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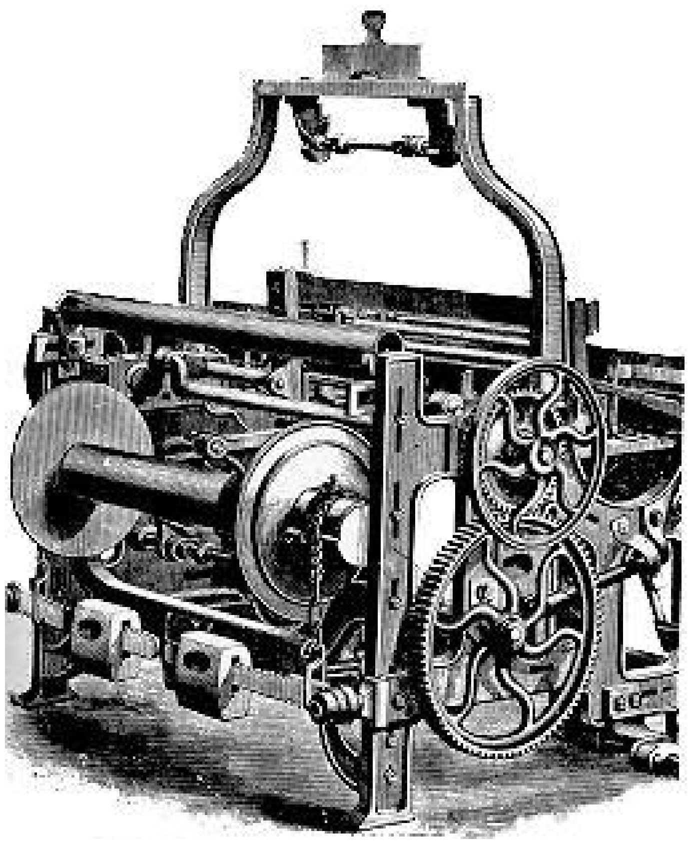

INDUSTRIAL PRODUCTIVITY TRAINING MANUAL

Version 2.0

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CAES
CENTER FOR ADVANCED ENERGY SYSTEMS

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Introduction

Background

As part of the Climatewise program, Professor Muller and other technical staff of the OIPEA have been involved with adding an energy and waste component to the PICOS supplier development program run by General Motors. As part of these activities, the GM people observed an IAC style assessment in New Jersey. Professor Muller then spent a week in Charlotte observing a PICOS assessment. During this information exchange it became clear that IAC assessments could be more effective if additional efforts were put into direct productivity issues. Recognizing that we have had training courses for center directors on energy and waste, it was concluded that an additional course should be assembled on productivity.

Evaluation of the GM PICOS™ Assessment Program

The PICOS program is a long running industrial assessment service provided by GM for their suppliers based carefully on the Toyota Production System. The goal of the program is to improve the productivity of suppliers and pass the savings on to GM, which has a policy of continually paying less for a product each year. They are proud that they never tolerate price increases.

The workshops, as they are called, use a team of normally two Supplier Development Engineers who are in the plant for 3.5 days. These are people with a variety of backgrounds and for the most part are not engineers. They make some suggestions themselves, but rely mostly on working groups of plant personnel to come up with cost saving ideas. Implementation of good ideas is expected to be *immediate*. Layout changes, for example, are often accomplished while the PICOS team is still there.

Until recently, staff in the PICOS program did not concern themselves with waste or energy, but focused entirely on productivity issues. We can learn a great deal from the general approaches they use, but proprietary concerns will prohibit us from adopting any of their practices directly.

Goals and Extent of the training program

We hope to provide some background material, but concentrate on a number of worked examples of various kinds of productivity recommendations. The goal of the training is to provide directors with several tools which they can apply *directly*. Additionally, by showing the large impact of some of these recommendations, it is hoped that director's themselves will be motivated to develop their own novel tools and fixes.

PRODUCTIVITY TOOLBOX

Toolbox Introduction

The Toolbox is intended to supply you with a method of arriving at the necessary metrics which are required to write up and present Assessment Recommendations for Productivity. Usually these can be thought of as the costs or values of those things which go to make up Cost/Piece or Pieces/Person/Hour. Generally the type of productivity AR which can be recommended on a one day visit can be classified as something that Increases Pieces/Person/Hour or Decreases Cost/Piece. In our presentation we further break these categories down to help you identify the major concepts which allow the creation of Assessment Recommendations. We hope you will find them possible to produce during a one day audit and that the manufacturer will find them sufficiently rewarding to implement.

Increases Pieces/Person/Hour
a. Bottleneck Mitigation
b. Defect Reduction
c. Quick Changes
d. Labor Optimization
e. Preventive/Predictive Maintenance

Decreases Cost/Piece
a. Purchasing
b. Floor Layout
c. Inventory
d. Burden/overhead
e. Scheduling

Whether defect reduction increases pieces/person/hour or decreases cost/piece is somewhat arbitrary. Frequently if an action does one it also does the other. The principal metrics which are needed for ARs are:

1. **Labor Costs** - Skilled union, unskilled union
Skilled non-union, unskilled non-union
Also like to know Fringe Cost of Labor.

2. **Cost of Inventory** Carrying Cost
Cost of Raw Material

3. **Cost of Space** - Warehouse
Manufacturing
Office

4. **Cost Per Piece** (Overhead+Labor+Materials)Cost/Piece

5. **Overhead** - Cost of virtually everything besides direct raw material and direct labor. Includes energy and waste.

6. **Profit** - (Sales Price/Piece) minus (Cost/Piece)

At first glance you might conclude that these are proprietary numbers which a manufacturer may be unwilling to tell anyone outside (or even inside the company), but we think we can present an approach which both you and the manufacturer will find acceptable.

FIRST TRY

1. During the initial contact and follow up before the visit get company personnel to provide the numbers needed at the same time they are supplying energy consumption numbers, sales figures, number of employees, and other facts about their manufacturing organization that we have always requested before the performance of an Industrial Assessment. Use the **PRODUCTIVITY METRICS sheet** to make sure nothing is forgotten.

SECOND TRY

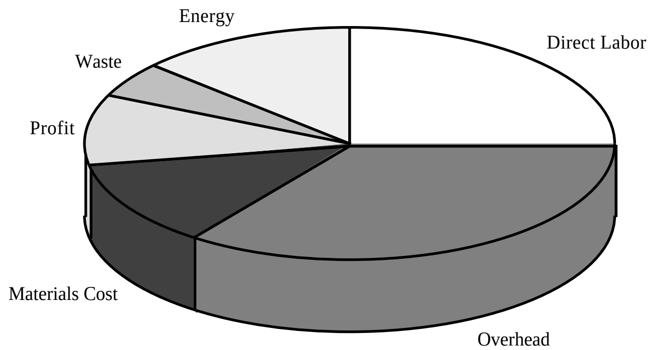
2. If the numbers were not all forthcoming before your arrival try to get company personnel to provide them during the opening interview. Again have the **PRODUCTIVITY METRICS sheet** with you as you ask for the information.

FINAL TRY

3. If the necessary numbers are denied to you during this opening interview then present the **PRODUCTIVITY METRICS sheet** which is prepared before you ever enter the plant. This sheet has blanks for the information desired but contains (in parentheses) assumed values for many of the metrics which should be estimated for your part of the country. Get the plant personnel to commit to the reasonableness of the numbers or if they find your numbers unacceptable to give an alternative value which you can use in your productivity enhancement ARs. This approach allows the manufacturer to keep the information which he deems most private from appearing. It will also allow the IAC to provide Productivity ARs which are reasonable and, even if not exact, will/should motivate the company to action.. The order of magnitude of the numbers should be correct under this approach and should "sell" the idea.

We also recommend that you include these metric values and assumptions in the introductory section of your reports (similar to or along with Plant Background summary) so that all values used to make the productivity calculations are readily apparent to the manufacturer.

Information in this section is used throughout the report when estimating material, labor, or productivity cost savings opportunities. The information was provided by facility personnel or is based on regional averages. An important task early in the assessment process is the estimation of the manufacturer's relative costs of operation. An example is shown in the pie chart below. This is a critical step which will allow your team to focus on those areas which offer the most opportunities. Gathering the information on the **PRODUCTIVITY METRICS sheet** will allow this.



Cost per Part = Gross Sales / # of Pieces

It is probably apparent that there are still some things such as Cost or Value of Inventory which can't be judged without knowing the cost per piece and how many pieces are in inventory, so help from plant personnel will always be needed.

Additional useful information for labor cost and the cost of space is given on the following pages.

PRODUCTIVITY METRICS SHEET

Labor Costs:

Type of Labor	**Actual**	**Assumed**
Production Worker:	________/hr	($19.47/man-hour)
Skilled Technician:	________/hr	($25.96/man-hour)
Engineering (contracted):	________/hr	($100/engineer-hour)
Engineering (in-house):	________/hr	($38.94/man-hour)

(Items above in parentheses indicate total cost to the company, including 35% fringe)

Fringe Rate: ______% (35%)

Raw Material Costs:

Material/Resource	Yearly Usage	Unit Price
Water Treatment		
Water Usage:		/hcf ($2.50/hcf, 1 hcf = 100 ft^3)

Production Information:

Overhead: (includes _____ , _____ , _____ , _____) _____% (100%)

Profit Margin: _____% (10%)

Cost per Piece to Produce: $______/piece

Inventory and Floor space:

Value of Floor space: _______/ft^2/yr ($5.00/$ft^2$/yr)

Inventory Carrying Cost: _____% (15%)

Raw Material Inventory: Quantity = ______ Value = ______

Work-In-Progress Inventory: Quantity = ______ Value = ______

Finished Goods Inventory: Quantity = ______ Value = ______

Table 1: Cost of Labor[1]

Trade	Basic Rate Incl. Fringes		Rate w/ Overhead and Profit	
	Hourly	Daily	Hourly	Daily
Skilled Workers Average (35 Trades)	$24.65	$197.20	$41.10	$328.80
Helpers Average (5 Trades)	$18.60	$148.80	$31.20	$249.60
Foreman Avg., inside ($0.50 over trade)	$25.15	$201.20	$41.95	$335.60
Foreman Avg., outside ($2.00 over trade)	$26.65	$213.20	$44.45	$355.60
Common Building Laborers	$19.00	$152.00	$32.00	$256.00
Asbestos Workers	$26.90	$215.20	$44.65	$357.20
Boilermakers	$28.05	$224.40	$44.65	$357.20
Bricklayers	$24.55	$196.40	$40.75	$326.00
Bricklayer Helpers	$19.50	$156.00	$32.35	$258.80
Carpenters	$23.80	$190.40	$40.10	$320.80
Cement Finishers	$23.25	$186.00	$37.15	$297.20
Electricians	$27.50	$220.00	$42.75	$342.00
Equipment Operators, Crane or Shovel	$25.40	$203.20	$40.75	$326.00
Equipment Operators, Medium Equip.	$24.35	$194.80	$39.05	$312.40
Equipment Operators, Light Equip.	$23.40	$187.20	$37.55	$300.40
Equipment Operators, Oilers	$20.75	$166.00	$33.30	$266.40
Equipment Operators, Master Mechanics	$25.95	$207.60	$41.60	$332.80
Glaziers	$23.80	$180.40	$38.85	$310.80
Lathers	$23.70	$189.60	$38.20	$305.60
Marble Setters	$24.65	$197.20	$40.90	$327.20
Millwrights	$25.10	$200.80	$40.25	$322.00
Painters, Ordinary	$22.20	$177.60	$36.30	$290.40
Painters, Structural Steel	$23.10	$184.80	$48.20	$385.60
Paper Hangers	$22.40	$179.20	$36.65	$293.20
Pile Drivers	$23.95	$191.60	$42.95	$343.60
Plasterers	$23.30	$186.40	$38.30	$306.40
Plaster Helpers	$19.75	$158.00	$32.45	$259.60
Plumbers	$28.30	$226.40	$44.55	$356.40
Rodmen (Reinforcing)	$26.40	$211.20	$48.60	$388.80
Roofers, Composition	$21.55	$172.40	$39.20	$313.60
Roofers, Tile and Slate	$21.60	$172.80	$39.30	$314.40
Roofer Helpers, Composition	$15.35	$122.80	$27.95	$223.60
Sheet Metal Workers	$27.35	$218.80	$44.05	$352.40
Sprinkler Installers	$30.35	$242.80	$47.85	$382.80
Steamfitters or Pipe Fitters	$28.30	$226.40	$44.55	$356.40
Stone Masons	$24.70	$197.60	$41.00	$328.00
Structural Steel Workers	$26.50	$212.00	$50.50	$404.00
Tile Layers (Floor)	$24.00	$192.00	$37.95	$303.60
Tile Layer Helpers	$19.25	$154.00	$30.45	$243.60
Truck Drivers, Light	$19.40	$155.20	$31.85	$254.80
Truck Drivers, Heavy	$19.70	$157.60	$32.35	$258.80
Welders, Structural Steel	$26.50	$212.00	$50.50	$404.00
Wrecking	$19.00	$152.00	$36.15	$289.20

[1] *Means Repair & Remodeling Cost Data,* R.S. Means Co. Inc., 15th Edition.

Space Optimization

The value of space is an important resource that is sometimes overlooked in manufacturing facilities visited by the IACs. Some companies who own the space they occupy do not view it as having significant value. A result is that the operations are expanded into all available space in an unoptimized manner. Potentially valuable floor space is used for equipment graveyards or storage of outdated products, unused buildings are allowed to deteriorate and diminish in value, and dilapidated buildings are left standing (resulting in higher tax and insurance costs).

Four basic options can be explored in an effort to improve the return from presently unoptimized space:

- Optimize existing floor layout and:
  - lease excess space to outside interests (see AR#24)
  - reduce leased space requirements (see AR#21)
  - avoid new construction for future expansions
- Demolish dilapidated space to reduce tax and insurance expenses (see AR#22)

Examples of cost savings calculations for the above opportunities are included in this manual in the noted AR write-ups. Tables 2 and 3 can be used to estimate cost benefits for space related opportunities. In addition to the quantities listed in the tables, other possible savings opportunities which should be considered include: reduced or avoided operating costs for the space (lighting, HVAC, etc.), and reduced transportation costs (if traveling between two sites can be eliminated by consolidating operations).

Table 2: Value of Space[2]

Location	Size	Sale Prices ($/ft²) Central City	Sale Prices ($/ft²) Suburban	Lease Prices ($/ft²/yr) Central City	Lease Prices ($/ft²/yr) Suburban	Vacancy Indicators
Atlanta	0 to 20,000 sf	$22.00-27.00	$37.00-52.00	$2.75-4.25	$3.25-5.50	Moderate shortage
	20,000-60,000 sf	$17.00-22.00	$21.00-32.00	$2.25-3.50	$2.50-4.50	Moderate shortage
	60,000 sf and up	$14.00-18.00	$17.00-21.00	$2.00-2.50	$2.25-3.75	Moderate shortage
Boston	0 to 20,000 sf	n/a	$40.00-45.00	n/a	$4.25-4.50	Moderate shortage
	20,000-60,000 sf	n/a	$32.00-35.00	n/a	$3.75-4.00	Balanced market
	60,000 sf and up	n/a	$25.00-30.00	n/a	$3.50-3.75	Substantial shortage
Chicago	0 to 20,000 sf	$27.00-34.00	$42.00-55.00	$3.50-4.00	$4.00-5.50	Moderate shortage
	20,000-60,000 sf	$21.00-24.25	$36.00-38.25	$2.90-3.00	$3.80-3.90	Moderate shortage
	60,000 sf and up	$12.50-17.00	$23.00-29.00	$2.25-2.60	$3.60-3.65	Substantial shortage
Dallas	0 to 20,000 sf	n/a	$33.00-37.50	n/a	$3.95-4.50	Moderate shortage
	20,000-60,000 sf	n/a	$27.00-28.00	n/a	$3.60-3.75	Moderate shortage
	60,000 sf and up	n/a	$25.50-26.00	n/a	$3.50-3.60	Substantial shortage
Denver	0 to 20,000 sf	$30.00-35.00	$30.00-37.00	$3.50-4.00	$3.75-4.00	Substantial shortage
	20,000-60,000 sf	$25.00-26.00	$26.00-27.00	$3.25-3.50	$3.25-3.50	Moderate shortage
	60,000 sf and up	$22.00-23.00	$23.00-24.00	$2.90-3.00	$2.90-3.00	Moderate shortage
Los Angeles	0 to 20,000 sf	$57.00-63.00	$62.00-80.00	$5.50-6.00	$5.52-7.00	Moderate shortage
	20,000-60,000 sf	$48.00-53.00	$58.00-60.00	$4.50-4.80	$5.16-5.40	Moderate shortage
	60,000 sf and up	$39.00-41.00	$39.00-48.00	$4.30-4.40	$4.20-4.40	Moderate shortage
New York	0 to 20,000 sf	$30.00-50.00	$45.00-60.00	$4.00-7.00	$4.75-6.25	Moderate shortage
	20,000-60,000 sf	$25.00-40.00	$35.00-50.00	$3.25-5.00	$4.25-5.50	Balanced market
	60,000 sf and up	$20.00-35.00	$25.00-43.00	$3.00-4.25	$3.75-4.50	Moderate oversupply
Orlando	0 to 20,000 sf	$35.00-40.00	$35.00-40.00	$3.75-4.00	$3.75-4.00	Substantial shortage
	20,000-60,000 sf	$25.00-30.00	$25.00-30.00	$3.50-3.60	$3.50-3.60	Substantial shortage
	60,000 sf and up	$20.00-21.00	$20.00-21.00	$3.15-3.25	$3.15-3.25	Substantial shortage
Phoenix	0 to 20,000 sf	$30.00-50.00	n/a	$3.75-6.50	n/a	Moderate shortage
	20,000-60,000 sf	$23.00-35.00	n/a	$2.75-4.00	n/a	Moderate shortage
	60,000 sf and up	$20.00-28.00	n/a	$2.75-3.25	n/a	Balanced market
Washington D.C.	0 to 20,000 sf	$35.00-60.00	$30.00-70.00	$2.00-4.00	$3.00-9.00	Balanced market
	20,000-60,000 sf	$30.00-45.00	$30.00-45.00	$2.00-4.00	$3.00-6.50	Moderate shortage
	60,000 sf and up	$25.00-35.00	$20.00-40.00	$2.00-3.75	$3.00-6.50	Moderate shortage

[2] *1996 Comparative Statistics of Industrial and Office Real Estate Markets*, Society of Industrial and Office REALTORS and Laudauer Associates Inc., phone(202) 737-1150

Table 3: Cost of Maintaining Space[3]

($/ft^2/yr)

Location	Region	Real Estate Taxes	Insurance (Fire and Liability)	Structural & Roof Maint.	Common Area Maint.	Total Cost
Atlanta	Central City	$0.48	$0.07	$0.15	$0.23	$0.93
	Suburban	$0.33	$0.07	$0.15	$0.23	$0.78
Boston	Central City	$1.75	$0.10	$0.14	$0.61	$2.60
	Suburban	$0.75	$0.08	$0.12	$0.50	$1.45
Chicago	Central City	$1.35	$0.08	$0.15	$0.35	$1.93
	Suburban	$1.41	$0.08	$0.15	$0.35	$1.99
Dallas	Central City	n/a	n/a	n/a	n/a	n/a
	Suburban	$0.55	$0.05	$0.05	$0.20	$0.85
Denver	Central City	$0.50	$0.10	$0.03	$0.25	$0.88
	Suburban	$0.55	$0.10	$0.03	$0.35	$1.03
Los Angeles	Central City	$0.60	$0.25	$0.07	$1.15	$2.07
	Suburban	$0.84	$0.12	$0.08	$0.36	$1.40
New York	Central City	$1.50	$0.21	$0.20	$0.25	$2.16
	Suburban	$3.00	$0.30	$0.20	$0.20	$3.70
Orlando	Central City	$0.50	$0.10	$0.10	$0.15	$0.85
	Suburban	$0.40	$0.10	$0.10	$0.15	$0.75
Phoenix	Central City	$1.20	$0.20	$0.12	$0.35	$1.87
	Suburban	$0.80	$0.15	$0.10	$0.10	$1.15
Washington, D.C.	Central City	$1.10	$0.10	$0.30	$0.25	$1.75
	Suburban	$0.60	$0.10	$0.25	$0.35	$1.30

[3]*1996 Comparative Statistics of Industrial and Office Real Estate Markets*, Society of Industrial and Office REALTORS and Laudauer Associates Inc., phone(202) 737-1150

Productivity Questions

One more useful component of the Toolbox is a set of questions which can be asked (where they are applicable) to determine the likelihood of producing particular Productivity Enhancement ARs. The question list should accompany you to the plant and be used as reminders both in the sense of what to look for and what information to seek to complete an AR.

General

- If you can make more product, can you sell it?
- Do you ever run overtime to meet production goals or compensate for defective batches? (related costs)
- Do you have any plans for expansion?
- Average value and quantity of each type of inventory (raw materials, purchased components, in-process products, finished goods)?
- What is the **lead time** of the product/process? ("product" could also be object for the next operation)

Increasing Pieces/Person/Hour

Bottleneck Mitigation

- How has the operation changed over time? (product, equipment, procedure)
- What is the optimal rate of this process/procedure?
- Why is this process/procedure the bottleneck?

Defect Reduction

- What percentage of products are inspected?
- In what stages/locations of the process do the most rejects (or clean-up) occur?
- What are the most common types of defects?
- How much does each type of defect or clean-up cost per year (labor, material, lost production time, extra equipment or processes--i.e., regrind--etc.)?
- What causes each type of defect?
- Are in-process and/or finished goods inventories built up due to potential defect problems in the production process (to ensure that the customer gets the products on time)? If so, what percent of existing inventory is considered excess? What is the value and quantity of overstocked goods in inventory?
- Do standardized procedures exist for the processes where defects most often occur?
- Does one machine operator produce significantly fewer defects than others?

(If so, that operator's expertise should be used to develop *standardized operating procedures* for training less effective personnel.)

Quick Changes

- How much time does it typically take to setup XYZ machine?
- Do you need to do any adjustment to the machine?
- Do you need to use any gauges or other measurement devices to adjust the machine?
- How many different tools do you need for the setup of XYZ machine?
- Can the setup be performed by the operator or is a specialist needed?
- Do you need a period of time when you run pieces which are used just to get rid of initial problems?
- Do you need to idle the machine for a while to bring it up to speed or to a proper temperature?
- How do you clamp pieces to the machine? Do you use the same fasteners in all the cases?

Labor Optimization

- What percentage of the cost of production is labor? Direct / Indirect?
- What is the pay scale?
- What is the pay rate premium for late shifts?
- Do you run overtime due to the lack of skilled personnel?
- What is the cost of overtime?
- Is this a union shop?
- Do you ever work overtime to meet production goals? Why?
- Are you lacking labor in a particular skill?
- Are you keeping up with preventative maintenance?

