DEVELOPING FIXED-FEE SEAL AGREEMENTS TO IMPROVE PUMP RELIABILITY

by

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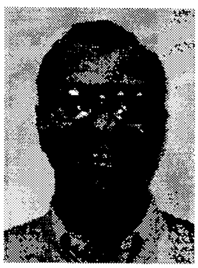

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ABSTRACT

Long-term contractual agreements between a mechanical seal supplier and an end-user have proven to be a very effective method for improving equipment reliability. Successful agreements change the focus of a user/supplier relationship from a purchasing function to asset management using a team approach with common goals:

- Increase equipment reliability.
- Reduce equipment and seal life-cycle cost (LCC).
- Increase onsite reliability support.
- Provide mutual financial benefit to both the user and supplier.

The goals of any agreement must be aligned and the structure must be properly established to achieve maximum benefit. Furthermore, a clearly understood win/win approach must be developed and maintained in order for any agreement to succeed.

INTRODUCTION

Increasing globalization and fluctuating prices have resulted in volatile margins for petrochemical industries. These unpredictable margins have forced most refineries and chemical plants to make dramatic changes in the only arena they can control—operating expenses. As a result, maintenance departments have come under increasing pressure from their production department customers to improve pump reliability and reduce downtime in order to meet company profit plans. However, with fluctuating profits, maintenance departments are compelled to work more effectively with less, as operating budgets are slashed and manpower reduced.

This situation has adversely affected the ability to move from a reactive mode to a more progressive proactive mode. To fill these resource gaps and to achieve corporate objectives, maintenance departments have sought unique and nontraditional solutions.

One nontraditional solution is a contractual agreement between a user and a single mechanical seal supplier. The decision to enter into such a contract is usually preceded by the recognition that mechanical seal failures are the most common reason sealed pumps are taken out of service. Obvious savings can be accrued by lowering this percentage. The reduced user maintenance staff makes it necessary to increase reliance on the expertise of seal suppliers and potentially enter into nontraditional agreements with one supplier to achieve these savings.

The objective of this paper is to educate those who may not have previously considered a vendor alliance and to validate those who have. To accomplish this objective, the following topics will be discussed in depth:

- Comparative benefits of fixed fee agreements
- Examples of successful programs
- Contractual and organizational structure of successful user/supplier relationships
- Pitfalls and problems occurring when a fixed-fee agreement does not live up to expectations

PUMP AND SEAL LIFE

Previous authors have shown that mechanical seals represent the largest first failure for centrifugal pumps. Bloch and Geitner (1997) studied a population of 2560 pumps and found that mechanical seals accounted for 34 percent of the repairs (Figure 1). Their data suggest that any improvement in seal life would have a corresponding, but smaller, improvement on pump life. However, improving seal reliability has a secondary impact on pump reliability that the chart does not show. This can be illustrated if one thinks of the mechanical seal as a fuse.

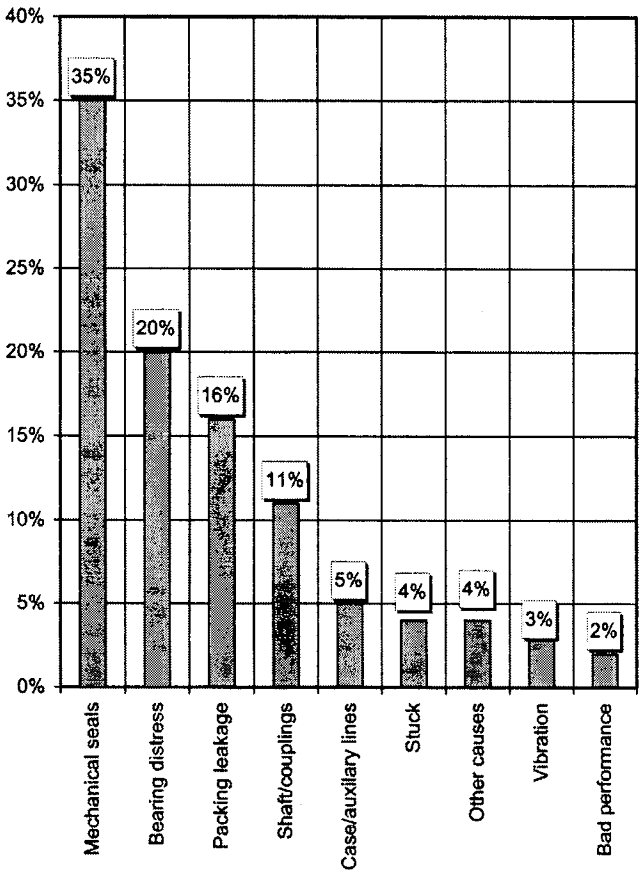

Figure 1. Mechanical Seal Failures as a Percent of Overall Failures.

Many seal failures are caused by conditions outside the seal system. Flach, et al. (1998), investigated the root cause of seal failures for chemical plants and refineries. Their study showed that process related problems were the most frequent cause of seal failures, accounting for 38 percent of the total. By contrast, seal design and selection accounted for only 24 percent of the failures they analyzed. Cavitation and misalignment are also apparent causes of seal failures; however a bearing failure, which then results in a seal failure, frequently results from these mechanical problems (Mikalonis, 1999). Because seals are precision engineered with close tolerances, seals tend to visibly fail before bearings, therefore masking perceived bearing life unless a root cause failure analysis is completed for each failure. Even apparent bearing failures may not be a result of bearing design, but rather maintenance and operating practices.

By focusing attention on seal failures the condition of the equipment can often be ascertained. Failure analysis of seals is a valuable tool in identifying root cause problems that exist outside the seal system. Vibration, misalignment, and shaft whip, to name a few, can be diagnosed through close examination of the seal failure mode and seal parts. The resultant corrective actions will improve not only the seal reliability, but also the reliability of other components. In this way the overall reliability of the pump increases above what can be gained by improvements of the seal alone.

PUMP AND SEAL LIFE-CYCLE COST

The impact that seals have on pump cost can be shown with life-cycle cost (LCC) models. Wallace et al. (2000), presented a paper at the Seventeenth International Pump Users Symposium in which they discussed LCC of a common API pump. Their work showed that the single largest cost driver for a pump, with the exception of operations or energy cost, was maintenance. In their study, maintenance accounted for 10 percent of the LCC as compared to the initial purchase price, which only accounted for 7 percent. Figure 2 is a graphical representation of their data. This LCC model clearly demonstrates that improving reliability will affect a greater total cost reduction than negotiating a lower initial price.

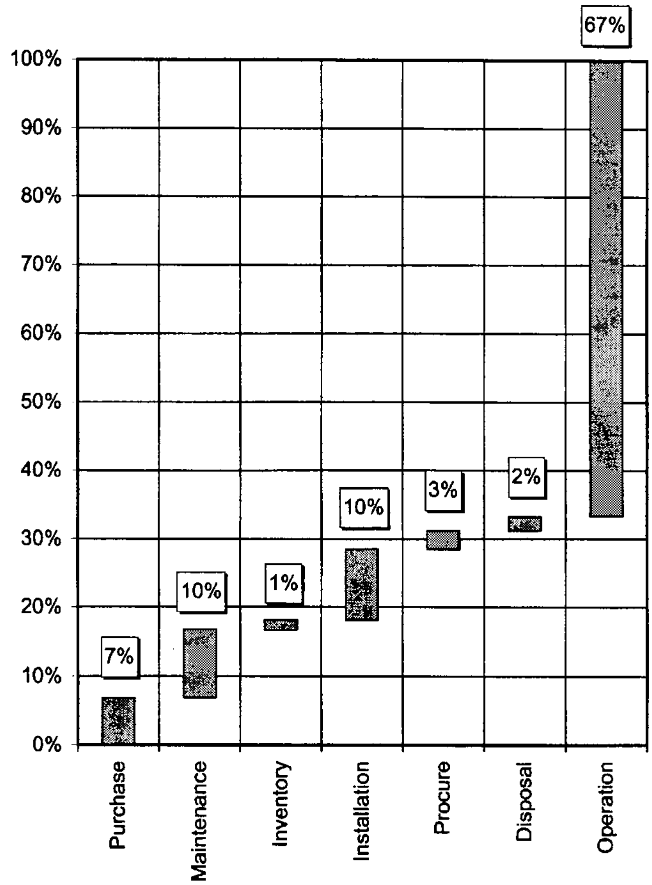

Figure 2. Centrifugal Pump Life-Cycle Cost.

