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Process Optimization Guide for Military Manufacturing and Maintenance Facilities

by
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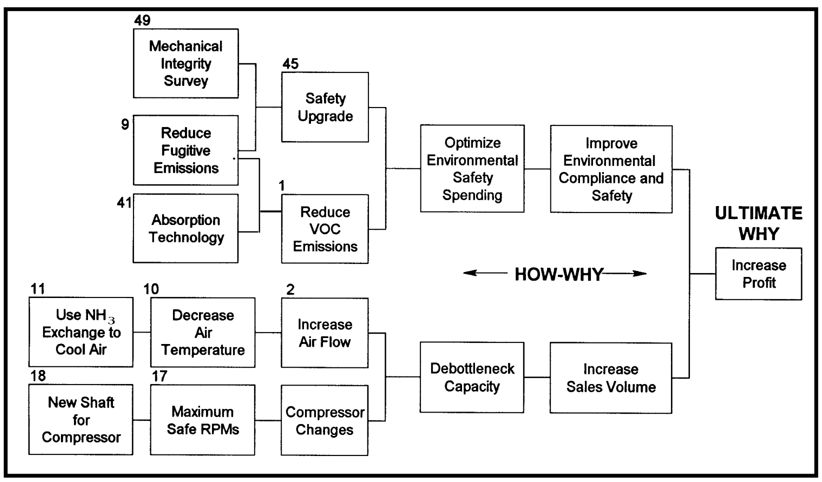

Industrial facilities operated by the Department of Defense (DOD) consume significant amounts of energy and emit large quantities of pollutants. Recent Executive Orders issued by the President set goals for increased energy efficiency and reduced emissions for these industrial facilities.

Cost-effective compliance with these directives and more stringent environmental regulations in the existing DOD industrial bases will require a thorough evaluation of the industrial activities and their potential for improvements. Through process optimization (PO), energy and environmental performance can be improved by analyzing and changing the manufacturing and maintenance processes themselves to increase productivity. Significant energy and environmental improvements are by-products of optimizing capacity utilization, and reducing rework, scrap, and off-specification product.

From a cost perspective, process capacity, materials, and labor utilization are far more significant than energy and environmental concerns. However, all of these issues must be considered together to achieve DOD's mission of military readiness for manufacturing and maintenance facilities in the most efficient, cost-effective way. This report provides a PO guide that shows the methodology and technique in conducting PO audits, presenting results, preparing reports, and implementing recommended projects. PO guidelines and expert advice for DOD manufacturing and maintenance facilities are also listed.

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Foreword

This study was conducted for the U.S. Army Corps of Engineers (HQUSACE), under Project 40162784AT45, “Facility Infrastructure Technology”; Work Unit XB8, “Industrial Energy Optimization Technology.” The technical monitor was Mr. Young Yue, HQIOC-IS.

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1 Introduction

Background

Many processes used in the military's manufacturing and maintenance facilities are based on processing methods developed 20 to 50 years ago. These processes were designed prior to three major constraints imposed in today's society: energy, environment, and lower operating budgets. Although relatively insignificant in the past, today the first two factors can drive the cost up unacceptably, and may even close down an operation. Effluent limitations are becoming more stringent at both the State and Federal levels. Older processes were not designed to meet these unanticipated changes.

Due to competition, commercial industries have adapted to the new requirements, but Federal government facilities have been slow to adapt for a number of reasons. Passage of the Federal Facilities Compliance Act has provided new impetus for process improvement and pollution control. To meet this challenge, the Department of Defense (DOD) has set goals to reduce both energy use and pollution generation. Executive Order 12759 directs all Federal agencies to improve the energy efficiency of their buildings and industrial facilities by 20 percent from 1985 to 2000. That figure has been further increased to 30 percent by 2005, with water conservation measures also added. Additional legislation requires the Army to: (1) reduce the use of energy and related environmental impacts by promoting renewable energy technologies, (2) have a 50 percent reduction in toxic chemicals and pollutant releases to the environment by 2000, (3) incorporate waste prevention and recycling in everyday operations, (4) acquire and use "environmentally preferable" products and services to the maximum extent possible, and (5) periodically modify procurement guidelines to incorporate the latest U.S. Environmental Protection Agency (USEPA) guidance. The Army's goal for reduction in waste disposal is that the generation level in 1999 will be 50 percent less than it was in 1994.

These goals cannot be met by focusing solely on energy generation or "tail-end" waste treatment solutions. An overall understanding of material demand and waste generation, without radically altering the basic production process, is required to meet these goals. Too often processes have been designed to meet theoretical maximum in demand, due to the relatively low cost of meeting that demand in the past. The increased cost of these demands warrants a closer look at requirements. Emerging technologies in process monitoring, feedback control, and contaminant treatment can meet these goals, maintain mission readiness, and, in some cases, even improve process efficiency and/or save money.

Energy and environmental performance are improved as a direct result from analyzing and changing the manufacturing and maintenance processes themselves to increase productivity. Significant energy and environmental improvements are by-products of optimizing capacity utilization, and reducing rework, scrap, and off-specification product. From a cost perspective, process capacity, materials, and labor utilization are far more significant than energy and environmental issues. However, all of these issues must be considered together to achieve DOD's mission of military readiness for manufacturing and maintenance facilities in the most efficient, clean, cost-effective way.

Objective

The objective of this work was to produce a Process Optimization (PO) Guide to provide DOD facility personnel with an illustrated resource on how to analyze and significantly improve existing DOD manufacturing and maintenance processes. The PO Guide will show how to optimize these processes, resulting in less energy consumption, less pollution, and significantly lower overall operating cost with equal or greater military readiness.

Approach

The PO Guide outlines a methodology to uniquely re-engineer manufacturing and maintenance processes. This is accomplished by linking process changes to cost and performance improvements, utilizing cost equations, process modeling, and innovation techniques.

This guide was developed based on decades of auditing experience obtained in private industries and public organizations. The three-level, five-phase PO program is described in detail in the Chapters 3 and 4. Debriefing of auditing results is then discussed. PO guidelines, expert advice, and integration of energy and process systems for DOD facilities are provided, followed by conclusions and recommendations.

Scope

This PO Guide addresses manufacturing and maintenance processes at DOD facilities, including metal working, plating, painting/de-painting, explosives/ chemicals production, load-assemble-pack (LAP) processes, and utility systems (steam, compressed air, etc.).

Mode of Technology Transfer

It is planned for the information presented in this report to be disseminated as an Army Research, Development, and Acquisition Bulletin. It is recommended that the PO Guide be presented at the World Energy Engineering Congress Conference, and transferred to the Headquarters Industrial Operations Command (HQIOC), Installation Support, for further distribution.

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 yd	=	0.9144 m
1 sq in.	=	6.452 cm^2
1 sq ft	=	0.093 m^2
1 sq yd	=	0.836 m^2
1 cu in.	=	16.39 cm^3
1 cu ft	=	0.028 m^3
1 cu yd	=	0.764 m^3
1 gal	=	3.78 L
1 lb	=	0.453 kg
1 kip	=	453 kg
1 psi	=	6.89 kPa
°F	=	(°C x 1.8) + 32

2 Process Optimization Overview

What Is Process Optimization?

Process Optimization (PO) is pursued by initiating a PO Audit that utilizes the experience and skills of facility personnel combined with a unique process audit methodology, developed by ETSI Consulting, Inc. The methodology re-engineers the manufacturing and maintenance processes by identifying solutions to critical cost issues that exist in the current process. The concept extends conventional energy and environmental auditing into the manufacturing, maintenance, and repair processes. More significantly, the PO approach expands the range of solutions to include any site-specific, critical, cost-sensitive issues that have a major impact on facility operating costs and mission.

The purpose of PO is to significantly improve the financial performance of the facilities operations by using a highly-focused, systematic methodology. PO does not optimize individual systems, subsidize less important objectives, or compromise readiness. Rather, PO achieves an overall optimum at lower total cost while achieving the facility's mission of military readiness. The result is 50 to 250 process solutions to critical cost issues.

The PO approach maximizes the use of audit time by analyzing only the most important inputs and outputs to the manufacturing, maintenance, and repair processes. These include:

- *facility capacity* — critical to readiness under alert conditions and/or actual military conflict. These conditions require a time-compressed ramp-up of facility capabilities.
- *labor utilization* — to always provide highly trained core personnel with the ability to extend capabilities and capacity.
- *materials utilization* — to always have the capability to provide adequate weapons when required.
- *energy and environmental performance* — to achieve reliable and efficient systems that are in full compliance.

The Five Phases and Twelve Steps of the PO Audit

Process Optimization is begun by initially implementing a Level I PO Audit. The PO Audit is 2 to 5 days of intense process re-engineering that follows a systematic 12-step methodology through five phases. Figure 1 presents the Twelve Steps of the PO Audit as a Process Flow Diagram (PFD) of the audit itself. The five audit phases are:

1. Financial Analysis of the Process (Steps 1-3)
2. Analyzing the "As Is" Process (Steps 4-5)
3. Creating the "To Be" Process (Steps 6-7)
4. Estimating Savings, Cost, and Payback (Step 8)
5. Prioritize and Obtain Commitment for Implementation (Steps 9-12).

The following brief description is provided for each step in Figure 1:

Phase I – Financial Analysis of the Process

Step 1. Identify "critical cost issues" in the manufacturing and maintenance processes that adversely impact operation efficiency, cost, energy, environmental, and overall performance in achieving the facility's mission of defense readiness.

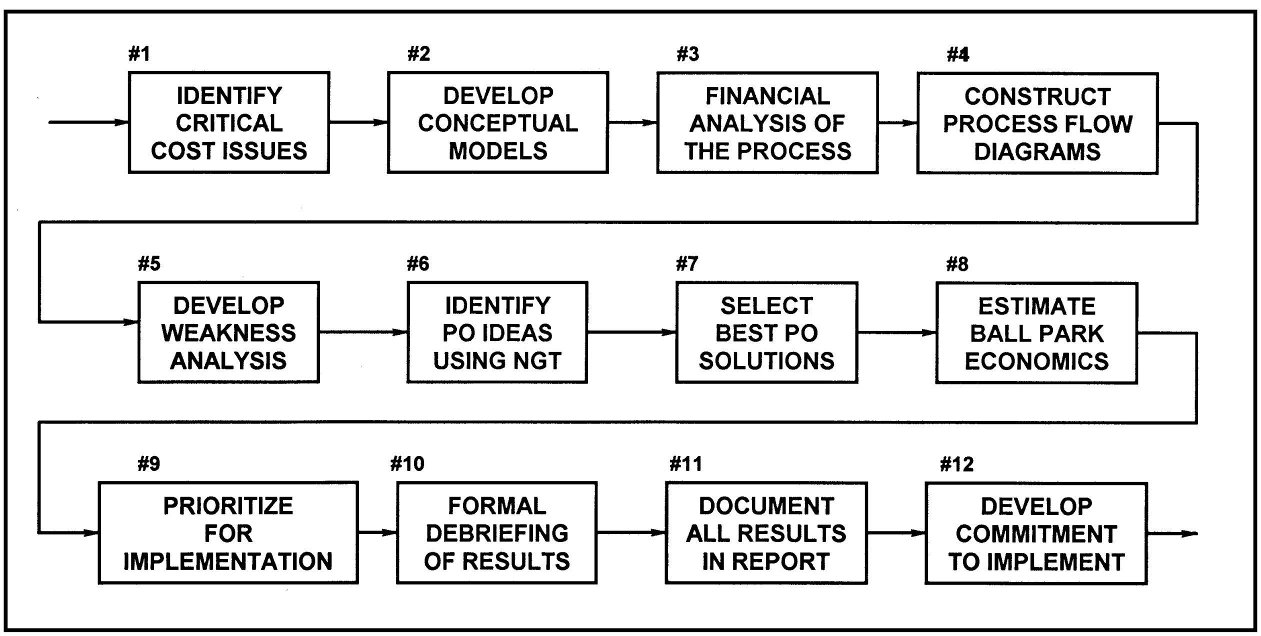

Figure 1. The 12 steps of the PO methodology.

Step 2. Conceptually model the existing manufacturing and maintenance operations combining engineering and financial models. Special PO definitions, concepts, and analytical tools are provided.

Step 3. Financially analyze the manufacturing and maintenance processes to develop the total cost of site-specific critical issues. Specific issues and specific processes that have the greatest economic potential for improvement are targeted. Develop the annual savings that would result from an arbitrary 10 percent cost improvement for each critical issue, i.e., 10 percent less rework, 10 percent less scrap, 10 percent better use of energy, or 10 percent greater capacity utilization.

Phase 2 - Analyzing the "As Is" Process

Step 4. Develop a Process Flow Diagram (PFD) to quantitatively define key technical values and costs as inputs and outputs to the major process steps. The PFD steps use a "format key" to consistently input data for each critical step. Critical process steps show estimated annual values for material balance, labor, energy and environmental issues. These inputs and outputs also include approximate annual economic balances.

Phase 3 - Creating the "To Be" Process

Step 5. Constructively initiate a Weakness Analysis that questions and challenges the existing process steps. Specific steps on the PFD are identified as the #1 bottleneck, the high scrap step, labor intensive step, quality problem step, energy-intensive, environmental problem, or otherwise excessively costly. Each of these critical issues is clearly located in the PFD and only these steps are addressed in identifying solutions. The resulting PFD is "populated" with relevant technical and economic data, representing a picture of critical cost issues.

Step 6. Apply the Nominal Group Technique (NGT) to identify a wide range of solutions to energy, environmental, and other critical cost issues in target processes. This technique forces individual participant concentration and independent/joint participation by using silent idea generation.

Step 7. Select from a wide range of process solutions the "best solutions" that offer the greatest savings potential and best chance of implementation. The selection method uses a weighted voting procedure that is based on criteria of whether the process (a) produces significant savings, (b) is "doable," and (c) is low risk.

Phase 4 - Estimating Savings, Cost, and Payback

Step 8. Develop ballpark economics for the “best solutions” by utilizing the 10 percent cost improvement factors developed in Step 3 to estimate net annual savings, expense, or capital cost to implement and simple payback. If total scrap costs $2 million per yr (scrap cost equation), then a 10 percent reduction is worth $200,000/yr. If idea #36 has been selected as a “best idea,” what percent reduction in scrap will result from this idea — 1, or 5, or 10 percent? If the PO team agrees, it will reduce scrap by 4 percent then it is worth 4/10 x $200,000/yr or $80,000/yr. If the audit team estimates Idea #36 to cost $40,000, then it has a 6-month simple payback.

Phase 5 - Prioritize and Obtain Commitment for Implementation

Step 9. Categorize and group process solutions as to ease of implementation. Categories include “slam dunks” (no cost, no risk), “lay-ups” (minor expense, low risk), “free-throws” (medium expense or capital, medium risk), “3 pointers” (high capital and high risk), and “Hail Mary’s at the buzzer” (very high risk, but could beat the competition). Process solutions are further grouped as people solutions, operational costs, or capital money.

Step 10. Summarize results in a formal debriefing session to obtain top management buy-in and authorization to pursue the development of major process changes. Buy-in and authorization is critical to moving forward in implementing the larger PO solutions.

Step 11. Document all PO Audit results in a concise report including the basis behind the economics for the best process changes. All flip charts developed during the on-site work sessions are fully developed and presented in the appendix to this report.

Step 12. Secure commitment within the command/organization by proposing an initial Implementation Plan. The Implementation Plan identifies specific paths forward to determine the effectiveness of each PO solution, secures funding, and ensures timely implementation.

Audit Results and Expectations

The results from a Level I PO Audit are 50 to 250 process improvement solutions that address one or more critical cost issues. PO financially analyzes the manufacturing and maintenance/repair processes to guide and focus the technical effort. Only process steps that are energy-intensive, or have environmental problems, or clearly waste materials or labor are evaluated. This results in the maximum use of audit time and the greatest financial contribution from the PO effort. Typical audits have reduced energy by 20 to 40 percent (or more), environmental emissions/discharges by 40 to 60 percent, and overall operating costs by 3 to 6 percent (or more).

The Level I, II, III PO Program

The PO program is done at 3 levels (Table 1):

- Level I: 2-5 Days The PO Audit provides solutions with ±40 percent cost estimates.
- Level II: 2-6 Months Develop/test/fund PO ideas within ±10 percent cost estimates.
- Level III: 1-3 Yr Implementation of large investment project.

These potential solutions are screened and the best (top 20 percent) are provided with the audit team's best guess as to ballpark economics, including savings, cost, and payback. However, only 10 to 20 percent of the PO Audit will be realized ("Slam Dunks" and simple "Lay-ups") if the audit team cannot obtain commitment to pursue the other 80 to 90 percent of the ideas from facility management. Top management commitment is necessary to move ahead with the larger process improvements that require further "development" to secure funding. What is involved in "developing" these larger process improvements? This requires a Level II PO effort.

Level II Analysis

Development of the larger process improvement opportunities is achieved by a Level II analysis. This effort most often requires a combination of in-house and outside support. Based on the success of the Level I Process Audit, a Level II analysis is usually recommended.

Table 1. Process optimization level definitions.

Level 1	Level II	Level III
• Profit opportunity analysis • Identify 50-100 process changes • Identify top ideas • Measure nothing; guess at everything • ± 40% dollar estimates • Implement no-cost ideas	• Pursue top ideas from Level I • Develop additional new ideas • Measure everything; guess at nothing • Detail economic analysis for appropriation grade estimates • Implement low cost ideas	• Implementation of capital projects: - detail design and engineering - procurement, construction, and startup

Level II analysis "guesses at nothing — measures everything," quantifying both the Level I and new Level II ideas to change the old process. A specific Level II scope and approach to use on-site and off-site resources are best jointly developed by review and discussion of results documented in this Level I report. The Level II Process Optimization effort is a much larger effort requiring 60 to 180 days, or more. Level II identifies additional process improvement ideas and develops and evaluates the leading process modifications from the Level I Audit. All critical, technical, and economic assumptions are verified by field measurements, engineering calculations, and accurate economic data. Process improvement ideas that pass the Level II engineering and economic analyses are presented to management with "appropriation grade" cost estimates for funding and implementation. Actual implementation is a Level III effort requiring detailed engineering, procurement, construction, startup, and commissioning.

Some ideas are developed and implemented in Levels I and II because they involve no engineering or capital funds. These are most often "people solutions" that change an operating procedure or introduce a different work practice. People solutions would seem to be easy, but in practice they are often the most difficult to implement and to sustain. This is because they involve a change in human behavior and/or a change in culture. If we have been rewarded by our management in the past from working fast (example, a piecework program), then we find it difficult to change to a work environment that puts quality first, production second.

Why Do PO? What Are the Reasons Behind PO?

The primary drivers behind PO are effectiveness and efficiency in carrying out the facility's objectives at optimum cost. Effectiveness addresses the direct contribution of the processes in successfully achieving site objectives. Efficiency addresses the best (optimum) use of process resources (materials and time). Effectiveness and efficiency includes the impact of process energy and the environment. The PO drivers for DOD manufacturing and maintenance operations should not be substantially different from those in the private sector. PO drivers for the private sector are:

- Customer — a commitment to 100 percent satisfaction
- Competition — now global rather than regional
- Technology — now information, not just materials
- Speed to market — reducing order fulfillment cycle time.

The DOD drivers that parallel the private sector are:

- Customer — the nation and its defense
- Competition — outsourcing manufacturing/maintenance and the "bad guys"

- Technology — a definite current DOD edge
- Speed to market – rapid deployment in time of crisis and sustained operations.

The private and the military sectors should both adopt the same aggressive three-word motto to ensure success: "**Change, Focus, and Speed**." We must **change**, adapting to new conditions and requirements around us. We must **focus**, targeting only the critical, most costly, problem issues, and the processes in which they are found. Finally, we must increase **speed**, quickly identifying and implementing the best process solutions.

In the past, energy improvements have primarily been made by addressing the efficiency of on-site energy production (boilers, air compressors, etc.). Likewise, past environmental improvements have been made by using tail-end cleanup approaches such as bag houses on dusty process exhausts or improving wastewater treatment efficiency. These approaches may not be adequate to meet DOD energy and environmental goals. We should look for energy solutions at the end of the steam pipe at the process. We should go down the stack or up the sewer to find solutions to environmental problems. The problems and solutions are found in the processes themselves, not in the infrastructure supporting the processes. To meet yr 2000 goals, the DOD must optimize it facilities' processes, reducing waste (time and materials), emissions, and energy inefficiency at the point of origin—the manufacturing and maintenance processes.

PO Definitions and Concepts

The PO methodology broadly defines manufacturing and maintenance processes in such a way as to assist in analysis and identification of process solutions. Process is defined as "all operations or functions that consume resources" (time, people, materials, energy, etc.). The term process includes:

- operating conditions (temperatures, pressures, cycle time, etc.)
- operating procedures and practices (people issues)
- basic technology (chemistry, physics, heat transfer, etc.).

The definitions of "Process" versus "Equipment" are represented in Figure 2, in which the operations inside the box are processes, while the box itself represents the building and equipment. Inputs (raw materials, energy, labor, etc.) and outputs (intermediate or finished product, waste, scrap, emissions, etc.) are represented in physical terms (units/yr, number of people, etc.) and financial terms ($/yr, unit costs). We should primarily focus our attention on the fundamental process or what is happening — GOOD or BAD — to the raw material and why, rather than how well is the machine or equipment performing.

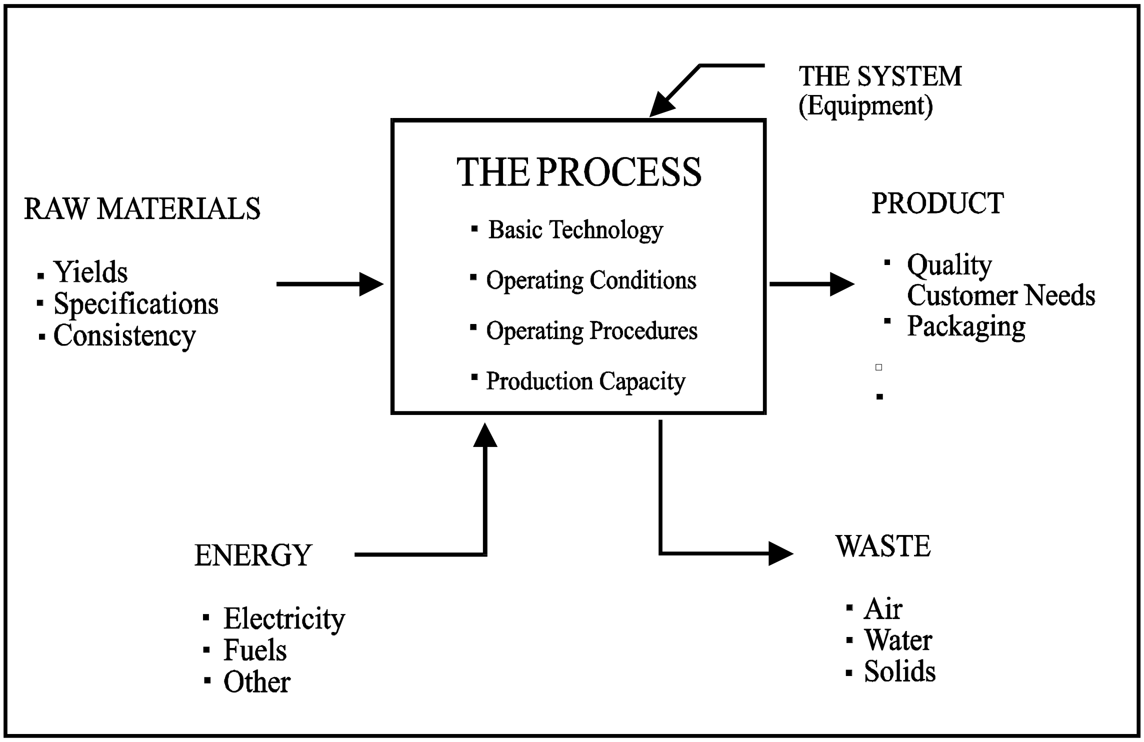

Figure 2. Defining process and defining optimization.

For example, in the paper mill, we want to initially understand and improve the environment of the pulp as it is converted into dry sheet paper in the paper machine and secondarily, consider how to improve the machine. The first may lead us to the second, but only after we have explored operating conditions, people procedures, and the basic chemistry, physics, and heat transfer that directly impact the "processability" of pulp.

The term "optimization" in the PO context also needs clarification. *Optimization* is defined as "to make as good or as effective as possible." We should recognize that optimization is actually an ongoing effort. This is because the requirements of the process are changing. It would be accurate to say that we are "shooting at a moving target. " The process requirements change because:

- The requirements of the customer change (increase).
- Technology changes (improves).
- The business or operating environment changes (market direction, product demand).
- Our competitors change (improve).

Audit Preparation and Audit Team Selection

A Level I PO Audit requires minimal preparation by the site team. Selection of audit team participants from the site is the first and most important preparation item. Site participants can vary from four to eight or more, depending on the number of critical issues and processes that are targeted. The participants should be individuals who are knowledgeable and experienced in the operational, technical, maintenance, and utility functions. The individuals should be selected based on their knowledge of the specific processes in which the target critical issue(s) are found. The ideal audit team is diverse in its background and will contain multiple disciplines and levels, and open minded, innovative individuals. The audit team systematically follows the PO methodology under the guidance of an experienced PO audit facilitator.

A second preparation item for audit team members is to review for approximately 30 minutes the PO methodology and audit steps as found in the PO Audit Notebook (Appendix A). Each member of the audit team receives an audit notebook 2 to 3 weeks before the on-site work sessions. The notebook is an information, preparation, and execution guide. The purpose of the audit notebook is to introduce the methodology and to provide a place to organize all audit results as the team works through each audit phase. Example techniques and results from past audits are presented in the audit notebook. A table of contents for the audit notebook and introductions to each section are presented in Appendix A. The Two-Day PO Audit Work Plan is presented in Appendix B.

A third preparation item is for each audit team member to take 10 minutes prior to the PO Audit to independently write down critical cost issues such as "too much rework." The purpose of the critical cost issue list is to determine where the Audit Team can most profitably spend its time. Critical issues are problems and/or opportunities that in a small way (but daily) result in excessive costs, or that occasionally (but in a big way) impact cost. The critical issue lists are to be brought to the audit session to be developed into a combined list by the full Audit Team.

Several additional preparation items are useful if readily available. It is helpful to organize available annual revenue (or operating budgets) and annual operating costs into a simple format prior to the audit. The format is illustrated and explained in the next chapter. The financial data are used to develop cost equations and 10 percent "What If" benefits for critical issues. The data can be approximate, yet are treated as confidential information. Also useful is a simple Process Flow Diagram (PFD) showing the major steps in the manufacturing or maintenance operations. The PFD is further developed during the audit by "populating" each step with operating and cost data. Finally, plans should be made to use a large conference room as PO Audit headquarters, equipped with an overhead projector and two or more flip charts on easels. An eat-in group lunch is typically the most practical.

3 PO Audit Phases and Steps

Phase I: Financial Analysis of the Process (Steps 1, 2, 3a, 3b, 3c)

The PO methodology uniquely screens the financial aspects of the process to provide initial guidance and focus for the technical analysis. The financial analysis is used later as a basis from which savings can be estimated for the top process solutions. The first task is to identify site-specific, critical cost issues.

Critical Issue List (Step 1 in Figure 1)

The very first activity in the PO Audit is for the Audit Team to identify critical, site-specific cost issues. Critical issues are frequent minor or occasional major operating problems. Critical cost issues could also be missed opportunities, not just problem issues. Critical cost issues are any facility-specific conditions or events that result in excessive cost or significant loss of profits over several years.

The purpose of the critical issue list is to target the most significant problems and/or opportunities for financial analysis, and to identify those processes in which the critical issue is prevalent. In this way, the critical issue list targets both issues and specific process areas. Examples of critical issues include low utilization of raw materials (low yields, high scrap, waste, etc.), low utilization of production capacity (a bottleneck step, high downtime, inadequate maintenance, etc.), or people issues (turnover, training, communications, management, etc.).

The critical issue list is developed in two ways. First, each audit team member is requested to spend 10 minutes to independently identify a short list of the most costly critical process issues prior to the audit. Second, on the initial audit day, each team member is requested to rethink their list, and the team jointly develops a composite group list. An abbreviated Nominal Group Technique (NGT) is used to identify and select the top 2 or 3 most critical issues. The NGT, presented in Appendix C, is a very productive method of generating ideas. It is used throughout the PO Audit to maximize innovation of the Audit Team. Often multiple critical issues can be combined into an end effect such as capacity bottleneck, high scrap, or an energy/environmental problem. An example of combining critical issues into an end effect is that inadequate maintenance leads to high downtime that results in low capacity utilization of the facility. Low facility capacity utilization is the “end effect.” End effects are central issues that directly impact profits or, for non-profit operations, directly determine a budget surplus or deficits.

Relationship Between PO Critical Issues

The PO approach recognizes the strong interdependence and relationship between the drivers behind PO. Process effectiveness and efficiency inherently improves the cost performance of the facility. However, an effective and efficient process also uses less energy and produces less pollution. If a manufacturing process bottleneck is identified and eliminated, then less energy is consumed per unit of output because the facility’s fixed energy is spread over more output. If a PO analysis identifies ways to reduce scrap, rework, or off-specification product, then the energy and environmental emissions associated with excessive scrap, rework, or off-specification are eliminated.

Furthermore, the PO approach recognizes the interdependence between energy consumption and environmental emissions. If a PO analysis discovers how the manufacturing or maintenance processes can be successfully accomplished with less steam, then less fuel is consumed by the boilers, resulting in less NOx and SO_2 emissions. For example, 1000 lb less steam production results in 170 lb less CO_2 emissions from the boiler stacks. Likewise, a PO analysis that optimizes the process at lower compressed air consumption will reduce electricity consumption of the air compressor. The result is less CO_2 emissions from the local utility’s coal-fired power plant. Specifically, 100 SCFM reduction compressed air reduces compressor motor load by 16 kW, equivalent to 350 lb CO_2 per hour. On a quantity basis rather than rate basis, 1000 cu ft of compressed air production requires 2.7 kWh of electricity, which in turn results in 58 lb of CO_2 emissions. Eliminating 1000 cu ft of wasted air will not only save money ($0.18 in electricity at $0.05 /kWh), but it will also eliminate 58 lb of CO_2 emissions. Energy and environmental emissions are directly linked; reducing the first always reduces the second, and both reduce operating costs.

Develop Conceptual Models (Step 2)

The PO methodology uses conceptual models to enhance the Audit Team’s abilities in process analysis and innovation. Figure 3 shows an engineering model showing the major inputs and outputs to a hypothetical, overall manufacturing, or maintenance process.

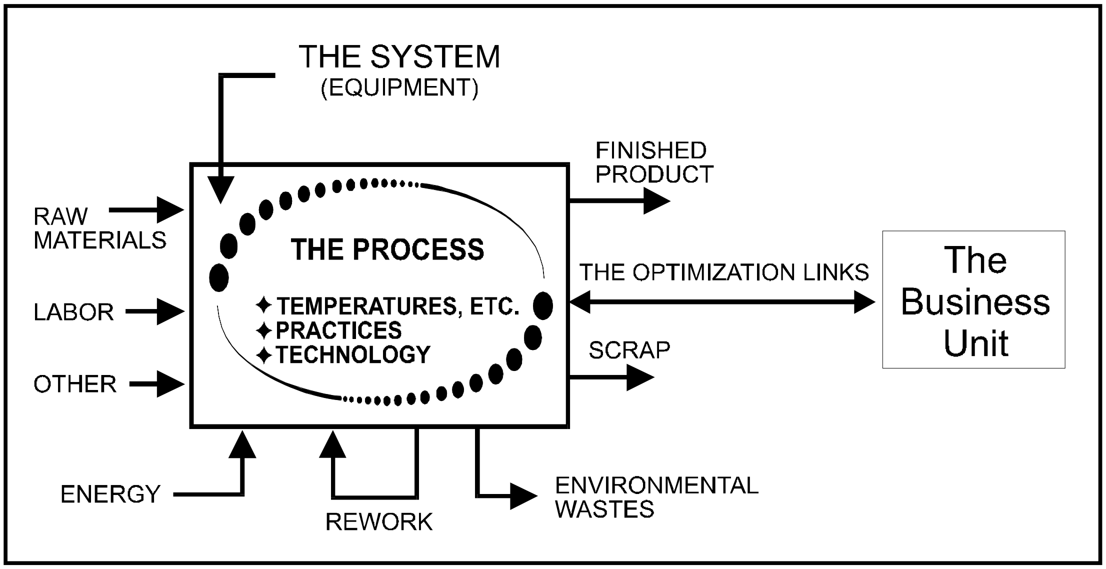

Figure 3. An engineering conceptual model.

No matter how thorough we might be with the technical/engineering efforts, our primary objective of implementing cost-effective process solutions will be difficult. This is because there are two groups within every organization that must be satisfied. The first group is the technical team that thinks an engineering model is totally adequate and sufficient because it explains everything in technical terms. These terms would include mass balances, product flow rates, cycle times, energy balances, chemistry, BTUs, kWh, BOD, etc., to define inefficiencies and to identify process improvement solutions (Figure 3). Note that no costs are shown.

The second group is the financial team, which is often less interested in the engineering model and much prefers to use a financial model to identify and implement process or business solutions (Figure 3). The financial model might use spreadsheet Proformas, Life Cycle Costing (LCC), Net Present Value (NPV), and make decisions based on Internal Rate of Return (IRR). Note that no technical numbers are shown. In many organizations, the two groups simply do not talk the same language. Final success requires that both groups participate in initially developing financial incentives to change the old process and, at the end, financially valuing the top ideas with net annual savings, capital cost, and simple payback. We say, “If we want to talk to a duck, we must quack like a duck.” The technical group must learn to quack profit and costs, and the financial group must learn to quack process and engineering.

The communication and optimization link between the engineers and their model (Figure 3) and the financial thinkers and their model (Figure 4) are combined in Figure 5.

