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EXAMPLES FROM P2 AND ENERGY ASSESSMENTS AT SMALL TO MEDIUM SIZE MANUFACTURERS

by

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Introduction

Using engineering student-faculty teams, the U.S. Department of Energy sponsored Industrial Assessment Center (IAC) at the University of Louisville does free pollution prevention and energy assessments at small to medium size manufacturers (SIC 20-39) in Kentucky and Indiana. Each client plant must meet three of the following four criteria:

- Annual energy bills less than than $1,750,000 and more than $50,000
- Gross annual sales of less than $75 millon
- Less than 500 employees
- Lack a dedicated energy/waste engineer
- Lack of in-house staff to perform these analyses

The program criteria and assessment procedures are briefly described and summaries of assessments at a sheet fed offset (lithographic) printing plant and 2 denim jeans prewashing plants are presented.

Assessment Procedure

The primary objective of the IAC is to identify and evaluate opportunities for energy conservation and waste minimization. Prior to the site visit the following plant information is requested:

- Copies of utility bills: water, sewer, gas, electricity, any other major fuel used, e.g., coal for a full year
- Equipment List
- Lighting List
- Plant Layout
- Process Flow Diagram
- Chemical List

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- **As they apply:** Annual hazardous waste generator report, SARA 313 Toxics Release Inventory Form R, Air permits, Wastewater permits, Waste analyses
- Annual quantities and costs for hazardous waste and solid waste transportation and disposal.
- Other waste management costs, e.g., permit fees, taxes, analyses, maintenance, supplies, labor, & administration for above wastes, wastewater treatment, air pollution control

If any of the requested data is not readily available or additional arise, they are obtained or developed during or after the site visit.

Generally the energy assessments are primarily prescriptive, while the waste assesssments are primarily descriptive. Data are gathered primarily during a one day site visit which usually proceeds as follows:

- Plant overview and briefing, followed by a more intensive interview for the waste team.
- Separate guided plant tours for the energy and waste teams. The waste team tour usually takes longer since the focus is on the process from raw materials in the door to wastes and products leaving the plant. During the tour the services of plant personnel other than the host(s) may be needed, e.g., plant electrician to aid in measuring power factor, operator to collect waste samples, maintenance supervisor to verify operating conditions, etc.
- Obtaining or determining needed data during the plant tour by interviewing operators, instrumental energy related measurements, and shooting photographs and/or video with the client's permission.
- Debriefing meeting with the host(s) following the audit, to discuss preliminary findings and identify additional information needs. Separate meetings may be needed for energy and waste.

Following the site visit, energy conservation and waste reduction recommendations which look promising are pursued. Additional contact with plant personnel is often necessary to verify data, obtain additional information, etc.

Assessment Recommendations

Assessment recommendations (ARs) for energy conservation and pollution prevention/waste minimization are identified both during and following the plant visit. So far as possible we try to address the client's priorities. Since site visits are brief, the ARs may be limited in scope. In developing the ARs, literature, vendors, P2tech (listserve), and other resources are used to obtain information on methods, equipment, and costs to evaluate technical and economic feasibility. Capital investment, operating costs, and potential materials and waste management savings are estimated, and a simple payback period (no time value of money) is determined. Sometimes, net positive value is also used as an indicator of economic feasibility.

On the waste side, potential savings in most cases address direct costs, primarily reduced material requirements and waste disposal. Labor, maintenance, and supplies, e.g., waste drums, are also estimated as available and/or necessary. Indirect costs such as record keeping are usually not accounted for in the ARs because of the uncertainty in allocating them to specific wastes. Furthermore, many of these costs are not readily attainable and are often unclear as they are often merged with other costs. However, as available, permit fees, taxes and chemical analysis costs are generally accounted for. Other savings not usually quantified include elimination or reduction of a variety of future possible costs, such as those related to changing emission standards and regulations, potential future liability, and improving general employee safety and health and environmental quality.