Figure 3 presents the LCC model for a typical 2 inch API 682 single pusher seal. As with the pump, the maintenance costs are roughly equal to the purchase price. Additionally, inventory management costs are roughly equal to purchase and maintenance cost. Together these three elements account for more than 75 percent of the seal LCC. This model shows that large opportunities exist not only in the initial price paid for a seal, but also in long-term maintenance and inventory management costs.

The LCC model is used to identify the largest cost drivers when developing a seal management program and seal alliance contract. Initiatives that positively impact the major cost drivers will form the backbone of a total seal management program. For example, assuming the LCC model presented above is correct for the given population of pumps and seals, any total seal management program should equally address the purchase price, the maintenance cost and reliability, and the cost of inventory. Since installation, procurement, and design cost are minimal, the program would address these only as a secondary issue.

COMPARATIVE BENEFITS OF A FIXED-FEE AGREEMENT

A contractual agreement between a user and a supplier can take many forms, but not all these forms can be used for a total seal management program. The four most common options are listed in ascending order of user commitment:

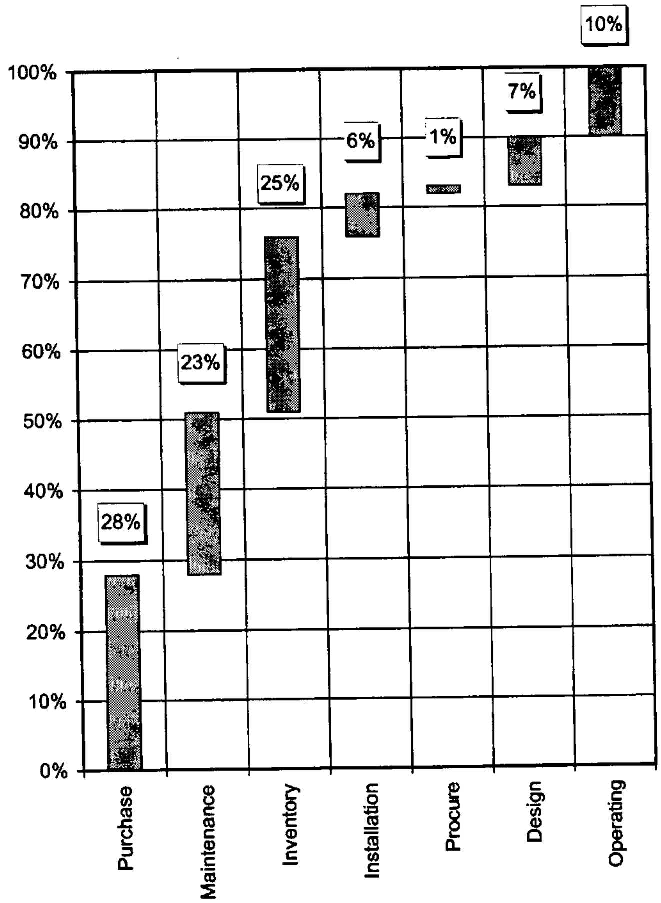

Figure 3. Mechanical Seal Life-Cycle Cost.

- Purchasing agreement
- Preferred source agreement
- Primary or sole source agreement
- Fixed-fee agreement

Purchasing and Preferred Source Agreements

Purchasing and preferred source agreements tend to perpetuate the traditional user/supplier relationship. No incentive is developed for the supplier to provide any services beyond what is needed to complete the sale, and the user typically only gains some first cost concessions.

Primary or Sole Source Agreement

A primary or sole source agreement (or PS agreement) stipulates that a user nominates one supplier as their first choice for all new and upgraded seal applications. In general, the user decides what equipment is eligible for a new or upgraded seal based on availability, reliability, and user-owned seal inventory levels. In return for this commitment, the supplier will provide:

- First cost discount on new and upgraded seals.
- A complete survey of all sealable equipment.
- An inventory management program.
- A training program.
- Additional technical assistance.

Equipment reliability is enhanced by a team approach to all aspects of the agreement. Together the user and supplier form an alliance or seal improvement team (SIT) to accomplish a:

- Standardization plan.
- Inventory management plan.
- Bad actor list.
- Bad actor resolution/corrective action plan.
- List of key performance indicators (KPIs).
- Training program.

Program savings are realized through:

- New and upgraded seal discounts.
- Inventory reduction and management.
- Increased mean time between repair (MTBR) due to bad actor resolution.
- Decreased emissions violations due to improved seal technology.
- Energy and/or product savings when external flushes are eliminated through use of improved seal technology.
- Increased product familiarity leading to fewer installation and operational errors.
- Reduced installation and operational errors due to training.

Under this type of agreement, however, many barriers to reliability progress remain. The most common barrier is the approval cycle required to implement a seal system change. The barriers and/or delays may occur at any step in the implementation cycle including purchase order approval, management of change (MOC) paperwork, availability of manpower or time to install the equipment, and general resistance to change. Proposals can languish for months until a purchase order is approved, then the seal might not be installed for many more months due to manpower shortages or equipment availability. It is not uncommon for a bad actor to fail many times before the solution is implemented. Removal of these barriers is within control of the user; the supplier usually plays only a small, initial role in seal reliability improvement.

Equipment reliability will dramatically improve with a successful PS agreement, but any barriers to change will markedly slow the improvement. Often the barriers will come and go as user personnel and profitability shifts. Mechanical seal improvement programs frequently stall or stop completely when the user experiences unfavorable economic conditions.

Figure 4 shows the progressive MTBR of a refinery with a successful PS agreement. The alliance had its greatest influence early in the program when literally hundreds of new seals were installed. After reaching about seven to eight years MTBR, further improvement requires operational and "cultural" paradigm shifts that are far more difficult to effect.

On the other hand, Figure 5 shows the MTBR of a plant with a PS agreement where significant barriers exist as described above. In this particular case, the plant purchased about 35 seals to address bad actor pumps, many of which have not yet been installed. In the meantime, these same bad actor pumps have failed repeatedly.

Another significant barrier to progress is the lack of data or tools to generate reliability indices. Many users do not have work order data trustworthy enough to create bad actor lists or trend plant MTBR. Without these measures, it is extremely difficult to effect change. The seal supplier may have the tools to generate lists, charts, and graphs, but they first need a cooperative user to supply the data.

Fixed-Fee Agreement

A fixed-fee agreement (FF agreement) contains many of the same elements as a PS agreement with one notable exception: the user pays the supplier a fixed yearly fee that covers all seal costs (new and repaired) for a specified equipment population. Before the contract is signed, the user and supplier negotiate a fee based

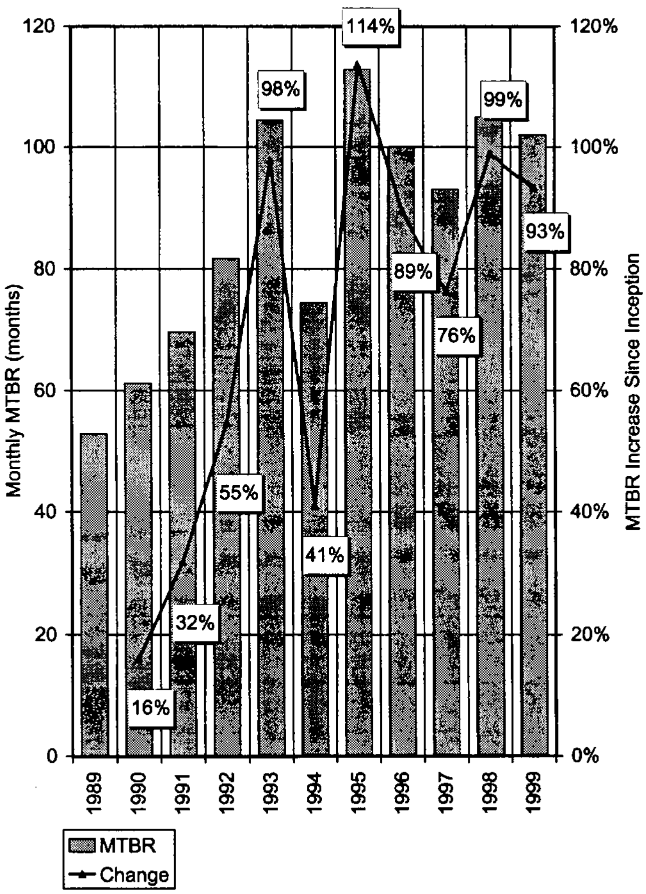

Figure 4. Monthly MTBR for Successful PS Agreement.

