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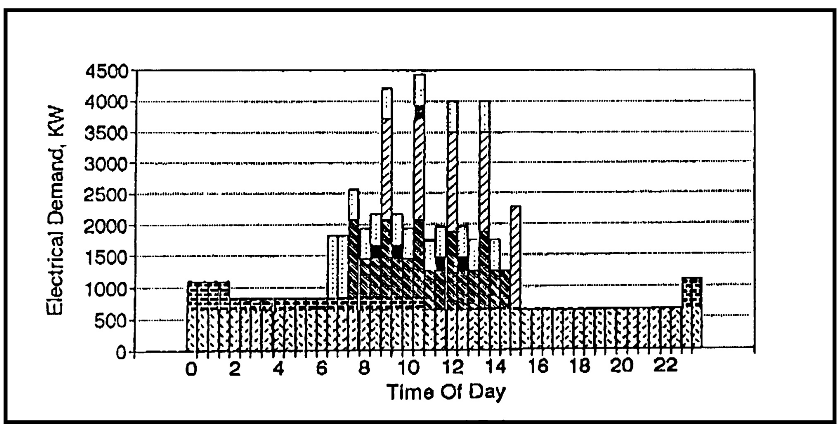
Process Energy and Pollution Reduction (PEPR) Level I Review at the Watervliet Arsenal, New York

Mike C.J. Lin
Walter P. Smith
Philip Darcy
Steve Dunstan
Darcy Byrne-Kelly
Krista Henderson



The U.S. Army Construction Engineering Research Laboratory (CERL) held a Process Optimization (PO) workshop and performed a Level I Process Energy and Pollution Reduction (PEPR) Audit 1-5 February 1999 at the Watervliet Arsenal, NY. The primary objective of the audit was to financially and technically review the Arsenal's manufacturing steps and to identify process changes that will significantly increase performance and efficiencies. A corollary objective was to transfer process optimization techniques to WVA's team to analyze other processes.

A significant number of process improvements were identified for the heat treat, plating, and energy systems. The combined value from process changes could potentially improve WVA's operating margins by approximately $5.8 million per year, with a $683K capital investment. Ideas requiring such investment, however, must be developed further, tested, and re-analyzed based on a Level II (in-depth) analysis in which all assumptions are verified. The Level II analysis will generate "appropriation grade" process improvement projects for submission to top management for funding.

Executive Summary

A Process Optimization (PO) workshop and a Level I PEPR Audit of the Watervliet Arsenal (WVA) Heat Treat, plating processes, and energy systems were conducted on 1-5 February 1999. The audit was highly successful, largely due to the participation of key production and utility personnel. The audit was sponsored by the U.S. Army Construction Engineering Research Laboratory (CERL) to increase WVA's competitiveness. The rationale of the PO Audit is that a competitive facility can expand its business. An audit notebook was provided to participants before the audit that included work plan and example work products from past audits.

The primary objective of the audit was to financially and technically review the manufacturing steps and to identify process changes that will significantly contribute to increased performance and efficiencies. A corollary objective was to transfer process optimization techniques to WVA's team to analyze other processes. The methodology determined the savings potential by first identifying and quantifying major cost issues in the existing process (Phase 1), analyzing the existing production processes (Phase 2), identifying potential process changes that can improve facility performance (Phase 3), and estimating the dollar value of the top ideas (Phase 4).

A total of 21, 34, and 31 process improvement ideas were identified as solutions to critical cost issues in Heat Treat, plating, and energy systems, respectively. The audit team reviewed the list of process improvements and selected the potential solutions as to "Best Ideas" and (no-cost/no-risk) "Slam Dunks." Finally, the team developed the value (profit contribution) and cost of an individual idea or combination of similar ideas by utilizing the 10 percent incremental "What If" cost values initially developed for each process. Table E1 lists the economic results.

The combined value (contribution to budget surplus) from process changes to increase production loading and improve energy efficiency could potentially improve WVA's operating margins by approximately $5.8 million per year with a $683K capital investment.

Table E1. Economic highlights of audit results: process improvements to optimize heat treat, plating, and energy systems.

Idea #	Description	Savings (K$/yr)	Capital Cost (K$)	Payback (mo)
	Heat Treat (cf. Table 10)			
1	Expedite lab results to save 8 hr	250	0	Immediate
14	Mask part with two workers	105	0	Immediate
2	Optimize hold time at 68 vs. 72 hr	88	0	Immediate
17	Train to reduce rework from 3 to 2 percent and improve safety/environmental program performance	52	0	Immediate
11	Increase furnace loading	1732	500	3.5 mo
	Plating (cf. Table 15)			
1,13	Provide more spare parts to reduce procurement time	437	0	Immediate
13,22,24	Improve project management with better communication, less downtime	407	0	Immediate
8	Run all production on 2x24 hr schedule vs. 5x8 hr schedule	1572	0	Immediate
16	Aggressively market/sell available WVA capacity	514	0	Immediate
28	Return chemicals to vendors for disposal	300	0	Immediate
11	Install new liner for minor chrome plating tanks	20	8	4 mo
	Energy Systems (cf. Table 20)			
30,31	Turn unnecessary daytime and nighttime lights off	105	0	Immediate
23	Reduce pressure of air agitation	3	0	Immediate
8	Shut centrifugal air compressor down on weekends	80	0	Immediate
1	Reduce air exchanges during nights and weekends	47	0	Immediate
3	Reduce compressed air leaks by 50%	40	0	Immediate
2	Reduce compressor motor load from 100 to 96 psig	11	0	Immediate
13,14	Replace Vortec® coolers with air blowers	15	15	12 mo
19,20	Automate steam monitoring to save 7.5%	64	160	30 mo
Grand Total		**5842**	**683**	**1.4 mo**

The Level I Audit produced a list of process improvements, notable for the quantity and quality of the suggestions. "Slam dunks" (no-cost/no-risk) can be implemented almost immediately. Process ideas requiring investment, however, must be developed further, tested, and re-analyzed based on solid engineering data and hard economic numbers, which will come from a Level II analysis. The Level II effort is an in-depth analysis in which all assumptions are verified. The end product from Level II is a group of "appropriation grade" process improvement projects for submission to top management for funding.

Foreword

This study was conducted for Headquarters, U.S. Army Industrial Operations Command (HQIOC), under the Industrial Waste Stream Pollution Prevention and Minimization Project, TTP No.15PR09; Work Unit BS8, "Process Energy and Pollution Reduction." The technical monitor was Chris Vercautren, AMSIO-EQC.

The work was performed by the Energy Branch (CF-E) of the Facilities Division (CF), U.S. Army Construction Engineering Research Laboratory (CERL). The CERL principal investigator was Dr. Mike C.J. Lin. Larry M. Windingland is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The CERL technical editor was William J. Wolfe, Information Technology Laboratory.

The Director of CERL is Dr. Michael J. O'Connor.

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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: the need to conserve energy, the need to preserve the environment (and comply with environmental regulations and laws), and the need to lower operating budgets. Although relatively insignificant in the past, the first two factors can now drive up production costs unacceptably, to the point where an operation may be forced to shut down. Effluent limitations, for example, are becoming more stringent at both State and Federal levels. Older processes were not designed to meet these unanticipated changes.

Competition in the marketplace has forced commercial industries to adapt to new requirements. Federal government facilities, by contrast, 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 for both reductions in 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 (a figure that was further increased to 30 percent by 2005, with water conservation measures also included). Additional legislation requires the Army to: (1) reduce the use of energy and related environmental impacts by promoting renewable energy technologies, (2) show 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 a 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 enable the Army to meet these goals, maintain mission readiness, and, in some cases, even improve process efficiency and/or save money.

Analyzing and changing the manufacturing and maintenance processes themselves to increase productivity can also directly result in improved energy and environmental performance. 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 the DOD's mission of maintaining military readiness by operating its manufacturing and maintenance facilities in the most efficient, clean, and cost-effective way possible.

This project was initiated by the U.S. Army Construction Engineering Research Laboratory (CERL) on behalf of the Watervliet Arsenal (WVA) in Watervliet, New York. Energy Technology Services International, Inc. (ETSI) and MSE Technology Applications, Inc. (MSE) provided consulting and engineering support. The purpose of the Process Energy and Pollution Reduction (PEPR) Review was to identify process, energy, and environmental improvements that could significantly improve WVA's competitive position, and result in their demonstrated ability to produce additional, high quality output at far lower per-unit cost.

Objectives

The primary objective of this work was to financially and technically audit the manufacturing steps, and to identify process changes that will significantly contribute to increased performance and efficiencies at WVA. A corollary objective was to transfer process optimization techniques to WVA's team to analyze other arsenal processes.

Approach

A 1-day on-site Process Optimization (PO) training workshop was conducted. The training ensured that the project team would be familiar with concepts of process optimization and the many techniques to analyze the existing process and identify innovative solutions. An audit work plan and schedule were then developed. Table 1 lists the members of the PO Audit Team. The team used methodology developed by ETSI Consulting, Inc. which uniquely re-engineers manufacturing and maintenance processes. Process changes are linked to performance improvements via cost equations, process modeling, and innovation techniques. This methodology has been used successfully in more than 100 industrial facilities over the past 4 years. Some of the audits in DOD facilities include: Amron, Pine Bluff Arsenal, Norfolk Naval Shipyard, Teledyne Wah Chang, and the San Diego Naval Aviation Depot. The methodology determined the savings potential by first identifying and quantifying major cost issues in the existing process (Phase 1), analyzing the existing production processes (Phase 2), identifying potential process changes that can improve facility performance (Phase 3), and estimating the dollar value of the top ideas (Phase 4). Audit results were briefed in the presence of the base Commander and top management staff to gain support and commitment of implementation of the top ideas. Table 2 gives the debriefing agenda.

Table 1. Process Optimization (PO) Audit Team.

Watervliet Arsenal Personnel	
Albright, Steve	Duenas, Vanessa
Biekiewicz, George	Dussalt, Tom
Bova, Bob	Fish, Alice
Brooks, Donald	Gageway, Al
Burns, Dennis	Harris, William
Cole, Mike	Hosko, Richard
Collins, Charles	Kellogg, JoAnn
Darcy, Phil	Reidle, Steve
Davies, Bob	Trevett, Dave
Dearstyne, Lynn	Trombly, Joe
Dennis, Gary	Wheatley, Don
CERL	
Lin, Mike	
MSE Technology Applications, Inc.	
Byrne-Kelly, Darcy	
Cannon, John	
Dunstan, Steve	
Henderson, Krista	
ETSI Consulting, Inc.	
Smith, Walt	

Table 2. PEPR Audit at WVA: Debriefing Agenda, 5 Febuary 1999.

INTRODUCTIONS	Phil Darcy
BACKGROUND	Mike Lin
THE PO APPROACH	Walt Smith
Critical Cost Issues	
MFG Cost Structures	
PFDs and OLBs	
Identify PIs/ECOs	
Economic Analysis	
RESULTS	
Heat Treat Process, etc	JoAnn Kellogg
Plating (3 Processes)	Dave Trevett
Energy/Environmental Systems	Phil Darcy
QUESTIONS AND ANSWERS	Open Session
PO Audit Critique	Audit Team
Closing Remarks	Commanding Officer and WVA Management Staff
PARTICIPANTS	
WVA	
Col. Gene E. King, Commander Watervliet Arsenal	
John Bachinsky, Dir. Installation Services	
Charles Cornwell, Dir. Operations Directorate	
John Sadack, Dir. Public Works	
Ron Neissen, Chief, Safety, Health & Environmental	
Charles Collins, Chief, Heat Treat	
Bob Bova, Operation Directorate	
Vanessa Duenas, Public Works	
Donald Brooks, Public Works	
George Biekiewicz, Public Works	
Dave Trevett, Benet Weapon Labs	
Phil Darcy, Environmental Division	
JoAnn Kellogg, Environmental Division	
CERL	
Mike Lin	
MSE	ETSI
Steve Dunstan	Walt Smith
Darcy Byrne-Kelly	
Krista Henderson	
John Cannon	

Scope

The Level I PEPR review included the following three tasks:

- Task 1 - 1-Day Process Optimization Workshop
- Task 2 - 4-Day Process Review and Results Debriefing
- Task 3 - Summary Report.

The review focused on the reduction of energy and emissions including air, water, and solid waste. Specific techniques presented in the workshop were applied to the targeted processes including processes involving the base utility systems, major and minor plating processes, and heat treating processes. Results from the PEPR review will be used to develop required capital investment by process change. A number of potential process modifications and technology options were identified and evaluated for further development.

