The results were promising enough that a flood of requests came in to start rebuilding the 1200 pumps in that division to the new standards. The area maintenance department formed a team from maintenance and engineering to create a process to control the requests. They developed the "greensheet," simply a green colored piece of paper that attempted to put boundaries on the rebuild process (Figure 9). Maintenance identified problem pumps using WARP and collected as much of the pump detail information as possible. The Green Sheet was then sent to one of the production engineers to have the operational data like flow, head, fluid, vapor pressure, hours of operation, deadheading, etc., added to the sheet. The sheet was then forwarded to plant engineering to check if the existing pump was the correct size. Not all pumps were rebuilt based on number of work orders and cost history, but many were redone because the existing pump and baseplate had to be replaced because it was nonrepairable.

*Table 7. TPA Pump Reliability Data.*

**TPA Department 5/89 - 5/90 (Before)**

| PUMP | SIZE | HP | RPM | BASE | PIPE | FAILURES | FAILURES PER PUMP PER YEAR |
|---|---|---|---|---|---|---|---|
| GA-13 | 4x3-10 | 10 | 1740 | 1 | 3 | 15 | |
| GA-113 | 4x3-10 | 10 | 1740 | 4 | 4 | 9 | |
| GA-113A | 4x3-13 | 40 | 1770 | 1 | 1 | 15 | |
| GA-213A | 4x3-13 | 20 | 1755 | 1 | 2 | 14 | |
| SE-AS/A | 6x4-13 | 25 | 1770 | 1 | 4 | 4 | |
| HI-12 BA-10S | 4x3-10 | 100 | 3565 | 4 | 2 | 18 | |
| | | | | | Total: | 75 | |
| | | Average: | | 2.1 | 2.8 | | 9.38 |

**TPA Department 10/90 - 10/91 (After)**

| PUMP | SIZE | HP | RPM | BASE | PIPE | FAILURES | FAILURES PER PUMP PER YEAR |
|---|---|---|---|---|---|---|---|
| GA-13 | 4x3-10 | 10 | 1740 | 4 | 4 | 2 | |
| GA-113 | 4x3-10 | 10 | 1740 | 4 | 4 | 0 | |
| GA-113A | 4x3-13 | 40 | 1770 | 4 | 3 | 1 | |
| GA-213A | 4x3-13 | 20 | 1755 | 4 | 5 | 1 | |
| SE-AS/A | 6x4-13 | 25 | 1770 | 4 | 4 | 0 | |
| HI-12 BA-10S | 4x3-10 | 100 | 3565 | 4 | 3 | 3 | |
| | | | | | Total : | 7 | |
| | | Average: | | 4.0 | 3.8 | | 0.88 |

DESCRIPTION OF PUMP STATION:

W.O.# POWER PANEL# LOCATION
CONTACTS: MAINT.PHONE # OPERATION PHONE #
DESIRED COMPLETION DATE ACTUAL DATE
PAST COST FOR PRIORITY RANKING

OPERATING CONDITIONS:
MAT'L/FLUID PUMPED SPECIFIC GRAVITY
GPM MAX. NORMAL MIN. HEAD
AV. HRS. RUNNING DEADHEADED VISCOSITY TEMP.
% SOLIDS SUCTION PRESS. DUTY CYCLE
NPSHA VAPOR PRESSURE

PUMP SPECIFICATIONS:
MANF.: TYPE: SIZE:
IMPELLER SIZE & TYPE: SHAFT:
BEARING HOUSING SEALS: WET PARTS MAT'L:
OPTIONS:

SEAL SECIFICATIONS:
MANF: MODEL/TYPE:
O-RING MAT'L: PURGE: RATE/PRESS.:
MOUNTING: CARTRIDGE OPTIONS:

GUARD SPECIFICATIONS:
MAT'L. TYPE/GAUGE: 304SST 16 Ga. DESIGN TYPE: PUMP BASE MOUNTED

COUPLING SPECIFICATIONS:
MANF.: SIZE: TYPE:
MOTOR BORE/KEYWAY: DROPOUT LENGTH:
PUMP BORE/KEYWAY: TAPER-LOK:

MOTOR SPECIFICATIONS:
HP: RPM: FRAME: MMI# PHASE:
ENCLOSURE: VOLTAGE: SERVICE FACTOR: WIRE SIZE:
TERMINAL BOX LOCATION: ROTATION: MOUNTING:

BASE SPECIFICATIONS:
GROUTED TYPE - CONSULT STANDARDS - GROUT/CONCRETE SPECS:

*Figure 9. Pump Data Collection Sheet.*

During the same time the greensheet process was being used, training in pump reliability was also being addressed.