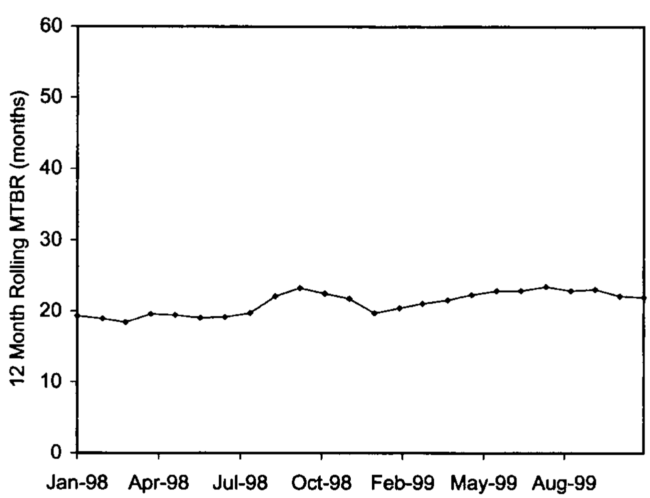

Figure 5. MTBR for Problematic PS Agreement (12 Month Rolling Average).

on many factors including equipment population, historic seal spend, equipment MTBR, and inventory value. Typically this type of contract also includes an inventory buyback by the supplier (including both supplier's and competitor's seal inventory).

The services offered by the supplier and the team approach to reliability improvement within a FF agreement is fundamentally the same as a PS agreement with the addition of:

- More focused onsite application support by the supplier.
- Reliable and timely repair data collected by both the supplier and the user to ensure accurate MTBR calculations.

The commercial terms of a FF agreement typically include a fixed and declining fee over a five-year period and MTBR goals at specified intervals.

In a FF program, the seal supplier is essentially in charge of the plant seals. The supplier makes the decision whether to repair or change a seal based on the equipment performance and the availability of inventory. Upgrades to a completely different seal technology are usually limited to a certain number per year, and the supplier decides which pumps will get upgraded seals. Clearly the biggest "risk" to the user is finding a supplier who can provide the necessary technical expertise to manage a user's mechanical seal program.

When a FF agreement is successfully executed, it is a truly win/win relationship. With a fixed and declining revenue base from a user, the supplier has a tremendous incentive to increase MTBR, thus reducing the repair cycle. This in turn provides a significant economic benefit to the user as costly repairs are avoided. Some FF agreements have incorporated additional risk/reward clauses that benefit the supplier when MTBR milestones are reached. A risk/reward component increases the incentive for the supplier to achieve the user's MTBR goals by rewarding the supplier with shared savings.

Another benefit to the user in a successful FF program is the ability to accurately predict not only total plant seal spend but also LCC for the next five years. An accurate prediction would not be possible with a PS agreement.

As might be expected, MTBR improvements are often greatly accelerated with a FF program because many of the barriers to change are avoided by giving the supplier more control. This results in a dramatically reduced approval cycle time. By example, Figure 6 shows the MTBR trend for a major refinery with a FF agreement.

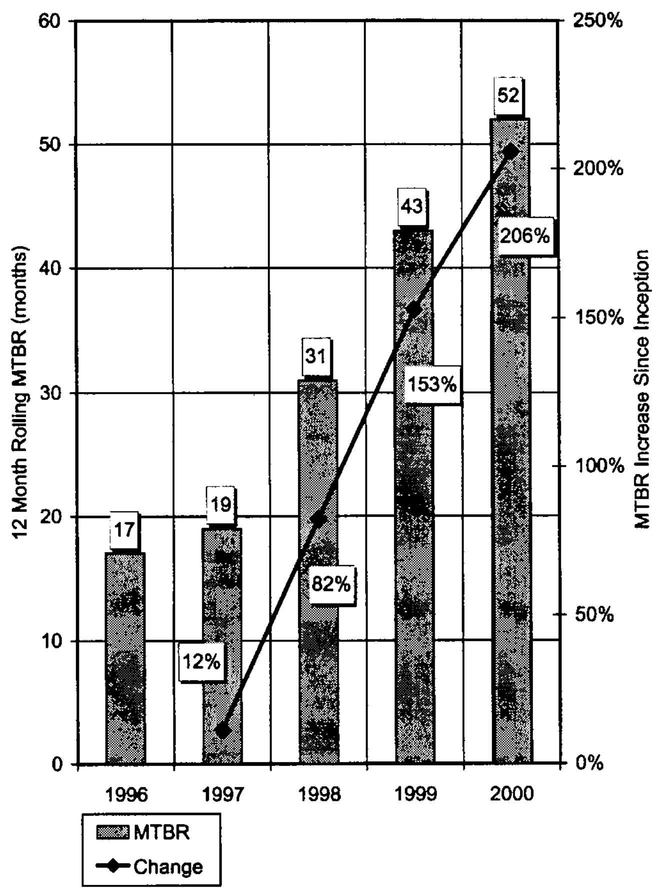

Figure 6. MTBR for Successful FF Agreement (12 Month Rolling Average).

Comparative Summary

Table 1 summarizes the main aspects of successful PS and FF agreements. There is some commonality, but substantive differences exist.

Table 1. Summary of Agreement Aspects.

Agreement Aspects	PS Agreement	FF Agreement
Common goal to improve MTBR	Yes	Yes
Formation of Seal Improvement Team	Yes	Yes
Plant equipment survey	Yes	Yes
Standardization plan	Yes	Yes
Inventory management and reduction	Supplier's seals only	All Seals
Inventory purchased by supplier	No	Yes
Regularly reported Key Performance Indices	Yes	Yes
Comprehensive training program	Yes	Yes
Primary control of seal program	User	Primarily Supplier
Benefits of increased MTBR accrue to:	User	User and Supplier
On-site application engineer	Not usually	Usually
Negotiated reduction in seal expenditures	No	Usually
Accelerated reliability improvements	Sometimes	Usually
Supplier shares in program risk/reward	No	Yes
User realizes program savings:		
• Lower LCC	Yes	Yes
• Inventory reduction	Yes	Yes
• Reduced emissions violations	Yes	Yes
• Energy/Product savings from elimination of external flushes	Yes	Yes
• Fewer human errors due to training	Yes	Yes
• Seal expenditures	Sometimes	Usually

Because of the accelerated MTBR gains FF programs offer, they are becoming the preferred agreement choice when a user is developing a total seal management program. Suppliers are increasingly eager to develop FF agreements because of the shared risks and team control of the program. The development and management of FF agreements will be discussed in detail, however, many of the same concepts can be applied to PS agreements.

CRITICAL SUCCESS FACTORS

While FF seal agreements offer many benefits over purchase and preferred supplier agreements, developing and maintaining them requires the completion of many critical tasks. A maintenance department cannot simply decide they want a FF agreement, contact their favorite seal supplier, then sit back and expect the program to bring the reliability benefits and reduced LCC described above. First the user must accurately describe the status of the current pump maintenance program. They must then evaluate their suppliers and choose one who has the capabilities to meet the plant's specific goals. Finally, an implementation plan must be developed that will define the roles and responsibilities of each party, identify key tasks, and prioritize the work.

