A TEAM APPROACH TO QUALITY PUMP PROCUREMENT AND INSTALLATION

by

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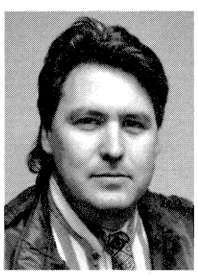

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ABSTRACT

There are three factors that will enhance smooth equipment startup, operation, maintenance, and reliability in any new process plant:

- Initial pump design and selection
- Proper installation
- Consistent operational support and training

These factors can be positively addressed only if engineering, production, and maintenance utilize a team approach. This requires a major shift in paradigms and the setting aside of conflicting subgoals or individual goals that the different groups may have.

This presentation will review the long-term reliability approach used during a recent $35M expansion project, highlighting the following areas:

- Initial project review of design basis by Process, Production, Design, Maintenance, and Construction groups
- Equipment specification, bidding and selection criteria
- Project team interface during engineering, design, manufacture and installation
- Field checks and testing
- Operational training
- Startup support and followup

Results of one and one-half year's of operation are presented. This project is contrasted with another major project that ran concurrently in the area. The other project failed to use the team approach and met with vastly different results.

INTRODUCTION

Most chemical companies understand that improving machinery reliability is key to cutting plant operating costs and remaining competitive in today's fast paced and rapidly changing business environment. At the BASF Freeport site, a Reliability Group was created to assist Maintenance and Production in identifying possible causes of failure. The group would also suggest and implement corrective measures in an effort to improve MTBR (mean time between repair).

BASF recognizes that teamwork and communication are essential components of the quality process. A $35M grassroots Wastewater Treatment Plant capital project presented an excellent opportunity to try the team approach to pump specification, procurement, and installation. The primary goal of this team was to specify, select, and install equipment in such a way that the result would be a reduction of startup problems and improvement of the plant's MTBR.

PAST METHODS: ENGINEERING *VS* PRODUCTION

Large capital projects are often handled by works engineering groups, corporate engineering offices, or sometimes by outside engineering and construction companies. The machinery specialists in these organizations are entrusted with the task of selecting pumps and installing them. Plant operations often entrusts the design to the engineers until they are ready to "push the button." Maintenance and Reliability are sometimes not consulted until equipment has already been ordered, or, in the worst case, delivered. In most cases, the critical communications between buyer and user occurs too late in the project, resulting in poor rapport, mediocre installation, increased startup problems, and overall higher costs.

So, it often happens that the owner is not satisfied with the final results. One reason is the lack of a common definition of a "successful project." To Engineering, a successful project may be one that simply meets schedule and budget. Operations, while also wanting this, would also be concerned with low long-term operating cost and good equipment reliability.

Project critiques bring up the following list of problems that can impact startup and long-term reliability:

- Process design engineers did not state or specify pump design criteria for *all* operating conditions, such as startup, part load, or emergency operations.
- Project/Construction Managers did not consider all of Maintenance's or Production's requirements.
- Machinery engineers relied solely upon owner's technical standards. Some are often not kept up-to-date or are incomplete.
- The plants have local "plant requirements" that were not communicated to the machinery engineer.
- Machinery engineers did not consider plant preferences for vendors with exceptional field maintenance service, vendor stocking programs, site spare parts compatibility, or maintenance technician familiarity with equipment.
- Machinery engineers did not communicate all requirements to pump vendor.
- Communication breakdown between vendor's local sales office and vendor's engineering/fabrication office.
- Lack of communication between the pump vendor and its subvendor
- Inadequate pump vendor and subvendor quality control
- Insufficient and poorly documented inspection and testing at manufacturer's facility
- Damage during shipment or installation
- Insufficient inspection upon arrival at job site
- Installation instructions missing or insufficient
- Installation instructions ignored by contractor
- No field follow up by machinery, construction, or maintenance engineers
- Lack of vendor interest and "ownership" in installation resulting in poor followup
- Lack of experience in engineering, maintenance, and production disciplines
- Missing or late reviews of documents

A quick look shows that the majority of problems could be addressed by better communication, at the right time, and by teamwork between the various parties of the project.

