

Pollution Prevention Through Productivity Improvement

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ABSTRACT

Reported herein are results from 50 1996-98 Colorado State University Industrial Assessment Center (CSU IAC) industrial assessments at small and medium-size manufacturing plants. The assessments were conducted by engineering faculty and students associated with the CSU IAC. Each assessment includes a full-day plant visit and follow-up engineering and economic analyses of data pertaining to plant operations. Assessment reports provide recommendations for implementation of practices that can conserve energy, reduce waste, and improve productivity. Results from the 50 assessments demonstrate that recommended productivity improvement practices can also prevent formation of wastes and polluting emissions. A total of 61 productivity improvement recommendations were made, 14 of which provide pollution prevention with concomitant, quantifiable cost savings. Such cost savings are associated with improving management of raw materials, reducing generation of off-specification product, recycling cooling water, improving inspection and testing procedures, reducing batch sizes, and upgrading production equipment. For the 14 productivity improvement recommendations with pollution prevention benefits, the annual cost savings due to pollution prevention are \$502,140, whereas the total annual cost savings for the 14 recommendations are \$1,484,310. In other words, 34% of the cost savings for these productivity improvement recommendations is attributable to pollution prevention. The results thus demonstrate that improving productivity in manufacturing operations can prevent formation of wastes and polluting emissions.

INTRODUCTION

Supported by the U.S. Department of Energy, the CSU IAC performs industrial assessments for small and medium-size manufacturing firms. We have previously reported on predecessor CSU outreach programs for pollution prevention¹, combining pollution prevention with energy conservation², and addition of productivity improvement³. This paper identifies pollution prevention benefits associated with recommended productivity improvement practices. During the 24-month period beginning October 1, 1996, CSU IAC personnel carried out 50 industrial assessments at small and medium-size manufacturing facilities. Reported herein are data from these industrial assessments that demonstrate quantifiable pollution prevention benefits for 14 such productivity improvement recommendations.

ASSESSMENT PROTOCOL

Objectives

The two broad objectives of the CSU IAC program are as follows: (1) Serve small and medium-size manufacturers by recommending cost-effective practices that can save money and conserve resources, and (2) provide opportunities for CSU engineering students to acquire practical industrial experience. The specific objectives of an industrial assessment are to identify and

evaluate opportunities to conserve energy, reduce waste, and improve productivity. In manufacturing operations, typical energy utilization functions include lighting, operating electric motors and electronic equipment, generating and utilizing compressed air, generating and utilizing steam, heating, cooling, and transportation. Energy conservation opportunities, with emphasis upon industrial operations in the western states of the U.S., have been compiled⁴. Wastes can include hazardous and nonhazardous process-generated wastes in the forms of air emissions, liquid wastes, and solid wastes. Handbooks of industrial pollution prevention practices have been assembled^{5, 6}. Productivity improvement issues can include scheduling of tasks, purchase, storage and transfer of materials, set-up procedures, production bottlenecks, downtime, production equipment and capacity, inspection and testing, and operator training. An IAC training manual for productivity improvement has been prepared⁷.

Tasks

Each CSU IAC assessment includes the following sequence of tasks:

- Select manufacturing plant and schedule visit.
- Acquire pre-assessment data.
- Select team and visit plant.
- Identify assessment recommendations (ARs).
- Evaluate ARs.
- Prepare and submit assessment report.
- Conduct implementation survey.

The following criteria are employed to select manufacturing plants for CSU IAC assessments:

- SIC Code 20-39.
- Gross annual sales do not exceed \$75 million.
- No more than 500 employees at the plant site.
- Annual utility bills \$75,000 to \$1.75 million.
- No in-house professional staff to perform the assessment.

Additionally, the plant should be located within 150 miles of the CSU campus in Fort Collins. The industrial assessment is provided at no out-of-pocket cost to the plant. Moreover, plant personnel have no obligation to act on any of the CSU IAC recommendations. The CSU IAC is one of 15 western IACs managed by University City Science Center. The 15 eastern IACs are managed by Rutgers University.

Plant Visit

A team of CSU IAC faculty members and students visits the manufacturing plant for one full workday. The visit includes a guided tour of production facilities and waste-generating operations. The host and guide for the plant tour is often either the plant manager or the facilities manager. CSU IAC personnel obtain data for the past 12 months concerning utilities, wastes, and raw materials. CSU IAC personnel observe production operations and interview

plant personnel. The plant visit concludes with a wrap-up session with plant personnel.