Site Evaluation

The purpose of the site evaluation is to determine the goals and objectives of the FF agreement. Since FF agreements are total seal management programs, as opposed to a simple service and supply arrangement, the user must develop a plan that defines desired outcomes in precise terms. Using this plan, the supplier and user will be able to provide maximum reliability increases and lowest LCC. This plan is initially provided to the supplier via the request for proposal (RFP). The RFP must include accurate user data so that the supplier can more exactly define the costs and opportunities associated with the program. Accuracy is critical because the level of risk the supplier assumes is minimized (though not necessarily eliminated) by accurate data. Risk is inherent in a FF agreement and a fair level of risk for both parties motivates the desired results. Too much risk can result in the opposite outcome.

Seal and Pump Characterization

The site evaluation is initiated with an analysis of the pump and seal population characteristics. Typical questions that should be considered during this phase are:

- What is the population of sealable pumps?
- How is API 682 to be applied?
- Are the pumps mostly API or general service?
- How many dual seals are used and how many pumps are double ended?
- What is held in inventory and what is the inventory value?

The data gleaned from these questions is critical to the supplier's model of expected expenditures.

Many times collecting and evaluating these data lead to surprises that can produce "quick hit" benefits beyond the expected program savings. Examples might be:

- Excess inventory stored outside the warehouse.
- Improper application of technology.
- Inconsistent application of technical standards.

Spend and Reliability Data

The annual spend on mechanical seals and seal repair services and the corresponding pump reliability must be known or estimated during the RFP stage. The spend and reliability data should be as accurate as possible to ensure a fair fee negotiation and to help the supplier forecast expected costs. Generally a trend over the prior three years will provide sufficient detail.

It is not uncommon for the user to discover during this process that their data are not very reliable. When this occurs, assumptions can be jointly developed to provide the needed data. The ensuing contract under these circumstances must provide flexibility so adjustments can be made if the assumptions prove erroneous.

Special Requirements

Any special requirements and goals must be fully disclosed. The user may decide, for example, to exclude certain difficult services from the contract when there is little the supplier can do to effect change. These exceptions will generally be rare but may be appropriate. Other special requirements may include exotic material needs, environmental goals, equipment criticality, etc. This information will help the supplier craft a site-specific agreement that meets the expectations of all those involved.

Supplier Selection

The goal of supplier selection is to choose a supplier who is capable of providing the greatest impact on LCC and whose capabilities closely match the user's needs. To meet this objective, potential suppliers are evaluated not only on pricing, but also on stated and proven capabilities in the following areas:

- Inventory management
- Reliability improvement
- Implementation effectiveness
- Program execution

Typically supplier selection begins with a list of OEMs who currently supply seals to the site. The list can quickly be narrowed to possibly two or three by eliminating those who cannot provide support to the entire installed base and who have virtually no presence at the site. This does not mean that suppliers with less than 5 percent of the installed base should automatically be disqualified if other important criteria are met. A cost-of-change factor will be part of the evaluation process when a small market share supplier is considered. There have been many successful agreements where the selected supplier held less than 10 percent of the installed base and, conversely, major suppliers have failed to meet expectations. Only suppliers who do not have the infrastructure in the region or those who are capable of supplying only special applications should be categorically eliminated from consideration.

Once the two or three qualified suppliers are identified, a choice is made by weighing all criteria relative to its impact on LCC. A selection or decision matrix is often used to accomplish this task.

Contract Structure

For FF agreements to capture the highest level of LCC savings, a positive, sustainable relationship between the user and supplier must be developed. The contract language outlines the structure and legal commitments for the relationship, but it is not a vehicle for developing the relationship. The relationship is developed and cultivated by the daily actions of both parties as they demonstrate a commitment to meeting the contract goals and objectives. In other words, the user and supplier must manage to the reliability goals and not to the contract. This being said, the contract is still needed to protect the interests of each party and should be carefully crafted so that commitments are clearly understood.

The primary purpose of the contract is to lay out the legal commitments between both parties and to set a basic program structure. The body of the contract defines the business relationship, the broad intent of the contract, and other traditionally legal requirements such as indemnification clauses, warranties, patent rights, etc. It is outside the scope of this paper to discuss these particular aspects in detail.

The remainder of the contract lays out the framework and expectations of the program. Experience has shown that problems develop when expectations are not clearly defined. To minimize this potential, the contract should address the following:

- Program cost
- Concept definitions
- Program equipment
- Reliability goals, performance indicators, and reporting
- Seal improvement team
- Technical assistance provided by the supplier
- Consequences of unimplemented recommendations

Program Cost

Obviously the contract should identify the financial commitments of the program. The financial commitments include the annual fee associated with a defined population, provisions for changes to the equipment population, and the inclusion of bonuses or penalties for exceeding or not meeting program goals. This section should also address expenditures outside the contract fee including discounts for new nonprogram seals, the cost for technology upgrades, parts and repair services for nonprogram equipment, and the cost of accessories not covered in the annual fee.

Concept Definitions

A contract section devoted to definitions of significant concepts is crucial. Misunderstandings of specific contractual terms have lead to expensive disputes. Some definitions to consider are:

- *MTBF*—Show the exact formula used to calculate reliability, identify what constitutes a failure or event, and indicate if seal or equipment reliability is to be measured.
- *Technology upgrades*—Define what constitutes a change in technology (for example, a change from a wet seal to a dry gas seal or from packing to a seal), how many, if any, are covered in the annual fee, and whether modification to a cartridge qualifies.
- *Similar technology conversions*—Identify what specific types of seal changes are covered by the annual fee.
- *Exclusions*—Specifically identify those pieces of equipment or special processes that will be excluded from the annual fee.

Program Equipment

The pricing of a FF agreement is dependent upon the number and type of equipment included in the contract. The contract should identify clearly which equipment is included in the program and which will be excluded. For example, which portions of the seal flush plan are to be covered as program equipment? An equipment list and/or a list of exclusions may accomplish this.

Reliability Goals, Performance Indicators, and Reporting

FF agreements are reliability-focused programs and are keyed on specific reliability goals. These must be plainly stated in the contract. Sometimes, after the reliability data has been collected for a few months, it becomes apparent that the actual numbers vary from those stated in the contract. If bonuses or penalties are paid based on reliability, then the reliability goals listed in the contract must be modified. On the other hand, the user and supplier may decide to amend the contract even when bonus or penalty clauses do not exist. If it is acknowledged that the plant reliability data are not accurate and a change of reliability goals is likely, then the contract should state that modification might be required.

The contract should stipulate how and when the program performance is reported. Quarterly reporting is common and may include MTBF, pump cost, and inventory reduction goals. Other site-specific performance indicators are often also built into the contract.

Seal Improvement Team

The crucial role of the seal improvement team (SIT) necessitates inclusion of its existence and charter in the contract. The mission of the SIT is to manage the daily requirements of the program and foster the user/supplier relationship. Specific responsibilities and accountabilities of the SIT should be documented and should include detailed tasks under these broad headings:

- Program infrastructure (for example, plant survey, standardization, etc.)
- Performance management and reporting
- Long-term planning, goal setting, and objective development
- Conflict resolution
- Agreement modifications
- Incentive or penalty assessment

It is important that the SIT members be identified in the contract by job title, not by name. It is also important that the SIT comprises the right mix of management and staff (generally speaking, one to two managers and three to four staff members). If the SIT has the incorrect level of management then the team will either be too far removed from the work process to effectively manage the program, or they will not have the appropriate authority to make decisions. One example of SIT membership is:

- User Rotating Equipment Engineer
- User Mechanical Foreman
- User Materials Coordinator
- User Craft Supervisor
- Supplier Sales Engineer
- Supplier Applications Engineer

Technical Assistance Provided by the Supplier

The contract should outline specific technical resources provided by the supplier. This is often in the form of a full-time, onsite Application Engineer (AE), but can also include offsite or part-time support. The size of the covered population and the initial reliability will dictate what type of support is provided. The expected duties should also be clearly delineated. Sample duties are:

- Maintain all databases including inventory, rotating equipment population, and selected performance indicators.
- Monitor inventory consolidation and reduction.
- Coordinate delivery of seals.
- Participate in the SIT.
- Assist in documentation of records.
- Assist with troubleshooting and corrective action development.
- Assist with training.