*Pump Sizing and Education*

Pump sizing, installation, and reliability soon became of interest. Training, however, was needed. This became a turning point in the company's knowledge. Over the last couple of years, the rotating equipment team has sponsored in-house training on baseplate design, up-to-date grout techniques, piping, and pump sizing and operation.

The plant maintenance division also formed a team with a mission to "Train maintenance mechanics in the concepts of pump and seal operation to solve pump reliability problems, using data, a pump trouble shooting matrix, and a seal selection guide. Also develop training specifically for operators to change operational practices that cause pump reliability problems."

The team of six mechanics and three engineers created a pump diagnostic class aimed at maintenance mechanics. It was designed to personally teach maintenance mechanics the typical problems with pumps. Without getting their buy-in and involvement, pump reliability on a large scale would not work. The class teaches what happens to flow, head, and horsepower when an oversized impeller is installed. It also teaches what happens if motor speed is increased; if a pump is deadheaded; how line sizes are chosen; what goes into sizing a pump; how to install a pump; and how to troubleshoot a pump. The course is also excellent for engineers inexperienced with pumps. To date, over 600 mechanics and 100 engineers have been trained in the proper techniques of pump installation and operation. This has become essential in changing the culture.

## RESULTS

The results of class one alignments, good baseplate and piping design, up to date grout techniques, and pump theory classes, have been excellent. Because of the results of the first several pump installations, over 400 pumps have been installed on capital projects or reinstalled since 1991. To verify if the standards work, 91 pumps in one operating area that were installed to the new standards were studied over the last four years. Each pump had to be visited to grade it on installation and verify nameplate information. Therefore, not all 400 pumps were included, because of the amount of work involved.

The pumps included in the study (Table 8) are listed by the MMIS identification number. Also listed is the pump size; the horsepower; rpm; rebuilt date or installed date; a pipe and baseplate rating; and the number of seal, bearing, coupling, or gasket failures in 1991, 1992, 1993, and 1994. The base and piping ratings were on a scale from one to five, with one being the worst and five being the best. If the base was free-standing it was scored a one, and if it was grouted by the standard, a score of five. But if the grout application was poor, the rating would be three. Similarly, if the piping had elbows, valves, or obvious pipe strain, the rating would be one, and if the piping was installed to the standards, it would receive a five.

Not all the pumps in the study were installed or reinstalled in 1991. Some were done in 1992, others in 1993. Each work order was read to determine if it was related to the pump's reliability. All work orders not related to the pump were eliminated. Work orders to insulate, steam trace, and replace valves were not counted. Only work orders on seals, head gaskets, bearings, and couplings, were counted. Some installation dates could not be 100 percent identified and therefore were left blank.

Exact records were not kept on the hydraulic fit of these pumps. But more than half of these pumps were checked for hydraulic fit. Most that were checked required smaller impellers, and in a few cases, a smaller pump. Although good records were not maintained, it is believed that adjusting the hydraulic fit helped increase mean time between failures (MTBF).

*Table 8. Pump Failure Spread Sheet. Included are rebuilt pumps and new capital installations to new standards.*