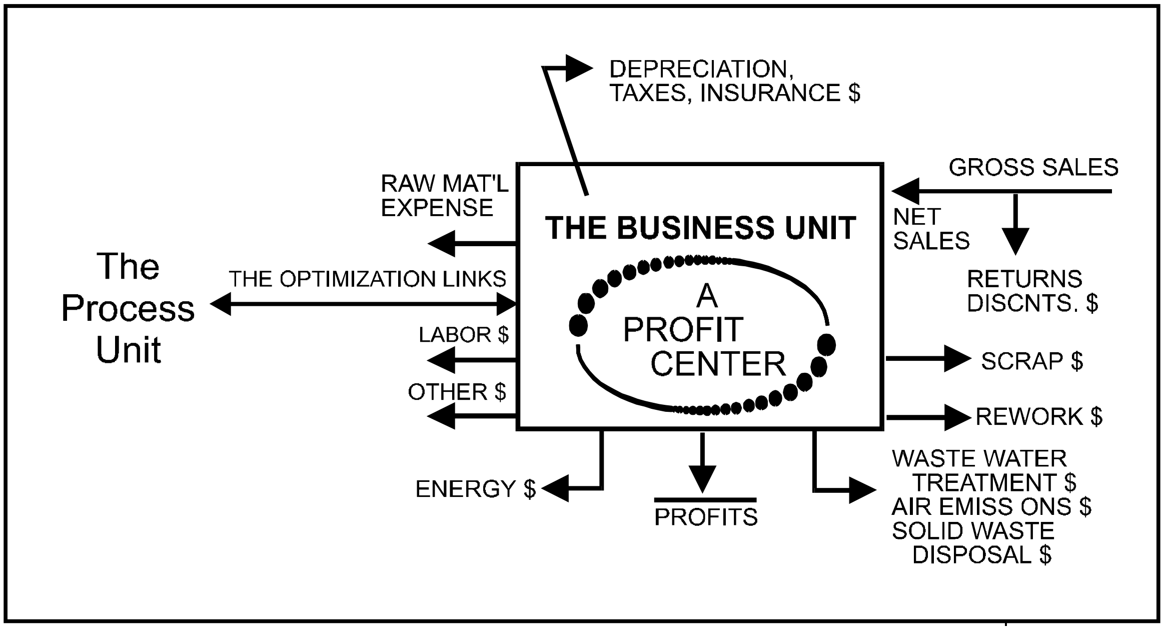

Figure 4. A financial conceptual model.

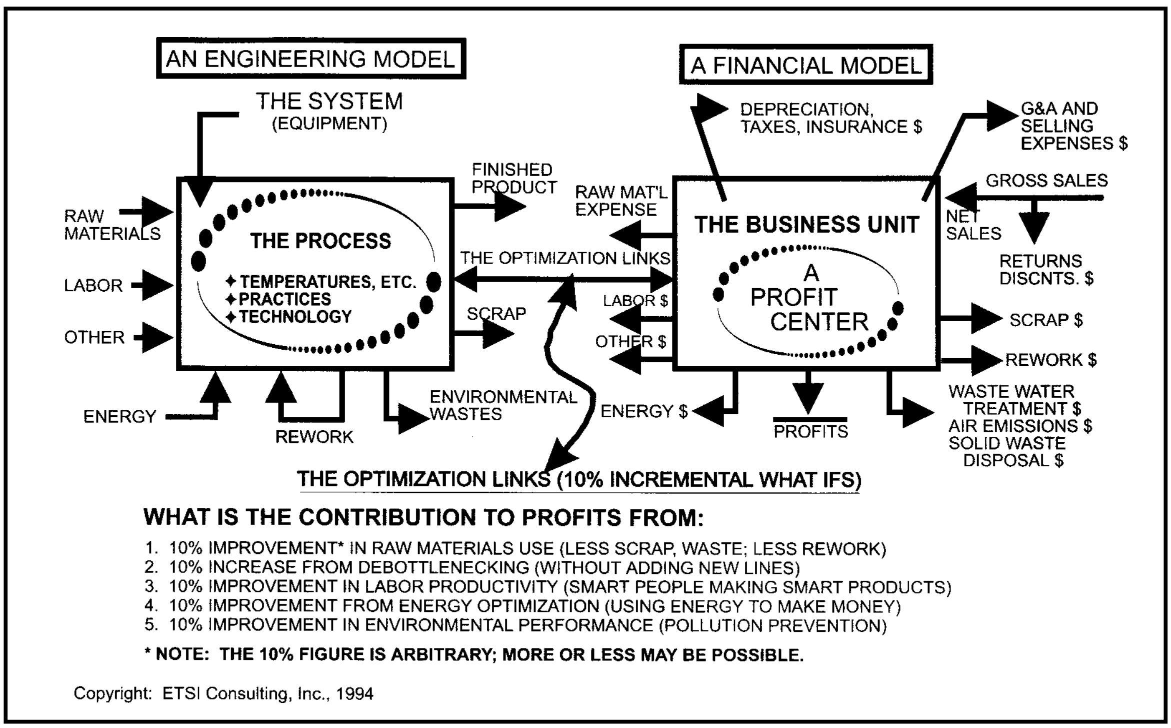

Figure 5. Linking engineering and financial models with cost equations and 10-percent what-if improvement benefits.

The relationship between the two models is connected by cost equations. The engineering and financial models provide the basis to develop cost equations that in turn allow 10 percent improvement benefits to be calculated for critical cost issues. The 10 percent “What If” annual benefits are easily computed from cost equations. The sequential development of the manufacturing cost structure

(Step 3A), the 10 percent incremental “What If” improvement benefits (Step 3B), and the total cost equations are described and illustrated in the next section.

Revenue (or Budget) and Manufacturing Cost Analysis (Step 3A)

The financial analysis of the process begins with a simple accounting of annual revenue (or budget) and annual costs for total facility operation. The cost analysis can be developed for a major process area (i.e., Paint Department) that is impacted by a top critical issue or for the entire facility’s operations. The format of the revenue and manufacturing cost structure is presented in Table 2.

The purpose of this type of analysis is to consider what happens to the bottom line when potential, yet to be identified, PO solutions are implemented. The bottom line is profit (or loss) for the private sector or budget surplus (or deficit) for the government or non-profit sector. The question is, “how much money is saved on an annual basis from a 10 percent improvement in a critical cost issue?” Specific 10 percent “What If” improvement factors are illustrated in Step 3B.

Ten Percent Incremental “What If” Factors (Step 3B)

The revenue (or budget) and manufacturing cost structure provides the basis for a classical “fixed and variable cost analysis.” This analysis calculates how much can be saved annually from an incremental increase in facility production and/or maintenance operations. Table 2 illustrates the contribution to the bottom line from an arbitrary 10 percent increase in facility capacity utilization from higher production output. An annual analysis of variable and fixed cost and revenue increases from a 10 percent increase in production/sales requires a full 10 percent increase in raw material cost (100 percent variable). However, operating labor and other expenses are not 100 percent variable with production. A 10 percent increase in production would typically require only a 2 percent increase in hourly labor (20 percent variable), because capacity is constrained by machine, process, and work methods issues, not head count. Likewise, usually only a 1.0 percent increase in electrical energy is projected (10 percent variable) because 90 percent of the energy consumption is fixed for a relatively small production rate increase of 10 percent. What typically results with a 10 percent increase in output is that the marginal or incremental unit cost is half of the unit cost of standard output. This is because an incremental 10 percent additional output does not add to the fixed costs, and primarily adds raw material to the variable costs.

Value of 10 Percent Incremental Capacity Increase

Table 2 provides an example where only raw materials are 100 percent variable, meaning 10 percent more output in budgeted production/sales, worth $3.6 million/yr, consumes 10 percent more raw materials, costing $1.5 million/yr (10 percent of the $15 million annual cost of raw materials). However, other costs are mostly fixed with production rate. Labor, energy, and other direct costs were judged to be only 20 percent variable meaning that a 10 percent increase in production only results in a 2 percent increase in these costs (see right column in Figure 5). The end result is that the 10 percent increase in output provides 10 percent more budget revenue ($3.6 million/yr) but costs only $1.79 million to produce. The new profit or surplus was $3.60-$1.79 or $1.81 million/yr, which increased original surplus from $4.0 to $5.81 million/yr, a whopping 45 percent increase in surplus. The original product cost $32 million for 15 million units or $2.13/unit, while the 10 percent additional output only costs $1.79 million for 1.5 million units or $1.19/unit. Recognizing that the marginal cost to produce 10 percent more product (or service) is approximately half the standard cost, the facility is now provided with an incentive to debottleneck output *and* has a way to value an X percent increase. In this case, 10 percent was worth $1.81 million/yr or 1 percent is worth $181K/yr.

The revenue and cost structure also allows estimates of other 10 percent “What If” savings benefits. For example, in Table 2 a 10 percent increase in labor productivity would be worth 10 percent of the $6 million/yr labor or $600,000/yr. A 10 percent reduction in energy would be worth 10 percent of $2 million/yr or $200,000/yr. If scrap were 20 percent of raw material, labor, and energy costs (20 percent of 15 + 6 + 2 million) or $4.6 mil/yr, then a 10 percent reduction would be worth $0.46 mil/yr. The scrap example is expressed in the form of a cost equation (20 percent of 15+6+2 million = $460,000/yr). These values are calculated in Table 3. This concept is further explained in Step 3C.

The arbitrary 10 percent values are not goals, but are intended to only identify relative impact on profits or budget surplus without necessarily indicating at this point how to specifically achieve the improvements. More or less than a 10 percent improvement may be possible. How to achieve an X percent improvement benefit by identifying specific process solutions is described in Phase 2 (Steps 3 and 4) and Phase 3 (Steps 5 and 6). Review Figure 1.

Both the order (most to least) and magnitude of the incremental 10 percent “What If” benefits are often a surprise to the PO Team (Table 3). Almost always a 10 percent higher use of facility capacity is at the top of the list.

Table 2. Revenue (or budget) and manufacturing cost structure.

Item	Basis	Mil.$/Yr.	+10%
1. Revenue (or budget)	18 Mil. Units @ $2.00	36.0	3.60
2. Cost to produce			
A. Raw materials	15 Mil. units @ $1.00	15.0	1.50*
B. Operating labor	100 people @ $60K	6.0	0.12**
C. Purchased energy	Electricity + fuels	2.0	0.04
D. Other direct	Maintenance, supplies	3.0	0.03***
E. Indirect	Taxes, depreciation, insurance	1.0	0.00†
F. G & A, overhead	Support costs	5.0	0.00†
G. Total cost	Sum A through F	32.0	1.79
3. Profit (or surplus)	= Revenue – Total Cost = $36.0 - $32.0 = 4.0		

* Raw Materials are almost always 100% variable with production rate, +10% X $15.0 ml X 1.0 (100% variable) = $1.5 Mil.

**Labor productivity is judged to be only 20% variable with production rate, +10% is 10% X $6.0 Mil X 0.2 (20% variable = $0.60 mil.

***Scrap at a 20% level is calculated directly as follows, -20% is 10% X (15+6+2) X 10% = $0.46 mil.

†Energy is calculated directly based on $2.0 mil/year, -10% is 10% X ($2.0 mil (year) = $0.20 mil.

Table 3. Ten percent incremental “what if” benefit factors (reference Table 2).

Item	Basis	Benefit
1. Capacity = Incremental Revenue – Incremental Costs	= 3.6 Mil - $1.79 Mil	= 1.81 Mil
2. % Productivity	= 10% of $6.0 Mil Labor	= 0.60 Mil
3. % Scrap	= 20% Scrap X (15+6+2) X 10%	= 0.46 Mil
4. Energy	= 10% or $2.0 Mil Energy	= 0.20 Mil

It is interesting to note that, although energy is a cost factor, it represents only a fraction of other more cost-sensitive issues, such as improvement in capacity use, labor productivity, and materials use. The Level I 10 percent “What If” economics are not presented as a precise manufacturing cost analysis, but rather approximations to provide direction to the Audit Team in targeting which critical issues offer the greatest economic opportunity. The 10 percent “What If” benefits can also be used to develop the economic value (savings) from a specific process improvement idea.

Total Cost Equations for Critical Issues (Step 3C)

The purpose of the total cost equation approach is to totally capture *all* costs associated with a particular critical issue. The cost equations present all annual present costs and all foreseen future costs for critical cost/problem issues such as high scrap, rework, or excessive water use. Once developed, the cost equation of a critical issue can be immediately expressed as a 10 percent “What If” benefit.

For example, if the cost equation for "rework" is found to total $1.5 million per yr, then the 10 percent "What If" benefit from eliminating 10 percent rework is $150,000/yr. All costs are expressed on an annualized basis. These costs would include:

- *Current costs*: Mostly variable such as raw materials, labor, maintenance supplies, outside services, purchased energy, etc.
- *Current indirect costs*: Mostly fixed such as administrative, factory overhead, depreciation, taxes, insurance, etc.
- *Consequential costs*: These costs, typically found elsewhere in the accounting system, are a direct consequence or result of a critical problem/cost issue. These might be reliability for energy systems, administrative costs for environmental compliance, low capacity use due to maintenance issues, high labor requirements due to excessive scrap, etc.

The cost equation uses "activity based costing" for critical cost/problem issues. We can identify the total cost in net present dollars of a system problem by adding horizontally all direct, indirect, and consequential costs. Tables 4, 5, and 6 exemplify three total cost equations. Again, the purpose of collecting all costs as a cost equation of a critical issue is to truly understand the total financial magnitude of the problem. This understanding provides two or three times the motivation or incentive to control this cost because the cost equation total is often two or three times greater than expected.

The Revenue (or Budget) and Manufacturing Cost Structure (Table 2) and the total cost equations (Tables 4, 5, and 6) provide the basis for calculating a list of Incremental 10 percent "What If" benefits. Such a list is presented in Table 7 from a PO Audit of a paint manufacturing facility. The #2 item on the list "10 percent reduction in off-specification paint batches" is presented in Table 6 where the total cost equation includes eight separate components.

Phase 2: Analyzing the "As Is" Process (Steps 4 and 5)

The second phase of the process audit uses special techniques to systematically analyze existing operating procedures, practices, operating conditions (temperatures, speeds, and pressures), and the application of new technology. Conceptual process thinking is used to quickly understand basic production steps and the value added by each step. A "conceptual" process model, in its simplest form, is to imagine in "first person" that we are raw material that is being converted by many steps to finished product. We should ask, "Why are "they" heating us up (to 150 °F)? What is magic about 150 °F (why not 140 °F or 170 °F)?

Table 4. Application of total cost equation for energy and energy systems: $/Year = Sum1-19 (All Direct + Indirect + Consequential Costs).

Costs	Example* K$/Year
Direct Costs of Energy and Energy Systems (% Variable)	
1. Purchased electricity (20%)	3000
2. Purchased fuels (20%)	2000
3. Operating labor (10%)	1000
4. Operating supplies (20%)	100
5. Maintenance labor (10%)	500
6. Maintenance materials (20%)	300
7. Water (50%)	100
8. Water treatment (20%)	100
Subtotal direct costs	$7100
Indirect Costs of Energy and Energy Systems (0% Variable)	
9. Outside mechanical services	50
10. Consulting and legal services	50
11. Salary Labor and management recharge	500
12. Plant services recharges	200
13. Environmental costs	200
14. Taxes	300
15. Depreciation (debt service)	2000
16. Insurance	300
Subtotal Indirect Costs	$3600
Consequential Costs Due to Energy and Energy Systems (0% Variable)	
17. Plant downtime due to energy systems	600
18. Quality problem due to energy systems	200
19. Lost sales due to energy systems	400
Subtotal Consequential Costs	$1200
Total cost equation for all direct, indirect & consequential cost	$11,900
Total cost equation = SUM (7100 + 3600 + 1200) =	$11,900
Conclusion: Purchased energy is $5000K/yr (items 1 and 2) with $7100K of total direct cost ($5281K/yr. is variable). However, total owning and operating cost for energy supply is $11,900K/year, or 2.4 times purchased energy.	
* Example Industrial Facility: 1,000,000 FT^2, 8 MW, 100 Kpph, $20 Mil Energy System Investment, 20 Operators, 8 Mechanics/Electricians	

Table 5. Total cost equation (TCE) for water and wastewater systems.

Example*	K$/Yr.
Direct Costs of Water/Wastewater Systems	
1. Purchased cost of water	100
2. Water treatment for BFW, CTW, etc.	100
3. Operating labor for water systems	200
4. Operating supplies for water systems	30
5. Maintenance labor for water systems	60
6. Maintenance supplies for water systems	30
7. Electricity to pump water throughout facility	600
8. Fuel as heat lost in discharge water	130
9. Wastewater treatment costs	120
10 Raw materials in wastewater	80
Subtotal Direct Costs	$1450
Indirect Costs for Water and Wastewater Systems	
11. Outside services (mechanical, consultants, etc.)	10
12. Salary labor and management recharge	30
13. Plant service recharges	20
14. Environmental permits	10
15. Taxes on investments in water systems	30
16. Depreciation on investments in water systems	220
17. Insurance on water systems	30
Subtotal Indirect Costs	$350
Consequential Costs of Water and Wastewater Systems	
18. Plant downtime due to water systems	50
19. Fine for permit violation	20
20. Quality problems due to water systems	10
21. Lost sales due to water systems	20
Subtotal Consequential Costs	$100
Total Cost of Direct + Indirect + Consequential Subtotals	$1900
Total Cost Equation = SUM (1450 + 350 + 100) = $1900 K/YEAR	
Conclusion: Purchased water is $100,000/year, but the total owning and operating cost of the water and wastewater systems are $1,900,000/year…19 times purchased water cost	
* Example Industrial Facility: 1,000,000 Square Feet, 275,000 GPD, 4 Operators, 1 Maintenance Mechanic, 110 ppm WW Concentration	

Table 6. Total cost equation (TCE) for off-specification batches (k$/yr).

Data

- 126 batches were considered as off-specification in 1995.
- An additional 30% were subsequently determined off-specification (39 batches).
- Total off-specification batches were 165.
- Percent off-specification was (165/2600) x 100 or 6.35%.

Estimates

1. Off-spec batches consumed 6.35% (or more) of plant capacity. Capacity cost from Figure 1 = (6.35%/10.0%) x $3.575M = $2.27M/year.
2. Two-thirds of the raw materials in off-specification batches cannot be reworked (2/3 x 0.0635 x $30M = $1.27M/year.
3. Operating labor in off-specification is 1.5 times normal batches or $6.5M x .0635 x 1.5 = $619K/year.
4. Overtime ($400K in 1995) due to off-specification is 25% or $400K x 0.25 = $100K/year.
5. Disposal cost ($418K in 1995) includes 60% due to off-specification or $418K x 0.60 = $250K/year.
6. Other direct cost (operating supplies, energy, etc. at $3.5M in 1995) in off-specification is $3.5M x 0.0635 or $222K/year.
7. Claims ($2,000K in 1995) were 15% from off-specification or $2,000K x 0.15 = $300K/year.
8. Premium freight ($600K in 1995) was 1/3 from off-specification or $600K x 1/3 = $200K/year.

Calculations

$$Total\,Cost\,Equation\;for\;Off\;Spec.(K\$/Year)=\sum_{1}^{n}(All\,sources)$$

$$TCE=\sum_{1}^{n}(Direct\cos ts+indirect\cos ts+consequential\cos ts)$$

$$=\sum_{1}^{8}(1capacity+2\,raw\,materials+3labor+4O.T.+5\,disposal+6other\,direct+7\,claims+8\;freight$$

$$=\sum_{1}^{8}(1:2{,}270K+2:1270K+3:619K+4:100K+5:250K+6:222K+7:300K+8:200K$$

$$=\sum_{1}^{8}(\$5{,}231K\,/\,year)$$

Conclusion

Therefore, a 10% reduction is worth $523K/year.

Table 7. Incremental 10% "what if" improvement in profit-sensitive issues (K$/year).

Item	Issue	Basis	K$/Year
1	10% production increase/sales by debottlenecking existing plant processes/equipment*	Reference Figure 1: Variable/Fixed Cost Analysis (right hand column, Line 5)	$3,575
2	10% reduction in off-specification batches	Off-specification batches are 10% of total. 10% less reduces 10% to 9%.	523**
3	10% increase in labor productivity	Reference Figure 1: 10% of Line 2B	650
4	10% reduction in claims	$2,000,000 in 1995	200
5	10% reduction in working capital	$700,000 in 1995	70
6	10% reduction in utility costs	Reference Figure 1, Line 2D $500,000 in 1995	50
7	10% reduction in disposal cost	Reference Figure 5: $400,000 (1995)	40

* The purpose of developing values for an arbitrary 10% improvement is to compare the profit sensitivities of different cost issues. Nowhere in the standard industrial chart of accounts do we find the cost of off-specification batches or the value of a 10% capacity increase. The 10% figure is not a goal; more or less may be possible depending on the quantity and quality of the process improvements identified. The 10% "what if" figures are to be used to initially guide the Process Audit Team, and to assign value to an individual solution or a group of solutions for the cost issue.

** These are itemized as a Total Cost Equation (TCE) in Figure 11. The cost of off-specification batches includes many direct and indirect cost components, as well as the cost consequences of off-specification batches.

If the process is cutting steel plate, we might ask, "Why are they cutting me so fast? How can the cut be smoother to minimize a bottleneck in grinding? Why is the scrap bin in Step 8 so full? How much (percent) scrap is produced in Step 8 and at what annual cost?

Conceptual Process Thinking: The "Zero Scrap" Process

Conceptual thinking is characterized by imagining what the facility's operations would be like under ideal circumstances. An example would be zero scrap production. This has been referred to as "imagineering." If scrap production were zero, "How much materials could be saved? How much energy could be saved? How much less pollution would there be, and how much less labor would be required? One plant manager of a Fortune 500 company estimated that his hypothetical "zero scrap" process would require 40 percent fewer employees. That plant manager would have a hard time getting the 40 percent unneeded employees to help eliminate scrap (and therefore themselves).

A better way to state the issue and opportunity is to show that the zero scrap process would be so competitive that the business would grow by 50 to 60 percent and every employee would be needed. Furthermore, the zero scrap process would be so profitable from the added quality and additional sales that the employees would not only keep their job, but also receive bonuses.

Conceptual Process Thinking: The "No Cooling Tower" Plant

Conceptual thinking, similar to the hypothetical plant with zero scrap, is the manufacturing facility that has no cooling towers. The purpose of a cooling tower is to reject waste heat. A plant with many cooling towers must operate processes that produce large quantities of "waste" heat. These processes are thermally inefficient and good candidates for PO. One option is to recover and use the waste heat and eliminate the cooling towers. While recovering waste heat from a process may be an attractive project, a higher objective would be to modify the process to reduce the amount of waste heat to the point that it is no longer economical to recover. Management likes to save energy dollars, but they especially like solutions that avoid risky, capital intensive projects like waste heat recovery. Several options might be considered with regard to cooling towers and waste heat.

Option #1

Can the process be optimized to produce less waste heat? This would reduce the load on the cooling tower and, at the same time, reduce the requirements for heat input from plant utilities. This would be a win-win-win situation: (1) reducing cooling tower load that saves energy; (2) reducing process steam load that saves additional energy, and (3) creating new available capacity in both the cooling towers and the boilers. This available capacity has future value that can be quantified in today's dollars as NPV by deferring capital investment in additional cooling towers and boilers. A simple cost equation is required. Elimination of waste heat by process changes should be given top priority.

Option #2

Can the process waste heat be used or integrated into other process streams that currently use steam or hot water? This approach considers matching and cross-exchanging a cold process stream that requires heat with hot process streams that require cooling towers for cooling. The Audit Team would develop a simple heat sink-heat source diagram to consider heat integration by cross exchange. This is also a win-win-win situation as in Option #1, but this requires investment in heat exchange equipment.

Option #3

Can the process cooling loads be accommodated by shifting the duty on one lightly loaded cooling tower to another on the central cooling water loop? This provides the opportunity to shut down the lightly loaded, inefficient, unnecessary tower, saving significant fixed pumping and fan energy.

Process Flow Diagram, PFD (Step 4)

The first physical task in analyzing the existing process is to develop a Process Flow Diagram (PFD) for the major process steps. The properly developed PFD is a numerical picture of the process and its problems (Figure 6).

The PFD is one of the most useful tools for analyzing the existing process because it provides an opportunity to combine engineering data (material flow, cycle times, etc.) with cost data (scrap losses in K$/yr, etc.). The PFD is developed from discussion of the process steps and a walk-through process tour. The PFD begins on a flip chart with a list of steps indicating sequential material or workflow as boxes or blocks in series and in parallel. A process "step" is defined as any operation that significantly adds value to the intermediate product while consuming resources (people, materials, energy, etc). The PFD is "populated" with process data, economic information, and problem areas are highlighted such as: #1capacity bottleneck step, quality problem area, energy intensive step, high scrap step, etc. Figures 7 and 8 show example PFDs.

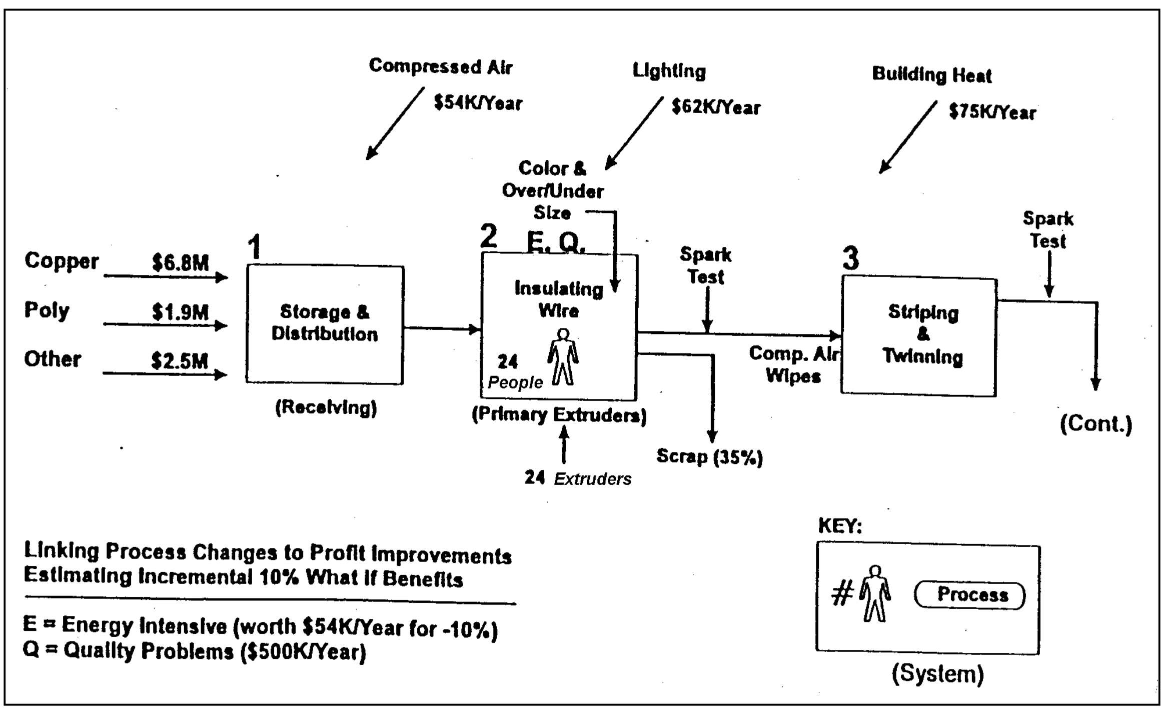

Figure 6. Block process flow diagram and weakness analysis.

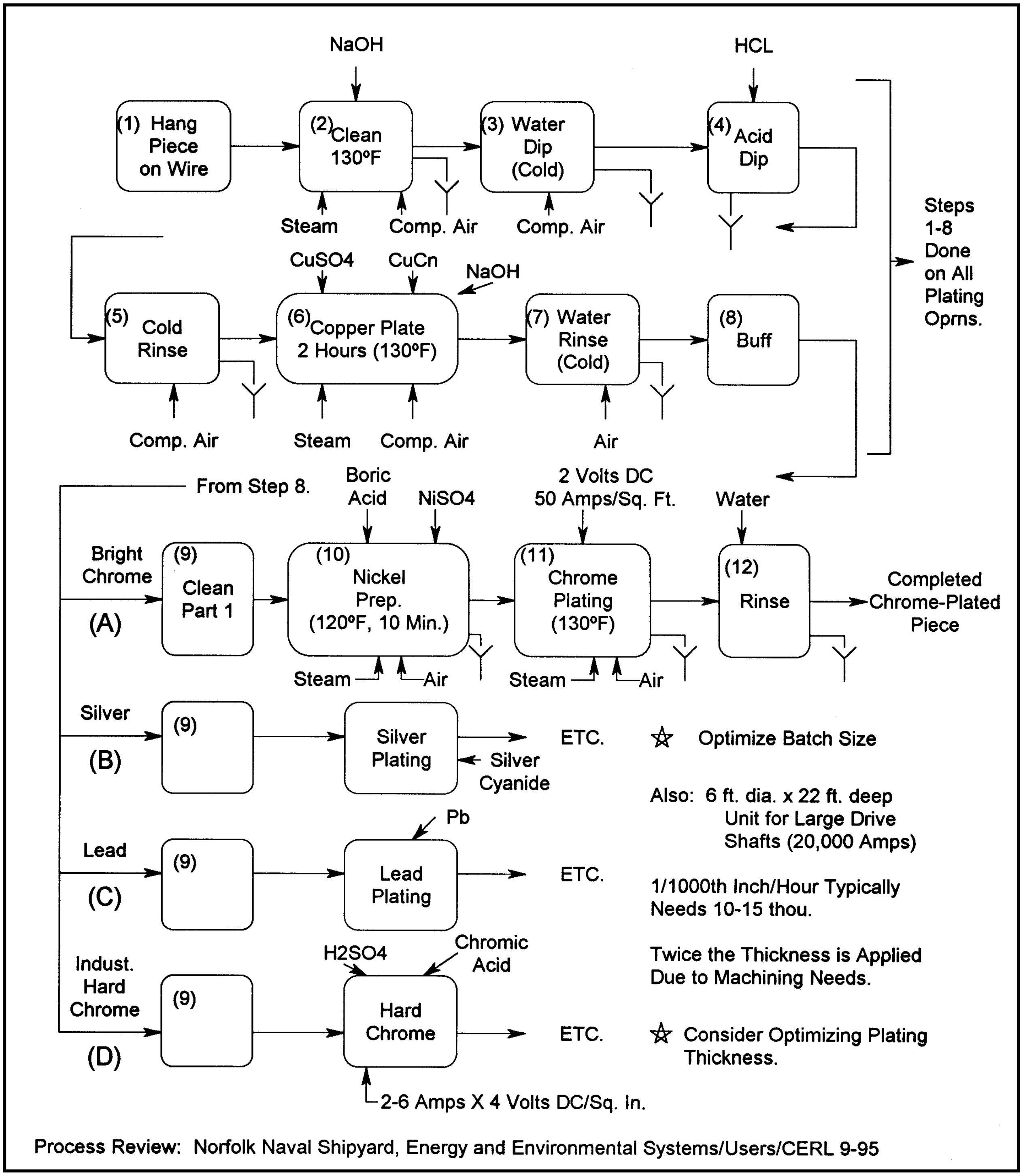

Figure 7. Process flow diagram – plating shop #36, Bldg. 195, Norfolk Naval Shipyard.

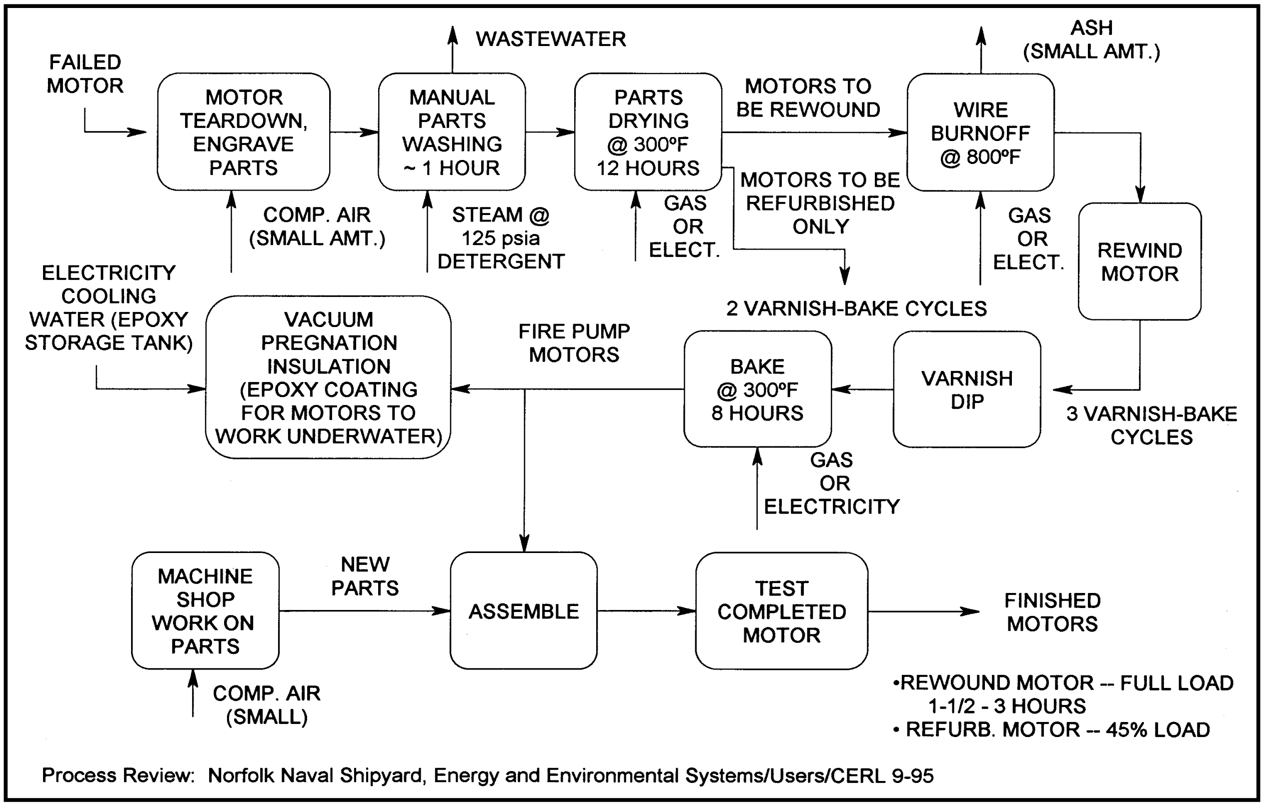

Figure 8. Process flow diagram – motor rewind process, Norfolk Naval Shipyard.