The assumptions, data and calculations used to estimate energy consumption and waste generation, and costs, savings and payback for the ARs are reported in detail. Thus changes or corrections may be easily made should the client not agree with the data or assumptions. The estimates are intended to be conservative. When suggested ARs involving engineering design and significant capital investment are attractive to the company and engineering services are not available in-house, it is recommended that a consulting engineering firm be engaged to do the detailed design and cost estimating for implementation. For some ARs, testing may be appropriate to verify anticipated performance of suggested methods. Some ARs may be more speculative in that research and development may be required.

Additional waste minimization and energy conservation considerations are identified and briefly described. These items are not presented as ARs due to insufficient time for research, insufficient data, or unfavorable economics. Some of these measures would require relatively long payback periods (>4yrs.) or save less than $200/yr, or were otherwise beyond the scope of the assessment.

Assessment at a Printing Plant

The plant does sheet fed lithographic (offset) printing using soy-based inks to make tray cards for compact discs and labels for cassette tapes. Production rate is 80 millon units/mo. with annual sales of about $30 millon, with 170 employees. The company is a small quantity hazardous waste generator and does not submit SARA 313 Toxic Release Inventory reports. Process waste water from image processing and fountain tank cleaning are sent directly to the POTW after silver recovery from fixer. The VOCs consist primarily of aliphatic and aromatic napthas, with blanket wash being the major contributor. Non isopropyl fountain solution is primarily used.

Customer provided proofs go through image processing to (presensitized) aluminum plate making. The plates are used in makeready prior to the actual printing job. Ink is removed from the press ink wells afterjob completion, and the wells and rollers are cleaned with blanket wash and solvent wetted rags. The rollers are not cleaned when the same colors are to be used on the next job or the existing job is to be continued on the next shift. The product is then sent to the bindery for cutting, folding, and stapling, and the packaged product is then shipped. The overall process flow is shown in Figure 1, the energy usage summarized in Table 1, and the waste generation summarized in Table 3.

The plant has implemented the following waste minimization efforts: switching from petroleum-based to soy-based inks; VOC reduction by improved production planning and scheduling; reusing plastic wrap from incoming paper shipments; reusing pallets for in-plant storage and product shipments; off-site corrugated recycling; silver recovery; mylar film recycling; recycling un-useable aluminum plates; reuse and recyle of plate developing chemical containers; use of make ready waste paper to remove ink from presses after job completion; off-site waste paper recycling; switch from xylene based cleanup solvent to naptha based; just in time and first in-first out inventory control for ink; ordering paper cut to size; and changing from a (hazardous waste) solvent based parts washer to an aqueous biodegradable detergent.

Recommendations for pollution prevention and waste minimization are summarized in Table 4. Additional waste minimization possibilities that were not costed out include:

- Automated ink blending and dispensing
- Testing and reuse of expired ink, possibly by blending
- Ultraviolet curable inks
- Sending metal bands from incoming paper and plate shipments to a scrap metal dealer
- Taking back empty boxes from customers for reuse
- Solvent recovery from rags
- Digital (computerized) image processing
- Enclosed automated blanket wash delivery

Recommendations for energy conservation are summarized in Table 5. Additional energy conservation measures considered but not costed out include:

- Reduce demand cost on electricity by off-peak hour scheduling of energy intensive operations
- Light timers in areas not always occupied
- Set back thermostats in areas such as offices

Assessments at 2 Denim Jeans Prewashing Plants

Both plants perform stone and enzyme washing of jeans from various jeans manufacturers. The plants have annual sales of about $4,000,000 (Plant A) and $6,000,000 (Plant B), and about 125 and 110 employees, resp. One plant has an adjacent industrial laundry, and the other a commercial dry cleaning-laundry operation. The industrial laundry has caused Plant A's total effluent to exceed the POTWs criteria for oil and grease. At each plant, the respective effluents from each operation are combined and sent to a POTW. Between the 2 plants, a combined total of about 200 millon gallons/yr. of water are used to process about 14 millon pair of jeans. Sewer bills are based on the amount of water used rather than the actual effluent discharged to the POTW. However, a significant amount of incoming water is lost by evaporation in transporting washed jeans to the drier, in the driers, from the warm wastewater and entrained in the removed lint (as shown in Figure 2).