Mode of Technology Transfer

It is anticipated that the information presented in this report will be disseminated in the Army Research, Development, and Acquisition Bulletin. It is recommended that the results be presented at the 1999 DOD Maintenance Symposium (Depot Maintenance Technology/Best Business Practice Session).

2 Process Optimization (PO) Workshop

PO Audit Training Objectives and Goals

A PO Audit is undertaken to make major performance and efficiency improvements in all significant manufacturing operations. The primary training objective of the PO Audit at Watervliet Arsenal was to transfer to the audit team new skills that will help to improve WVA's ability to identify and quantify process, energy, and environmental improvement ideas.

Table 3 outlines the full day training and planning program provided to WVA personnel on the first day of the audit week. A 500-page training notebook and reference guide was prepared and sent to WVA 3 weeks before the scheduled audit. Table 4 lists a detailed outline of the training modules. Section 10 of the notebook contains a Process Optimization (PO) Guide for Military Manufacturing and Maintenance Facilities. Figure 1 shows the cover page of this 114-page guide.

Table 3. PO Audit training program outline.

	PO AUDIT TRAINING: AM SESSION
1	Purpose, Objectives, Goals
2	Introduction to the Methodology
3	Identifying CCIs and Target Processes
4	Financially Analyzing Target Process and CCIs
5	Analyzing the "As-Is" Process/Operations
6	Developing the "To Be" Processes
	PO AUDIT PLANNING: PM SESSION
1	Purposes for Audit Planning
2	PO Audit Approach
3	Group Workshop to Identify CCIs
4	WVA Budget/Operating Cost Analysis
5	Daily Work Plan for PO Audits
6	Initial Development of OLBs and PFDs
7	Preparation List for Audit Participants

Table 4. PO Audit notebook, 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 including the final report.
SECTION ONE: OBJECTIVE, ETC.
PO Audit: Objective, Goal, Expectations Audit Team Participants Schedule: 2- or 3-Day Work Plans
SECTION TWO: INTRODUCTION TO THE METHODOLOGY
Process Optimization (PO) Brochure, An Introduction PO Level I Audits: Project Results from Several of 72 Audits The Process Optimization Methodology: The Four Phases Who Must be Involved: Knowledgeable Site Individuals PO Audit Preparation Items: Minimal
SECTION THREE: CRITICAL COST ISSUES LIST
A List of Costly Problems Provides a Check List of Needed Solutions Problem Areas Can Be Operational or Technical Guides the Audit Team on Where to Spend Its Time
SECTION FOUR: PHASE I – FINANCIAL ANALYSIS OF THE PROCESS
Uniquely Identifies Critical Cost Issue Developing the Manufacturing Cost Structure (Fixed – Variable Analysis) Cost Equation for 10% Capacity Increase: Format and Example 10% Benefits from Manufacturing Cost Structure, Example(s) Cost Equations© that Also Include Indirect and Consequential Costs
SECTION FIVE: PHASE II –-ANALYZING THE "AS-IS" PROCESS
Example Process Flow Diagrams, PFDs Analysis of First Pass Yields – Example(s) Where-Why© Diagrams to Target Problems & Solutions
SECTION SIX: PHASE III – DEVELOPING THE "TO BE" PROCESS
The Nominal Group Technique (NGT) to Enhance Brainstorming Example List of Process Changes to Higher Production Rates Example List of Process Changes for Reducing Rejects Example List of Changes to Optimize Energy Use Selecting (Voting) and Grouping "Best Ideas": Slam Dunks, Free Throws, etc.
SECTION SEVEN: PHASE IV – ESTIMATING NEW PROFIT CONTRIBUTION
Developing Ball-Park Economics on "Best Ideas": Audit Team Estimates Examples of Capacity/Output/Sales Increase Reducing Reject Rate Economic Summary Including a "Slam Dunk" List
SECTION EIGHT: Wrap-Up Meeting
Wrap-Up Meeting: Purposes Agenda Wrap-Up Meeting: Presentation Materials Initial Implementation Planning The Next Step: Level II Analysis, Verifying Level I

SECTION NINE: SUPPORTING INFORMATION, HOW-WHY DIAGRAMS
How-Why© Diagram: Capacity by Debottlenecking Choke Points How-Why© Diagram: Energy Optimization Process Audits Client List: Completed Audits from 1998
SECTION TEN: FINAL AUDIT REPORT
Executive Summary, Economic Results Example Table of Contents Example List of Appendices

Process Optimization (PO) Audit Methodology

Table 5 outlines the PO Audit methodology and work plan. The Level I PO Audit methodology follows four phases over an intense 2- to 5-day, on-site audit period, including:

1. Phase 1 - Targeting critical cost (problem) issues and financially analyzing the process
2. Phase 2 - Analyzing the process steps in which costly problems are found
3. Phase 3 - Identifying process change solutions that have the greatest potential dollar value
4. Phase 4 - Estimating the economic result (net savings, capital investment, and simple payback).

Figure 2 shows the four audit phases.

The PO methodology, developed by ETSI, is a remarkably effective approach to improved profitability. The methodology financially and technically audits the process in four phases at several levels of depth. PO focuses on key profit issues, site-specific to the manufacturing or operating processes. The focus could include debottlenecking production capacity, using raw materials more efficiently, improving product quality, solving environmental problems, reducing scrap and rework, improving energy efficiency – essentially, the point is to identify and address anything that constrains profits or that is potentially a major cost optimization issue.

Process Optimization (PO) Guide

For Military Manufacturing and Maintenance Facilities

Prepared For: U.S. Army Corps of Engineers Construction Engineering Research Laboratories

Prepared By: Energy Technology Services International, Inc. (ETSI)

Date: June, 1998

The DOD has set goals for reduction in energy use and pollution generation to comply with Executive Order 12759. These goals cannot be met by focusing solely on conventional approaches of energy efficiency and tail-end waste treatment. The greatest opportunity for energy and environmental improvements is to analyze and optimize the manufacturing and maintenance processes, changing these processes to significantly reduce their energy demands and pollution levels. The Process Optimization (PO) Guide is provided to DOD facility personnel as a resource on how to analyze and optimize these processes at significantly lower overall cost while achieving the DOD energy and pollution goals. The energy and environmental goals are easier to meet when the process optimizes the utilization of the facility's capacity, materials and labor.

Figure 1. First page, *Guide for Military MFO and Maintenance Facilities*.

Table 5. Process Optimization methodology and work plan.

Phase 1: Targeting Processes with the Greatest Financial Potential
Identify "Critical Cost Issues" (CCIs): problems or opportunities that waste money
Develop management cost structures, 10% "What Ifs" and cost equation
Target processes with the largest potential savings and most realistic chances of implementation
Phase 2: Analyze the "As-Is" Process
Process flow diagrams
One line balances
Where – why diagrams
Heat sink – heat source diagrams
Phase 3: Developing the "To Be" Process
Identifying process improvements to CCIs
Select top 20% of the process improvements by vote
Categorize ideas as to end benefits: improved utilization of raw materials, labor, or facility capacity
Grouping ideas as to ease of implementation (slam dunks, etc.)
Phase 4: Estimating the Dollar Value
Economic estimates of net savings, capital cost, and simple paybacks
Debrief session to review preliminary results and management commitment
Document all results in concise report with basis for savings and cost estimates

The methodology financially and technically audits the processes over a 2 to 5-day period at a Level I depth. A characteristic of the Level I audit depth is that the team "guesses at everything, measures nothing." The audit combines the specific on-site knowledge and skill of plant process and operating personnel (very good guessers) with the more general manufacturing experiences from selected consultant support. Experienced process auditors facilitate the audit methodology.

The PO Audit initially determines the potential dollar value of process improvement through a brief analysis of the existing manufacturing cost structure (Phase 1). This profit-focused approach serves two important purposes. First, costs are used as guidance at the beginning of the audit; secondly, costs are used as a way to quickly estimate budget economics on individual and group recommendations at the close of the audit. Cost equations are developed that link process changes to profits. The annual contribution to profits from an arbitrary 10 percent improvement in capacity, 10 percent reduction in scrap, 10 percent reduction in environmental emissions or energy, etc., are estimated. Audit time is therefore spent where the greatest dollar potential is found.

Figure 2. The Process Optimization methodology.

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

The PO Audit uses engineering and financial conceptual models to understand how the process works and where the most practical process changes are (Phase 2). The existing "As-Is" process is quantified using color-coded Process Flow Diagrams and One-Line Diagrams on flip charts. Existing process problems and both old and new solutions to these problems are jointly identified and rethought using Weakness Analysis. All of this sets the foundation to re-engineer and create the "To Be" process through group brainstorming using Nominal Group Techniques (Phase 3).

Process Optimization Results

The result from the 2 to 5-day Level I PO Audit is a list of more than 100 process changes jointly identified by the audit team. Budget costs and annual savings are estimated for the top ideas. No cost and low cost ideas are singled out for early implementation. The results are shown in a How-Why Diagram that connects all process change ideas to each other in a unique road map to the ultimate goal of increased profits (Phase 4). Results are documented in a concise technical report that includes budget economics on the top profit improvement ideas.

The quantity and quality of the more than 100 process improvement ideas identified in the Level I audit will determine the next step. The next step (Level II) "develops" the top ideas from Level I by testing the ideas and quantifying the outcome with accurate engineering data and hard economics. Recalling that the Level I audit is characterized by "guess at everything and measure nothing," Level II "guesses at nothing and measures everything." Verifying and quantifying the top Level I ideas and identifying additional process changes are major undertakings requiring 50 to 100 days on site. The final product from this Level II PO Analysis is a collection of "appropriation grade" cost estimates of low risk, and fast payback process improvement projects.

3 Process Optimization of the Heat Treat Process

Heat treating, plating, and process energy and environmental systems were selected by WVA as primary targets for process optimization/re-engineering. These areas were selected because they had not received a lot of attention before, and because it was assumed that significant improvements could be made. Process optimization audits usually find the largest dollar contributions (savings) in three resource areas:

- *Improved utilization of raw materials.* This is achieved through less scrap, rejects, wasted supplies, etc.
- *Improved utilization of labor.* This is achieved through more efficient practices and procedures, less rework, improved management and, better worker communication, and improved productivity.
- *Improved utilization of plant capacity.* Improved capacity utilization is achieved by debottlenecking the production rate without adding labor or major capital investment. WVA production capabilities can be improved by work simplifications that eliminate non-value-added steps or activities, selective use of new technology, and more aggressive efforts to expand production by utilizing the existing, large manufacturing capabilities in new market areas inside and outside the traditional DOD customer base.

In addition, process optimization audits often find significant opportunity in a fourth area: improved utilization of the energy and environmental infrastructure and its supporting ongoing expense and capital budgets.

Critical Cost Issues (CCIs): Heat Treat

The PO Audit always begins by working with the highly experienced, on-site experts to identify the area's most costly problems (opportunities for improvement). The audit team went to the Heat Treat production area to get, first hand, the opinions of the "artisans" working in these processes on a daily basis. Table 6 lists 20 CCIs for the Heat Treat area. The group ranked the magnitude of each CCI for impact on the performance of Heat Treat operations (high, medium, or small).

Table 6. Critical cost issues (CCIs): heat treat.

CCI No	Description	Rank: H = high M = medium S = small	Category: C = capacity utilization R = raw material P = labor utilization
1	Lack of work at WVA	H	C
2	Politics sometimes affects the WVA work force	H	P
3	Equipment does not work correctly (robbing parts)	H	C
4	Furnaces do not work as they should	H	C
5	Manual operations cause ergonomic problems	M	P
6	Lack of fixturing to position parts	H	C
7	Lack of communication, which results in rework problems with breech & block causes 3% rework	H	P,C,R
8	Lack of data/information to document that #7 is real	M	C,R
9	Old equipment (some 50 yr old)	S	C
10	Illogical routing of work	M	P
11	Operators not well informed	S	P
12	Problems are never solved	H	P
13	Not throttling back equipment when possible	S	C
14	Quality problems with raw materials	H	R
15	Too much paperwork	H	P
16	Paperwork missing with pieces of equipment	S	P
17	Wasted heat (too hot, have the doors open)	S	C+P
18	WVA Heat Treat area is not allowed to take in private work	H	P
19	Losing technology because not using it and there is no one to pass the experience on to	M	C,P
20	No spare parts	H	C

The CCIs were further categorized or grouped as to their end effect on the three key resource utilization factors: capacity, raw materials, and people. The list indicated that many problems exist, or conversely, that there were many significant opportunities to improve the financial performance of the Heat Treat operations.