Process Energy Analysis Techniques

The PO guide for DOD facilities places special emphasis on energy and environmental issues as critical audit objectives. Facility energy data for consumption and costs for electricity, fuels, steam, etc., are collected.

One Line Balance

A One-Line Balance for Electrical presents a picture of electrical supply, distribution and end-use (Figure 9 and 10). Estimates are made of the power flow (kW) and cost (annual dollars) to major users (Figure 11). A One-Line Balance for thermal energy estimates the average annual steam flow (Klb/hour) and annual cost to major users (Figure 12). Figure 13 shows an OLB for water and wastewater.

Fuel Cycle Efficiencies

An estimate may be made of the facility-wide Fuel Cycle Efficiency (FCE). The FCE shows the large distribution losses that often exist in big manufacturing facilities. For example, Figure 14 shows 100 units of fuel input to the boilers only provides in 57 units of fuel to the process. This facility has very efficient boilers at 81 to 84 percent. Many large DOD facilities have FCEs well below 50 percent. The summertime FCE can be 30 percent or less.

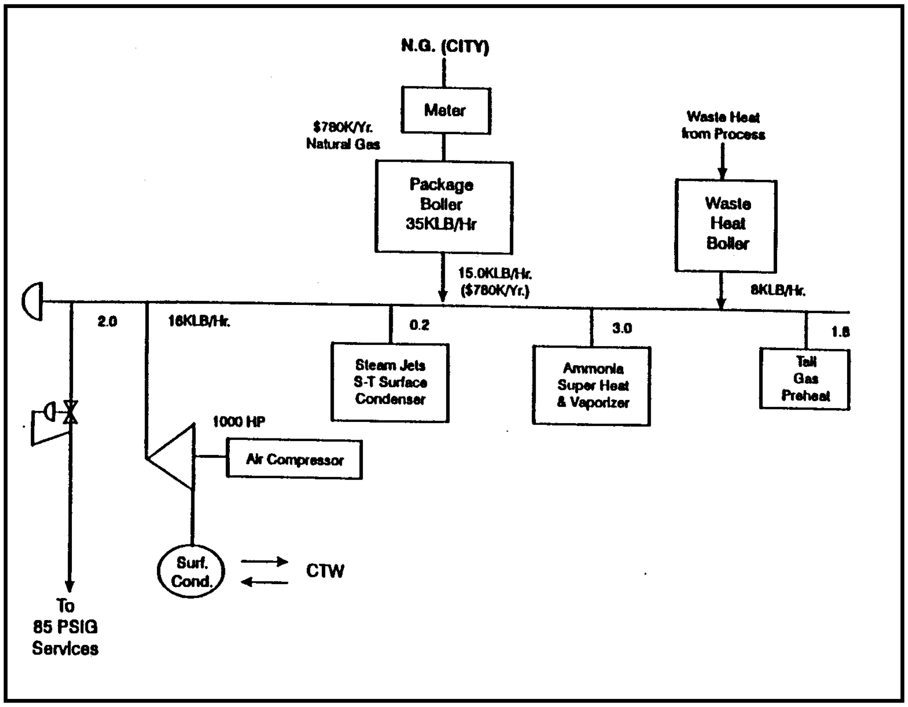

Figure 9. One line balance: steam, Norfolk Naval Shipyard.

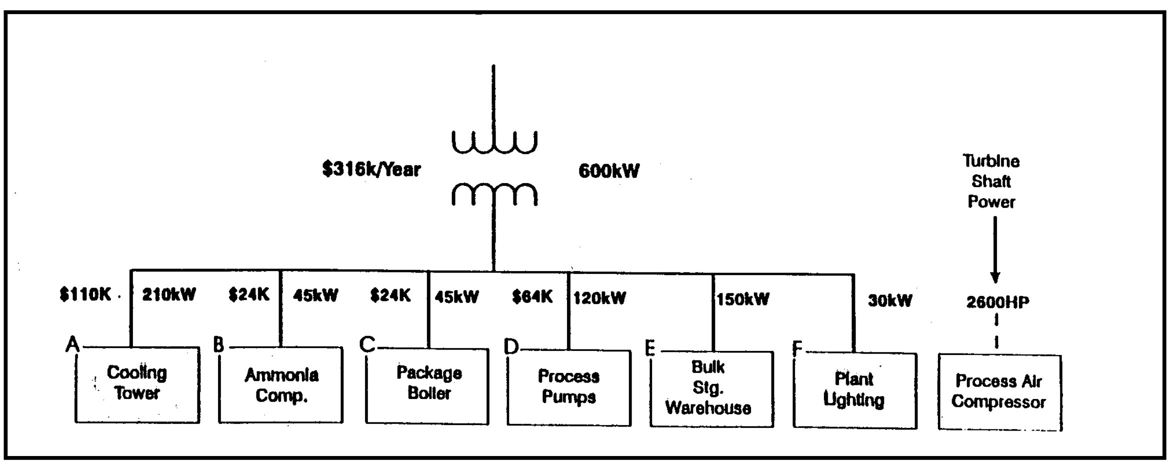

Figure 10. One-line balance: electric (basis: $316K/year @ $0.06/kWh = 5.25M kWh/year).

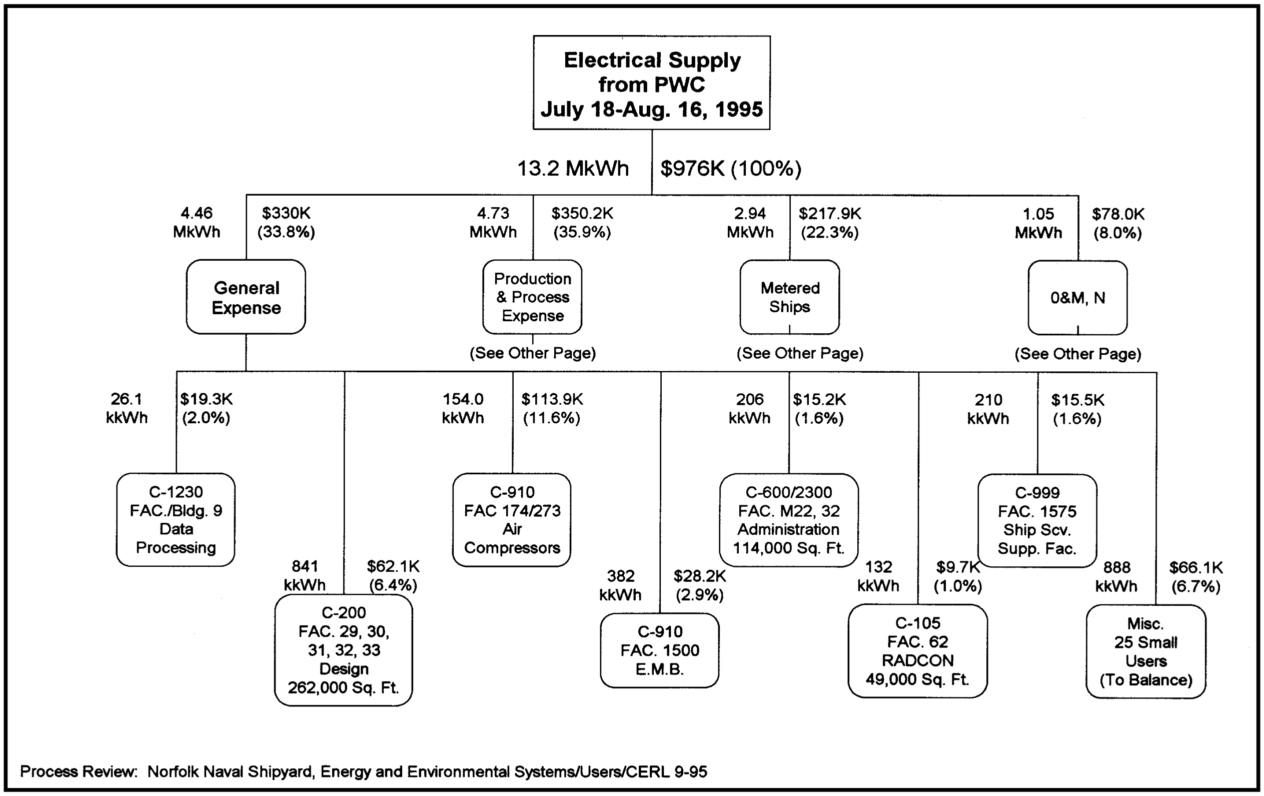

Figure 11. One-line balance: electricity, Norfolk Naval Shipyard, August 1995.

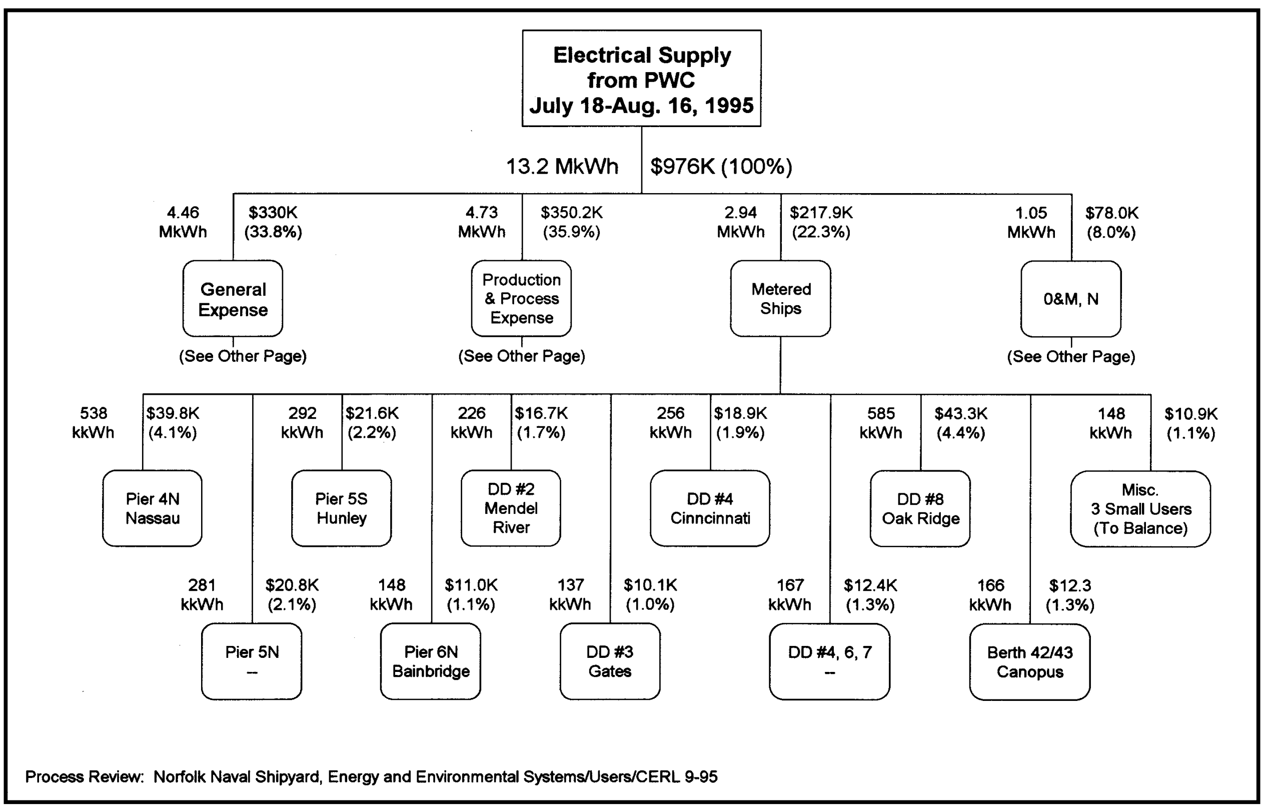

Figure 12. One-line balance: electricity, Norfolk Naval Shipyard, August 1995.

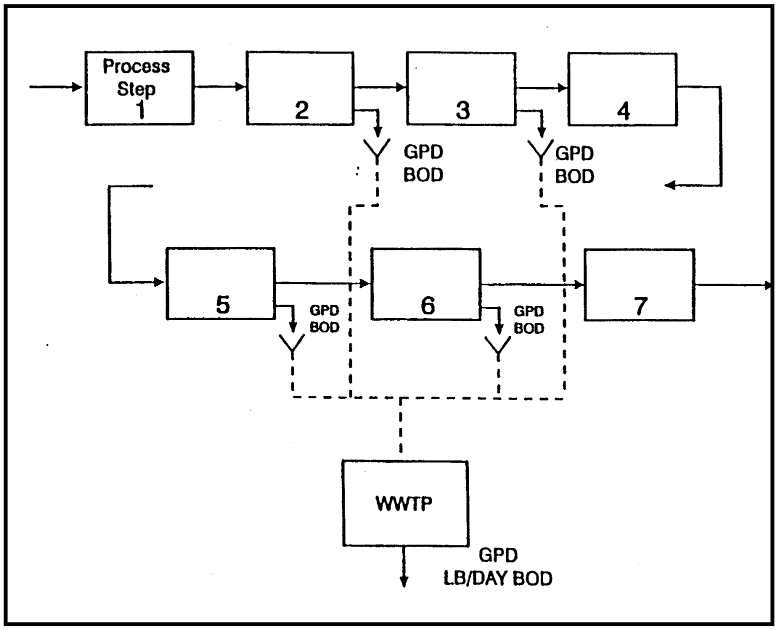

Figure 13. One-line balance: wastewater, Norfolk Naval Shipyard.

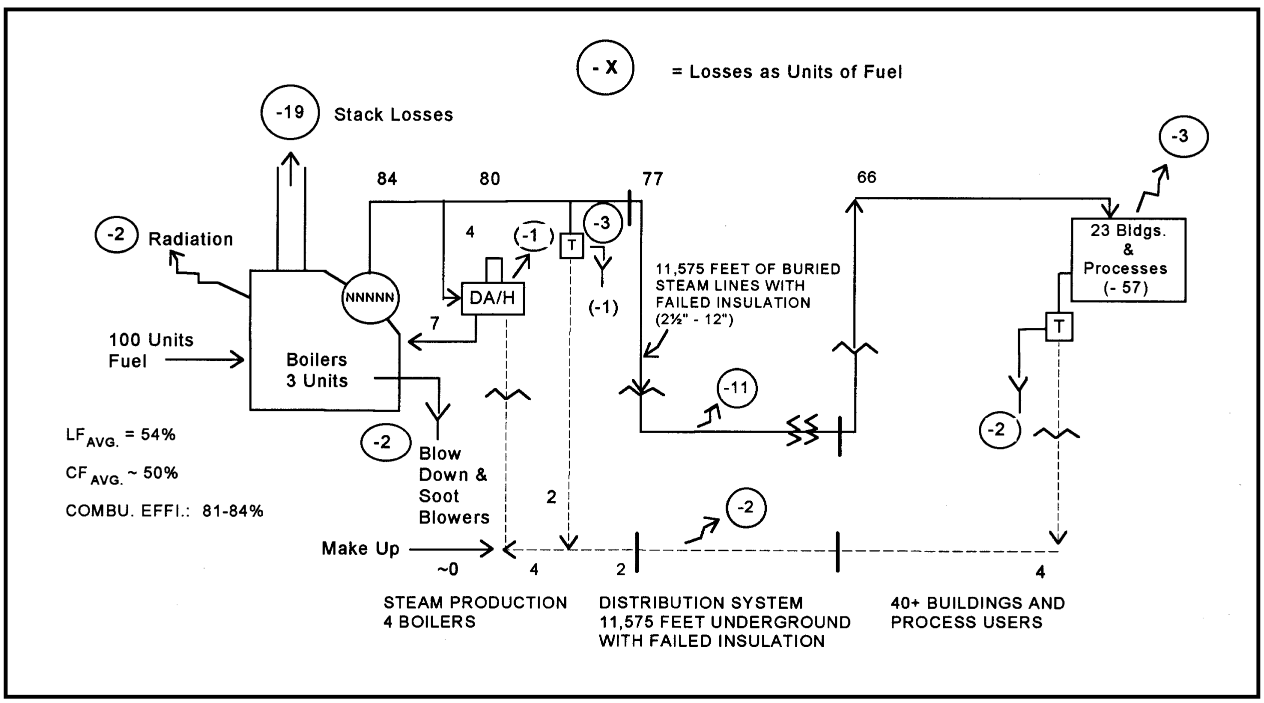

Figure 14. Fuel cycle efficiency.

Heat-Sink-Heat-Source Diagrams

A Heat-Source and Heat-Sink Diagram can be developed by the Audit Team to stimulate ideas for heat recovery (Figure 15). The Heat-Source and Heat-Sink Diagram is a Level I “pinch” analysis that considers the opportunities to cross-exchange the hot process streams which require cooling with the cold process streams that require heating. Currently, the hot streams use cold utilities for cooling (CTW, CHW, etc.) and the cold process streams use hot utilities for heating (steam, hot water, and downtime). The result minimizes both cold and hot utilities by process heat integration, saving significant amounts of energy. This is Option 2 for the “no cooling tower” plant previously mentioned. Typical industrial process heat recovery is only a few percent of total site energy consumption.

Weakness Analysis: A Picture of Critical Cost Issues (Step 5)

In the Weakness Analysis, the Audit Team focuses on where the process is flawed; problem areas are noted in the PFD. This is done by identifying and discussing specific problem areas in the existing process that contain critical cost issues. The team identifies the number one and two capacity bottleneck steps, the energy-intensive step(s), and the labor-intensive step(s). The team discusses where and why the process is weak with regard to each critical issue, and documents its findings on What-Where-Why Diagrams (Figure 16). The entire process as it is currently operated is questioned and challenged in Phase 2, setting the foundation for Phase 3: Creating the New, Modified (To Be) Process.

Phase 3: Creating the “To Be” Process (Steps 6 and 7)

The third phase of process optimization creates the “new” process by identifying both general and specific process changes that significantly improve the facility’s financial performance targets and objectives. The process operating conditions (temperatures, speeds, etc.) are challenged, and procedures and practices of the existing process are questioned. New technology is considered for specific process steps or more widely for substitution in broad process areas.

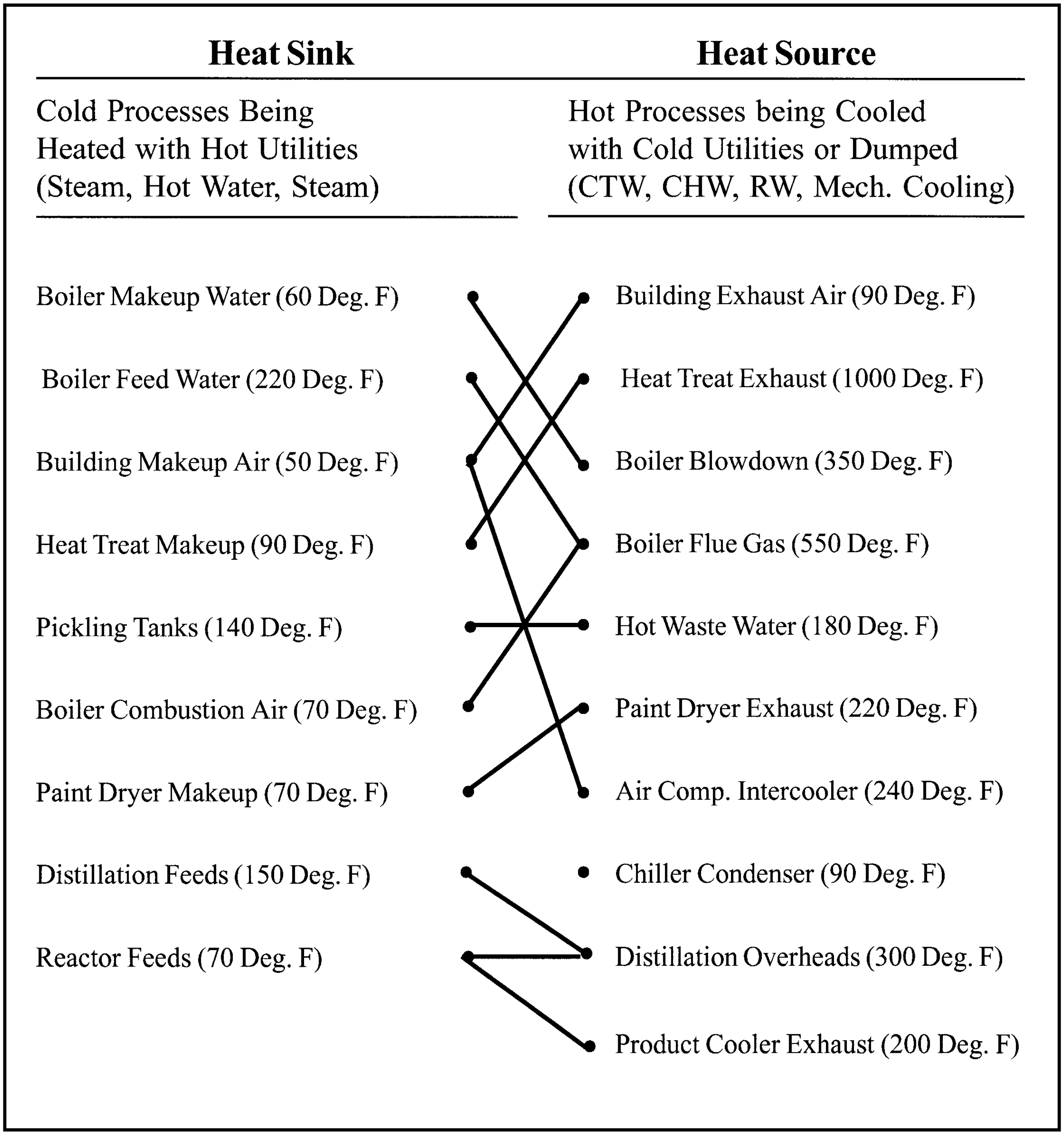

Figure 15. Heat sink-heat source diagram.

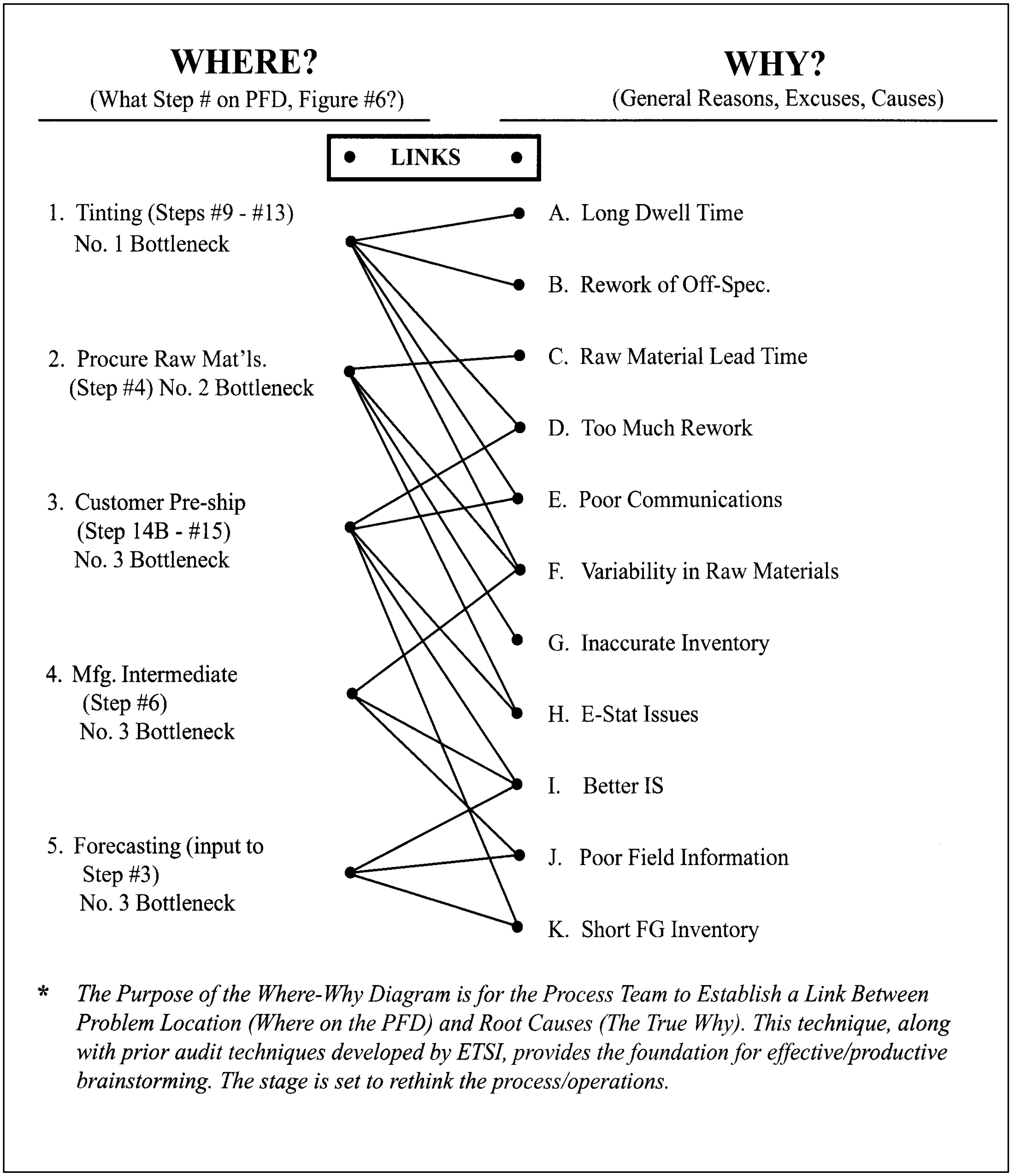

Figure 16. Where-why diagram: capacity bottlenecks (connect specific process "where's" with general "why's."

Learning To Be a "Process Thinker"

Typical process optimization thinking would:

1. Consider lowering or raising a temperature to improve the process performance, not simply to lower energy input. How can energy solve an operating problem?
2. Question the purpose of a particular operating procedures, even its reason to exist. Is the procedure adding a value and contributing to the facility's objective?
3. Consider the impact of a weekly production schedule or maintenance schedule on overall cost, labor productivity, energy efficiency, and environmental issues.
4. Combine production steps to eliminate an obsolete step or coordinate better to reduce delays between the steps.
5. Consider new technology to improve the performance of the existing process by using better communication devices and control systems.
6. Propose combining two departments, either physically or under a single management team.
7. Promote total system solutions by further use of team-based efforts such as practiced in the PO Audit.

How can the process better use its input resources (raw materials, labor, energy, etc.) and its outputs (product quality, plant capacity, and environmental issues) to achieve the facility objectives?

Processing technology is usually based on a combination of in-house technology and years of experience in specific processes. The success of a facility's operations is in how well it practices this knowledge and technology, and in the consistency of its application. Regardless of the performance level of the current process, it always seems that a Level I Process Audit identifies dozens of intriguing ideas and novel technical and operational solutions.

Using NGT to Identify Process-Based Solutions (Step 6)

An abbreviated, yet simple and effective, method is used to identify process-centered solutions. The method, called the Nominal Group Technique (NGT), requires silent idea generation. NGT is structured, time-compressed brain-storming rather than the traditional no rules style of brainstorming in which everyone talks at once. A detailed listing of the six NGT steps is found in Appendix C. The technique "forces" participation and concentration of all team members. The quality and quantity of the ideas are enhanced by total concentration on a well-defined Objective Statement. NGT requires silent, independent brainstorming (6 to 8 minutes) and silent listing of one idea at a time from each participant in round-robin fashion. Many of the best ideas, both old and new, are identified by the facility operating staff. The broad background of off-site personnel and their lack of detailed knowledge of the specific process are often an advantage in introducing new process thinking. The facilitating skills and expertise in process analysis of consultant participants are important in bringing the effort through the financial analysis (Phase 1), analysis of the existing process (Phase 2), and brainstorming solutions (Phase 3).

The NGT session(s) focus only on critical issues identified from the economic analysis done in Phase 1 and the physical/technical analysis in Phase 2. The most profitable and/or the best cost impact areas are typically found to be increases in production rate capability or maintenance and repair service capacity by debottlenecking, improvements in materials use (less scrap and rework), and labor use. These are the most lucrative for potential cost control because quite simply, they consume the most dollars.

Energy and site-specific environmental issues are particularly important target issues in this PO Guide. It has been emphasized that process changes that improve the use of facility capacity, materials, and labor (the high dollar issues), also simultaneously improve the performance of the energy and environmental issues. If operating capacity is increased by debottlenecking, then energy and environmental emissions are decreased per unit of output. For example, if output requirements are increased by 50 percent due to an “Alert Status,” energy per unit of output typically drops by 20 percent. If material use improves (less rejects, rework, and returns (the 3Rs) by process changes, then the energy consumed and emissions/wastes generated due to the non-productive secondary operations are eliminated. For example, if rejects are reduced from 15 to 5 percent for a production operation that is 10 percent energy, then overall energy is reduced by (15 to 5 percent) x 10 percent, or 1 percent. So energy and environmental performance are not only linked to each other, but also to the performance of the process operations. Improving one almost always improves the other.

Selecting “Best Ideas” (Step 7)

The “best ideas” must be selected based on the knowledge and experience of site personnel. The audit team, primarily site process experts, judges the economic benefits and costs for a particular process solution. The best ideas are selected by each participant distributing 20 votes among the brainstormed list, with up to 3 votes maximum per idea. The selection criteria are that the idea: (1) must contribute significantly to savings (i.e., $100,000 per yr, not $10,000 per yr), (2) must be “manageable” or “doable” with time and money (i.e., 1 yr, not 6 yr to implement and must be cost effective with acceptable simple payback), and (3) must be low risk. The “best ideas” are the 20 percent that receive the most votes; these will be developed with ballpark savings, cost, and payback.

Phase 4: Estimating Ballpark Savings, Cost, and Simple Payback (Step 8)

The goal of Phase 4 is to quantify the potential annual savings, total implementation cost, and simple payback for the top process improvement ideas. Economics are in the accuracy range of ±30 to 50 percent, definitely not precise engineering estimates. However, since the ideas have been selected as the strongest, most “doable” ideas, the paybacks are very short, typically well under 1 year. If a 6-month payback is incorrectly estimated and saves 40 percent less than expected and costs 40 percent more than expected, the payback is 14 months—still a very strong project.

There are several ways for the Audit Team to quickly develop ballpark economics on the best ideas. The first is from “factored estimates” using the Incremental, 10 percent “What If” annual Benefit Value determined in Phase 1. For example, if the total cost of scrap were calculated to be $3,800,000/yr at an 18 percent level, then a 10 percent reduction would reduce total scrap from 18 percent to 16.2 percent (1.8 percentage points). The contribution to savings from a 10 percent reduction in scrap would, therefore, be 10 percent of $3,800,000 or $380,000/yr. This factor; i.e., $380,000 per yr per 10 percent reduction in scrap, can be used to estimate the value of individual ideas to reduce scrap. For example, if idea #27 was, “Reduce scrap at the PFD Step #6 by improved temperature control in Step #4,” and the Process Audit Team’s consensus is that overall scrap can be incrementally reduced by 1 percent (i.e., from 18 percent to 17 percent), then the dollar value of this idea is approximately half (1.0 percent/1.8 percent) of the 10 percent figure. Therefore, the annual contribution to profits is (1.0/1.8) or 55 percent of the $380,000 per yr, or $211,000. If the team estimates that improved temperature control can be achieved with a $40,000 investment, the idea has a potential payback of 40/211 or 0.19 yr, only 2.3 months.

A second approach to estimating ballpark savings is for the Audit Team to consider scrap levels during times when temperature control was poor versus good. If knowledgeable facility participants estimate scrap levels were 21 percent ±2 percent during periods of poor temperature control and 17 ±1 percent during periods of good temperature control, the difference of 4 percent is attributed to control problems. Assuming improved control can be achieved 50 percent of the time, an average 2 percent reduction in scrap might be expected. If a 1.8 percent reduction is worth $380,000/yr, a 2.0 percent reduction is worth (2.0/1.8) x $380,000 or $422,000/yr.

The cost to implement the process improvements is also a responsibility of the Audit Team. Again, the local experience of site personnel and outside expertise of off-site participants are combined to provide ballpark expense and/or capital cost estimates to "install" the idea. A wide cost (and savings) accuracy range of ± 30 to 40 percent is allowed by the Audit Team to encourage the input and comfort level of everyone. Actual accuracy of the team's estimates is often better than this allowance.

Notice that the savings per year and the cost to implement ideas are primarily determined by **plant or facility experts** on the Audit Team. This on-site input, although preliminary and approximate, provides the answer to a frequently asked question of the PO methodology. We are often asked, "How can anything significant be discovered and quantified in only 2 to 4 days?" The answer is, "The quantity and quality of PO solutions are largely because we combine the experience and knowledge of key site personnel (very knowledgeable on facility operations and cost) with the process analysis and innovation techniques of the PO methodology and the process facilitation expertise of the consultants."

Phase 5: Developing Commitment for Implementation (Steps 9-12)

There are three critical times in the chronology of PO with regard to securing necessary management commitment and support. The first critical time is obtaining management approval to do the Level I audit, the second critical time is after the audit to get permission to pursue PO opportunities that require further development and capital investment (the Level II analysis), and the final critical time is in obtaining approval of funds for actual project implementation (detailed engineering, procurement, installation, startup, and commissioning). The second critical time period to secure management support begins at the audit debriefing/wrap-up session.

This critical time period ends during and shortly after the formal presentation of the final audit report to management, approximately 4 to 5 weeks after the audit. Suggestions on strategies to obtain this critical management support that keeps the PO effort from stalling are briefly addressed in the next section on the PO Audit Debriefing Session and more completely in Chapter 6, "Implementing and Sustaining PO Audit Results."

4 Process Optimization Audit Debriefing Session

A wrap-up debriefing at the close of a PO audit presents preliminary results and conclusions. Appendix D gives a 40- to 60-minute agenda in which individual audit team participants summarize initial findings. Preliminary economic results (savings, implementation cost, and payback) are presented for the “best” solutions to several critical issues. The “slam dunk” list (no cost/no risk) is summarized with estimated annual savings. Slam-dunk ideas can be implemented immediately because they have zero cost and zero risk – no one is required to approve a slam-dunk.

