Completing the Last Step in O&M Cost Reduction

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This summary paper describes the approach and implementation methodology to take the battle for reducing process operations and maintenance (O&M) costs to the absolute minimum level. Formatted in three sections, it covers:

- O&M Evolution - From Reactive to Proactive
- Making the Case - Project Proof of Principal
- The Economic Incentive - A Measured Savings

The net result of understanding and carefully implementing this new approach to operating and maintaining your plant can dramatically impact your facility's bottom line.

Evolution of The Proactive Approach

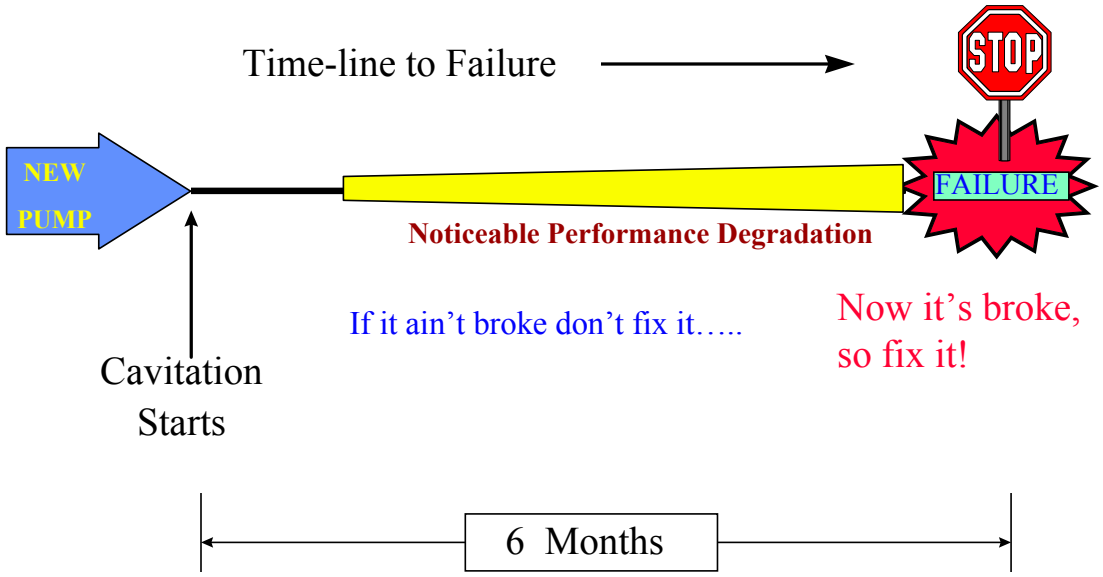
Degradation happens. Maintenance managers often subscribe to a rigid preventive maintenance (PM) philosophy because it has been made obvious to them that by not following these precepts, they open themselves and their companies up to being blindsided by some very unpleasant surprises. Like the result of not replacing the O-ring seals every 5 years as recommended shows up as 30 gallons of lubricating oil on the plant floor that almost made it to the storm sewer. Then there was the critical process pump that had to be replaced every 6 months, resulting in significant (and predictable) production losses. So experience makes them firm believers in following even the unpopular tear-down-and-measure-the-tolerances routines of the PM paradigm.

Using that critical process pump example, we can illustrate the four basic approaches to the O&M process and show how these approaches can influence the efficiency, reliability, and safety of the plant. The process pump was nothing special - a single stage centrifugal unit driven by a 50-horsepower variable speed motor. It pumped 1100 gpm of water with a discharge head of 150 psig. A very common piece of plant equipment. Without going into the intricacies of life-cycle degradation mechanisms and root cause analysis, here's a brief sketch of the O&M options.

Reactive or Corrective Maintenance (CM) is the old "if it ain't broke don't fix it" line. This approach is the perennial run to failure mode. It is simplicity itself, requires no forethought, and (at least up to the point of machinery failure) requires the least support from the O&M crew and infrastructure. In this particular case, the pump started cavitating from the day it was installed This degradation mechanism was responsible for extreme erosion of both the impeller and the pump casing.