Financial Analysis of Heat Treat Processes

The next step in Phase 1 of the PO methodology is to financially analyze the process area. To do this, the annual budget and corresponding manufacturing costs must be identified for the Heat Treat operations. Table 7 lists the budget and manufacturing costs.

Table 7. Budget and manufacturing cost structure: heat treat.

Item #	Description	Basis (Annual)	K$/YR	% Budget	+10% capacity (K$/YR)
1.0	Department budget	240 units/yr@$39.4K (breech rings & blocks)	9450	100%	945
2.0	Manufacturing (MFG) costs				
2.1	Raw Materials	240 units/yr@$71.1K	4110	43.5%	411 (100% variable)
2.2	Labor: Touch Other Total	 14@$45K 42@$75K 56@$67.5K	 630 3150 3780	 40%	 0
2.3	Energy	Electric & fuels	500	5.3%	5 (10% variable)
2.4	Other	Direct & indirect	1060	11.2%	7 (7.5% variable)
2.5	Total MFG cost	(sum 2.1 to 2.4)	9450	100%	423
3.0	Contribution from +10%	(1.0 minus 2.5)			**522

**Conclusion: $522K/YR of budget surplus will result from an incremental 10% increase in output by debottlenecking.

The analysis of Heat Treat costs structure is not a precise accounting exercise, but is rather an approximation of budget and cost. The analysis has two purposes: (1) to initially target the major cost areas (and their relative magnitude) that offer the greatest economic potential for improvement, and (2) to do a financial analysis of the process that provides a method at the close of the PO effort (end of the day for Heat Treat) to "value" the PO improvement ideas for net annual saving (K$/yr). This important second benefit from the financial analysis of the process comes from the 10 percent "What If" economics for Heat Treat presented in Table 8.

Table 8. Ten percent "what if" economics: heat treat.

Item #	Description	Basis	Surplus from +10% Improvement (K$/YR)
1	Capacity utilization	Table 7 Right Column	522
2	Raw materials utilization	10% of $4110K/YR	411
3	Labor utilization	10% of $3780K/YR	378
4	Energy utilization	10% of $500K/YR	50

The purpose of identifying major revenue and manufacturing costs is to develop the total cost impact for cost sensitive issues such as production output increase, yield improvement, labor utilization, inventories, etc.

Table 8 summarizes the bottom line benefits resulting from a 10 percent improvement in capacity (right hand column) along with 10 percent improvement contributions from other cost-sensitive issues. The largest 10 percent "What If" benefit would be to improve the department's capacity utilization by an arbitrary 10 percent (5 percent would therefore be worth half of the 10 percent figure or $261K/yr, where 10 percent is worth $522K/yr). The $522K/yr value was calculated by the variable-fixed analysis in the right column of Table 7. One can conclude that the marginal or incremental cost to produce 10 percent more ($423K/yr) is approximately half of the budgeted amount ($945K/yr) for a $522K/yr budget surplus. The significance of this fact is that it highlights the importance of bringing new work into WVA. The best way to be competitive is to "grow the business" rather than focus only on "downsizing" the business.

The second and third 10 percent "What If" benefits in Table 8 are $411K/yr from a 10 percent increase in raw material utilization, and $378K/yr from a 10 percent increase in labor utilization. The term "labor utilization" is meant to include all WVA labor: management, technical support, planning/scheduling, quality assurance/control, department leaders, etc. — not just "touch" labor on the department floor. A 10 percent improvement in energy utilization is worth $50K/yr — only a small fraction of capacity, raw materials, and labor.

Analyzing the Existing "As-Is" Processes

Phase 2 of the PO methodology analyzes the existing processes as they are currently operated. The first step is to develop a simplified process flow diagram (PFD) (Figure 3), and to "populate" the PFD with all available data relevant to the major CCIs.

Developing the "To Be" Process

Phase 3 of process optimization creates the "new" process by identifying both general and specific process changes that significantly improve the financial performance. The operating conditions (temperature, 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.

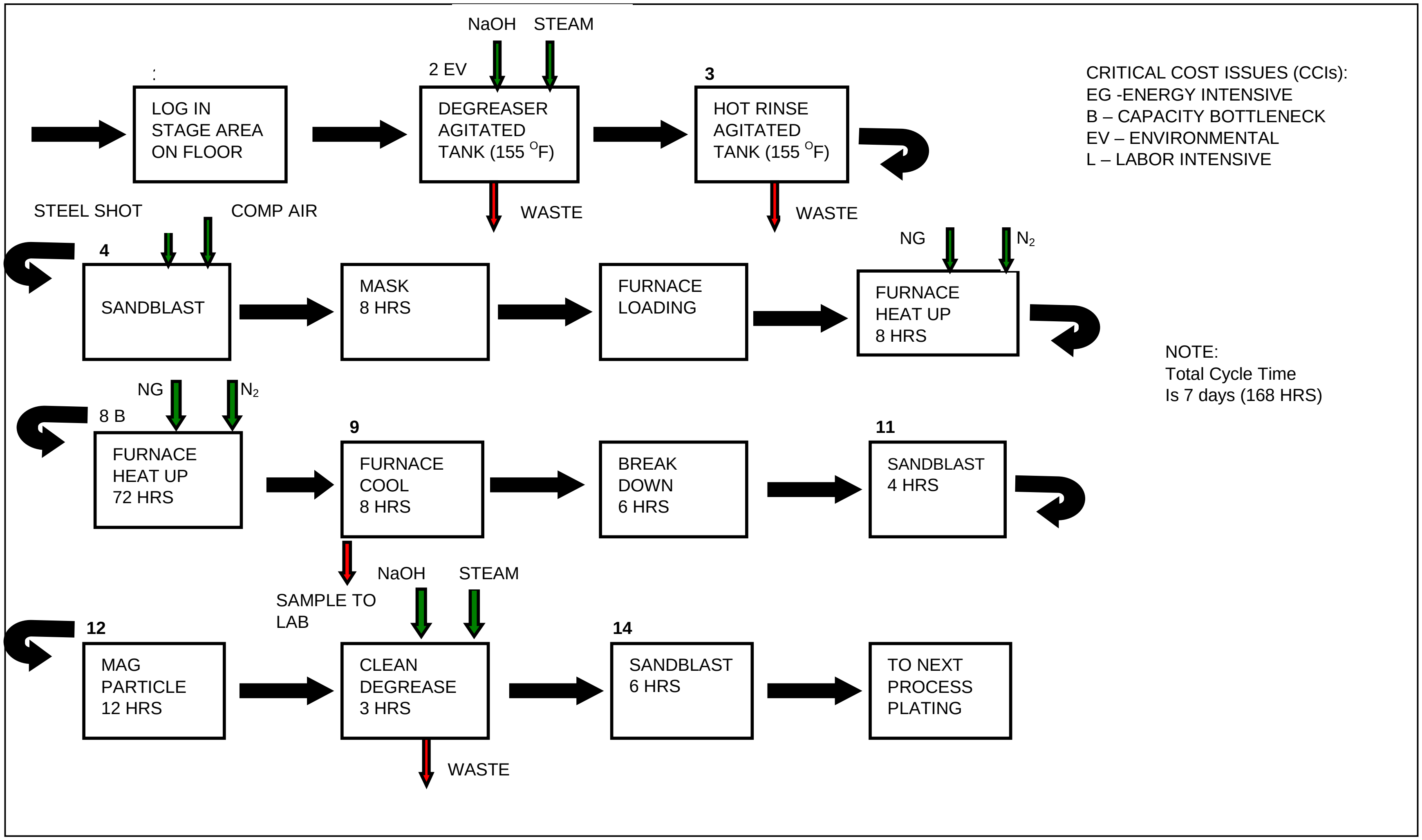


Figure 3. Process flow diagram (PFD): heat treatment process.

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. Utilize low energy process
6. Utilize high yield technologies.

How can the process better utilize its input resources (raw materials, labor, energy, etc.) and its outputs (product, quality, plant capacity, and environmental investment) to make money?

The WVA's manufacturing technology is based on more than 150 years of expertise in the production of large bore cannons and associated armaments for the armed forces. WVA's success is in how well employees practice this know-how and 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 called the Nominal Group Technique (NGT) is used. NGT requires Silent Idea Generation (SIG). 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. The department's operating personnel and facility technical staff identifies many of the best ideas, both old and new. The broad background of off-site participants 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 has been important in bringing the effort up to the point of brainstorming.

Table 9 lists solutions to Heat Treat CCIs that were identified by the PO Audit Team in an NGT, SIG structured brainstorm session. The Object Statement is listed at the top of Table 9, and clearly indicates that the focus of the session was to identify solutions in specific target areas while meeting the overall requirements of optimizing the process without compromising safety, quality, or morale.

Table 9. Solutions to Heat Treat CCIs.

Idea No.	Process Change Solution	Votes Bold ≥14	Category
1	Coordinate with the laboratory to minimize test time (takes 34 hr).	**15**	Slam Dunk (SD), People Issue
2	Optimize hold time at less than 72 hr.	**14**	Operations Issue
3	Do #1 by performing test ourselves.	4	
4	Do #1 by e-mailing lab results back to Heat Treat.	9	SD, People Issue
5	Replace step #13 (clean/hot rinse step) with alternate cleaning technology to eliminate step #14 (2nd sandblasting step).	9	
6	Compress cycle times in steps 2, 3, 7, 8, 9, and 13 with better controls and instrumentation.	**15**	Capacity Issue
7	Improve schedule to minimize waiting on paperwork, equipment, and people.	1	
8	Mask faster by alternate means.	6	
9	Faster heat up/cool down to compress Heat Treat cycle.	10	
10	Do #9 by forced convection to cool from 400 °F to 100 °F.	**15**	Capacity Issue
11	Optimize furnace load from 12 to 16 blocks by force convection of inert gas.	**14**	Capacity Issue
12	Find a way to sandblast.	11	
13	Better lifting devices to improve block logistics.	5	
14	Have more than 1 person perform the masking step.	10	SD, People Issue
15	Automate processes include furnace with a Distributive Control System (DCS) to optimize cycle time and quality.	**15**	Capacity Issue
16	Do #7 by providing more spare parts and planning ahead.	2	
17	Improve technical and operational understanding of processes by additional training.	8	Operations Issue
18	Degrease by biodegradable chemical vs. current material (sodium hydroxide).	6	
19	More cross training to improve labor utilization.	8	
20	Recover and reuse sodium hydroxide and rinse to reduce disposal cost.	8	SD, Capacity Issue
21	Provide employee incentive for quality, productivity improvement.	3	
OBJECTIVE STATEMENT: Identify process solutions (changes in operating conditions, procedures, people, and technology) to optimize the process (Heat Treat, Sandblasting, and Degreasing) to result in significant cost savings with equal or greater safety, quality, and morale. Note: A 10% improvement in the utilization of raw materials, labor, and capacity is worth $411K/yr, $378K/yr, and $522K/yr, respectively.			

The PO Audit Team identified a total of 21 process change solutions. Had additional department operating personnel, or time, been available, it is believed that three times this number of process change solutions might have been identified.

The “best ideas” from each brainstormed session were then selected by each participant by distributing 20 votes among the list, up to three votes maximum per idea. The selection criteria were that the idea: (1) must contribute significantly to profits (i.e., $100,000 per year, not $10,000 per year); (2) must be “manageable” within constraints of time and money (i.e., that the idea would take 1, not 6 years, to implement, and that it would be cost effective); and (3) must be low risk.

The audit team reviewed and discussed the identified process improvements, selected the top ideas by vote, and grouped the solutions according to ease of implementation and value. The ideas were further screened and categorized as “slam dunks” (zero cost, zero risk), capacity issues, people issues (training or communication), or maintenance/operations issues. The “slam dunks” and ideas receiving greater than 14 votes (listed in Table 9 in bold print) were then selected for preliminary economic analysis.

Economic Analysis of Results

Finally, the audit team developed a consensus on the value of individual ideas or combinations of similar ideas. The 10 percent incremental “What If” cost analysis developed in Phase 1 for higher output was used to estimate savings where a +10 percent was worth $522,000/year and 1 percent was worth $52,200/year.

Table 10 details the basis of the nine ideas that were quantified with “ball park” economics (net savings, capital cost, and simple payback). These “best ideas” are titled and presented in the Executive Summary of this report (p 3).