Purpose

The debriefing session has multiple purposes. The attendees are middle and top facility management along with the audit team participants. The first purpose is to present preliminary results, providing an opportunity for the management and audit team to clarify the technical assumptions and economic basis for the “best” PO ideas. This immediate group-review provides a “sanity check” as to how technically and economically solid the ideas are and how practical and doable they are.

A second purpose is to secure top management “buy-in.” The wrap-up debriefing session provides an ideal forum to secure the second pivotal time—getting permission to pursue the process changes (Level II analysis). This is done during the debriefing session when a particularly outstanding PO idea is presented by a site audit team member and the audit team says to senior manager, “If this idea, after further analysis and testing, is as good as it seems, will you support it?” The idea might save $120,000/yr without any investment, or it might be a PO capital investment that saves $600,000/yr with an installed cost of $200,000 for a 4-month payback. How can the top brass say anything but, “Yes – pursue the ‘development’ of the idea and, if it proves to be as good as it seems, we will provide the funding?” Once they have gone on record verbally, it makes pursuing the analysis further almost guaranteed.

A third purpose of the wrap-up, debriefing session is to begin initial prioritizing and planning for implementation (Level III). This involves presenting strategies and organizational means to define a path forward for Level II development and Level III implementation of the PO Audit results. The fourth (final) purpose of the debriefing session is to punctuate the Level I PO Audit with an orderly close.

The How-Why Diagram is a unique tool for initial implementation planning. The How-Why Diagram relates all randomly generated Process Improvement (PI) ideas to each other and to the object statement with the connecting questions: How-Why. The ultimate "Why," positioned at the far right of the H-WD, is to increase profit though process optimization by process change? The "How" ideas from the brainstorming lists to accomplish this goal, are positioned to the left, forming branching networks. Adjacent ideas answer the question "How" by looking at the idea to the left and "Why" by looking at the idea to the right. The resulting network of ideas, linked by How and Why, uniquely provide a road map pointing to the strongest set of solutions. Figure 17 is a standard format, relating all areas of profit improvement to each other and to profit ideas. The How-Why Diagram to specifically increase profits by optimizing energy is presented in Figure 18, which connects 65 Process Ideas as a Roadmap to Profits. Figure 19 shows the How-Why Diagram to specifically optimize capacity and other operations by connecting 35 Process Ideas as a Roadmap to Profits.

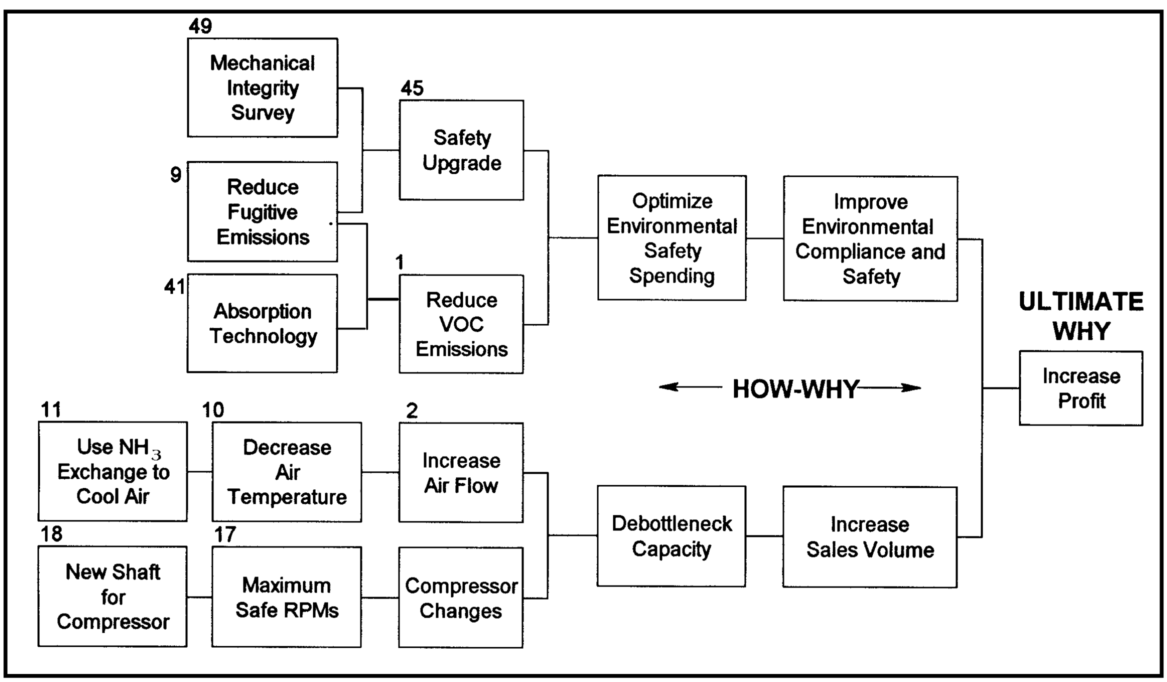

Figure 17. How-why diagram: connecting process changes to each other and to profits.

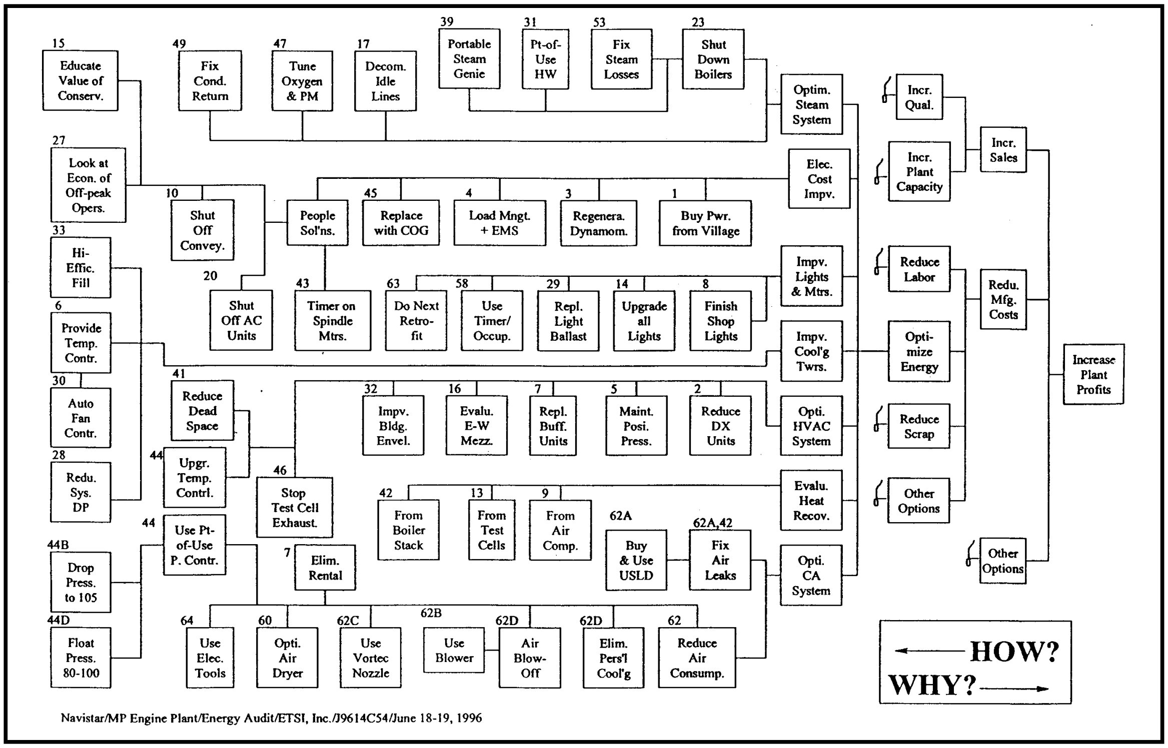

Figure 18. How-why diagram: connecting/grouping 65 energy improvement ideas to each other and to Navistar profits.

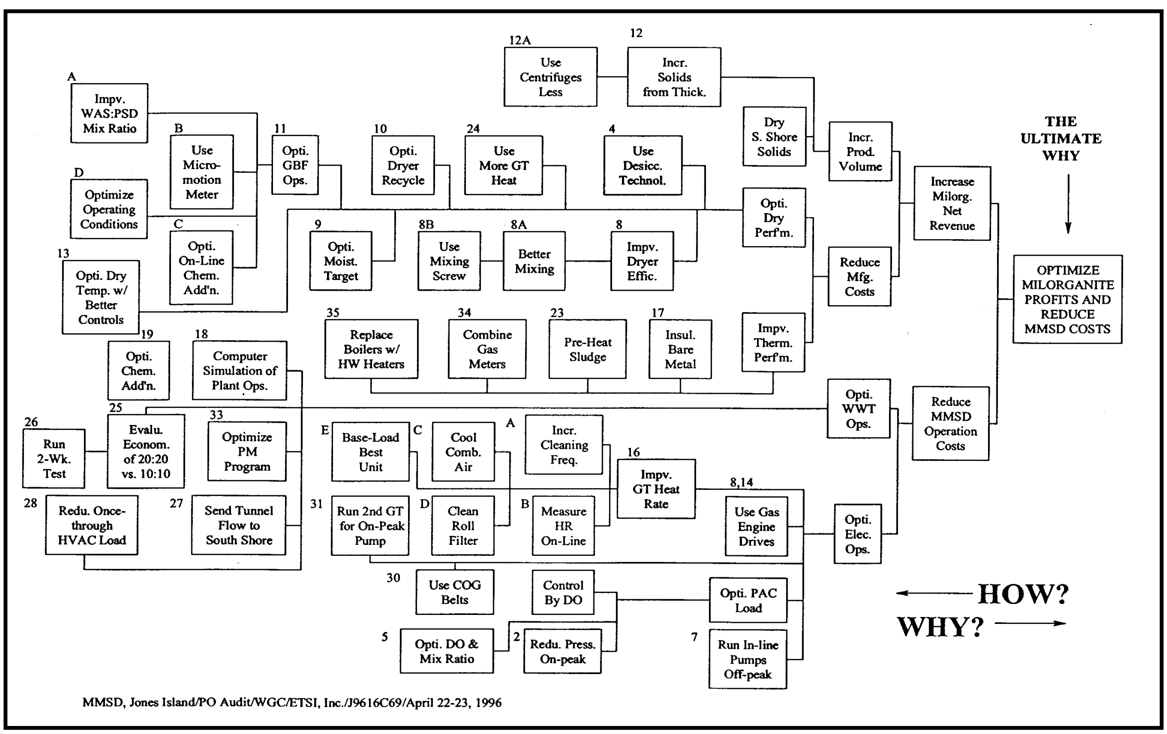

Figure 19. How-why diagram: connecting 35 process energy ideas to each other and to improved cost/profits.

Developing an Implementation Plan

The Level I Process Audit determines the economic potential from process changes. The 2 to 5 day analysis is not intended to be precise, but rather is meant to screen many process opportunities at a Level I depth in only a few days. The Level I analysis allows an approach of “guess at everything, measure nothing.” Fortunately, site experts provided the guesses. The quantity and quality of process improvements identified in the Level I Audit almost always suggest that significant potential exists. These potential gains can be accomplished by pursuing an aggressive PO program. The continuation of the PO methodology is typically recommended by conducting a Level II analysis, which develops the larger PO improvement ideas.

Successful on-time implementation requires efficient planning and project management but, to a greater extent, successful implementation requires interpersonal skills and experience in Organizational Behavior (OB) and group (team) dynamics. A simple, yet effective model is used: involvement leads to commitment, and commitment leads to implementation. This important subject is directly addressed in Chapter 6, “Implementing and Sustaining PO Audit Results” (p 89), by Dr. John K. Butler of Clemson University School of Management. Dr. Butler’s insights into the organizational behavior issues of PO come from his in-depth involvement and graduate teaching in the field and direct experiences in industrial PO Audits and PO Training Workshops (Sabbatical with ETSI: January-April, 1998).

The PO Audit Report

The PO Audit Report provides complete documentation of all audit results. The input for the report consists of the 30 to 50 flip charts that the audit team results developed during the on-site audit period. The report provides a concise Executive Summary that highlights how the Audit Team selected the target critical cost issue from a financial analysis of the process. The audit objectives, goals, and economic results are summarized in the Executive Summary. The report describes how the Audit Team followed the PO methodology to identify and quantify process solutions to the site-specific critical cost issue(s). Appendices A and B, respectively, give a Table of Contents and List of Appendices.

The report appendices document *all* flip chart results including: (1) the facility’s critical cost issues, (2) revenue (budget)/operating cost structure, (3) operating cost as percent of net revenue (or budget), (4) total cost equations for complex critical issues, (5) list of incremental 10 percent “What If” benefits, (6) the Process Flow Diagram(s), (7) Where-Why Diagram(s), (8) One Line Balances, (9) time-line diagram, (10) brainstormed lists of process improvement ideas, (11) How-Why Diagram, and (12) economic summary tables with basis for savings and costs.

A discussion of strategies and tactics for implementing the potential PO ideas provides an initial path forward. Conclusions, recommendations, and the next immediate steps are provided. A draft report of a Level I PO Audit is provided of the facility audit team within 3 to 4 weeks of site work.

5 PO Guidelines and Expert Advice For DOD Facilities

How and Where to Look for PO Opportunities in DOD Facilities

Process Optimization (PO) is achieved by first financially auditing the process. If the objective of a PO Audit is to fully achieve a DOD facility's mission of military readiness *at lower cost* without comprising safety, quality, or morale, then we must start with an analysis of existing operating costs. The financial analysis of the process provides audit direction and focus by targeting critical cost issues. Critical cost issues are problems or opportunities that regularly waste operating funds. Typical critical cost issues for DOD facilities (or any facility) are low use of facility capacity (overhauls per month), low use of processing materials (high scrap or rejects), or low use of manpower (low productivity or high rework).

The financial analysis also determines the annual value (dollars saved) by partially solving the number one and/or number two critical cost issues. This is done by capturing all annual costs that are directly, indirectly, or consequentially associated with the particular critical cost issue. Direct costs are labor, materials, etc.—variable with operating levels. Indirect costs are facility investments, insurance, overhead, etc.—fixed with operating levels. Consequential costs of a critical problem issue are costs that have secondary effects (result, consequence, and upshot). Examples are: high scrap or rejects not only consume direct costs of raw materials and labor but high scrap or rejects also consume facility production capacity; i.e., output is lower partly as a "consequence" of high scrap.

The next phase of the process audit uses special techniques to systematically analyze existing operating procedures, practices, operating conditions (temperatures, speeds, pressures), and current technology. Conceptual process modeling is used to quickly understand the basic production steps and the value added by each step. A "conceptual" process model, in its simplest form, is to imagine that we are raw material that is being converted by many steps into finished product. Why are "they" heating us up (to 150 °F); what is magic about 150 °F (why not 140 °F or 170 °F?); why are "they" cutting us and producing so much scrap, etc.?

We can “identify” with the process and achieve a completely different perspective when we “think like a piece of raw material.”

For DOD manufacturing and maintenance processes, thinking like a piece of raw material or operating supplies would be to imagine we are plate steel to be used in the repair of a damaged naval aircraft. Process operation might include cutting, grinding, welding, cleaning, machining, painting, or plating. Or we might be a critical electronic part from a certified supplier to be installed in the upgrade of an aircraft navigation, missile guidance, or communications system. The installation of the part may be routine, but for a variety of reasons the installation requires excessive time and many attempts before passing final testing. In this case, we must think in the first person like the electronic part questioning and challenging the many series and parallel installation steps from initial inspection to final testing to eliminate the many causes that result in delays.

A Process Flow Diagram (PFD) is a picture of the existing process. The PFD is an import visual aid for several reasons. First the PFD, which is progressively “developed” by the audit team over a 30- to 60-minute period, results in a basic understanding by the entire Audit Team of the existing process steps as they are currently done.

Second, the PFD is “developed” in such a way as to always include and emphasize process steps that involve the critical cost issue(s). If a critical cost issue is an operating bottleneck that consumes excessive time, then the particular bottleneck step would be provided with estimated data, including “time-in-step” (average, shortest, longest, and theoretical).

A “time-line analysis” would also be developed to identify causes for delays and to note individual time periods for each cause. The time-line would be generally divided into “uptime” and “downtime.” The Audit Team would develop existing operating data on uptime to include: machine speeds, cycle times, and manpower staffing. The Audit Team would also develop estimates of downtime delays including delays in scheduling, waiting on parts, communication, travel times, manpower, etc.

A third unique feature of the PFD is that steps involving the critical cost issues are “populated” with both technical *and* cost data. For example, the Number One production bottleneck step would be provided with input and output data of maximum production rate ceiling, cycle times, temperatures, yields (or reject rates), and labor (head count on direct and support labor). However, uniquely, the bottleneck step would *also* be provided with estimates of the annual cost impact and/or cash flow. For example, the annual savings from a 10 percent increase in output/productivity would be clearly identified on the bottleneck step. The annual cash flow of raw materials input and intermediate product output would be identified for the high scrap step, as well as the total annual cost of scrap. The labor-intensive step would be indicated by annual labor cost input (20 people at $35K/yr or $700,000/yr). Likewise the energy intensive step would show an estimated consumption of Btus and kWhs as both quantity and annual dollars.

Identifying, analyzing, and quantifying problem areas are referred to as Weakness Analysis of the existing process steps. A Where-What-Why Diagram done as three columns on a flip chart provides the Audit Team with an integrated perspective of the problem location, its effect, and its possible causes. Where is the process flawed (step # on the PFD), what is specifically flawed, to what degree, and why (causes)? The entire process as it is currently operated is challenged and questioned. This sets the stage for the Audit Team to create the modified/improved process by identifying process changes to solve the target critical cost issue.

PO Audit Scope of Work for DOD Facilities

The following paragraphs define the general Scope of Work:

Location: The project location is:

A sample list of DOD processes and facilities are provided.

Objective: The objective of the project is to conduct and present a Process Optimization Audit. The Process Optimization Audit seeks to improve processes, reduce costs, and will have emphasis on, but not be limited to, energy, environmental, and water conservation aspects of the industrial processes involved. The ultimate goal is cost reduction for this facility. The Process Audit Team should identify all possible Process Improvements/Energy and Environmental Conservation Opportunities (PI/E-ECOs) and develop some of these into Process Improvement/Energy and Environmental Conservation Projects (PI/E-EECPs). The Process Audit team should also evaluate, and make recommendations on all possible no-cost or low-cost operating and maintenance efficiency improvements. The audit will provide PI/E-ECPs with ballpark economics including net annual savings, total installed cost, and simple payback.

Scope of Work: The Level I Industrial Process Audit should involve preliminary calculations and analyses (engineering and economic) of individual processes, equipment, electrical and mechanical systems, process HVAC systems, and selected utility distribution systems. The focus is 80 percent on how energy is used, and 20 percent on how it is provided to the end-user. The audit tasks include, but are not limited to, developing various PI/EECPs, with approximate cost estimates containing sufficient detail such that PI/EECPs can be further evaluated to the point of direct funding.

General DOD Processes for PO Audit Scope

Army Processes: Steam cleaning vehicles and parts, disassembling vehicles, electroplating vehicle components, heat-treating components, abrasive blasting for removing old paint, machining, welding, engine and transmission overhaul, vehicle testing (dynamometers), sheet metal fabrication, assembling vehicles, spray painting vehicles and parts, electronics repair.

Air Force Processes: Cleaning aircraft and parts, disassembling aircraft, electroplating aircraft components, heat-treating components, stripping and blasting for de-painting aircraft, machining, welding, engine overhaul, sheet metal fabrication, assembling aircraft, spray painting aircraft and parts, random repair, electronics repair.

Navy Processes: Heat-treating components, stripping and blasting for de-painting parts and components, machining, welding, boilermaking (boiler overhaul), shipfitting (fabricating ship components), pipefitting, sheet metal fabrication, assembling ship components, spray painting ships and parts, motor rewinding, electronics repair, maintenance of diesel and nuclear power systems.

PO Audit Goals for DOD Facilities: NADEP, San Diego

The following are example PO Audit Goals for Process Auditing at the Naval Aviation Depot (NADEP) on North Island in San Diego, CA. The PO Audit goals should be achieved by the completion of PI/E-ECOs identified and developed during the audit:

1. *Perspective*: All PI/E-ECOs should be proposed based on energy, environmental conservation, and financial results and should be evaluated from a perspective of the DOD as opposed to a perspective of the Individual Activity occupying a particular facility, building, or area.

2. *Maintenance*: Minimization of maintenance requirements is considered a goal. However, all potential PI/E-ECOs are to be considered with specific characterization regarding maintenance increases or decreases.
3. *Reliability*: Maximization of reliability shall be considered during PI/E-ECO evaluation development. Any measure not increasing the overall or individual reliability of the system shall be so noted.
4. *Database*: All data should be input into a database that can be sorted.
5. *Cost*: Minimization of net total costs is a direct objective. This includes costs associated with utilities, maintenance, reliability, and manpower, all of which directly contribute to owning and operating the technologies proposed as compared to existing technologies.
6. *Increased Quality*: A direct objective of this project will be to provide the Government with increased quality for both existing and proposed equipment and systems that are recommended.
7. *Increased Useful Life*: Increased useful life of equipment and systems at the affected activities is considered a goal.
8. *Permanence*: Providing permanence of the installed PI/E-ECO related to this project is also a direct goal.

Example Processing at NADEP, San Diego

The following examples are existing manufacturing and maintenance processes and critical cost issues being analyzed and optimized at DOD Naval Aviation Depot (NADEP) in San Diego, CA:

1. Sling Test Facility - Weight Test Equipment
2. A/C Overhaul Rotary Wing Bldg. - Autoclave, Anodizing
3. A/C Metal Parts Fabrication Repair Building. - Welding
4. Overhaul & Repair Bearing Shop - Cleaning - Alternative Process, Cleaning Exhaust - Chem. Vapor Loss, Scrubber Chemicals, Safety
5. Repair Shop Bldg. - Foundry, Painting, Drop hammer
6. Engine Test Stand Bldg. - Test Stand

7. O&R A/C Engine Overhaul Shop - San Blast, Metal Fabrication

8. Composite Remanufacture/Repair Facility - Vacuum System

9. Engine Overhaul Shops Bldg. - Flow Bench Welding, Sandblast/Shotpeen - CA.

10. Sandblast/Shotpeen Alternative Process, Sandblast/Shotpeen - Safety

11. Helicopter Rotor Blade Test (Spin Tower) - Motor Generator - 1 Frequency Generator

12. Avionics Shop - Motor Generator - 2 Frequency Generators

13. Stripping Bldg. #2 - Aircraft Washdown

14. Stripping Bldg. #1 - Aircraft Washdown

15. Repair & Misc. - NAVAVNDEP

- Heat Treat - Local Vacuum Furnaces
- Painting - Powder Coat vs. Paint, Infrared Heating, Increase Throughput, Oven Heat Loss
- Plating - Water, Steam, Drag-out, Energy, Pollution
- Plating Exhaust - Chem., Vapor Loss, Scrubber Chemicals, Move to Above Tanks
- Plating - Tank Air Agitation, Oven Energy, Tank Covers
- Cleaning - Water, Steam, Drag-out, Energy, Pollution
- Cleaning Exhaust - Chem. Vapor Loss, Scrubber Chemicals, Move to Above Tanks
- Cleaning - Tank Air Agitation, Oven Energy, Tank Covers
- Sandblast/Shotpeen - Compressed Air, Alternative Process, Safety

Processes and Potential Recommendations: NADEP, San Diego

The following are manufacturing and maintenance/repair PO Audit scope and potential recommendations:

1 PLATING

1.1 Recommend and provide economic analysis of methods to reduce water usage

1.2 Recommended and provide economic analysis of methods to reduce steam usage

1.3 Recommend and provide economic analysis of methods to reduce dragout of chemicals

1.4 Recommend and provide economic analysis of methods to modify the present process to reduce energy, water, and/or pollution

1.5 Recommend and provide economic analysis of methods to reduced airflow over cleaning tanks with resultant chemical loss and required treatment of the chemicals that go into the various scrubbers

1.6 Recommend and provide economic analysis of methods to eliminate air agitation in applicable tanks

1.7 Recommend and provide economic analysis of methods to reduce energy usage in ovens

2 CLEANING

2.1 Recommend and provide economic analysis of methods to reduce water usage

2.2 Recommended and provide economic analysis of methods to reduce steam usage

2.3 Recommend and provide economic analysis of methods to reduce drag-out of chemicals

2.4 Recommend and provide economic analysis of methods to modify the present process to reduce energy, water, and/or pollution

2.5 Recommend and provide economic analysis of methods to reduce airflow over cleaning tanks with resultant chemical loss and required treatment of the chemicals that go into the various scrubbers

2.6 Recommend and provide economic analysis of methods to eliminate air agitation in applicable tanks

2.7 Recommend and provide economic analysis of methods to reduce energy usage in ovens

3 SANDBLAST/SHOTPEEN

3.1 Recommend and provide economic analysis of methods to reduce compressed air usage

3.2 Recommend and provide economic analysis of alternative equipment to produce the same or similar cleaning or surface

3.3 Provide layout of proposed equipment

3.4 Recommend and provide economic analysis of methods to provide more safety to operators

4 HEAT-TREAT

4.1 Recommend and provide economic analysis of providing all vacuum furnaces in heat-treat shop

4.2 Provide layout of proposed equipment

4.3 Provide spreadsheet listing of proposed equipment if readily available from facility records: manufacturer, part number, unit cost, number of units, total cost, installation labor cost per unit, material cost per unit, total installed cost, triaging cost, time to install, time existing equipment will be out of operation, methodologies to prevent downtime on a critical component

5 PAINTING

5.1 Recommend and provide economic analysis of providing powder coating of parts painting

5.2 Recommend and provide economic analysis of providing infrared heating as applicable to painting operations

5.3 Investigate methods to increase throughput of shop

5.4 Recommend methods to prevent heat being lost from ovens not being used for production - walk-in oven and overhead oven

6 BEARING SHOP

6.1 Recommend and provide economic analysis of alternative methods of bearing overhaul, i.e., a completely automated bearing cleaning facility

6.2 Alternatively, recommend and provide economic analysis to revise the ventilation system in the shop to provide a safe environment for the operators to reduce fume drag-out

7 AVIONICS SHOP

7.1 Recommend and provide economic analysis of providing two solid state generators versus the four motor-generator sets

8 SPIN TOWER

8.1 Recommend and provide economic analysis of providing one solid state generator versus the existing motor-generator set.

Expert Advice: PO Strategies and DOD Process Descriptions

Expert advice seems to imply immediate, precise answers to almost any questions on any subject. A complete database of process solutions may be available in the future, but they are not available today. This is because, in general, processes are far too diverse, complex, and unique to have a set of immediate solutions to all questions concerning a particular process's critical cost issues. Perhaps a better introduction to this section is Expert Guidance. Nevertheless, we will use Expert Advice with the qualifying statement above.

The PO Team of Expert Advisers

The singlemost important expert advice is to start the PO Audit with a team of local experts, follow the ascribed PO methodology, and watch the psychology of the PO Audit operate inside the Audit Team.

The fundamental premise and psychology of the PO Audit is quite simple. The premise is that the local experts already know what the critical cost issues are and have already identified most of the answers. The problem is often that: (1) the experts do not have time to work on PO solutions, or (2) they are working independently, not as a team, and/or (3) they are not using systematic PO methodology to quickly identify, screen, and quantify their solutions.

The PO Audit is often questioned by facility insiders and outsiders. How can anything significant in the way of optimizing a process be accomplished in only a few days during a PO Audit? After all, isn't someone supposed to be working on process optimization? The answer is yes, but probably not using a fast, intense, highly structured PO methodology.

Dramatic PO results are possible because of group dynamics, synergism, and the "open team play" that occurs in the PO Audit under the following Audit team selection criteria and perquisites:

1. The PO Audit Team must consist of the "right people," carefully selected from site experts who are or could be actively involved in process improvement.

2. The Audit Team includes participants from different backgrounds, bringing many common, but also unique experiences and skills in the specific <u>critical cost issue areas</u>. Multiple level teams are encouraged from within the process area organization.

3. The PO Audit Team is encouraged to explore unproven ideas, take personal risks, and provide approximate, not precise, guesstimates and estimates.

4. A final audit team selection criterion is that individuals should ideally be creative people, team players, and good guessers/estimators.

Expert Advice for DOD Processes and the PO Team

The following expert advice is provided for PO Audits of military manufacturing and maintenance facilities. The facility mission is superior military readiness with today's necessary objectives of optimum lower overall cost, energy efficiency, and environmental compliance.

The PO approach holds great potential for improving the process operations of typical DOD manufacturing and maintenance facilities. These processes include metal working (heat treating, welding, etc.), cleaning and plating, de-painting and painting, explosives and chemicals production, LAP (load, assemble, and pack) line operations, and utility systems (comp. air, water steam, electricity, motors, etc.).

The following discussion is not intended as a detailed technical treatment of these processes, but rather to illustrate special PO techniques and considerations. The illustrations should be combined with the three lists of Expert Advice on General PO (26 ideas), Utility Systems (71 ideas), and Energy/Water (296 ideas) presented at the end of this section.

The PO Approach and Analytical/Innovation Tools

In each case (metalworking, painting, etc.), the five-phase/twelve-step PO methodology should be generally followed (Figure 1). It is important to "second guess" what the critical cost issues are before the audit analysis and innovation session is scheduled to be sure the key, local experts are available to participate. If scrap is a target issue in the facility machine shop then the key individuals that make scrap, measure scrap, and dispose of scrap should be properly represented during the audit session. Furthermore, each audit team participant should have reviewed his personal PO audit notebook prior to the audit session (see PO Notebook, Appendix A). Of particular importance are the audit objective, goals, manner in which it is done, and audit team preparation items like individual lists of critical cost issues to facilities.

Metal Working

Metal working for DOD facilities involves dozens of different processes (heat treating, cutting, welding, machining, etc.). In all cases, the top one or two critical cost issues must be identified by the audit team, their total annual cost impact (cost equation) estimated, and the arbitrary 10 percent factor calculated. If high scrap is a target issue, the total annual cost equation for scrap must be estimated based on the existing scrap level. The total cost impact of 18 percent scrap level would include the following annual costs: (1) directs costs “in” scrap (materials, direct labor, energy, etc.), plus (2) indirect costs “in” scrap including: fixed equipment cost at a 10 percent (?) replacement value, fixed labor costs, fixed facility overhead cost, etc., plus (3) consequential costs “in” scrap including the fact that scrap reduces machine shop capacity/output per week, scrap results in additional environmental emissions, and scrap results in “secondary operations” of collection, storing, disposing, etc. The total annual cost of scrap varies widely for manufacturing and maintenance operations, but it is often 3 to 5 times what facility management thought and typically 1 to 3 times the unit cost of first quality product.

Scrap and its measurement should be precisely defined for the DOD processes under consideration. The definition may be “all purchased materials that do not end up meeting Military Specifications and are not available for consumption.” This is a common scrap definition that would include all unavoidable “waste” (scrap from cutting disks out of plate steel), all rejects (disks that were not circular), and all in-process parts that cannot be reworked. However, this introduces the concept of First-Pass-Yield (FPY) versus overall yield (OAY). Of 100 units of starting materials how many were first quality and made it into the field for consumption without any secondary operations (in-process rework or as reworked of returns)? It could be that, of 100 units of starting material, 10 units were rejected as scrap to the dumpster, 20 units were reworked in-process, and 6 units were returned for upgrade rework. In this case the FPY is 100-10-20-6 or 64 percent. Overall yield would be 100-10 or 90 percent. However, if half of the in-process rework and up-grade (returns) rework were later rejected to the dumpster, the FPY would still be 64 percent but the overall yield would now be 100-10-10-3 or 77 percent, not 90 percent. The local definitions of scrap, yields, and the 3 Rs (rejects, rework, and returns) must be openly discussed for clarification and complete audit team understanding.

Cleaning and Plating

Cleaning and plating at DOD manufacturing and maintenance facilities involve metal/part surface preparation and metallic coating processes. These processes usually involve hot aqueous solutions of acids and/or inorganic metals resulting in significant hazardous waste water generation. Again, as in metalworking, the first audit team task is to financially analyze these processes. The critical cost issue is usually the environmental impact from hot, acidic, or heavy metal liquid wastes. The cost impact, however, must also recognize the cost of raw material losses, sewer, and energy losses. The total cost equation for these process discharges can easily be 10 times the initial water cost to include 3 to 4 times chemical costs, 2 to 3 times in sewer charges, and 1 to 2 times in energy (Btu) value.

A useful PO technique to analyze water/wastewater discharge is an “inverted” one-line energy system balance (Figure 9). The typical PO one-line energy balance starts at the top of the flip chart with boilers or air compressors and estimates the total lb/hr or CFM generation (top), distribution by pressure level (mid chart) to all process end users (K lb/hr or CFM). The task is to account for all generation, including losses. The same technique can be applied to environmental systems. In this case, the process end-users are at the top (not bottom) of the one-line diagram. The energy “distribution” system diagram takes the form of an environmental wastewater “collection” system diagram. The wastewater treatment plant for process discharges is a final convergence point at the bottom of the flip chart. All streams are estimated as to flow rate (MGD) and concentration (ppm).

This type of analysis leads to a PFD of waste and wastewater. The audit team can now focus its analyses and innovation skills on how to modify the cleaning and plating processes to produce less waste by changing (optimizing) the process(es). The approach is an “up-the-pipes and/or down-the-stacks” concept that recognizes that often the best solution to waste water is to change or modify the process to make less — not to improve the efficiency of the WWTP.

De-Painting and Painting

Many DOD facilities are responsible, as part of long-term scheduled maintenance, for repainting of a wide variety of military equipment. This equipment varies in type and size from light vehicles to tanks, aircraft support equipment to C130s, and small Coast Guard vessels to aircraft carriers. In all cases the processes involved required de-painting (surface preparation) and painting. The total cost of these processes is rarely known. These processes, depending on the level of detail, can be represented as PFDs with 10 to 30 process steps in series and parallel. Three critical cost issues with paint/de-paint are materials (paint) losses, energy (compressed air), and environmental emissions. These processes are reviewed in this context.