Preventive/Predictive Maintenance

- Are there shutdowns of the production process?
- Are these shutdowns unscheduled?
- What are the duration and frequencies of these shutdowns?
- What are the reasons for the unscheduled stoppages?
- What is the cost/hour of production downtime?

Decreasing Cost/Piece

Purchasing

- How often are raw material deliveries received?
- Are raw materials delivered based on the supplier’s convenience or planned needs at your facility?
- How long do raw materials or purchased components remain at your facility before they are used?

Floor Layout

- Do you rent, lease or own the facility (or another)? (cost $/ft^2/yr)
- How do you account for the cost (or value) of space? (cost $/ft^2/yr)
- How many different products do you make?

Inventory

- How much floor space is used for each type of inventory? What is the assigned value (if any) of that floor space ($/ft^2/yr)?
- If it is determined that there is excess inventory of some type, why is that excess inventory needed?

Burden

- Is new construction planned? How much and why?
- Do you manufacture or store goods in any other building nearby?
- Would you be able or want to have a rent paying tenant occupying any portion of your building complex?
- Do you place any value on equipment or facilities which seem to be "junk"? (If not, it may be economical to scrap junk and use the freed space, or demolish dilapidated facilities)

Scheduling

- Do you have operations where different sequencing of jobs would eliminate some non-value added operations, such as cleaning, setups etc.? If the answer is YES, identify these operations. What would be the right sequencing to eliminate these operations?
- Do you have large size batch operations?
- What is the company's operating schedule (including vacations, number of shifts, overtime)?
- Ask questions about ratio indicators.

First ratio is production lead time to actual value added time to manufacture a part.
Second ratio is speed of the process (rate of production) to sales rate.
Third ratio is number of pieces to number of work stations or operators in a line segment.

- Identify processes or operations which you feel are more costly than they should be.
- Do you use push or pull system in your manufacturing process?
- If overhead cost is too high, why?
- Do you experience multiple handling or multiple inspection?

CONCEPTS FOR PRODUCTIVITY ENHANCEMENT

PART I

Increasing Pieces/Person/Hour

Quick Changes

Introduction

The preparation of any machine to perform a specific task or operation is called setup time. It is possible to divide the setup tasks into two groups: internal and external. **Internal setup** is the time used for setup while *the process cannot continue*. Since internal set-up tasks require a break in production, it is critical to minimize their duration. **External setup** time is the time used to prepare machines and tooling for the next operation *without stopping the process*. Since production continues making useful goods in the meantime, it is not as essential as with the internal setups to cut down the time required for the external setups.

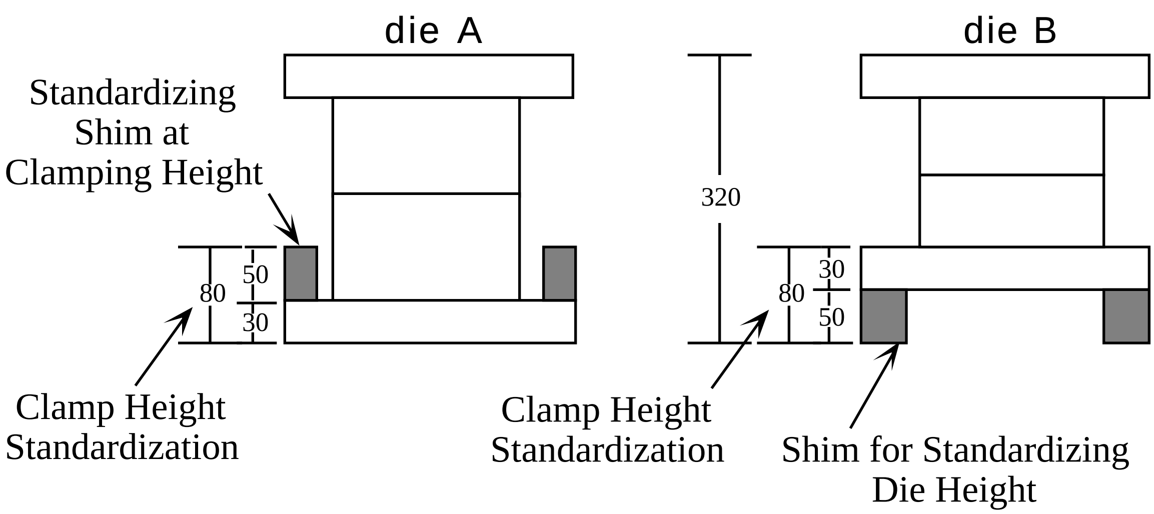
In order to determine how to shift internal setups into external setups, one must study the shop floor conditions in great detail. Even during a one day assessment it is possible to discover great opportunities for time savings during setups, although the estimated reductions might be less than if an extended investigation was conducted. Changing from internal to external setup usually cuts time by 30% to 50%. The first step is to identify internal and external setup tasks. Informal discussions with the workers and observation of the process often suffices. The second step is to convert as many internal tasks as possible into external. The third step involves the streamlining of all setups, thus cutting their time. From the previous statements it is obvious that shortening of the internal setup time has much higher priority. One point should be brought to attention. Keeping setup changes out of the hands of the machine operators merely creates a class of setup experts. Operators must be involved--external setup does not mean a different location or different people.

EXAMPLES OF HIGHER EFFICIENCY

Preheating new dies for molding operations can be used as one example. Storage areas could use waste heat from the molding operation and thus eliminate the necessity of running the cold press and producing unwanted parts which have to be reground and processed again later. (Of course preheating can also be achieved using a source of heat other than waste heat. Even additional heaters might be justified if the energy cost for preheating the molds is lower than the cost of imperfect runs).

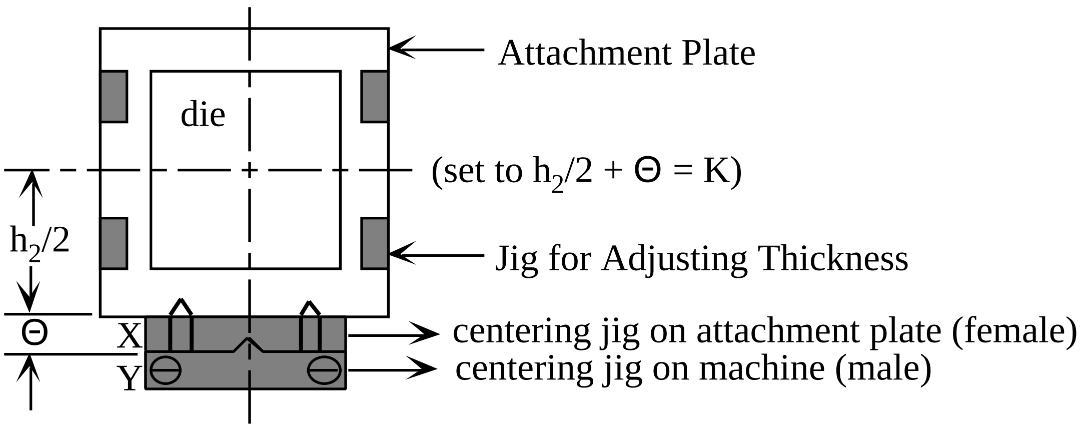
Vacuum molding needs an almost complete vacuum. To achieve that using a vacuum pump takes quite some time. A quicker method of creating the vacuum in the mold is to attach a cylinder to the mold using tubing with a valve. The volume of the cylinder should be about 1000 times that of the mold cavity. During the molding operation vacuumize the tank. Then, after preparing the mold, the valve is opened and the air from the mold will rush into the cylinder. The process is finished with the vacuum pump to achieve complete vacuum, but this time the operation will take fraction of the original time.

Another example could be standardizing the height of die. If one is higher than the other, welding of supporting legs can eliminate press shut height adjustment and enables the operator to use the same length bolts for clamping. The major benefit is the same shut height of the press, though. The adjustment of the height is tedious and time consuming and very critical for the proper operation of the press. Use of the same length bolts is a bonus.



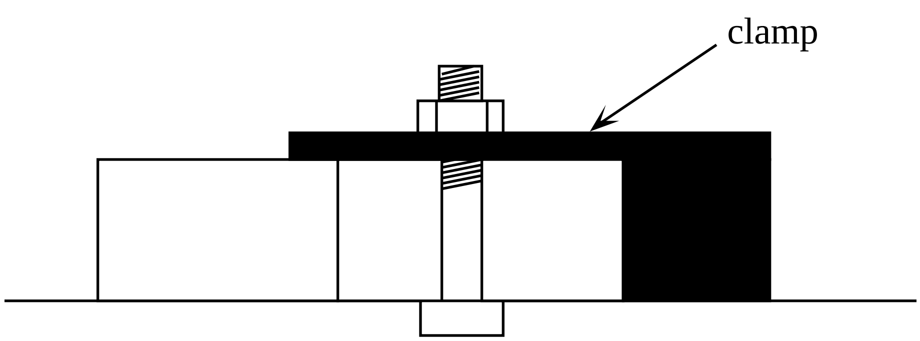
Die Height Standardization

Positioning of a jig on a table by trial and error adjustment can be virtually eliminated by machining center holes and corresponding pins. Also, same size bolts should be used for all dies, thus the operator doesn't have to change tools.

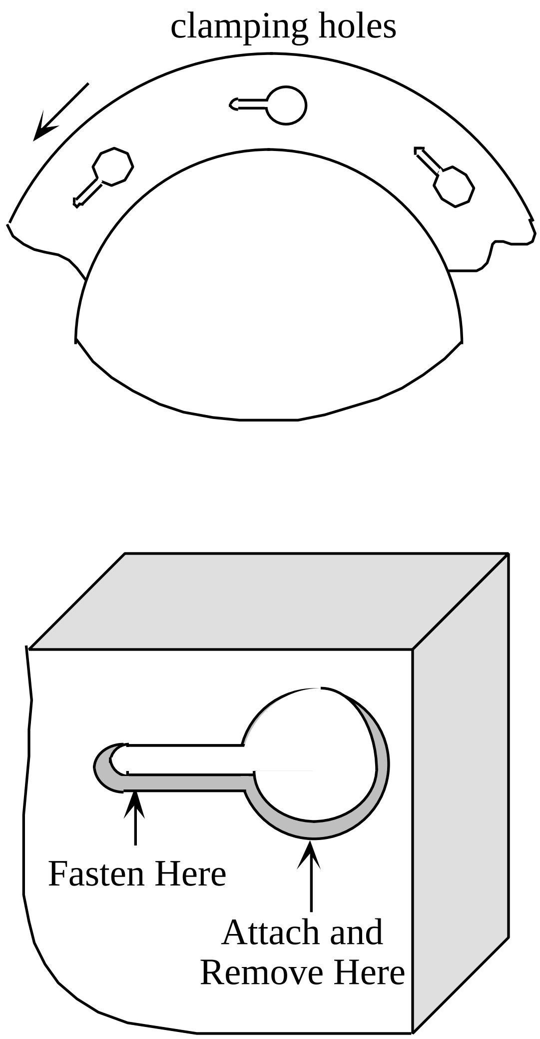


Centering Jigs

One-turn clamping is a way to fasten and unfasten a piece using a single turn. One should not be required to turn the nut all the way out of the thread of the screw, especially getting it through a length of a bolt that is too long and doesn't help in any way in attaching. Use of U-shaped washers could also be implemented. Pear shaped holes for fasteners are another option.



The Clamp Method



Pear-Shaped Holes for Clamping by Turning

Other great delays in production are caused not by inspection or transportation, but by time spent waiting for the processing of one lot to be completed before another lot can be processed. If the waiting periods could be eliminated, production time could be cut. (Based on available data, common reductions are as much as two fifths.) This can be accomplished by standardizing both processing quantities and processing times.

Standardizing processing quantities can be achieved fairly easily, the real problem lies in standardizing processing times. This is because different machines perform various operations and do not take the same times. The capacities of machines vary as well. In some cases the disparity among machines cannot be eliminated. Then the goal should be at least not to produce more than necessary. In other words, the highest output machine should not automatically be the targeted pace (meaning that there normally would be an effort to bring the capacity of slow machines up by parallel processing or other productivity improvements), but the pace is set based on actual needs. The result could be that the fast machine has to wait. The goal is not to overproduce because if something goes wrong all pieces in stock (or manufactured in the previous operation and waiting for the next machine) are wasted. The quantities produced should be the quantities needed. It is important to bear in mind, however, that while machines can be idle, workers must not be because the cost of manpower is generally far higher than the cost of amortizing machines.

The major difficulty in the production of relatively small quantity lots of any product is either the number of setup operations or the length of time it takes to perform them. However, frequent setups are necessary to produce a great variety products. Even if the number of setup operations cannot be reduced, the time involved can be. When demand calls for high diversity and low volume, one remedy is to build up inventory. If, after objective evaluation, it is found that inventory is excessive and setup times rather long, the reduction of a setup time should enable the reduction of inventory.

Principles

- Adjustment cannot depend on feeling or experience
- Functional clamps should be used over screws
- If screws are necessary, design them in such a way that one turn will fasten and unfasten the fixture
- Dovetail connectors, pins, cams, wedges should be used
- Intermediary jigs should be used, that is external setup application
- Movements should be combined or linked together
- Parallel operations should be conducted
- Setups should produce defect free products from the very beginning of the run
- Quick connect and disconnect
- Centering adjustments should not have to be made, it should be automatic when part are pressed together (using pins, etc.)

Questions to Ask

The auditor should always ask questions pertaining to setup times and practices. Asking how much time setups take is an obvious one. In some cases the answers given will immediately alert the auditor and call for his attention. There is no absolute value for a proper setup time--an engineering judgment must be used. The auditor should ask questions which will give him answers as to whether the practices listed in the PRINCIPLES paragraph are used. If not, a great opportunity may present itself at once.

- How much time does it typically take to setup XYZ machine?
- Do you need to do any adjustment to the machine?
- Do you need to use any gauges or other measurement devices to adjust the machine?
- How many different tools do you need for the setup of XYZ machine?
- Can the setup be performed by the operator or a specialist is need?
- Do you need a period of time when you run pieces which are used just to get rid of initial problems?
- Do you need to idle the machine for a while to bring it up to speed or to a proper temperature?
- How do you clamp pieces to the machine? Do you use the same fasteners in all the cases?

Symptoms/Indicators

One of the most revealing indicators is excessive inventory. Inventory build-up is one definite consequence of long setup times (among possible other reasons). Long lead times indicate large lot sizes and the reason for large lot sizes is most likely long setup times. If during the plant tour one notices idle machines, a possible reason to consider is that the machine is waiting for a trained personnel to do the setup. Of course, there could be a variety of reasons for an idle machine.

Related ARs

Two ARs are included under this category. However, it seems that the pictures and concepts are at least as helpful as the case studies.

- DECREASE CHANGE OF DIES & START-UP TIMES
- USE FIXTURES TO REDUCE LATHE SET-UP TIMES
- INSTALL A ROTATING NOZZLE CAROUSEL TO REDUCE SET-UP TIMES
- EMPLOY MODULAR JIGS TO REDUCE PROCESS SET-UP TIMES

Assessment Recommendation No. 1
Decrease Die Change-Out & Start-Up Times

Assessment Recommendation Summary

Estimated Cost Savings = $1,820,000/ year

Estimated Implementation Cost = $3,040,000

Simple Payback Period = 1.7 years (about 20 months)

General

Two major difficulties in the production of relatively small quantity lots of any product are: i) the number of production line changes ("set-ups") required, and ii) the length of time it takes to perform each set-up. Frequent set-ups are necessary to produce a great variety of different products; however, long set-up times are not always necessary and should be avoided--*especially* when set-ups must occur frequently.

The setup procedure can be divided into two operations:

internal setup -- operations which can be performed only when the machine is shut down (or at least not producing useful products)

external setup -- operations which can be performed while the machine is running

The first step to reducing set-up times should be to shift as many operations as possible into the external set-up mode. While this may not reduce the total time spent performing and preparing for the set-up, it WILL reduce the amount of time that the production equipment is off-line. For example, it is a common mistake for a technician to waste valuable time by retrieving tools after the production line has been shut down. A solution to this problem is to deliver all needed tools to the machine PRIOR to shut down. Further, the tools should be organized so the technician knows exactly where each tool is located and no time is wasted searching for misplaced tools.

Documented results across a wide variety of industries indicate that set-up times are commonly reduced by as much as 95% once reducing set-up times is identified as a priority and quick-change strategies are implemented.[4]

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4 Shigeo Shingo, "A Revolution in Manufacturing: The SMED System", Productivity Press, 1985, p. 113

Existing Practice and Observation

The following description is based on our conversations with experienced staff and not actual observation of a procedure because during our visit a change of dies on the production line was not performed.

The set-up team, consisting of 8 specialized technicians, brings in new dies and mounts them into the individual molding stations. Next, the timing of the piston pushing the gob out of the fore-hearth is changed, the shoots leading to the individual dies are replaced, and the intervals in between the shears' cuts are synchronized to produce the proper sized gobs. These procedures typically take anywhere from 1 to 4 hours, depending on whether just the molds need to be changed or whether the process also needs to be changed. Most of these operations are presently carried out sequentially.

The second stage of the set-up process involves the fine tuning of the glass temperatures, cooling air flows, mechanical timings, and mold alignments. This second stage of the set-up procedure, referred to as "start-up," may take from 4 hours to 3 days. Since minimal written standardized procedures presently exist, each technician goes about these adjustments in his own way and experience plays a large role in the speed of the adjustment process. Production personnel stated that there are "many different paths to the same point," meaning that each technician may use a different path but they are all experienced enough to eventually obtain the desired results. The average set-up time was said to be about 20 hours, from the time the previous run is shut down until glassware of acceptable standards is obtained for the new product.

On average, there are 60 production changes per month. Since there is only one team capable of making the changes, the 24-hour period available in one day is not fully utilized. Hence, if a "start-up" procedure is still in process when the first shift set-up team leaves, no adjustments are made until the following morning and that night's production hours are wasted.

Recommended Actions

Reduce die change-out and start-up times by implementing the following:

- ***Utilize the knowledge of your most experienced technicians to develop standardized procedures for all phases of change-out and start-up*** -- This should include a sequence of start-up adjustments. Although there are "many different paths to the same point," establishing a standard set of guidelines about which path to take will reduce guesswork and the associated costly time delays.

- ***Design a tool kit which will hold all change-out tools in an organized manner and deliver the kit to the machine prior to shutting down the production line*** -- This will save time presently used searching for tools

- ***Deliver all jigs, dies, etc. to the machine prior to shutting down the production line*** -- This will minimize production line down-time which is presently used for retrieving these items

- ***Develop a troubleshooting guide describing common start-up problems and their fixes*** -- This will reduce guesswork when responding to problems

- ***Purchase and install two-level platforms*** -- This will save time during the change-out phase by allowing technicians to work on the upper level adjustments at the same time other technicians are performing mold change-outs and other lower level adjustments. These actions cannot presently be performed simultaneously.

- ***Install Strain Gauges*** -- This will allow quicker mold alignments.

- ***Install Temperature Sensors*** -- This will allow quicker temperature adjustments and better control.

Several of the suggestions above are already under investigation by plant personnel, including the development of standard procedures. Based on the large potential cost savings, the quickest possible implementation is recommended.

Anticipated Savings

Since the savings mentioned in the **General** section (a 95% set-up time reduction) seem too aggressive and also because they are based on sometimes time-consuming analyses of the setup operations, our recommendation is based on estimates made by experienced staff at your company. Being conservative, we will consider saving only one fifth of the existing set-up time. Based on the recommendations, this number was considered reasonable by the production manager.

The gross sales per processing hour, GSH, can be obtained as follows:

GSH = Gross Sales / (Annual Operating Hours for All Lines - Setup Times for All Lines)
= ($45,000,000/yr)/[(10 lines)(8400)hrs/yr - (60 chg/mon.)(12 mon./yr)(20 hr/chg)]
= ($45,000,000/yr) / [(84,000 hrs/yr) - (14,400 hrs/yr)]
= ($45,000,000/yr) / (69,600 hrs/yr)
GSH = $647 / hr per production line

It is assumed that during set-up time, molten gobs of glass are dripped into the basement and are later crushed and used as cullet. Hence, no additional raw material costs will be incurred for a production line as a result of the set-up period because the gobs will be recycled and added to the furnace as cullet. The value of raw materials added to the furnace for each production line is $10.06/hr. In addition, it takes 1,200 Btu/lb less heat to melt cullet than it does to make glass from virgin raw materials. From this value, it was determined that it costs $5.32/hr less to re-melt the cullet which is collected during the set-up period as compared to virgin raw materials.[5]

The value of the saved production time, VST, is estimated as:

VST = GSH - CMS - CES

where

CMS = Cullet Material Savings, $10.06/hr per production line
CES = Cullet Energy Savings, $5.32/hr per production line

Thus,

VST = ($647/hr) - ($10.06/hr) - ($5.32/hr)
VST = $631.62/hr per production line ≈ $632/hr per production line

> We estimate the value of saved production time as $632/hr per production line, assuming that the time lost could have been used to produce salable products.

The following calculation is an estimate of labor saved by performing this recommendation[6], based on a labor rate of $25.96/hr.

5 Office of Technology Assessment. 1989. Facing America's Trash: What Next for Municipal Solid Waste

6 The calculation assumes that the saved labor time is put to productive use in other areas of the facility. To be conservative, however, these cost savings have been omitted from our annual cost benefit estimates. Even with all labor savings neglected, the potential cost benefit is substantial.

Time Saved per Setup = 0.20 x 20 hr = 4 hrs

Wages Saved = ($25.96/hr) x (4 hr) = $103.84 / setup per person

Wages Saved per Setup = (8 people) x ($103.84 / setup per person) = $830.72 / setup

Hence,

Wages Saved per Year = (60 chg/month) x (12 month/yr) x ($830.72 / setup)

Wages Saved per Year = $0.60 x 10^6 / year

By reducing the present set-up periods by an average of 4 hours each, the annual cost benefit, ACB, would be:

Annual Cost Benefit = (Production Time Saved) x (Value of Saved Production Time)

ACB = [(60 chg/month) x (12 month/yr) x (4 hr/chg)] x [$632/hr]

ACB = $1.82 x$10^6$ / year

Implementation

The estimated costs for the specific recommendations listed previously include:

1) *Labor for equipment installation and preparation of setup tooling and standard procedures,*

The labor involved is estimated at 4 weeks of work for each furnace, for 8 people working 8 hour days at a labor rate $25.96/hr. Hence,

Labor Costs = ($25.96/hr) x (4 wk/person/furnace) x ...