This situation created a reactive scenario that looks something like -

The Reactive Time Line



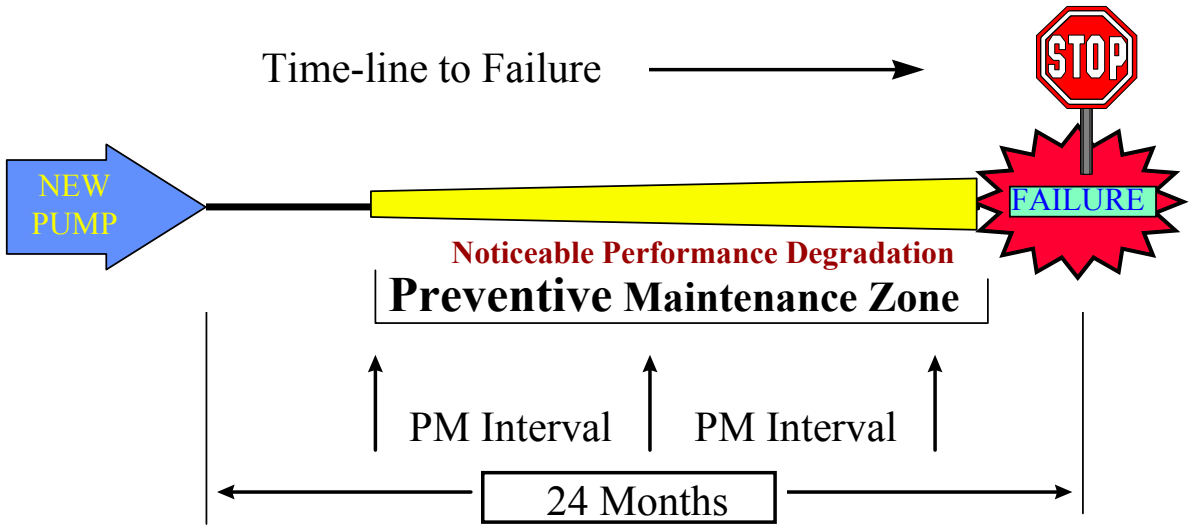
In a reactive mode, little, if any, attention is paid to ensuring that the operating conditions are within the design envelope and, consequently, the actual service performance and life-span of the equipment are substantially below the estimates of the manufacturer. The equipment is simply run until it either catastrophically fails, or it no longer can provide its intended function. At that time (usually around 2 a.m.) the equipment must be replaced.

While reactive maintenance does make economic sense in some instances (replacing a light bulb for instance), in a vast majority of process applications it is by far the most expensive O&M mode going. It is still, surprisingly, the predominant method of plant operation in the U.S. despite the high product loss, capital equipment loss, total manpower expenditure, and accident rate that result.

Preventive Maintenance is the art of periodically checking the performance or material condition of a piece of equipment to determine if the operating conditions and resulting degradation rate are within the expected limits. If they are not, a search for the reason for the more rapid degradation must be sought so the problem can be corrected, or at least mitigated, before the machine fails.

The method is illustrated below -

The Preventive Approach



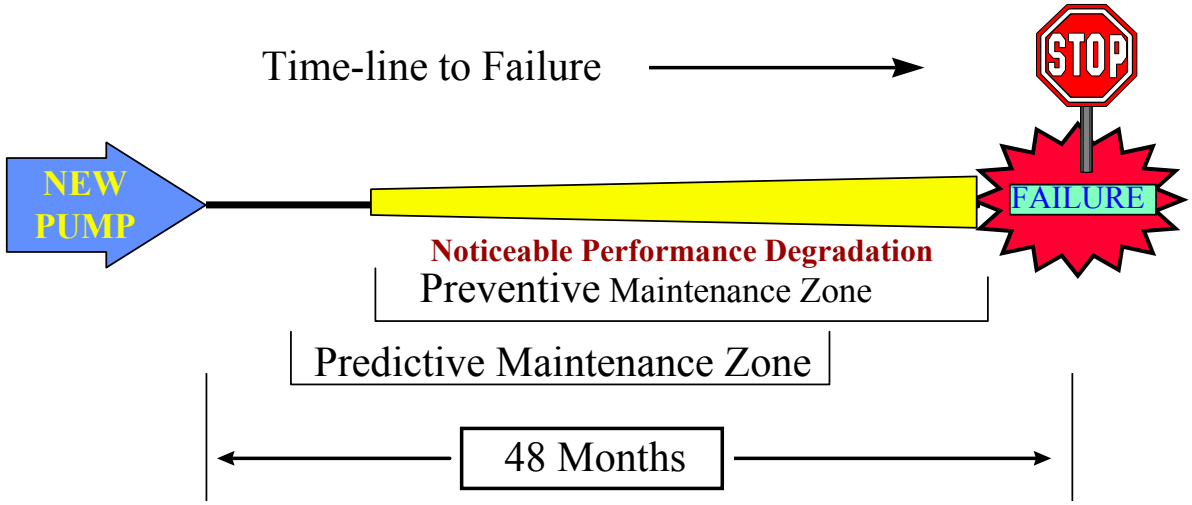
The tests, inspections, servicing or parts replacement actions are done on a service life (e.g. hours of operation) or purely on a time-in-service basis. Note that for our hypothetical case, the service life was extended by a factor of four due to an awareness of the rapid decline in pump condition caused by cavitation and an attempt to slow down this degradation mechanism. Unfortunately we still do not have a grip on the root cause. Although accurate failure statistics allow the test interval to be optimized, catastrophic failures are still likely to occur. The PM method is also very labor intensive, much unneeded maintenance is performed, and incidental damage to equipment is widely reported as a result of poor maintenance practices. A PM system can, however, be a cost effective strategy when the life span of the equipment is well understood and consistent. Studies in the utility industry report a reactive to preventive life cycle cost savings in the 12 to 18% range. Thus this methodology, while it significantly reduces the O&M cost over the purely reactive variety, still allows abrupt failures to spoil an otherwise good night's sleep.