The critical cost issues for painting are: (a) materials (#1), (b) labor (#2, sometimes #1), and (c) environmental/energy #3/#4. Materials (paint) losses largely depend on the (1) type of paint, (2) the method of application, (3) practices of the organization/work force, and (4) the requirements of the customer(s). Likewise, labor costs and impact on energy/environmental issues also depend on the same four factors: (1) type of paint, (2) how it is applied, (3) operating practices, and (4) customer demands. Other cost issues and operating situations vary, but generally, the factors listed largely determine the paint/de-paint process performance (quality, output, efficiency, or reliability compliance).

The facility personnel that are directly involved in paint/de-paint understand local paint processes better than anyone else and, as usual, are critical to the PO efforts. The PO methodology is provided solely to enhance the ongoing efforts of process improvements in these operations. Material losses must first be quantified.

If the DOD equipment to be painted is an airplane, what is the paint yield? How many gallons of paint end up "on" the plane compared to gallons consumed? Material yield practices for typical paint systems vary widely from 50 to 90 percent. Several paint and application technologies dramatically improve yield, energy, and environmental performance. These are electrostatically applied powder paint and High Volume, Low pressure (HVLP) spray guns. These should be considered as potential PO solutions.

Paint "practices" are also very important in optimizing yield, productivity, quality, and energy/environmental performance. Practices are *more* important than procedures in that practices are what actually happen, while procedures are what are written in the "book." The two frequently are not the same and often neither one will produce an optimum end result. The PO Audit Team should look carefully and circumspectly at the de-paint/paint practices and procedures.

Finally, there are customer requirements. These, in the TQM context, would largely determine the required results. Customer requirements are extremely important. For military products and services, it can mean the difference between mission success and failure, which is ultimately measured in winning or losing. The customer requirements are military readiness, 100 percent of the time at 100 percent of the *required* level. If history repeats, the recent dramatic change in the world stability could be short lived.

Painting is an energy and environmental intensive process. This industry has, within the last 10 years, greatly reduced waste in materials and energy. Significant progress has also been made in environmental performance. Today powder coat paints are available with 40 to 80 percent less solvent emissions. The PO Team should consider what, how, and at what value can powder coat paint systems replace the solvent (VOC) systems.

A second PO opportunity exists in considering the application of water-borne, non-solvent based paints to reduce the VOC environmental problem of hazardous solvents and global warming from solvent based paints. The automotive industry has made dramatic changes to apply this technology with the electro (or E Coat) paint processes.

Chemicals and Explosives Production

DOD facilities manufacture a wide variety of chemicals and explosives including nitric acid, acetic acid, acetic anhydride, ammonium nitrate, nitrocellulose TNT, nitroglycerin, and propellants. These manufacturing processes result in environmental emissions including tail gas and unreacted NO_x from the nitric acid absorption column, uncondensed reactants from distillation column vents, VOC's and dust from condenser vents and dissolving tanks, VOCs and NO_x from scrubber vents, PM_{10} from dryer and kettle scrubbers, and a variety of solvent emissions from propellant manufacture.

The PO Audit would use existing emissions estimates available from facility personnel to develop a Process Flow Diagram (PFD) specifically focused on emissions. From this “picture” of emissions the most serious offending sources (versus permit levels) would be singled out for analysis and innovation. A list of process change solutions would be identified and screened as to effectiveness.

A PO Audit of DOD chemicals and explosives would also focus on manufacturing efficiencies of capacity use, raw materials use (yields), and labor productivity. The same basic PFD for emissions would be used to note the No. 1 capacity bottleneck, the No. 1 low yield step, and the labor-intensive step(s). The energy intensive step would also be noted on the PFD. In separate sessions of analysis and innovation, the existing manufacturing operations would be questioned and challenged. The results would be long lists of process improvement ideas that would optimize capacity, yield, labor, and energy. The Audit team would select the “best” ideas and develop “ballpark” economics of net annual savings, capital cost, and simple payback.

Load, Assemble, Pack (LAP) Line Operations

LAP line operations have been analyzed in a Level I PO Audit of the TA Smoke Grenade process at Pine Bluff arsenal (ref. Northrup, J. Process Improvement Report, Level I TA Smoke Grenades, July 1996.). The audit identified 70 potential process ideas to increase output, 30 ideas to reduce environmental problems, and 33 ideas to reduce energy waste. Economics were estimated for 14 “best” capacity ideas with combined annual savings of $3,500,000 at an installed cost of $1,200,000 for an average simple payback of 4.1 months. Economics were also estimated for five environmental ideas that could potentially reduce the annual $10,500,000 environmental budget by $1,100,000 at an investment of $50,000 for an average simple payback of less than 1 month. Economics were also estimated for critical issue No. 3, energy. Eight process energy ideas were estimated to reduce the sites $3,160,000 annual energy costs by approximately $1 million at a cost of $435,000 for an average simple payback of 5 months.

Expert Advice: Thought Starter and Potential PI/ECO

The following two lists are intended as thought starters to assist the PO Audit Team in identifying Process Improvements (PIs) and Energy Conservation Opportunities (ECOs). This form of Expert Advice assists in identifying both process problems, their end effect, and possible solutions. For example: improve working conditions (the problem) to improve productivity (the end effect) by increasing ventilation (a solution).

General Process Improvement Opportunities

1. Reduce operating cost by optimizing the process
2. Reduce cost of product or service by eliminating waste
3. Optimize maintenance costs to increase capacity utilization
4. Increase process throughput by reducing cycle times
5. Optimize yields by reducing off-specification product
6. Reduce scrap/wastage/breakage by modifying the process causes
7. Reduce rework by not taking short cuts that make rework
8. Reduce downtime by optimizing planning and scheduling
9. Improve product quality by improved process control
10. Improve repeatability/consistency by using Statistical Process Control (SPC)
11. Improve safety by thinking about the safest way before starting

12. Reduce pollution/hazardous waste by modifying the processes that cause it
13. Reduce labor cost by optimizing labor use
14. Optimize overtime by analyzing the causes and correcting them
15. Simplify processes by eliminating unnecessary, non-value added steps
16. Reduce number of process steps by questioning and challenging their value
17. Improve tooling/fixtures/jigs to increase capacity use
18. Improve working conditions to improve productivity by increasing building ventilation
19. Reduce work hours/day or days/week by working on the important things
20. Improve process specifications/documentation to treat continuous improvement
21. Reduce inspections without reducing quality by eliminating unnecessary inspections
22. Optimize inventory by optimizing procurement/logistics
23. Improve WIP tracking by using process simulation computer models
24. Improve tools to increase productivity and product quality
25. Simplify inspections by eliminating unnecessary requirements
26. Increase accuracy, timeliness, applicability, and usefulness of the inspection by optimizing the inspection processes.

The second list of 296 potential Energy and Water Conservation Opportunities (ECOs) are a wide range of supply-side possibilities in the facility's utility production and distribution systems and some demand-side possibilities for reducing loans.

Energy and Water Conservation (Optimization) Opportunities

1. Energy Management Control System (EMCS) installation, replacement, and alteration
2. Install demand limiting control system
3. Install duty cycling control system
4. Install economizer cooling control system
5. Install hot/chilled water supply temperature reset control systems
6. Install supply air temperature reset control system
7. Install temperature setup/setback control system
8. Install time of day control system
9. Install ventilation purging control system
10. Install single building controllers (DDC)
11. On/off controls (electronic time clocks)
12. Check steam trap sizes to verify they are adequately sized to provide proper condensate removal
13. Consider opportunities for flash steam use in low temperature processes
14. Consider pressuring atmospheric condensate return systems to minimize flash losses
15. Consider relocation or conversion of remote equipment such as steam-heated storage
16. Evaluate insulation of all uninsulated lines and fittings previously thought to be uneconomic
17. Evaluate potential for cogeneration in multi-pressure steam systems presently using large pressure-reducing valves
18. Evaluate production scheduling of batch operation and revise to minimize startups and shutdowns
19. Implement regular steam leak survey
20. Install condensate return system

21. Install cross connect lines on steam distribution systems
22. Install insulation on steam distribution systems
23. Install steam metering and monitoring systems
24. Investigate economics of adding insulation on presently insulated lines
25. Review mechanical standby turbines presently left in the idling mode
26. Review operation of long steam lines to remote single-service applications
27. Review operation of steam systems used only for occasional services, such as winter-only tracing lines
28. Review pressure-level requirements of steam-driven mechanical equipment to consider using lower exhaust pressure levels
29. Review requirements of heated storage vessels and reduce to minimum acceptable temperatures
30. Survey condensate presently being discharged to waste drains for feasibility of heat recovery
31. Check flue for improper draft
32. Chiller retrofits
33. Cooling tower retrofits including high efficiency fill, VSD fans, fiberglass fans, hyperbolic stack extensions, fan controls, VSD pump drives, and improved distribution nozzles
34. Install air-atomizing burners for oil-fired boiler systems
35. Install automatic boiler blow-down control
36. Install automatic vent dampers on boilers
37. Install flue gas analyzers for boilers
38. Install low-excess-air burners
39. Install condensing economizers
40. Isolate off-line boilers
41. Provide proper water treatment to reduce fouling
42. Replacement of central plant with distributed satellite systems
43. Replacement of satellite boilers with central plant
44. Downsize boilers with optimum burner size and FD fans
45. Shut down large boilers during summer and use smaller boilers
46. Upgrade of natural gas-fired boilers with new controls (low NOx burners)

47. Check expansion tank sizes on hot water systems
48. Chilled water temperature reset
49. Consolidation of existing HVAC equipment in either an existing building or group of buildings
50. Create air movement with fans
51. Duty cycling for demand control
52. Eliminate or downsize existing HVAC equipment in either an existing building or group of buildings by improvements in building envelope; reductions in lighting or plug loads; etc.
53. Fans and pump replacement or impeller trimming
54. Free cooling cycle by piping chilled water to condenser during cold weather
55. Heat recovery from cooling oil in screw compressors
56. Heat recovery through de-superheating
57. Install a thermal storage system
58. Install add-on heat pumps
59. Install air cleaners in HVAC system
60. Install booster pumps on hot water systems
61. Install decentralized water heaters
62. Install desiccant cooling systems
63. Install economizer cooling systems
64. Install evaporative precooling on 100 percent make-up air
65. Install evaporative cooled or water cooled condensers
66. Install ground-water source heat pumps
67. Install evaporative cooling systems with or without a heat pipe
68. Install modular HVAC units
69. Install roof-spray cooling systems
70. Install secondary pumping systems
71. Install variable air volume HVAC systems
72. Install water heater blankets on water heaters
73. Install liquid pressure amplifier on reciprocating compressor systems
74. Insulate hot water pipes

75. Insulate HVAC ducts
76. Insulate HVAC system pipes
77. Insulate water storage tanks
78. Insulate low side refrigerant lines
79. Investigate use of gas engine driven chillers
80. Isolate off-line chillers and cooling towers
81. Night setback or turning off equipment
82. Install packaged air-conditioning unit replacement
83. Paint roofs with long lasting white roofing material
84. Preheat feedwater with reclaimed waste heat
85. Us e primary/secondary pumping configurations on central plants
86. Provide for avoiding artificial loading (hot gas bypass at low loads)
87. Reduce air flow rates in HVAC ducts
88. Reduce ammonia head pressure
89. Reduce over pumping on chilled water systems
90. Reducing compressor speed in over capacity system
91. Reduce non-condensable gases in refrigerant systems
92. Replace absorption with electric drive chillers
93. Replace existing electric motors with efficient motors
94. Replace forced air heaters with radiant heaters
95. Replace indirect fired heaters with direct fired heaters
96. Replace air conditioning and heating units with heat pumps
97. Replace inefficient window air-conditioners with high SEER units
98. Resize chillers
99. Retrofit with higher coefficient of performance (COP) equipment
100. Stage multiple chillers
101. Use energy efficient direct contact water heating systems (98 percent efficient)
102. Use heat pump water heaters
103. Use of absorption to reduce electric demand
104. Use smaller water heaters for seasonal requirements

105. Use gas absorption chillers where appropriate
106. Variable speed drivers for fans and pumps
107. Window air conditioning replacement with central system
108. Caulk and weather-strip doors and windows
109. Use daylighting or skylighting with dual-glazed low "e" glass
110. Determine roof insulation values and recommend roof replacement as appropriate
111. Install air flow windows
112. Install exterior shading
113. Install interior shading
114. Install local ventilation systems for hot areas (vice central ventilation system)
115. Install movable windows
116. Install operable windows
117. Install reflective surfaces on roof and walls as appropriate
118. Install revolving doors or construct vestibules
119. Install storm windows and multiple glazed windows
120. Install vapor barriers in ceilings and roofs
121. Install vapor barriers in walls
122. Insulate ceilings and roofs
123. Insulate ceilings, roofs, floors, and walls using spray-on insulation
124. Insulate floors
125. Insulate walls
126. Seal vertical shafts and stairways
127. Use tinted or reflective glazing or films
128. Weatherization/fenestration improvements
129. Window coverings and awnings
130. Window replacement
131. Install dimming control for areas close to windows
132. Install dimming controls for areas with skylights
133. Install high efficiency electronic ballasts
134. Install high-pressure sodium lighting in selected areas

135. Install LED exit signs
136. Install LED traffic signals
137. Install low pressure sodium lighting in selected areas
138. Interior and exterior lighting replacement
139. Make lighting control improvements
140. Install lighting for parking lots or athletic fields
141. Use occupancy sensors (where applicable)
142. Reduce illumination levels
143. Use reflective solar window tinting
144. Remove or replace lenses
145. Replace all incandescent bulbs with compact fluorescent
146. Use high-efficiency fluorescent lighting
147. Use reflectors to provide more efficient lighting
148. Use task lighting
149. Use light color material when re-roofing to reduce solar gain
150. Use multiple switching for selected lighting levels in offices, conference rooms, etc.
151. Use natural lighting in perimeter office spaces
152. Use timers and photocells for controlling outdoor lighting
153. Heat recovery for water heating
154. Install double bundle chillers
155. Install piggyback (absorption systems)
156. Install water-loop heat pump systems
157. Preheat combustion air, feed water or fuel oil with reclaimed waste heat
158. Reclaim heat from boiler blowdown
159. Reclaim heat from combustion system flue
160. Reclaim heat from prime movers
161. Reclaim heat from refrigeration system hot gas
162. Reclaim heat from steam condensate
163. Reclaim heat from waste water
164. Reclaim incinerator heat

165. Recover heat from light systems
166. Conversion of electric heaters to natural gas radiation/convection
167. Correct power factors
168. Electric heater replacement on standby generators with a heat pump
169. Install energy-efficient transformers
170. Install electrical meters
171. Investigate cutting impellers on pumps to match loads
172. Motor replacement with high efficiency motors >10 HP
173. Power factor correction depending on tariff considerations
174. Reduce power system losses
175. Reduce demand charges through load shedding, operational changes, and/or procedural changes
176. Replace refrigerator with high efficiency units
177. Replace oversized electric motors
178. Use thermal energy storage systems
179. Replace transformer with amorphous type transformers
180. Use emergency generators during load shedding
181. Use variable speed drives
182. Install agricultural waste-fired boilers
183. Install geothermal space and water heating
184. Install skylights
185. Install solar heating where applicable
186. Install urban waste pyrolysis systems
187. Install urban waste-fired boilers
188. Install photovoltaic system
189. Use photovoltaic water pumping
190. Use solar domestic hot water
191. Use wind power generation
192. Use wind power water pumping
193. Replace air compressor and add receivers
194. Automate blow-off nozzles on air compressor storage tanks

195.Check proper size of air pressure regulators and lubricators

196. Construct new cogeneration facilities

197. Convert compressed air systems to distributed systems

198. Eliminate air leaks

199. Install automatic traps/drains in larger air systems

200. Install storage surge tanks to buffer compressed air load fluctuations

201. Install compressed air metering

202. Install gas meters

203. Landscape/plant trees to reduce air-conditioning loads

204. Install molten carbonate fuel cell

205. Optimize loading with multiple air compressors

206. Recover waste heat from air compressor cooling system

207. Reduce excessive line air pressure losses, i.e., increase pipe diameter

208. Reduce air line pressure

209. Reduce plug loads using devices to shut off equipment not being used

210. Reduce sewage pumping/sewage reduction

211. Replace air-driven motors with electric motors

212. Replace existing air compressors with more efficient units

213. Replace existing electric motors with efficient motors

214. Replace oversized air compressors

215. Rewire lighting and other systems to allow personnel to shut off sections of systems - rather than leaving entire systems running

216. Use after coolers in multi-stage air compressors

217. Use blower/fans instead of compressed air for cooling, drying, or blow-off operations

218. Use energy efficient air blow-off nozzles

219. Use energy efficient v-belts for air compressors

220. Use energy-efficient air drying systems

221. Use larger area air-intake filters

222. Use outside intake air for air compressors

223. Boilers - capture steam condensate for reuse

224. Boilers - install automatic controls to treat boiler make-up water

225. Dishwashers (replacement) - install low temperature dishwashers that sanitize primarily through the use of chemical agents rather than high water temperatures

226. Dishwashers (retrofit) - install electric eye or sensor systems in conveyor-type machines so that the presence of dishes moving along the conveyor activates the water flow

227. Eliminate all single pass water use

228. Equipment cooling, control make-up water and reduce blowdown by adding temperature control valves to cooling water discharge lines in equipment such as air compressors and refrigeration systems

229. Equipment cooling, use cool air compressors with a closed loop system

230. Evaporative cooling systems - consider side stream softening for very large cooling loads

231. Evaporative cooling systems - install drift eliminators or repair existing equipment

232. Evaporative cooling systems - install softeners for make-up water; side stream filtration (including nano-filtration, a form of low-pressure reverse osmosis); and side stream injection of ozone

233. Evaporative cooling systems - install submeters for make-up water and bleed-off water for equipment such as cooling towers that use large volumes of water

234. Evaporative cooling systems control cooling tower bleed-off based on conductivity by allowing bleed-off within a high and narrow conductivity range. This will achieve high cycles of concentration in the cooling system and reduce water use in cooling tower

235. Replace faucet (with units that have infrared sensors or automatic shut-off)

236. Install central tower and remove once through cooling

237. Install irrigation control systems

238. Install subsurface irrigation

239. Install water flow restrictors on shower heads and faucets

240. Install automated watering systems for landscaping, golf courses, etc.

241. Install covers on swimming pools and tanks

242. Install devices to reduce the time flushometers are letting water flow

243. Install devices to save hot water by pumping water in the distribution lines back to the water heater so hot water is not washed - for use in BOQs and homes

244. Install industrial waste/sewage metering

245. Install water metering

246. Landscape irrigation - install irrigation timers to schedule sprinkler use to off-peak, night, or early morning hours, when water rates are cheaper and water used is less likely to evaporate.

247. Landscape irrigation - use low flow sprinkler heads instead of turf sprinklers in areas with plants, trees, and shrubs.

248. Landscape irrigation - use sprinkler controls employing soil tensiometers or electric moisture sensors to help determine when soil is dry, and gauge the amount of water needed.

249. Landscape irrigation - use trickle or subsurface drip irrigation systems that provide water directly to turf roots, preventing water loss by evaporation and runoff.

250. Install low flow toilets

251. Painting - recycle water used to collect overspray paint by treating water with dissolved air flotation and filter dewatering system to separate toxic solids

252. Photo and x-ray processing - install temperature control valve to reduce flow when not developing

253. Photo and x-ray processing - reduce flow to manufacturer's specifications for actual operating conditions

254. Photo and x-ray processing - install solenoid valve to shut-of rinse and cooling flows when product is not being developed

255. Plating and metal finishing - treat rinse water to recover valuable metals or chemicals to return to plating bath, with clean water returned to rinse system

256. Rinsing and cleaning - install timers and tamper-proof conductivity controllers to control quality of water in rinses

257. Rinsing and cleaning - install ultrasonic cleaning equipment

258. Rinsing and cleaning - install water-saving technologies or modification that are specifically geared toward each facility. Examples are counter-current rinsing, drag-out tanks or first stage static rinses, spray systems, flow reduction devices

259. Rinsing and cleaning - recalculate laundry formulas for less water use

260. Install water conservation device (reduced pumping and water heating)

261. Use water reclamation techniques.

262. Xeriscaping with native plants
263. Check belt tension on electric motors
264. Check for air leaks in HVAC system
265. Check flue for improper draft
266. Checking for oversized pumps, that currently operate with a discharge valve in a throttled condition, to lower system pressure
267. Clean air filters in ducts
268. Clean and maintain lighting systems
269. Clean boiler surfaces of fouling
270. Clean evaporator and condenser surfaces of fouling
271. Development of peak-shaving strategies
272. Dishwashers (operational modifications) - limit water temperature and flow rate settings to manufacturer's recommendations. To avoid compromising the sanitation process, do not set water temperature below 180 °F
273. Exhaust hot air from attics
274. Lower heating and raise cooling temperature setpoints
275. Lower hot water temperature and development of peak-shaving strategies
276. Lower humidification and lower hot water temperature
277. Lower humidification and raise dehumidification setpoints
278. Maintain steam traps
279. Raise evaporator or lower condenser water temperature
280. Rebalance ducting systems
281. Rebalance piping systems
282. Reduce hot water consumption
283. Reduce operating hours for escalators and elevators
284. Reduce operating hours for lighting systems
285. Reduce operating hours for space heating and cooling systems
286. Reduce operating hours for ventilation systems
287. Reduce operating hours for water heating systems
288. Reduce the generation of indoor pollutants
289. Reduce ventilation rates

290. Reduce water or steam flow rates in pipes
291. Remove scale from water and steam pipes
292. Repair ducting and piping leaks
293. Repair steam system controls
294. Reset supply air temperatures
295. Set heating setpoints back when the building is not occupied
296. Use load-shedding

Rules of Thumb for Utility System ECOs

Rules of Thumb for ECOs are intended to provide energy professionals and part time practitioners with guidelines by which to identify and evaluate the potential of ECOs. The Rules of Thumb are shortcut methods, factors, typical percentage results, and formulas to calculate energy system ECO performance and to quantitatively analyze and estimate economics of savings and installed cost.

1 ENERGY MANAGEMENT AND ECONOMICS

1.1 Plant Energy Audits**:** Initiate formal plant energy audits by trained audit teams that identify ECOs that can reduce the facility's Purchased Energy Cost (PEC) by 15 to 25 percent over a 1- to 3-year period with typical paybacks under 2 years.

1.2 Unit Energy Costs: Develop incremental, variable only, unit energy costs as a Cost Basis of Savings (CBoS) to value ECOs savings on a variable cost basis.

1.3 One Line Balance (OLBs): Develop One Line Balances for steam, electricity compressed air with an accuracy of ±20 percent. OLBs are used to identify opportunities in their respective utility system and to assist in providing a basis for quantities and cost saved.

1.4 Strategic Energy Plan: Implement a formal Strategic Energy Plan (SEP) with additional annual savings of 2 to 4 percent of annual PEC.

1.5 Energy Performance Index (EPI): Develop and track an overall Energy Performance Index (Btu/unit product) as a regression model to monitor program performance. Generally saves up to 0.5 percent of the PEC.

1.6 Plant Utility Indices: Establish and track plant utility indices as efficiency guidelines to save up to 1 percent of the annual PEC.

1.7 savings resulting from accountability, accounting, troubleshooting, project verification, and overall feedback on the financial contribution from the EM Program.

1.8 Optimize Water Treatment: Optimize water treatment performance to save 2 to 5 percent of the annual cost of water treatment.

1.9 Shut it Off: Shut off energy to facility systems when not needed. Typically saves more than 1 percent of the annual PEC

2 STEAM SYSTEMS

2.1 Boiler Efficiency: Optimize flue gas conditions to reduce percent 0_2, flue gas temperature (°F), and CO concentration. Table 8 lists how the incremental changes in flue gas conditions improve a nominal 150 psi boiler efficiency.

2.2 Maximize Use of High Efficiency Boiler: Maximize the operating hours and loading of the highest efficiency boilers to typically reduce fuel consumption by 1 to 3 percent at zero cost.

2.3 Run Minimum Safe Number of Boilers: Operate minimum number of required boilers to safely and reliably meet the facility's steam needs resulting in typical savings of 3 to 6 percent of the annual fuel expense at no cost.

2.4 Reduce Boiler Steam Pressure: A 10 psig reduction in boiler pressure setpoint will reduce boiler fuel as shown (case where no steam turbines are used):

- 150-200 psig saves 0.2 percent
- 100-149 psig saves 0.4 percent
- 50-99 psig saves 1.0 percent

2.5 Heat Loss versus Insulation Thickness: 1 in. of insulation reduces bare pipe heat loss by approximately 70 percent; 2 in. reduces the remaining 30 percent loss by 70 percent or 21 percent for 91 percent total; 3 in. reduces the last 9 percent by 70 percent or 6.3 percent for a total of 97.3 percent. Two inches is the "economic" thickness for 80 percent of the applications. Well-insulated distribution systems for a 50 million BTUs/hr steam distribution system will typically have 2 to 4 percent heat loss. Losses for this system with average insulation performance will lose 6 to 10 percent while poorly insulated systems can lose 15 percent or more. These losses through various quality of insulation are fixed losses independent of steam flow rate.

2.6 Pipe Insulation: Insulate Steam Systems when pipe surface temperatures are ≥160 °F cold climate or ≥190 °F warm climate. Fuel costs, inside/outside building and safety must also be considered. Paybacks usually occur in 18 to 48 months.

2.7 Removable, Soft Insulation: Install soft-cover, blanket insulation on uninsulated steam valve bodies and fittings will typically result in a 6-month payback for $3.00/mm Btu boiler fuel.

2.8 Steam Trap Losses: A typical steam trap loses 1 to 2 lb/hr of live steam during normal operation. A failed trap can lose 20 to 80 lb/hr of live steam. Replacement or repair can result in a payback of 1 month.

2.9 Steam Leaks: Establish a leak identification and repair program. Leaks for a well-maintained plant are < 1 percent, typically 2 to 4 percent, poorly maintained 10 percent or more. Table 9 lists "rules of thumb" for estimating the annual cost of steam leaks.

2.10 Sizing Condensate Lines: Condensate return piping should typically be 50 percent of the diameter of the steam pipe it serves.

3 HVAC&R SYSTEMS

3.1 HVAC&R Unit Costs: The incremental cost for HVAC heat is typically $5.00/klb ($3.00/MM Btu) and $50/k ton-hour ($0.05 /kWh) for chilled water cooling.

Table 8. How incremental changes in flue gas conditions improve a nominal 150 psi boiler efficiency.

Flue Gas	Efficiency Condition Change	Change
0_2 (percent)	-1.0 percent	+0.66 percent
Temp (°F)	-10 °F	+0.25 percent
CO (ppm)	-100 ppm	+0.10 percent

Table 9. Steam leak rules of thumb.

Rate Blow			$/Year
Type	(lb/hr)	Length (in.)	@5.00/Klb
Wisp	2	4	90
Small	10	12	450
Medium	30	36	1350
Large	170	72	7500

3.2 Chiller Efficiencies: The typical industrial centrifugal chiller operates at an approximately COP of 5.0 and 0.70 kW/ton (0.85 kW/ton with CHW and CT energy). A new, high efficiency, chiller can operate at 0.55 kW/ton (0.65 kW/Ton with CHW and CT energy).

3.3 HVAC & R Formulas: The following formulas are useful in calculating heating and air conditioning loads:

(a) Sensible Heat, Btu/hr = 108 x CFM x ΔT (°F)

(b) Total Cooling, Btu/hr = 4.5 x CFM x ΔH (Btu/lb dry air)

(c) Water Side, Btu/hr = 500 x GPM x ΔT (°F)

(d) Latent Load, Btu/hr = 0.67 x CFM xΔ Grains

(e) Fan Load, HP = CFM x ΔP (in. w.c.)/4000

(f) Duct Pressure Drop (in. w.c.) ΔP/100 ft = 0.15 in. w.c.

(g) Fan Laws: CFM, SP (Static Pressure), HP (Horse Power).

(1) $CFM_2/ CFM_1 = RPM_2/RPM_1$

(2) $SP_2/ SP_1 = (RPM_2/RPM_1)^2$

(3) $HP_2/HP_1 = (RPM_2/RPM_1)^3$

3.4 Increase CHW Temp: For each 1 °F increase in CHW supply setpoint the chiller compression motor load will DECREASE 1.5 percent. This is a zero cost ECO.

3.5 Decrease Conden. CTW Temp): For each 1 °F decrease in CTW to the chiller condenser, the chiller compressor load will decrease 1 percent. Zero cost ECO.

3.6 CTW to Centrifugal Chiller: Centrifugal SMC Chillers use 3 GPM of condenser CTW per ton with a 10 °F ΔT.

3.7 CTW to Single Stage Absorber: Single stage absorption refrigeration machines use 4.5 GPM of CTW per ton with an 18 °F ΔT. This is more than twice the cooling load of a centrifugal unit.

3.8 Steam to Single Stage Absorber: A single stage absorption chiller consumes 17 lb/hr of 15 psig steam per ton CHW produced.

3.9 Steam to Two-Stage Absorber: Two-stage absorption chillers consumes 10 lb/hr of 125 psig steam per ton CHW produced

3.10 Cooling Tower Efficiency: An efficient cooling tower will achieve a 7 °F approach to the current wet bulb temperature. Typically CT only achieve 9 to 12 °F approaches to wet bulb resulting in a 2 to 5 percent increase in chiller compressor load. CTW cost $0.08/Kgal. @$0.05/kWh.

4 COMPRESSED AIR SYSTEMS

4.1 Organize for Success: Form a small, part-time Compressed Air (CA) Team responsible for implementing CA ECOs.

4.2 CA Audit: Initiate a formal audit of CA generation, distribution, and use.

4.3 Unit Cost of CA: Incremental, electricity only, unit cost of CA is $0.18/KCF at $0.05/kWh, 24 BHP/100 SCFM and 20 percent for auxiliary.

4.4 Total Unit Cost of CA: Total, variable and fixed, unit cost of CA is $0.33/KCF; $0.18 electricity, $0.038 debt service, $0.025 operating and maint. Labor, $0.025 materials and supplies and $0.012 taxes, insurance, miscellaneous. CBoS for CA is $0.18/kWh.

4.5 Critical Cost Issue List: Identify major critical cost issues (problems or opportunities) in the CA systems or operations that represent higher than normal annual costs.

4.6 Total Economic Impact of CA: Develop the total annual cost of CA on the facilities bottom line. This includes all direct costs (typically variable), indirect costs (typically fixed), and all consequential cost of CA such as reliability, product quality, environmental, etc., that are a direct consequence from a CA problem. Rule of Thumb 4.4 illustrates variable and fixed costs of $0.18 and $0.15/kch. Consequential cost might add another $0.03 to $0.07/kch.

4.7 One Line Balance: Develop by team estimates the CA flow (KCFM) and cash flow (K$/yr) that “accounts” for all generation distribution (by psi level) to all major users.

4.8 Pattern of Use: Estimate a typical 7-day system load profile (maximum, average, minimum), load duration curve, and hours of use of major compressor units as a base case for identifying and quantifying CA ECOs.

4.9 Run Minimum Number Machines: Operate the minimum number of machines to reliably, safely, and economically meet facility requirements.

4.10 Maximize Use of Efficiency Machines: Maximize the operating hours at optimum load for the highest efficiency machines.

4.11 Balance Loads: Match output on machines of near equal efficiency to eliminate blowoff (venting).

4.12 Part Load Operation: Optimize part load efficiency by load following with reciprocating or rotary screw units to keep centrifugals from venting.

4.13 Minimize Blow-off (Venting): Integrate multiple large centrifugal units with special compressor controls to minimize blow-off, trend efficiency, and to diagnose mechanical problems.

4.14 Minimize Use of Least Reliable Machines: Identify the least reliable (and/or highest maintenance machines) to minimize use and evaluate replacement economics.

4.15 Intercooler Temperature: Economically provide optimum low temperature cooling tower water to intercoolers and aftercoolers.

4.16 Aftercooler Performance: The typical aftercooler should remove 70 percent moisture and requires 3 GPM of CTW per 100 SCFM.

4.17 Optimize CTW Treatment: Optimize cooling tower water treatment to provide good heat transfer (low scale) and reliability (low corrosion).

4.18 Once Through Cooling: Eliminate once-through cooling with city water by installing a cooling tower. Once through City water is $1.00/Kgal, CTW is $0.08/Kgal.

4.19 Lube Oil Cooler: Properly maintain lubricating oil cooler performance for efficiency and reliability.

4.20 Synthetic Lube Oil: Use synthetic oil on reciprocating and screw machines that are low oil consumers. Saves 1 percent energy.

4.21 Motor Drives: Specify energy efficiency motors to save 4 to 6 percent of motor load with 2-yr payback.

4.22 Alternate Drives: Evaluate back pressure steam turbine drives ($0.015/kWh) and/or reciprocating or combustion turbine drives in a cogeneration topping cycle.

4.23 COG Belt Drive: Replace standard V-belt with high-efficiency COG type V-belt saving 1.5 percent of drive energy for 3-month payback without shaft change.

4.24 Air Intake Location: Air intake should be from coolest location, typically outside. A 5 °F temperature difference reduces motor load by 1 percent. Compressor room air is often 10 to 40 percent hotter than outside air depending on whether it is summer or winter.

4.25 Inlet Filter ΔP: Maintain inlet filter ΔP below 6 to 8 in. of w.c. where 5 in. cost 1 percent of motor load.

4.26 Inlet Guide Vanes (IGV): Replace butterfly inlet valve with inlet guide vane (IGV) design to reduce compressor motor load by 2 to 4 percent with 9 to 18 months payback.

4.27 Energy Efficiency Dryers: Specify a high efficiency dryer such as “Heat of Compression” and operate unit properly. “Heatless” dryers are not recommended as they use and dump CA to regenerate desiccant.

4.28 Dew Point Control: Optimize dew point by controlling to meet requirements on “as needed” basis rather than timer controls.

4.29 Recover Heat of Compression: The heat of compression is typically rejected to the cooling tower. However, 95 percent of this heat (approximately 230,000 Btu/hr per 100 HP of compressor drive) can be recovered with a plate heat exchanger to preheat boiler makeup water. Air-cooled units can be directly used as building heat during winter and exhausted during summer.

4.30 PM Program: Establish a predictive and preventive maintenance program. A complete program typically saves 2 to 3 times its cost.

4.31 Reduce Compressor Pressure: A 1 percent motor load savings for each 2 psig reduction in setpoint can result down to a point that is limited by the highest pressure user. This is a no cost ECO.