Both plants pay substantial wastewater BOD_5 and total suspended solids surcharges to their POTWs. Solids are another major waste, primarily consisting of lint from the washers and dryers. Other significant wastes include pit sludge, cardboard, and shrink wrap. Plant A is not a hazardous waste generator; Plant B is because of solvent (PERC) recovery in their dry cleaning operation. Neither submits SARA 313 Toxic Release Inventory reports. Air permits are required for Plant A for the dryers, but not for Plant B which is in a different state. Pit sludge and washer lint is landfilled as special waste for Plant A and as ordinary trash for Plant B.

The process is generally similar for both plants as shown in Figure 2 for Plant A. Jeans are delivered by the jeans manufacturers and then transported to the washers where water and chemicals are added. Jeans are washed according to customer specifications, i.e., chemicals, cycles, etc. Plant B pays for its washing chemicals, while in Plant A their customers pay. Wastewater from the washers primarily containing dye, lint, and rocks (when stone washing is used) is pretreated for suspended solids removal before discharge to the POTW. Solids removed from the water are landfilled. The washed jeans are dried and particulates (lint) in the exhaust gas are removed in wet lint collectors. These solids are landfilled as well. The dried jeans go to finishing and shipping as needed, and are shipped back to the jeans manufacturer or directly to retail stores.

The wastewater treatment schemes differ slightly for Plants A and B, and are shown in Figures 3 and 4. In A, lint, rocks, and other solids are removed from the washwaters in 2 pits and by a vibrating screen (30-60 mesh). Settling in the pits is not desired since their primary purpose is equalization. In plant B, solids are removed from the wastewaters by a 150 mesh screen, a vibrating screen, a cyclone and a settling basin in series. In both plants, heat is recovered from washwaters in a heat reclaimer, to preheat incoming city water.

Each plant has implemented various waste minimization measures. Suppliers take back unused chemicals that previously were flushed through the washers to the sewer. Some chemical suppliers will take back empty plastic drums which would otherwise be landfilled. Plant A has gone to automated chemical metering for liquidson all their washers. Plant B uses scoops to meter both liquids and powders from the central chemical storage drums and transport and add them individual washers, with significant spillage occuring at each step.

One manufacturer delivers jeans in heavy duty plastic containers, which can be used for weighing and transport in the finishing process, and for shipping out finished jeans. The plastic boxes last longer than the "palletainers" with cardboard sides, which eventually are landfilled. In plant A the wet lint collectors use recycled water following the vibrating screen, instead of fresh city water. City water is recirculated in Plant B's in the dryer wet lint collector. Incoming pallets are used for finished jeans shipments and in the respective adjacent industrial laundry and dry cleaner. Damaged pallets go to a reconditioner.

Energy usage is summarized in Table 5 and recommendations for energy conservation in Table 6. Additional energy conservation measures considered but not costed out include those mentioned above for the printer and in addition for Plant B:

- Reducing compressed air leaks
- Preheating combustion air or makeup water with stack gas heat recovery

Waste generation is summarized in Table 7 and pollution prevention/waste minimization recommendations in Table 8. Additional waste minimization possibilities that were not costed out include:

- Improve free and emulsified oil removal from Plant A's industrial laundry wastewater prior to combining with denim washing effluent to POTW by e.g., dissolved air flotation, coalescing cartridge filter, emulsion breaking, microfiltration or ultrafiltration
- Have Plant A's suppliers ship jeans in heavy duty plastic containers rather than palletainers (racks with cardboard sides) and use plastic boxes for jeans weighing and transport within the plant, and shipping finished jeans
- Replace foldable cardboard boxes used in Plant A for in-plant jeans transport, with stackable or plastic containers or canvass bags
- Automate chemical metering and injection in Plant B
- Improve operating practises in Plant B for metering chemicals to washers
- Reduce suspended solids (and associated BOD) loadings to

POTW and surcharges by adding coagulation/flocculation, finer mesh backup screen, polishing filter, or replacing vibrating screens with a rotating drum screen or container filter.