TEAM FORMATION

It was decided to form the Pump Team at the start of the project. The Team charter was to select reliable pumps that met the requirements of the project and to identify plant needs that were consistent with project and plant goals. The Team consisted of the Machinery Engineer from Corporate Engineering, the Reliability Engineer from the Site Reliability Group, and the Maintenance Mechanical Group Leader from the Technology. The Manufacturing Representative from Production and the Lead Project Engineer were constantly informed of the team's progress and participated in key meetings and decisions. The team chronology is shown in Figure 1.

Initial meetings stressed the team goals, communication guidelines, and the individual responsibilities of each team member. During the first visit to the plant, the following general issues were discussed:

- Timely distribution of documents and responsibility for reviews
- Plant philosophy regarding reliability
- Plant pump selection criteria and preferences
- Approved vendor lists and plant experience with vendors, vendor support, and inspection and testing philosophy at the pump manufacturer's plant
- Plant vendor preferences for auxiliary items such as seals, couplings, and drivers
- Plant involvement in installation, and pre-startup activities
- Parts stocking and vendor stocking programs

MAINTENANCE AND OPERATIONS REQUIREMENTS

When developing the mechanical specifications there are tendencies to rely solely upon the company standards and the project piping and instrumentation diagrams and flowsheets. However, this often misses many of the mechanical requirements that are specific to a plant site or to a unit within the plant. Sometimes, special process requirements may be overlooked. Technical standards are provided to cover most of the engineering needs of an organization. Unfortunately, plant or process specific requirements cannot generally be included.

Technical standards are often the only document used by the larger engineering offices for equipment specifications.

This means that plant or project specific requirements are sometimes not conveyed to the machinery engineer. This results in surprises when the equipment is delivered, with resultant discussion and disagreement during the installation phase between engineering and plant. At this time, little can be done to correct problems without a schedule delay or incurring additional costs.

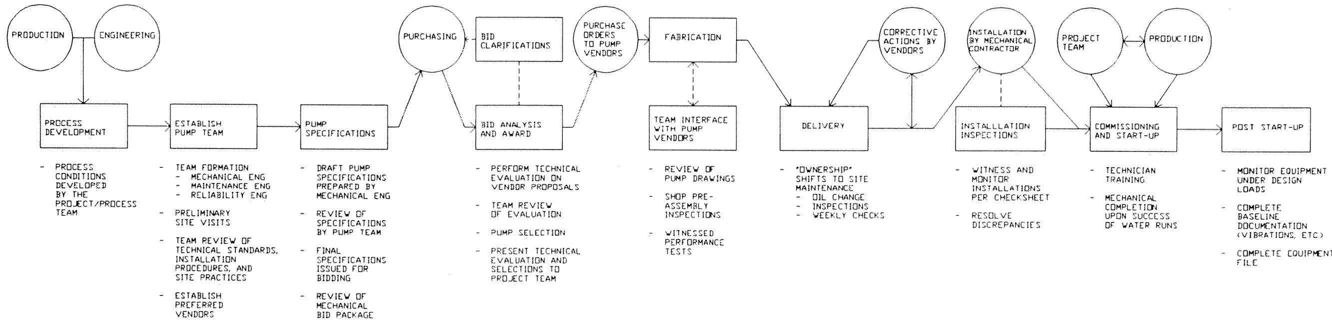

Figure 1. Pump Installation Team Chronology.

PURCHASE SPECIFICATION

A well defined specification is the basis for a professionally engineered project. It should state design flow conditions for the pumping equipment, severe duty considerations (erosives, corrosives, extreme temperature, etc), and also define short term excursions (operation under reduced flow at startup, turndown operation, emergency conditions, etc). It should also describe the project philosophy and include plant specific requirements. The Wastewater Treatment Plant project, though well designed, was not completely defined, and some process parameters were still being evaluated as the pumps were being specified and selected. This demanded continuous and timely communication within the Team and with the vendors.