... x (40 hr/wk) x (8 people) x (3 furnaces)

Labor Costs = $99,686

2) *The purchase and installation of jigs and strain gauges for all 78 production dies,*

Based on a quote already obtained by facility personnel, the cost of the required six strain gauges per die is $35,000, including installation. Hence,

Strain Gauge Costs = ($35,000 per die) x (78 dies)

Strain Gauge Costs = $2.73 x 10^6

3) *ten two-level platforms,*

Platform Costs = (10 platforms) x ($5,000/platform) = $50,000

4) temperature sensors (3 per fore-hearth)

The estimate is based on the price for an infrared temperature sensor capable of reading temperatures up to 3000 ˚F. The sensors cost $5,500 a piece. It is assumed that 3 sensors per fore-hearth will be installed.

Sensor Costs = (3 sensors/fore-hearth) x (10 fore hearths) x ...
... x ($5,500/sensor)

Sensor Costs = $165,000

Finally, the combined estimated implementation cost is:

Imp. Cost = Strain Gauge Costs + Platform Costs + Sensor Costs + Labor Costs
Imp. Cost = $2.73 x 10^6 + $50,000 + $165,000 + $99,686 = $3.04 x 10^6

The simple payback period can be calculated from the following equation:

Payback Period = (Implementation Cost) / ES
= ($3.04 x 10^6) / ($1.82 x10^6 /yr)
Payback Period = 1.7 years (about 20 months)

Conclusion: It is important to realize the potential in implementing this recommendation. We do not pretend to have thorough enough knowledge of your existing procedures to be able to specify the definite steps which are needed in order to achieve the indicated savings or an accurate implementations cost. However, based on case histories from other facilities, the present lengthy set-up times at your facility, and conversations with plant personnel, the estimated cost savings are considered reasonable. Due to the large savings potential, we hope that the above example will reinforce your present efforts to reduce set-up times and serve to focus your attention on this critical part of your operations.

Assessment Recommendation No. 2
Use Fixtures to Reduce Lathe Set-up Times

Assessment Recommendation Summary

Estimated Cost Savings = $378,000/year

Estimated Implementation Cost = $29,180

Simple Payback Period = 0.08 years (about 1 month)

Background

The company makes washing machines which are sold around the world. The production of the washing machines is at approximately one machine every ten minutes. The company sales are $70,000,000. The company offers four different models of washing machines in terms of hardware. There are more models if software variations (therefore more programming options) are considered as well.

Existing Practice and Observation

A four-spindle lathe is used to machine the diameter of shafts used for the revolving blades in washing machines. A delicate adjustment needed to be made for the lathe cutting bits. Since it was a single purpose lathe machine the opportunity to convert internal setup into external setup was obvious. Before the improvement program began, the cutting bits were changed inside the machine and because of close tolerances required, a number of gauges had to be employed. That was one of the most time consuming adjustments, as is generally the case when gauges are employed.

Recommended Action

Make fixtures for holding the lathe cutting bits. Perform the bit alignment while the machine is running and have the fixture ready for a swap when needed. It is recommended that in the new process the bits are held in a holder which is mounted precisely in a predetermined position on the lathe machine. The change now encompasses the switching of a holder instead of the individual bits. While the machine is running the bits are mounted into a holder and still adjusted using a variety of gauges, but the whole process became an external setup not taking time from production.

Anticipated Savings

Material = $575/fixture

Labor involved represents the manufacture of the fixtures.

Average Number of Setup Changes per Month = 30

ES = (# of pieces/hr) x (value of a piece) x (original time - new time) x (# of setups/year)

ES = (200 pieces/hr) x ($31.5/piece) x (15 min - 5 min) x (1/60 hr/min) x 30 x 12

= $378 000/year

ES = $378 000/year

In this case the savings represent lost production on the machine.

Implementation

Labor Rate = $40.00/hr

Time to Manufacture = 1 week

People Involved = 3

Number of Fixtures Needed = 4

Labor = ($40.00/hr) x 1.4 (fringe benefits) x (1 week) x (40 hr/week) x 3 (people)

= $6,720/per fixture

Implementation Cost = (575 + 6 720) x 4 = $29,180

Simple Payback = (29,180) / (378,000) = 0.08 years = (approximately 1 month)

Assessment Recommendation No. 3
Install a Rotating Nozzle Carousel to Reduce Set-up Times

Assessment Recommendation Summary

Estimated Cost Savings = $60,750 / year

Estimated Implementation Cost = $4,200

Simple Payback Period = less than one month

Background

The company makes metering pumps predominantly for the American market. The production rate is about fifteen pumps an hour. The company sales are $85,000,000. The pump models differ by size. The pumps are hydraulically actuated tubular diaphragm type. One pump assembly can have up to six different head arrangements, which are mounted on a single gearbox. However, all the hydraulically actuated diaphragm pump arrangements share the basic idea of an intermediate fluid which has to be filled into the cylinder of a pump at a certain position as the pump proceeds on the line.

Existing Practice and Observation

The filling of the cylinder cavity is performed with nozzles which are positioned above the filling hole in the cylinder. Since the cylinder sizes differ, the nozzle has to be changed and repositioned every time there is a change of a pump size. The change and position adjustment takes a skilled operator about five minutes. For all that time the pump assembly line is shut down. After the nozzle is properly adjusted it automatically fills the pump cavity.

Recommended Action

The fix of the problem consisted of rotary mounting hardware making it adaptable to different types of pump cylinders. As a result of this improvement, the manual change and adjustment of the nozzles before the next type of a pump started being produced was eliminated. As stated above, even though the filling of the intermediate fluid was automatic when the production line was running, the line had to be stopped for five minutes for the manual adjustment before the run could resume. After the change, the rotation is initiated by a switch which positions the multiple rotating carousel with different nozzle location into the proper place. The rotation takes a couple of seconds. Since the existing nozzles were utilized in the design of the rotating fixture, the expenses were minimal amounting to approximately $1,200 per fixture.

Anticipated Savings

Material and Labor for the New Nozzle Carousel = $1,200
Average Number of Pump Sizes per Month = 10

ES = Estimated Savings = *Net* Sales Increase
ES = (# of pieces/hr) x (value per piece - material cost per piece) x (time saved) x (# of changes/yr)
ES = (15 pieces/hr) x ($950/piece - $500/piece) x (4.5 minutes) x (1/60 hr/min) x 10 x 12
ES = $60,750/year

In this case the savings represent lost production on the line. Energy cost increases are assumed to be negligible, and gross labor costs will remain unchanged because the laborers who are presently waiting during the changes will be producing additional pumps during the recovered change time. We have assumed that the only costs which will increase due to increased pump production are the raw material costs.

Implementation

Implementation requires the manufacture and installation of the nozzle carousel ($1,200). The cost of material was estimated at $800 and labor at $400. It was recommended to buy an extra set of nozzles as a backup in case of failure of existing ones. The cost estimate obtained from the nozzle manufacturer was $300 a piece. Since 6 extra nozzles were needed, $1800 of expenses have to be added to the cost of the project.

The simple payback period can be calculated from the following equation:

Payback Period = (Implementation Cost) / ES
= ($4,200) / ($60,750/yr)
Payback Period = 0.07 years (less than 1 month)

Assessment Recommendation No. 4
Employ Modular Jigs to Reduce Process Set-up Times

Assessment Recommendation Summary

Estimated Cost Savings = $117,450/yr

Estimated Implementation Cost = $8,115

Simple Payback Period = 0.1 years (about 1 month)

Background

The company manufactures connecting rods for combustion engines. The sales are about $30,000,000/yr. The number of employees at this location is 170. The facility is housed inside a single 200,000 ft^2 steel beam construction type building.

Existing Practice and Observation

The aluminum die cast parts were delivered into the stock. Then the parts were transferred to the line where they went through the following process. First reference holes were made, then a bolt hole was drilled. The oil hole was drilled followed by large end cut. The cap was attached and the whole assembly bored out. The total time involved was five hours and forty-two minutes. During setups, the trained setup technicians came to perform the desired change. The operators, in the meantime, were cleaning around the line. The jigs for different operations were very heavy and therefore they had to be removed with the help of a crane. In addition, the drill had to be removed because it was in the way when the jigs were replaced. Centering adjustments were required when a jig, cleaned off with petroleum jelly, was lifted onto a table.

Recommended Action

Employ jigs which would be modular. That way the heavy base part of a jig can stay in place all the time and different parts of the jig are replaced as needed. *The manipulation with the crane is completely eliminated.* All the modular parts must be manufactured with centering holes or grooves so manual adjustment after installation is not needed.

Anticipated Savings

There is an elimination of one person during the setup operation because now the adjustment is not needed and the operator can perform the task alone. The time to perform the setup is estimated to take about one hour.

$$PLM = [(25\ chg/month) \times (12\ month/yr) \times (4.7\ hr/chg)] \times [\$45/piece] = \$63{,}450\ /\ year$$

where
PLM = Production Lost Money
Wages of qualified mechanic = $40,000
Wages Saved $40,000 x 1.35 fringe benefits = $54,000

$$ES = PLM + Wages\ Saved = \$63{,}450 + \$54{,}000 = \$117{,}450\ /\ year$$

where
ES = Estimated Savings

Implementation

Implementation requires manufacturing eight different fixture subassemblies. The main bodies of existing jigs can be used. The time involved is estimated as three weeks. Based on the same wage structure as for mechanics the cost of the change would be:

$$COST = (8\ hours \times 5\ days \times 3\ weeks) \times \$25.96/hour = \$3{,}115$$

Material cost was estimated for $5,000.

Total Cost = $8,115

The simple payback period can be calculated from the following equation:

Payback Period = (Implementation Cost) / ES
= ($8 115) / ($117 450/yr)
Payback Period = 0.1 years (about 1 month)

Bottleneck Mitigation

Introduction

A bottleneck in manufacturing is that process (or procedure) which restricts the entire operation from running faster. It is usually identified by **waiting**; either by workers, or by (idle) machines. Identifying and alleviating a bottleneck in the manufacturing process allows an increase in throughput (pieces/person/hour) of a particular process, or of the entire plant. In most cases, this will increase revenue, however it could also be used to reduce production lead time.

In order to identify a bottleneck, the issue should be brought up during the interview; however two cautions are noted here. First, many companies do not consider the effect of the **net production rate**, including scrap, on a bottleneck. They might not define a process/procedure as a bottleneck if a defective part is produced and it can be re-used as a raw material. Examples of such industries are paper, glass, plastics, and metals. Second, it is important to realize that the perceived (or "theoretical") bottleneck may not, in fact, be the real bottleneck. Discussions about this topic with machine operators is advised, if possible.

Alleviating bottlenecks is often accomplished by installation of improved equipment or tools. It can also be accomplished by the purchase of manufactured parts, by parameter control (temperature, humidity), or higher quality raw materials. For example, a sewing factory manager described the hand threading of the needles as the bottleneck. Upon questioning, operators complained that the quality of the thread made it difficult to thread the machines. Changes in the specifications of the thread *eliminated* this bottleneck at a minimal cost to the company.

Increasing the production rates can have **additional costs** involved, such as increased raw materials, labor, or energy use. On a per unit or per piece basis, however, these quantities should remain constant or even decrease in some cases. Conversely, industries that have high internal rejection rates may not require more raw materials if the defect rate is reduced. If alleviating the bottleneck also reduces re-work, the recommendation may not require more labor. If a new piece of equipment is installed, or an existing one optimized, it may not use more energy. In most instances, the relationship between increased revenue and increased profits will be based on the amount of information available and should be handled on a case by case basis.

Questions

- How has the operation changed over time?
  (product, equipment, procedure)
- What is the optimal rate of this process/procedure?
- Can you sell more product, if you can make it?
- Are you considering expansion?
- Why is this process/procedure the bottleneck?
- Do you ever run overtime to meet production goals? (related costs)

Indicators / Symptoms

- Waiting - for people, product, machines, tools
- Excess Inventory (raw materials or in process)
- Excessive motion or transportation

Related Recommendations

- PURCHASE / INSTALL MORE EFFICIENT MACHINERY
- PURCHASE BETTER TOOLS
- CHANGE THE SPECIFICATION OF RAW MATERIALS
- CONTROL PROCESS PARAMETER (TEMPERATURE, HUMIDITY)
- USE AVAILABLE "LESS EFFICIENT" EQUIPMENT

Assessment Recommendation No. 5
Add Machine Operators to Reduce Production Bottleneck

Assessment Recommendation Summary

Estimated Cost Savings = $208,780 /yr.

Estimated Implementation Cost = $47,520

Estimated Payback Period = 0.23 years (~3 months)

Existing Practice and Observation

During interviews with plant personnel, it was stated that the production bottleneck in the plant should be the tire press division; however, it was noticed that the tire presses are idle for about 10% of the time because they are waiting on in-process material from the previous process (tire machines). Automatic and manual tire machines construct the structure of the tires so they can be molded in the presses. There are 75 automatic and 50 manual tire machines. The automatic tire machines process 9 tires per hour and require only one operator. The manual machines are less efficient, producing only 6 tires per hour with one operator. With two operators, the manual machines can each produce about 9.7 tires per hour. Since this results in a lower tires per person rate (and a higher labor cost per tire) in the tire machine division, only one operator is presently used on the manual machines.

The operating cost for the tire presses are relatively unchanged by increases in production, so if the presses were to operate at maximum capacity there would be very little additional operating costs. According to management, the company can sell all the tires it can produce (at the current price) and opportunities to increase the total plant output are of great interest.

Recommended Action

A second machine operator should be added to the manual tire machines in order to increase the production enough to keep the tire presses operating continuously. The additional operators on the manual tire machines will increase the cost of producing each tire in the tire machine division, but will lower the overall production cost per tire by eliminating the existing idle time of the tire presses. Idle time at the tire presses is a waste of the labor efforts of the press operators.

Anticipated Savings

Under the present operating conditions, at maximum output the tire machines can only produce 23,400 tires a day and are doing so. If a second operator is added to the manual tire machines for all shifts, the maximum daily output from the tire machines division will be 27,840. If the tire presses are operating continuously they can only mold 26,000 tires a day, so it will not be necessary to keep two operators on all of the manual machines during every shift. Only enough extra operators to increase production to 26,000 tires per day will be will be needed to eliminate the idle time of the presses. The number of estimated additional operator-shifts per week is 88.

We have conservatively assumed that the only costs *per unit* which will be affected by the increased production of tires will be from these two divisions (machines and presses). As the total production is increased, the *total* costs for each other division will increase but the cost *per unit* should remain the same. For example the *total* cost for raw materials will increase because more tires will be made, but the raw material costs *per tire* will not be affected. These increases in total cost will be proportional to the increase in revenue from sales of the new tires.

The annual total cost savings, ATS, achieved by the addition of a second operator on some of the manual tire machines can be determined using the following equations:

Operating cost with one operator on the manual tire machines:

CIA = The cost per tire (tire machine division) with only one operator

CIA = [(CPO x HRO) x (NAM + NMM)] / TAO + TMC

CPO = Cost per hour for machine operator

HRO = Hours of production operation

NAM = Number of automatic machines operating

NMM = Number of manual machines operating

TAO = total amount of tires produced per day with one operator

TMC = cost to operate the tire machine for each tire

CIA = [($32.50/hr x 24 hrs) x (75 + 50)] / (23,400 tires) + ($0.75/tire)

CIA = $4.92 per tire in tire machine division

CTP = The cost per tire to mold the tires produced by single operators

CTP = (NTP x HRO x CPO) / TAO + CPT

NTP = number of tire presses (there is one operator per tire press)

CPT = cost to run the press per tire

CTP = (145 presses) x (24 hrs) x ($32.5 / hr) / (23,400 tires) + ($0.33/ tire)

CTP = \$5.16 / tire

TTPO = The total for the two processes with one operator

TTPO = CIA + CTP

TTPO = \$4.92/tire + \$5.16/tire

TTPO = \$10.08 per tire

<u>Operating cost with two operators on manual tire machines:</u>

CSO = cost per tire (tire machine division) with second operator

CSO = (CPO) / (MPR) + TMC

MPR = additional tires/hr produced by second operator on manual machines

CSO = (\$32.5 / hr) / (3.7 tires / hr) + (\$0.75)

CSO = \$9.53 / tire

The extra tires that are produced will not require any additional operators at the presses, therefore no labor costs at the presses will be associated with the additional tires--the workers will now be producing tires during the time previously spent waiting for tires to be delivered. The only additional costs that will be incurred at the tire presses are for the increased maintenance and energy costs of the machinery.

CPS = cost for the press to make additional tires (no additional labor costs apply)

CPS = CPT

CPS = \$0.33 per tire

TTPT = Total cost per tire for the two processes with two operators

TTPT = CSO + CPS

TTPT = \$9.53 / tire + \$0.33 / tire

TTPT = \$9.86 per tire

The unit savings per tire, UST, for additional tires produced will be:

UST = TTPO - TTPT

UST = \$10.08 / tire - \$9.86 / tire

UST = \$0.22 per tire

Finally, the total annual cost savings, ATS, can be calculated using the following formula:

ATS = SPA x NAT x DPY

SPA = Savings per additional tire produced

NAT = Number of additional tires produced per day

DPY = Production days per year

ATS = ($0.22/tire) (2,600 tires/day) (365 days/yr.)

ATS = $208,780 / yr

The company has determined the cost to make one tire including all expenses is $26.00 when operating the presses at a 90 percent level. From the previous conclusions, the cost per tire will drop as the presses begin to operate at a rate closer to 100 percent. It was stated that the cost per tire will only change in these two areas if the additional operator is used on the manual tire machines. The cost per tire will drop to $25.78 for the additional 2600 tires produced, a twenty-two cent drop from the cost to make the first 23,400 tires.

Not included in the above savings calculations is the additional revenue produced by the sales of the extra tires. Assuming a 10% profit on each tire, the increased annual revenue obtained from producing the extra tires (not including the savings calculated above) would be (0.10) x ($26.00/tire) x (2600 tires/day) x (365 days/yr) = $2,467,400/yr.

Implementation and Simple Payback

The additional workers that are hired to work on the manual tire machines will have to be trained to operate the machines. The total cost to train the operators, CTO, can be determined using the following equation,

CTO = NOW x THT x CPT

NOW = number of workers to be trained

THT = number of hours that the workers will be trained

CPT = The hourly rate paid for time while training

CTO = (88 workers) (24 hours) ($22.50 /hr)

CTO = $47,520

Payback Period = Implementation Cost / ATS = $47,520 / ($208,780/yr) = 0.23 yrs (~3 months)

Assessment Recommendation No. 6
Install Refrigeration System to Cool Product

Assessment Recommendation Summary

Estimated Additional Revenue = $285,000/yr
Net Profit Increase = $24,700/yr
Estimated Implementation Cost = $13,611
Simple Payback Period = 7 months

Existing Practice and Observation

The process of manufacturing thin plastic sheets for the printing industry involves melting the raw materials and pellets, mixing them with pigments and other additives, and molding them into rolls. The rolls are then trimmed, and passed through a cutting machine which cuts them into the desired finished width and length. They are then stacked to a pre-determined count, packaged and shipped. Management has indicated that the company sells all of the sheets produced and would like to increase production levels in order to gain increased market share.

The bottleneck in the process is the cutting machine which is presently running at approximately 1000 sheets per hour. According to the manufacturer of the equipment, this machine should be producing 1500 sheets per hour. The reduced production rate is due to the fact that the sheets stick together if the machine is run any faster. The operators feel that high humidity levels are the cause of the sticking. The option of air conditioning the entire facility to alleviate the problem was rejected by management.

Discussions with management reveal that your company is considering the purchase of a second machine to reach production goals. This new machine would cost approximately $150,000.

Tests in the production area have indicated that the humidity levels are not above those recommended by either the manufacturer of the cutting machine, or the supplier of the raw materials. Further discussions with the manufacturer of the raw materials uncovered that it is, in fact, a temperature parameter that is being exceeded. They stated that the sheets would stick together if the surface temperature of the finished product was above 100˚ F. Measurements of the surface of the film indicated temperatures averaging 120˚ F.

Recommended Action

Install a refrigeration system with ducting to blow cool air both under the sheet leaving the cutting machine, and on top of the stack of film. Calculations show that 180,000 Btu/hr. of refrigeration is required to reach desired temperatures and production rates.

Anticipated Savings

The operating cost of the refrigeration equipment is estimated to be about $3,800/yr.

Estimated Savings = Net Profit Increase = IP x hr x V x P - OC

Where IP = increased production/hr

hr = hours of production 30 hrs/shift x 4 shifts/wk x 50 wk/year

V = Value of Product ($/sheet)

P = Profit Margin (assumed to be 10%)

OC = annual operating cost of the refrigeration equipment

Est. Savings = (500 sheets/hr) x (6,000 hr/yr) x ($0.095/sheet) x (0.10) - ($3,800/yr)

Est. Savings = $24,700/yr

Implementation

Implementation of this recommendation requires that two 100,000 Btu/hr air conditioning units be purchased, with one ducted to the bottom of the leaving sheets, and the other directed to the top of the stack. Each unit should be controlled by an infrared temperature sensor. This will provide some redundancy in the event that one unit is out of commission.

The controllers should be specified with either Proportional Integral or Fuzzy Logic Control; and with alarms. We also recommend that the unit have the capability of recording the production rate of the cutting machine.

Refrigeration units ...$600/ ton	
200,000 BTU/hr x 1 ton/12,000 BTU x $600/ton	= $10,000
Infrared Temperature Sensors (4)	$396
Controller (2)	$378
Labor: 20 hr x 2 installers x $40/hr	$1,600
Ancillary Equipment (utilities, etc.) add 10%	$1,237
Total	**$13,611**

Assessment Recommendation No. 7
Replace Old Lathe With New Automatic Multi-station Tool

Assessment Recommendation Summary

Estimated Increased Profit = $239,000/yr

Estimated Implementation Cost = $67,500

Simple Payback Period = 0.28 years (~ 3.4 months)

Existing Practice and Observations

Machined piece orders have been sufficient to use the full year's time of four machine operators. Increased demand for pieces indicates that up to 50,000 more pieces could be sold if produced. Competition is making inroads on profit margin. Production on the four present machines has been 220 pieces per hour. Direct labor costs for the machine operators are estimated to be $23 per hour and the operator works 2,080 hours per year. Current production is 440,000 pieces per year. Raw material costs are about $1,100,000 per year. Spoilage rate (defects) average 3.85% for the current machines. Overhead (Burden) costs are estimated at 200% of direct labor costs for this company. Annual sales are $2,000,000 per year for these pieces. Competition has been putting pressure on the company to maintain its profit margin and sales level. It is believed that lowering production cost can result in increased sales and profits

Recommended Action

Purchase a new automatic multi-head machine tool which is estimated to produce 180 pieces per hour to replace three of the current machines. This machine can still be operated by a single operator. The new machine cost is estimated as $75,000 including installation and removal costs of three old machines. The new machine is expected to use the same amount of power per part but have only a 1% spoilage rate.