Consequences of Unimplemented Recommendations

Unresolved corrective action within the context of a FF agreement is a potential and often overlooked source of conflict. Root cause analysis will, at times, identify seal or pump modifications that require capital investment or downtime. Financial or scheduling constraints may necessitate deferment of these modifications; however, this deferment may compromise MTBR and the supplier's financial stake. Identification of this situation in the contract along with a method for a fair resolution helps avoid perception problems in the future. One method to address this situation empowers the SIT with the authority to reclassify program equipment as nonprogram if corrective actions are documented but not implemented, thus requiring the user to pay for repairs of that equipment outside the annual fee. The supplier would offer parts and repair services for this nonprogram equipment at the discounted rates stated in the contract.

Implementation Plan

A crucial step in a successful alliance is the transition from contract negotiation to contract implementation and maintenance. Often the people who negotiate the contract are not the same individuals who will be implementing it on a daily basis. For this reason, a kick-off or rollout meeting is necessary. This meeting must include the negotiating team and the individuals who will manage the alliance.

This meeting has four objectives:

- Clarify and discuss all elements and goals of the contract.
- Address any concerns about and/or objections to these elements.
- Identify the SIT.
- Reiterate unqualified Plant Manager support for the alliance and outline a mechanism for dispute reconciliation.

After this transition, lines of communication and responsibilities must be well understood and honored on a daily basis. Any breakdown must be addressed quickly to avoid systemic problems. Upper management must actively support the alliance and not hesitate to become involved when necessary. A user leader or mentor must be appointed to provide focus for the program objective and to champion changes.

When roles and responsibilities are not clearly defined, and accountability is not enforced, the alliance can lose its focus and fail to meet its objectives. A breakdown of responsibilities and communication and the absence of strong leadership are exemplified in one notable instance. During the first year of a FF agreement at a 1000 pump refinery, the MTBR declined from 38 months to 33 months. At $5000 per repair, this translated to over $200,000 lost during that year. In this particular case the transition was vague, roles and responsibilities were poorly defined, a specific reliability improvement program was not identified, and there was no accountability. By contrast, another fixed-fee site (same user) improved MTBR from less than 24 months to 60 months in four years, with a subsequent pump spend reduction of over $2 million per year. This site has a highly cooperative team with common goals.

Relationships and Conflict Resolution

The bedrock of any agreement is not the contract itself, but rather the people who work with it every day. Successful alliances have a seamless interface between supplier and user personnel. Teamwork is not a cliché; it is effortlessly practiced. Personal bonds are developed among all the parties, resulting in trust. There is strong leadership and vision. Disputes rarely occur, but if they do, arbitration roles and procedures are clearly defined, and the outcome has unqualified support from all parties. Figure 7 shows the principals of conflict resolution and agreement management.

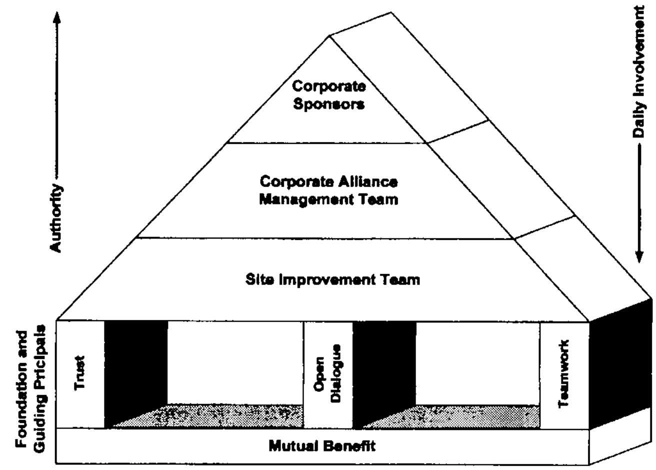

Figure 7. Conflict Resolution Pyramid.

When communication breaks down and a conflict ensues, critical time and effort are often expended at the expense of efforts toward reliability improvement. At one FF site, a dispute arose when the supplier assumed that the user would purchase upgraded seals outside the contract fee. Under this assumption, the supplier manufactured all the seals and presented the bill to the user. However, the user did not have the same understanding and a full-blown standoff ensued. It took several months of negotiations between the user and supplier to resolve the problem, culminating in a team from each company traveling to the site where they evaluated the situation and arbitrated the solution. Estimated dispute resolution expenses for both the user and supplier was in the tens of thousands of dollars.

Managing the Alliance

As stated above, successful alliances are managed to goals, not to the words of the contract. Additionally, the SIT manages all aspects of the alliance from standardization to reliability improvement with a team approach. The SIT will develop, supervise, and manage the following throughout the term of the agreement:

- Survey of plant equipment included in the contract.
- Standardization plan.
- Key performance indicators.
- Reliability improvement.
- Inventory reduction and management.
- Training.

Survey of Plant Equipment Included in the Contract

In a FF agreement, the plant survey is perhaps the most critical first step. The supplier usually conducts the survey and the information is input into a computer database for access by the SIT. The survey should include, at a minimum, the following data:

- Equipment model, type, serial number.
- Seal model, type, size, materials, flush plan.
- Process description, temperature, pressures.
- Fluid properties (specific gravity, viscosity, vapor pressure).

While there are usually no direct economic benefits gained by completing the survey, it provides the data necessary to finalize standardization, reliability improvement, and inventory reduction. In addition, a well-maintained equipment database often provides the most accurate and comprehensive picture of plant equipment ever available to the user.

Standardization Plan

Standardization of the mechanical seals at a user site accomplishes three objectives:

- Identification of the most appropriate sealing technology for a given product or service classification
- Inventory reduction
- Greater familiarization of specific seal types

A good standardization plan will reduce the number of seal types used in most plants to four or five. An aggressive standardization program can further reduce the number of sizes of each seal type.

Substantial economic benefits can be realized when a comprehensive standardization plan is fully implemented. First, the installation of an appropriate sealing system in a given application will improve reliability and thus reduce overall maintenance expense. Second, inventory reduction will be an automatic by-product through elimination of different seal types used in the same or similar services. Last, as the number of different seal types is reduced, there is greater familiarization by both the mechanics and operators leading to fewer installation and operating errors.

It is difficult to quantify or predict savings resulting from installation of the appropriate seal system or from product familiarization, but the savings from inventory reduction are readily apparent. It is not uncommon to reduce the value and quantity of plant inventory by more than half over the course of a five-year contract. A large plant may carry close to $1,000,000 worth of mechanical seal inventory. Assuming an 18 percent cost of holding, which includes warehouse overhead, taxes, and the cost of capital invested in the inventory, the savings amount to $90,000 per year after the inventory is purchased and removed from the user's site.

Key Performance Indicators

Key performance indicators (KPIs) measure progress to alliance goals and justify the continuation, renegotiation, or cancellation of a contract. Because of their relative importance, KPIs must be chosen early in the alliance program and data must be collected from day one. At a minimum, MTBR data should be calculated regularly to track reliability improvement and achievement of mutual economic goals. MTBR should measure equipment reliability, not simply seal life. Equipment MTBR broadens the focus of the SIT to pump system improvements and captures the additional reliability benefits from seal failure analysis.

KPIs must be reported at least quarterly to ensure accountability. Lack of progress to goals must be reviewed in detail by the SIT to determine the root cause and the corrective/preventive action(s). Sometimes poor progress is outside the control of the SIT, for example, a major fire or natural disaster. When this occurs, it is critical to document the facts and publish this along with the KPIs.

Infrequent reporting of KPIs can allow an alliance to meander or stall thereby not realizing the potential economic gains for both the user and supplier. This specific situation is dramatically illustrated by the example given above where the MTBR of a refinery declined from 38 to 33 months over the course of a year. Among other problems, KPIs were not routinely reported over this time period allowing the problem to worsen over the 12 months.