4.32 Point-of-Use Pressure Control: Allow the setpoint to automatically float based on a control signal from the highest-pressure user. This can generally average an additional 2 to 4 psig pressure reduction at the compressor.

4.33 Lower High Pressure User: Reduce the pressure requirements of the high-pressure user. These could be sticking air cylinders and/or unnecessary equipment or operator demands. An example is high-pressure paint sprayers versus HVLP units.

4.34 Reduce System ΔP: Identify and relieve piping system ΔP bottlenecks.

4.35 Air Traps: Establish a formal trap program. A failed trap can lose 10 to 100 SCFM costing $950 to $9500/yr @$0.18/KCF. Approximately $100/CFM-yr.

4.36 Fix Leaks: Industrial facilities leaks range from 10 to 40 percent of air production. A facility with 1000 SCFM of production at 25 percent leaks is losing approximately $24,000/yr. Typical leaks range from small 3 CFM @ $300/yr, medium 20 CFM @ $1,000/yr, large 30 CFM @ $3,000/yr. Purchase an ultrasonic leak detector ($1,000 to $3,500) to support the program.

4.37 ID Peakers: Identify and reduce CA loads that strongly contribute to peak demand. These users actually cost up to twice the average cost per CFM ($0.36 versus $0.18/KCF).

4.38 Optimize Processes to Use Less or Zero CA: Re-engineer CA out of the processes by technology and/or procedural changes. Savings of 15 to 40 percent have been achieved.

4.39 Storage Tanks: Install surge/storage tank at high volume, short period, pulsing users.

4.40 PRV for Emergency Supply: Install a normally closed high to low pressure system PRV for backup of low-pressure header.

4.41 Decommission Idle Distribution Legs and Machines: Install airtight blank flanges to isolate and depressurize idle legs. Valve off idle machines. If leaks are 25 percent and 20 percent of the systems are idle, then system-wide energy costs are reduced by 5 percent.

4.42 Management and CAT Feedback: Formally provide facility management with the financial contribution of the CA Program on a quarterly basis. Provide CAT members and “customers” economics on specific projects/programs as achieved.

6 Implementing and Sustaining PO Audit Results

This chapter presents tactics for implementing the solutions developed in a Process Optimization (PO) audit. When the PO team completes its audit, the work is not over. In some ways, it is just beginning because, unless the team members can do something with their solutions, the audit has just been an interesting exercise. The end of a PO audit is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning.

The PO audit sets goals, reflecting the incredible improvement opportunities that PO offers. However, regardless of how good these goals are, nothing happens without a road map on how to reach these goals. The PO team needs to provide a path showing how their ideas can be put into practice.

The process improvement solutions constitute the PO plan. The contributions to cost savings and revenue generation connected with this plan can be quite significant. However, these benefits are seldom free. All of the solutions, except the “slam dunks,” have costs and risks associated with them. Therefore, the PO team members must do more than simply articulate their plan to others in the organization. They must also ensure that others *understand* and *commit* to the plan.

These others include at least two groups: (1) *executives*, who have the power to allocate resources to the plan, and (2) *operators*, who do the actual work in carrying out the plan. Members of both these groups are vital for implementing a plan. Without resource allocation, there is no plan, merely a set of hopes and dreams. Without people to carry out the plan, nothing gets done. Often, the PO team members are hierarchically below executives and above operators. Therefore, they need both upward and downward influence to gain the required understanding and commitment.

Commitment to a plan includes: (1) a subjective agreement with the values and goals of the plan, and (2) the motivation to work toward making the plan succeed. Commitment can have three levels: *resistance*, *compliance*, and *internalization*. One goal of the PO team members is to overcome resistance to their plan, convince others to comply with the plan, or (preferably) inspire them to internalize the plan.

Identifying and Responding to Implementation Barriers

There are several possible barriers to implementing PO—reasons why people tend to resist implementing process improvement solutions. These barriers tend to focus on people's fear and anxieties such as:

1. Fear of losing their jobs because the new methods are more efficient than the old. Fewer people might be needed with the new system than with the old one. This fear is quite understandable in view of the numerous recent corporate downsizings. "If they do away with my job, they won't need me any more."

2. Fear of separation from their friends. "I might be transferred to another unit, another town, or another State where I will not know anyone."

3. Fear that they won't be able to perform the new tasks or procedures and that they will lose money. "My pay is tied to my performance, and I don't know how well I'll be able to do my new job."

4. Fear of the unknown. "I feel very anxious because I don't know what to expect from this new system."

5. Reluctance to break old, comfortable, well-established habits, and to spend time and effort to learn new procedures. "I have a lot invested in learning my current job and it will be a real pain and a waste of time to learn all those new things. If I have to move to another town, I'll have to find another doctor, dentist, schools for my kids, …"

Several traditional tactics for overcoming resistance include *coercion*, such as threats of punishment for failing to comply; *manipulation*, such as covert attempts at distorting facts to make them seem more favorable; *negotiation*, such as offering something of value in exchange for reducing resistance; and *communication*, such as arguing for the logic of the new ideas or educating people by providing all the facts and clearing up misunderstandings. Although these traditional tactics can be effective, they tend to produce compliance at best. For example a worker might say, "OK, I'll work on ISO 14000 because they told me to," or an executive might say, "I'll advocate ISO 14000, but I don't really identify with it. All that stuff about a clean environment is going to lower our profits."

In contrast to the traditional tactics for overcoming resistance, *participation* in the process of generating solutions promotes real commitment. People who are directly involved in developing process improvement solutions tend to internalize the solutions because some of the ideas are their own. They have a stake in the solutions and they will work hard to ensure that the solutions are successfully implemented. The following passage from *The Wisdom of Teams* (J.R. Katzenbach and D.K. Smith, 1993, Harper Collins, pp 245-246) illustrates this point.

> …Brigance's small group became a real team, and in forty-five days also delivered a set of "clean sheet" recommendations that compellingly challenged the existing approach to marketing. That's the good news.

Implementation, however, turned out to be another problem entirely. Neither Brigance's team nor higher-level management paid enough attention to involving the people who would have to make the new organizational arrangements work, either before or after the recommendations were made. In an all-too-typical pattern, the team made its recommendations, had a terrific discussion with top management, and then disbanded. Those in the marketing department most affected by the recommendations were neither asked to, nor did they, spend any time understanding the basis for the suggested changes. Not surprisingly, since the recommendations implied a number of risks for them, the marketing people, whether intentionally or otherwise, just waited top management out. Nothing much happened.

Even the most successful task forces can run into this handoff dilemma. To avoid it, the transfer of responsibility for recommendations to those who must implement them demands top management time and attention. Almost always, we have observed, the more top managers assume recommendations will "just happen," the less likely it is that they do. At its worst, as seen in the case of Brigance's team, the accepted recommendations are given to managers who have neither the understanding nor conviction to put them into place.

By contrast, the more involvement task force members have in actually implementing their own recommendations, the more likely they are to get implemented. Top management can exploit the performance opportunity inherent in task force recommendations by allowing the members to make them happen. However, to the extent that people outside the task force will carry the load of implementation, top management can boost the performance opportunity by ensuring that those people get involved as early as possible – well before the recommendations are finalized.

Such involvement takes many forms, including participating in interviews, helping with analyses, contributing and critiquing ideas, and conducting experiments and trials. At a minimum anyone responsible for implementation should receive a briefing on the task force's purpose, approach, and objectives at the beginning of the effort as well as regular reviews of progress along the way.

The more they are involved, the more those who will be implementing benefit from the time to understand, buy into, and even shape the recommendations. Missing the handoff is almost always the Achilles heel for teams that recommend things.

The message from Katzenbach and Smith's excellent book on how to make teams work is totally consistent with our belief that involvement leads to commitment and commitment leads to successful implementation. The trick is how to involve the relevant people in a PO audit. Clearly, in large organizations, it is difficult to involve everyone who needs to be committed to implementing the PO solutions.

While involvement in the idea generation process promotes commitment, the type of commitment tends to be relatively private. Other people need not be aware of private commitment; failure to follow through might lead to guilt, but does not cause public embarrassment. In contrast, another kind of commitment comes about as a result of public exposure. When managers publicize their plans and ideas, they become accountable for achieving results. This means they are publicly answerable for meeting others' expectations, which they have created. Public accountability enforces public commitment. The following diagram illustrates how public and private commitment can be generated and that these two types of commitment can lead to successful implementation (Figure 20).

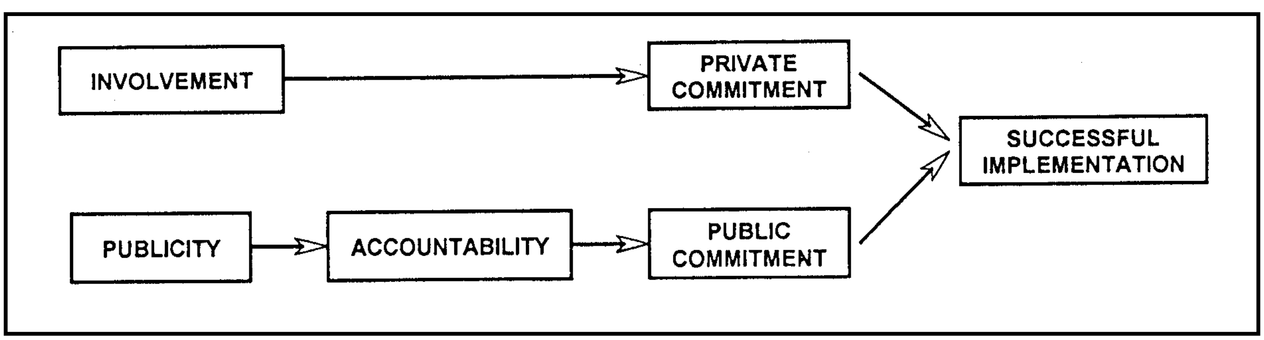

Figure 20. How public and private commitment combine to result in successful implementation.

Deming and Ford - Participation from the Top

Here is a story about Ed Deming and Henry Ford that illustrates the importance of top management involvement.

> Henry Ford decided to launch a company-wide effort on Quality, which would have Statistical Process Control (SPC) at its foundation. Since Deming was one of the world-renowned experts on SPC, Ford invited Deming to present an extensive seminar on the subject. Ford introduced Deming to more than 300 managers and executives, who were seated in an auditorium. After praising Deming for his accomplishments in Japan and elsewhere, Ford stepped off the stage and walked down the aisle toward the exit door.
>
> Just before Ford reached the door, he turned around to watch Deming begin his seminar. To his surprise, Deming was right behind him! Ford said, “Aren’t you going to do your seminar?” To which Deming replied, “Not without you.”

Framework for Implementing a PO Plan

There is an important difference between “developing” a PO Implementation Plan based on Level I PO “planners” without input from the “doers.” The actual implementation of the IA is much more difficult.

The following framework includes Audit results and the actual “implementation” of a PO Plan that achieves real savings resulting in a more competitive position. The development of an IP is a relatively easy job, most often done by the eight steps for putting a PO Implementation Plan into action and for sustaining that effort. These steps make use of the connections among involvement, publicity, accountability, commitment, and successful implementation. They are based on the premise that the success or failure of a PO audit is determined before the audit begins.

1. Secure Championship from Top Management

- Executives with the power to commit resources for implementation must understand the principles and goals of PO. They must appreciate the potential benefits.
- Top managers must display a visible sign showing their commitment. This could mean that the CEO must be totally involved as Deming courageously

insisted. Lesser signs could take the form of a written directive such as a letter or memo. It could be a formal speech. It could be a structural change such as moving key members of the PO team into offices near each other or near an executive who is championing the PO effort.

- Top management must promise to protect people's job security. Some ideas might lead to elimination of some jobs. People need reassurance that, although some jobs might go away, the facility will find other spots for them.
- Top management must provide resources such as time and space for the PO team to meet.

2. Selection of PO Team Members (ideal PO team size is 7 to 11 members).

- Top managers must be involved in selecting members of the PO team.
- The PO team must have a leader who reports directly to the CEO or at least to the executive who is championing the project. For a small organization, this leader could be the CEO. The leader must be someone who knows the operating processes and is respected by everyone in the origination.
- If there is a union, someone from the union should be on the PO team. The approach must be up front and honest. When people are brought on board right at the beginning, they will see how straightforward PO is and appreciate how it can benefit workers as well as managers. Reducing costs and increasing revenues mean more resources for everyone.
- Membership on the PO team must be balanced in terms of technical people, managers, supervisors, and workers. It should also be "cross-functional," i.e., it should include people with different types of expertise and from different departments in the organization.

3. Education about PO, which can take the form of seminars, videotape programs, articles, and even visitations of other plants that have been involved in PO audits.

- Top managers must be educated to the extent that they understand the principles and techniques of PO. Buy-in requires understanding.
- The PO team members become the experts on PO. More time and money are spent developing these team members than anyone else.
- All others who participate in putting the PO ideas into practice need to understand where the solutions come from. Again, buy-in requires understanding.

4. Pilot Runs - Implementing PO solutions, except the "slam dunks," facility-wide can be risky because only the "slam dunks" have no cost and no risk. A "pilot run" is a primer for future runs.

- Select the areas where the pilot runs will be made. These areas should be where there is the highest probability of success. Start with these and move to other areas. Start with the "slam dunks."

- Set stretch goals with numbers and time binders. Publicize them so everyone can see them (Publicity → accountability → implementation).
- Develop an activity-based program. The activities are the specific actions needed to carry out each idea. An activity-based program lists these activities and specifies who will do them.
- Develop an activity-based schedule. The schedule repeats the list of programmed activities and plots them on a Gantt chart showing when each activity will be accomplished and how long it will take.
- Develop an activity-based expense budget. Such a budget lists the programmed activities again and assigns costs to each activity. One way of calculating these costs is to multiply the amount of each resource needed, times the costs of that resource. For example:

  (Number of employees)(Average cost per man-hour)(Number of hours) = $

  These numbers, except the salary or wage figures, can be taken directly from the program and schedule.
- Review and measure current performance. Without a picture of operations before implementation, there is no way to determine improvement. Before-after comparisons can be highly motivating
- Keep the rest of the plant informed. This is important for at least two reasons. First, informing others can build enthusiasm for future projects. Secondly, informing others tends to prevent them from conjuring up false rumors. If people do not know what is happening, they will invent something.
- Be ready for a major disaster. Murphy is alive and well.

5. Presentation to Top Management. (This is the PO audit debriefing.)

- Sell the high-priority solutions from the PO audit to the CEO and/or a team of executives. Preparation for this selling job should be thorough because you do not want the results of the PO audit to be shot down at this point. All members of the PO team should participate in this.
- Include a cost/benefit analysis derived from a combination of the activity-based budget and the dollar allocations established in Phase IV of the PO audit. For costs, explain where the money will come from and where it will go. For benefits, describe the savings of costs or generation of revenue determined in the PO Audit.
- Get formal approval to proceed with implementation.

6. Employee Training

- Include all affected workers
- Present an overall perspective of what PO is trying to accomplish. Give them the big picture as well as the detail of the portion they are involved in. People with a broad perspective can offer more useful ideas than those with tunnel vision.

- Show employees how they can benefit from the PO plan.
- Review the work plan with employees. Ask for their participation and expect and welcome their ideas. They are the experts at their jobs. Do not assume that PO team members are the only experts. Avoid the “not invented here” mistake.

7. Report on Pilot Run to Top Management. (This serves as a formal closeout of the pilot run, ending it with a bang instead of a fizzle.)

- Document the problems encountered and lessons learned – things to avoid the second time around. This PO team will disband and members will scatter, so documentation is important.
- Make a formal presentation to top management with honest assessment of the pilot runs’ successes and failures.
- Recommend whether to expand to another pilot run or to full implementation.

8. Expand to Next Pilot Run or Facility-Wide Implementation

- Select the next PO solution to be implemented.
- Consider parallel pilot runs.
- Emphasize continuous improvement. From project to project, the cost saving or revenue generation should continuously improve.

7 Integrating Energy and Process Systems for DOD Operations

Integrating energy and process systems provides expanded opportunities to DOD facility managers to contribute to the facility's objectives. This chapter of the PO Guide reviews two technical articles published in *Energy User News* (Part I -- Integrating Energy and Process Systems -- Linking Energy Systems and Process Operations to the Bottom Line of Your Business, Walt Smith, ETSI Consulting, Inc. EUN -- April, 1997 and Part II -- Process Optimization: Integrating Energy and Process Systems, Walt Smith, ETSI Consulting, Inc., EUN - May 1997). Both articles are reprinted in full in Appendices E and F, respectively. The purpose of this review is to apply the article's analysis and innovation concepts to processes at DOD manufacturing and maintenance facilities.

Stepping Out of the Box

The proper integration of industrial energy and process systems requires that we restate the old question, "How can we improve the efficiency of our energy supply systems for lower energy costs?" into a broader context. Rather, we should ask, "How can we **optimize** our energy and manufacturing/maintenance processes **together, as one,** to achieve our mission objective of military readiness at lower costs?" This must be done without compromising safety, quality, or morale. More briefly stated, "How can we use energy differently, in better (optimized) ways to **solve daily problems** in our military manufacturing/maintenance role?"

Applications to DOD Facilities

The DOD manufacturing and maintenance facility mission several decades ago was simply military readiness. This mission statement of the 1970s and 1980s is still true, but has been modified in the 1990s to incorporate several important additional requirements. These requirements are military readiness at optimum cost while meeting energy and environmental compliance. These new requirements must be met under vastly different facility operating levels. Logically, we must consider different plans for the different operating modes.

This calls for processes and systems at DOD facilities to have far greater range of efficiency capabilities than are currently found. We require processes and systems with greater flexibility over a wide range of operating levels.

The Army, Navy, and Air Force manufacturing and maintenance facilities are unique in their mission and priorities. Their peacetime capacity use is logically very low, ranging from 10 to 30 percent of what it might be during an extended period of large conflict. The challenge is how to optimize a facility that typically operates at 20 percent capacity use for 80 percent of the time, but must be capable of quickly achieving 100 percent plus capacity use for the remaining 20 percent war time. Optimizing materials and labor use under these extreme ranges of facility operating levels are equally challenging.

The Problem

Typical DOD industrial facilities and many private sector facilities have typically been designed to operate at full capacity use to achieve the lowest cost per unit of output, highest energy efficiency, and most effective environmental performance. Operation at levels significantly less than 100 percent output greatly increases cost per unit of output and percentage of energy losses. This is because two of the three primary operating cost areas, capacity and labor use are largely fixed-cost controlled. Also, the two compliance objectives (energy and environmental performance) are likewise mostly fix-cost controlled. Basically we have industrial processes and systems that have been designed to operate at full speed, yet we find ourselves operating them at 20 percent of designed output for 80 percent of the time. So, how do we optimize the ship to operate effectively and efficiently at both haul speed and slow ahead?

Problem Analysis and a General Solution

The general solution to an energy supply system that is designed to operate efficiently at 100 percent output, yet must provide utilities to processes operating at 20 percent output is "better integration of the energy and process system." First, let us explore the full nature of the problem. Optimization of these systems would ideally match supply to demand on an "as needed" basis. The ideal match of energy supply to process demand is well expressed in the Cardinal Rule of Energy Management. This rule states that system optimization is achieved when we "provide *reliable*, efficient energy supply to the *legitimate* process demand on an *as needed basis*." The three important issues in the rule are:

1. **Reliable, efficient energy supply** - “Reliable” essentially means meeting the process demand 100 percent of the time at 100 percent of the required level. Reliability, in most situations is more important than efficiency. However, in the past when competition was not so intense, we could afford to attempt 100 percent reliability. This would call for operating three boilers; each at 40 percent loaded, rather than two boilers, each at 60 percent loaded. The former provides greater reliability, but lower efficiency, approximately 58 percent at 40 percent load versus 70 percent at 60 percent load. One must ask, “Is the added reliability worth the additional 20 percent fuel expense?” The answer is, “It depends on the likelihood and the cost consequences of the outage.”
2. **Legitimate process demand** – Legitimate process demand is not the norm for industrial facilities. In fact, 20 to 40 percent of the energy supplied cost is typically not legitimate demand, but rather the result of mismatched supply and demand, false loads from system distribution losses, and nonoptimized processes. This second, dominant issue of challenging the legitimacy of the process demand is the primary reason behind the PO Guide.
3. **On an as needed basis** – The third issue in the rule directly addresses the inability of the supply systems to load follow and match the hourly process demands. The energy supply-systems generally do not load follow. They have poor “turn down.” Likewise, the process demands do not operate efficiently at part load. Industrial processes often have even worse part-load energy efficiencies than the energy systems supplying the processes.

Part Load Inefficiencies at DOD Facilities

DOD Manufacturing and Maintenance facilities with many acres and buildings are particularly vulnerable to energy and process inefficiencies at part load operation. This is because they often have large, old central energy supply systems with very high fixed losses (constant at all levels of operation). This, coupled with the normal peacetime level of operation of 20 percent of design, results in high Specific Energy Consumption, or SEC (BTU/unit of product or service).

Figure 21 shows the impact of large, central energy supply systems at low manufacturing levels, based on Figure 22. The purpose of this illustration is to show the importance of identifying ECOs that reduce both variable and especially fixed energy at part load operation. The consumption of energy as a function of production for many industrial facilities is only 20 percent variable and 80 percent fixed over the range of 80 to 100 percent output.

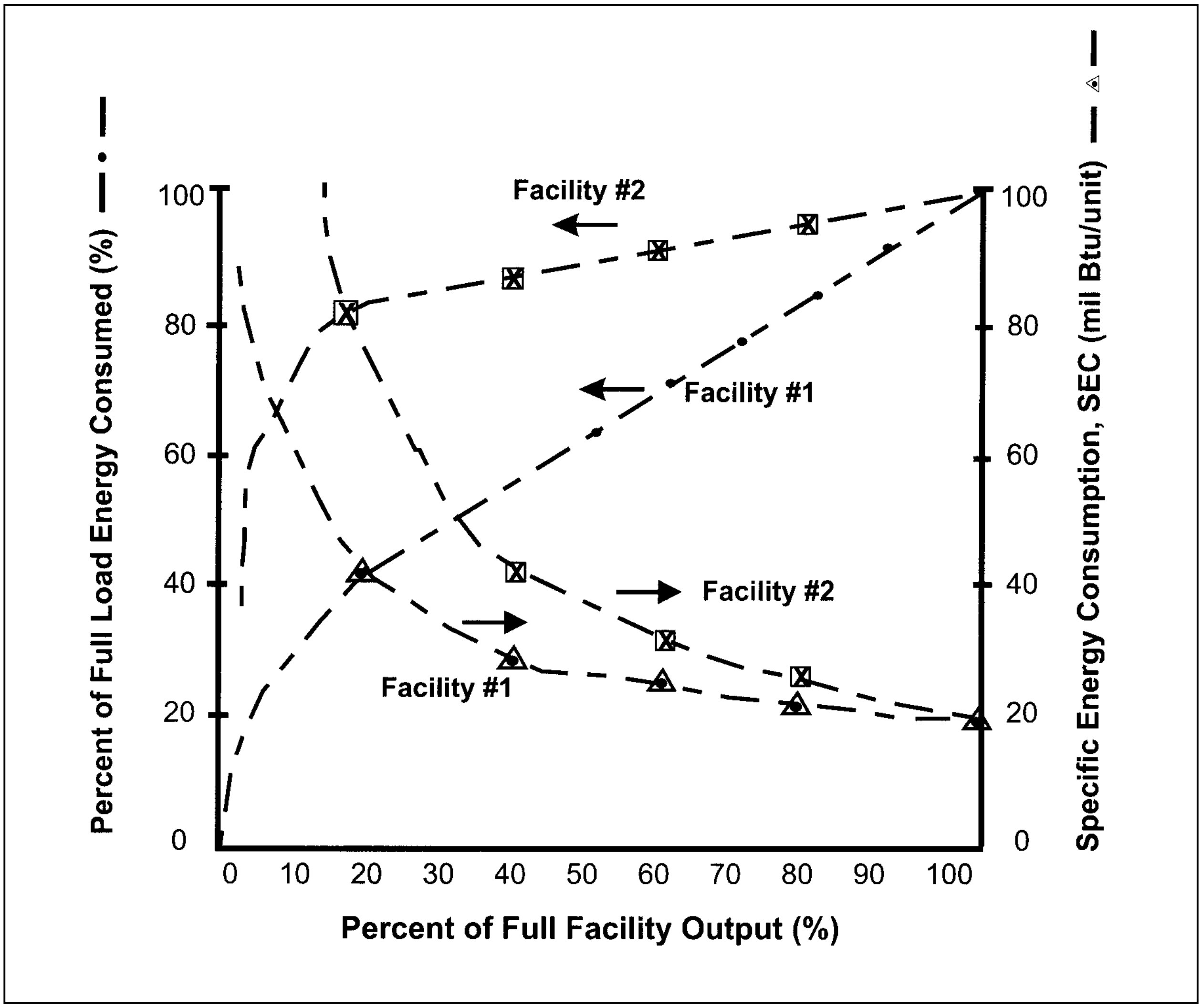

Figure 21. Part-load inefficiencies at large facilities.

So, at near 100 percent output, the energy consumption is 20 units that vary proportionally with production and 80 units that are fixed, i.e., that do not vary with production. However, at 90 percent output, the energy consumption is 90 percent of the variable 20 units (18 units) and the fixed units remain the same (80 units) for 98 units total. The facility consumes 100 units at 100 percent output, and 98 units at 90 percent output, resulting in higher energy per unit.

The graph in Figure 21 represents the part load energy performance for two possible DOD facilities with large central systems and high system losses. Both facilities show declining consumption of full production energy at part load operations. Facility #1 reduces some fixed energy at part load operation, while Facility #2 did not or could not reduce fixed energy. The impact of declining part load operation on the SEC (BTUs/unit) was dramatic with the SEC for Facility #1—rising exponentially from 20 million BTUs/unit at 100 percent output through 44 at 20 percent output.

1 Production Output (%)	2 Thousands of Units per Period	3 Fixed Energy Bills, BTU (%)	4 Vari. Energy Bills, BTU (%)	5 Total Energy Bills, BTU (%)	6 Total Energy (% of 100% Output)	7 Spec. EG Consum. Mil. BTU/Unit (5/2)	8 Fixed Energy Bil. BTU (%)	9 Vari. Energy Bil. BTU (%)	10 Total Energy Bil. BTU (%)	11 Total Energy as % of 100% Output	12 Spec. EG Consum. Mil. BTU/Unit (10/2)
		Facility #1 - Some Fixed Reduction					Facility #2 - No Fixed Reduction				
100	15	240 (80.0)	60 (20.0)	300 (100)	100	20.0	240 (80.0)	60 (20.0)	300 (100)	100	20.0
80	12	210 (81.4)	48 (18.6)	258 (100)	86	21.5	240 (83.3)	48 (16.7)	288 (100)	96	24.0
60	9	180 (83.3)	36 (16.7)	216 (100)	72	24.0	240 (87.0)	36 (13.0)	276 (100)	92	30.7
40	6	150 (86.2)	24 (13.2)	174 (100)	58	29.0	240 (90.9)	24 (9.1%)	264 (100)	88	44.0
20	3	120 (90.9)	12 (9.1)	132 (100)	44	44.0	240 (95.2)	12 (4.8)	252 (100)	84	84.0
0	0	0	0	0		0	0	0	0	0	

Figure 22. Part-load inefficiencies at large industrial facilities.

Facility #2, where fixed energy was not reduced with part load operation, rises more quickly from 20 million BTU/unit at 100 percent to 84 at 20 percent, and to infinity at 0 percent output. This illustration emphasizes the increased importance of reducing fixed energy for DOD Facilities, especially at low, part load operations. Table 10 lists common energy supply, distribution, and process boiler/steam losses at DOD facilities.

For other system losses for DOD facilities, see Chapter 5, Rules of Thumb for Utilities ECOs including Steam Systems, HVAC & R, and Compressed Air Systems. Table 11 lists energy technologies that are highly applicable to DOD facilities with widely varying loads and a large percent of fixed loads. The integration of energy and process systems inherently encourages total (single) system optimization. The PO Audit methodology provides a path to achieve integration of energy and process systems by total (single) system optimization.

Table 10. Common energy supply, distribution, and process boiler/steam system losses at DOD facilities.

Fixed Losses	Variable Losses
1. Boiler radiation	1.Boiler stack losses
2. Steam distribution piping	2. Boiler blowdown
3. Steam valve bodies	3. Deaerator/heater vent
4. Steam leaks	4. Excessive boiler pressure
5. steam traps	
6. Condensate lines	

Table 11. Technologies applicable to DOD facilities.

1. Variable speed drives on fans, pumps and processes
2. Removable, blanket valve body insulation
3. Cascade CHW temperature off wet and dry bulb temperature
4. Inlet guide vane control on centrifugal air compression
5. Two speed cooling tower
6. High efficiency cooling tower retrofits
7. Decommission idle distribution system
8. Cog belts for utility and process driver
9. Floating set point control off high pressure user
10. Energy management and control systems

The Path to a Complete Set of Solutions

The integration and optimization of manufacturing energy, environmental, and process systems at lower overall cost is accomplished by initially executing a PO Audit. The PO Audit uniquely begins with a macro economic analysis, targets critical cost (problem) issues, and determines the contribution to a facility's bottom line if a portion (arbitrarily 10 percent) of the most costly problems is solved. Dozens of items on the critical cost issue list are narrowed to a few fundamental issues. For most industrial facilities, these are to optimize the use of three primary issues: capacity use, raw material use, and labor use. These are primary issues because they determine 70 to 85 percent of the facility's financial performance potential and typically consume 80 percent of the facility's operating costs.

The PO Audit at the initial Level I effort is a 2 to 5 day intense analysis of several carefully selected critical cost problem issues. The results are 50 to 150 innovative process changes for the processes in which the problem cost issues originate. The 50 to 150 process changes are potential PI/ECOs (Process Improvement/Energy or Environmental Opportunities) that are further analyzed, screened, and selected as PI/ECPs (Process Improvement/Energy or

Environmental Projects), the top 20 percent, “best” PI/ECOs. The 10 to 15 final PI/ECPs are further developed in a Level II effort with hard technical and economic data and actual facility prototype testing. Results from the Level II analysis are a group of solid projects, recommended for funding. Implementation (Level III) involves detailed engineering, procurement, installation, start up, and commissioning of the PI/ECPs.

8 Conclusions and Recommendations

DOD manufacturing and maintenance facilities can benefit greatly from an integrated, systematic analysis of their energy/environmental systems when combined with their manufacturing operations. The Process Optimization Guide is provided to DOD facility personnel with an illustrated resource on how to optimize a facility's processes and operations in conjunction with their supporting energy and environmental systems.

The key elements that guarantee success from a PO Audit are:

- The involvement of key facility personnel who know what the problems are, where they are, and have thought of many solutions.
- The involvement of facility personnel results in ownership of their ideas (solutions) which, in turn, develops commitment for implementation.
- The PO Audit immediately focuses on site-specific, critical cost (problem) issues which, if solved, will make the greatest possible economic contribution to facility's bottom line (budget).
- The "process" is specifically defined and modeled both financially and technically.
- Process flow diagram(s) of the critical cost/(problem) issues present only relevant technical and cost data.
- A weakness analysis questions and challenges the existing process, identifying where the process is flawed: bottlenecks, high scrap steps, and steps that are labor intensive, quality problems, energy intensive, environmental problems, or otherwise excessively costly points in the process.
- A long list of 50 or more solutions to each sharply focused critical cost (problem) issue(s) are identified by the Audit Team using the nominal group technique for silent idea generation.
- The Audit Team screens and selects the "best" process improvements and develops ballpark economics as to annual savings, installed cost, and simple payback.
- Initial implementation planning is begun in a debriefing wrap-up session at the conclusion of the on-site audit period.
- All results are documented in a concise report including the basis behind the individual process improvements (scope, savings, and cost).

The following results and expectations are based on more than 100 PO Audits successfully completed by ETSI, Inc. over the past 4 years. These audits typically identified solutions to site-specific critical cost (problem) issues that, if implemented, potentially could:

1. Lower overall manufacturing and maintenance costs by 3 to 10 percent or more.

2. Debottleneck the No. 1 and No. 2 process bottleneck steps to achieve 20 to 50 percent greater capacity use.

3. Reduce material waste (scrap, rejects, rework, and returns) by 10 to 30 percent or more.

4. Improve labor productivity by 20 to 50 percent.

5. Reduce overall and unit energy consumption by 20 to 30 percent or more.

6. Reduce facility air emissions, wastewater discharges, and solid waste disposal by up to 50 percent.

7. Establish a trained on-site PO Team that has the commitment to implement process improvement/energy conservation opportunities (PI/ECOs) because of their involvement.

8. Result in capital and operating budgets that are re-directed to optimize investments and expenses for the true critical cost/problem issues by implementing PI-ECOs. This results in the greatest possible opportunity for success of the facility's mission.

The proven track record of successful PO Audits (see Appendix G) and application of this PO Guide should provide the DOD with a more effective and faster way to meet its goals in their military manufacturing and maintenance facilities.

It is recommended that the following steps be taken:

1. Initiate an aggressive PO program and obtain top management support
2. Select representative facilities
3. Train facility personnel
4. Conduct PO audits and economic studies

5. Prioritize projects for funding and implementation
6. Transfer appropriate technology to all installations.

Through process optimization, energy and environmental performance can be improved as a direct result from analyzing and changing the manufacturing and maintenance processes themselves to increase productivity. Significant energy and environmental improvements are by-products from optimizing capacity use, and reducing rework, scrap, and off-specification product. From a cost perspective, process capacity, materials, and labor use are far more significant than energy and environmental issues. However, all of these issues must be considered together to achieve the DOD's mission of military readiness in the most efficient, and cost-effective way.

Appendix A: The PO Audit Notebook — A Guide for the Audit Team

PO Notebook Contents

The success of PO efforts in DOD facilities and the private sector largely depends on the "proper" introduction of what it is, to whom the introduction is made, how it is done, and how to follow through with timely implementation.

The purpose of the PO Audit Guideline is to ensure that:

1. The Level I Audit is properly introduced to all appropriate levels of the organization (Training Workshop?)
2. The most productive individuals are selected to participate in the audit
3. The audit team understands what PO is and how it is doing
4. A commitment for implementation is secured by "initially" involving the decision makers, the audit team and the operations people responsible for the target processes that are impacted by the critical cost issue(s).