Anticipated Savings

Annual Sales per year/Parts per year = $4.546 per part

Current Direct Labor Cost	=	$191,360
Fringe Costs for Labor (35%)	=	$66,976
Current Cost of Raw Material	=	$1,100,000
Overhead at 200% Direct Labor	=	$382,720
Total Estimated Cost	=	$1,741,000

Estimated Cost Per Part = $3.957 per part

Profit per part (estimated) = $4.546/part - $3.957/part = $0.589/part

Estimated Profit margin = 15%

Estimated Profit = (Annual Sales - Annual Costs) = $259,000/yr

Using the new machine and one of the current machines production will be 480,660 pieces per year. If it is estimated that overhead costs will remain the same due to increased debt costs and perhaps marketing and sales costs, but decreased direct labor costs, then conservatively:

Future Direct Labor Cost	=	$95,680
Fringe Costs for Labor (35%)	=	$33,490
Future Cost of Raw Material	=	$1,175,000
Overhead	=	$382,720
Total Estimated Cost	=	$1,687,000

Estimated Cost Per Part = $3.510 per part

Cost Savings per Part = $3.957 per part - $3.510 per part = $0.447 per part

The manufacturer will thus have room to increase profit margin and produce more parts than the previous years. Assuming all the goods can be sold at the current price per part the profit would be:

480,660 parts/yr x ($4.546 per part - $3.510 per part) = $497,960/yr

The increase in profit would be:

$498,000/yr - $259,000/yr = $239,000/yr

Of this increased profit about $196,850 is the increase due to decrease in cost per part and the remaining $42,150 is due to the increased sales with a better margin.

Implementation and Simple Payback

The cost of the new machine with installation is $75,000. The salvage value of the three old machines is estimated to be $7,500. The net implementation cost is then $67,500 and the simple payback is:

($67,500) / ($239,000/yr) = 0.28 years (~ 3.4 months)

Defect Reduction

<u>Introduction</u>

The concept of defect reduction should be a focal point when considering potential productivity improvements in industrial facilities. Time spent producing defective parts can be costly to manufacturers, wasting labor efforts, energy, raw materials, and requiring increased costs for inspection, inventory, material handling, and clean-up.

A shortcoming of many statistically based quality control systems, where inspections are performed at the end of the production line, is that they are intended only to separate the defective products from the good products. While this effectively reduces the number of defective products which are passed along to the customer, it does very little if anything to reduce the number of defective items *produced*. The time between the detection of the defect and feedback to the process line is often hours or days--too long to be of much use.

Often, the most difficult task in identifying and estimating the potential benefits of an assessment recommendation is obtaining reliable information. Fortunately, the nature, frequency, and causes of product defects are normally well-known by quality control personnel or machine operators. The major tasks involved in making a defect reduction recommendation will be:

1) identifying those defects which are *most costly*,
2) determining *why* those defects occur, and
3) recommending actions which will *reduce or eliminate the defects*.

The first two items above can normally be determined by questioning plant personnel (see the question list in the next section for guidance). <u>One note of caution:</u> *it is important to distinguish between defect rate and scrap rate.* A process can yield a large number of defects but zero scrap if the defective items are re-used in the process. Such a process is said to have a low "internal yield," or high "internal scrap rate." In such a case, the defects may be "hidden" from management (because there are no defective parts to be seen) but may result in significantly reduced productivity because the number of acceptable items produced by the machine or process will be less than optimal.

Once the nature of the most costly defects are identified, installing new sensors may be a common solution or at least part of the solution. Sensors can be used to detect the occurrence of defects and, more importantly, provide valuable feedback either to machine operators *or directly to the process equipment.* Feedback from the sensors to machine operators may be achieved using flashing lights and/or buzzers which are triggered by the sensor output. *This feedback can be used to identify the causes of defects and can lead to equipment, process, material, or procedural modifications which will reduce those defects in the future.*

Defects should be detected as soon as possible after they have occurred to avoid additional value-added processes from being performed on a product which is already defective. In fact, sometimes the defect can be detected *before* it occurs. If the *conditions* which cause a defect are known (e.g., temperatures, humidities, pressures, movements, positioning, broken or chipped tools, etc.), sensors can be installed to detect when those conditions occur and adjust the appropriate parameters or stop the process before defects are produced.

Immediate feedback can also be used to prevent "serial defects" (a large batch of defective products) by shutting down the production line until the cause of the defect is identified and fixed, or by indicating to the operators that parameter adjustments (temperature, pressure, etc.) are needed. In cases where serial defects are a common problem, shutting down the process or machine is recommended unless the start-up efforts are extensive. When defects commonly occur as abnormalities or isolated incidents, it is usually best not to shut down the production line, but to automatically reject the defective part and scrap, recycle, or repair it.

Various types of sensors are available which can be used to detect parameters such as:

- Positions
- Shapes (2D or 3D)
- Dimensions
- Presence of foreign matter
- Damage/Displacement
- Color mismatch
- Pressure
- Temperature
- Humidity
- Vibration
- Counts or cycles
- Timing

The most thorough quality control system is one in which 100% of the products are inspected after each process, and feedback from the point of defect detection to the operation which caused the defect is immediate. Using people to conduct 100% inspections would be extremely expensive and impractical in most circumstances. Often, however, sensors may be used to perform 100% inspections with high reliability and a very low cost. They have the capability to inspect at high rates of production and provide visual, audio, or process control feedback.

Questions to Ask

- What percentage of products are inspected?
- In what stages/locations of the process do the most rejects (or clean-up) occur?
- What are the most common types of defects?
- How much does each type of defect or clean-up cost per year (labor, material, lost production time, extra equipment or processes--i.e., regrind--etc.)?
- What causes each type of defect?
- If you can make more product, can you sell it?
- Are overtime hours ever worked to meet production demands or compensate for defective batches? If so, how many man-hours per year, and at what average pay rate?
- Are in-process and/or finished goods inventories built up due to potential defect problems in the production process (to ensure that the customer gets the products on time)? If so, what percent of existing inventory is considered excess? What is the value and quantity of overstocked goods in inventory?
- Do standardized procedures exist for the processes where defects most often occur?
- Does one machine operator produce significantly fewer defects than others? (If so, that operator's expertise should be used to develop *standardized operating procedures* for training less effective personnel.)

Symptoms/Indicators

- High defect rates
- High scrap rate
- Large in-process or finished goods inventories
- Large inventory of scrap
- Frequent regrinding, in-process recycling, repair/rework, etc.

Related ARs

- MODIFY EQUIPMENT, PROCESSES, OR PROCEDURES TO REDUCE PRODUCT DEFECTS
- DEVELOP STANDARDIZED PROCEDURES TO REDUCE PRODUCT DEFECTS
- INSTALL SENSORS TO DETECT, REJECT, AND COUNT DEFECTIVE PARTS AND PROVIDE FEEDBACK (TO REDUCE INSPECTION COSTS, SERIAL DEFECTS, OR ADDING VALUE TO DEFECTIVE PARTS)

- INSTALL SENSORS TO DETECT AND CONTROL CONDITIONS WHICH LEAD TO DEFECTIVE PRODUCTS (TEMPERATURES, HUMIDITIES, PRESSURES, MOVEMENT, POSITIONING, ETC.)
- INSPECT PARTS EARLIER IN THE PRODUCTION PROCESS (TO REDUCE ADDING VALUE TO DEFECTIVE PARTS)
- INSPECT RAW MATERIALS PRIOR TO PROCESSING OR WORK WITH SUPPLIERS TO IMPROVE RAW MATERIAL SELECTION OR QUALITY (TO AVOID DEFECTS)

Assessment Recommendation No. 8
Reduce Defects By Reducing Bottle Tipping

Assessment Recommendation Summary

Estimated Production Time Savings = 630 hrs/yr

Estimated Cost Savings = $398,160/yr

Estimated Implementation Cost = $152,094

Simple Payback Period = 0.4 years (5 months)

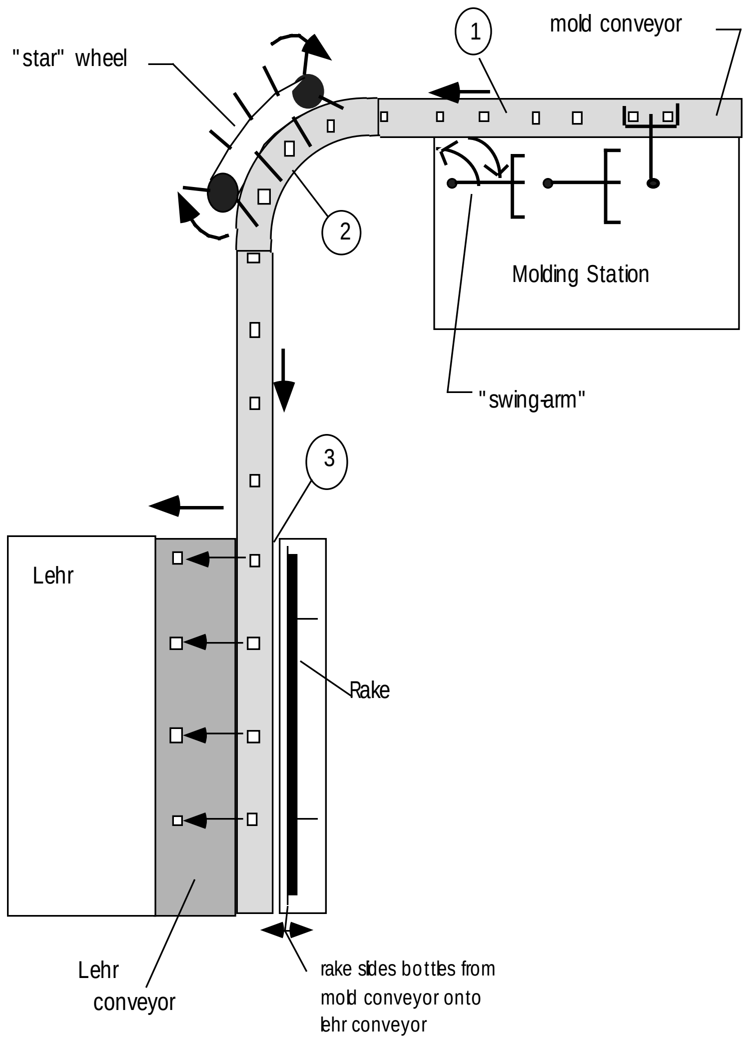
Existing Practice and Observation

During the assessment visit, a significant percentage of the glassware on several of the production lines was observed to be knocked over during movement from the molding stations to the entrance of the Lehrs (annealing ovens). The bottles were typically knocked over during one of three processes:

1) when being slid from the molding stations onto the conveyor line by the "swing-arms,"
2) during the turn in the conveyor line at the "star" wheel, and
3) while being pushed by the rake from the molding station conveyor onto the Lehr conveyor.

These locations are indicated in AR#8, Diagram #1. Most instances of fallen glassware occurred at locations 1 and 3.

At the molding stations, freshly molded glassware is removed from a mold and placed on a level surface next to the conveyor. A mechanical device ("swing-arm") then slides the glassware onto the moving conveyor. When the line operator notices that the glassware from one of the molding stations is repeatedly being knocked over, the operator makes a small adjustment to the swing-arm to eliminate the problem. Based on experience, the operator knows the necessary adjustment to make. Although the required adjustments are minor and usually take less than one mold cycle to perform (less than 10 seconds), the time from when the glassware begins to be knocked over until the operator fixes the problem was observed to be extensive (resulting in 10 or more consecutive tipped glasses before the problem was fixed). At a typical molding station, there are 6 to 8 molds and swing-arms which the operator must monitor and *frequently* adjust. Due to the need for the operator to make such frequent adjustments, it seemed as if the operator was "fighting a losing battle" and that re-design or modification of the transfer devices (swing-arms, rakes, interfaces between conveyors, etc.) is needed in order to significantly reduce the amount of fallen glassware for an extended period of time.



AR#8, Diagram #1: Plan View of Glassware Transport System from Molding Stations to the Lehr Entrance

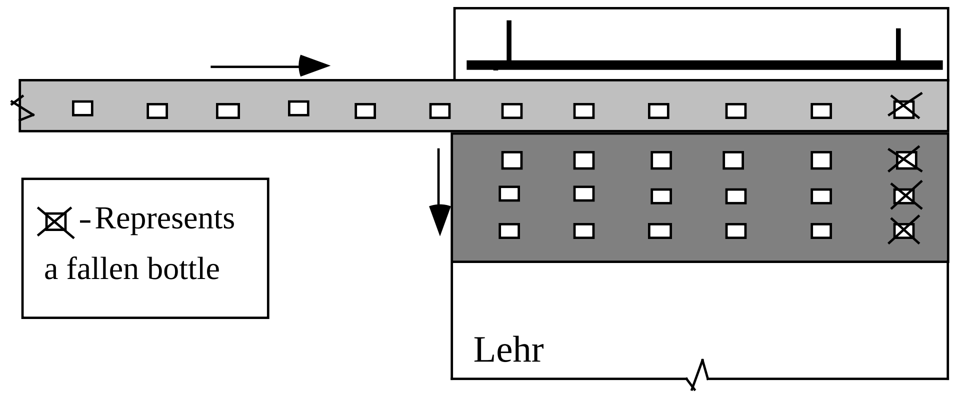
The rake at the Lehr entrance moves back and forth across the molding station conveyor to (and from) the Lehr conveyor. On the forward stroke (from the molding station conveyor to the Lehr conveyor), the rake pushes glassware onto the Lehr conveyor. On the reverse stroke for several of the production lines, the rakes were observed to remain just above the conveyors and therefore knock over the glassware which moved behind the rake while it was in front of the molding station conveyor (see AR#8, Diagram #2). On other production lines, the rake is *raised* on the reverse stroke so it passes over the glassware (see AR#8, Diagram #3). No additional knock-downs occur at the raising rakes. According to facility personnel, all rakes are presently capable of raising on the return stroke and rake motion adjustment is a common part of the production line set-up procedures. Observations of inefficient rake motion on the day of the assessment may indicate that either some of the rakes are prone to becoming "unadjusted" or that the rake adjustment portion of the set-up procedures is sometimes not properly performed.

According to the selector personnel in the "cold room" inspection and packaging area, glassware which exits the Lehr and has been knocked over is *immediately* rejected because of surface defects. ***On the line(s) with non-raising rakes and glassware with a geometry susceptible to tipping, 25% of the glassware entering the Lehr was observed to be knocked over.*** Tall, slender, and/or "top-heavy" glassware is most susceptible to falling over. Facility personnel claim that 9 of the 10 production lines have frequent problems with fallen glassware.

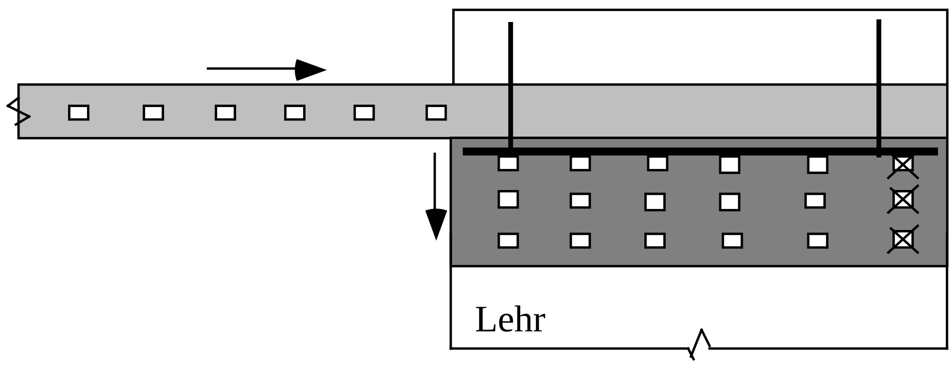
Recommended Action

Reduce product defects by installing sensors which detect when glassware is being knocked over and provide immediate feedback (a flashing light) to the line operators. These sensors should also be capable of recording the number of tipped bottles which occur over a period of time (per shift) to provide feedback to management regarding machine and operator performance. More importantly, modify (or re-design) the mechanical devices which are causing the glassware to fall over, primarily: 1) the "swing-arms" which slide the glassware onto the conveyor in front of the molding stations, and 2) the rakes which push the glassware onto the Lehr conveyor.

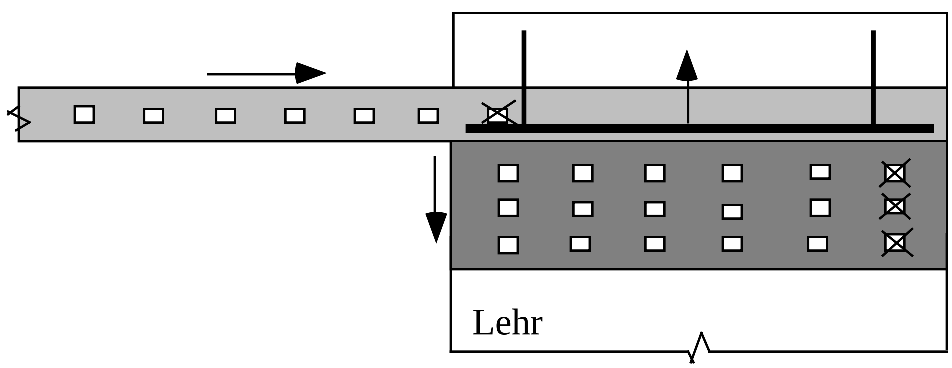
Since there is a wide degree of variance between product sizes and shapes, and some shapes are more prone than others to being knocked over, design changes which may reduce the knock-over rate for small glassware may not work for large glassware (and vice-versa). Hence, it may also help reduce the amount of fallen glassware to attempt to schedule similar (in terms of size and shape) glassware to be produced on the same line whenever possible.



Positon #1 - Rake Back

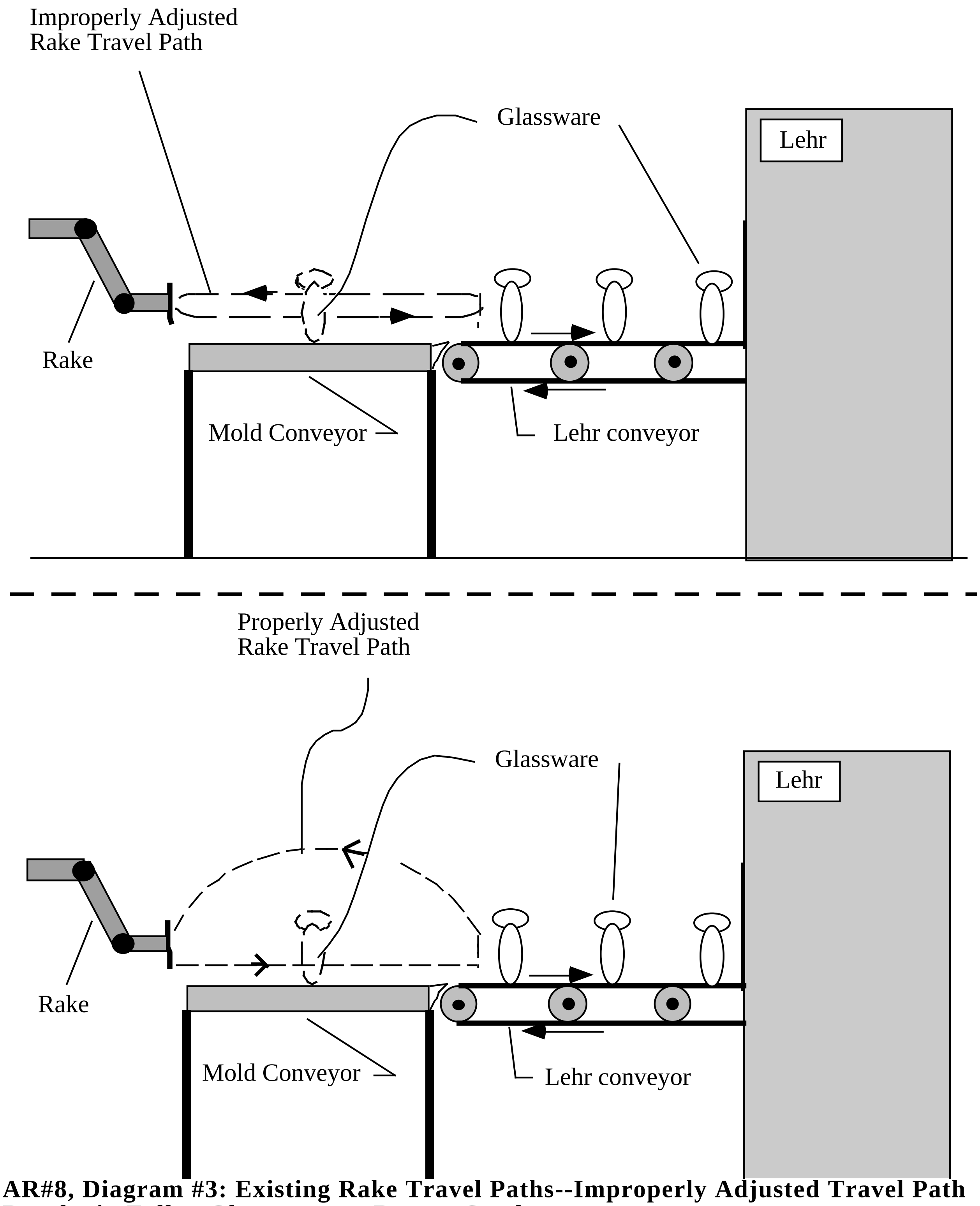


Position #2 - Rake Forward



Position #3 - Glassware Knocked over on Rake Return

AR#8, Diagram #2: Plan View of Glassware Transfer from Mold Station Conveyor to the Lehr Conveyor



AR#8, Diagram #3: Existing Rake Travel Paths--Improperly Adjusted Travel Path Results in Fallen Glassware on Return Stroke

Anticipated Savings

This analysis includes the following assumptions:

- Nine of the production lines have frequent problems with fallen glassware (based on interviews with facility personnel).

- Twenty-five percent of the glassware on those 9 production lines is prone to tipping due to the size and shape of the products. For the glassware shapes which are prone to tipping, an average of 10% of the glassware entering the Lehrs is knocked over. This assumption is based on observations by our assessment team on the day of our visit and, again, is considered to be conservative (on the day of the assessment, as much as 25% of the glassware entering the Lehrs on several of the production lines was observed to be tipped over).

- Seventy-five percent of the fallen glassware can be prevented by implementing this recommendation. This is viewed to be a *conservative* assumption, based on results achieved in other industrial facilities. Actual reductions in fallen glassware should be greater.