Assessment Report

The primary purpose of the assessment report is to convey recommendations to the plant manager. The recommendations are to implement specific cost-effective practices in the areas of energy conservation, pollution prevention, and productivity improvement. Recommendations are based upon analysis of data pertaining to plant operations. The assessment report is normally sent to the plant manager within 60 days after the plant visit. The report summarizes pertinent utility, equipment, and waste data. For example, CSU IAC personnel often perform a lighting survey and inventory major plant equipment, including electric motors, compressors, boilers, fans, ovens, and refrigeration equipment. Current energy conservation and pollution prevention practices are identified. A process flow diagram is prepared. Monthly electric, gas, water, sewer, and waste management costs are quantified for the 12-month period immediately prior to the date of the plant visit. The report then recommends implementing specific practices to reduce costs, conserve resources, and improve productivity. The technical and economic analyses that support each recommendation are given, including data, assumptions, and equations. Six to twelve months after the site visit date, the plant manager is contacted by CSU IAC personnel to obtain information concerning implementation of recommendations.

RESULTS

Presented in Table 1 are the productivity improvement recommendations with concomitant, quantifiable pollution prevention benefits. Included are plant SIC codes, principal products, and data regarding waste reduction, annual savings, and implementation. For the 50 industrial assessments conducted during the 24-month period commencing October 1, 1996, a total of 61 productivity improvement ARs were reported. Of this total, 14 ARs provide quantifiable waste reduction benefits, including costs savings. In the sections that follow, each of these 14 ARs is discussed.

Plant 381. Principal products of this Denver manufacturing facility include ice cream and yogurt. Raw materials include dairy liquids and solids, sweeteners, flavors, colors, and yogurt cultures. The process includes mixing, pasteurizing, packaging, cooling, and shipping. The AR is to increase the production capacity of the second container filling line. Savings are mainly attributable to reduced labor costs. Concomitant waste reduction is attributable to reduced overflow with the improved product metering system. This AR was implemented on April 1, 1997.

Plant 385. The principal products of this Westminster, CO manufacturing facility are aerial manlifts. Raw materials include angle iron, steel sheets and plates, steel rods and tubes, fiberglass, and various mechanical, electrical, and hydraulic components. The process involves machining, cutting, punching, welding, assembly, plating, painting, and testing. The AR is to reduce the number of color changes in the painting line. Savings result from a combination of reduced labor costs and reduced waste paint and solvent disposal costs.

Plant 386. The principal products of this Englewood, CO manufacturing facility are kitchen and bathroom counter tops. Raw materials include particle board, laminated plastic sheets, and adhesives. The process involves cutting and machining, gluing, painting, assembly, and testing.

The AR is to install a conveyor between two mechanized work areas. Use of the conveyor will reduce generation of off-specification counter tops. Savings result from reduced expenditures for raw materials and waste disposal.

Plant 387. The principal products of this Greeley, CO manufacturing facility are cooked dried beans. Raw materials consist of dried raw beans, corn oil, spices, and water. The process entails washing, soaking, cooking, drying, and packaging. The AR is to reduce the cooker venting and purging lines. This will reduce generation of off-specification products. Savings result from reduced expenditures for raw materials, processing, and waste management. This AR was implemented on February 1, 1998.

Plant 388. Principal products for this Boulder, CO manufacturing facility are flow sensors and flow meters. Raw materials include prefabricated stainless steel probes, stainless steel stock, metal housings, electronic components, and fittings. The process includes machining, welding, polishing, assembly, testing, and packaging. The AR is to install a chiller for water used in the testing area. Implementation will prevent wide swings in water temperature and thus improve control of testing conditions. Moreover, implementation will reduce generation of waste water. This AR was implemented on December 1, 1998.

Plant 389. This Longmont, CO facility produces injection molded plastic parts and molds. Raw materials include plastic pellets and steel blocks. The molding process entails drying the pellets, loading pellets, molding, cooling, assembly, and packaging. CNC and EDM technologies are used to machine molds and tooling. The AR is to install runnerless molding equipment that can reduce generation of waste raw material. Cost savings result from reduced expenditures for raw materials and waste management. The runnerless system can have its greatest impact for plastics that cannot be ground and reused, such as clear polycarbonate.

Plant 392. Personal respiratory equipment is manufactured at this Westminster, CO facility. Raw materials include injection molded plastic parts, wires, housings, connectors, electronic and mechanical assemblies, and molecular sieve adsorbents. Manufacturing operations include wave soldering, fastening, assembly, adsorbent regeneration, testing, and packaging. The AR is to implement a bar code reader and electronic traveler for various parts and assemblies. Implementation can reduce costs for labor needed to correct improperly coded and installed components. The number of rejected assemblies and components that become waste can thus be reduced. This AR was implemented on June 1, 1998.