An inquiry specification is the first document to be prepared by the Machinery Engineer. Hernandez [1] is an excellent source for the essentials of a good inquiry. It demands a major effort to write a complete and comprehensive package. This project was no exception. The inquiry specification required information from many disciplines:

- Process and Operations provided information on a complete operating range, quantity and type of corrosives, and erosives, and acceptable metallurgy.
- Reliability group provided information on site preferences, such as preferred seal suppliers, coupling suppliers, enhanced pump design features for longer life, and selection criteria.
- Maintenance group gave their recommendations for seal selection, installation procedures, and historical data and past experience on various makes of pumps.
- Electrical group supplied motor data, approved motor suppliers, and variable frequency drive considerations for some applications.
- Materials group reviewed the metallurgy and recommended paint systems for the motors, pumps, guards, and baseplates.

In addition to the company's technical standard for pumps, the equipment specification listed additional requirements for baseplates, inspection, and testing. The approved vendor list was carefully screened to find those suppliers who have a strong service history with the site. The inquiry specification was reviewed by all team members.

TECHNICAL BID EVALUATION

Proposals were carefully reviewed against the inquiry documents. All exceptions taken by vendors were evaluated. Vendors were contacted through the Purchasing Department for reconciliation.

The technical evaluation considered items like bearing life, shaft stiffness, and impeller sizing and design flow *vs* BEP (best efficiency point). Aside from the cost of the equipment and options, other factors were taken into account. These were a power debit and maintenance experience.

A power debit was applied against the less efficient pumps. This accounted for the added cost of power used by a less efficient pump over the life of the pump. Current and predicted interest rates and the cost of power were part of the power debit calculation.

Most companies consider nine to twelve years as the average life of rotating equipment (before it is retired due to plant closure, debottlenecking, or expansion). However, this leads to a very high power debit figure. If applied indiscriminately, it can bias the selection toward the more efficient pumps regardless of other factors such as cost or mechanical reliability. A three year pay out period was used for this project and the estimated dollar value was included in the specifications. The power debit was of consequence in the selection of only eight percent of the pumps.

Pumps built to the same standards often have different MTBR, due to component design differences between vendors and varying standards of quality control. If a plant has a comprehensive maintenance database, these differences can be easily quantified. As the bid list was held to pump vendors with a favorable plantsite repair history, it was decided not to include any estimated cost of repairs in the evaluation. This prescreening based on history eliminated any subjective or judgmental opinions that could unfavorably bias the bid evaluation.

The vendor proposal, technical evaluation, and purchase recommendations were reviewed by plant Maintenance and Reliability personnel. An inherent danger in giving wide internal review of these packages is the difficulty of keeping commercial terms confidential. Disclosure of vendor proposals between suppliers would have been considered a breach of confidentiality. This was prevented by providing cautionary notices on the bid packages.

After the bid evaluation, it was decided to obtain the majority of the pumps from two suppliers. As the bids fell within an acceptable range, the final selections were based more upon technical factors than cost. Four other suppliers provided the few special pumps that were outside the range of the large orders.

PUMP MANUFACTURER QUALITY EFFORT

Once the order had been placed with a pump supplier, the design effort shifted to the manufacturer. The requisitioner's focus shifted to the drawing and delivery schedule, and conformance to quality standards by the manufacturer. All of the agreements reached during the pump selection process were included in the revised data sheets issued to the vendor as a contract document.

In an ideal situation, if the purchase requisition is comprehensive and is carefully written and the pump is bought from a known established supplier, then the pump should meet all the requirements of the customer. The process of design and fabrication involves many organizational subunits of the supplier and its subvendors. Lack of communication or commitment can result in nonconformance. The old philosophy was that if the vendor did not perform according to the purchase contract, the pump would be sent back to be fixed. This assumes that all the errors were caught by field inspection, and there was sufficient time to make the repairs. The approach on this project was based on the concept of partnerships. Both the supplier and the purchaser were part of a team working toward the common goal of obtaining a pump that met the specification. Instead of the adversarial relationship, this strategy asked the question, "How can we help each other meet the mutual goal?"