- The time saved due to the decreased defect rate (if the defect rate decreases, the required quantity of acceptable glassware will be produced in a shorter amount of time) can be used to make other products and no production line idle-time will occur as a result of the increased production rate.

- The annual production hours for a production line are considered to be the annual plant production hours minus the average monthly set-up hours per production line.

The annual cost savings, ACS, was calculated as follows:

$$ACS = NPL \times APH \times FPT \times PFTG \times FTGA \times FTG \times (1 - RR) \times SLR$$

where

NPL = number of production lines with tipping problems, no units
APH = annual production hours, hrs/yr
FPT = fractional productive time (fraction of the facility operating hours for each production line which are non-setup hours), no units

PFTG = present fraction of tipped glassware (fraction of the total glassware that was observed to be tipped over), no units

FTGA = fraction of tipped glassware that is avoidable, no units

FTG = fraction of "tippable" glassware (fraction of products on these production lines whose shape and size make them prone to tipping), no units

RR = typical rejection rate for a batch of glassware, no units

SLR = shutdown loss rate (cost per hour for a production shutdown), $/hr (per production line)

According to facility management, about 60 glassware "shapes" are produced in a typical month. Each "shape" change requires a mold change-out and process set-up. The average combined set-up and change-out time is about 20 hours. Production lines in the plant are in operation 24 hrs/day, 7 days/wk, 50 weeks a year, for a total of 8400 hrs/yr. Hence, the annual production hours per production line, APH, can be estimated using the following equation:

APH = FPH - TMS x (12 months/yr) x AST / TNPL

where;

FPH = facility's annual production hours, hrs/yr

TMS = total number of monthly production changes ("set-ups"), no units

AST = average duration of a set-up period, hrs

TNPL = total number of production lines in the facility, no units

Thus,

APH = (8400 hrs/yr) - (60 set-ups/month)(12 months/yr)(20 hrs/set-up) / (10)

= (8400 hrs/yr) - (1440 hrs/yr)

APH = 6,960 hrs/yr

The fractional productive time, FPT, is the *fraction* of the facility operating hours for each production line which are non-setup hours. Thus, FPT = APH / FPH = 6960 / 8400 = 0.83. According to facility production management, thirty-five percent of the glassware produced is rejected. Thus, we will use a value of 0.35 for the typical rejection rate, RR.

Finally, the annual cost savings is estimated as

ACS = (9)(6960)(0.83)(0.10)(0.75)(0.25)(1 - 0.35)(632)

ACS = (9)(70 hr/yr)($632/hr) = (9)($44,240/yr)

ACS = $398,160/yr

The number of hours per year which would be made available for producing additional products if the bottle tipping problems are improved is estimated as 70 hr/yr (per production line), representing a [(70 hr/yr) / (6960 hr/yr)] x 100% = 1% productivity increase.

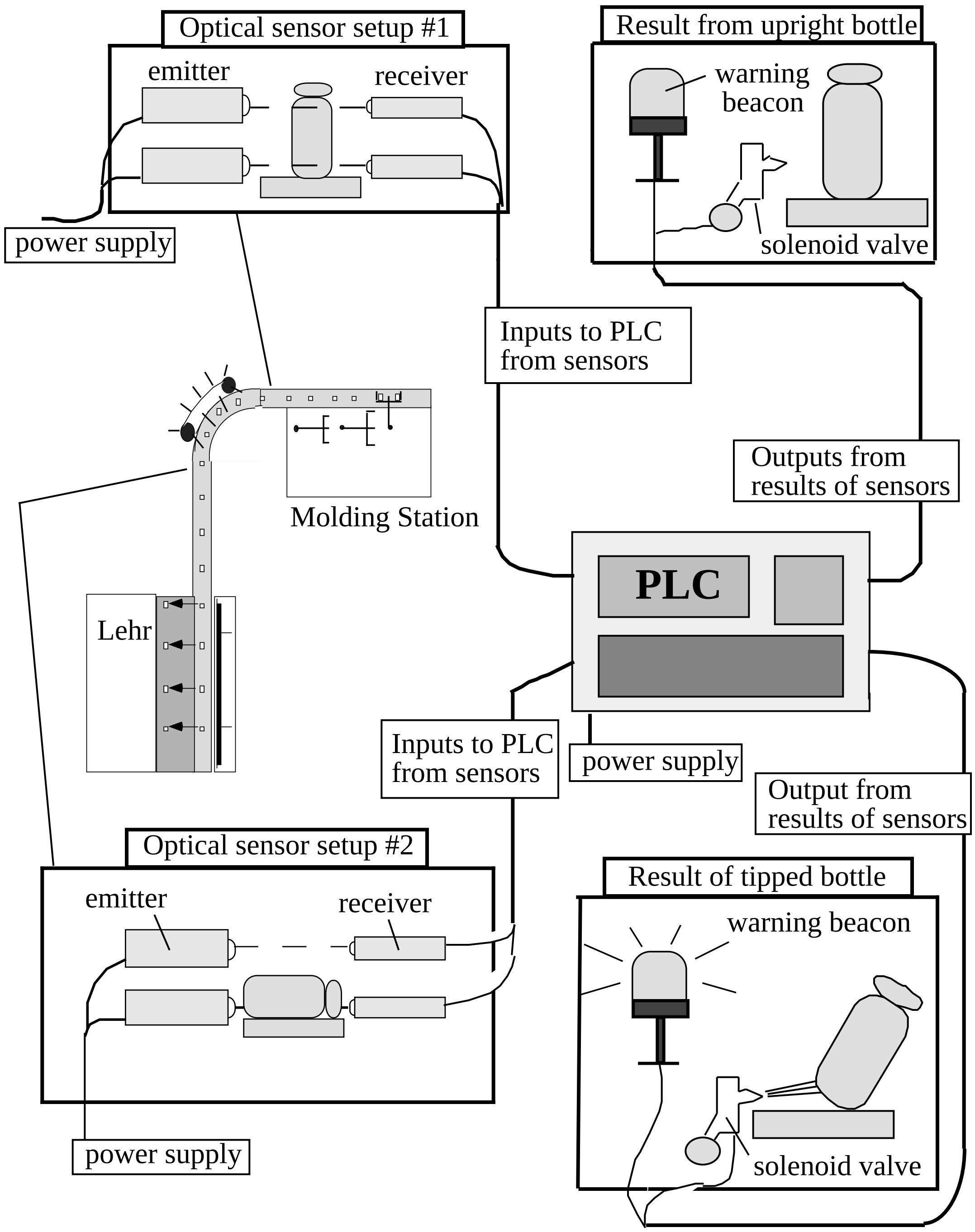
Implementation

Re-design and modification of the mechanical devices which are causing the glassware to fall over will require an in-house study. The production lines should be observed for extended periods of time, documenting the most common causes of fallen glassware on each production line and the actions taken by the mold operators to correct each type of problem. This will expose the mechanical components which need to be re-designed and may also suggest possible solutions (based on the mold operator's present methods of repairing each problem). Re-design of the mechanical components is estimated to require 200 engineering hours, at $100/hr , for a total of $20,000 in engineering expenses. Fabrication, purchase, and installation of new components is estimated at a total of $100,000, resulting in a total estimated project cost of $120,000. Based on results in other facilities, this estimate is considered to be higher than the expected costs but is subject to change dramatically depending on the required modifications which are uncovered by the in-house study and engineering recommendations.

A representation of the proposed tipped glassware sensing system is shown in AR#8, Diagram #4. The system would be capable of sensing:

1) when a bottle (or a number of bottles in a pre-set period of time) has fallen,
2) setting off a beacon (flashing light) to warn the line operator of the problem,
3) rejecting the fallen bottles using compressed air (to prevent wasted time in the cold room handling fallen glassware), and
4) recording the pieces of fallen glassware during a pre-set period of time.

A set of two through-beam optical sensors would be needed at each sensing station, with one sensor located just above the conveyor line at the bottom of the glassware and the second sensor located at an adjustable position vertically above the bottom sensor. The mounting bracket for the sensors should allow the vertical adjustment of the top sensor to allow the system to be used for glassware of various heights.



AR#8, Diagram #4: Proposed Tipped Glassware Indicator System

If a bottle is upright, the beam from both sensors will be interrupted and no action will be taken by the programmable logic controller (PLC). This is shown in the "Optical sensor set-up #1" box in Diagram #4. If a bottle has fallen, only the bottom beam will be interrupted and a signal will be sent to the PLC which, in turn, will: 1) switch on the beacon, 2) momentarily open the solenoid valve on the compressed air nozzle (to blow the fallen bottle off of the conveyor), and 3) add to the count of fallen glassware. This is shown in the "Optical sensor set-up #2" box in Diagram #4. One PLC can control *at least* two of the sensing stations.

The purchase and installation of a programmable logic controller, two warning beacons, two solenoid air valves and four through-beam optical sensors would be required to place two sensing stations on a production line. The approximate cost for the components are $860 for the PLC, $148 each for the warning beacons, $49 each for the solenoid valves, and $203 each for the optical sensors. Implementation will also require the fabrication of adjustable mounting brackets (for the optical sensors) which can be created in the company machine shop. An approximate cost for the design and fabrication of the sensor mounting assembly is estimated at $1000. Modifications to the existing compressed air line to allow the use of the solenoid controlled compressed air bottle rejecters would cost an additional $500 per system. Hence, the total installed cost for the fallen bottle sensing system would be $3,566 per production line, or $32,094 for 9 production lines.

The simple payback period can be calculated with the following equation:

Payback Period = (Implementation Cost) / ACS
= ($120,000 + $32,094) / ($398,160/yr) = ($152,094) / ($398,160/yr)
Payback Period = 0.4 years (5 months)

Assessment Recommendation No. 9
Develop Standard Procedures to Improve Internal Yields

Assessment Recommendation Summary

Estimated Cost Savings = $95,753 / yr

Estimated Implementation Cost = $60,881

Estimated Payback Period = 0.67 years (8 months)

Existing Practice

The plant receives unfinished automotive parts from other companies and is contracted to make and attach rubber gaskets onto the different automotive parts. The gaskets are attached to the parts so the parts can be packaged and shipped to the retailers. Workers take the gaskets while they are hot and mold them onto the parts to allow the gasket to cool and solidify. After the gaskets have cooled the parts receive a final inspection before being packed for shipping. If the gaskets have any type of defect or did not mold properly to the part, the rubber gasket is then removed and placed back into the rubber melt to be reused. The part also gets sent back and has to go through the process again. All the gaskets that don't meet standards are recycled and all the parts without gaskets are cycled through the process until they receive an acceptable gasket.

The average worker applies 120 gaskets an hour to the automotive parts and approximately 99 of the gaskets pass the final inspection. The other 21 gaskets are removed, re-melted, and remolded so that they can be re-applied to other parts. Each worker that applies the gaskets receives incentives determined by the average amount of acceptable gaskets that they can attach per day. All the inspection is done by separate personnel to ensure that there are no unacceptable gaskets being allowed to be packaged. Several of the more experienced operators are able to receive much higher incentives than the rest because of their larger acceptance rates. One operator explained that he is able to produce less defects because he realigns the machines before each of his shifts. He was taught how to do this by another operator but there is no company procedure to teach the newer operators how to realign the machines. The experienced workers do not offer to teach all the new operators because they feel it will hurt the incentives that they receive. The operators that realign the machines have an acceptance rate of about 105 out of 120. The operators who don't realign their machine have an acceptance rate of 99 out of 120. The contracted rate the company receives for making and attaching the gaskets is an average of $0.74 per gasket.

Recommended Action

Use the knowledge of the best machine technician to help reduce the internal scrap rate of gaskets for the less experienced operators. Have the technician develop a company procedure for realigning the machines so all the operators can realign the machines before their shifts. The realignment alone will increase the acceptance rate of the gaskets by approximately 6 percent.

The company has a low *shipped* defect rate because it inspects every gasket before packaging and removes all the bad gaskets to be re-melted. However, the *internal* defect rate (defects which occur within the process) was found to be about twenty percent for most operators. The re-melting ensures that there is no wasted material, but if twenty percent of the gaskets have to be removed and re-melted, then twenty percent of the operator's time and the energy required to melt the rubber are wasted.

Anticipated Savings

The annual increased production, API, will be the increased amount of acceptable units per hour that the operators will be able to produce. This can be determined by the following equation:

API = IPR - ATB

where,

IPR = new production possible from increased rate

IPR = NWS x NOS x HPS x DPY x (NPR - OPR)

NWS = number of workers per shift

NOS = number of shifts operating

HPS = number of hours per shift

DPY = number of days per year in operation

OPR = old average production rate, units per hour

NPR = new average production rate, units per hour

IPR = (22) (2 shifts) (8 hours/day/shift) (260 days/yr) (105 -99)(units/hr)

IPR = 549,120 units per year

ATB = annual production lost due to aligning machines before each shift

ATB = NOS x NWS x DPY x TTA x NPR

TTA = time required to align machine each time

ATB = (2 shifts)(22 workers/shift)(260 days/yr.)(0.166 hrs/alignment)(105 units/hr)

ATB = 199,399 units/yr.

Hence, the annual increased production will be:

API = (549,120 units per yr.) - (199,399 units per yr.)
API = 349,721 units per yr.

There will be no additional labor needed to produce these additional units so the cost of the labor per unit will be zero. This will result in an increased profit margin. The profit per gasket will now include the money that was budgeted to go toward the labor of the gasket because the additional gaskets have no labor costs. Estimating the existing profit margin to be 10%, the profit on the additional gaskets was calculated to be 37% because of the absence of labor costs. The annual total cost savings, ACS, will be the additional profit earned from the increased output of gaskets.

ACS = API x PPU x PM
PPU = price received per unit of output
PM = profit margin
ACS = (349,721 units/yr) ($0.74/unit) (37 %)
ACS = $95,753 / yr.

It should be noted that the machine maintenance and energy costs per acceptable part will also decrease and contribute to the above savings. In an effort to be conservative, we have neglected these extra savings.

Implementation

The production lost due to implementation, PLI, will be the time that the production is down for the training of operators and the time the experienced operators need to create the standard operating procedures. The cost of this production time can be determined as follows:

PLI = PDT + TCP

where
PDT = production lost due to down time for training
PDT = DPD x PPD
DPD = number of days production will be down
PPD = production per day

PDT = (2 days) (32,736 units/ day)
PDT = 65,472 units

TCP = production lost from operator working on standard procedures
TCP = NOF x TPR x TWP
NOF = number of operators working on procedures
TPR = production rate for these operators
TWP = time spent working on procedures
TCP = (4 operators) (105 units / hr) (40 hrs)
TCP = 16,800 units

Hence, the production lost from implementation is:

PLI = 65,472 units + 16,800 units
PLI = 82,272 units

The total cost of implementation, ITC, will be equal to the cost of the units lost,

ITC = PLI x PPU
ITC = (82,272 units) ($0.74/ unit)
ITC = $60,881

(The number above is higher than the actual costs because it includes raw material and energy costs which wouldn't be increased during production down time.)

Payback Period = Implementation / API
= $60,881 / $95,753 / yr.
Payback Period = 0.67 years (8 months)

Preventative/Predictive Maintenance (PM)

Introduction

There are many economic analyses which point out the value of PM but they are usually of a complexity and detail to make them useless for the IAC director during a one day audit. These generally fall under the heading of risk management which is important to the manufacturer but difficult to properly assess during a one day audit.

There are, however, sub-categories of PM which can form the basis of useful recommendations and which can be presented in a way likely to provoke management into implementing them. These are ARs which can be related to unwanted shut downs of the assembly/production lines. Savings may be present in terms of reduced energy costs and repair costs from improved maintenance practices , but we expect that the greatest cost savings will result from reduced downtime. If the company cannot (will not) indicate the cost per hour of production downtime it can be easily estimated with normally obtained data, i.e. annual sales, operating hours, labor costs, raw material costs, etc. Examples of costs for downtimes in various industries are summarized in the following table.[7]

Estimated Downtime Costs for Selected Industries

Forest Industries	$7,000/hour
Food Processing	$30,000/hour
Petroleum & Chemical	$87,000/hour
Metal Casting	$100,000/hour
Automotive	$200,000/hour

Questions to Ask

- Are there shutdowns of the production process?
- Are these shutdowns unscheduled?
- What are the duration and frequencies of these shutdowns?
- What are the reasons for the unscheduled stoppages?
- What is the cost/hour of production downtime?

[7]Revelt, Jean. *Evaluating Electric Motors*. Linclon Electric Company, Cleveland, Ohio.

Symptoms/Indicators

This type of recommendation will probably only be identified by discussion with plant personnel as the occurrence of an unscheduled shut-down while you are present is unlikely. Since the shut-downs are usually documented by the line foreman or other management, it is possible to identify the cause of the shut-downs and their duration. The rewards for recommendations which can reduce or eliminate these shut-downs can be reported with some confidence and be logically defended. The scheduled shut-downs should be investigated to see if they would benefit from "quick change" approaches.

Related ARs

Two case studies are included under this heading, but asking questions may elicit an entirely different AR than the two we present here.

- ELIMINATE SHUT-DOWNS OF CONTROLS DUE TO OVERHEATING
- TREND MOTOR TEMPERATURES AND VIBRATIONS LEVELS TO PREDICT MOTOR FAILURE

Assessment Recommendation No. 10
Eliminate Shutdowns of Controls Due to Overheating

Assessment Recommendation Summary

Estimated Productivity Savings = 16 hrs/yr
Estimated Cost Savings = $10,112/yr
Estimated Implementation Cost = $812
Simple Payback Period = 0.09 years (1 month)

Existing Practice and Observation

During the assessment visit, several computer systems "crashed" (shut down) because the internal temperature in the computer control cabinets exceeded the maximum allowable cabinet temperature. There are two computer controls which are most susceptible to overheating shutdowns. Both are located in the Process Control/Computer Room (see Figure 1). One is referred to as the "516 Forming Controller" and the other is the "570 Electronic Commander." According to a plant electrician, these controls shut down whenever the internal temperature in the cabinets exceed 85˚F. When these controls shut down, the associated production line stops. Once the problem is traced to the computer cabinet, the cabinet is opened and a reset button must be pressed. To prevent another shutdown, the doors to the cabinet are left open and fans are placed in the room until the room temperature becomes cool enough to allow the cabinet doors to be closed again. To avoid dust build-up in the cabinets, the doors are closed as soon as the outdoor temperature is low enough for the HVAC system to maintain the desired room temperature.

The minimum shutdown period consists of 15 minutes to re-start the computer and at least another 30 minutes to re-start the production line. In addition, the computer sometimes shuts down during second or third shift when the available staff is not trained to fix the problem. This results in even longer production shutdowns of up to 7 hours. According to a plant electrician, about 16 hours of production line shutdowns were caused by these cabinets overheating in 1995. The cost of lost production when a line is shut down is estimated to be about $632/hr per production line.

This problem has existed during very hot weather since the systems were installed, indicating that the cooling equipment for the room is undersized (no additional heat generating equipment has been added to the room). Common engineering practice is to design cooling equipment to provide the desired room temperatures for 97.5% of the cooling season (i.e., for 2.5% of the cooling hours, a typical system is undersized and will not be able to maintain the desired room temperatures). The existing cooling equipment may have been sized in this manner, neglecting the potential costs in lost production caused by the room overheating.

Recommended Action

Eliminate costly production shutdowns due to overheating computer control cabinets by installing temperature sensors and warning lights on the cabinets. Since the shutdowns are said to occur when the internal cabinet temperature exceeds 85˚F, the sensor can be installed inside the cabinet and wired to a warning light which can be installed on the cabinet exterior (or another, more visually noticeable location). The sensor can be set to send a signal to the warning light when the internal temperature of the cabinet exceeds 80˚F. When this temperature is exceeded, the warning light will flash indicating to the technicians in the control room that the cabinet should be opened in order to prevent a production shutdown.

A more expensive solution would be to install additional cooling equipment to ensure that the room remains cool enough during *all* hours of the year.

In addition to either of the recommendations above, control room personnel or someone on the electrical staff for *all* shifts should be trained on how to get the computer system back on-line whenever a shutdown due to overheating occurs. This will minimize lost production time. A standard operating procedure should be written by personnel on the electrical staff who are presently trained to deal with these problems. This procedure should be presented to all qualified staff who may be in the facility when this problem arises. A list of these staff members, should be attached to the cabinets to minimize time wasted searching for someone who is qualified to correct the problem.

Anticipated Savings

The annual cost savings, ACS, can be calculated as follows:

ACS = ALPT x SLR

where;

ALPT = annual lost production time due to overheated computer controls (for all production lines combined), hrs/yr

SLR = shutdown loss rate, $/hr (per production line)

Thus,

ACS = (16 hr/yr)($632/hr)

ACS = $10,112/yr

Implementation

For each of the two computer control cabinets, implementation of the overheating warning system will require the purchase and installation of a temperature sensor, a warning beacon, a 5 amp relay, and an AC/DC voltage adapter. This system is shown on the following page.

The material costs for these items are shown in the table below. The estimated installation for each system will require about 6 hours at $27.50 per hour, or $165 per system. The resulting total approximated installation cost is $812.