REBUILT PUMPS

| MMIS ID # | SIZE | HP | RPM | DATE REBUILT | BASE RATING | PIPE RATING | FAILURES PER YEAR 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|
| 120-CB-G-342 | 3x1-1/2-8/73 | 3 | 1800 | Dec-91 | 5 | 5 | | 0 | 0 | 0 |
| 120-HEAD-G-506 | 3x1-1/2-10 | 3 | 1200 | | 3 | 4 | 2 | 1 | 1 | 1 |
| 120-HEAD-G-507 | 3x1-1/2-10 | 3 | 1200 | | 3 | 4 | 2 | 0 | 0 | 0 |
| 120-HEAD-G-508 | 6x4-10/76 | 15 | 1800 | Apr-91 | 5 | 5 | 2 | 2 | 1 | 0 |
| 120-HEAD-G-509 | 6x4-10/76 | 15 | 1800 | Apr-91 | 5 | 5 | 2 | 0 | 5 | 0 |
| 120-HEAD-G-515 | 4x3-13 | 10 | 1800 | | 2 | 3 | 0 | 1 | 1 | 0 |
| 120-HEAD-G-517 | 3x1.5-10/10 | 10 | 1200 | Dec-90 | 3 | 5 | 1 | 0 | 1 | 0 |
| 120-HEAD-G-518 | 3x1.5-10/10 | 10 | 1200 | | 3 | 5 | 1 | 0 | 0 | 0 |
| 120-HEAD-G-519 | 6x4-10/75 | 15 | 1800 | Jan-91 | 5 | 5 | 0 | 1 | 0 | 0 |
| 120-HEAD-G-520 | 6x4-10/75 | 15 | 1800 | Jan-91 | 5 | 5 | 1 | 0 | 0 | 0 |
| 120-HEAD-G-523 | 6x4-13 | 40 | 1800 | | 5 | 2 | 0 | 1 | 0 | 0 |
| 120-HEAD-G-524 | 6x4-13 | 40 | 1800 | | 5 | 2 | 1 | 0 | 0 | 0 |
| 120-HEAD-G-525 | 4x3-10/9 | 15 | 1800 | Dec-91 | 5 | 2 | 0 | 0 | 1 | 0 |
| 120-HEAD-G-526 | 4x3-10/9 | 15 | 1800 | Dec-91 | 5 | 2 | 2 | 0 | 0 | 0 |
| 120-HEAD-G-527 | 4x3-10/94 | 15 | 1800 | Oct-92 | 5 | 5 | 0 | 0 | 1 | 1 |
| 120-HEAD-G-528 | 4x3-10/94 | 15 | 1800 | Mar-93 | 5 | 5 | 0 | 0 | 1 | 0 |
| 120-HEAD-G-537 | 1.5x1-82/65 | 2 | 1800 | | 5 | 5 | 0 | 0 | 0 | 0 |
| 120-HEAD-G-538 | 1.5x1-82/65 | 2 | 1800 | | 5 | 5 | 0 | 0 | 0 | 0 |
| 120-HEAD-G-541 | 3x1.5-10/90 | 3 | 1200 | Sep-93 | 5 | 5 | | | 0 | 0 |
| 120-HEAD-G-542 | 3x1.5-10/90 | 3 | 1200 | Sep-93 | 5 | 5 | | | 0 | 0 |
| 120-HEAD-G-543 | 3x1.5-10/90 | 3 | 1200 | Sep-93 | 5 | 5 | | | 0 | 0 |
| 120-HEAD-G-544 | 4x3-10/84 | 3 | 1200 | Jul-93 | 5 | 4 | | | 1 | 0 |
| 120-HEAD-G-528 | 4x3-10/84 | 15 | 1200 | Oct-93 | 5 | 4 | | 1 | 1 | 0 |
| 120-HYD-G-152 | 6x4-13/13 | 30 | 1800 | Jul-91 | 5 | 5 | 3 | 2 | 2 | 3 |
| 120-HYD-G-153 | 4x3-13/13 | 30 | 1800 | Oct-91 | 5 | 5 | 0 | 1 | 1 | 1 |
| 120-HYD-G-161 | 4x3-13 | 30 | 1800 | Jul-93 | 5 | 5 | 0 | 1 | 3 | 1 |
| 120-HYD-G-162 | 4x3-13 | 30 | 1800 | Sep-93 | 5 | 5 | 2 | 3 | 2 | 5 |
| 120-MIX-G-205 | 1.5x1-8 | 2 | 1800 | Oct-91 | 5 | 3 | 3 | 1 | 1 | 0 |
| 120-MIX-G-204 | 1.5x1-8 | 2 | 1800 | Oct-91 | 5 | 3 | 1 | 1 | 0 | 0 |
| 120-MIX-G-205 | 1.5x1-8 | 2 | 1800 | Oct-91 | 5 | 3 | 1 | 0 | 0 | 0 |