Purchase Order Review Meeting

Ensuring quality in the end product is based on a number of factors: communication of the agreed purchase requirements to the vendor's engineering personnel, and the vendor's design engineering, and its fabrication, quality control, testing, and inspection programs.

The usual first step in the supplier's organization is for the sales office (or distributer) to communicate the requirements of the purchase specification to the vendor's design engineering office. Some vendor sales representatives will send the whole package received from the customer, including all technical standards. Other vendors expect their sales staff to sift through the customer's requirements and transmit only the deviations from their standard design. Technical standards can be confusing and time consuming. Requisitions may not be clearly written. Bid revisions, options, and changes made prior to ordering may cloud the issue. Sales personnel may not completely know all the optional features of their pumps. All these can result in a failure to completely communicate the needs of the customer to the engineer finalizing the design of the pump. A post-award meeting pays big dividends in ensuring the completeness of this communication. This should take place one to two weeks after the order is placed between the customer's requisitioning engineer and the supplier's design engineer. It allows them to review the order line by line, and clarify needs, requirements, and resolve uncertainties.

Sales personnel, owner's inspector, and customer's purchasing agent may also attend. An additional gain is that face-to-face meetings provide the basis for more cooperative interaction between all parties and raise the visibility of the order in the vendor's schedule. Post-award meetings do add cost in dollars and time. For very small orders or projects on a tight budget a telephone conference call may be a better option.

Post-award meetings were not conducted for this project. This was due to time constraints and the opinion that the selected vendors had demonstrated better quality in the past. This decision resulted in a few surprises during the performance testing and shop inspection stages. These surprises are discussed later in CASE HISTORIES.

Benchmarking and Measurement

An important part of quality control is benchmarking. One aspect of this is the degree to which the manufacturer adheres to his own design tolerances. In the past, the authors' company would take newly-delivered pumps at random, completely disassemble them, and measure components against tolerances. It was found that some pumps from reputable suppliers failed this test. The problem with this approach is that the vendor's warranty could be voided if a vendor's representative is not present to witness the disassembly, measurements, and reassembly. It also adds to the cost and schedule.

For this project, attempts were made to shift this measurement responsibility to the suppliers. The first step was to ask suppliers to put clearances and tolerances of mating parts on the drawings, to enable faster repairs in the field. Company technicians spent a few days at one of the manufacturing facilities prior to the assembly stage. They picked parts at random and checked them or observed vendor's measurements. A significant number of parts were found to be out-of-tolerance. These were corrected before assembly. In the opinion of this team, the cost of the technician's time and travel was justified by the potential problems that were identified.

Witnessed Inspection by Owner

In addition to obtaining material certification for all alloy components and hydrotests of pressure-containing parts, it was decided to have witnessed performance test for all pumps. This added to the cost of the equipment, but it brought the assurance that the equipment would perform to specification. An outside inspector provided this service on behalf of the company. The requisitioning engineer, the unit maintenance engineer, and the operations engineer visited the two main suppliers to see the first few performance tests themselves. These visits served to highlight the importance the company assigned to quality, served to instruct the outside inspector, and provided buy-in from the plant personnel.

CASE HISTORIES

As stated earlier, the bids for pump fabrication and delivery were awarded to four vendors. With each vendor, different problems arose that underscores the importance of a team approach toward selection and procurement.