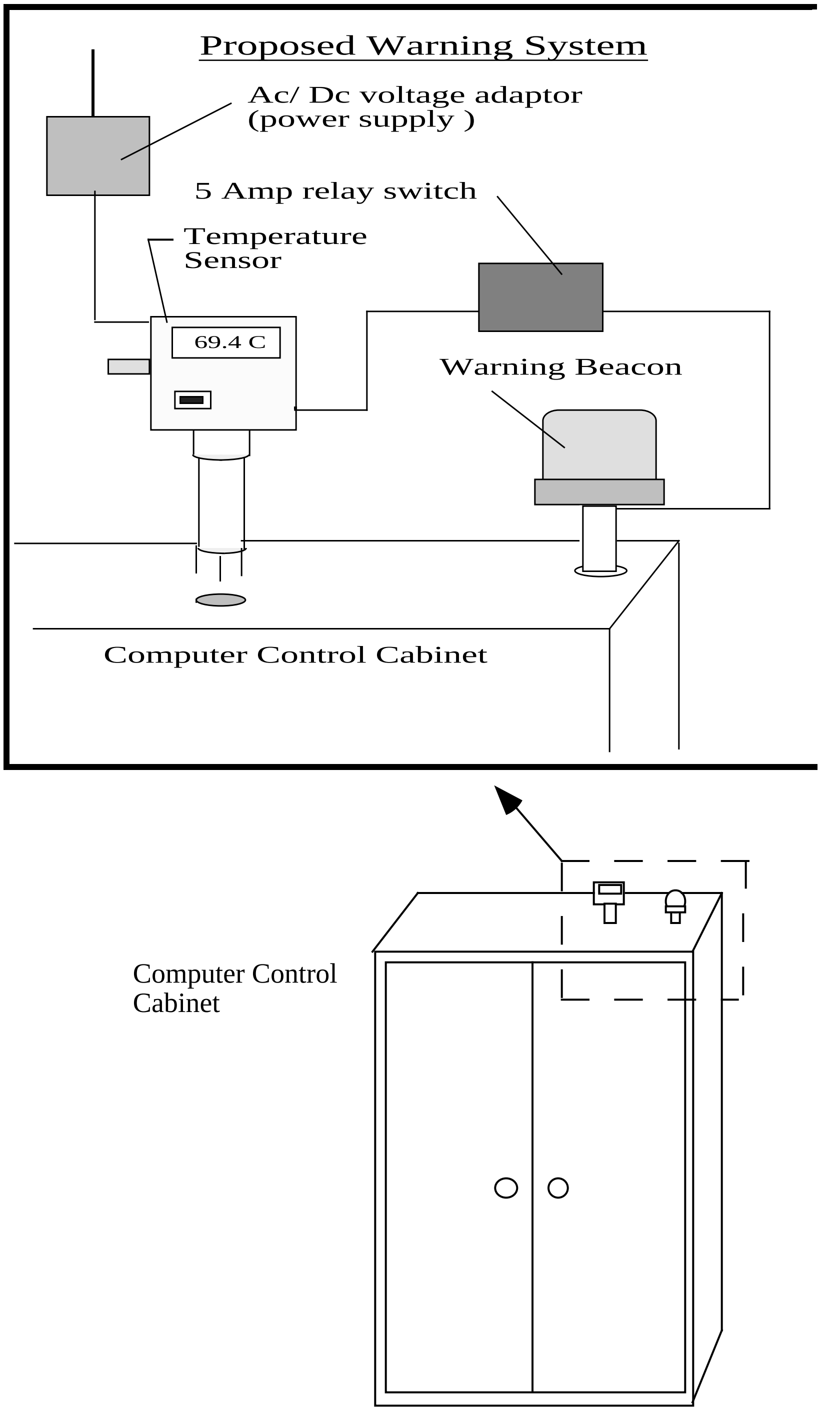
Item Description	Unit Cost	No. of Warning Systems Needed	Total Cost
Temperature Sensor	$115	2	$230
Warning Beacon	$86	2	$172
5 Amp Relay	$15	2	$30
AC/DC voltage adapter	$25	2	$50
Labor (6 man-hours)	$165	2	$330
Total	**$406**	**2**	**$812**

Hence,

Payback Period = (Implementation Cost) / ACS = ($812) / ($10,112/yr)

Payback Period = 0.1 years (about 1 month)

As mentioned previously, there are other alternatives to solving this problem and eliminating costly production shutdowns which occur as a result of overheated computer controls. Other feasible options may include: 1) increasing the cooling capacity of the existing cooling system (install an additional cooling unit), or 2) rearranging the cooling system supply and return air ducts to provide more efficient cooling. These options would be more expensive than the proposed warning system but would likely also result in a return on the invested capital in less than two years. The bottom line is: the control shutdowns are economically avoidable and there are a number of options available.


Proposed Warning System
Ac/ Dc voltage adaptor
(power supply)
5 Amp relay switch
Temperature
Sensor
69.4 C
Warning Beacon
Computer Control Cabinet
Computer Control
Cabinet

Assessment Recommendation No. 11
Begin a Predictive / Preventive Maintenance Program

Assessment Recommendation Summary

Estimated Cost Savings = $21,353/yr

Estimated Implementation Cost = $4,200

Simple Payback Period = 0.2 years (about 2 months)

Existing Practice and Observation

Presently, very little preventive maintenance is performed at the facility due to a stated lack of manpower. As a result, some motors and process equipment were observed to be very dirty and poorly maintained, and motors are repaired only when failure occurs. In addition, motors and process equipment operate in a very hot environment which contributes to shortened component lives and equipment failure rates which are higher than normal . These factors combine to result in unexpected (and costly) process downtimes. Neglecting small motors (conveyor motors, etc.), there are about 20 motors which are critical to production operations, including air compressors, cooling fans, and the furnace air supply fans. The combined ratings of these motors total 3,350 hp.

Recommended Action

Establish a predictive/preventive maintenance program which will include periodically cleaning equipment and taking measurements on critical process equipment which will indicate potential problems and allow the scheduling of maintenance and repairs to a convenient time, thus allowing the avoidance of costly process downtime. An outside consultant can be hired to perform periodic measurements and/or organize and train your staff to perform them.

Anticipated Savings

Cost savings can result from three areas:

1) Reduced un-planned process downtime,
2) Reduced motor rewind costs, and
3) Reduced motor electricity costs.

Savings for each of the above were estimated as follows:

1) Reduced Un-Planned Production Downtime:

According to a survey of maintenance references and consultants, it takes about 8 hours to remove and replace a failed production motor, including: 1) accessing the motor, 2) electrical disconnection, 3) unbolting, 4) motor removal, 5) acquiring the replacement motor, 6) installing and aligning the replacement, and 7) restarting the process line. Depending on the size of the motor, labor union requirements, availability of a replacement motor, and the nature of the production line, motor replacement could take much longer. Using 8 hours per replacement, and assuming there are 3 un-planned motor failures per year on critical process motors, the estimated production cost savings due to implementing a preventive maintenance program is:

Production Cost Savings = (Motor Failures/yr) x (Lost Prod. Time/Failure) . .
. . . x (Cost of Lost Prod.) = (3 failures/yr) x (8 hrs/failure) x ($632/hr)
Production Cost Savings = $15,168/yr

2) Reduced motor rewind costs.

Utility representatives have indicated that in a survey of facilities with no preventive maintenance programs, motor rewinds represented 85% of the total number of motor repairs (on average). After preventive maintenance programs were established, the number of rewinds was reduced to about 20% of the total. It is assumed that similar results can be achieved at this facility.

Since records of motor repairs and costs were not available, the table below was used to obtain an average cost per motor repair for both the existing maintenance methods and after a preventive maintenance program has been established. The *average* cost of a motor rewind for this facility was estimated as:

$$\text{Ave. Cost of Rewind} = (N_{40} \times RWC_{40} + . . + N_n \times RWC_n + . . + N_{800} \times RWC_{800}) / N_T$$

where

N_n = number of motors at the facility with horsepower “n”, no units
RWC_n = estimated cost of rewinding a motor with horsepower “n”, no units
N_T = total number of motors (considered in this analysis) at the facility, no units

Motor Size, hp	Cost of Rewind[8]	Cost of Reconditioning[9]	Recondition vs. Rewind Premium
40	$1,020	$340	$680
60	$1,295	$431	$864
75	$1,500	$500	$1,000
100	$1,610	$536	$1,074
125	$1,820	$606	$1,214
250	$2,915	$971	$1,944
800	$7,735	$2,578	$5,157

The *average* cost of reconditioning (bearing replacement, alignment, cleaning, varnishing, etc.) a motor for this facility was estimated similarly. The results for both are:

Estimated Average Cost of a Motor Rewind (for this facility) = $2,258/rewind
Estimated Average Cost of Reconditioning a Motor (for this facility) = $752/recondition

Then,
Existing Average Repair Cost per Motor = 0.15 x $752/recondition + 0.85 x $2,258/rewind
Existing Average Repair Cost per Motor = $2,032/repair

and after a preventive maintenance (P.M.) program is established,

Average Repair Cost per Motor with P.M. = 0.80 x $752/recondition + 0.20 x $2,258/rewind
Average Repair Cost per Motor with P.M. = $1,053/repair

For four motor repairs per year, the existing repair costs are estimated as:

Existing Repair Costs = (Motors Repaired/yr) x (Average Repair Cost)
Existing Repair Costs = (4 motors/year)($2,032/motor) = $8,128/yr

and the repair costs after implementing a P.M. program are estimated as:
P.M. Repair Costs = (Motors Repaired/yr) x (Average Repair Cost)
P.M. Repair Costs = (4 motors/year)($1,053/motor) = $4,212/yr

8 Nadel, S., Shepard, M., Greenberg, S., Katz, G., and de Almeida, A., *Energy Efficient Motor Systems, p. 264.*
9 Assuming the cost of rewinding a motor is 3 times that of reconditioning a motor.

Hence, the annual reduced motor repair costs are estimated as:

Reduced Repair Costs = Existing Repair Costs - P.M. Repair Costs

Reduced Repair Costs = $8,128/yr - $4,212/yr = $3,916/yr

3) Reduced Motor Electricity Costs.

Although it is difficult to accurately estimate motor system efficiency improvements which are achievable in your facility without performing a complete survey of the motor systems, including voltage, power, vibration, and temperature measurements, we recognize that efficiency improvements would most likely occur as a result of implementing a P.M. program, and will assume these savings to be 2%. Cases have been documented where the efficiency improvement resulting from improved maintenance practices was as high as 10-15%. Among other factors, these savings could result from:

- Improved lubrication
- Proper alignment and balancing
- Correction of voltage imbalances
- Reduced motor temperatures
- Reduced efficiency losses caused by motor rewinds and failures
- Improved drive system performance

Energy savings are estimated as:

Energy Cost Savings = (Total hp of Motors Considered) x (Load Factor) x (Operating Hours) . .

. . . x (Percent Savings) x (0.746 kW/hp) x (Elec. Usage Cost)

= (3,350 hp) x (0.75) x (8400 hr/yr) x (0.02) x (0.746 kW/hp) x ($0.0308/kWh)

= (314,887 kWh/yr) x ($0.0308/kWh)

Energy Cost Savings = $9,699/yr

Total Cost Savings:

The total estimated annual cost savings provided by instituting a preventive maintenance program for your motor systems is:

Total Cost Savings = Production Cost Savings + Reduced Repair Costs + Energy Cost Savings

Total Cost Savings = $15,168/yr + $3,916/yr + $9,699/yr = $28,783/yr

Implementation

The costs of implementing a preventive maintenance program were estimated as follows:

1) **In-house Labor:** Estimating that it would require 2 hours of an electrician's time per month per motor to perform preventive maintenance procedures, the in-house labor costs would be (1 hrs/month/motor) x (20 motors) x (12 month/yr) x ($25.96/man-hour) = $6,230/yr.

2) **Materials:** A vibration meter and temperature probe can each be purchased for about $1000 and $200, respectively. The electrical instrumentation required should already be a part of the existing instrument supply. Additional material costs for items such as filters and lubrication will be greater than normal initially, but it is assumed that over time these costs will be negligible in comparison to benefits resulting from reduced repair costs and increased operating efficiencies.

3) **Consulting Costs:** It is assumed that a preventive maintenance consultant will be required to provide initial support and training for the program, then provide on-going inspections bi-annually. The initial training is estimated to require 5 days at $600/day, for a total of $3000. The bi-annual inspections would each require one day and, together, would cost $1200/yr. The consulting rate is about $600 per day, and about 30 motors can be diagnosed per consulting day.

The above costs are of two types: 1) initial investment, and 2) continuing investment. The continuing investment is estimated to be $6,230/yr + $1,200/yr = $7,430/yr and the initial investment is estimated to be $3,000 + $1,200 = $4,200. Subtracting the continuing investment from the total cost savings yields:

Net Cost Savings = $28,783/yr - $7,430/yr = $21,353/yr

The simple payback period for implementing a motor preventive maintenance program would be:

Payback = ($4,200) / ($21,353/yr) = 0.2 years (about 2 months)

Labor Optimization

Introduction

Labor cost saving opportunities arise when worker's **Time or Skills Are Under-Utilized**. Many factories have operations that have remained unchanged for decades. Workers are performing tasks better performed by automated equipment, such as inspecting or packaging. Some are being asked to move product excessive distances, wasting time and labor dollars. Ineffective production leads to a disinterested, discouraged and inefficient work force. Workers perform less than ideally when (they feel) their efforts have little or no effect on the result. Examples of this include unclear definitions of defects, duplicative inspection, and equipment that goes out of adjustment as soon as it is corrected. In order to apply new technologies, workers need to be trained in their operation.

Training of the existing work force can meet company's needs without the expense of hiring of new personnel. Manufacturers sometimes have idle workers because work rules don't allow them to perform different tasks. It is not uncommon to find manufacturers that are not keeping up with maintenance, because the maintenance crew is busy "putting out fires"; yet other workers have time to spare. Some of these firms are even in a hiring mode, intending to introduce more skilled labor while existing personnel are under-utilized. This is particularly troublesome when the firm does not need full time help. In these cases, many companies will run overtime shifts to meet production levels.

Development of **Standard Operating Procedures** will allow manufacturers to demystify the process/procedure and train or cross-train existing personnel to perform needed operations efficiently. Particular attention should be paid to the employee who is an "artist" or an "expert". The existence and acceptance of this practice is a guarantee of variance in production, and an obstacle to training personnel. For example, a factory that had "expert" set-up men who took as much as eight hours to get a process running acceptably. When asked what the particular settings were, they responded that there were no dials for the settings, and those settings were not prescribed, but adjusted by "feel." After the set-up was standardized and the company conducted training courses, other workers were able to set up the process in half the time, markedly increasing the yield of the production line.

Counterproductive **Incentives** have also been a culprit in the effort to optimize labor. Arguments about which end of the line produced a defect, and incentives that encourage an employee to keep "secrets" of production to himself/herself are common. Elimination or modification of the incentive in doubt will allow all workers to share a common goal, increased quality production, and encourage sharing of successful experiences. Piece-work is a particularly insidious danger. A manufacturer of cast steel valves for the nuclear power industry had three separate operations performed on the part before checking to see if the casting was acceptable. The reason? The machinists got paid for piece-work. If these machinists had only worked on good castings, the production rate of the factory would have increased dramatically, reducing the labor cost, and therefore the overall cost of a piece. Most workers, if given the proper information and tools, would prefer to produce a quality product.

Questions

- What percentage of the cost of production is labor? Direct / Indirect?
- What is the pay scale?
- What is the pay premium for second and third shifts?
- Do you run overtime due to the lack of skilled personnel?
- What is the cost of overtime?
- Is this a union shop?
- Do you ever work overtime to meet production goals? Why?
- Are you lacking labor in a particular skill?
- Are you keeping up with preventative maintenance?

Indicators/Symptoms

- Idle workers, machines, or tools
- Ineffective production, or operations
- Excessive transportation or motion (walking, etc.)
- Excessive hand labor

Related ARs

- INSTALL AUTOMATED EQUIPMENT
- ELIMINATE SHIFT WORK
- ELIMINATE/REDUCE OVER TIME BY TRAINING OR CROSS-TRAINING EMPLOYEES
- INTRODUCE JOB SHARING (TRAINING)
- SUBCONTRACT WORK
- ELIMINATE/MODIFY INCENTIVE PROGRAM
- DEVELOP STANDARD OPERATING PROCEDURES TO REDUCE LABOR COSTS

Assessment Recommendation No. 12
Install Automated Glassware Packing Equipment

Assessment Recommendation Summary

Estimated Cost Savings = $1,109,432/yr

Estimated Implementation Cost = $1,600,000

Simple Payback Period = 1.44 years (17 months)

Existing Practice and Observation

Various grades (qualities) of glass are sold, with the quality depending on the customer's standards. The following table is a breakdown of the percentage of total production for each glass quality grade at this facility during the month prior our assessment, including the percentage of bottles packaged for each grade.

Selection (Grade)	Percent of Sales	Percent Packaged
A+	0.17	49.19
A	0.55	46.70
B+	22.30	59.44
B	41.49	57.08
C+	1.66	71.31
C	33.19	67.38
C-	0.64	70.59
Totals	**100%**	**61.3%**

Presently, 100% of the glassware exiting the Lehrs is manually inspected and packed. According to management personnel in the quality assurance department, glassware requiring a grade quality of "B" or lower could be packaged by automatic packaging machines--this is the method used in some other cosmetic glassware manufacturing facilities. According to the table above, about 77% of the products sold during the month prior to our assessment could have been packaged using an automatic packing machine.

The present actions of each inspector/packer include:

1) removing the glassware from the conveyor,
2) examining the glassware for small cracks by holding it in front of a light at various angles,
3) placing the good pieces in boxes for shipping and the rejected pieces back on the conveyor to be dumped onto the cullet collection piles in the basement,
4) taping or gluing the filled boxes shut, and
5) retrieving new boxes and packaging materials.

Because many of the defects are very small and would be difficult to consistently and reliably detect automatically using optical sensors, 100% manual inspection is believed by management to be a "necessary evil" to ensure that only quality products are shipped to customers. However, the *inspecting* process occupies less than 50% of the time of an inspector/packer.

Almost half of the company's employees work in the cold room inspecting and packaging operations (289 out of 600 employees). According to management personnel in the quality assurance department, inspector/packers are assigned to each production line according to the speed of the production line. It is estimated (by management) that each person can inspect 22 to 25 pieces per minute, and the typical production line has at least 4 inspector/packers working at a time. As many as 7 inspector/packers at a time are assigned to the faster lines.

Furnace #7 and the four connected production lines are used primarily to produce the high volume/lower grade (quality) products which would be best suited for automatic packing. In addition, plans have been made to increase the capacity (tons/day) of furnace #7 in the near future, making the installation of automatic packers even more attractive

Recommended Action

Install automatic glassware packaging machines on the Furnace #7 production lines.

Since the small nature of many of the common defects are thought to necessitate manual inspections, **the value of the inspector/packer's time should be maximized by using them primarily to inspect glassware.** With a case packer installed, the workers on the conveyor line will be able to devote most of their time to the valuable inspecting process.

Anticipated Savings

This analysis includes the following assumptions:

- Four packaging machines will be installed, one on each of the #7 furnace production lines. This assumption is based on installing the packing machines on the lines which produce the high volume/lower quality glassware. Of course, ***only one machine should be installed initially to allow a performance evaluation and design improvement period. After the initial system has been properly adjusted and has proven its worth, the remaining machines should be installed.***

- Each packaging machine will allow the re-assignment of two laborers per shift, for four shifts. This is viewed to be a conservative assumption, based on interviews with management in the quality assurance department and observations during our on-site assessment. More than 50% of the inspector/packers' time is presently spent performing actions associated with packaging. The typical number of inspector/packers presently working on each production line is 4. It is assumed that a properly designed packaging machine will be capable of eliminating at least half of the present labor efforts (or nearly *all* of the present packaging labor), or 0.5 x 4 workers/line = 2 workers/line. ***Based on previous experience with similar packaging equipment in similar applications, personnel in the quality assurance department at the facility felt that a reduction from 7 to 3 workers on one line would be reasonable.***

- There are approximately 6 shape changes per production line per month, and each shape change will require the packaging machine to be re-adjusted. According to manufacturer's literature, each re-adjustment will require 30 minutes of a skilled operator's time. Adjustments will be necessary when the number of pieces per box, layers per box, piece shape and size, or box size changes.

- The average annual earnings for an inspector/packer is $30,000 and, with an overhead rate of 35%, the annual cost to the company for each inspector/packer is 1.35 x $30,000/yr = $40,500/yr. Also, the equivalent hourly rate of a skilled packing machine set-up technician is assumed to be $25.96/hr, based on $40,000/yr with a 35% overhead rate.

The annual cost savings, ACS, achieved by installing automatic packaging equipment will be due to avoiding labor expenses which are required when the products are packaged manually. These savings were estimated as follows:

ACS = NP x [LE x NS x CPL - MSC x (12 months/yr) x ST x THR - MOC]

where

NP = number of automated packers to be installed, no units

LE = laborer equivalence for each automatic packer (number of laborers it would take to perform the work of one automated packer), units = people/line/shift

MLR = labor required for operating a packing machine, units = people/line/shift

NS = number of shifts during which the packer would be used, units = shifts

CPL = annual cost per laborer, units = $/yr/person

MSC = monthly shape changes per production line, units = changes/month/line

ST = packing machine set-up time per shape change, units = hr/change

THR = hourly rate for a packing machine set-up technician, units = $/hr

MEC = annual electric operating cost for a packing machine, units = $/yr

According to manufacturer's information, each machine requires a maximum of 10 kW of electric heat for the hot-melt box closing system and 50 cfm of 100 psig compressed air. During normal operation, the electric heaters are on about 50% of the time. In addition, manual operation of a packing machine is estimated to take 25% of a laborer's time (for keeping the machines loaded with cardboard and glue, clearing an occasional jam, etc.). The annual electric operating cost for each packing machine, MEC, may be estimated using the following equation:

MEC = [KW x UF + V_f x HP x K] x [EDR x (12 months/yr) + HRS x EUR]

where

KW = rating of electric heaters, no units

UF = usage fraction for electric heaters (fraction of time operating), 0.50 (no units)

V_f = volumetric flow of air to a packing machine, scfm

HP = power required for a centrifugal compressor to produce compressed air at 100 psig, 0.23 hp/scfm

K = conversion constant, 0.746 kW/hp

HRS = annual hours of operation, 8400 hrs/yr

EDR = average cost of electric demand, $10.39/kW-month

EUR = average cost of electricity usage, $0.0308/kWh

Substituting the appropriate values,

$$MEC = [\ (10)(0.50) + (50)(0.23)(0.746)\ ] \times [\ (10.39)(12) + (8400)(0.0308)\ ]$$
$$= [\ (163 \text{ kW-month/yr})(\$10.39/\text{kW-month}) + (114{,}064 \text{ kWh/yr})(\$0.0308/\text{kWh})\ ]$$
$$= [\ (\$1{,}694/\text{yr}) + (\$3{,}513/\text{yr})\ ]$$
$$MEC = \$5{,}207/\text{yr}$$

Thus, the estimated annual cost savings can be calculated as follows:

$$ACS = NP \times [\ (\ LE - MLR) \times NS \times CPL - MSC \times (12 \text{ months/yr}) \times ST \times THR - MEC]$$
$$= (4)[\ (2 - 0.25)(4)(40{,}500) - (6)(12)(0.5)(25.96) - (5{,}207)\ ]$$
$$= (4)[\ (\$283{,}500/\text{yr}) - (\$935/\text{yr}) - (\$5{,}207/\text{yr})\ ]$$
$$= (4)[\ (\$277{,}358/\text{yr})\ ]$$
$$ACS = \$1{,}109{,}432/\text{yr}$$

Implementation

Case packers are available which can perform all of the following operations:

- construct the boxes,
- organize the inspected bottles into the desired grid,
- include corrugated spacers between the glassware,
- pack the glassware in the boxes in single or multiple layers,
- glue or tape the box closed, and
- eject the packed box onto a finished goods conveyor.[10]

Case packers are commonly used in the glass container and cosmetics industries and machines are available which have the capability of being used for a wide range of products. Adjustability is required for this application due to the variety of sizes and shapes of glassware which are manufactured on each production line.