Table 10. Economic analysis of results: Heat Treat.

Idea # (cf. Table 8)	Title	Basis for Savings and Cost	Net Savings K$/YR	Capital Cost K$	Payback (mo)	Category
3	Do HT test by operator, not in lab	Save 20 of 168 hr =12%	(12%/10%)*522 =627	100	2 mo	P
1	Expedite lab results to save 8 hr	Save 8 of 168 hr =4.8%	(4.8%/10%)*522 =251	0	Immediate	P,SD
14	Mask part with 2 workers instead of 1	Save 3.6 of 168 hr =2.1%	(2.1%/10%)*522 =110	0	Immediate	P,SD
2	Hold time optimization (68 hr vs 72 hr)	Save 4 of 168 hr =2.4% Cost 92 hr ($400/hr) = $37K/yr	(2.4%/10%)*522 =125 gross - (37) exp =88 net savings	0	Immediate	O,SD
17	Train to reduce rework from 2% to 1% and improve safety / environmental program performance	2% rework to 1% 14 operators	(1%/10%)*522 =52	0	Immediate	O,SD
15	Automation to optimize throughput	Save 5 of 168 hr =3.0%	(3.0%/10%)*522 =157	100	7.6 mo	C
10	Forced convection heat up/cool (400 °F to 100 °F)	Save 4 of 168 hr =2.4%	(2.4%/10%)*522 =125	Fix unit	Immediate	C,SD
11	Forced convection for holding tank to increase furnace loading from 12 to 16 blocks	16 vs 12 blocks % increase = (16-12)/12 = 33%	(33%/10%)*522 =1722	500	3.5 mo	C
		Sub Total	$3,132K/yr	$700K	2.7 mo	

SD-slam dunk
P-people implemented strategy
C-capital cost implemented strategy
O-operational implemented strategy

4 Process Optimization of the Plating Process

Critical Cost Issues (CCIs): Plating

The PO approach for the second process(es) again begins by working with the highly experienced, on-site experts to identify the area's most costly problems (opportunities). The audit team met with the personnel in the minor and major plating areas (3), to get the first hand opinions of the "artisans" working in these processes on a daily basis. The results (Table 11) are a list of 10, 8, and 5 CCIs for the three plating processes, respectively. The group discussed the magnitude of each CCI impact on the performance of the plating operations. The list indicated that many problems exist, in other words, that many significant opportunities exist to improve the financial performance of the plating operations.

Financial Analysis of the Plating Processes

The next step in Phase 1 of the PO methodology is to financially analyze the process area. To do this, the annual budget and corresponding manufacturing costs must be identified for the plating operations. Table 12 presents the budget and manufacturing costs. The analysis of budget and costs is not a precise accounting exercise, but rather an approximation of budget and cost. This is done to: (1) initially target the major cost areas (and their relative magnitude) that offer the greatest economic potential for improvement, and (2) provide a method at the close of the PO effort to value PO improvement ideas as to net savings (K$/yr).

The purpose of developing values for an arbitrary 10 percent improvement (Table 13) is to show the relative sensitivities of different cost issues. Nowhere in the standard industrial chart of accounts does one find the cost saved from a 1 percent yield improvement or the value of a 10 percent capacity increase. The 10 percent figures are not goals; more or less may be possible depending on the quantity and quality of the process improvements identified. The 10 percent "What If" figures are to be used to initially guide the Process Audit Team, and later to assign value to an individual solution or group of solutions for the cost issue.

Table 11. Critical Cost Issues (CCIs): problems (wasted raw materials, labor, plant utilization) for minor plating ($Mn_3(PO_4)_2$ & Cr) and major plating (total three processes).

	Minor Plating ($Mn_3(PO4)_2$)		Minor Plating (Cr)		Major Plating (Gun Tubes, Cr)
1	Environmental problem with sodium hydroxide	1	Tank linings are failing at surface levels	1	Low work loads
2	Temperature and pH controls	2	Temperature controls not accurate	2	Equipment down time due to pumps ($15-20K), XGR ($50K), tank liner
3	Equipment downtime	3	Too much heat loss in PFD steps #5 & #7	3	Lack of fixtures limits amps to 21000, but have 40000 amp capacity
4	$Mn_3(PO4)_2$ bath cycles too much with low work and the load volume	4	Low work loads	4	Instrumentation and controls are not adequate
5	Life of the baths is too short	5	Lack of spare parts	5	Salt loading in scrubbers was once a problem
6	Inspection does not follow military specifications of the quality assurance (too subjective)	6	20% rework (i.e., 24/120 tubes per year require replating).		
7	Hoist limitations, only lifts 1 unit but the baths are designed for 3 units	7	The hoist system is rated for 1 ton, but baths hold 3 tons		
8	Lack of real time process information	8	Equipment downtime is too high		
9	Too many manual operations				
10	Lack of user friendly automation				

Table 12. Budget and manufacturing cost structure: plating.

Item #	Description	Basis (Annual)	K$/yr	% Budget	10% Capacity (K$/yr)
1.0	Department Budget	240 units/yr@$41.3K (breech rings & blocks)	9900	100%	990
2.0	Manufacturing (MFG) Costs				
2.1	Raw Materials	240 units/yr@$71.1K 3K	3430	34.6%	343 (100% variable)
2.2	Labor:				
	Touch	14@$45K	495		
	Other	3342@$75K	2475		
	Total	56@$14.3K	2970	30.0%	0
2.3	Energy	Electric & Fuels	1500	15.2%	120
2.4	Environmental		700	7.1%	0
2.5	Other	Direct & Indirect	1300	13.1%	20
2.6	Total MFG Cost	(sum of #2.1 to #2.5)	9900	100%	483
3.0	Contribution from +10%	(#1.0 minus #2.6)			*507
*Conclusion: $507K/YR of budget surplus will result from a 10% increase in output by debottlenecking.					

Table 13. Ten percent "what if" economics: plating.

Item #	Description	Basis	Surplus from +10% Improvement (K$/yr)
1	Capacity utilization	Table 12 right column	507
2	Raw materials utilization	Table 12, 10% of $3430K/YR	343
3	Labor utilization	Table 12, 10% of $2970K/YR	297
4	Energy utilization	Table 12, 10% of $1500K/YR	150
5	Environmental	Table12, 10% of $700K/YR	70

Analyzing the "As-Is" Process

Figures 4, 5, and 6 show PFDs for the three plating processes. Each major step for the plating processes is shown: 11 for $Mn_3(PO_4)_2$, 9 for Cr, and 10 for major plating. Chemical and energy inputs are noted where significant, as well as temperatures and cycle times. Potential critical steps are noted on the PFD as energy intensive (EG), capacity bottleneck (B), environmental intensive (EV), and/or labor intensive (L). The total cycle time for the generic part entering $Mn_3(PO_4)_2$ plating was 2.25 hours, and for chrome (all rework/repair) was 10 hours.

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 into a finished product." In other words, we ask ourselves why are "they" heating us up (to 150 °F); what is magic about 150 °F (why not 140, 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 — a cannon block of potentially first quality material for WVA.

* °F = (°C x 1.8) + 32

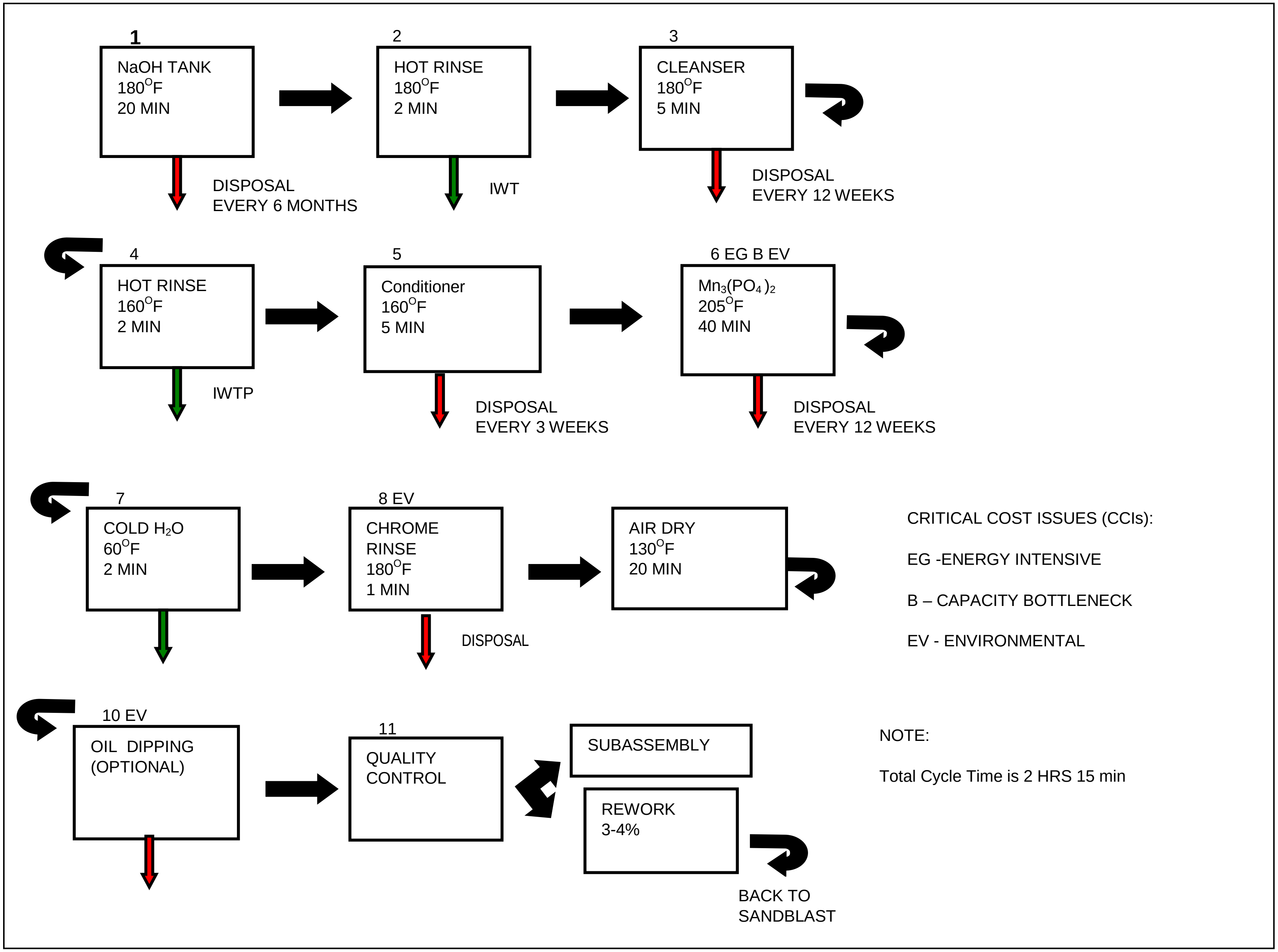


Figure 4. Process flow diagram (PFD): $Mn_3(PO_4)_2$ plating process.