- Additional wastewater treatment to reduce BOD and allow for water reuse by e.g., carbon adsorption or chemical oxidation
- Soften incoming water
- Keep rainwater out of lint dumpster and allow drainage from wet lint
- Recycle shrink wrap and increase corrugated recycling

Figure 1: Process Flow Diagram (Printing)

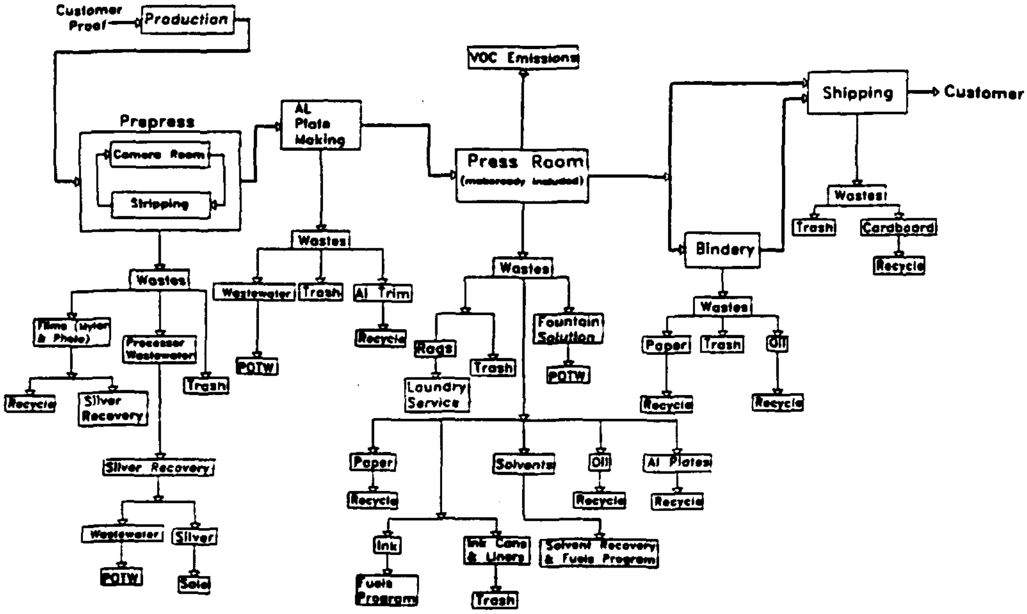

Table 1 - Energy Usage Summary (Printing)

Electricity		Natural Gas	
(kWh)	($)	(ccf)	($)
3,772,378	$ 95,495	1849	$ 958

Table 2 - Summary of Energy A-Rs (Printing)

AR No.	Description	Potential Conservation (MMBtu/yr)	Potential Savings ($/yr)	Resource Conserved	Impl. Cost ($)	Payback Time
1	Install High Efficiency Lighting	315	$4,596	Electricity	$2,430	6 months
2	Improve Overall Power Factor		$12,198	Electricity	$4,420	3 months
3	Improve Power Factor on Individual Equipment		$313.72	Electricity	$240	10 months
	TOTALS	315	$17,108	—	$7,090	

Table 3 - Waste Generation (Printing)