The conveyors which presently extend from the Lehr exits to the opening of the cullet trenches will most likely need to be replaced or supplemented by conveyors designed to properly feed the automatic packing machine. This additional expense has been considered and is included in the estimated implementation costs.

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[10] Supermatic Package Machinery Inc., Fairfield, NJ, (201)575-6350.

Manufacturers of case packers[11] and conveyor systems[12] which are commonly used in the cosmetics industry were contacted. Each company will custom design their machinery to fit a specific customer's needs and will test their equipment using the customer's products before shipping the equipment to the customer. Installation of the equipment can also be performed by technicians from the equipment vendors. Estimates of implementation costs were obtained from equipment manufacturers, based on descriptions of the existing conditions at this facility.

Installed cost of a fully adjustable case packer capable of packaging glassware in multiple layers of 12, 24, 36, or 48 bottles per layer was estimated to be about $350,000. The installed cost for the conveyor system was estimated to be about $50,000. So the installed cost per line will be about $400,000 and the total cost for installing the packaging systems on 4 production lines would be about $1,600,000. The simple payback period would be:

Payback = (Imp Cost)/(Cost Savings) = ($1,600,000)/($1,109,432/yr) = 1.4 yrs (17 months)

Automatic inspection/rejection methods should also be considered when designing the new packaging and conveyor system. This could provide additional savings by reducing the manual labor required for inspecting, requiring manual inspections only for detecting small scale defects which can't be detected automatically. By using a conveyor system which takes the rows of glassware exiting the Lehr and removes them in single file lines, optical inspection systems could be used to *automatically* :

1) reject glassware with large defects. According to data obtained from the quality assurance department, about 40% of the rejects have large scale defects which would be detectable by optical inspection devices.

or

2) for the products with lower quality requirements, determine if containers are acceptable.

Savings and implementation costs for automatic inspecting have not been considered in this recommendation.

[11] Supermatic Package Machinery Inc., Fairfield, NJ, (201)575-6350.
[12] Garvey Corporation, Blue Anchor, NJ, (800)257-8581.

Assessment Recommendation No. 13
Install Magazine Between Machines to Reduce Costs

Assessment Recommendation Summary

Estimated Cost Savings = $211,704 /yr.

Estimated Implementation Cost = $14,690

Simple Payback Period = 0.07 years (less than one month)

Existing Practice and Observation

Presently the process of assembling light bulbs is performed by four workers and two machines. The first step in the assembly of the light bulbs is feeding the materials into machine A by worker number 1. This machine then takes the materials needed to assemble the mouthpiece of the light bulb and attaches the mouth piece to the light housing. The output from machine A is then stocked on pallets and transferred to a temporary storage area by worker 2. The bulbs are taken to the storage room because machine A has a higher output rate than machine B and an overflow supply of bulbs will begin to develop between the two machines. The semi-finished products remain in this area until worker 3 transports them to machine B where they are loaded into the machine by worker 3. Machine B then finishes the product and packages it for sale. Once the product is finished by machine B, the fourth worker transfers the light bulbs to the pallets and takes the pallets to the finished product storage area.

The production line is in operation for about 4992 hrs / year and machine B is in operation for all of this time. Machine A is in operation for about 95% of the production operation time (based on interviews and observations). Machine A can operate at an output level of 5.72 units/minute and machine B can operate at 5.2 units/minute. When both machines are operating at full capacity, an excess of unfinished inventory is created by machine A. For this reason, machine A is periodically shut down while machine B reduces excess inventory. Presently, about 5% of the bulbs received by Machine B are defective.

Recommended Action

Replace the present process of transporting the light bulbs from machine A to the storage area and back to machine B by linking the two machines together. The linkage would consist of a magazine between the two machines that would automatically shut down the first machine when the storage area in the magazine exceeded 100 light bulbs and automatically turn it back on when there are only ten light bulbs left in the magazine. This will compensate for the different production rates of the two pieces of machinery. The installation of the magazine will reduce labor requirements of this operation by eliminating the need for the two workers who are presently required to transport the light bulbs between machines. In addition, the defects which occurred from the extra packing and transportation of the bulbs will be reduced.

Workers estimated that less that one percent of the light bulbs produced by machine A are defective. Then that at least 80% of the defects come from either the transportation process or removing the bulbs from the machine. There will also be no more need for the temporary storage area that was previously required to house unfinished bulbs, freeing that area for other uses.

Anticipated Savings

The annual reduction of man hours savings, AMHS, is the reduction of two workers that are needed to work the production line.

AMHS = (MPLB - MPLA) x HRS x CPH

where

HRS = annual hours of operation, 4992 hrs/yr.
CPH = cost per hour for workers (including fringe), $19.47
MPLB = workers per line before implementation, 4
MPLA = workers per line after implementation, 2

AMHS = (4 - 2) x (4992 hrs/yr.) x ($19.47 /hr)
AMHS = $194,388 /yr.

The annual savings from reduction of defects, ADS, is the savings seen from the decrease of the defect rate from the estimated present amount of 5% to about 2%. This is possible due to the replacement of the 4% defects rate caused by the intermediate transportation with an estimated 1% defect rate caused by the magazine.

ADS = UPY x CPU x (ODR - NDR)

where

UPY = units produced per year, 1,560,000 bulbs
ODR = old defect rate, 5%
NDR = new defect rate, 2%
CPU = average value per unit (bulb), $0.37

ADS = (1,560,000 bulbs/yr.) x ($0.37/bulb) x (0.05 - 0.02)
ADS = $17,316 /yr.

The total annual cost savings, ACS, is then due to the sum of the reduction of man hours savings and the reduction of defects savings, and can be calculated with the following equation.

ACS = AMHS + ADS
ACS = $194,388 /yr.+ $17,316 /yr.
ACS = $211,704 /yr.

It should also be noted that there will be additional indeterminable savings from the reduction in transportation costs and reduction of storage space that is required. The existing transportation of bulbs to the storage area and back requires equipment that needs to be fueled and maintained daily. This equipment will no longer be required, or may be used for other purposes.

Implementation

Implementation requires the design, construction, and installation of the magazine. The design and construction of the magazine can be contracted to a conveyor manufacturer company and will cost approximately $9,000. The installation of the magazine will require two steps: the arrangement of the machinery and the connection of the magazine, and the respective costs are estimated as $3340 and $2350. Hence the total installed cost would be $14,690.

The simple payback period can be calculated with the following equation:

Payback Period = Implementation cost / ACS
= $14,690 / $211,704
Payback Period = 0.07 years (less than one month)

Assessment Recommendation No. 14
Cross-Train Existing Personnel to Avoid Lost Time

Assessment Recommendation Summary

Estimated Cost Savings = $24,000/year
Estimated Implementation Cost = $10,000
Simple Payback Period = 0.42 years (about 5 months)

Background

The company is a manufacturer of luxury light fixtures. The production is not fully automated and depends on skills of different operators or craftsmen. The sales are about $17,000,000. The sale volume is not very high relative to sales in dollars because the company caters to a niche market. The product is expensively priced. There is only one shift operation at this time and because of special high level skills required the company is not successful in finding people for a possible second shift.

Existing Practice and Observation

The company cannot satisfy all demands of the market. There is a constant backlog on received orders because the lamps are not produced fast enough. Discussions with the supervisor revealed that the company looses approximately 5 work days every year when employees are absent due to sick leaves or other reasons. Normally, when somebody takes a sick day or other leave of absence there is enough work to be finished that it doesn't cause any problems. However, there are days (on the average 5 a year; reflection of occasional slower production caused by the lack of trained personnel is calculated into this number) when the production has to be diverted into auxiliary work or workers are asked to go home because the key employee is missing and the job cannot be finished.

Recommended Action

Cross train all the employees in different aspects of the manufacturing process so there is always somebody available with the skills necessary to keep the production running. We propose that the company provides this training of employees on a regular basis to keep all the operators up to date all the time. Rotation of the operators should be established as a practice. We assume that the training can be accomplished in after work hours, thus without any loss to production but with pay to the employees.

Anticipated Savings

Realized Profit = $10,000/day

Labor Rate = $50.00/hr

Cost to the Company = ($50.00/hr) x (1.4 fringe benefit) = $70.00/hr

(For the purpose of this calculation we consider $50.00/hr rate, since that is the direct cost to the company. Fringe benefits will be paid regardless.)

People Involved = 13

Annual Time Allocated for Training = 1 week

Number of Operators to Be Trained = 10

Cost of Training = (13 people) x (40 hours) x ($50.00/hr) = $26,000/yr

ES = [($10,000/day) x (5 days)] - ($26,000/yr) = $24,000/year

Implementation

There is very little cost associated with the original planning and scheduling of the training. If we estimate the total cost of such activity as $10,000, we believe that it is very conservative number.

Implementation Cost = $10,000

Simple Payback = ($10,000) / ($24,000) = 0.42 years = (approximately 5 months)

CONCEPTS FOR PRODUCTIVITY ENHANCEMENT

Part II

Decreasing Cost/Piece

Scheduling

Introduction

Scheduling we want to introduce is not a scientific discipline studied by industrial engineers. In one day assessment it would be extremely difficult to be able to collect all the data required for detailed calculation of optimum batch sizes, sequencing of operations, and so on. The calculations involved also demand more time to process and in most cases extensive computer programming is a significant part of such undertakings as well. What we would like to address here is something which can be done in one day visit.

The first type of scheduling recommendations could involve better planning in cases when changeover of certain types are involved. We can use as an example painting or printing operations. Better sequencing of runs from light to dark color can eliminate cleaning operations during color changes. In painting operations it is typically cleaning of the paint guns, in printing houses it would be cleaning of cylinder blankets or spray jets. Since the lighter colors are effected by the darker ones to a large degree, the cleaning operations must be performed very thoroughly and their partial elimination would lead to significant savings.

As the second example of schedule changes within production we can introduce a concept of elimination of waiting for batches of products. If performed in all sequential operations for one part or product, it can free up precious resources of the company. The illustration of this concept is documented by the "Machine Shop Scheduling" case study. In some cases the reorganization of work schedules could be helpful. It would usually involve cases in which the company knows that the market for their product exists. A case like that calls for either speeding up the whole production, which might be quite beyond a scope of one day audit, or adding a new work shift for achieving the desired output per day. Of course, steps like that involve hiring more people and thus are a considerable expense to the company; however, if the potential profit justifies the expansion, we feel it is a step in the right direction.

Scheduling and Just-in-time are closely related. The purpose of scheduling of all production runs is to produce parts as cheaply as possible, keep the work load more or less constant, and deliver parts quickly to their destination. While scheduling production runs in order to keep a constant throughput is a complicated matter beyond the scope of a one day assessment, the basic ideas related to scheduling in a JIT environment can be evaluated and conveyed by an assessor within the time frame given.

Just-in-time is usually associated with lead times for a manufactured product. If we extend the concept, JIT can be applied in between different production steps. At this point the close relationship to traditional scheduling of production runs becomes obvious. To make useful and quick analysis of a process it is possible to use ratio analysis.

The first ratio is production lead time to work content. Of course, the ideal ratio is 1:1, in other words to get the part, we have to wait only the time which is necessary to produce that one part. That is ideal and for practical purposes we would be satisfied with ratios in single digits. But we can see quite commonly ratios of 1:100, even 1:1000. Sometimes the lead times are in weeks, but the actual time when the part is worked on can be counted in minutes, at the most in hours. As an illustration we can use an example from a plastic parts manufacturer. The lot consists of 10 000 parts which have to be extruded. After extrusion there is a trimming operation. Trimming takes just three seconds but because of the lot arrangement it takes almost eight and a half hours before the last part is trimmed. In other words, the lead time for the next operation is just that long. If the trimming machine is moved to a physical proximity of the extrusion machine, the lead time could be shortened to the time necessary for the process. This example also shows that there is not a magic easy way to classify the problems of productivity since the same example could be used in the "Floor Layout" section.

The second ratio is speed of the process to sales rate, or, instead of the sales rate of the finished final product, we can consider a component at the next manufacturing operation. This is not an average output rate, which also includes setup times, down time, breaks, etc.. The ratio applies to a single part only. If we are talking about two operations within the process, then our target ratios are the times that these two processes take.

The third ratio is number of pieces to number of work stations or operators in a line segment. Every idle piece, every pallet with parts waiting or being delivered long distances raises this ratio. This ratio can also be used to analyze office work. We will illustrate the concept using the case from the machine shop. There are one hundred different lots to be processed and ten machinists to do the job. Consequently, ninety lots are idle waiting their turn while only ten are worked on. The ratio is 10:1 and indicates that a better scheduling of jobs is necessary. If the average job takes five weeks when the ratio is 10:1, the average would be only one week if the ratio were shortened to 2:1. That would mean only two job lots per machinist. At the shorter ratio each actual job processing takes the same amount of time as before, but waiting time is cut five times.

There are specific manufacturing processes, where long times involve annealing, melting, or exposure for a specific time to a specific substance. During those times the piece is only indirectly worked on and the lead time is long. A good example could be baking of enamel paints. The ratio differences with and without baking are enormous. On the other hand, there is obviously an opportunity to shorten the bake time. That is not to say that we perceive such a change as trivial. However, the ratio gives us a hint of where a significant potential for a reduction in time for the manufacture of a painted part exists. The reduction might not be possible if the process cannot be modified or replaced with equally satisfying treatment but shorter in duration.

Questions to Ask

- Do you have operations where different sequencing of job would eliminate some non-value added operations, such as cleaning, setups etc.? If the answer is YES, identify these operations. What would be the right sequencing to eliminate these operations?
- Do you have large size batch operations?
- What are typical leading times for your products? ("product" could also be object for the next operation)
- What is the company's operating schedule (including vacations, number of shifts, overtime)?
- Ask questions about ratio indicators.
- Identify processes or operations which you feel are more costly than they should be.
- Do you use push or pull system in your manufacturing process?
- If overhead cost is too high, why?
- Does your product experience multiple handling or multiple inspections?

Symptoms/Indicators

Excess inventory and especially in-process inventory are good indicators that it should be possible to reduce both by better scheduling. A lot of movement of parts using fork lifts is an indication of either bad scheduling, poor floor layout, or both. The companies should be concentrating on using a pull system (production is based on *orders received*). Push systems (*speculative* production, where items are pushed through production) are most likely inefficient.

Related ARs

- OPTIMIZE LOT SIZES TO MINIMIZE INVENTORY CARRYING COSTS
- SCHEDULING PRODUCTION RUNS TO MINIMIZE SET-UP TIMES
- ADD A SECOND PRODUCTION SHIFT

Assessment Recommendation No. 15
Optimize Lot Sizes to Reduce Inventory Carrying Costs

Assessment Recommendation Summary

Estimated Cost Savings = $61,524/year

Estimated Implementation Cost = None

Simple Payback Period = Immediate

Background

The machine shop performs all machining operations for steel pinion gears. The company then sells the gears to A gear box manufacturer. The company also makes other gear sets which are sold to different gear box manufacturers but also as individual units from a catalogue. The sales of the company are $27,500,000.

Existing Practice and Observation

The company has a one week lead time for any size gear manufactured. The manufacturing of one gear consists of a hobbing operation from raw material and then drilling and boring operation for the bore. The shop processes forty gears per lot. The value of these forty gears varies, based on the size, but on the average it is estimated to be $11,000. It takes twelve minutes to drill and bore each gear, which totals eight hours, one shift, to process all forty. The lead time for the fortieth gear is apparently 480 minutes, but the real machining time is only twelve. Since the gear which is machined right now was at one point the fortieth in the waiting line, it, too, had to wait forty minutes for twelve minutes of machining. From that we see that the waiting time of 480 minutes is valid for all the gears. 480 minutes represents one shift and we certainly can say also one banking day. On the average the company processes 370 lots of gears per year.

Recommended Action

The recommended action is based on the idea that in-process inventory costs the company money. Since the boring of the gear takes twelve minutes, and the operator does not have to attend the machine during those twelve minutes, he can pick up the next gear from the previous operation and have it ready when the gear on the machine is finished. This way the batch operation is completely eliminated.

Anticipated Savings

Value of the batch = $11,000

Since the company processes 370 lots a year and 480 minutes represent one day in terms of banking hours, an $11,000 batch is around the whole year as in-process inventory which costs the company at least the money lost to other investments. If we consider a conservative rate of return for the company to be 10%, the loss is:

ES = (Inventory) x (Rate of Return)
ES = ($11,000/yr) x (0.1)
ES = $1,100/year

Implementation

There is not a direct implementation cost. The requirement is just to change the routine of the operator.

Simple Payback = Immediate

Conclusion

Although the savings are not too much in this case, it is important to realize that the recommendation deals only with one case of in-process inventory, which was the most obvious and did not require any investment, changes in layouts of the plant, etc.. On the other hand if all steps of all operations are looked at and approached in a similar fashion, the savings generated will be significant. Another benefit of this approach is that each piece is inspected individually and not as a part of a batch. Therefore, should a problem occur, the corrective action can be taken immediately, making rework necessary for just one piece instead of many.

Assessment Recommendation No. 16
Add a Second Production Shift

Assessment Recommendation Summary

Estimated Cost Savings = $445,690/yr.

Estimated Implementation Cost = $9,107

Simple Payback Period = less than one month

Existing Practice and Observation

Mirrors are purchased and shipped to the plant in crates with either a polished edge finish or raw edge finish. The manufacturing process begins by cutting the mirrors into the desired shapes and sizes. At this point the mirrors are either framed or decorated by a variety of methods. The majority of the manufacturing process consists of the decoration of the mirrors which has to be performed by hand. The two main types of decoration that are used on the mirrors is silk screening and attaching pictures or designs to the back of the mirror. After production is complete the products are then packed and shipped directly to the customers. The manufacture has not been able to meet the excessive demand for his product while operating only one shift. The majority of workers are bussed in by the company from a neighboring city which as an abundant supply of men and women willing to work for minimum wages.

Recommended Action

The recommended course of action is to add a second operating shift to the production in order to meet the excessive demand and maximize profits. The operation of a second shift will allow the company to decrease the cost per product which can increase the profit per product or allow the product to be sold by the company at a lower price to gain a larger share of the market. The fixed cost that had is being absorbed by the production of only one shift will now be able to be split up between the to shifts. This will allow the overall percentage of the non-production related expenses to decrease on a per mirror basis. One concern of management was the ability to maintain an acceptable production rate on the second shift and avoid internal theft while management was not there to watch over the operation. There will be extra management hired to supervise the operation on the second shift and additional security measures taken to deter internal theft.

Anticipated Savings

The annual total benefit from the extra profit, ATS, can be calculated as the amount of profit generated by a second shift minus the operating costs:

ATS = (TAS x PVA x APP) - (ASC + AGC)

where;

TAS = total annual sales
PVA = percentage of value added to the product
APP = annual percentage of profit
ASC = annual cost of the night supervisor (including benefits)
AGC = annual cost of the security guard (including benefits)

Hence the additional profit will be,

ATS = ($13.5 million)(40%)(10%) - ($59,450/yr. + $34,860/yr.)
ATS = $445,690/yr.

Implementation

The implementation of this assessment will require the addition of a night supervisor to monitor the second shift and the installation of a security system. The night supervisor will be required to be supervise all the operations of the second shift and maintain an acceptable production rate. The security system will cost $9,107, which includes the purchase and installation of a walk through metal detector. The security system will be monitored by one security guard. Only one system will be required at the main entrance because that is the only entrance the employees can use. The premium costs for labor on the second shift were neglected due the amount of available labor. The total implementation cost will be $9,107.00.

Payback Period = Implementation cost / ATS
= $9,107 / $445,690/yr.
Payback Period = 0.02 years (less than one month)

Purchasing

Introduction

Improvements in raw material and component purchasing procedures can lead to significantly reduced purchasing, in-house material handling, and inventory carrying costs. For the IAC program, the most likely recommendations related to purchasing will involve cases where extensive efforts handling purchased goods are *observed.* In these cases, it may be possible for the IAC client to work with their suppliers, negotiating delivery methods or schedules which will reduce the in-house costs.

During the plant assessment, raw material and purchased component inventories should be surveyed, paying close attention to any in-house labor efforts associated with handling those materials. If significant labor efforts are spent measuring materials, it may be possible to negotiate with material suppliers to provide their products in premeasured quantities, allowing a reduction of in-house labor. If existing delivery schedules require significant floor space and labor efforts for handling raw materials, it may be profitable to switch to a just-in-time delivery schedule. Finally, if the usage volumes for a raw material are large but deliveries are small and frequent, it may be beneficial to purchase the materials in bulk to receive volume discounting. In this case, the bulk discount would have to be greater than the increased carrying costs incurred due to the requirement to house more raw materials at the manufacturing facility at one time.

Questions to Ask

- How often are raw material deliveries received?
- Are raw materials delivered based on the supplier’s convenience or planned needs at your facility?
- Inventoried quantities and values of raw materials?
- How long do raw materials or purchased components remain at your facility before they are used?

Symptoms/Indicators

- Large amounts of time/labor spent mixing, measuring, or unpackaging raw materials
- Large volumes of raw materials or purchased components in inventory
- Labor efforts spent transporting raw materials or purchased components (multiple transportations of raw materials and purchased components occur because purchased goods are not received Just-In-Time)

Related ARs

- RECEIVE RAW MATERIALS OR PURCHASED COMPONENTS ON A JUST-IN-TIME BASIS TO REDUCE INVENTORY CARRYING COSTS
- RECEIVE RAW MATERIALS OR PURCHASED COMPONENTS ON A JUST-IN-TIME BASIS TO REDUCE MATERIAL HANDLING COSTS
- ORDER RAW MATERIALS IN CUSTOMIZED PACKAGING TO REDUCE IN-HOUSE MIXING OR MATERIAL HANDLING COSTS
- PURCHASE RAW MATERIALS IN BULK QUANTITIES TO OBTAIN VOLUME DISCOUNTING
- SUBCONTRACT WORK TO REDUCE OVERALL COSTS OF PRODUCTION

Assessment Recommendation No. 17
Schedule Wood Chip Deliveries According to Demand

Assessment Recommendation Summary

Estimated Cost Savings = $28,768 / yr.

Estimated Payback Period = Immediate Payback

Existing Practice and Observation

The plant receives deliveries of wood chips by truck from the vendor according to the vendor's schedule. The wood chips are dumped into the storage pit until the cyclone is ready to pull them out of the pit and transport them into the factory for use in the process. The level of the wood chips must be kept within a certain range in order to insure that the trucks are able to unload the chips into the pit and the cyclone is able to transport the wood chips into the factory. When the storage pit becomes over-filled the trucks that are making the deliveries are unable to unload into the pit, creating backups in the delivery schedule. If the level of the wood chips gets too low, the cyclone is unable to pull the chips out of the pit and production must be halted.