Case History—Vendor 1—Centrifugal Pumps

Vendor 1 provided 24 pumps of various sizes to the customer company. A good business relationship exists between the two. This supplier has been willing to provide tolerances and fits critical for repair and assembly of the pumps. Plant technicians visited the vendor's shops prior to assembly and found some shaft and seal tolerances outside the vendor's own specifications. These were immediately corrected. During the first few performance tests, the pumps operated as designed. Vibration and temperature rise were found to be acceptable. Shaft runouts were checked on three of the pumps and found within tolerance. However, a number of flaws were evident to the team. These included low spots in flange gasket surfaces, motor alignment holes that were machined part way through when the mounting pads were machined, poor paint application, baseplate welding not according to customer's specification, and coupling guards that did not adequately protect rotating components. These defects were quickly repaired by the supplier. When the pumps were delivered, additional problems were found. Epoxy paint had been sprayed in the bellows of the outer seals, and the seal glands were not properly oriented. The supplier incurred expenses for additional inspection and subsequent repair.

Case History—Vendor 2—Centrifugal pumps

Vendor 2 supplied 13 pumps of various sizes to the customer company. This supplier provided critical tolerances rather reluctantly. Part dimensions were checked, but not documented prior to assembly. It was found that this supplier asked its local sales staff to sift through the customer specifications and compile a list of options and deviations from their standard design. This list was all that was sent to the factory engineering office. Hence, customer's technical standards or purchase specifications were not available for the pump vendor's design team. Some of the customer's requirements such as shaft runout and type and duration of testing were not communicated to the factory. Of the three pumps disassembled for runout checks, one was within customer's specification, one was within supplier's specifications, and one exceeded both. The one that had failed was found to have a defective bearing carrier. All other pumps were then physically checked for runout, as this vendor had no form of assembly documentation to verify that critical checks were conducted. These were found to be within supplier's specification, but not the customer's. On delivery, baseplates on four pumps were found to be stitch welded (as opposed to specified continuous weld), and corrosion had already started in the joints. This was corrected by the supplier. Baseplate mounting pads were not parallel, and excessive shimming was needed under most pump and motor feet for alignment.

Case History—Vendor 3—Self Priming Centrifugal Pumps

Only two pumps were purchased from this supplier who did not deviate from his standard design. The order was placed through a local sales distributor. Approval drawings were received from and returned to the distributer. Due to turnover in the sales staff, these drawings were not returned to the pump supplier. The customer company's expeditor was told that every thing was on schedule. The supplier had not followed up when approval drawings were not returned in time, and the customer had overlooked the missing certified prints. These pumps were delivered much later than required, and it was found that the baseplate paint did not meet specification.

Case History—Vendor 4—Sample Pumps

Twelve small gear pumps were purchased for sampling service for the plant's analyzer systems. Process requirements called for low flow with no pulsations. Although the product was specified as clean, small strainers were installed at the suction of each pump. The pumps that were purchased had one metal gear running against a soft plastic gear. Pump performance turned out to be very poor. A large amount of trash in the product stream caused frequent choking of the strainers. The small amount of dirt that passed through the strainers caused premature wear of gears and shafts. The average life of these pumps was only a few months.

The main reason for the incorrect pump selection was wrong assumptions about the quantity and type of erosives in the product stream. Another factor was inadequate communication between company Process, Maintenance, and Design Engineering groups. Since these were low cost pumps, insufficient importance was assigned to their selection.

ONSITE INSTALLATION

As each group associated with the project had somewhat different objectives to fill, the key to the success of this project was timing. The decision on how equipment is to be installed cannot be made or discussed after the mechanical contractor has mobilized and the rotating equipment has been delivered. Project management will tend to view these issues as extra work that will extend the scope and schedule, which translates to dollars.

The mechanical installation for the Wastewater Treatment Plant project was discussed and negotiated early on in the project. In this negotiation, compromises were made. A good example would be that of onsite storage. On past projects, there has been the tendency for Construction to set new equipment out of the way and not worry about the equipment until the schedule called for installation. Maintenance and Production would be left out of the discussions on storage considerations.

One of the first agreements of this project was ownership. Upon delivery, the Maintenance members of the team were notified. A thorough checkout of each piece of equipment was conducted, the oil was changed, and the reservoirs filled. If some discrepancy was found by the technician, the Construction Supervisor and the Pump Team were notified. In a few cases, the pumps were disassembled for inspection. In a few other cases, the pump vendor was requested to make corrective repairs. Each piece of equipment was wrapped to protect it from the climate, but with easy access so the shafts could be spun on a scheduled basis.