Predictive Maintenance (PDM) advocates measurements aimed at the detection of degradation mechanisms themselves, thereby allowing the degradation to be understood and eliminated or controlled, prior to significant physical deterioration of the equipment.

These usually nonintrusive measurement methods allows us to detect and correct the potential for degradation considerably earlier in the equipment degradation scenario. Technologies such as vibration analysis, oil analysis, thermography and condition monitoring pushes our problem recognition capability to the leading edge of the degradation envelope.

So now our time line now looks like -

The Predictive Edge



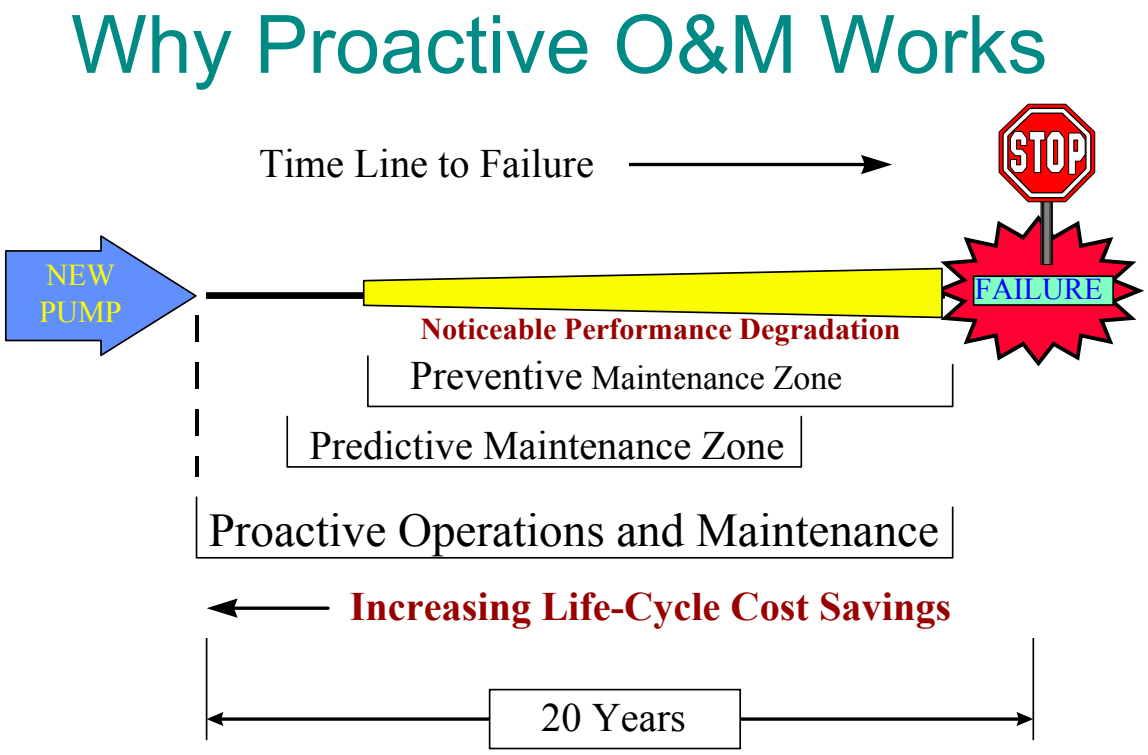
The application of this technology results in :

- marked increased equipment life
- earlier corrective actions taken
- decreased process downtime
- decreases in maintenance parts and labor
- better product quality
- decreased environmental impact
- energy savings.