The purpose of the PO Audit Notebook is to provide the Audit Team with an information, preparation, and execution guide in advance of the on-site PO Audit analysis. The guide is intended to introduce PO audit participants with the PO methodology. Special tools and techniques are provided through example materials from past audits. These materials are for audit planning, preparation, and execution. Each member of the Audit Team is expected to review these starting materials before the audit. The Audit Guides contain 10 sections as outlined in the Table of Contents and section cover pages in Appendix A.

The PO Audit Notebook contains the following sections:

- Section 1: Introduction: The PO Guide
- Section 2: Process Optimization Overview
- Section 3: Process Optimization Audit Methodology and Technique
- Section 4: Process Optimization Audit Debriefing

- Section 5: Implementing and Sustaining PO Audit Results: Strategies & Tactics
- Section 6: Process Optimization Audit Report
- Section 7: Process Optimization Guideline and Expert Advice for DOD Facilities
- Section 8: The PO Audit Notebook: A Guide for the Audit Team
- Section 9: Integrating Energy and Process Systems by Applying PO
- Section 10: Conclusions and Recommendations.

PO success is measured by timely implementation. The success largely depends on properly communicating the dramatic gains from PO and the participation of all individuals that will be required for implementation.

INFORMATION, PREPARATION, and AUDIT EXECUTION GUIDE

This guide is intended to introduce Process Optimization (PO) Audit participants to the methodology and special techniques through examples from past audits. These materials are for audit planning, preparation, and audit execution. The Audit Team should review these starting materials and add site-specific results to the notebook during the audit, including the final report.

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AUDIT TEAM PARTICIPANTS

Name	Title and/or Responsibility	Organization
1. Walt Smith	PO Audit Facilitator	ETSI, Inc.
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

SECTION 1: AUDIT OBJECTIVES, GOALS, AND AUDIT TEAM

The purpose of the Process Optimization (PO) audit is to financially and technically audit the production steps to identify process changes that will significantly contribute to lower costs and increased profitability.

The manufacturing *process* is broadly defined as those operations that consume resources (raw materials, labor, and energy). The process definition encompasses changes in operating conditions (temperature, cycle times, etc.), operator practices and procedures (people issues), and fundamental technologies (physics, chemistry, and heat transfer).

The objective of the Level I Process Optimization Audit is to identify 50 to 100 process improvements to significantly increase profits. Higher profits are achieved by: (1) optimum use of resources (raw materials, yields, energy, labor, other), (2) increased product sales and/or production rates by quality improvements and/or capacity increases, (3) optimum capital investments, and (4) innovative, cost effective solutions to environmental and safety issues.

Typical program goals in these areas can include a 3 to 15 percent reduction in overall manufacturing cost from a 5 to 50 percent increase in selling price and/or plant capacity use, and the avoidance of potentially millions of dollars of unnecessary capital investment over 5 to 15 years.

In a Level I audit, the potential for increased profit is based on the assumption that the existing manufacturing process, practices, and procedures can be changed, that existing operating conditions can be optimized, and that new technology can be used in specific process steps. Company goals cannot be realized by conventional cost cutting measures that support the old, existing processing methods and technology.

The organization of a Process Audit uses the talents of the site's technical and operating staff, the broad outside experiences of local utility personnel, and the technical/facilitating skills of experienced consultants. Participation by three to six knowledgeable, key site personnel is critical to the success of the audit. The Audit Team functions as a cohesive team, systematically pursuing process and energy optimization using a 2- to 5-day Process Audit Work Plan. PO Audit notebooks were prepared for each audit team member and used as a guide through the audit process.

SECTION 2: INTRODUCTION TO METHODOLOGY

The purpose of this section is to provide the Audit Team with a general introduction and overview of ETSI's PO auditing methodology. An overview is professionally presented in a four-page brochure and audit project results are highlighted for 8 of the 72 process audits completed within the last 3 years.

The Level I Process Optimization audit follows four major phases over a 2 to 5 day period:

- Phase 1. Analyzing the manufacturing structure cost to estimate "10 percent Improvement Economics."
- Phase 2. Analyzing and quantifying the existing process to focus on process weaknesses.

- Phase 3. Creating the new or modified process, resulting in large profit improvements.
- Phase 4. Estimating new profit from top ideas to set priorities for implementation.

The PO approach follows the methodologies and techniques of the Level I Process Optimization Audit, developed by Energy Technology Services International, Inc. (ETSI). This methodology determines the profit potential, quantifies the existing process, and uniquely identifies potential process improvements. The approach is unique in its exclusive focus on the manufacturing process and the use of the plant's manufacturing cost structure to guide the effort and connect process change to profits. Level I analysis uses conceptual engineering and financial models to identify where and how the process can be changed. Quantifying and analyzing the existing process provides the foundation for effective brainstorming. Team action and group dynamics look at new and old ideas using cost equations and conceptual models.

Introductory notebook materials describe what PO audits are, define the term "process," and outline the four audit phases. Participation by key individuals from the facility and some minimal preparation are required.

The Process Optimization Audit, although sometimes sponsored by the utility company, is *not* an energy audit. While energy is a focus, other more profitable issues are addressed. The focus on energy is used in the methodology as a technical entrée into the manufacturing process, to identify where and how energy and other resources/inputs can be used better (optimized) to increase profits.

SECTION 3: "CRITICAL ISSUES" LIST

The purpose of the Critical Issues List is to target problem and opportunity areas for audit analysis and solutions. Prior to the audit, each participant is requested to take 10 to 30 minutes to independently list major, profit-sensitive conditions or events related to the process that result in financial losses.

It is helpful to attempt to estimate the potential annual dollar loss impact of each critical issue on your list. A composite list from our individual lists will be developed during Phase I of the audit. Please use this form to begin your list.

Potential Annual Losses ($)

No.	*CRITICAL ISSUE*	*Dollar Loss (K$/Yr)*
1.		
2.		
3.		
4.		
5.		

SECTION 4: ESTABLISHING POTENTIAL DOLLAR VALUE (PHASE I)

The first step in ETSI's Process Audit is to establish the Potential Dollar Value (PDV) from process changes. The objective is to estimate the potential contribution to profitability from process improvements in different cost categories. PDV targets specific manufacturing issues with the largest potential and establishes the relationships to both the process and to profits. This is done by incremental or marginal cost analysis and by developing "cost equations" that reflect total issue cost.

The financial analysis of the process begins with the manufacturing/operating cost structure. The operating cost and financial data allow estimates of annual contribution from incremental improvements in various cost categories. This information, although an approximation, is considered highly confidential, and is not to be communicated to third parties.

Improvements to annual bottom line profits are referred to as "Incremental 10 percent What If's." The annual contribution from a 10 percent increase in production/sales is determined from the manufacturing or operating cost structure. An analysis of annual variable and fixed cost increases from a 10 percent increase in production/sales requires a full 10 percent increase in raw material cost (100 percent variable); however, operating labor and other expenses are not 100 percent variable with sales. A 10 percent increase in production would typically require only a 2 percent increase in hourly labor (20 percent variable), because capacity is constrained by machine, process, and work methods issues, not by head count. Likewise, usually only a 1.0 percent increase in electrical energy (10 percent variable) is projected, because 90 percent of the energy consumption is fixed for a relatively small production rate increase of 10 percent.

The arbitrary 10 percent values are not goals, but intended to only identify relative impact on profits without necessarily indicating at this point how to specifically achieve the improvements. More or less than a 10 percent improvement may be possible.

Both the order (most to least) and magnitude of the incremental "What If's" are often a surprise to the Audit Team. It is interesting to note that, although energy is a cost factor, it represents only a fraction of other more profit-sensitive cost issues, such as improvement in capacity and yields. These economics are not presented as a precise manufacturing cost analysis, but rather as Level I approximations to provide direction and incentive to the Audit Team. If this level of financial and technical analysis indicates major potential from process analysis and innovative changes, a Level II effort is appropriate.

SECTION 5: ANALYZING THE EXISTING "AS IS" PROCESS (PHASE II)

The second phase of the process audit uses special techniques to systematically analyze existing operating procedures, practices, operating conditions (temperatures, speeds, pressures), and current technology. Conceptual process modeling is used to quickly understand the basic production steps and the value added by each step. A "conceptual" process model, in its simplest form, is to imagine that we are the **raw material** that is being converted by many steps to finished product. Why are "they" heating us up (to 150 °F); what is magic about 150 °F (why not 140 °F or 170 °F?); why are "they" cutting us and producing so much scrap, etc.?

The first step in analyzing the existing process was to develop a Process Flow Diagram (PFD) for the major process steps. The PFD is developed from discussion of the process steps and a walk-through process tour and documented on a flip chart. The PFD is populated with process data, economic information, and to highlight problem areas (the capacity bottleneck step, quality problem areas, energy intensive step, high scrap step, etc.).

If energy is a cost issue of the audit, Plant Energy Economics are presented showing consumption and costs for electrical, fuels, steam, etc. A "One-Line Balance: Electrical" estimates the consumption and cost of kWh/yr and dollars to major users. A "One-Line Balance: Thermal" estimates the average annual steam consumption (Klb/yr) and cost to major users. An estimate of the facility-wide Fuel Cycle Efficiency and a Heat-Source and Heat-Sink Diagram is developed by the Audit Team to stimulate ideas for heat recovery. Typical industrial heat recovery is less than 5 percent of total site energy consumption.

Identifying and discussing problem areas in the existing process is referred to as Weakness Analysis. The capacity bottleneck steps, energy-intensive steps, and the labor-intensive step are revisited. The Team discusses Where and Why the process is weak with regard to each critical issue documented on a Where-Why Diagram. The entire process as it is currently operated is questioned and challenged in Phase II, setting the foundation for Phase III: Creating the New, Modified (To Be) Process.

SECTION 6: CREATING THE NEW "TO BE" PROCESS (PHASE III)

The third phase of process optimization creates the "new" process by identifying both general and specific process changes that significantly improve profitability. The operating conditions (temperatures, speeds, etc.) are challenged, and procedures and practices of the existing process are questioned. New technology is considered for specific process steps or more widely for substitution in broad process areas. Typical process optimization thinking would: (1) consider lowering (or raising) a process temperature, (2) question the purpose of a particular production procedure or even the need to do it at all, (3) challenge the amount of process waste heat and changing the process to minimize it rather than trying to recover the waste heat, (4) eliminate or combine production steps, (5) use low energy process, and (6) high yield technologies. How can the process better use its input resources (raw materials, energy, etc.) and its outputs (product, quality, plant capacity, and environmental investment) to make money?

Processing technology is usually based on a combination of in-house technology, and years of experience in specific processes. The success of the company is in how well they practice this knowledge and technology, and in the consistency of its application. Regardless of the level of current process technology, it always seems that a Level I Process Audit identifies dozens of intriguing ideas and novel technical/economic solutions.

An abbreviated, yet simple and effective brainstorming method is used called the Nominal Group Technique requiring Silent Idea Generation. The technique "forces" participation and concentration of all team members. The quality and quantity of the ideas are enhanced by total concentration on a well-defined

Object Statement during independent, silent brainstorming (5 to 7 minutes), and silent listing of one idea at a time from each participant in round-robin fashion. Many of the best ideas, both old and new, are identified by the facility technical staff. The broad background of Utility Company personnel and their lack of detailed knowledge of the specific process are often an advantage in introducing new process thinking. The facilitating skills and expertise in process analysis of the consultant participants have been important in bringing the effort up to the point of brainstorming.

Brainstorming focuses on priority issues identified from the economic analysis done in Phase I. Although the most profitable areas are typically found to be increases in production rates by debottlenecking and improvements in yields, energy and other site specific issues can also be targeted for improvement provided time allows.

SECTION 7: ESTIMATING NEW PROFIT FROM "BEST IDEAS" (PHASE IV)

The purpose of this session is to quantify the potential annual savings, total implementation cost, and simple payback from the top process improvement idea. Economics are in the accuracy range of ±30 to 50 percent, definitely not precise engineering estimates. The "Best Ideas" were selected by the site Audit Team and, as such, they are assumed to be technically and economically feasible.

The best ideas are selected by each participant distributing 20 votes among the brainstormed list, up to 3 votes maximum per idea. The selection criteria are, the idea: (1) must contribute significantly to profits (i.e., $10,000 per yr, not $1,000 per yr), (2) must be "manageable" with time and money (i.e., 1 year, not 6 years to implement and be cost effective), and (3) must be low risk. These leading ideas are highlighted in the Executive Summary section of the report.

There are several ways for the Audit Team to quickly develop Ballpark economics on the "Best Ideas." The first is from "factored estimates" using the Incremental, 10 percent "What If" Annual Benefit Value determined in Phase I. For example, if scrap reduction was calculated to cost $3,800,000/yr at an 18 percent level, then a 10 percent reduction would reduce total scrap from 18 percent to 16.2 percent (1.8 percentage points). The contribution to the bottom line would, therefore, be $380,000/yr. This factor, i.e., $380,000 per yr per 10 percent reduction in scrap, can be used to estimate the value of individual ideas or a group of complementary ideas. For example, if the idea is, "Reduce scrap at the PFD Step #6 by improved temperature control in Step #4," and the Process

Audit Team consensus is that overall scrap can be reduced by 0.9 percent points (i.e., from 1.8 percent to 0.9 percent), then the dollar value of this idea is approximately half (0.9%/1.8%) of the 10 percent figure. Therefore, the annual contribution to profits is half of the $380,000 per yr or $160,000. If the team estimates that improved temperature control can be achieved with a $40,000 investment, the idea has a potential payback of 3 months.

A second approach to estimating “ballpark” economics is for the Audit Team to consider scrap levels during times when temperature control was poor versus good. If knowledgeable team participants estimate scrap levels to be 21 percent ±2 percent during periods of poor temperature control and 17 ±1 percent during periods of good temperature control, the difference of 4 percent is attributed to control problems. Assuming improved control can be achieved 50 percent of the time, an average 2 percent reduction in scrap might be expected. If a 1.8 percent reduction is worth $380,000/yr, a 2.0 percent reduction is worth $422,000/yr.

Notice that, in the Level I PO Audit, the value (worth) of ideas is primarily determined by plant or facility experts on the Audit Team. This on-site input, although preliminary and approximate, provides the answer to a frequently asked question of the ETSI PO methodology. We are often asked, “How can anything significant be discovered in only 2 to 4 days?” The answer is, “Only because we combine the experience and knowledge of key site personnel with the process analysis and facilitating skills of our methodology, techniques, and facilitator(s).”

SECTION 8: WRAP-UP MEETING, CONCLUSIONS, AND NEXT STEP

A Wrap-up Meeting at the close of a Level I Audit is important to provide preliminary results and conclusions from the on-site exercise. A typical 40-minute meeting agenda is provided where individual audit team participants summarize initial findings. The “slam dunk” list (no cost/no risk) is summarized with estimated annual value. The next actions are discussed; in particular, “Do the preliminary results justify more in-depth process optimization efforts?”

The purpose of the Level I Process Audit is to determine the economic “potential” for additional profit from process changes. The 2-day analysis is not intended to be precise, nor can or should it be. The quantity and quality of process improvements identified in the Level I Audit almost always suggest that significant potential exists. The audit site can accomplish these potential profit gains by pursuing an aggressive program of Process Optimization. The continuation of the Process Optimization methodology is typically recommended by conducting a Level II Audit analysis.

Level II Process Optimization is a larger effort (40 to 100 days) to identify additional process improvement ideas and to **develop and evaluate** the leading process modifications from the Level I Audit. All critical, technical, and economic assumptions from the Level I Audit are verified by field measurements, engineering calculations, and accurate economic data. Process modifications that pass the Level II analysis are presented to management with “appropriation grade” cost estimates for funding and implementation.

Low-cost/no-cost (“slam dunk”) process ideas from a Level I analysis are typically implemented quickly. However, the greatest profit opportunities need to be developed further. Development of these larger process improvement opportunities is achieved by a Level II effort. This effort most often requires a combination of in-house and outside support. Based on the success of the Level I Process/Profit Audit, a Level II analysis is usually recommended. Level II analysis “guesses at nothing—measures everything,” quantifying both the Level I and new Level II ideas to change the old process. A specific Level II scope and approach to use on-site and off-site resources is best jointly developed by review and discussion of results documented in this Level I report. ETSI, Inc. and RMT can provide a Level II proposal based on this review and discussions.

SECTION 9: SUPPORTING INFORMATION AND IMPLEMENTATION PLAN

This section of the PO Audit notebook is for compiling financial and process “reference” materials prior to and during the audit. Audit participants are encouraged to compile process information into **their** notebooks for use in the audit. Example materials might include a competitive market survey, technology literature search, historical information, or data on a critical issue/problem. Look at your “critical issues” list and locate supporting information to be shared with the team during the audit.

A second purpose of this notebook section is to begin development of an Implementation Plan for process changes (new and old) identified during the audit. A unique ETSI technique that has been successfully used to implement the 50 to 150 process changes from a Level I PO Audit is the How-Why Diagram. This technique pictorially organizes and connects process improvement ideas from the brainstorming list to each other and to profitability for a target critical issue (i.e., scrap, capacity, etc.).

The How-Why Diagram (H-WD) relates all randomly generated ideas to each other and to the object statement with the connecting questions: How-Why. The ultimate “Why” positioned at the far right of the H-WD, is to increase profit. The “How” ideas from the brainstorming lists to accomplish this objective are positioned to the left, forming branching networks. Adjacent ideas answer the question “How” by looking at the idea to the left and “Why” by looking at the idea to the right. The resulting network of ideas, linked by How and Why, uniquely provide a road map pointing the strongest set of solutions toward the ultimate objective of increased profitability. Examples from past audits will clarify.

SECTION 10: FINAL AUDIT REPORT CONTENTS, NEXT STEP, AUDIT REPORT

The Audit Report provides complete documentation of Audit results. A draft report is provided within 3 to 4 weeks of the audit for site review and edit. A final report (3 to 6 copies) is returned within 1 week of receiving site review/edit. Example report, Table of Contents, List of Appendices, and typical Conclusions, Recommendations, Next Step are provided in this section.

Conclusions, Recommendations, Next Step

The purpose of the Level I Process Audit is to determine the economic “potential” for additional profit from process changes. The brief, Level I analysis is not intended to be precise, nor can or should it be. The quantity and quality of process improvements identified in the Level I Audit almost always suggest that significant potential exists. Your company can accomplish these potential profit gains by pursuing an aggressive program of Process Optimization in a Level II analysis. The Process Optimization methodology should continue.

Low-cost/no-cost (“slam dunk”) process ideas from this Level I analysis will be implemented quickly. However, the greatest profit opportunities need to be developed further. Development of these larger process improvement opportunities is achieved by a Level II effort. This effort most often requires a combination of in-house and outside support. Based on the success of the Level I Process/Profit Audit, a Level II analysis is recommended. Level II analysis guesses at nothing – measures everything, quantifying both the Level I and new Level II ideas to change the old process. A specific Level II scope and approach to use on-site and off-site resources are best jointly developed by reviewing and discussing results documented in this Level I report. ETSI, Inc. can provide a Level II proposal based on this review and discussions.

Appendix B: Process Optimization (PO) Work Session 2-Day Work Plan

DAY ONE:

8:00 a.m. Introductions, Work Session Purpose, and Goals

8:15 a.m. The PO Methodology: What, How, Results (Quick Review)

- Linking Process to Profits
- What is it? How is it done?
- Typical Results

9:00 a.m. Work Session Phase I: Establishing Potential $ Value

- Identifying the Manufacturing Cost Structure
- Calculating 10 Percent What If Economic Benefit
- Developing a Financial Model of the Process

10:00 a.m. Work Session Phase II: Analyzing the "As Is" Process

- Optimization Concepts
- Process Analysis Techniques (PFD, OLB, HS/HS, W-W)
- Develop a Working Block Process Flow Diagram (PFD)

10:30 a.m. Review Critical Issues List

11:15 a.m. Work Session Phase II: Target Issue #1 (continued)

- Tour of the Target Process
- One-Line Utility Balances
- Weakness Analysis: Process Flaws
- Heat Sink-Heat Source Analysis
- Where-Why Analysis for Scrap, etc.

12:15 p.m. Lunch (Eat In)

1:00 p.m. Work Session Phase III: Creating the "To Be" Process (Issue #1)

- Questioning and Challenging the Manufacturing Process
- Brainstorming Using the Nominal Group Technique
- Creating the "New Process via Silent Idea Generation"

2:30 p.m. Selecting the "Top Process-Profit Ideas" (Issue #1)

- Selection Criteria
- Voting Method
- Qualitative Analysis

3:30 p.m. Estimating Budget Economics for Top Ideas (Issue #1)

- Annual Contribution to Profit
- Budget Installed Cost and Time Frame
- Simple Payback (Months)

4:30 p.m. Demonstrate How-Why Diagram: Issue #1

5:00 p.m. Adjourn

DAY TWO

8:00 a.m. Review Day One, Q&A

8:30 a.m. Target Process-Profit Issue #2, #3, etc. (Phase II)*

- Revisit Basis for 10 Percent What If Benefits
- Re-tour Process/Revisit PFD
- Weakness Analysis, Issue #2, #3, etc.

9:30 a.m. Creating the To Be Process, Issue #2, #3, etc. (Phase III)

- Questioning and Challenging the Manufacturing Process
- Brainstorming with the Nominal Group Technique
- Creating the New Process via Silent Idea Generation

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*Issues #1, #2, and #3 are determined by the financial analysis of the process from the manufacturing cost structure. The issues are typically the largest profit contributions from the arbitrary 10 percent "What If" economics. For example, Issue #1 may be capacity debottlenecking where a 10 percent increase might have been worth $2 million per year toward profits. Issue #2 may be scrap reduction where a 10 percent reduction might have been worth $1 million per year toward profits. Issue #3 may be energy optimization where a 10 percent improvement might have been worth $500,000 per year toward profits.

10:30 a.m. Selecting the Top Process-Profit Ideas, Issue #2, #3, etc.

- Selection Criteria
- Voting Method

11:15 a.m. Estimating Budget Economics, Issue #2, #3, etc.

12:15 p.m. Lunch (Eat In)

1:00 p.m. Develop How-Why Diagram: Issue #2, #3, etc.

1:30 p.m. Preparation for Wrap-Up Presentation to Management

- Presentation Agenda
- Organize Results on Flip Charts/Overheads
- Summarize Economics for Top Ideas

2:45 p.m. Wrap-Up Presentation by Work Session Team to Plant Management

4:15 p.m. The Next Step: Level II PO Analysis?

5:00 p.m. Adjourn

Appendix C: Nominal Group Technique (NGT) of Structured Brainstorming

The NGT approach to generating ideas is a simple, effective, and productive way to maximize results in a short period of time. The technique forces participation and concentration of all team members by silent idea generation (no talking). The session (all 6 steps) requires 50 to 60 minutes, depending on the number of participants and depth of discussions. The steps are:

#1 Object Statement (3 minutes)

Clearly define the target objective as an "Object Statement" and write at the top of the flip chart. Example...

Object Statement: Identify process changes (operating conditions, procedures and/or technologies) to optimize scrap at lower levels, resulting in a significant increase in operating profits. A 10 percent reduction is worth $380,000/yr (from PO Audit, Phase 1).

#2 Silent Idea Generation (7 minutes)

Each participant should silently and independently list any process ideas that will contribute toward the Object Statement. The ideas, if possible, should be two-part, one-liners such as "reduce scrap in Step 6 by improved control of temperature in Step 4." You will have 6 to 8 minutes to develop your list. As stimuli for identifying improvement ideas, a Process Flow Diagram, Where-Why Diagram, and other analytical techniques are in view on flip charts around the room. A walk-through tour of the target process steps that produce the highest scrap levels, discussions, and the analyses on flip charts all set the stage to generate solutions to reduce scrap.

#3 Compiling Group List (15 minutes)

A master list is compiled from individuals by listing ideas on the flip chart below the Object Statement. One idea at a time is provided from each individual in round-robin fashion until all individual lists are depleted. Still, no talking is allowed during Step #3 because brainstorming is continuing. Individuals should add new ideas to their list or modify someone else's idea as the group list is developed.

#4 Discussion for Clarification (10 minutes)

Any idea that needs clarification by the originator can now be requested. Usually, only a few of the typically 40 to 80 ideas require clarification. Also, any ideas that are truly identical can be combined into one.

#5 Voting and Selecting "Best Ideas" (10 minutes)

The "best ideas" are selected by independent voting where each participant is allowed typically 20 votes. You may assign up to three votes on one single idea, not exceeding your 20-vote limit. The voting criteria are: (1) must contribute significantly to profits, (2) must be manageable or doable within a reasonable time and acceptable payback, and (3) must, with proper evaluation, be low risk. All votes are tallied beside each idea, and the top approximate 10 to 20 percent are considered for economic analysis (Phase 4).

#6 Grouping "Best Ideas" and Identifying "Slam Dunks" (10 minutes)

Ideas are grouped several ways, first as (a) people solutions, (b) capital investment solutions, or (c) solutions requiring expense money from an operating budget; second, any idea that the audit team believes to be no-cost and no-risk is designated a "slam dunk"; third, if time allows, other idea groupings can be determined, including "lay-ups" (small expense, cost and low risk), "free throws" (moderate expense and medium risk), "three pointers" (capital projects with moderate risk), and "the Hail Mary at the buzzer" (high risk, but can win the game). The idea of grouping by class or funding and level of risk is to rank ideas as to ease of implementation. The "slam dunk" ideas (zero cost and zero risk) should be implemented within 24 hours. The #1 barrier to implementing any recommendation is getting permission or approval. Considering that "slam dunks" are by definition zero cost and zero risk, no permission or approval should be necessary.

Appendix D: Wrap-Up Meeting Agenda

	Presenter
1. Introductions, Background	____________
2. Audit Objective, Goal and Expectations	____________
3. PO Audit Methodology: How It Is Done	____________
4. Audit Results	
A. Phase I: Financial Analysis of the Process	
• Manufacturing Cost Structure	____________
• Ten Percent "What If" Benefits	____________
B. Phase II: Quantifying the "As Is" Process	
• Process Flow Diagram Including Dollars	____________
• Where-Why Diagram to Target Opportunity	____________
C. Phase III: Creating the "To Be" Process	
• Brainstorming List: Profit Issue #1	____________
• Brainstorming List: Profit Issue #2	____________
D. Phase IV: Estimating Annual Profit Contribution	
• Annual "Ballpark" Economics: Issue #1	____________
• Annual "Ballpark" Economics: Issue #2	____________
• "Slam Dunk" List: No Cost, No Risk	____________

5. Discussion and Assessment of PO Audit Results ____________ Group

6. Conclusions Next Actions and Schedule ____________ Group

7. Closing Remarks, Adjourn

Appendix E: Integrating Energy and Process Systems

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Walt Smith is president of Energy Technology Services International Inc. (ETSI), a consulting company of networked experts in Candler, N.C. ETSI provides a range of energy services, including comprehensive industrial and commercial audits, cogeneration feasibility analysis, integrating energy and process systems through process optimization audits, and seminars on more than 30 energy-related topics.

Integrating Energy and Process Systems

Linking Energy Systems to Process Operations and to the Bottom Line of Your Business

By WALT SMITH

This is the first part of a two-part series that introduces the concepts and business benefits of integrating energy and process systems. Part two, which will appear next month, will fully develop the methodology of process optimization (PO) and illustrate actual PO audit results with several case studies.

Now is the time for technical managers of energy and facility infrastructure to broaden their views of energy systems to include the rest of the business. The possibilities to improve the bottom line of a facility's operation and services are many times greater if supply-side utility systems are integrated with demand-side process end users by expanding our thinking about energy systems.

Stepping Outside The Box

There are many advantages to broadening our view and "stepping outside of our box." First, we can better serve the customer. Facility energy systems serve important operating need. The better we understand the needs of process end users, the better value we can provide. For example, if an adjustable speed drive (ASD) can reduce energy consumption by 50-70 percent, it may also, through more precise speed control, solve process quality problems.

In this expanded view, the dollar contribution of the ASD to the business by eliminating the quality problem may be more than five times what the limited view of energy savings alone would produce.

Additionally, energy end users can offer many energy solutions, both in process areas and in supply system operations, provided we ask for their input and listen to their answers.

How can we expand our thinking about energy systems and better integrate the supply side with the demand side? First, we should focus on how to better use energy to make money rather than simply reduce energy costs. Approaching energy responsibilities in this way, we will discover new and different possibilities to improve the profitability of a facility. This approach introduces an obvious but undervalued idea: optimizing, rather than reducing, energy to improve operating profits.

Integrating Systems and Energy Optimization

The concept of optimizing a resource like energy requires the resource to be optimized with respect to something. In the expanded view, that something is profits, both for today and tomorrow. Optimization improves total system benefits by presuposing that things can be done better, no matter how well they are being done today. Optimizing energy does not maximize efficiency, but rather maximizes energy performance. Optimum energy performance results in the greatest possible contribution to the business. The definition of performance not only includes supply efficiency and reliability, but also encompasses the direct contribution of energy to production capacity, employee productivity, product quality, customer satisfaction, and environmental benefit.

Energy contribution can be optimized and still satisfy many disparate issues. All considerations are included by building a cost equation that optimizes energy performance and includes all issues where the supply, conversion, distribution, and end-use of energy systems have an effect on the bottom line.

Cost Equations for Integrating Energy Performance

The cost equation is the engineering version of the accountant's cost sheet. While the accountant follows standard accounting practices to set up cost centers that add costs vertically, engineers are trained to think horizontally, in the form of equations. Engineers and accountants sometimes have professional differences in regrouping cost components of profit-sensitive issues that completely capture the total cost. The cost equation approach includes not only direct variable and indirect fixed costs, but also consequential costs that are a direct result of energy use (see Figure 1A).

A lighting project illustrates the cost equation concept. We know that we can include an annual savings credit for air conditioning when installing high-efficiency lighting. Often this results in 15-25 percent savings beyond the direct lighting energy savings. However, we do not usually take into account the value of extended lamp life and reduced maintenance. We certainly do not credit our new, properly designed lighting systems by quantifying the resulting improvements in employee satisfaction, product quality, and reduced safety incidents, or the productivity improvements and customer satisfaction that we can document. If we did, the return on a lighting project with a four-year simple payback might be well under two years.

ABC Inc. Example

ABC Inc. had an environmental problem with water and wastewater that escalated to \$5.5 million per year. This was in part because of production increases, but mostly because of municipal sewer taxes levied for a new city wastewater treatment plant. The manufacturing process used large amounts of hot water that carried both energy and raw material into the sewer. While the problem was recognized and an on-site pretreatment plant was under construction, the economic consequences of the water and wastewater issues were not fully quantified. An analysis was performed using a cost equation that added seven separate water-related cost elements. The total annual cost was discovered to be \$11.5 million, more than twice the \$5.5 million often mentioned in city tax figures.

FIGURE 1A: COST EQUATIONS FOR OPTIMIZING ENERGY PERFORMANCE

$$\text{Cost (\$/Year)} = \sum_{1}^{n} (\text{Direct Costs}) + (\text{Indirect Costs}) + (\text{Consequential Costs})$$

FIGURE 1B: COST EQUATION FOR W/WW* AT ABC INC.

$$\text{Cost (K\$/Year)} = \sum_{1}^{n}$$

(1)	Purchased Cost	@	\$ 1,800K/Year
(2)	Pretreat Cost	@	\$ 1,700K/Year
(3)	Sewer Tax Cost	@	\$ 5,500K/Year
(4)	Admin./Support	@	\$ 300K/Year
(5)	Net Fuel/Htg. Cost	@	\$ 300K/Year
(6)	Net Pumping Cost	@	\$ 700K/Year
(7)	Raw Mat'ls. Cost	@	\$ 1,200K/Year

$$\text{Cost (K\$/Year)} = \sum_{1}^{7} (\text{Individual Items Above}) = \$11{,}500\text{K/Year}$$

* W/WW is Water/Wastewater

The larger cost was determined by using the cost equation concept that legitimately included three groups of costs: direct, indirect, and the unique consequential costs that are a direct result of this process. Looking at each cost group (see Figure 1B):

- *Direct Costs* include the purchase or supply cost of water, operating costs for the new pretreatment plant, sewer taxes, and all other routine direct operating labor and maintenance costs.
- *Indirect Costs* include all asset-based fixed costs (taxes, depreciation, and insurance), all associated fixed environmental support costs (administration and permits), and all routine technical support costs.
- *Consequential Costs* are all current and foreseeable variable and fixed costs, including the net present value of future capital. Most of the consequential costs were found buried in the accounting system. The consequential costs include such items as water treatment for boiler feedwater and cooling towers, significant electricity to pump water, and net fuel to heat water. Also significant in the water-wastewater cost equation are a variety of process yield issues where the water enters the facility clean but leaves the processes with valuable raw materials. Here, resource recovery can play an important role.

The bottom line of ABC Inc. was dramatically improved as the result of a PO audit that focused on water-wastewater conservation, process energy, process optimization and reengineering changes to increase plant capacity.

A Fortune 500 Company Survey Results

A good example of less-than-complete understanding of total system cost comes from an unnamed Fortune 500 company. That company surveyed more than 50 of its manufacturing plants for an accounting of water and wastewater costs. Most plant managers responded that water was not a significant cost

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issue, routinely $100,000 per year to purchase, compared with other utilities such as electricity at $1 million per year or more. Further analysis using the cost equation approach concluded that while the average plant spent $1 per kilogallon (kgal) to buy water ($100,000 per year), it spent $8 per kgal ($800,000 per year) to buy, treat, pump, heat, use, abuse, and dump this water. This meant that what appeared to be a $100,000 per year item was actually $800,000 per year. The plant managers were shocked.

The result was a dramatic change in priorities that redoubled the efforts for cost-effective solutions to what was now recognized as a significant economic issue. The final outcome was more than a 50 percent reduction in water-wastewater use and cost over a three-year period, in spite of a continued escalation of unit cost for supply and discharge.

Practicing System Integration and Process Optimization

We can duplicate the success of ABC Inc. and the Fortune 500 company, but not by applying traditional cost reduction approaches. Cost reduction efforts focus on such issues as restructuring the organization and re-engineering business activities, not changing the production process. Most of these activities occur either before or after the actual manufacturing process. While a traditional cost reduction approach can contribute to improving the bottom line, it is far more profitable to work on integrating energy systems and optimizing them and the manufacturing process.