Reliability Improvement

The most significant economic benefit of a successful FF agreement is the resultant increase in equipment reliability. While it is true that reliability can be improved without a user/supplier agreement, evidence shows that reliability improvement is greatly accelerated when all the critical elements of a FF agreement are accomplished.

Why does this occur? First, the supplier not only becomes part of the user's reliability team, but also brings seal system expertise to the problem resolution process. Second, a well-chosen seal supplier will have a breadth of knowledge beyond seals to the entire pump system. The supplier has specific incentives to be an integral part of the team because improved reliability improves both the supplier and user's bottom line. Also, as earlier explained, a FF agreement often eliminates or streamlines barriers to change, thus permitting more rapid response and a proactive approach. Finally, added resources in the form of onsite technical assistance and organizational tools such as the equipment database provide the means to hasten the reliability improvement program.

It is very important to mention here that these services are provided by the supplier as part of the annual fixed-fee and that the fixed-fee is typically negotiated at or less than the user's current annual seal expenditure. These additional services provide incentive for the user to initiate a contract and incentive for the supplier to reduce costs through improved equipment reliability.

Inventory Reduction and Management

A FF agreement will usually include an inventory buyback by the supplier. The inventory will be managed in one of two ways:

- A vendor stocking program where seal inventory is stored at the supplier's facility, or
- A consigned stock program where the seal inventory is stored at the user's site.

Either way, the user avoids the cost of inventory ownership and management. Yearly savings are typically 15 to 25 percent of the initial inventory value annually, so the savings are cumulative. This is validated by the LCC model, which shows that inventory costs are a significant part of overall equipment expenditures.

The inventory buyback and management by the supplier increase the supplier's incentive to implement the standardization plan and reduce inventory. At the same time, it encourages the supplier to use existing inventory before making a change unless the change results in improved reliability.

Training

An ongoing component of all successful FF agreements is a comprehensive training program. The supplier will provide free onsite training and discounted classroom training. Typical audiences include maintenance and operations personnel covering topics such as seal fundamentals, seal flush plans, and seal diagnostics.

The main purpose of training is to improve user personnel's understanding of mechanical seals and their operation, thus improving the quality of installation, maintenance, and operation of the seal system. A successful reliability improvement program includes knowledgeable people at all stages of the life of a seal.

Most users understand the inherent benefit of training and provide the time and resources needed to facilitate this training.

Training directly affects equipment reliability by reducing infant mortality. This is a very important concept in any reliability improvement program. While MTBR is a good measure of the inherent reliability of plant equipment, taken alone it is rarely enough to identify specific problems that inhibit future progress. Infant mortality is a precise and addressable issue that directly affects plant reliability. It is measured by counting the number of failures occurring within one to three months of the previous failure for the same piece of equipment. For the most part, this measures human error at any point in the cycle.

Training, adherence to well-documented procedures, and reliance on trusted suppliers can directly influence the incidence of infant mortality. As infant mortality declines, MTBR will increase dramatically. Premature failures are most often the result of improper assembly, repair, or operation of equipment. The root cause of infant mortality can often be traced to insufficient knowledge of repair procedures, OEM requirements, and the damaging effect of incorrect operation on equipment. An appropriately focused training program will minimize most of these causes.

Figure 8 is a graphical representation of infant mortality. These data are from a FF agreement that has been in progress for two years. During this time, training and adherence to maintenance procedures have been a strong focus. At the end of the second year, repeat failures declined over 75 percent from the pre-contract year, and at an estimated \$5000 per repair, this translates to annual savings of over \$200,000.

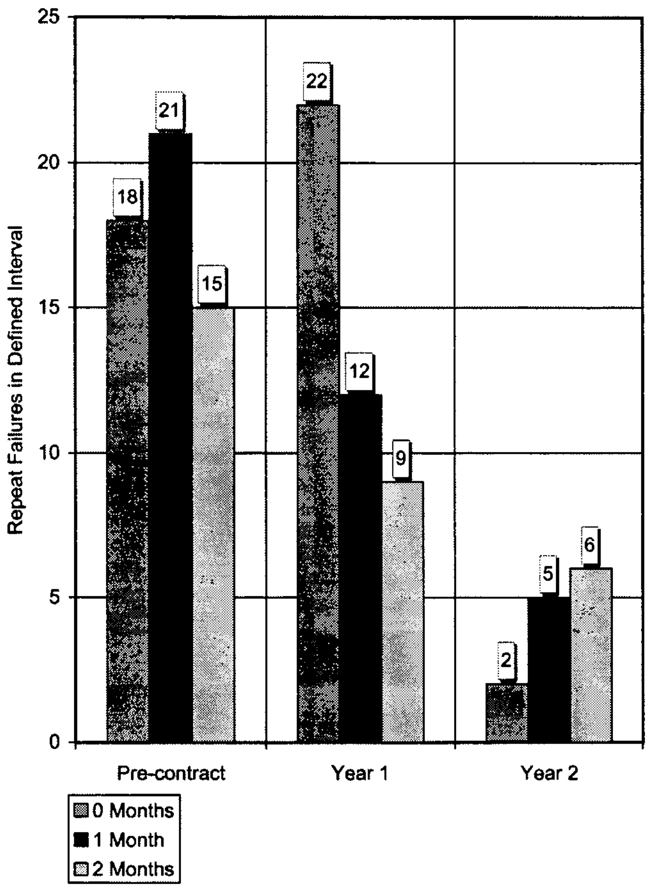

Figure 8. Infant Mortality.

CASE STUDIES

Two case studies are presented to illustrate how key elements of the contractual process detailed above determine the ultimate success or failure of a fixed-fee agreement. Table 2 provides a brief summary of each study. These plants were chosen because of their similarities. Specifically they are both refineries of similar size who have signed a fixed-fee agreement with the same supplier. However, the results of the cases vary in both reliability improvement and life-cycle savings.

Table 2. Case Study Description.

Description	Case Study #1	Case Study #2
Plant type:	Refinery	Refinery
Sealed equipment population:	437	384
Date Fixed Fee signed:	October 1999	January 1998
MTBR at signing:	30 months	24 months
MTBR at six months:	19 months	47 months
Seal expenditure savings (increase):	\$103,000	(\$72,000)[1]
Inventory savings (increase):	\$46,000	\$84,000
Reliability savings (increase):	(\$27,000)[2]	\$420,000
Annualized yearly savings (increase):	\$122,000+	\$210,000+

(1) Yearly Fixed Fee was negotiated at a higher rate than previously reported seal expenditures. The User acknowledged that historical expenditure data did not an accurately represent actual expenditures.

(2) A successful FF will incur real reliability savings as MTBR improves. In this case, however, reliability declined resulting in approximately \$27,000 additional maintenance expenditures (i.e. negative savings).

Case Study #1

As can be readily seen by the MTBR graph in Figure 9, expected post-contract reliability gains are not occurring at this plant. Several of the critical elements described previously are not in place, resulting in a disappointing start to this program. In addition, recordkeeping issues have exacerbated the trend.

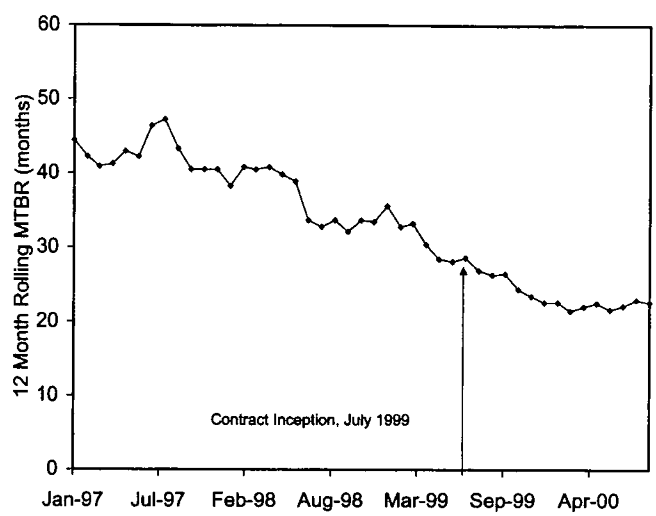

Figure 9. MTBR (12 Month Rolling Average)—Case Study #1.