The sum of these advantages adds another 8 to 12% to the savings over a good PM program. Root cause can usually be understood and, consequently, mitigation can be better targeted and repeating failures are history. On the negative side, the up-front investment in diagnostic equipment and the high level of staff training make this a more difficult pitch to an ever wary, cost conscious management. The savings are now usually in terms of avoided cost (a hard concept for management to grasp) and therefor become much more difficult to demonstrate and easier to forget.

Proactive Operations and Maintenance (POM) is the detection and diagnosis of off-normal equipment operation and the identification of the root cause stressor(s) responsible for the condition. This final step is the Laboratory's unique contribution to optimizing the O&M process.

Two things should be noted from this definition:
1) Operations has now been engaged and integrated into the maintenance equation, and
2) finding the root cause stressors (parameters outside the design envelope) responsible for the off-design condition is now the prime directive.



The use of computers and low cost sensors allow us to automate stressor recognition (what went out of spec), to run degradation mechanistic diagnostics (what's going wrong), and to perform a root cause solution (what needs to be done to correct the situation). The result is that a complete picture of the problem and its solution is presented to both the operations and maintenance staff. Asset management can now proceed using informed decisions based on known degradation rates and, in most cases, accurate estimates of equipment remaining life. Predicting and planning now become the bywords of the maintenance outages rather than brush fire and panic.

The savings provided by the proactive paradigm are estimated to be 5 to 10 % above the predictive approach, including all the initial investment costs. In going from a reactive to a proactive mode we now find a total production life-cycle cost savings on the order of from 25 to 40%. Part of our work at the Laboratory is to demonstrate that these savings are real, rather than simply a wishful projection.