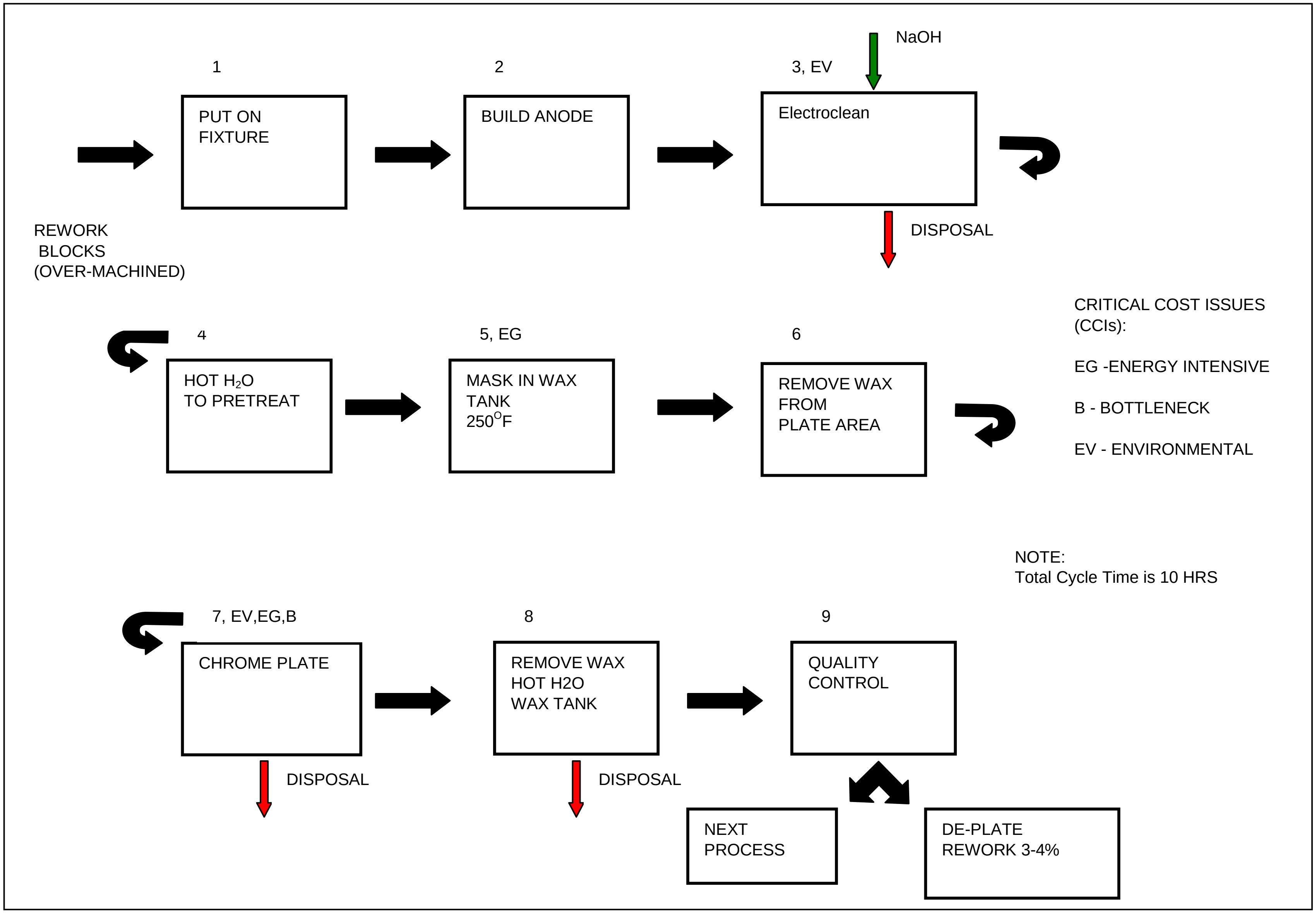


Figure 5. Process flow diagram (PFD): chrome (repair) plating process.

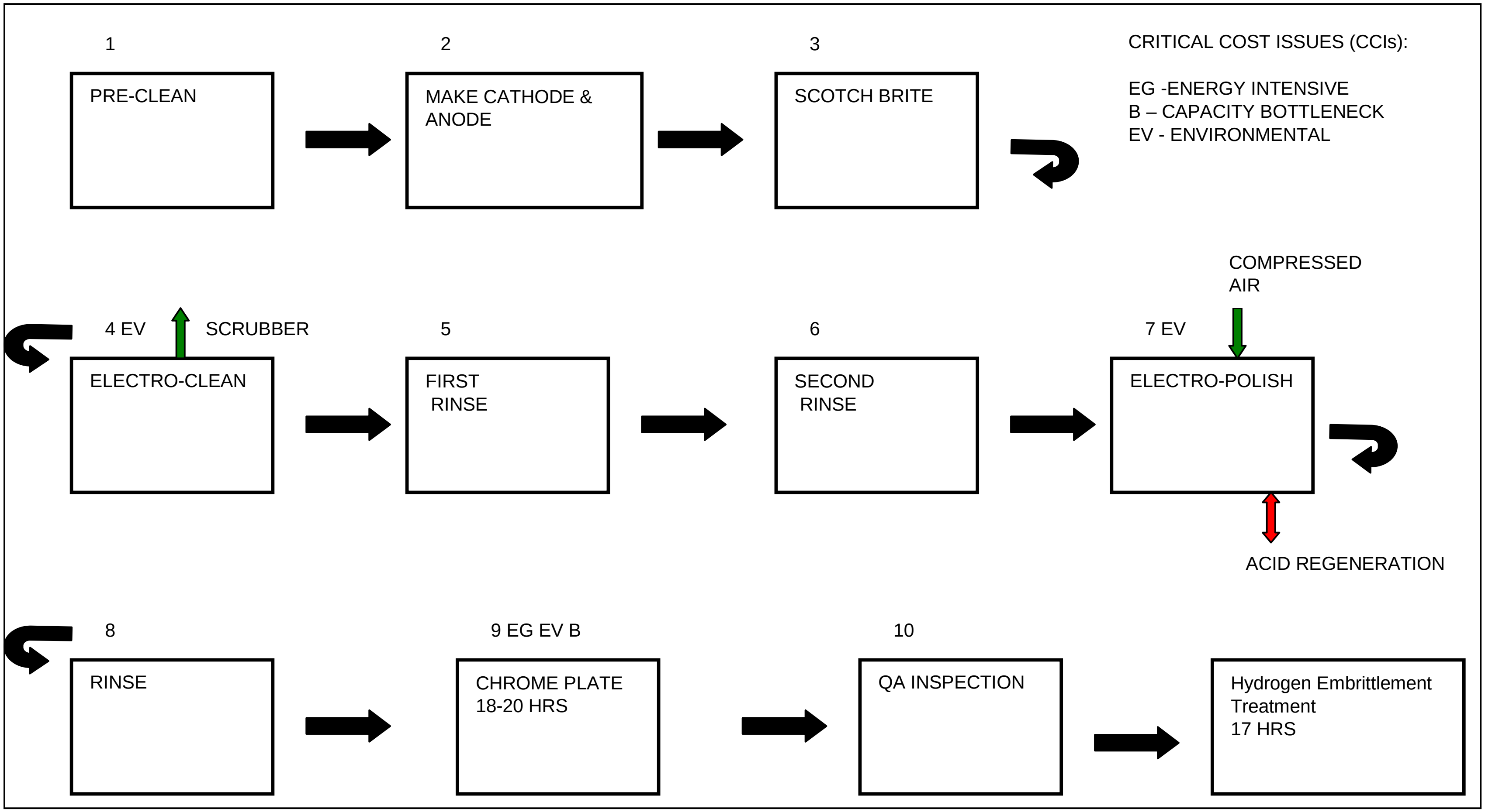


Figure 6. Process flow diagram (PFD): major plating (gun tubes) process.

The most financially rewarding issue to be analyzed was the increased utilization of existing plant capacity. This was combined with possible critical issues of Rejects, Rework, and Returns (the 3Rs). The 3Rs are logical contributors of plant capacity constraints because they not only waste raw materials and labor, but they also consume plant capacity. Much progress has been made in reducing the 3Rs, but additional improvement was believed possible.

Developing the "To Be" Process

Phase 3 of process optimization creates the "new" process by identifying both general and specific process changes that significantly improve the financial performance. The operating conditions (temperature, 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) use high yield technologies. How can the process better utilize its input resources (raw materials, labor, energy, etc.) and its outputs (product, quality, plant capacity, and environmental investment) to make money?

Table 14 lists solutions to Plating CCIs that were identified by the PO Audit Team in an NGT, SIG structured brainstorm session. The Object Statement is listed at the top of Table 14 and clearly indicates that the focus of the session was to identify solutions in specific target areas while meeting the overall requirements of optimizing the process without compromising safety, quality, or morale. The PO Audit Team identified a total of 34 process change solutions. Had additional department operating personnel, or time, been available, it is believed that three times this number of process change solutions might have been identified.

The "best ideas" from each brainstormed session were then selected by each participant distributing 20 votes among the list, up to three votes maximum per idea. The selection criteria were that the idea: (1) must contribute significantly to profits (i.e., $100,000 per year, not $10,000 per year), (2) must be "manageable" within constraints of time and money (i.e., that the idea would take 1 year, not 6 years to implement, and that it would be cost effective), and (3) must be low risk.

Table 14. Solutions to plating processes CCIs (three processes).

Idea No.	Process Solutions	Votes≥12 (Bold) & Slam Dunks	Category
1	Improve capacity utilization by reducing downtime with adequate spare parts	**13**	P
2	Recover and recycle by concentrating $MnPO_4$ tank solution to reduce chemical cost, hazardous waste, and increase capacity utilization	10	P
3	Reduce rinse tank overflow by cascade flow from one to the other	0	
4	Consider heavy zinc phosphate ($Zn_3(PO_4)_2$) to reduce chemical costs and hazardous wastes	5	
5	Reduce phosphate tank size by smaller compartments to reduce chemicals and waste	4	P
6	Increase hoist capacity to maximize the use of the big tanks	**18**	P
7	Provide additional training and better procedures for machining holes in blocks to reduce chrome plating rework	11	P
8	Run all production on continuous 2-day 24 hour schedule vs. 5 day 8 hour schedule in the $Mn_3(PO_4)_2$ process to minimize bath cycling, which causes problems (utilize major plating labor)	**16**	P, C
9	Reduce subjective QC by more consistent inspection decisions from a more definitive specification and inspection procedure	5	P, C
10	Reduce Cr_6 to Cr_3 by filtering to save cost and reduce waste	7	
11	Improve tank liners with long life materials, such as hyplon	**12**	C
12	Replace short life chemicals with longer life chemicals, such as zinc phosphate vs. manganese phosphate		
13	Reduce procurement time to reduce downtime	**12**	P
14	Engineer effective tank covers to reduce energy and environmental issues	5	
15	Utilize non-operating time for maintenance	4	SD,P
16	More effective marketing to increase workload	8	SD,P
17	Optimize control of hot rinse tanks temperatures to lower end of 180-200 °F with better instrumentation and control systems	**16**	C
18	Provide adequate number of fixtures	1	C
19	Develop energy and total cost balances for all critical issue steps of the PFD	10	
20	Do #17 for wax mask tank temperatures		
21	Do #17, 19, and 20 with a Distributed Control System		
22	Put maintenance personnel under direction of management. (e.g., BAC chiller was down 5 weeks. Estimate of waiting on repairs is 10% loss in capacity.)	**12**	
23	Improve communication and validity for chemical solution tests. Recently 15 tubes failed out of 120/yr for 12.5% loss in capacity utilization. A typical year has 2-8% failure	8	C
24	Improve communication between production and maintenance to strengthen predictive and preventive maintenance	5	P

Idea No.	Process Solutions	Votes≥12 (Bold) & Slam Dunks	Category
25	Do #24 by forming teams		
26	Do #24 by #22		
27	Extend bath life by 200% by external filtration to purge solids	**12**	
28	Return chemicals to vendor to reduce disposal cost	**16**	SD,P
29	Reroute recycled cleaned up scrubber water to chrome make up or chrome rinse tanks	8	
30	Set up an integrated process optimization team to reduce rework	8	P
31	Review process specifications for cost reduction opportunities including hazardous waste materials (i.e., free total acid ratio on chromic acid rinse could possibly be changed or eliminated as was once done)	**16**	C
32	Consider Phosphoric Acid Fuel Cell (PAFC) technology to cogenerate steam and electricity	3	
33	Ensure that new technical hardware installed to save money is not a burden on operations people	3	
34	Install magnetic drive pumps to eliminate seal leaks and environmental consequences	8	
OBJECTIVE STATEMENT: Identify process solutions (changes in operating conditions, procedures, people, and technology) to optimize the Minor Plating Processes ($Mn_3(PO_4)_2$ & Cr) and Major Plating Process (Gun Tubes) resulting in significant cost savings. A 10% improvement in raw materials, capacity, and labor utilization is worth \$343K/yr, \$507K/yr, and \$297/yr, respectively.			

The audit team reviewed and discussed the process improvements that were identified, selected the top ideas by vote, and grouped the solutions for their ease of implementation and value. The ideas were further screened and categorized as (zero cost, zero risk) "slam dunks," capacity issues, people issues (training or communication), or maintenance/operations issues. The "slam dunks" and ideas receiving more than 12 votes (indicated in Table 14 in bold print) were then selected for preliminary analysis.

Economic Analysis of Results

Finally, the audit team developed a consensus on the value (profit contribution) of individual ideas or combinations of similar ideas. The 10 percent incremental "What If" cost analysis developed in Phase 1 for higher output was used to estimate savings where a +10 percent was worth \$507,000/yr and 1 percent was worth \$50,700/yr.