| 120-MIX-G-206 | 1.5x1-8 | 2 | 1800 | Oct-91 | 5 | 3 | 0 | 1 | 0 | 0 |
| 120-PPTN-G-326 | 3x1.5-13/13 | 25 | 1800 | | 5 | 3 | 2 | 1 | 0 | 0 |
| 120-PPTN-G-327 | 3x2-13/13 | 25 | 1800 | | 5 | 3 | 1 | 0 | 0 | 0 |
| 120-TF-G-1A | 4x3-13/13 | 25 | 1800 | Mar-91 | 5 | 5 | 0 | 2 | 1 | 2 |
| 120-TF-G-8C | 8x6-14 | 10 | 880 | Nov-93 | 5 | 3 | 5 | 3 | 2 | 0 |
| 120-MIX-G-209 | 3x2-13/124 | 25 | 1770 | Oct-91 | 5 | 3 | 1 | 0 | 0 | 0 |
| 120-MIX-G-210 | 3x2-13/124 | 25 | 1770 | Oct-91 | 5 | 3 | 1 | 0 | 0 | 0 |
| 81-CA1-G-AR11 | 3x2-13/11 | 25 | 1740 | Jun-92 | 4 | 4 | 22 | 2 | 1 | 3 |
| 81-CA3-G-512 | 3x2-13/11 | 25 | 1740 | Mar-93 | 5 | 3 | 14 | 35 | 3 | 2 |
| 81-CA1-G-BP01 | 3x1.5-13 | 7.5 | 1740 | Jun-91 | 5 | 4 | 0 | 0 | 1 | 0 |
| 81-CA1-G-BP02 | 3x1.5-13 | 7.5 | 1740 | Jun-91 | 5 | 4 | 0 | 0 | 0 | 0 |
| 81-CA1-G-BP03 | 3x1.5-13 | 7.5 | 1740 | Jun-91 | 5 | 4 | 0 | 0 | 1 | 0 |
| 81-CAP-G-CC28 | 3x1.5-13/96 | 25 | 1750 | Aug-93 | 5 | 5 | 6 | 3 | 1 | 0 |
| 81-CAP-G-CC29 | 3x1.5-13/96 | 25 | 1750 | Aug-93 | 5 | 5 | 2 | 1 | 1 | 0 |
| 81-WASH-G-DF15 | 4x3-13/12 | 40 | 1770 | May-92 | 5 | 3 | 5 | 0 | 1 | 0 |
| 81-WASH-G-DF16 | 4x3-10/8 | 50 | 1770 | Nov-91 | 5 | 3 | 3 | 1 | 0 | 0 |
| 81-WASH-G-DF17 | 4x3-13 | 40 | 1750 | Jan-92 | 5 | 4 | 1 | 0 | 1 | 0 |
| 81-WASH-G-DF18 | 4x3-13 | 40 | 1750 | Mar-92 | 5 | 4 | 0 | 3 | 1 | 0 |
| 81-WASH-G-DF19 | 4x3-13 | 40 | 1750 | | 5 | 4 | 2 | 0 | 0 | 0 |
| 67-WS-G-11SLF | 2x1-10 | 5 | 1750 | Mar-93 | 5 | 5 | 7 | 5 | 0 | 0 |
| 67-WS-G-12SLF | 2x1-10 | 5 | 1750 | Mar-93 | 5 | 5 | 1 | 1 | 1 | 0 |
| 67-FW-G-1248 | 3x1.5-13 | 15 | 1750 | May-92 | 5 | 5 | 0 | 3 | 0 | 1 |
| 67-FW-G-1249 | 3x1.5-13 | 15 | 1750 | May-92 | 5 | 5 | 0 | 0 | 0 | 0 |
| 67-FW-G-1250 | 3x1.5-13 | 15 | 1750 | May-92 | 5 | 5 | 1 | 2 | 1 | 0 |
| 67-FW-G-110AC | 4x3-13R | 50 | 1750 | Dec-92 | 5 | 5 | 1 | 0 | 0 | 1 |
| 67-FW-G-111AC | 4x3-13R | 50 | 1750 | Dec-92 | 5 | 5 | 4 | 0 | 0 | 0 |
| 67-FW-G-R1T1S | 3x2-13/100 | 15 | 1750 | Oct-92 | 5 | 5 | 0 | 0 | 0 | 0 |
| 67-FW-G-1252 | 4x3-13 | 25 | 1750 | May-93 | 5 | 5 | 4 | 0 | 1 | 0 |
| 67-FW-G-1255 | 4x3-13 | 25 | 1750 | May-93 | 5 | 4 | 0 | 0 | 2 | 3 |
| 67-FW-G-1256 | 4x3-13 | 25 | 1750 | Dec-93 | 5 | 2 | 0 | 0 | 1 | 1 |
| 67-TF-G-11303 | 6x4-16/143 | 75 | 1750 | Jun-93 | 5 | 1 | 0 | 1 | 1 | 0 |
| 67-TF-G-12303 | 6x4-16/143 | 75 | 1750 | Dec-92 | 5 | 1 | 0 | 1 | 1 | 0 |