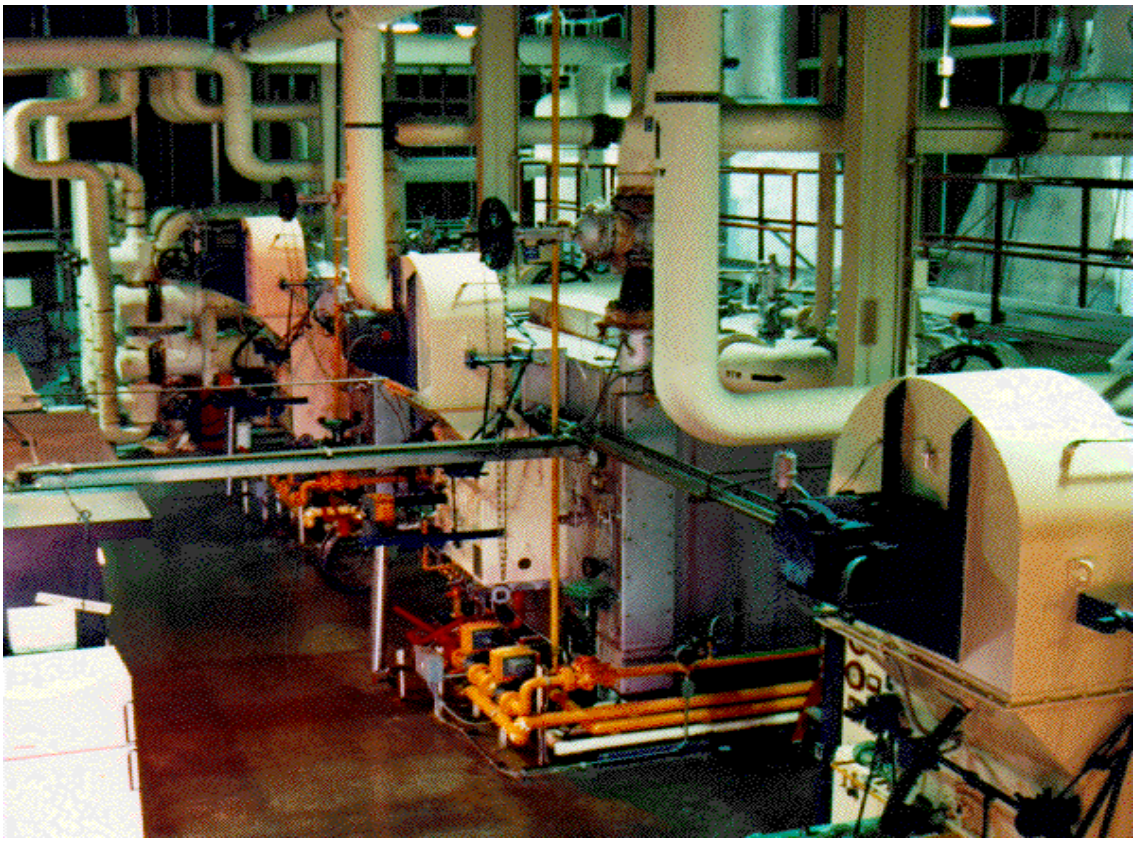
DSOM - The Proof of Principal Project

The United States Marine Corps (USMC) provided the Pacific Northwest National Laboratory (PNNL) with a perfect opportunity to demonstrate the effectiveness of this emerging proactive technology. The Marine Corps provides the thermal energy (heating and cooling) for its bases using central energy plants. Due mainly to reductions in the military forces, these plants, like all the DOD base installations, are being run with minimum O&M staffing and minimal data for cost effective O&M decisions. This situation resulted in the creation of significant improvement opportunities for plant O&M cost reduction.

The Central Heating Plant (CHP) at the Twentynine Palms, California base was selected as the site for the first implementation of the Decision Support System for Operations and

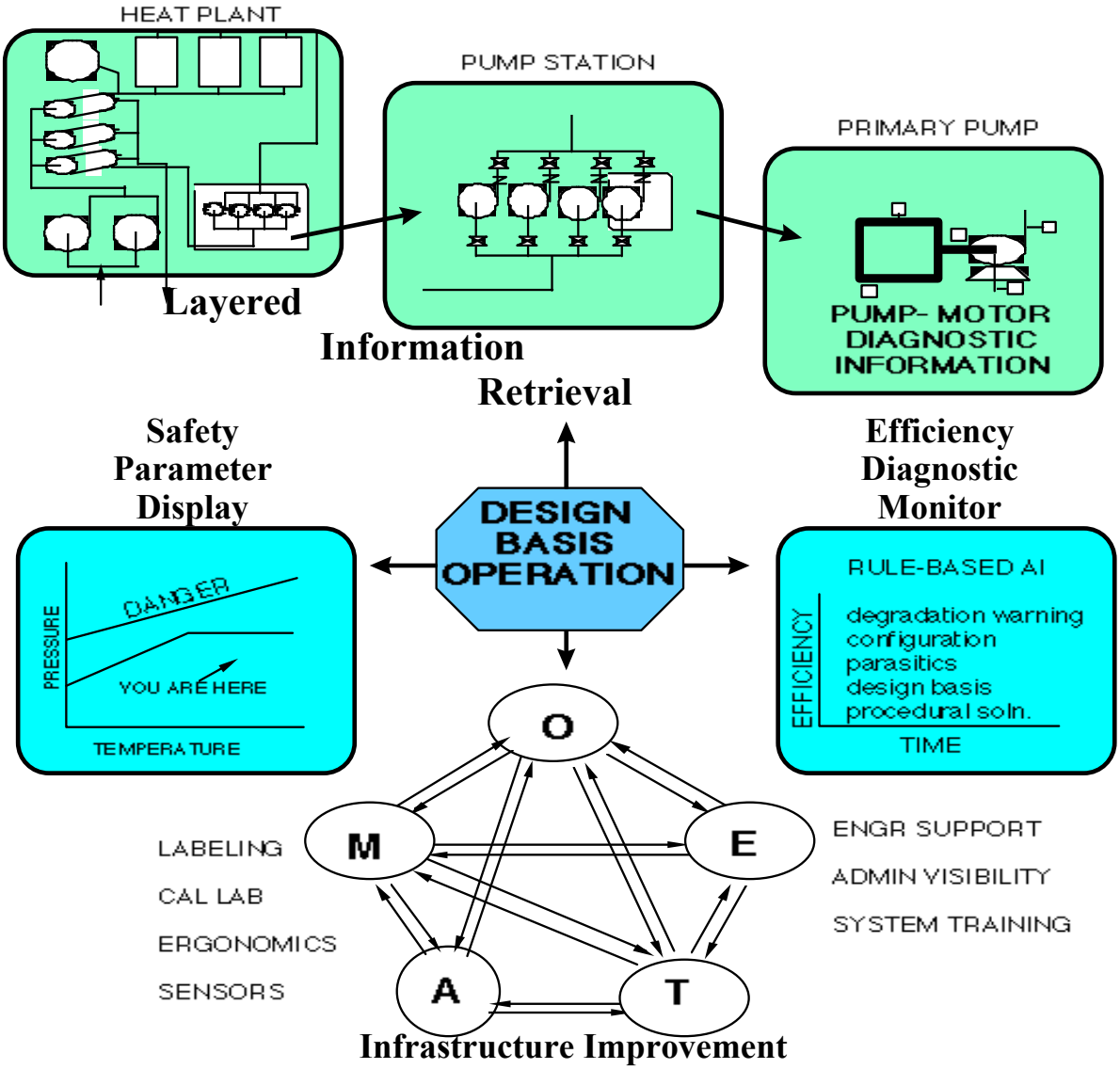
Maintenance, or the DSOM system. The plant is a gas-fired 120M Btu/hr pressurized hot water plant that supports approximately 15,000 Marines at the Air-Ground Combat Center.