Waste Type	Sources	Annual Quantity	Management Method	Waste Disposal Cost/(Revenue) $/yr
Wooden Pallets	Incoming Paper Incoming Al Plates	N.A. N.A.	On-site Reuse Reconditioned off-site Product Shipment Use	$0
Cardboard Boxes	Incoming Paper Incoming Al Plates	36 yds^3	Recycle	($1,350)
Mill Wrap	Incoming Paper	+	Trash	+
Steel Bands	Incoming Paper Incoming Al Plates	5000 lbs	Trash	N.A.
Plastic Wrap	Incoming Paper	N.A. +	On-site Reuse Trash (After Reuse)	N.A. +
Foil Backed Paper	Incoming Al Plates	+	Trash	+
Chipboard Dividers	Incoming Al Plates	+	Trash	+
55 gallon drums (metal and plastic)	Incoming Chemicals	N.A. 119 drums	Returned to Supplier On-site Reuse	0 $2,975* (lost deposit)
Silver/Negatives	Stripping Department (Photoprocessing)	20 lbs	Recycle	($1,680)
Aluminum (Plates & Trim)	Printing Press Al Plate Making	83714* lbs	Recycle	($60,000)
Ink	Expired Ink Printing Residual (Press)	32000 lbs	Fuels Program	$12,800*
Ink Cans	Expired Ink Printing	18332* cans (11054* lbs)	Trash	+
Ink Can Liners	Expired Ink Storage Printing Press	18332* liners	Trash	+
Press Paper	Makeready (Printing Startup) Printing Bindery	N.A.	Recycle	($1,143)
Solvent (Blanket and Roller)	Press Blanket and Roller Washes	22391 lbs 24000 lbs	Fuels Program Atmospheric Emissions	$6,230 $125 (permit fee)
Economist Thinning Spray	Printing Press	697 gal	Atmospheric Emissions	$0
Solvent Cleaning Rags	Printing Press	9000 rags	Laundry Service	N.A.
Films (Mylar & Photo)	Camera Room Stripping Room	1200 sheets	Recycle	($3,000)
Wastewaters	Camera Room Developer Stripping Room Processor Al Plate Room Developer Al Plate Room Finisher Al Plate Room Film Cleaner Press Fountain Solution	730000 gal	POTW	$848*
Hydraulic Oil	Printing Press Bindery	220 gal	Recycle	$200
Fountain Liners	Printing Press	+	Trash	+
Plastic Containers	Al Plate Making	N.A.	Recycle	N.A.
Glass Containers	Al Plate Making	N.A.	Recycle	N.A.
Film Cleaner Containers	Al Plate Making	+	Trash	+
Economist Containers (Thinning Spray)	Printing Press	+ N.A.	Trash On-site Reuse	+ N.A.
Cotton Wipes/Cheesecloth	Trash	+	Trash	+
Tissue	Stripping Room	+	Trash	+
Lubricating Powder	Printing Press	+	Trash	+
Anti Offset Powder	Printing Press	96 lbs	Trash	+
Staples	Bindery	+	Trash	+
Paper Cups	Printing Press	+	Trash	+
Shrink Wrap	Bindery	1 yd^3	Trash	+

Total Trash to Landfill Wastes	798 yds^3/yr
Total Trash Costs	($6,216)/yr

Key:

N.A. Not Available

+ Included in total trash disposal to landfill

* Estimation method described in Appendix I

Table 4 - Summary of Waste Assessment Recommendation (Printing)

Current Practice	Proposed Action	Estimated Net Annual Savings (Loss) & Reduction
Sending waste press cleaning solvent to off-site recovery/fuels program	a.) On-Site Recycling Unit	Waste Reduction: 9,333 lbs Investment: $8,875 Savings: $5,525 Payback: 1.6 yrs
	b.) On-Site Mobile Service	Waste Reduction: 9,283 lbs Investment: $0 Savings: $2,856 Payback: Immediate
Residual ink recovery and reuse	Use of coated ink can liners and increased recovery of ink from can	Waste Reduction: 3,373 lbs Investment: $460 Savings: $9,668 Payback: 0.6 mos
Waste soy-based ink to fuels program	Off-site recycling and using reblended black ink	Waste Reduction: 32,000 lbs Investment: $0 Savings: $33,570 Payback: Immediate
Empty steel ink cans and steel packing bands to landfill	Send scrap steel to steel recycler	Waste Reduction: 16,054 lbs Investment: $75 Savings: $377 Payback: 0.2 yrs
Leaving plunger cans for solvent-rag roller cleaning open	Keep cans closed immediately after use	Waste Reduction: 1,102 lbs Investment: $0 Savings: $347 Payback: Immediate
Using soy-based ink and VOC-based solvent to clean printing presses	Use of newly developed vegetable-based ink and non-VOC cleaning solvent	Net Annual Loss: ($171,848) Reduced VOC air emissions: 23,267 lbs Hazardous waste reduction: 22,591 lbs Investment: $0

Figure 2: Process Flow Diagram (Denim Washing)