Details of the computed values reported in Table 1 are as follows: Implementation of this AR can produce annual labor savings of \$3,260/yr (rounded value), assuming time savings of 8 hours per month and an hourly labor cost of \$34/hr, including overhead. This is the current labor cost of producing the 72 units per year that either require reworking or become waste. Implementation also provides a productivity increase of one additional complete unit per month, each of which sells for \$5,000/unit and costs \$2,800/unit to manufacture. The profit increase is thus \$26,400/yr, and total savings associated with installing an electronic bar code reader are \$29,660/yr. Waste reduction savings are 11% of total savings.

Plant 393. This Fort Collins, CO facility produces electronic controls for gas-fueled appliances. Raw materials include prefabricated circuit boards, electronic components, wiring, connectors,

housings, and conformal coatings and solvents. Manufacturing operations include assembly, wave soldering, coating, testing, and packaging. The AR is to increase the capacity of the plant to meet market demand. Implementation can thus increase throughput⁸. A combination of improvements is required, including modifying the conformal coating process, upgrading the virtual testing station, increasing production hours on the automatic insertion machines, and increasing the rate at which parts move through the wave solder machine. Increasing the number of employees at the manual inspection area is also recommended. Waste reduction is associated with conversion to a silicone conformal coating. This AR was implemented on January 1, 1998.

Plant 394. Aerospace hardware is manufactured at this Denver facility. Raw materials include metal castings, metal tubes, sheet metal, metal rods, fasteners, housings, plating chemicals, solvents, and cutting coolants. The AR is to increase the number of employees engaged in non-destructive testing (NDT). Expanding NDT functions can relieve a current production bottleneck and also reduce generation of scrap. Earlier detection of flaws increases opportunities for reworking off-specification parts.

Plant 414. This Loveland, CO facility produces Christian educational materials, including books, magazines, videos, and teaching kits. Raw materials include cardboard boxes, metal cans, printed materials, plastic components, and supplemental materials. Operations include sorting, assembly, packaging, warehousing, and shipping. The AR is to replace the plastic shrink wrap used on each boxed or canned product. Instead, use tape to seal boxed and canned kits. Savings result from reduced expenditures for shrink wrap and waste management.

A second AR for this facility is to reduce current batch sizes. A just-in-time (JIT) system can reduce inventories of components and finished products. A JIT operating system can also reduce quantities of outdated kits in the warehouse areas. Although some components from outdated kits can be salvaged for reuse, other components and the containers cannot be reused.

Plant 416. This Albuquerque, NM facility produces components for electronic communication equipment. Raw materials include printed circuit boards, wiring assemblies, integrated circuits, housings, and miscellaneous electronic components. Manufacturing operations include surface mounting, wave soldering, infrared curing, welding, etching, assembly, and testing. The AR is to reduce the number of defective components caused by static discharges. Such discharges can be reduced by increasing and controlling the humidity. Benefits include increased yield and reduced generation of scrap.

Plant 422. Pharmaceutical products are manufactured at this Fort Collins, CO facility. Raw materials include pharmaceutical agents, solvents, polymer, and packaging materials. Manufacturing operations include batch mixing, filling dispensers, and packaging. The AR is to reduce the size of the filter used after each batch is mixed. Benefits include improved yield and reduced expenditures for filter material.

Plant 430. This Boulder, CO facility manufactures pharmaceutical and herbal extracts. Raw materials include plant components such as leaves and bark, and solvents. The manufacturing process includes solvent extraction, chromatographic separation, drying, and equipment cleaning. The AR is to install spray drying equipment to reduce product loss during drying operations. Benefits include improved yield and reduced operating costs.

CONCLUSIONS

For the 14 productivity improvement ARs listed in Table 1, the total cost savings are \$1,484,310/year. For these ARs, cost savings attributable to concomitant pollution prevention benefits are \$502,140/year. In other words, 34% of the annual cost savings for these productivity improvement recommendations is attributable to pollution prevention. Waste reductions include nonhazardous liquids, hazardous liquids, solids, and air emissions. The results thus demonstrate that improving productivity in manufacturing can provide concomitant, cost-effective pollution prevention benefits.

It is not surprising that reducing generation of waste raw materials can improve productivity. Examples include ARs recommended for plants 381, 386, 387, 389, 422, and 430. In general, there is synergism between prevention of raw material waste and yield improvement. Also beneficial is improvement in parts tracking, inspection, and testing protocols. Examples include ARs recommended for plants 388, 392, 393, and 394. In these cases, the improvements provide for earlier and more cost-effective detection of defects. An unexpected result is the waste-reducing benefit of batch size reduction. Reducing batch sizes for plant 414 can reduce inventories of raw materials and finished products. This process improvement can reduce costs⁸ and also prevent formation of outdated products.