Table 15 details the basis of the ideas that were quantified with "ball park" economics (net savings, capital cost, and simple payback). These "best ideas" are titled and listed in the Executive Summary of this report (p 3).

The combined total savings are typically not achievable because some of these ideas compete with others, and one or the other (not both) would be done. Also, some ideas complement others; both must be done to realize full savings. However, of the $3250K Grand Total, approximately $1221 K/yr were “slam dunks,” which can be implemented almost immediately. Actually, very few required capital investment.

The economic analysis in a Level I PO Audit is typically ±40 percent accurate. The economics for the “best ideas” are largely developed by the site audit participants, who are very good guessers at ballpark savings and cost. Time limitations allowed the audit team to estimate less than half of the total ideas presented. A worthwhile follow-up task to transition from the Level I PO Audit to the more in-depth Level II Analysis is to review and expand the Level I results.

Table 15. Economic analysis of results: plating.

Idea # (cf. Table 14)	Title	Basis for Savings and Cost	Net Savings (K$/YR)	Capital *Cost (K$)	Payback (mo)
11	New Liner for Minor Cr Plating Tank	• Invest total $8000 new liner • Total cost* old liner replacement (material, labor, etc.) $23K/yr • Total cost new hyplon liner replacement (material, labor, etc.) $32K/10 yr (old liner change out annually vs. new liner change out every 10 yr)	$23K/yr (old liner) minus $32K/10yr or $3.2K/yr Net Savings $19.8K/yr	$8.0K	(8000/ 19800)= 0.4 yr or 4.8 mo
1,13	Adequate Spare Parts Reduce Procurement Time	10% increase capacity Labor Savings Expenses Net Savings	507 60 (130) 437	0	Immediate
24,22,15 SD	Communication/ Re-Organization to Reduce Non-operating Time for Maintenance	10% increase capacity Expenses Net Savings	507 (100) 407	0	Immediate
8	Production Scheduling Change for Minimal Cycling	30% increase capacity Decrease rework to 1.5% Net Savings	1521 52 1572	0	Immediate
16 SD	Marketing to Increase Work Load	20% increase capacity Expenses Net Savings	1014 (500) 514	0	Immediate
28 SD	Return Chemicals to Vendor for Hazardous Waste Disposal, etc.	Savings on disposal Increased chemical cost Net Savings	500 (200) 300	0	Immediate
Grand Total			**3250**	**8.0**	**~Immediate**

5 Process Optimization of the Energy Systems

Energy, Environment, and Water Economics

The optimization of WVA's energy systems also begins with a CCI approach that discusses the existing problems and/or opportunities in the present energy supply systems and in the consumption patterns of the end-users. WVA personnel believed that the greatest problems/opportunities for improvement lie in the electrical systems and especially in the system that involves production of compressed air. Confirmation of such "good hunches" comes from an analysis of the annual site-wide energy and utility (environmental, water, etc.) cost breakdown. Table 16 lists the WVA 1998 annual economics (costs) for out-of-pocket energy, environmental, and purchased water. At $2,400K, purchased electricity represents more than half (53 percent) of the $4,555K total purchased cost. Fuels are 21 percent of that total, environmental expenses about 20 percent, and water is approximately 7 percent. Electricity is a dominant cost and compressed air production is likely the major user of electricity.

Table 16. Energy, environment, and water economics (1998 actuals).

Item #	Cost Item	Basis	Annual Cost K$/yr	% Total	Unit Cost $/Unit
1	Electricity	33,000,000 kWh Peak 8,000 kW Avg 3,800 kW	2,400	52.7	$0.072/kWh
2					
A	Boiler NG	283,000 MMBtu	825		$3.00/MMBtu
B	Boiler #2 FO	50,000 gal	30		$0.63/gal
	Total boiler fuel		855	18.8	
C	NG to process	16,100 MMBtu	100	2.2	$4.00/MMBtu
D	Total fuels		955	21.0	
3	Total energy (1 + 2D)		3,355		
4	Environmental program		900	19.7	
5	Purchased water	129,000 Kgal	300	6.6	$2.33/Kgal
6	Total energy, environmental, water (3+4+5)		4,555	100.0	

Analysis of Electrical, Compressed Air, and Steam End Use

Energy supply and end use optimization requires the integration of both ends of the systems. This is best accomplished by developing One Line Balances (OLBs) that quantify the energy systems' supply/generation, distribution, and major end users. Figure 7 shows an OLB for WVA's electrical systems, accounting for all 33.3 MM kWh in 1998 as annual average kW and annual cost to all end users. The purpose of the OLBs is to provide guidance and focus to the audit team to identify the big dollar users and their annual costs of consumption. An additional purpose is to stimulate the audit team, as a group, to consider what Energy Conservation Opportunities (ECOs) best apply to the site-specific energy systems and will have the greatest chance of implementation.

The OLB for WVA electricity clearly shows that air compressors are the second largest user of power, consuming an average of 670 kW, or $423K/yr (17.6 percent) of the total power. Lighting was the largest single user group at 950 kW or $600K/yr (25.0 percent) of total power. Compressed air was, however, judged to be a more opportune target for improvement, and the audit team agreed that it was worthy of further analysis.

One pressing problem with WVA's high unit cost for electricity (7.2¢/kWh) is its relatively high demand charge due to its low load factor. Figure 8 shows the high daytime demand due to furnace operations.

Figure 9 shows the production, distribution, and end-use of compressed air (OLB: WVA Compressed Air). Air compressors and directly associated auxiliary equipment consume 22 percent of all electricity ($530K/yr of $2,400K/yr). The $530K/yr figure includes compressed air auxiliaries (cooling tower water to water coolers, dryers, etc.) in addition to the compressor motor drives, shown as $423K/yr on Figure 7. The top consumers of compressed air are:

1. Leaks ($130K/yr)
2. Machine lines ($87K/yr)
3. Pneumatic tools ($71K/yr)
4 a. Heatless dryers ($47K/yr)
  b. Sandblast ($47K/yr).

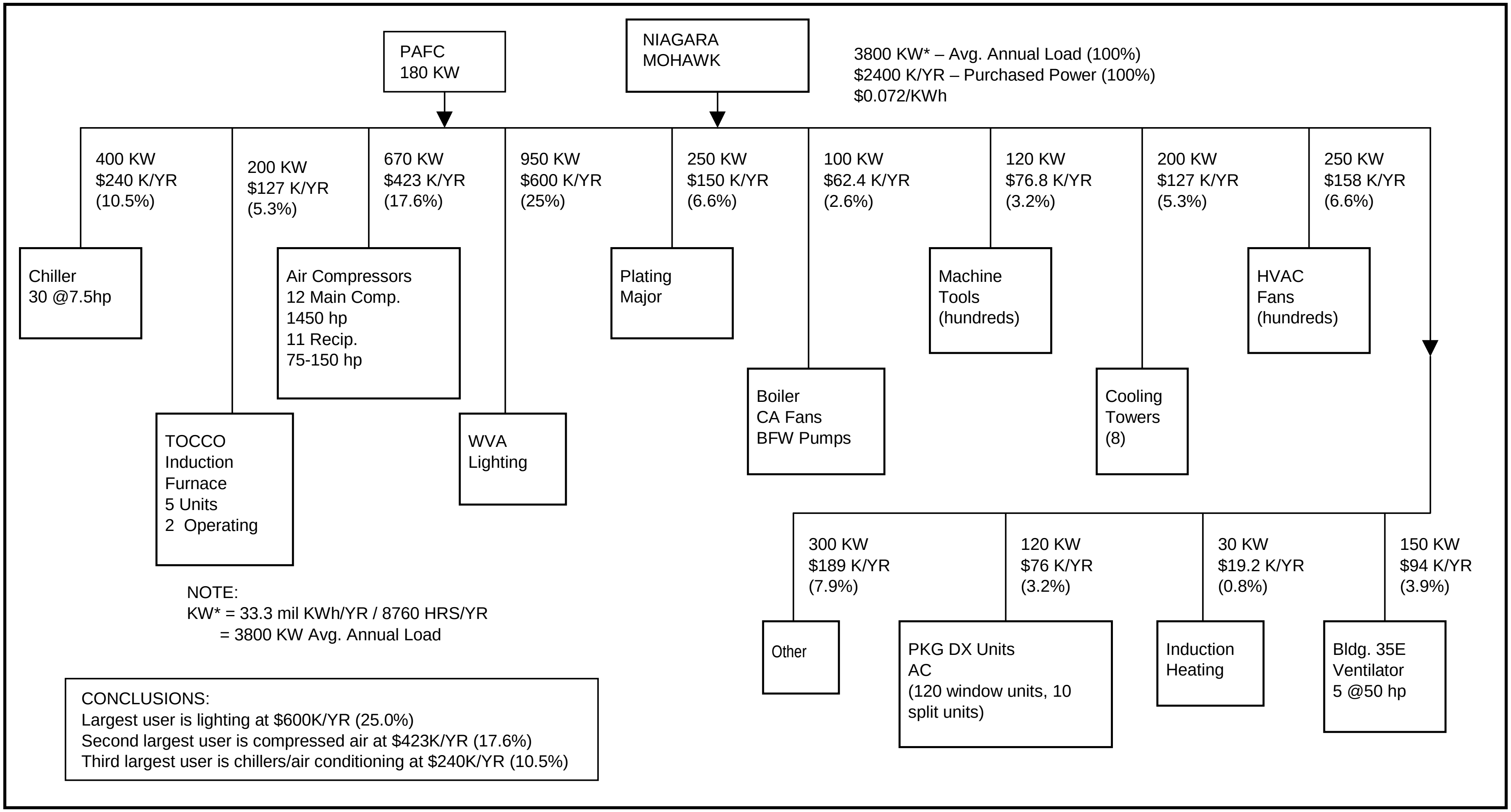


Figure 7. One line balance (OLB): WVA electric.

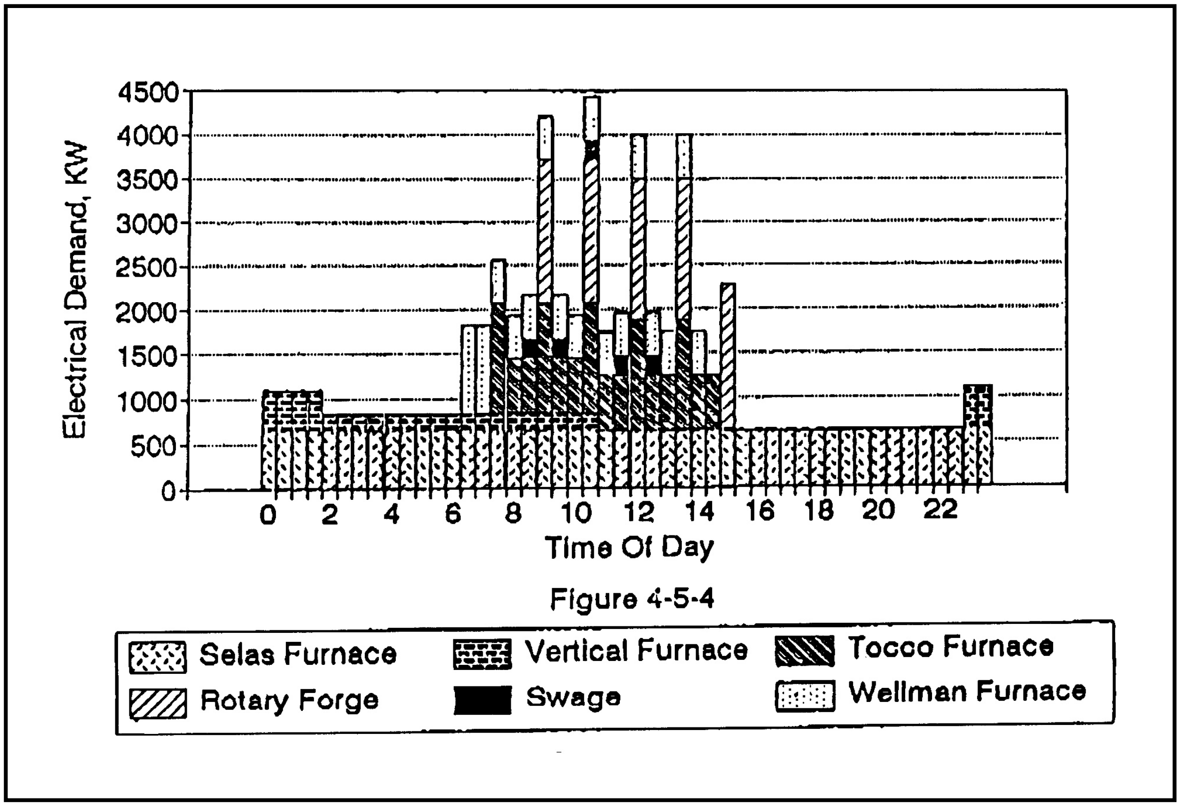


Figure 8. Hourly electrical demand for some WVA processes.