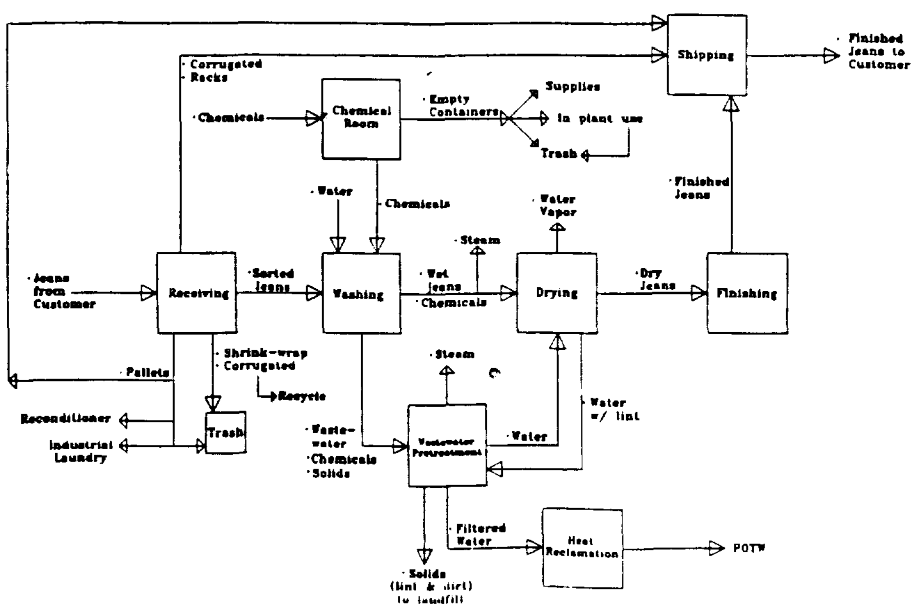

Figure 3 (Plant A): Water Flow Diagram

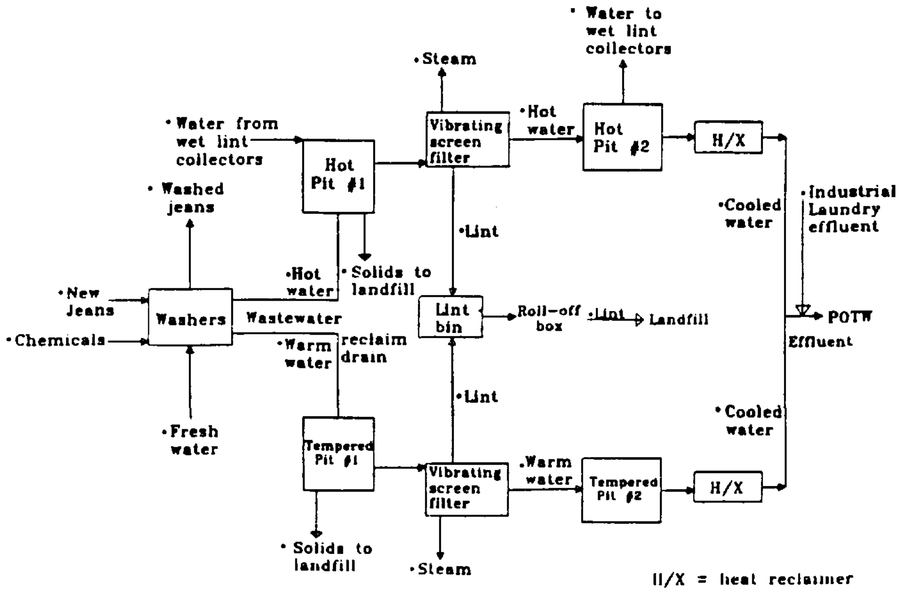

Figure 4 (Plant B): Wastewater Pretreatment System

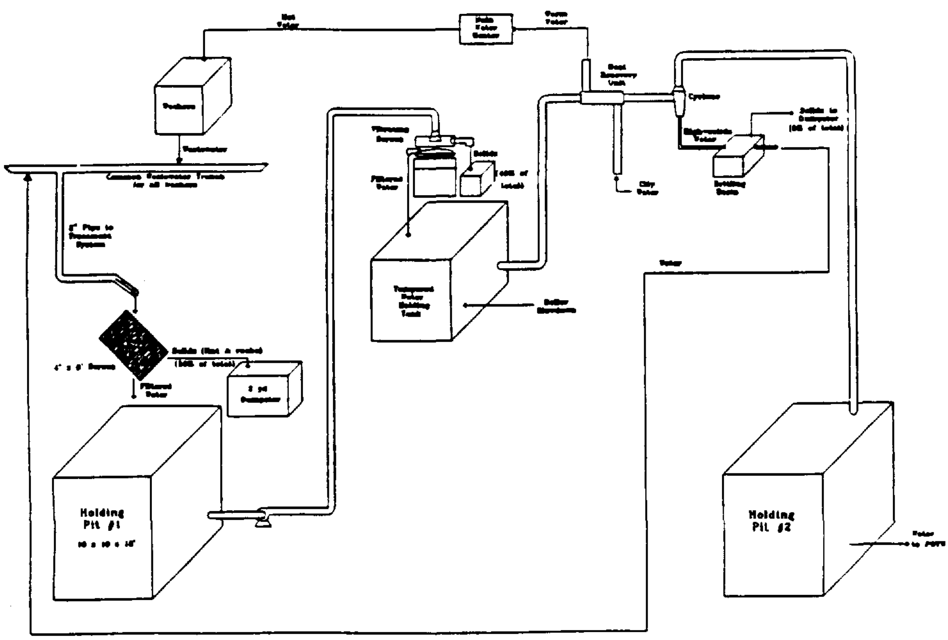

Table 5 - Energy Usage Summary (Denim Jeans)

Plant A

Electricity		Natural Gas	
(kWh)	($)	(Mcf)	($)
1,718,160	$95,282	59,983	$268,293

Plant B

Electricity		Natural Gas	
(kWh)	($)	(Mcf)	($)
4,071,649	$208,865	3,486	$15,750

Table 6 - Summary of Energy Savings and Costs (Denim Jeans)

Plant A

AR No.	Description	Potential Conservation (MMBtu/yr)	Potential Savings ($/yr)	Resource Conserved	Impl. Cost ($)	Payback Time
1	Use Outside Air for Compressor Intakes	9.9	$149	Electricity	$25	2 months
2	Install High Efficiency Motors	1,772	$26,635	Electricity	$22,850	10 months
3	Improve Power Factor on Individual Pieces of Equipment		$1,046	Electricity	$808	9 months
4	Insulate Heated Equipment	380.4	$1,593	Natural Gas	$1,146	9 months
5	Install High Efficiency Lighting	130	$2,255	Electricity	$2,077	11 months
	Total Savings	2,292	$31,678	—	$26,906	

Plant B

1.	Adjust Boiler Air-Fuel Ratio (2 Boilers)	4,701	$20,589	Natural Gas	$2000	1 month
2.	Compressor Intake	36	$586	Electricity	$10	1 week
3.	Replace Inefficient Motors	342	$5,551	Electricity	$4,400	10 months
4.	Install High Efficiency Lighting	131	$1,879	Electricity	$1,583	10 months
5.	Improve Power Factor on Individual Motors		$24,960	Electricity	$12,260	6 months
	Total Savings	5,210	$53,565	—	$20,829	4 months

Note that the calculated savings are based on the average cost of each energy source. For example, the average cost of electricity was $16.25/MMBtu; this includes the energy cost, the demand cost, the electric cost adjustment, and all other costs, including sales tax. A "law of diminishing returns" applies to the total cost savings. That is, the figure of $53,565 is based on the sum of the cost savings for each AR as if they were independent.

Table 7 - Waste Generation (Denim Jeans)