| 51-PPTN-31PWP | 3x1.5-82/70 | 3 | 1750 | Apr-93 | 5 | 5 | 0 | 3 | 2 | 0 |
| 51-PPTN-31BCC | 3x1.5-82/70 | 3 | 1750 | Apr-93 | 5 | 5 | 0 | 3 | 1 | 0 |
| 51-CAT-G-31CP | 2x1-10/94 | 10 | 1750 | Nov-93 | 5 | 5 | 0 | 4 | 0 | 0 |
| 51-CAT-G-32CP | 2x1-10/94 | 10 | 1750 | Nov-93 | 5 | 5 | 1 | 1 | 2 | 0 |
| 248D-BGI-G-AA11 | 2x1-10/90 | 5 | 1750 | Jul-93 | 5 | 3 | 8 | 21 | 11 | 1 |
| 303-TF-G-28A | 4x3-13 | 20 | 1750 | Jan-93 | 5 | 4 | 1 | 0 | 1 | 0 |
| 303-TF-G-28B | 4x3-13 | 20 | 1750 | Jan-93 | 5 | 4 | 0 | 0 | 0 | 0 |
| 303-TF-G-29A | 4x3-13 | 20 | 1750 | Jan-93 | 5 | 4 | 0 | 0 | 0 | 0 |
| 303-TF-G-29B | 4x3-13 | 20 | 1750 | Jan-93 | 5 | 4 | 0 | 0 | 0 | 0 |
| 303-TF-G-30A | 4x3-13 | 30 | 1750 | Dec-92 | 5 | 4 | 3 | 3 | 2 | 0 |
| 303-TF-G-30B | 4x3-13 | 30 | 1750 | Dec-92 | 5 | 4 | 3 | 4 | 0 | 1 |
| 303-TF-G-31A | 4x3-13 | 30 | 1750 | Oct-92 | 5 | 4 | 3 | 4 | 0 | 1 |
| 303-TF-G-31B | 4x3-13 | 30 | 1750 | Jan-93 | 5 | 4 | 1 | 0 | 0 | 1 |
| 303-TF-G-32A | 4x3-13 | 20 | 1750 | Jan-93 | 5 | 4 | 9 | 1 | 0 | 0 |
| 303-TF-G-32B | 4x3-13 | 20 | 1750 | Jan-93 | 5 | 5 | 2 | 0 | 0 | 0 |
| 303-TF-G-33A | 4x3-13 | 25 | 1750 | Jan-93 | 5 | 4 | 1 | 0 | 0 | 0 |
| 303-TF-G-34A | 4x3-13 | 30 | 1750 | Jan-93 | 5 | 4 | 3 | 3 | 0 | 0 |
| 303-TF-G-34B | 4x3-13 | 30 | 1750 | Jan-93 | 5 | 4 | 2 | 5 | 0 | 0 |
| 303-TF-G-35A | 4x3-13 | 30 | 1750 | Jan-93 | 5 | 4 | 4 | 1 | 0 | 0 |
| 303-TF-G-35B | 4x3-13 | 30 | 1750 | Jan-93 | 5 | 4 | 0 | 1 | 0 | 0 |
| 303-TF-G-35C | 3x1.5-13 | 15 | 1750 | Jan-93 | 5 | 4 | 0 | 0 | 0 | 1 |
| 303-TF-G-36A | 4x3-13 | 30 | 1750 | Jan-93 | 5 | 4 | 2 | 0 | 0 | 0 |
| 303-TF-G-36B | 4x3-13 | 30 | 1750 | Jan-93 | 5 | 4 | 0 | 0 | 0 | 1 |
| 71-BRM-G-LS16A | 3x1.5-10/94 | 7.5 | 1750 | Mar-93 | 5 | 5 | | | 0 | 0 |
| 71-BRM-G-LS16B | 3x1.5-10/100 | 7.5 | 1750 | Mar-93 | 5 | 5 | | | 0 | 0 |
| 71-BRM-G-LS16C | 3x1.5-10/100 | 7.5 | 1750 | Mar-93 | 5 | 5 | | | 0 | 0 |
| 71-BRM-G-AA13A | 2x1-10 | 7.5 | 1750 | Mar-93 | 5 | 5 | | | 1 | 0 |
| 71-BRM-G-AA13B | 2x1-10 | 7.5 | 1750 | Mar-93 | 5 | 5 | | | 0 | 0 |
| 71-BRM-G-AA13C | 2x1-10 | 7.5 | 1750 | Mar-93 | 5 | 5 | | | 3 | 0 |
| FAILURES/YEAR | | | | | | | 150 | 135 | 68 | 31 |
| FAILURES PER PUMP WITH DATA PER YEAR | | | | | | | 1.9 | 1.67 | 0.75 | 0.34 |
| MEAN TIME BETWEEN FAILURES IN YEARS | | | | | | | 0.53 | 0.6 | 1.34 | 2.94 |
| MEAN TIME BETWEEN FAILURES IN MONTHS | | | | | | | 6.32 | 7.2 | 16.1 | 35.2 |