Figure 10 shows an OLB for the WVA Steam System. Heating for 38 buildings on site consumes 94.1 percent of the total Central Heating Plant (CHP) output (262,100 MM Btu for 7 months, $855K/yr). Process steam (16,500 MM Btu/12 months, $100K/yr) is supplied year round by a dedicated boiler. The building loads are shown for groups of buildings with the largest eight of the 38 buildings consuming 58.8 percent of the total. System losses from the CHP and the distribution system are estimated at 24.6 percent, or $210K/yr. Tables 17 and 18 list estimates of monthly steam production (MM Btu) and yearly building loads (MM Btu).* Figures 11 and 12 show the hourly steam load on a monthly basis in lb/hr and Btu/hr. The building heating steam pressure is controlled at 125 psig for the entire heating season (October-April).

* Martin J. Savoie and Thomas E. Durbin, *Central Heating Plant Modernization Study for Watervliet Arsenal, New York*, TR 96/96/ADA318477 (U.S. Army Construction Engineering Research Laboratory [CERL], August 1996).

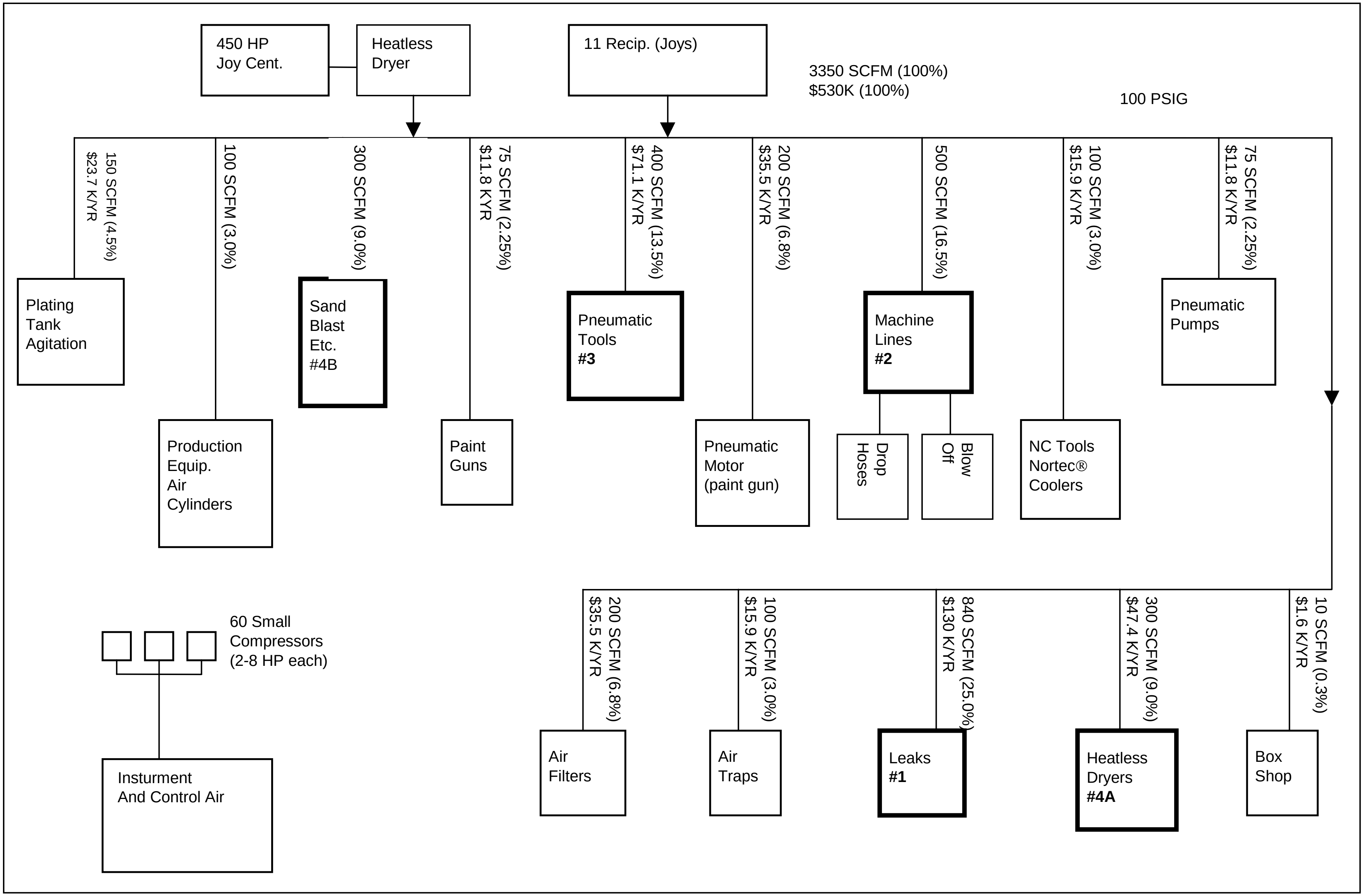
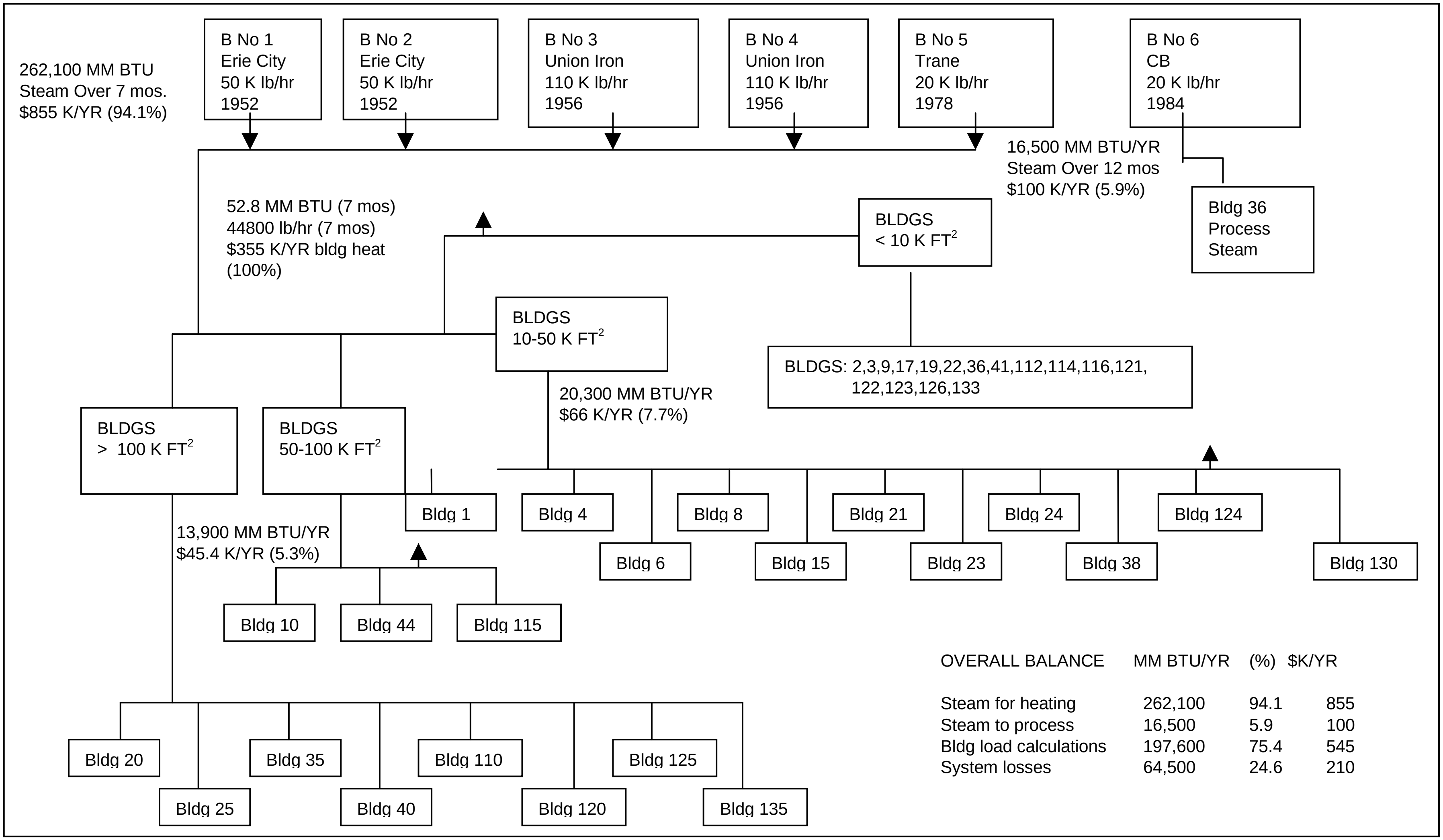


Figure 9. One line balance (OLB): WVA compressed air.



OVERALL BALANCE	MM BTU/YR	(%)	$K/YR
Steam for heating	262,100	94.1	855
Steam to process	16,500	5.9	100
Bldg load calculations	197,600	75.4	545
System losses	64,500	24.6	210

Figure 10. One line balance (OLB): WVA steam.

Table 17. Estimated monthly steam loads.

Month	Heatload (MM Btu)
January	43,699
February	43,293
March	41,880
April	26,258
May	5,717
June	3,166
July	1,941
August	3,004
September	3,509
October	25,904
November	35,545
December	45,544
7 months	262,100
12 months	278,600
Source: Savoie August 1996	

Table 18. Estimated building heat loads.

Building Number	Square Footage	Yearly Heat Load (MM Btu)	Avg. Heat Load (MM Btu/hr)
1	13,666	1,531	0.39
2	9,828	1,101	0.28
3	9,740	1,091	0.28
4	14,000	1,568	0.40
6	15,970	1,789	0.46
8	11,173	1,252	0.32
9	4,338	486	0.12
10	66,867	5,004	1.29
15	22,990	2,788	0.69
17	7,714	935	0.23
19	9,208	1,032	0.27
20	107,157	12,994	3.20
21	17,711	1,564	0.18
22	9,955	1,207	0.30
23	21,527	2,610	0.64
24	11,876	889	0.23
25	185,850	22,537	5.56
35	336,381	28,200	8.62
36	6,293	763	0.19
38	29,400	2,465	0.75

Building Number	Square Footage	Yearly Heat Load (MM Btu)	Avg. Heat Load (MM Btu/hr)
40	182,488	13,658	3.51
41	5,023	443	0.05
44	61,009	4,565	1.17
110	208,674	25,293	6.23
112	8,355	700	0.21
114	4,888	410	0.13
115	52,072	4,365	1.33
116	2,320	194	0.06
120	101,975	12,366	3.05
121	6,445	540	0.17
122	1,552	130	0.04
123	8,262	693	0.21
124	13,199	1,107	0.34
125	119,200	14,455	3.56
128	6,614	554	0.17
130	30,904	2,591	0.79
133	7,200	604	0.18
135	190,616	23,115	5.70

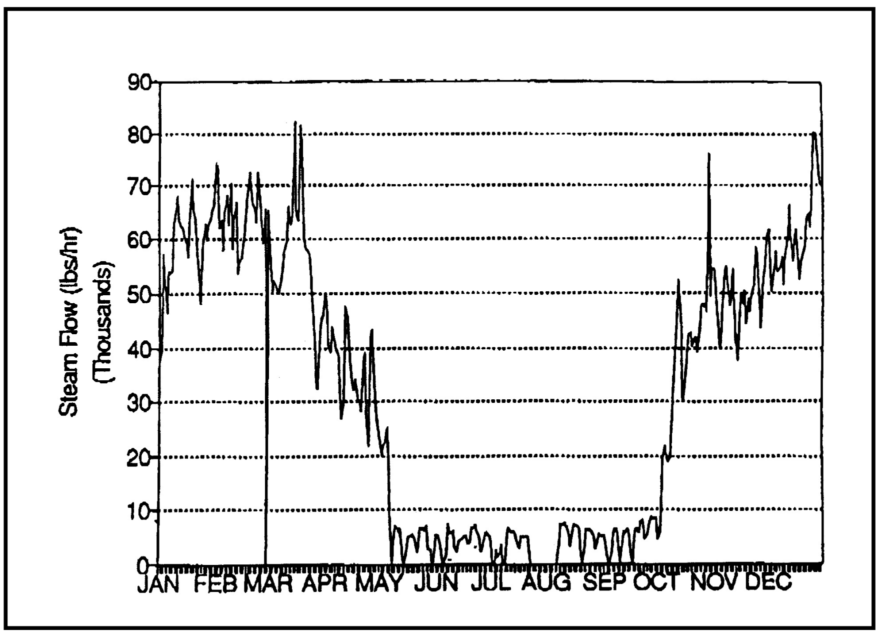


Figure 11. Steam load profile (klb/hr) for January – December 1993.