This simple agreement accomplished two goals. Maintenance was on board during the construction phase early in the project, taking responsibility for what ultimately would be theirs. Construction did not have to worry about tasks that were not their highest priority, but could delay startup and mechanical completion.

This team approach was continued throughout the course of construction and installation. The installation procedure was worked out in the early planning stages of the project. Engineering and reliability facets of installation were discussed so that the goals of both sides could be met.

INSTALLATION PROCEDURE

1. Remove pump and driver from baseplate. Clean pump and motor mounting surfaces. Inspect baseplate for sufficient vent holes to eliminate the possibility of trapping air between foundation and baseplate.
2. Chip top surface of concrete pedestal to remove laitance. Blow with air to remove dust or moisture. Wrap anchor bolts in polyurethane or other soft material so the grout does not stick to them.
3. Level pump and motor mounting pads to 0.002 in/ft. in both horizontal directions. Use cylindrical stainless steel bearing pads under the jackscrews. Flanges must be within 0.0625 in (1/16 in) using a machinist level (Starrett No. 98 or equivalent). Pump discharge flange must be level within 0.005 in/ft, both lengthwise and crosswise.
4. Form for epoxy grouting.
5. Mix epoxy carefully per grout manufacturer's specifications.
   a) Proper mixing temperature is important.
   b) Ensure sufficient quantity for a single pour.
6. After epoxy has set and cured, remove forms and clean up. Check baseplate for voids. Carefully fill voids, do not overpressure.
7. Mount pump and motor and rough align.
   a) Alignment: Couplings must be aligned (using reverse indication method) to within 0.003 in. Number of individual shims under motor feet must be kept to a minimum. Do not place shims under the pump feet.
   b) Piping: Piping must be supported independently and cause minimal stress on pump casing. Stress will be measured by placing dial indicators on pump coupling and loosening and retightening flange bolts. Maximum allowable deflection will be 0.003 in.
8. Final align. Use reverse indicator method.
9. Tighten suction and discharge flanges of the pump.
10. Recheck alignment.
11. Install flush piping and seal pots. Check markings on glad to match flush connections.
12. Connect motor and bump to check directions.

NOTE: If installed equipment is not to be used for an extended period of time, maintain lubrication and shaft rotation check schedules.

To facilitate this installation, a check sheet was developed for the Maintenance technicians assigned to the project (Figure 2). These maintenance technicians provided quality control assistance for both construction and maintenance. Each section on the check sheet reflected discussions and negotiations made early in the project. These early discussions alleviated most surprises, as the check facilitated early detection of problems, making correc-

PUMP INSPECTION/COMMISSIONING CHECKSHEET
PUMP ID:___
PUMP DESCRIPTION:___

PUMP DATA	KEY DATES
Pump Service___ Design Flow___ gpm Manufacturer___ Head___ Model/Size ___/___ Sp.Grav ___ Impeller: Size___ Mtl ___ Clearance ___ Motor: HP___ RPM___ Manuf___ Frame ___ Mechanical Seal (Single ___ Double ___ None ___): Manufacturer___ Model___ Flush Plan ___	Date / Inspector Delivery ___ ___ Notification ___ ___ Initial Inspection ___ ___ Installation ___ ___ Alignment ___ ___ Fit-up ___ ___ Start-up & Acceptance ___ ___ Eq File Complete ___ ___

INITIAL INSPECTION	NOTES
___ Visual Inspection - look for shipping damage, flaws, defects ___ Compare to vendor drawings - materials, dimensions, quality ___ On-site storage - oil, N2 purge (?), location ___ Obtain pump manuals, drawings for equipment file ___ Add pump to stored equipment preventive maintenance schedule ___ Initiate equipment checksheets, documentation, etc.	