In 1991, 79 pumps had 150 work orders, or 1.89 work orders per pump per year, or one work order every 6.32 months. With the application of the new pump installation standards, in 1994, 91 pumps, which included the original 79 pumps, had only 31 work orders. This corresponds to 0.34 work orders per pump per year, or one work order per pump every 35.2 months. This is an 82 percent increase in life.

Vibration of the pumps in this study was also significantly reduced. For instance, the 81-WASH-G-DF15 pump vibration changed as can be seen in Table 9, before and after. And a smoother running pump before the re-installation, 81-WASH-G-DF18, even ran smoother. On the average, pumps installed to the new standards run less than 0.1 in/sec. One tank farm which has 21 pumps that are primarily free-standing baseplates and poor piping, averages 0.178 in/sec overall vibration, where a group of 40 grouted pumps with good piping averages 0.071 in/sec (Table 10).

*Table 9. Pump G-DF15 Vibration Data.*

```
                        Before Rebuild

           Abbreviated Last Measurement Summary
           ************************************

        Database:  F:FLM-YARN.DAT
        Station:   BLDG. 81
        Report Date:  13-APR-92

                 MEASUREMENT POINT                  OVERALL LEVEL
                 -----------------                  -------------
G-DF15  - DSM PUMP FOR A2 TK.(1st fl.) (03-MAR-92)
1H - #1 MOTOR BRG. HOR.                              .191 IN/SEC
2H - #2 MOTOR BRG. HOR.                              .137 IN/SEC
2A - #2 MOTOR BRG. AXL.                              .236 IN/SEC
3H - #3 PUMP BRG. HOR.                               .660 IN/SEC
4H - #4 PUMP BRG. HOR.                               .504 IN/SEC
4A - #4 PUMP BRG. AXL.                               .456 IN/SEC


                        After Rebuild

           Abbreviated Last Measurement Summary
           ************************************

        Database:  F:FLM-YARN.DAT
        Station:   BLDG. 81
        Report Date:  13-APR-92

                 MEASUREMENT POINT                  OVERALL LEVEL
                 -----------------                  -------------
G-DF15  - DSM PUMP FOR A2 TK.(1st fl.) (03-MAR-92)
1H - #1 MOTOR BRG. HOR.                              .018 IN/SEC
2H - #2 MOTOR BRG. HOR.                              .024 IN/SEC
2A - #2 MOTOR BRG. AXL.                              .025 IN/SEC
3H - #3 PUMP BRG. HOR.                               .068 IN/SEC
4H - #4 PUMP BRG. HOR.                               .049 IN/SEC
4A - #4 PUMP BRG. AXL.                               .057 IN/SEC
```

Pump work orders in the cellulose esters division have dropped from 3206 in 1991 to 2770 in 1994. Even though more pumps were added to the population, work orders decreased 14 percent (Table 11). Approximately nine percent of the pumps in the cellulose esters division were installed to the new standards with a 14 percent reduction in overall work orders. Management considers this a major accomplishment.

## COST ANALYSIS

When management was first approached in 1991 to agree on the proposed baseplate, grout, and piping standards, data showed that a typical single seal failure for 316 stainless steel construction cost about $1,000. Assuming that a two year seal life instead of six months was possible, and using the $1,000 cost per seal failure, $3,000 would be saved in two years, or $7,500 would be saved in 5.0 years. To realize a 15 percent return on a capital investment with a five year life, engineering could justify spending $4,400 to reduce the seal failures. An estimate in 1991 to install a pump with the proper piping, and the new style baseplate with grout on a capital job, was about $3,000 more than the current installation costs. The analysis convinced management to adopt the proposed standards.