29 Palms USMC Base Heating Plant



The DSOM project was designed to provide a proof of principle by giving a clear before and after measurement of the savings potential of the proactive O&M concept. The project was built around the proactive approach and integrates 1) an understanding of degradation mechanisms from the Nuclear Plant Aging Research Program (conducted by the U.S. Nuclear Regulatory Commission), 2) the latest in computer technology at the Laboratory, 3) an integral root cause analysis methodology, and 4) the many years of hands-on O&M experience of the Twentynine Palms O&M staff, as well as the Laboratory's Predictive Operations and Maintenance Technology group. The end product is a set of computerized O&M tools that are based on accurate plant design information and provide the plant staff with guidance on cost and safety conscious decisions. The principle project information improvement areas are shown in the next figure.

DSOM 29 Palms Production Tools



At Twentynine Palms, the first version of the DSOM Proactive Tool Set provides the O&M crew with point and click information about the processes at the plant, system, and component levels. Both the safety and the efficiency of the process are monitored and root cause solutions to off-nominal operation, not simply operational problems, are automatically brought to the crew's attention. Design basis optimization is achieved and maintained by continued upkeep of all the O&M infrastructure elements required to effectively run the entire process (Operations, Maintenance, Engineering, Training, and Administration).

Measuring the Economic Incentive

The ultimate success of any concept must be judged by how well it performs. To be able to draw an accurate record of change, a detailed baseline characterization was performed. This included

not only the common metrics, such as plant overall operating efficiency and maintenance machinery repair records, but also the other functions that must be integrated in order to provide the infrastructure required for continuing efficient operation. Plant efficiency and equipment availability records continue to be kept and are forming a detailed pattern of change when compared to that baseline.

The initial effect of the 1993 installation of DSOM was an immediate enhancement of the plant's safety, reliability and available capacity. Quantitatively, the plant has increased thermal efficiency by 16%, reducing the plant's gas bill by a quarter of a million dollars each year. An increase in available capacity eliminated the need for a fourth burner unit, saving an additional $1M. Now, our real challenge now is to show that these savings are actually the smaller portions of the real life-cycle economics. To do this, we must perform a life-cycle cost projection, based on the data gathered thus far from the Twentynine Palms project.

To make the analysis simple, look at the "life" of the required process as providing sufficient thermal energy to support the base needs for the next 60 years. Include everything necessary to implement and support the plant in each of the various O&M modes (capital equipment, personnel, repair materials, and fuel). Lastly, for ease of comparison, put everything in today's dollars. Based on the previous reactive life-cycle costs at Twentynine Palms, the current data yields the following projected figures -

60 Year Site Life

Reactive to Proactive Savings:

Fuel	**15M**
Capital	**20M**
Maint.	**16M**

For 29 Palms => 33% Life-Cycle Reduction in O&M Cost

This projection shows that indeed, fuel savings are only the first chapter in the plant asset management book. Plant life extension, as seen in capital savings and maintenance cost avoidance, are both shown to be as important, or more important, in the bottom line. Including all up-front costs, this represents a maximum of a 4.5 year pay-back period and the ultimate in undisturbed managerial slumber.