INSTALLATION	NOTES
___ Witness equipment relocation, installation ___ Witness alignment - obtain alignment sheet for files ___ Witness grouting (epoxy grout only!) ___ Witness fit-up for pipe stresses ___ Witness final alignment (if required) ___ Ground wire installed	

PRE START-UP	NOTES
___ Seal flush installation - open, clear ___ Check lubrication - change oil if required ___ Check rotation ___ Review I/E installation - stop/starts, alarms, shutdowns ___ Pressurize seal to check for initial seal leaks	

START-UP	NOTES

___ Participate in initial start-up
___ Monitor pump, seal, and motor performance
___ Obtain vibration signatures for equipment file
___ Add pump to production lube and preventive maintenance schedule
___ Complete equipment file documentation:
   ___ Equipment drawings
   ___ Certified drawings on components
   ___ Spare parts list
   ___ Input equipment into champs	

Figure 2. Pump Inspection/Commissioning Checklist.

tions easier and cheaper. Baseline information on each piece of equipment was developed, which will be available for future troubleshooting.

TRAINING

Training was also an important step. Production developed detailed job analyses. Each step of operating the equipment and the process was outlined with quality and safety factors highlighted to ensure the proper and safe operation of each piece of equipment. Maintenance also reviewed the draft analyses to ensure that important reliability factors were included.

Each production and maintenance technician received formal training on the new facility. The analyses served as the "textbook" for that training.

RESULTS

Some plant startup experts say that one should anticipate a 20-25 percent failure rate of rotating equipment during the startup process and the first six months of operation. The Wastewater Treatment Plant (WTP) project installed over 50 medium to large centrifugal pumps. The startup was smooth, encountering no delays due to pump or mechanical problems. Less than two-thirds of the money budgeted for mechanical startup was used. Most of that was spent prior to startup on field checks and inspections.

Since startup, and for the first year of operation, only six seal failures have occurred. Two were due to pump cavitation caused by a syphon created in one of the process streams due to poor pipe design. One was due to a broken spring in the seal and two from operational error. The last failure was due to pump cavitation caused by a slug of foreign matter caught in the pump. No motor or bearing failures have occurred since commissioning. Post startup vibration checks show little or no deterioration in pump conditions. Total costs on pump repair to-date have been less than $20,000.

Another production facility constructed during this same time frame did not apply the same team approach toward procurement and installation. The project was plagued with numerous mechanical problems prior to and after startup. An inordinate amount of field work and revisions were required throughout the unit. The startup budget was depleted and over $40,000 was spent in just the first month on pump repairs. A comparison of typical equipment failures on two large projects is shown in Figure 3. The WTP project reflects the overall impact of the team approach.

Another reward for the team approach of installation has been a negligible increase in the routine maintenance budget. The site maintenance budget currently averages 3.6 percent of total installed cost. For the WTP project, the budget of routine maintenance increased only 1.7 percent of the total installed cost, while the expansion effectively doubled the equipment count in the WTP. Of this, only 0.8 percent was budgeted for mechanical maintenance. For 1993, the mechanical maintenance budget was favorable by six to seven percent.

	MECH. SEALS	EQUIP. BEARINGS	MOTOR BEARINGS	MOTOR WINDINGS
WTP	6	0	0	0
PLANT B	26	8	3	2

Figure 3. Failure Statistics.

OLD TRADITIONS *VS* NEW REALITIES

Traditionally, Engineering has not taken a proactive approach of asking Production what was wanted, or consulting Maintenance as to what was needed. Conversely, Production and Maintenance would postpone direct involvement until too late in the project.

This lack of interactive involvement can be overcome with frequent visits to the site/unit prior to and during construction. This can be augmented with frequent meetings of plant personnel at the engineering offices. Site personnel are at times reluctant to break away from their plants to participate in the early design stages. Unfortunately, this is when their input is most important. Engineering and plant management must support the active interaction with engineering, maintenance and production and not view it as a waste of time and money.