Problematic Issues

There are three fundamental challenges at this plant that are inhibiting or hiding the benefits of the agreement.

- There is no user leadership at the maintenance level.
- Upper management at the user end does not place enough priority on the progress of the program.
- Recordkeeping in the form of work orders has improved, resulting in additional, and more accurate, data.

User Leadership

Without a leader at the user end who provides a "big picture" overview of the agreement, managing the alliance is exceedingly difficult. A leader will ensure that all user personnel understand the program and will eliminate or reduce barriers to progress. A committed leader will instill credibility into the program. Without a user leader, the supplier must pick up this role; however, the supplier's effectiveness in this role is limited since the supplier has no authority.

At this particular plant there is no direct supervision of the mechanics. There is one Rotating Equipment Engineer who is responsible not only for the maintenance department but engineering projects as well. This dual role has diluted his attention to the alliance program, as he tends to focus his efforts on larger projects and thus "minds the dollars not the pennies." Standard repair procedures are in place, but they are infrequently followed, resulting in substandard repair quality and subsequent repeat failures. A supervisor with inherent leadership, credibility, and authority, and with a more singular responsibility, could provide the needed direction and training to make certain proper procedures are followed or developed.

Corrective Action—Because the supplier has been given responsibility to track the alliance progress, it is incumbent upon the supplier to bring this matter to the user's attention. The supplier responsible for the alliance at this particular site has many successful alliances with other users. These can be studied and recommendations can be made based on the organizational structure of the successful sites. In turn, it is then the responsibility of the user to follow through with these recommendations.

User Commitment

Upper management support is absolutely critical to the success of a FF agreement. This support is evidenced in the priority given to implementing specific upgrades and changes needed to improve reliability. Without this support and priority, skepticism and lack of funds hamper the progress of the program.

This plant, while embracing the concept of the alliance, has not put the priority on actions that are needed to effect rapid improvements. Upgrades to Seventh Edition back pullout retrofits are deferred while other projects unrelated to the alliance program are funded. The supplier has provided the proper seal and has recommended the needed system changes to improve MTBR, but flimsy shafts and poor bearing fits will seriously limit the positive effect of the seal change.

Corrective Action—All actions (or inactions) taken that detrimentally affect alliance progress must be documented and published. To any extent possible, the exact impact of these actions on the progress should be quantified, for example, evidence of avoidable failures or changes in procedures. In this particular case, management has been made aware of the problem, but has not shifted its priorities.

Recordkeeping

It is not uncommon for a plant to tighten up their recordkeeping practices when a FF agreement is implemented. Up until that point, there may or may not be vested interest in ensuring that the MTBR was accurately trended. In a FF agreement, both the user and supplier have a financial stake in the form of a risk/reward bonus when specified MTBR goals are met. This provides great incentive for both parties to scrutinize the methodology and emphasize the need to maintain accurate records.

At this plant, the effect of recordkeeping changes is reflected by the following statistics taken from the failure data:

- *Average number of work orders*—In the year prior to the contract the average number of work orders per month was 13, after the contract was signed the average increased to 20 per month.
- *Infant mortality*—Premature failures (within three months of the previous failure) appeared to increase by nearly 100 percent after the contract was signed, as shown in Figure 10. This statistic may be misleading because some plants (possibly this one) leave a work order open for several months and simply add subsequent failures to the original work order. This dramatic 100 percent increase is likely a combination of poor maintenance and poor recordkeeping practices.

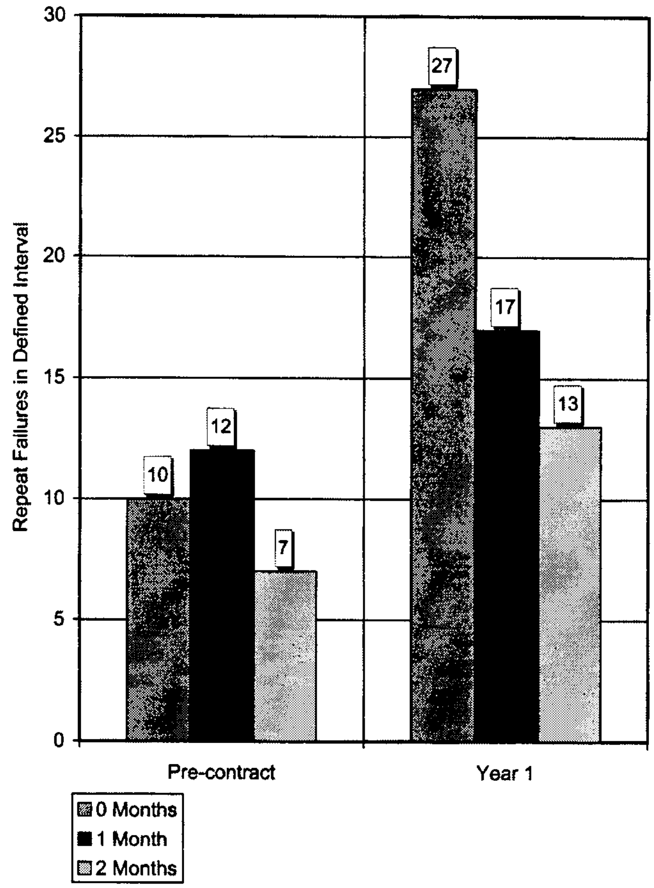

Figure 10. Infant Mortality—Case Study #1.

Corrective Action—The SIT should document and publish the change in recordkeeping methodology and continue current recordkeeping practices consistently. By the end of the first year, the lingering effect of this change should be negligible.

Cost Savings

Following are the reported cost savings from inception of this contract to September 30, 2000.

- Seal expenditure savings: $103,000
- Inventory savings: $37,000
- Reliability savings: ($27,000)
- Average yearly savings: $110,000+

(Note: A successful FF will incur real reliability savings as MTBR improves. In this case, however, reliability declined, resulting in approximately $27,000 additional maintenance expenditures (i.e., negative savings).)

Conclusion

Problems inherent in this plant are relatively few, but they have a wide and systemic influence on the desired outcome of the alliance—improved MTBR. Until management makes a stronger commitment to this program in the form of personnel, funding, and priorities, improvement will be negatively impacted.

Case Study #2

The MTBR graph shown in Figure 11 is typical of a successful alliance program. Note that the downward trend of MTBR was arrested after the fixed-fee program was implemented. It is not uncommon for some time to pass before the full effects of the program are seen in a 12 month rolling average trend. In this case, approximately one year after the program was implemented, there was a rapid increase in MTBR.

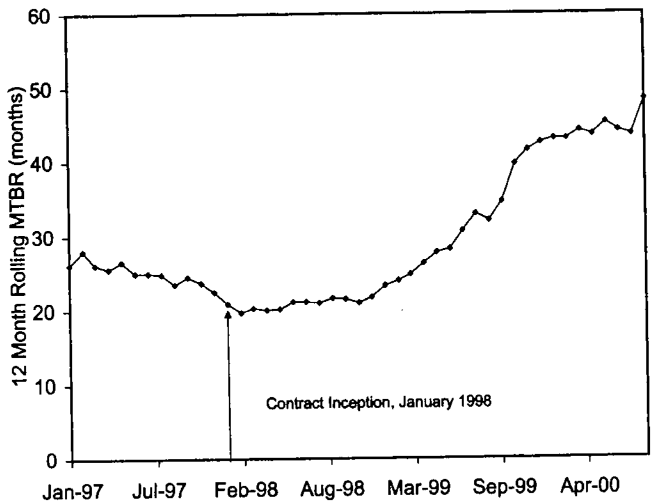

Figure 11. MTBR (12 Month Rolling Average)—Case Study #2.