Energy system integration and process optimization use unique methods to reengineer how the finished product is made. These methods optimize the manufacturing process by linking energy and process changes to profit improvement. Three of the many techniques used in a process energy optimization audit are cost equations, one-line balances (OLB), and process modeling. The cost equation concept, shown earlier, develops the total cost consequences of a profit-sensitive process and provides economic guidance as to where the audit team should spend its time. The OLB is a schematic diagram (see Figure 2) of a particular plant utility, such as steam generation, that estimates utility production, measured in average kilopounds

FIGURE 2: INTEGRATING ENERGY AND PROCESS SYSTEMS
ONE-LINE BALANCE, STEAM (ANNUAL AVG. KLB/HR)

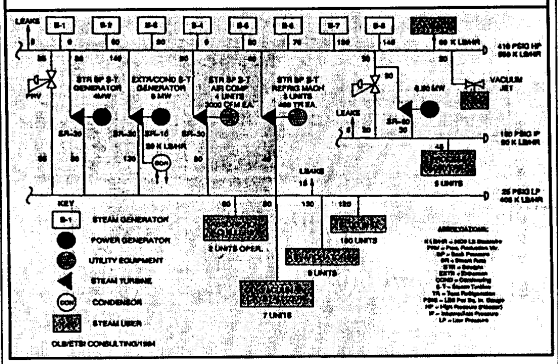
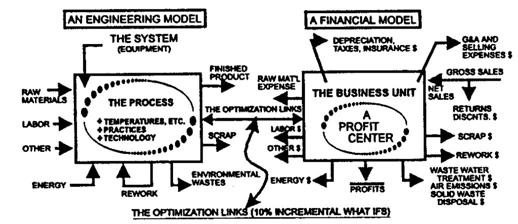


FIGURE 3: THE PROCESS OPTIMIZATION MODEL
LINKING PROCESS CHANGES TO PROFIT IMPROVEMENT
USING CONCEPTUAL MODELS



WHAT IS THE CONTRIBUTION TO PROFITS FROM:

1. 10% IMPROVEMENT* IN RAW MATERIALS USE (LESS SCRAP, WASTE; LESS REWORK)
2. 10% INCREASE FROM DEBOTTLENECKING (WITHOUT ADDING NEW LINES)
3. 10% IMPROVEMENT IN LABOR PRODUCTIVITY (SMART PEOPLE MAKING SMART PRODUCTS)
4. 10% IMPROVEMENT FROM ENERGY OPTIMIZATION (USING ENERGY TO MAKE MONEY)
5. 10% IMPROVEMENT IN ENVIRONMENTAL PERFORMANCE (POLLUTION PREVENTION)

* NOTE: THE 10% FIGURE IS ARBITRAR; MORE OR LESS MAY BE POSSIBLE..

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Figure 4
PROCESS OPTIMIZATION SERVICES: BARRIERS/RESPONSE

THE TOP EIGHT

BARRIERS	RESPONSE
1. You are not an expert in my plant's technology.	1. I am not an expert in your technology, but I'm an expert in analyzing processes. We have a unique methodology by which together we can analyze your process to increase profits.
2. We don't have time to do it. I lost a lot of good people in the last "down-sizing."	2. We have some very creative people in process optimization who can support your reduced staff.
3. We have people who do this sort of thing...in-plant quality improvement teams, etc.	3. Good. We need exactly those kind of people working with us to apply our unique methodology. We frequently find that "re-engineering" efforts are more focused on people activities rather than improving the mfg. process.
4. Our Management won't let us change the process (the "Sanctity of the Process").	4. Management may have once liked status quo. The situation today may be different with increased competition, higher manufacturing costs, and lower margins. Let's ask if we can change the process to increase profits.
5. We don't know how the process works; it just does (the "Mystique of the Process").	5. This is more common than one would think. All the "old" experts have retired? One of the major benefits from the process optimization approach is a better fundamental understanding of how the process works.
6. The process is working just fine; we're making money (if it "ain't broke," don't fix it).	6. Is the process truly optimized? What is the difference between the best profit month versus the worst loss month over the last few years? How much money could be made if the process were optimized? If parts of the process "ain't broke"...we won't fix them.
7. We have always done it this way (resistance to change).	7. New/different ways are not always better; however, living with outdated operations and technology can be risky. We look for the good and the not-so-good in the process... keep the former, change the latter.
8. There is no way to optimize this process (lack of proven methodology).	8. Not so! The process optimization (PO) methodology is proven. More than 70 PO audits have been done over the last 24 months alone. In every case, without exception, the client was more than satisfied.

Process Optimization Services/How to Sell – Copyright: ETSI Consulting

per hour (klbs./hr.) per year from boilers; distribution in klbs./hr. through each steam header; and process end use in klbs./hr. to dryers, building heat, etc. Not only is utility flow quantified in klbs./hr., but annual cost is also shown for each flow rate (10 klbs./hr., $438,000/year based on 8,760 hrs./year at $5/klb.). The OLB integrates supply with demand and links energy consumption and cost, and directs the process energy audit team where to spend its time.

A third technique is the use of process models (PM's). PM's also integrate supply-side energy systems with processes on the demand side and uniquely link engineering and financial issues. Modeling the process is done at two levels: conceptually in a level-one PO audit, and using software for an in-depth, level-two PO audit.

A conceptual model (CM) is shown in Figure 3, linking the engineering schematic of the process to a financial representation of the same process. The CM is used to determine the resulting total dollar value of improving various cost issues by 10 percent.

The modeling approach challenges existing process operating conditions, practices, and technology. This is accomplished by the audit team imagining that they are pieces of raw material passing through the process steps. In this imaginary scenario, team members can relate directly to the process and ask such questions as "Why are we being heated to 180 degrees F; why not 170 degrees or 190 degrees?" This technique challenges the status quo and introduces the idea of optimization.

Level-two PO audits use computer software to simulate process steps, quantifying cycle times, chemistry, and scrap levels. Level-two modeling allows the audit team to consider dozens of alternative scenarios, always moving the process closer to the optimum. The final result is usually a dramatic improvement in financial performance and an edge over the competition.

The PO audit challenges the status quo in a different way, by asking how energy can improve profits by solving scrap, capacity, product quality, and environmental problems, rather than the usual question of how can we simply minimize energy consumption and cost? Optimizing both energy and the manufacturing process allows access to 19 times more operating dollars than energy alone, if purchased energy is 5 percent of operating cost. Why the restriction of 5 percent of operating cost when energy touches each process step and affects all production operations that consume the other 95 percent of the costs? Improved profitability of nonenergy issues is a large benefit of process optimization. Now top management will listen to you, because you just mentioned the "P" word (profit), and you are showing interest in the "other" 95 percent of the cost issues that are the primary management focus.

Formalizing the Process Optimization Approach

PO is a formal, systematic, four-phase approach accomplished in levels or depths. The level one PO audit is a two-to five-day on-site effort that focuses on ways to improve the contribution of energy and other resources to profitability (see Figure 3). The PO audit objective is to identify and quantify as many potential process-energy improvements as possible, usually 50 or more. The top 10-15 percent of the process-energy ideas are quantified with estimated

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economics. Additionally, other nonenergy cost and profit issues are reengineered, providing an additional 100 or more process improvement ideas. In most cases the highest value ideas from the audit save raw material by increasing yields and lowering scrap by production capacity or output improvements, and by improving product quality by examining rejects, rework, and returns.

This explains how the potential cost savings from a PO audit can be 100 percent or more of total purchased energy.

The integration of in-plant supply-side systems, such as boilers and air-compressors, with production floor demand-side system users of steam and compressed air is a productive and powerful concept. The end result is a long list of potentially profitable process and energy ideas that are narrowed to a short list of best ideas for either immediate implementation or further development, analysis, and testing in the level-two PO audit.

Overcoming Barriers to Process Optimization

If PO is such a great concept, then why doesn't everyone integrate energy and process systems? Why haven't all companies already optimized energy and other cost- and profit-sensitive issues?

The answers lie in the list of barriers that prevent implementation of PO. All of these barriers are people issues, not technical issues. The barriers can include everything from turf battles or "you might make me look bad," to insecurity and defensive attitudes. However, there is an answer to every barrier. The top eight barriers and responses are presented in Figure 4.

As technical managers of energy and facility infrastructure, we can contribute more to the bottom line if we integrate energy systems with production operations and focus more of our attention on optimizing energy and process conditions. This activity requires "stepping outside our box" (the boiler house or mechanical room) and partnering with our customers.

Optimizing energy performance extends beyond the traditional plant energy supply and distribution systems. Energy optimization must include the possibilities for energy to solve such production and product problems such as capacity limitations, high scrap or high use of raw materials, product quality problems, or environmental issues.

A uniquely structured approach to integrating energy and process systems is the PO audit. The level-one audit methodology systematically analyzes the financial and technical potential of process improvements. PO audit techniques include cost equations, one-line balances, and process models. The process audit identifies specific ways to improve the effective use of energy, raw materials, labor, and other inputs.

The results optimize energy input along with production capacity, yields, product quality, and environmental benefits. All of these results provide solutions to profit-sensitive issues.

The PO approach is maximized by fostering an energy and process partnership that overcomes barriers between the supply and end-use functions. Once ways to quickly hurdle the PO barriers are in place, the joint process energy team can create remarkable financial results.

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INTEGRATING ENERGY AND PROCESS SYSTEMS QUIZ: Unit #4 of 12 TEST 4/97

The Energy User News/Association of Professional Energy Managers Energy Management Training Series is designed to provide nonspecialists with an introduction to the fundamentals of energy management. One training unit will appear in each issue of EUN during 1997, along with a quiz. Persons who pass all 12 quizzes in the series with a score of 70 percent or greater will receive a certificate recognizing their successful completion of the course. To have your quiz scored and credited, fill in the correct answers and return this form (or a photocopy) to Energy User News, Attn. Training Department, 201 King of Prussia Road, Radnor, PA 19089; fax it to (610) 964-4647; or take the quiz on the internet at http://www.energyusernews.com. Call (610) 964-4060 with questions. The training series is prepared under the direction of John L. Fetters, CEM, CLEP.

1. What is the fundamental commercial/industrial motivation for energy initiatives?
- **a.** Efficiency
- **b.** Reliability
- **c.** Savings or profits
- **d.** Technology

2. Integrating energy and process systems requires:
- **a.** Stepping out of our box
- **b.** Using energy to make money
- **c.** Optimizing, not reducing, energy
- **d.** All of the above

3. Integrating utility supply and end use demand systems is quickly done by:
- **a.** Developing a computer simulation of the entire facility energy system
- **b.** Developing a one-line balance by estimating average energy flow (kW, SCFM, or lbs./hr. and cost ($/yr.) of utility production
- **c.** Measuring actual loads on all low-voltage feeders
- **d.** Asking the Engineering Department to calculate steam flow to all major process equipment

4. A technique not used in the process optimization audit is:
- **a.** Capital cost allocation procedure
- **b.** Cost equations that link process changes to profit improvement
- **c.** One-line balances that integrate utility supply with process users
- **d.** Conceptual and computer modeling that challenges the status quo

5. The one way that energy does not contribute to the bottom line is:
- **a.** By identifying energy solutions to nonenergy issues or problems
- **b.** By considering total energy performance rather than efficiency only
- **c.** By leasing, rather than buying, energy-efficient equipment
- **d.** By capturing the total impact of energy with cost equations

6. What was the ABC Inc. and the Fortune 500 companies' surprise?
- **a.** The total cost of water/wastewater was far greater than expected
- **b.** Water/wastewater was not significant compared with their annual energy costs
- **c.** The cost-equation concept was disallowed by company accountants
- **d.** None of the above

7. How can supply and demand-side energy systems be integrated and processes be optimized to significantly increase profits?
- **a.** Contract for an energy audit on lighting and motors
- **b.** Perform a level-one process optimization audit
- **c.** Increase the representation of the energy committee
- **d.** None of the above

8. The process optimization audit does all of these except:
- **a.** Stresses global system optimization rather than single-issue suboptimization
- **b.** Links process changes to profit improvement with cost equations
- **c.** Reveals potential energy conservation measures
- **d.** None of the above

9. The common element for barriers to process optimization auditing is:
- **a.** Technology gaps
- **b.** Lack of proven methodology
- **c.** People issues (human nature)
- **d.** None of the above

10. Additional information is available on integrating energy systems, process energy systems, and process energy optimization from:
- **a.** Part II of Integrating Energy and Process Systems (EUN/APEM Training Series, May 1997 issue)
- **b.** ETSI Consulting, Inc. (704)-665-9323; FAX: (704)-665-2229
- **c.** Training Workshops by ETSI, Inc. provided at a client's site or at the University of Wisconsin (Madison) or NCSU (Raleigh)
- **d.** All of the above

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Appendix F: Process Optimization

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Walt Smith is president of Energy Technology Services International Inc. (ETSI), a consulting company of networked experts based in Candler, N.C. ETSI provides a wide range of energy and process/business services, including industrial and commercial audits, cogeneration feasibility studies, process optimization/reengineering audits, and seminar/workshops on more than 30 energy-related topics.

PROCESS OPTIMIZATION: Integrating Energy and Process Systems

By WALT SMITH

This is part two of a series on process systems. Part one introduced the concept and business benefits of integrating energy and process systems. Part two, "Integrating Energy and Process Systems," provides a way for manufacturing and business or service operations to reengineer critical, profit-sensitive issues. The approach goes beyond reducing energy costs (only 1-5 percent of revenue) to exploring solutions that optimize all operating cost and revenue inputs to the business. The approach integrates energy and process systems, using energy to solve operating problems. The primary focus should be on how to optimize (not reduce) energy to improve operating profits. Process optimization (PO) is accomplished through a PO audit that uses both conventional and nonconventional energy and environmental audit techniques. The operations and business processes are financially and technically audited, usually identifying 50-150 process changes that could achieve a 3-15 percent reduction in operating costs; a 10-50 percent increase in output and sales volume; and a 20-100 percent increase in profit margin.

These results provide the competitive edge companies seek. The benefits are attained by finding ways to remove bottlenecks in operations and business processes; increase labor productivity and performance; improve product and service quality; reduce scrap, waste, and rework; reduce equipment failure and downtime; accomplish pollution prevention and compliance; and optimize energy at the point of use.

PO: What is It? How is It Done?

The PO audit reengineers operations and business processes, significantly improving bottom-line results. The methodology works equally well for product manufacturers and businesses that provide services. The process definition includes operating conditions and technical setpoints (temperatures, cycle times, etc.); operating procedures and practices (work methods, people issues); and fundamental technologies (chemistry, physics, heat transfer, etc.).

The process is audited in four phases (see Figure 1) and at several levels of depth or precision (see Figure 2). Figure 1 summarizes the four phases that occur over a two-to-five-day period for a level-one audit. The objective of a level-one PO audit is to determine the potential to improve profitability by identifying 50-150 process improvement ideas and quantifying the top 20 percent.

One characteristic of a level-one audit is "guess at everything, measure nothing." The audit team combines site-specific business and process knowledge and skills of four to eight key facility personnel (outstanding guessers) with the outside experiences and process analysis know-how of PO consultants. Level-two PO analysis requires a far greater commitment of time (see Figure 2). Here larger, more complex process improvements are developed and, where necessary, evaluated on a prototype basis. The motto of the level-two analysis is "guess at nothing, measure everything." Level-two PO analysis delivers appropriation-grade economics for funding proven process changes.

Figure 1

The Process Optimization Methodology

PHASE 1 ➡	PHASE 2 ➡	PHASE 3 ➡	PHASE 4
Establish Potential Dollar Value	**Quantify The "As Is" Process**	**Create the "To Be" Process**	**Estimate "New" Profit Contribution**
• Connect Process to profit • The Level I Process Audit Concept • Manufacturing Cost Structure • Incremental 10% What Ifs • Cost/Profit Equations • Target Process and Process Team	• Block Process Flow Diagram • Material Balances • One-Line Balances • Calculate Process Efficiency • The 10% Efficient Process • Weakness Analysis (Problem Step)	• Brainstorming Process Changes • Review the Basis for Brainstorming • Ranking Profit Issues • Silent Idea Generation • Develop the Object Statement • Master List of >100 Process Changes	• The How-Why Diagram • Selecting Top Candidates • Estimating New Profits • Implementation Cost and Risk • Organize Preliminary Results • Closing Meeting with Management

Figure 2

Process Optimization Level Definitions

LEVEL I	LEVEL II	LEVEL III
• Profit Opportunity Analysis • Identify 50–100 Process Ideas • Identify Top Ideas • Measure Nothing; Guess at Everything • ±40% $ Estimate • Implement No-Cost Ideas	• Pursue Top Ideas from Level I • Develop Additional New Ideas • Measure Everything; Guess at Nothing • Detailed Economic Analysis for Appropriation-Grade Estimates • Implement Low Cost/Risk Ideas	• Implementation of Capital Projects • Detailed Design and Engineering • Procurement, Construction, and Startup

Level One PO Audit

Phase one determines the potential dollar value of the improvements by identifying critical, site-specific, profit-sensitive issues. The critical issues list consists of any condition or event that significantly affected monthly earnings over the past few years. Examples might include capacity bottlenecks limiting production, high scrap, poor on-time deliveries, or people issues (turnover, training, etc.). Next, annual operating revenue and costs are analyzed. This financial analysis serves two important purposes: to guide the audit team to find lost profits, and to help quickly estimate budget-grade (ballpark) economics on individual and group process improvement ideas. Operating revenue and cost structure provide a basis to calculate the annual contribution to profits from arbitrary 10 percent improvements in the top three or four critical issues. New profit or margin is calculated from a 10 percent improvement in capacity and sales, a 10 percent increase in labor productivity, and a 10 percent reduction in scrap, rework, energy intensity, or whatever was determined earlier to be a critical, profit-sensitive issue. Phase two numerically analyzes the "as is" processes using color-coded process flow diagrams (PFD's). Figure 5 shows the PFD from the Milwaukee Metropolitan Sewerage District (MMSD). Other analysis techniques include weakness analyses and where-why diagrams. Existing process problems are jointly identified and quantified by the audit team. Conceptual modeling is used to quickly understand the basic process steps and the value added by each. A conceptual process model, in its simplest form, is to imagine we are raw material being converted through many steps into finished product. For example, why are "they" heating us up to 150 degrees? Why not 140 or 170? Or why are "they" cutting us and producing so much scrap? The results from phases one and two provide the audit team with intimate familiarity with critical process issues and lay the foundation for identifying specific process changes (solutions). Phase three brainstorms solutions to critical issues to create the "to be" process. Operating conditions (temperatures, cycle times, etc.) are challenged, and procedures and practices of employees engaged in critical issues are questioned. New technology is considered for specific process steps or more widely for substitution in broad process areas. Typical process optimization thinking would consider lowering (or raising) a process temperature; question the purpose of a particular production procedure or

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even the need to do it at all; challenge the amount of process waste heat and changing the process to minimize it rather than trying to recover it; eliminate or combine production steps; use low-energy processes; and use high-yield technologies. How can the process better use its input resources (raw materials, energy, etc.) and its outputs (product quality, plant capacity, environmental investment) to make money? Brainstorming uses a simplified form of nominal group technique with silent idea generation that ensures full concentration and participation from all team members with high productivity. Multiple rounds of brainstorming produce 40-80 process solutions to each critical issue.

In phase four the best ideas are selected, categorized, and grouped in order of ease of implementation. Budget-grade economics are developed on the top process ideas. The top ideas are selected by each participant distributing 20 votes among the list, up to three votes maximum per idea. Selection criteria are that an idea must contribute significantly to profits (e.g., $10,000 or more per year, not $1,000); must be manageable with time and money (one year, not six to implement and be cost-effective); and must be low-risk. The audit team reviews the list of process improvements that were identified and, by discussion and vote, selects and groups suggested solutions for ease of implementation and dollar value. The ideas are screened and categorized as no-cost, no-risk; no-cost but difficult to implement; low-cost, low-risk; and ideas that need time and money but have a big payoff. The audit team develops consensus for the value as profit contribution of a combination of similar ideas. The 10 percent incremental "what if" cost analysis developed in phase one for critical issues is used to estimate the value of individual or groups of process improvement ideas. The level-one PO audit concludes phase four with a wrap-up, debriefing meeting to present preliminary results, clarify economics on top ideas, and gain management buy-in for implementation. This is the most important task in phase four. All audit results are documented in a comprehensive report providing economics on the top process solutions.

Figure 3 summarizes results from implementing process energy recommendations from audits of several automobile/truck manufacturing facilities.

A PO Audit: MMSD

A PO audit of the MMSD, Jones Island Operations, was performed April 22-23, 1996, with the participation of key site personnel. It aimed to financially and technically audit operations and manufacturing steps and identify process changes that would significantly reduce operating costs and increase contributions from the production of Milorganite. The overall production process (phase one) was financially analyzed, targeting Milorganite production for the top-line fertilizer market. The size and complexity of the Jones Island facilities are represented in the site plan. MMSD's operations completed a major modernization program at a cost of more than $2 billion over the past decade to become a state-of-the-art municipal wastewater treatment facility. Jones Island has an operating budget of $24.6 million per year. An analysis of the facilitywide revenue operating-manufacturing cost structure is presented. Raw material (raw sewage), unlike in most manufacturing operations, is not listed as an operating expense. In fact, it is a revenue stream in which residential, industrial, and commercial fees cover 77.4 percent of operating costs. The 10 percent annual improvement economics were summarized for plantwide operations. The objective to reduce costs by optimizing production rate and energy was a welcome challenge to the PO methodology. The Milorganite process was quantified with raw materials, labor, and other inputs and outputs (phase two). A walk-through process tour of manufacturing operations provided a basic understanding of major process steps, which were represented in a PFD developed by the PO team to focus attention on all cost-sensitive issues (see Figure 5). Other process schematics were available, but

Figure 4

Energy Optimization Brainstorming List: Milwaukee Metropolitan Sewerage District PO Audit

Object Statement: Identify energy/process improvements to significantly reduce energy cost (-10% worth $660,000/year) by optimizing energy use within permit limits (air and water), and with equal or greater product quality, labor productivity, safety, etc.

Idea Description	Votes
• Control air flow to feed channels by D.O.	6
• Reduce PAC pressure during on-peak time.	6
• Improve efficiency of dryers:	8
a. By better mixing to the dryers.	
b. Replace conveyor screw with mixing screw.	
• Produce a dryer press cake at more consistent level (16 ± 2.5 18 ±1.0):	8
a. Improve 80:20 to 70:30 WAS to PSD.	
b. Nuclear density meter or micro-motion meter (mass flow meter).	
c. Optimize chemical addition online.	
d. Mech. optimization (example: belt speed, cleaning, # presses).	
• Optimize use of GBTs in thickening:	0
— 5.5% solids and 40 TPD 6.5%.	
— less use of centrifuges.	
• Preheat sludge to presses and/or dryer.	5
• Find more use for GT heat (see #23).	3
• Process all South Shore solids at Jones Island.	7
• Combine two gas meters into one — $29K.	0

Figure 3

Process Energy Optimization Implementation

Item	Descriptive Title	Savings $/Year	Installed Cost ($)	Simple Payback
1.	Eliminate air blow-off on parts washer	$9,880	$0	Immed.
2.	Elimination of phosphate dry-off oven	40,000	0	Immed.
3.	Use of blower in lieu of compressed air	19,200	5,000	3 mos.
4.	Reduce temperature of paint strip tanks	7,300	0	Immed.
5.	Lower temperature in paint ovens	4,800	0	Immed.
6.	Replace furnace burners	61,200	24,600	5 mos.
7.	Change paint to reduce bake temperature	13,400	1,800	1.6 mos
8.	Eliminate washer by use of ethylene glycol quench	23,460	0	Immed.
9.	Eliminate vacuum system by tie to central system	3,400	500	1.8 mos
10.	Eliminate need for ovens by using hot glue	14,400	5,000	4.2 mos
11.	Eliminate brazing operation by design change	11,000	2,000	2.2 mos
12.	Eliminate a parts washer by using a paint compatible with die lube	23,000	1,800	0.9 mos
13.	Shut down infrared section of prime oven	23,000	0	Immed.
14.	Turn steam down or off to parts washers by using low-temp. detergents	123,300	0	Immed.
15.	Do touch-up painting in prime paint area and shut down separate booth	9,300	5,000	6.5 mos
16.	Use condensate to heat rinse tank instead of sewing and using steam	7,700	200	0.3 mos
17.	Eliminate unnecessary brake drum washing by plant testing	4,600	0	Immed.
18.	Clean brake shoes and flange plates in same washer	3,200	550	2.0 mos
	Total for 18 Projects	$ 402,180	$46,450	1.4 Mos

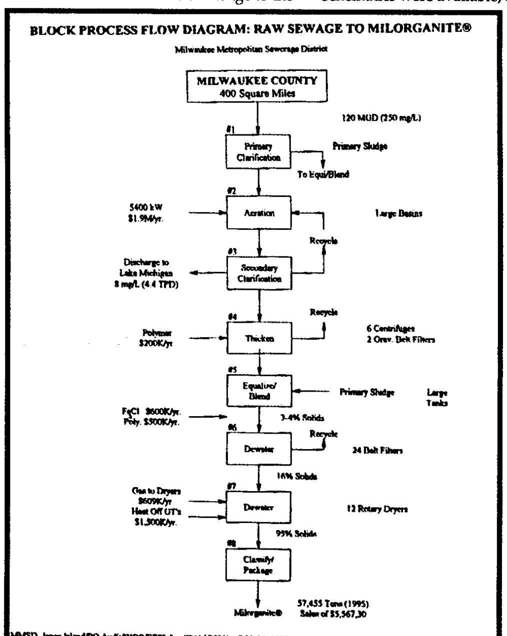

Figure 5

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Budget Economics for MMSD's Top Optimization Ideas

	Savings (K$/Yr.)	Cost (K$)	Payback (mos.)
Group A:			
5 no cost/no risk	673	0	Immed.
Group B:			
11 requiring cap. investment	2,260	1,818	10

they lacked the process and financial data added to the project team's PFD. The PFD was used by the audit team to identify problem steps (capacity constraints, energy intensity, etc.) and to discuss these cost-sensitive issues using weakness analysis techniques. One-line balances were developed that provided insight as to where, how, and how much fuel and electrical energy (and energy dollars) were used in facility operations. The development and quantification of the PFD and one-line balances set the foundation to brainstorm process changes (phase three). The goal is to improve MMSD's costs by optimizing all profit-sensitive inputs and outputs. The team identified 35 process ideas to optimize energy (see Figure 4). Plant experts played the major role in identifying both problems and solutions. Ideas were reviewed for clarification. Each team member independently selected the top ideas by assigning 15 votes, no single idea receiving more than three votes per team member. Seven ideas received eight or more votes. Ideas were further grouped into two categories: no cost/ no risk (nine ideas) and ideas with possibly less than a two-year payback (10 ideas). Finally, the team worked in smaller groups to develop budget economics (savings, cost, payback) on individual or groups of ideas previously judged to have high potential. The economics used the financial data and 10 percent incremental benefits developed in phase one.

Caution must be exercised when looking at the total dollars of both groups. Some projects compete with each other and one or the other would be done, but not both. Also, as some projects are pursued in level two, the economics often fall short of initial expectations. Most ideas must be developed further and, in some cases, pilot-tested. It is not recommended to immediately implement process changes without careful reevaluation and verification of technical and economic assumptions. The primary objectives of the level one process audit were to determine the economic potential for additional profit from process changes and to transfer the PO methodology. Many process and energy optimization ideas were identified and the top ideas were quantified. The quantity and quality of process improvements identified in the two-day level one audit suggests that significant potential exists. MMSD can accomplish these potential profit gains by pursuing an aggressive program of PO. Continuation of the PO methodology is recommended.

The PO audit methodology has been successfully applied in more than 100 cases at companies and operating facilities within the last three years. Companies in the metals, forest and paper products, chemical and pharmaceutical, oil and gas, food processing, automotive, textile and other industries also have received benefits from the PO approach. Non-manufacturing service operations such as medical, entertainment, government, and military also have received benefits from PO audits.

PROCESS OPTIMIZATION: QUIZ Unit #5 of 12

The Energy User News/Association of Professional Energy Managers Energy Management Training Series is designed to provide nonspecialists with an introduction to the fundamentals of energy management. One training unit will appear in each issue of EUN during 1997, along with a quiz. Persons who pass all 12 quizzes in the series with a score of 70% or greater will receive a certificate recognizing their successful completion of the course.

To have your quiz scored and credited, fill in the correct answers and return this form (or a photocopy) to ***Energy User News****, Attn. Training Department, 201 King of Prussia Road, Radnor, PA 19089, or fax it to (610) 964-4647; or take the quiz on the internet at http://www.energyusernews.com. Call (610) 964-5569 with questions. The training series is prepared under the direction of John L. Fetters, CEM, CLEP.*

1. Process optimization (PO) audits:
   a. focus primary on energy reduction.
   b. identify ways to change the process to increase profits.
   c. look for new technology rather than people solutions.
   d. None of the above
2. Process energy optimization:
   a. increases efficiencies in the boiler house and compressor room operations.
   b. looks for opportunities for energy efficient motors.
   c. questions and challenges the purpose of the motor and its contribution to process efficiency and profits.
   d. recommends insulation in steam and chilled water distribution systems.
3. Level IPO auditing is done:
   a. in four phases over a 2-5 day period.
   b. by level where Level! "guesses at everything, measures nothing.'
   c. by combining the knowledge and skills of key in-house participants with the process analysis experience of consultant/facilitators.
   d. All of the above
4. Integration of energy and process systems can be applied to:
   a. only industrial plants manufacturing products.
   b. business that offer services rather than products.
   c. both manufacturing and service businesses.
   d. only to large, energy-intensive facilities.
5. The most important task in the forth phase of a PO audit is:
   a. selecting, screening and grouping process ideas are the first step in implementation.
   b. providing budget-grade economics (savings, cost, payback at ±40%) are also critical for implementation.
   c. the wrap-up/debriefing of preliminary audit results pushes the Audit Team against a deadline, clarifies budget economics and confirms management "buy-in" on implementation.
   d. documenting results in final report.
6. The Level IPO audit success is primarily due to:
   a. linking process changes to profit improvements.
   b. the specialized skills from the consulting side.
   c. a comprehensive process simulation prior to the audit.
   d. None of the above
7. The "Example Results" from the Process Energy Analysis of Truck and Automotive Facilities
   a. illustrates how new technology can save money.
   b. demonstrates that process elimination can provide dramatic savings at almost no cost.
   c. indicate that management and workers don't care about energy efficiency and costs.
   d. None of the above
8. The "Case Study" of MMSD illustrated a unique facility with multiple purposes where the largest cost-sensitive issue was:
   a. yields in the production of Milorganite® fertilizer.
   b. energy representing approximately 27% of the annual operating budget. ($7 million of $25 million per year).
   c. meeting BOD permit discharge levels.
   d. lack of new technology.
9. The integration of energy and process systems is most important to managers of energy because:
   a. it focuses on profits rather than the cost side of the equation.
   b. it focuses outside of the boiler house and compressor room.
   c. it provides the information on how important energy supply is to production performance.
   d. None of the above
10. Process Optimization: Integrating Energy and Process Systems provides the greatest benefits to the business by:
    a. establishing better teamwork between suppliers and users.
    b. improving cost efficiency in energy conservation and distribution systems.
    c. using energy to selectively solve very costly operating problems.
    d. None of the above

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Appendix G: Process Audits Completed in 1995, 1996, and 1997

A. O. Smith, Inc.
Allied Signal Chemicals, Inc.
American Linen Supply Corp.
Amron Corporation, Inc.
Arcon, SRL (Romania)
Armcable, SRL (Armenia)
BASF Corporation (Anderson)
BASF Corporation (Morganton)
BASF Venezolana (Turmero)
Bombay Dyeing (India)
Branick Industries, Inc.
Bunge Foods, Inc.
Cabletron Systems, Inc.
Cape Industries, Inc.
Case Corporation
Centech, Ltd.
Central Products, Inc.
Chevron USA, Inc.
Connelly Container, Inc.
Conte Luna Foods, Inc.
Contech, Inc.
Cudahy Tanning Company
Deerfield Plastics, Inc.
Disney World, Orlando
Eastman Gelatine Corporation
Eli Lilly, Inc.
Engineered Polymers Corporation
Federal Beef Processors, Inc.
Flexible Technologies, Inc.
Forte, KFT (Hungary)
Frigidaire Corporation
GMT Microelectronics, Inc.
General Cable, Inc.
General Motors Corporation
Giddings & Lewis
Handy & Harman, Inc.
Hilados Flexilón, SA (Venezuela) (2)
IMC Nitrogen, Inc.
Karl Schmidt Unisia, Inc.
Kraft Jacobs Suchard (Hungary)
Ladish Malting, Inc.
Louys Lamp Plant, SRL (Armenia)
Matizol, SRL (Romania)
Milwaukee Metro Sewer District
Navistar/International Harvester (4)
Newton New Haven, Inc.
Nirite Chemical, SRL (Armenia)
Norfolk Naval Shipyard
NVF Company, Inc.
Ocean Spray, Inc.
Ohmeda, Inc.
Oreida Foods, Inc.
Pemex, SA (Tampico, Mexico)
Pepperidge Farm
Pine Bluff Arsenal (3)
Prime Resources Corporation
Red Star Yeast
Rehrig Pacific Company
Reichhold Chemicals, Inc.
Repap Wisconsin, Inc.
Sandvik-Milford Corporation
Schreiber Foods, Inc.
Simpson Paper, Inc.
Southeastern Wisconsin Products
The Spencer Turbine Company
Stanadyne, Inc.
Stirom, SRL (Romania)
Stoughton Trailers, Inc.
Strauss Engineering, Inc.
Superior Electric Company
Teledyne Wah Chang, Inc.
Topcraft, Inc.
Tri-Light Plastics, Inc.
Trinity Medical Center Hospital
Tubed Products, Inc.
Tungsram, KFT (Hungary)
Tyco International, Inc.
Universal Foods, Inc.
Vigoro Industries, Inc. (2)
Virco, Inc.
Virginia Industries, Inc.
Weinbrenner Shoes, Inc.
West Bend Company
Yardney Tech Products, Inc.