Cost has historically been the dominant factor in the pump selection process. A machinery engineer should be able to anticipate which pump selections will be accepted on technical merit. As is usually the case, the best defense is a good offense. The selection process should be biased toward strong *technical* reasons why certain pumps should be included in the project, even though they are not the cheapest. This can be facilitated by a good inquiry package. Other factors to consider are which vendors give uncommonly good service to the plant and technician familiarity with a particular vendor or product. This was done on the WTP project, and the pump selection was accepted in its entirety on the first pass.

Generic inquiry packages serve no useful purpose. Extra design and/or construction specifications, must be included in the inquiry, otherwise the manufacturer or construction contractor has no choice but to charge for adders. This erodes contingency money unnecessarily. Furthermore, a mediocre inquiry package gives little or no information to technically back up any decision to purchase a more expensive piece of equipment. A large project organization can be prone to poor inquiry packages. Because of the number of people who must review the package, it often becomes weak from over-editing. Critical design parameters that are key to long-term reliability and operation are often deleted from the original inquiry document.

Another stumbling block is the early entrenchment of project members who are inflexible toward change. It is crucial to obtain agreement early with those involved with pump selection and installation, as to the ultimate goals for total value to the company.

In the past, this company has foregone the post-award meetings with the vendors. Depending on the vendor, the information received by its manufacturing unit may little resemble the specifications originally submitted to the vendor sales representative. Some companies want only deviations from standard manufactured items sent to their manufacturing facility, others want the entire package sent to them. This creates information filters through which less and less of the original request makes it intact. Removing these filters through post-award meetings (face-to-face for larger parcels, conference calls for the smaller parcels) proves invaluable where it is done, and problematic where it is not.

AREAS FOR IMPROVEMENT

No project is without flaws. Some of the areas where this project could have done better include:

- Better storage of equipment. An enclosed storage building would better protect the equipment awaiting installation. Experience has shown us that static equipment requires more protection from the elements than that which is in-service.
- There are NO "small, insignificant" pumps. All pumps need to be treated with the same attention to detail, regardless of size.
- Closer review of piping design with respect to process flow and mechanical equipment requirements.
- Earlier buy-in from all parties. Significant amounts of time, money, and energy are wasted correcting problems at a later date. The earlier the buy-in, the better.
- Over-edited mechanical installation bid package. The bid package must be considered incomplete if specific installation procedures (e.g., methods of alignment or grout procedures) are desired but are not included in the package.
- Post-award meeting. Post-award meetings with the vendor's manufacturing representative to discuss equipment specifications on an item-by-item basis is extremely important. On some pieces of equipment, or smaller orders, a conference call may substitute for a face-to-face meeting.
- Improved database. There is a strong need for an improved maintenance database that can be used to determine a maintenance cost associated with poor installation. The same database should be expanded in order to find the maintenance cost of the different suppliers. That way, a maintenance debit could be used for the cheaper pumps that have a poor maintenance track record.

SUCCESSES OF THE TEAM APPROACH

The magnitude of the benefits of a team approach is so great that anyone undertaking a project, regardless of size, should not hesitate to incorporate a team approach at the onset.

Highlights of these benefits include:

- Improved "ownership" by all engineering members throughout the project.
- Early involvement of plant personnel (both Production and Maintenance).
- Excellent transition of responsibility from Engineering to the plant.
- Networking and sharing of information, both intracompany and intercompany.

CONCLUSION

The concept of a team approach is anything but new; however, the implementation is often novel. In a team approach, the differences in the team member objectives are replaced with a common objective to obtain the best total value for the company. Team members strive for a positive interaction to make the right decisions the first time. This effort requires team members to communicate well with one another. Therefore, all important considerations get addressed at the appropriate time during the execution of the projects.

For this project, the team approach was successfully utilized on a major capital project for the selection, procurement, installation, and operation of process equipment. The early assembly of the team members was a key factor in the success. The representatives from Engineering, Production, Maintenance and the Reliability groups were dedicated and knowledgeable about pump applications in a process environment. This helped ensure the necessary attention to details that is required for a quality job.

REFERENCES

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