By contrast with Case Study #1, this plant has strong user leadership in place, a strong commitment by upper management, and more consistent recordkeeping practices. While Case Study #2 has been in effect longer, it is important to note that reliability trends in this case study improved immediately and simultaneously with the inception of the contract, as can be seen below. Figure 12 shows monthly MTBR trended for the year prior to the contract (on the decline), and Figure 13 shows trending during the first year of the contract (increasing).

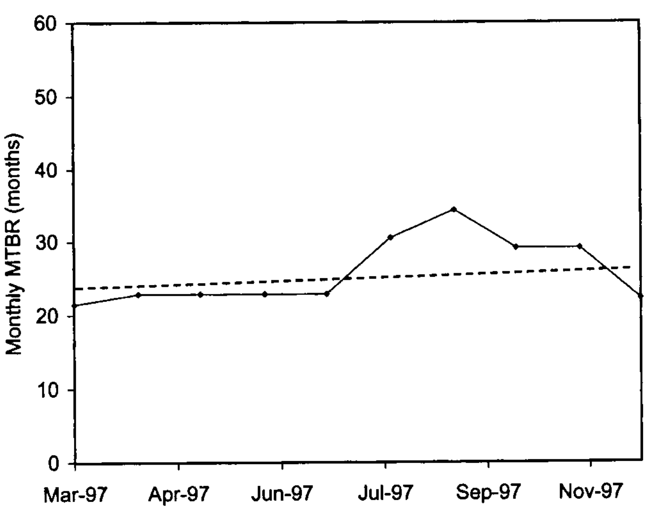

Figure 12. Monthly MTBR Trend Pre-Contract—Case Study #2.

By contrast, the monthly MTBR trend for Case Study #1 (Figure 14) shows a decline after the contract was signed.

User Leadership and Commitment

User commitment to a FF agreement will directly impact the bottom line for both the user and supplier. This is exemplified by aspecific case in point. The SIT identified a boiler feedwater

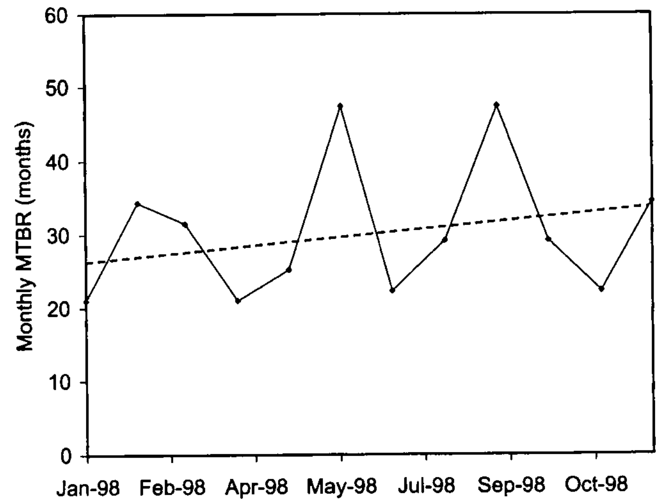

Figure 13. Monthly MTBR Trend Post-Contract—Case Study #2.

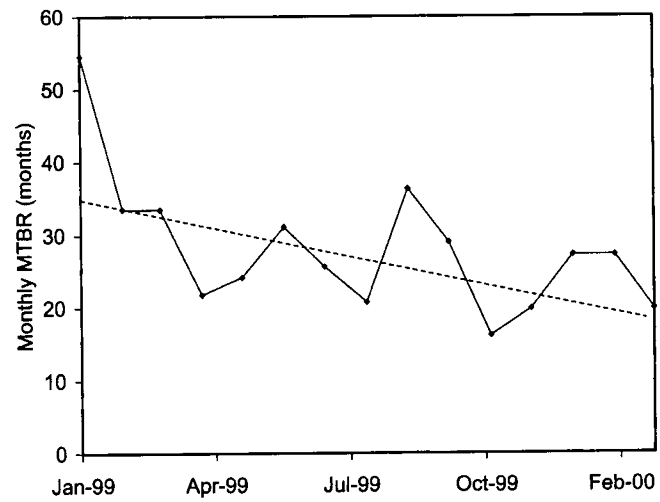

Figure 14. Monthly MTBR Trend—Case Study #1.

pump as a bad actor and performed a root cause analysis on the system. A corrective action plan was developed and presented to Operations. The Operations Department deflected repeated requests to implement the plan with the excuse that there was not enough time to do the work. The SIT then decided to remove this pump from the fixed-fee and charge the user directly for future repairs. This plan of action was taken to upper management and Operations. Realizing that their inaction would result in direct financial accountability, management approved the plan, and since that time no additional failures have occurred, resulting in over $20,000 savings during the past three years.

Recordkeeping

Maintenance records and procedures remained consistent prior to and after the contract was implemented.

- *Average number of work orders*—In the first year after the contract was signed, the average monthly work orders were the same as the prior year, whereas the second year saw a 38 percent decline.

- *Infant mortality*—In this case study, by contrast with Case Study #1, infant mortality declined markedly as shown in Figure 15. Training of both mechanics and operators at this site has been a very high priority for the SIT and there has been a heightened awareness of "doing it right the first time."

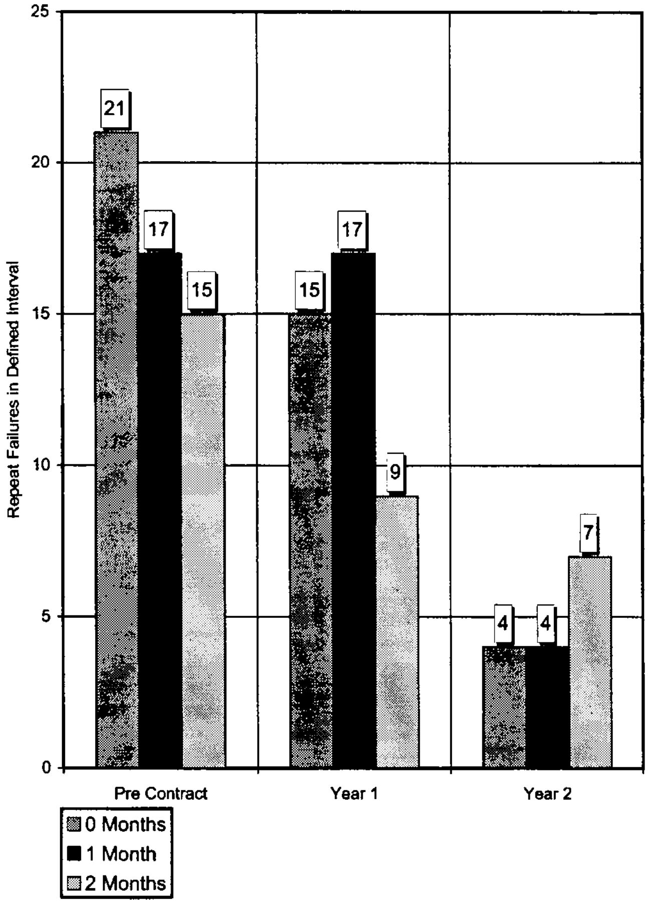

Figure 15. Infant Mortality—Case Study #2.

Cost Savings

Following are the reported cost savings from inception of contract to September 30, 2000.

- Seal expenditure savings: ($72,000)
- Inventory savings: $84,000
- Reliability savings: $420,000
- Average yearly savings: $210,000+

(Note: Yearly fixed-fee was negotiated at a higher rate than previously reported seal expenditures. The user acknowledged that historical expenditure data did not accurately represent actual expenditures.)

Conclusion

When a fixed-fee alliance is well conceived and well managed, tremendous financial benefit can ensue. Clearly, any way this alliance is measured, the benefits are evidenced. When this occurs it creates momentum to help ensure continued success and cooperation from all parties.

CONCLUSION

Fixed-fee agreements have been shown to effectively improve pump reliability and reduce life-cycle cost. However, unless the proper structure is placed around the agreement, the agreement may not bring the expected results. Careful consideration must be given to evaluating the needs of the site, developing a plan to implement the program, and continuous monitoring and management of the agreement. Without addressing these key issues, the agreement may fail to meet the expectations of the user and/or supplier.

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