*Table 10. Vibration Comparison of Poor Installation vs Good Installation.*

```
                        Vibration Index Report
                        *********************
      Database:   F:PL-ESTER.DAT
      Station:    B-120 TANK FARM  (FREE-STANDING & POOR PIPING)
      Route No.   2: 120T.F.(CR4207)
      Report Date:  02-MAY-95
OVERALL STATISTICS:
      Date Range          Machine    Point
    From       To          Total     Total
---------  ---------     --------    -----
01-JAN-94  02-MAY-95        21        126

Number of Invalid Readings Encountered:      0
****************************************************************
*****************         PK Velocity in IN/SEC     ***************
****************************************************************
OVERALL:
      Date Range          Overall
    From       To                (#DATA)
---------  ---------     -------------
01-JAN-94  02-MAY-95      .178 (1068)

                        Vibration Index Report
                        *********************
      Database:   F:PL-ESTER.DAT
      Station:    B-120 NORTH PUMPS (GROUTED & GOOD PIPING)
      Route No.   1: B-120 N PUMPS
      Report Date:  02-MAY-95

OVERALL STATISTICS:
      Date Range          Machine    Point
    From       To          Total     Total
---------  ---------     --------    -----
01-JAN-94  02-MAY-95        40        218

Number of Invalid Readings Encountered:      0
****************************************************************
*****************         PK Velocity in IN/SEC     ***************
****************************************************************
OVERALL:
      Date Range          Overall
    From       To                (#DATA)
---------  ---------     -------------
01-JAN-94  02-MAY-95      .071 (1651)
```

*Table 11. Overall Work Orders in the Cellulose Esters Division.*

| Cellulose Esters Division Pump Work Orders | |
|---|---|
| Dates | Work Orders |
| 5/4/91 to 5/4/92 | 3206 |
| 5/4/92 to 5/4/93 | 2976 |
| 12/12/93 to 12/12/94 | 2770 |

A more recent analysis of WARP data (Table 12) shows an average single seal failure today costs $1,970. Assuming a three year seal life instead of six months, and using $1,970 cost per seal failure, $9,850 will be saved in three years, and $16,416 would be

*Table 12. Average Seal Repair Cost.*

| PUMP | SEAL REPAIR COST |
|---|---|
| A | $2109 |
| B | $3046 |
| C | $2269 |
| D | $1139 |
| E | $3495 |
| F | $2371 |
| G | $1074 |
| H | $929 |
| I | $2028 |
| J | $1246 |
| AVERAGE | $1970 |

*Table 13. Average Pump Reinstallation Cost.*

| W.O. | Installation Cost |
|---|---|
| PH11910 | $9861 |
| PF62980 | $10596 |
| PW92080 | $17694 |
| PV33820 | $9672 |
| PV34630 | $8045 |
| PW06540 | $5677 |
| PV47810 | $8503 |
| PF33710 | $11380 |
| PV83190 | $22240 |
| PF75450 | $12101 |
| AVERAGE | $11576 |

saved in five years. A 15 percent return on a noncapital investment with a five year life, maintenance can justify spending $11,600 to reduce seal failures on existing pumps with seal life of 6 months. A WARP analysis of the average cost to retrofit an existing pumps to the proposed standards is $11,576 (Table 13).

Management typically approves capital investment or maintenance expense projects if there is a 15 percent or greater return on the investment. Collecting data that meets or exceeds a 15 percent return on investment over five years was a key factor in acquiring the money and having the standards adopted.

Because of the implementation of the new standards on the studied pumps, at least 119 work orders were avoided in 1994. Applying the average seal failure cost data (Table 12) to the 119 work orders saved, a 1994 savings of $234,430 was calculated. This maintenance money is now being used for other reliability projects in the department.

## CONCLUSIONS

A computerized maintenance management software program was needed to identify that pumps had the highest number of work orders. This created an atmosphere for change. The rotating equipment team worked with maintenance to pilot a few test pumps to test best practices learned through training. The astounding results were documented and presented to management several times over the past few years. Persistence in data collection and documentation created systemic change and decreased seal, bearing, coupling, and gasket work orders 79.3 percent on 91 pumps.

Today, the cost increase to install a pump the correct way on a capital project is between $4000 and $5000. Reinstallation, although justifiable, is more than twice that. This becomes another reason to spend the money during the capital phase of the project.

In 1991, two year seal life was a goal. Today, three year seal life is a reality. As more run time is experienced on these properly installed pumps, four and five year seal life may become a reality.

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