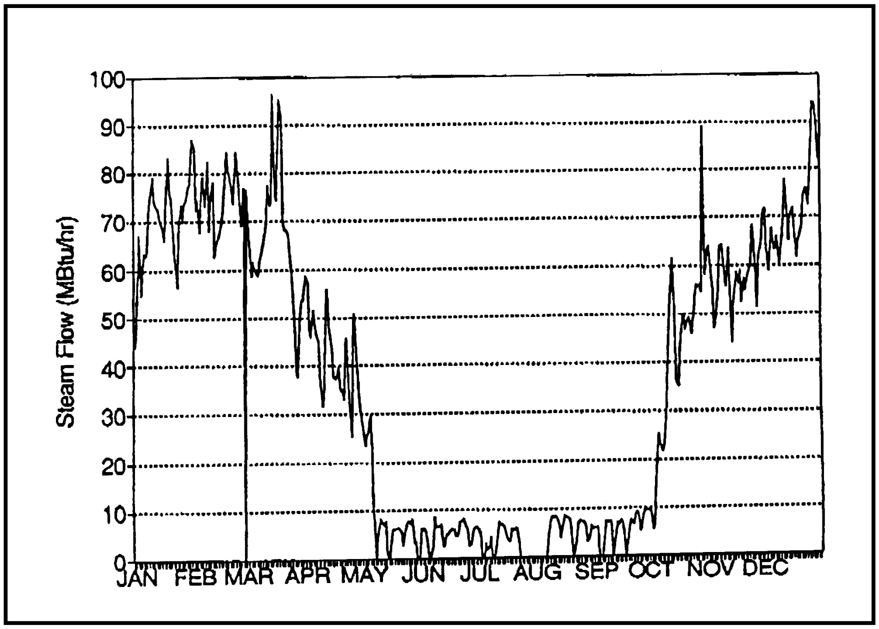


Figure 12. Steam load profile (MBtu/hr) for January – December 1993.

Solutions (ECOs) to Electrical and Compressed Air CCIs

The audit team brainstormed solutions to low efficiencies, high losses, and end-use waste in the electrical and compressed air systems and process consumers. Table 19 lists 31 potential ECOs to improve the performance of these systems. Items with ≥10 votes are indicated in bold and were selected for economic analysis along with items categorized as no cost/no risk "slam dunks."

Additionally, discussions of the central steam plant suggested the following potential ECOs should be evaluated for economics:

1. Lower CHP steam pressure set point from 125 psig to possibly 100 psig, which should be adequate for 95 percent of the heating season (slam dunk that saves boiler fuel by 2.5 x 0.4 % = 1.0 %).
2. Float CHP steam pressure set point from 60 to 125 psig based on outside temperature to further reduce system losses (saves 4 percent).
3. Improve insulation losses by installing blanket, soft cover insulation on uninsulated valve bodies and flanges.
4. Interrupt CHP steam heat to selected buildings that are not occupied during all or part of the 7-month heating season.
5. Decommission redundant segments of the CHP distribution system
6. Implement steam system ECOs listed in Table 20.

Table 19. Solutions to electrical and compressed air systems CCIs.

Idea no.	Process Change (Bold ≥10 votes) (SD = Slam Dunk)	Vote	Category
1	Reduce air circulation rate during nights and weekends in Bldg 35 to a safe level to decrease electricity consumption. SD	**22**	Fan Energy
2	Use point of use pressure controls to reduce steam and compressed air cost.	**14**	Compressed Air
3	Identify and repair leaks by forming a leak reduction team and purchasing an ultrasonic leak detection instrument.	**23**	Compressed Air
4	Find alternatives to shop equipment that use compressed air 24 hours a day (see #13 and #14 below).	**15**	Compressed Air
5	Shut off power to dead equipment. SD	**24**	Process Elec.
6	Consolidate manufacturing by operating only necessary production areas.	9	Operating Practices
7	Maximize use of the most efficient machines. (Is the centrifugal air compressor our best, most efficient unit?) SD	4	Compressed Air
8	Shut down centrifugal unit on all three day weekends. SD	**23**	Compressed Air
9	Improve instrumentation on electrical and compressed air systems with a power monitoring and control system.	9	Electrical
10	Plastic wrap on all leaky windows.	1	Bldg Envelope
11	Install more sub-meters for compressed air to provide performance feedback to utility personnel.	7	Compressed Air
12	Increase chiller temperature by 5 degrees in spring and fall. SD	0	Air Conditioning
13	Find alternative cooling for Vortec compressed air cooling for instrument panels in NC machines.	**10**	Compressed Air
14	Do #13 with a miniature air blower (approx. $1000 cost saves $2000/yr).	**10**	Compressed Air
15	Change compressed air to circulation pump for tank agitation.	6	Compressed Air
16	Install higher efficiency motor drives.	0	Motor Elec.
17	Recycle heat in building 110 from 450 hp air compressor with packaged heat recovery unit for building heat.	**13**	Heat Recovery
18	Consolidate loads by shutting down transformers. (Some systems are 6% loaded, yet we keep them on.) SD	**23**	Turn It Off
19	Automate steam distribution panel in Bldg 20 and relocate panel.	**11**	Steam (Fuel)
20	Meter plant steam system for feedback to the end users.	**10**	Steam (Fuel)
21	Replace HVAC fans with steam driven fans.	0	Fan Energy
22	Replace some steam unit heaters with direct gas fired units.	4	Fuel Efficiency
23	Reduce agitation pressure in plating tanks and shut off some of the pressure when not needed (see #15 above). SD	**14**	Compressed Air
24	Bring deep recessed lights to surface area and disconnect 25%.	3	Lighting
25	Reclaim condensate water from summer boiler and reuse it.	**24**	Boiler Fuel
26	Run a minimum number of production machines when possible (i.e., put dots on must run machines). SD	**10**	Operating Practices
27	Use summer boiler for heat up only and then switch to electric heat to hold temperatures.	6	Boiler Fuel
28	Dedicate one person to manage site-wide energy and to control the energy monitoring systems.	8	Management Issue
29	Reduce warm weather steam pressure to less than 125 psig to reduce distribution loss. SD	**14**	Boiler Fuel
30	Shut lights off when not necessary (5% of $600K = $30K/yr) SD		Operating Practices
31	Shut off excessive daytime lights usage (50% x $600K x 25% = $75K) SD		Operating Practices
Objective Statement: Identify process changes (operating conditions, practices, procedures, and of people and basic technology) to optimize the performance of the electrical and compressed air systems to resulting in significant cost reductions. Note: A 10% reduction in energy is worth $335K/yr, and a10% reduction in environmental costs is worth $120K/yr.			

Table 20. Economic analysis of results: energy systems.

Idea # (cf. Table 19)	Title	Basis for Savings and Cost	Net Savings K$/YR	Capital Cost K$	Payback (mo)	Category
30,31	Turn unnecessary daytime and night-time lights off	5% of $600K 25% of (50%) of $600K	30+75=105	0	Immediate	P,SD
23	Reduce agitator pressure	10% of $26K	3	0	Immediate	P,SD
8	Shutdown centrifugal air compressor on 3-day weekends	Save 280 cfm (26wks*3days/wk) = 78 days 1440 min/day * 280 cfm*78 days = 31450 kcf @ 30¢/kcf = $9400 for 1280cfm =$43K Use $80K/yr	80	0	Immediate	P,SD
1	Reduce air circulation rates during nights and weekends	50% of $94K	47	0	Immediate	P,SD
3	Reduce air compressor leaks by 50%	50% of $139K (65-25)=40	40	0	Immediate	P
2	Use point-of-use pressure controls to reduce motor cost for compressed air within 100 to 96 psig	4 psi reduction from (100-96=4) 2% of 530	11 Sub Total 286	0	Immediate	P
13,14	Alternate cooling for NC instruments	Air blower 20*500 = 10K Labor: 5K Total: 10K + 5K =15K	15	15	12 mo	C
19,20	Automate steam plant meter system (part of boiler emissions tracking project)	7.5% of 855=64K	64	160	30 mo	C
25	Reclaim condensate water from summer boiler	16500gal/day @ 20day/yr @ $1/gal	330	300	11 mo	C

SD-slam dunk
P-people implemented strategy
C-capital cost implemented strategy
O-operational implemented strategy

Economic Analysis of Results

Table 20 summarizes economics on the top ECOs selected from the brainstorming list on Table 19. Two different groups of ECOs were estimated: (1) no cost or expense only, and (2) those requiring capital investment. The no cost or expense only (seven ECOs) were estimated to collectively save a net of $286K/yr with no capital investment. Three ECOs requiring capital investments were estimated to save $409K/yr with an installed cost of $475K for an average payback of 1.2 years. Eleven of the 31 potential ECOs were judged to be slam dunks (no cost/no risk).

6 Conclusions and Recommendation

The purpose of the Level I Process Optimization Audit is to determine the economic “potential” for significant cost reduction from process changes. This is accomplished in a Level I analysis by identifying solutions to critical cost issues and estimating the economics for the top ideas. The 4-day analysis of multiple complex processes is not intended to be precise, nor should it be. The quantity and quality of the process improvements identified in the Level I Audit suggests that significant potential exists. WVA can accomplish these potential cost savings and growth in workload by pursuing an aggressive program of Process Optimization. Continuation of Process Optimization for other industrial processes is recommended.

Low-cost/no-risk (“slam dunk”) process improvement ideas from this 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 effort is recommended. A Level II analysis “guesses at nothing – measures everything,” quantifying both the Level I and new Level II ideas. The results are a set of demonstrated process improvements based on hard numbers. A specific Level II scope and approach as to how to use on-site and off-site resources are best jointly developed by review and discussion of results documented in this Level I report. CERL, MSE, and ETSI can provide WVA guidance and further assistance in identifying a specific Level II scope of work, respective roles, and the most expeditious path forward. This begins with a formal review of this report, combined with a planning session to organize the Level II program.

Acronyms

Btu	British Thermal Unit
CCIs	Critical Cost Issues
CERL	U.S. Army Construction Engineering Research Laboratory
CHP	Central Heating Plant
DOD	Department of Defense
ECO	Energy Conservation Opportunities
ETSI	Energy Technology Services International, Inc.
HQIOC	Headquarters, U.S. Army Industrial Operations Command
hr	hour
K	thousand
lb	pound
MM	million
mo	month
MSE	MSE Technology Applications, Inc.
NG	Natural Gas
NGT	Nominal Group Technique
OLB	One Line Balance
PEPR	Process Energy and Pollution Reduction
PFD	Process Flow Diagram
PO	Process Optimization
SIG	Silent Idea Generation
WVA	Watervliet Arsenal
yr	Year

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13. ABSTRACT ***(Maximum 200 words)***

The U.S. Army Construction Engineering Research Laboratory (CERL) held a Process Optimization (PO) workshop and performed a Level I Process Energy and Pollution Reduction (PEPR) Audit 1-5 February 1999 at the Watervliet Arsenal, NY. The primary objective of the audit was to financially and technically review the Arsenal's manufacturing steps and to identify process changes that will significantly increase performance and efficiencies. A corollary objective was to transfer process optimization techniques to WVA's team to analyze other processes.

A significant number of process improvements were identified for the heat treat, plating, and energy systems. The combined value from process changes could potentially improve WVA's operating margins by approximately $5.8 million per year, with a $683K capital investment. Ideas requiring such investment, however, must be developed further, tested, and re-analyzed based on a Level II (in-depth) analysis in which all assumptions are verified. The Level II analysis will generate "appropriation grade" process improvement projects for submission to top management for funding.

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