Plant A

Waste	Operation	Annual Quantity	Management Method	Annual Disposal Cost †
Effluent to POTW Surcharges (BOD,TSS)	Washing	140,000,000 gal	POTW	$163,503 $15,960 *
Unused Chemicals	Washing	N/A	Returned to supplier	$0
Solids from screen, Wet Lint (collector) (Wet)Total **	Water Treatment Drying	15% - 40% 60% - 85% 60 yd^3	Landfilled as special waste	 $2,260
Skimmer Oil & others	Oil Skimmer (Industrial Laundry)	660 gal	off - site reclamation	$230
Lint / Solids	Pit Cleanouts	100 yd^3	Landfilled as special waste	$3,500
Totes	Chemical Receiving	N/A	Returned to supplier	$0
Fiber Drums	Chemical Receiving	N/A	Used on site or cut & trashed	$0
Cardboard boxes	Receiving	4,000 lb ***	recycled	
General Trash, includes: Shrinkwrap Collapsible Cardboard Boxes White Paper Fluorescent Bulbs Damaged Pallets	Overall Denim Plant	800 yd^3 10,000 lb **** 100 N/A N/A 100	Landfilled (Reused or Reconditioned or trashed)	$2,200
	Total Waste to Landfill:	960 yd^3/yr		
	Total Landfill Cost:	$8,000/yr		

† - includes 6% tax

* Billed to Industrial Laundry

** Quantities and percentages are from estimates given at the plant

*** estimate - for boxes only; does not include other cardboard - See Appendix II

**** estimated - See Appendix II

Plant B

Waste	Operation	Annual Quantity	Management Method	Annual Disposal Cost ††
Effluent to POTW Surcharges (BOD, TSS)	Denim Washing	52,000,000* gal	POTW	$133,000 $27,300
Unused Chemicals	Washing	N/A	Flushed through washers	-
Solids from outdoor screen, from vibrating screen, from Settling Tank Lint in Baghouse Wet Lint (collector) Total	Water Treatment " " Drying "	330 yd^3 300 yd^3 33 yd^3 8 yd^3 8 yd^3 680 yd^3 *	Landfilled " " " "	$1,130 $630 $69 $18 $18 $1,870
Oils from machines	Maintenance	600 - 800 gal	Off-site Reclamation	$230
Lint / Rocks	Pit Cleanouts	36 yd^3/yr	Landfilled	$5,600
Cardboard Boxes	Receiving	N/A	Recycled	$0
Rocks	Washing	528,000 lbs	Reused, swept up with trash, collected in settling boxes, or goes to POTW with wastewater	
General Trash, includes: Shrinkwrap Empty Chemical Bags White Paper Fluorescent Bulbs Palletainers Pallets (damaged) Drums (some)	Overall Denim	2,330 yd^3	Landfilled " " " " " (Reused, Reconditioned or Trashed) (Returned, Reused, or Trashed)	$4,000
	Total Waste to Landfill:	3,250 yd^3/yr		
	Total Landfill Cost:	$11,500/yr		

†† - includes 5% tax

* estimates - see Appendix IV

Table 8 - Summary of Waste Assessment Recommendations (Denim Jeans)

Current Practice	Proposed Action	Estimated Net Annual Savings	Plant A	Plant B
Sewer charges are based on the volume of water purchased from the water company	Install a separate sewer meter and pay directly for the volume discharged	Waste Reduction:	0	0
		Investment:	$1,000	$1,000
		Savings:	$9,000	$24,300
		Simple Payback Time:	1.5 months	2 weeks
No water is recycled; all water used in all stages is fresh city water	Reuse the final 3 rinse stages of each wash cycle in subsequent washes	Waste Reduction:	34,000,000 gal	13,000,000 gal
		Investment:	$8,000	$10,500
		Savings:	$71,000	$41,500
		Simple Payback Time:	1.4 months	13 weeks
All lint generated at the facility is landfilled	Purchase baler/compactor to bale lint and give it away to prospective users	Waste Reduction:	18,000 lb	200,000 lb.
		Investment:	$5,000	$5,000
		Savings:	$3,100	$2,800
		Simple Payback Time:	1.6 years	2 years
Solids are allowed to settle in the first wastewater pits	Install an air diffuser to agitate the water in the pits, preventing solids from settling	Waste Reduction:	42,000 lb	15,000 lb
		Investment:	$1,000	$1,000
		Savings:	$1,700	$2,700
		Simple Payback Time:	31 weeks	19 weeks
Removal of suspended solids using a vibrating screen filter	Install a hydrocyclone in series with screen to increase solids removal	Waste Reduction:	280,000 lb	N/A
		Investment:	$3,100 - $5,600	
		Savings:	$5,600	
		Simple Payback Time:	0.6 - 1.4 years	