For the plants included in Table 1, the single, largest dollar savings for pollution prevention is attributable to improvement in the nondestructive testing protocol at plant 394. The single, largest dollar savings for productivity improvement is attributable to installation of spray drying equipment at plant 430. Follow-up implementation surveys have been completed for 1996-1997 program year assessments. These surveys demonstrate that approximately 50% of the ARs reported in Table 1 for this period were implemented.

The industrial assessments described herein also provide educational benefits for the participating CSU engineering students. These students obtain valuable experience in recognizing and evaluating practical, cost-effective ARs at actual manufacturing facilities. This experience complements traditional classroom and laboratory learning experiences.

REFERENCES

1. Edwards, H. W.; Kostrzewa, M. F. "Pollution Prevention at Small Manufacturing Plants," Paper No. 93-WA-87.07, 86th Annual Meeting & Exhibition, Air & Waste Management Association, 1993.
2. Edwards, H. W.; Kostrzewa, M. F. "Combining Pollution Prevention and Energy Conservation at Small Manufacturing Plants," Paper No. 94-RP137.04, 87th Annual Meeting & Exhibition, Air & Waste Management Association, 1994.
3. Edwards, H. W.; Kostrzewa, M. F. "Combined Pollution Prevention Assessments," Paper No. 98-MP13B.02, 91st Annual Meeting and Exhibition, Air & Waste Management Association, 1998.
4. National Renewable Energy Laboratory, *DSM Pocket Guidebook. Volume 4: Industrial Technologies*; prepared for U.S. Department of Energy and Western Area Power Administration, 1994.

5. Higgins, T. E. *Pollution Prevention Handbook*; CRC Lewis: Boca Raton, 1995.
6. Freeman, H. M. *Industrial Pollution Prevention Handbook*; McGraw-Hill: New York, 1995.
7. Muller, M. R.; Briggs, D.; Kasten, D.; Comer, K.; Simek, M.; Tierney, C.; Garcia, G. *Industrial Productivity Training Manual*, Rutgers, the State University of New Jersey: New Brunswick, 1996.
8. Goldratt, E. M.; Cox, J. *The Goal*; Second Revised Edition, North River Press: Great Barrington, MA, 1992.

Table 1. Pollution prevention benefits associated with productivity improvement recommendations for 1996-1998 industrial assessments.

Plant ID	SIC	Principal Products	Productivity Improvement Description	Annual Waste Reduction	Annual Waste Savings	Total Annual Savings	Waste Savings Percentage	Implementation
381	2024	ice cream and yogurt	increase capacity of second filling line	7,225 gal/yr non-haz waste	\$7,830	\$75,250	10%	4/1/97
385	3531	aerial manlifts	reduce color changes	360 gal/yr haz liquid waste	\$4,370	\$8,650	51%	No
386	2434	kitchen and bath countertops	install conveyor between the pinch roller and roll-o-matic	18,270 lb/yr non-haz solid waste	\$7,020	\$9,540	74%	No
387	2034	dried bean products	reduct venting/purging lines on cookers	195,000 gal/yr sludge 62,400 lb waste bean	\$30,000	\$45,600	66%	2/1/98
388	3824	flow sensors	install chiller to improve testing	124,800 gal/yr wastewater	\$6,030	\$6,030	100%	12/1/98
389	3089	injection molded plastic parts	purchase runnerless molding system	7,000 lb/yr non-haz solid waste	\$11,810	\$11,810	100%	No
392	3842	personal respiratory equipment	purchase bar code reader for parts tracking	72 units/yr	\$3,260	\$29,660	11%	6/1/99
393	3822	electronic controls for gas appliances	increase capacity of plant to meet market demand	330 gal/yr haz liq waste 2,400 lb/yr solvent emissions	\$9,120	\$122,340	7%	1/1/98
394	3728	aerospace hardware	increase number of employees at NDT	scrap parts ~3.70% of total scrap	\$330,000	\$330,000	100%	No
414	2731	Christian educational materials	replace packaging material	1,800 lb/yr non-haz solid waste	\$2,560	\$2,560	100%	-

Table 1. Pollution prevention benefits associated with productivity improvement recommendations for 1996-1998 industrial assessments (continued).

414	2731	Christian educational materials	reduce batch sizes	80,000 lb/yr non-haz solid waste	\$19,930	\$89,660	22%	-
416	3663	electronic communication components	reduce number of defect chips	39,000 units/yr	\$68,810	\$68,810	100%	-
422	2834	pharmaceutical products	reduce batch filter size	2 lb/yr	\$430	\$9,500	5%	-
430	2833	pharmaceutical and herbal extracts	install spray drying equipment	235 gal/yr haz liq waste	\$970	\$674,900	0.1%	-