The deliveries of wood chips are often made before the pit is able to accommodate them, requiring some of the chips to be removed from the pit. This task is performed by a 90 hp blower which forces the chips up through a silo and into a storage shed. It takes the blower approximately 1.5 hours to remove enough wood chips from the storage pit when it is full. On average, this is done three times a day. The chips are kept in the storage shed until the level in the pit is low enough. The wood chips are then moved back into the pit by an operator with a front-end loader. This operation requires about 15 hours per week.

Recommended Action

Have the supplier deliver the wood chips according to a fixed schedule, based on your company's demand for wood chips. This will eliminate the present need to have the wood chips moved from the storage pit to the storage shed and back to the storage pit. Savings on labor and energy costs will result. The storage shed can still be used as a buffer so if there are any problems with the shipments the extra wood chips could be used until the deliveries are resumed.

Anticipated Savings

The savings from the reduction in man hours, MHS, needed to move the wood chips from the storage shed to the storage pit can be calculated using the following formula,

MHS = HPW x CPO x WPY

HPW = number of hours per week spent moving wood chips

CPO = cost per hour of the person moving the chips (incl. fringe)

WPY = weeks per year of plant operation

MHS = (15 hr/week) x ($31.65 /hr) x (52 weeks/ yr.)

MHS =$24,690 / yr.

The annual electricity savings, AES, can be determined as follows:

AES = HPR x AEL x HPC x HPD x DPY x CPH

HPR = The horse power rating of the blower

AEL = The average electric load on the motor

HPC = The horse power conversion into kilo watts

HPD = The average hours per day the blower operates

DPY = days per year of plant operation

CPH = cost of electricity usage

AES = (90 hp) (.75) (.746 kw/hp) (4.5 hr/day) (360 days/yr.) ($0.05 / kWh)

AES = $4,078 / yr.

The annual total savings, ATS, can be determined using the following equation,

ATS = MHS + AES

ATS = $24,690 / yr. + $4,078 / yr.

ATS = $28,768 / yr.

Implementation and Simple Payback

Since the supplier is heavily dependent on your business and can be persuaded to begin deliveries according to your schedule, there will be no implementation cost for this recommendation. The payback will be immediate.

Assessment Recommendation No. 18
Purchase Materials from Supplier in Customized Packaging

Assessment Recommendation Summary

Estimated Cost savings = $24,945/yr.

Estimated Payback Period = Immediate

Existing Practice and Observation

Your company presently receives materials from suppliers in standard amounts and divides the materials into useful quantities so the ingredients can be combined to form the right compounds for the process. There is a team devoted to processing the materials as they arrive and breaking down the packages so the materials can be measured out and sent to the mixers. Once the materials are separated into the proper amounts they are all combined in the mixers.

Recommended Action

Require the suppliers to package the materials in immediately useful quantities and use soluble packaging. This will eliminate the need to measure the raw materials in-house, allowing the pre-measured packages to be removed from the shipping containers and directly added into the mixers. The soluble packaging will dissolve once the reactions in the mixers begin to take place.

Savings of several types will result. Labor costs will be reduced by eliminating the need to weigh out the materials into proper amounts. Spillage of the raw materials which occurs during measurement and transportation to the mixers will be eliminated. Presently workers are given fifteen minutes to clean themselves off every time they are finished a shift or are taking a scheduled break. Additional time is spent cleaning the area that is used for measuring and transporting the materials. The company estimates that approximately two percent of the raw materials are wasted in the combination of processes that are necessary before the materials are placed in the mixers. There are presently three employees working in receiving and a large percentage of their time is spent handling the raw materials. If the new type of packaging is implemented then the receiving labor requirements could be reduced to two employees.

Anticipated Savings

The man hour savings, MHS, can be determined using the following equation:

$$MHS = (RMH + TSC \times NOE) \times AHR \times DPY$$

RMH = reduced man-hours per day

TSC = time the employees are given to clean materials off per day

NOE = number of employees who work with materials

AHR = hourly rate for employees in receiving (including fringe)

DPY = number of days per year the operation runs

MHS = (8 hrs/day + 0.5 hrs/day x 2 employees) x ($29.25/hr) x (260 day/yr.)

MHS = $68,445/yr.

There will be an annual increase in operating cost, OCI, which must be considered with the cost savings. A premium of 5% will need to be paid to the supplier in order to have the materials packaged as requested. This will be slightly off-set by the 2% reduction in the amount of wasted materials achieved by using the customized packages. The net annual increase in the raw material cost will be:

OCI = AMC x (PCP - SWM)

AMC = The total annual cost for raw materials

PCP = The premium percentage paid for packaging

SWM = The percentage savings of material wasted

OCI = $1,450,000/yr. x (5% - 2%)

OCI = $43,500 / yr.

The annual total savings, ATS, will be:

ATS = MHS - OCI

ATS = ($68,445 / yr.) - ($43,500 / yr.)

ATS = $24,945 / yr.

Implementation

Aside from the cost premium for the customized packaging, no implementation costs will be associated with this recommendation. Once implemented, the payback will be immediate.

Assessment Recommendation No. 19
Install Polystyrene Pellet Storage Silo and Receive Bulk Delivery Discount

Assessment Recommendation Summary

Estimated Cost Savings = $175,082/yr

Estimated Implementation Cost = $100,000

Simple Payback Period = 0.6 years (7 months)

Existing Practice and Observation

Currently, the company receives their raw polystyrene pellets in gaylords. The company also leases a remote warehouse for storage of raw materials and finished goods. Gaylords are temporarily stored in the remote warehouse, then delivered to the production facility. At the production facility, the gaylords are transported to the raw materials processing area by means of a forklift, aerated, then loaded into the material hoppers. Approximately nine gaylords are used per day.

Recommended Action

The recommended action is to install an adjacent outdoor silo to store the polystyrene pellets, allowing bulk delivery discounts to be obtained. There will only need to be one delivery to the silo every month. This will greatly reduce the present polystyrene purchase and handling costs, and will also reduce the warehousing costs associated with these raw materials.

Anticipated Savings

An average of nine gaylords are used per day. At any given time the company has about 90 gaylords stored in the warehouse. The cost of the warehouse is $0.23/sq.ft. per month. The gaylords are stacked 3 high and are at 16 sq.ft. per skid. The total warehouse space needed is 480 sq. ft. The rent paid every year for this amount of warehouse space is $1,325.

It takes approximately twenty minutes to transport, open, and remove the contents of a gaylord. When using nine gaylords per day, three hours are spent handling the gaylords. The company runs on a 350 day per year work cycle. Therefore, 1050 hours are spent in the handling of the gaylords. This translates into about $14,175 per year in labor costs, assuming a labor rate of $13.50/hr (based on $20,000/yr plus 35% for fringes).

There is also the added benefit of a lower price for the transportation via bulk tanker trucks as opposed to transport with gaylords as a medium. It is $0.05 cheaper per lb. to transport by way of tanker truck. About 270 gaylords were used per month. Each gaylord is 1000 lbs., and at $0.05[5] less per lb., the savings in transportation were $13,500 per month or $162,000 per year.

Therefore, the cost savings per year (CS) can be estimated as:

CS = WS + LC + TC

where,

WC = Warehouse Cost
LC = Labor Cost
TC = Transportation Cost

CS = $1,325/yr + $14,175/yr + $162,000/yr
CS = $177,500/yr

Implementation

It is recommended that two 12 ft. diameter by 60 ft. high silos be installed. A silo this size can hold 100,000 lbs. of material. This would mean that the company would receive only one delivery of material per month via tanker truck. The cost for all parts, and installation is $50,000[6] per silo, or $100,000 total. Operation cost for the silos will be approximately 10% of the previous labor cost, or $1,418 per year. A nominal value of $1,000/yr is estimated for silo maintenance. These operation costs (OC) would be subtracted from the cost savings.

Net Cost Savings = CS - OC = $177,500/yr - $2,418 = $175,082/yr

Therefore, the total cost savings will pay for the implementation costs in approximately 7 months.

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[5] Monsato Corp., Polystyrenics Div.
[6] Universal Dynamics Inc., NJ

Burden Analysis

Introduction

Indirect expense of a manufacturing organization is called by various short names. The most common are burden and overhead. A wide variety of items are included and could be made up of the sum of:

- Salaries and wages of foremen, inspectors, clerical employees, crane operators, etc.
- Purchasing, receiving, and shipping.
- Utilities (heat, light, water, etc.) , maintenance
- Taxes, insurance, rentals, and depreciation
- Administration(sales, technical, and management) and marketing.

The selling price of a widget could be broken down into the sum of:

- Direct cost of labor and material.
- Factory overhead costs
- General administrative and marketing costs
- Profit

In cost accounting the overhead is frequently everything mentioned above except direct labor and profit. Some parts of overhead vary with production rates and some do not. This is why it is difficult to assign a truly accurate value of burden to each item produced.

The rate is usually predetermined by the accountants, e.g. if the burden rate is 300%, a product is charged $3.00 for every dollar of direct labor cost. It does not follow that if one of two alternative new machines involves $50,000 less in direct labor cost than the other it will also involve $150,000 less indirect manufacturing expense. It is best for our purposes to keep the two separate and look for reductions of direct labor charges or indirect burden charges and calculate the savings separately. In order to properly judge the savings involved in "downsizing," we would like to know the fringe costs of labor. As rule of thumb we can estimate this to be about 40% if the company can't provide a better number. Keep in mind that the employer must match the employees contribution to social security and Medicare and may pay for vacation time, medical insurance, retirement plans, profit sharing, etc.

We have obviously been involved in calculating reductions in burden since the inception of the EADC program, as first reduction of energy consumption and more recently reduction of waste generation are direct reductions of burden. Part of our increased agenda is to look at those parts of burden which we have hitherto ignored but which might very well constitute the difference between an organization making a profit and one headed for bankruptcy and shut down.

Questions to Ask

- Is new construction planned? How much and why?
- Do you manufacture or store goods in any other building nearby?
- Would you be able or want to have a rent paying tenant occupying any portion of your building complex.
- Do you place any value on equipment or facilities which seem to be "junk"? (If not, it may be economic to scrap junk and use the freed space, or demolish dilapidated facilities)

Symptoms/Indicators

- Large unused areas on the factory floor
- Using two nearby buildings
- Empty or unused buildings on the property
- Large equipment "graveyards" on the property

Related ARs

- REDUCE COST OF BUILDING PROPERTY
- COMBINE FACILITIES INTO ONE AND ELIMINATE ASSOCIATED COSTS WITH THE BUILDING WHICH HAS BEEN ABANDONED
- TEAR DOWN BUILDING ON PROPERTY TO REDUCE TAXES, INSURANCE, AND UTILITY COST
- FREE UP SPACE IN BUILDING TO:
    - A.) RENT OUT UNUSED SPACE
    - B.) AVOID CONSTRUCTION COSTS

Assessment Recommendation No. 20
Condense Operation Into One Building

Assessment Recommendation Summary

Estimated Cost Savings = $123,697/yr.

Estimated Implementation Cost = $65,497

Simple Payback Period = 0.53 year (6 months)

Existing Practice and Observation

The daily operation of the company are divided into two stages that are performed in two separate manufacturing locations. The locations are approximately three miles apart and the travel time between them is, on average, fifteen minutes. There is a significant number of personnel that must commute between the two locations on an every day basis. In addition it takes time to have products transported between locations. The main location houses the offices, warehousing and, some of manufacturing. The auxiliary location is approximately one fourth the size of the main location and is only used for manufacturing. There is a large portion of the main building that is not being used efficiently. This area is mainly used to store excess inventory and out of date products.

Recommended Action

The recommended course of action is to create room in the main location and move the operations from the auxiliary building into the main building. There is a significant amount of space in the main building that is being under-utilized and is believed to be able to be reorganized and moved to the main storage area. This will relieve some of the burden on the company by eliminating the second building's expenses as well as save in the time that is lost in the commute between the two locations.

Anticipated Benefits

The total annual savings of rent, ARS, will be the reduction in rent that the company will need to pay because of the termination of the 15,000 ft^2 building.

$$ARS = TAR \times ARR$$

where;

TAR = total area rented

ARR = area rental rate

hence the savings from rental is,

ARS = 15,000 ft^2 x \$5.10 /ft^2/ yr.

ARS = \$76,500 / yr.

The annual savings of man hours, AMS, can be contributed to the elimination of the need to commute between the two locations is estimated as,

AMS = TTC x NPC x HRC x TYC x DWY

where;

TTC = time it takes to commute

NPC = number of people that have to commute

HRC = average hourly rate for the people commuting

TYC = number of times a day to make trip

DWY = number of days worked per year

hence the savings from commuting is,

AMS = (0.25hrs/trip)(7 workers)(\$24.65 /hr)(2 trips/day)(312 days/year)

AMS = \$26,917 / year

The annual trucking savings, AST, would be from the elimination of trucking costs that are presently necessary to transport the unfinished products from the main location to the second building and back again to the main location.

AST = CPT x TPD x DPY

where;

CPT = cost per trip for truck

TPD = trips per day that are made

DPY = days per year that trucks run

hence the savings from trucking are,

AST = ($65.00/trip)(1 trip/day)(312 days/ yr.)
AST = $20,280 / yr.

The annual total savings, ATS, are :

ATS = ARS + AMS + AST
ATS = ($76,500/yr.) + ($26,917/yr.) + ($20,280/yr.)
ATS = $123,697/yr.

Implementation

The Implementation will require moving of all the essentials from the auxiliary building to the main building as well as the reorganization of the main building's storage areas. To reorganize the storage areas the use of in-house personnel will be utilized and will require overtime pay. There will be one hundred man-hours allotted at a rate of $36.97/hr to produce an organization cost of $3697. A moving company will be contracted to move the operations from the auxiliary building to the main building. There will be twenty-two pieces of machinery ranging from three tons to two hundred pounds that will need to be moved at a total cost of $17,300. There will also be a production down time that needs to be accounted for. The production will be shut down for one week in order to make the necessary movements from the auxiliary warehouse to the main warehouse. It should be noted that if the move is scheduled then it might be possible to have the employees take one week of their vacation during this period to avoid additional down time. The lost production will cost approximately one week of the total annual sales which amounts to $44,230. The total implementation cost for the recommendation will be $65,497.

Payback Period = (implementation cost)/ ATS
= ($65,497) / ($123,697/yr.)
Payback Period = 0.53 years (approx. six months)

Assessment Recommendation No. 21
Demolish Building to Reduce Tax & Insurance Fees

Assessment Recommendation Summary

Estimated Cost Savings = $54,600/yr

Estimated Implementation = $118,000

Simple Payback Period = 2.2 years (26 months)

Existing Practice and Observation

The company has several buildings that have been constructed since the original factory was established. The additions were made to the original plant to accommodate expanded production and increase the available storage space. The construction quality of the additions is not that of the main building and in recent years some of the additions have been neglected due to their diminishing requirements. There is one building that is no longer of any real use and is at the point were repairs will cost more than the building is worth.

Recommended Action

The recommended action is to demolish the 1948 warehouse and move anything of value to either of the adjacent warehouses that are at less than maximum capacity. The building is assessed as a development property and the last reassessment was performed before the building began to deteriorate. In demolishing the building the annual taxes and insurance for the building will be eliminated.

Anticipated Savings

The annual savings from the elimination of the taxes, AST, for the building that will be demolished can be determined using,

AST = TPA x TAD

where;

TPA = The tax rate per area[13]

TAD = The total area being demolished

Hence the savings from taxes are,

[13] 1996 Comparative Statistics of Industrail and Office Real Estate Markets,Society of Industrial and Office Realors, Washington, D.C.

$AST = (\$1.72 /ft^2/yr.) \times (30,000 ft^2)$
$AST = \$51,600 / yr.$

The annual savings from the insurance, AIS, this is the amount of insurance that is being paid to keep fire and liability insurance on the building. It can be determined using,

$AIS = IRA \times TAD$

where;
IRA = The insurance rate per square foot[14]
TAD = The total area being demolished

Hence the savings from the insurance is,

$AIS = (\$0.10 / ft^2 /yr.) \times (30,000 ft^2)$
$AIS = \$3,000$ per year

The annual total savings, ATS, is the savings per year from the demolition of the building and is comprised of the savings from taxes and the savings from insurance.

$ATS = AST + AIS$
$ATS = (\$51,600 / yr) + (\$3000 / yr)$
$ATS = \$54,600 / yr$

Implementation

The implementation requires demolishing the warehouse, and removal and disposal of the construction materials. Any salvage value of material will be incorporated into the cost of the disposal of the material. The demolition costs are determined by the volume of the building, 360,000 ft^3, and the cost for the type of building (steel framed), \$0.21 ft^3.[15]. The demolition also includes the loading and hauling of the rubbish hence, the demolition of the building will cost approximately \$90,000. The disposal of the material consists of dump charges that is determined by the type of material and the volume (cubic yards) being disposed. It is estimated that there will

[14]Based on information obtained from Comparative Statistics of Industrail and Office Real Estate Markets

[15]Means Repair and Remodeling Cost Data 15th Annual Edition, R.S. Construction Company, Kingston, MA

be 800 yd^3 of material that needs to be dumped at a rate of $35.00 per cubic yard[16]. The total dump charges will be $28,000 resulting in an implementation cost of $118,000.

Payback Period = Implementation cost / ATS
= ($118,000) / ($54,600/yr)
Payback Period = 2.2 years (26 months)

[16]Based on information obtianed from the Means repair and remodeling cost data

Inventory

Introduction

There are four major *types of inventory* in industrial facilities:

- Raw materials
- Purchased components
- Work-in-progress
- Finished goods

Associated with each of the above types of inventoried goods are *carrying costs* , the most notable of which are:

- Investment costs (time value of money tied up in inventoried goods)
- Cost of product damage or spoilage
- Cost of product obsolescence
- Cost of storage space
- Handling & transportation (in-house)

Although the magnitudes of each of the above costs may vary from one manufacturer to the next, it is easy to recognize that each of the costs will continue to grow in time. In fact, if inventoried periods are long enough, the carrying costs can exceed the profits gained from the eventual sale of the products and a net *loss* will result. For this reason, it is desirable to minimize inventories of all types.

The Japanese believe that inventory is one of the greatest forms of waste and make every effort to achieve production systems which don't require it. This is in contrast to many traditional American and European production systems which have viewed inventory as a necessary evil, needed to compensate for deficiencies in the manufacturing process such as:

- Long set-up times
- Frequent machine breakdowns
- Lack of predictive/preventive maintenance
- Excessive ***manufacturing lead times*** (due to process bottle-necks or poor process layout)
- Defective raw materials or purchased components

The most important reason to consider inventory levels may be for use as an *indicator* of other, process-related problems which should be investigated further (listed above). Once the root cause for excess inventories is identified and addressed, reducing inventory carrying costs may be shown as a secondary benefit for solving the original problem. For example, if long set-up times are identified as the cause of large finished-goods inventories in a manufacturing facility and a recommendation is made which will reduce the set-up times significantly, the annual savings could consist of: i) reduced production downtime, and ii) reduced inventory carrying costs.

In terms of minimizing inventory carrying costs, the *ideal* inventory situation is: i) to stock only the raw materials and purchased components which are immediately needed, ii) to have zero in-process inventory, and iii) to only produce finished goods in the amount that they are immediately needed. For most of the small- to medium-sized manufacturers served through the IAC program, this will be an unattainable goal because they may lack the buying power and production volumes necessary to achieve such a system.

Minimal raw material inventories are achieved by requiring material suppliers to provide Just-In-Time *deliveries*. To be economical, very large raw material volumes are normally required (to minimize transportation costs) and suppliers must be able to reliably deliver all needed materials upon short notice (or raw material needs must be well known in advance of the delivery date). Zero (or minimized) in-process inventories may be achieved through the use of continuous processing systems, where the product flows continuously from one process to the next until completion. Finally, finished goods inventories can be nearly eliminated by using a Just-In-Time *production* system--scheduling production lots based on the immediately required orders. Obviously, many factors (production volumes, product variety, product type, order lead time, seasonality of production, supplier scheduling, etc.) aside from inventory levels affect the practicality of all three of the above mentioned concepts.

Large-scale manufacturers have the power to dictate just-in-time deliveries by their suppliers and the resources to realistically consider continuous processing methods and just-in-time manufacturing. In many cases, manufacturers served by the IAC program will be on the “receiving end” of just-in-time mandates and will be required to *provide* just-in-time deliveries to their customers. This may result in the storage of large supplies of finished goods to ensure timely deliveries and customer satisfaction.

Even though the size of the manufacturers served by the IAC program may limit the extent to which inventories can be realistically reduced, the principals and importance of inventory reduction should be recognized and pursued in all practical opportunities. **Where inventory levels are found to be excessive, the *reasons* for the manufacturer’s perceived need for large inventories should be investigated.** Such investigations may lead to recommendations to: reduce process bottlenecks, modify floor layouts to reduce production lead times, shorten set-up times, improve maintenance or establish *predictive* maintenance procedures, develop standardized procedures, buy new equipment, etc.

Questions to Ask

- Average value and quantity of each type of inventory (raw materials, purchased components, in-process products, finished goods)?
- How much floor space is used for each type of inventory? What is the assigned value (if any) of that floor space ($\$/ft^2/yr$)?
- If it is determined that there is excess inventory of some type, why is that excess inventory needed?
- If excess inventories are needed because of some process-related inefficiency or problem, what are the present average ***manufacturing lead times*** for the products whose inefficient production requires the maintaining of excess inventory?

Symptoms/Indicators

- Physical observation of large inventories
- Long set-up times
- Frequent equipment downtime
- High defect rates
- Lack of a preventive maintenance program

Related ARs

- MINIMIZE INVENTORY TO REDUCE INVENTORY CARRYING COSTS
- MINIMIZE INVENTORY AND OVERPRODUCTION TO REDUCE INVENTORY "SPOILAGE"
- REGAIN PARTIAL VALUE OF INVENTORY BY RECYCLING OR SELLING AS SCRAP

NOTE: Inventory reductions and the resulting reduced carrying costs should be considered as a secondary benefit achieved by reducing set-up times or machine breakdowns, improving maintenance practices, reducing/eliminating process bottlenecks, improving floor layout, reducing overproduction, etc.

Assessment Recommendation No. 22
Eliminate Old Stock and Modify Inventory Control

Assessment Recommendation Summary

One-time Savings:

Estimated Energy Usage Savings = 1,593 MMBtu

Estimated Energy Cost Savings = $5,743

Estimated Raw Material Savings = 1,459,838 lb.

Estimated Raw Material Cost Savings = $13,284

Total Estimated One-time Cost Savings = $19,027

Continued Savings:

Capital Investment Savings = $2,854/yr

Cost Benefit from Reclaimed Floor Space = $21,114/yr

Total Estimated Continued Cost Savings = $23,968/yr

Estimated Implementation Cost = $9,640

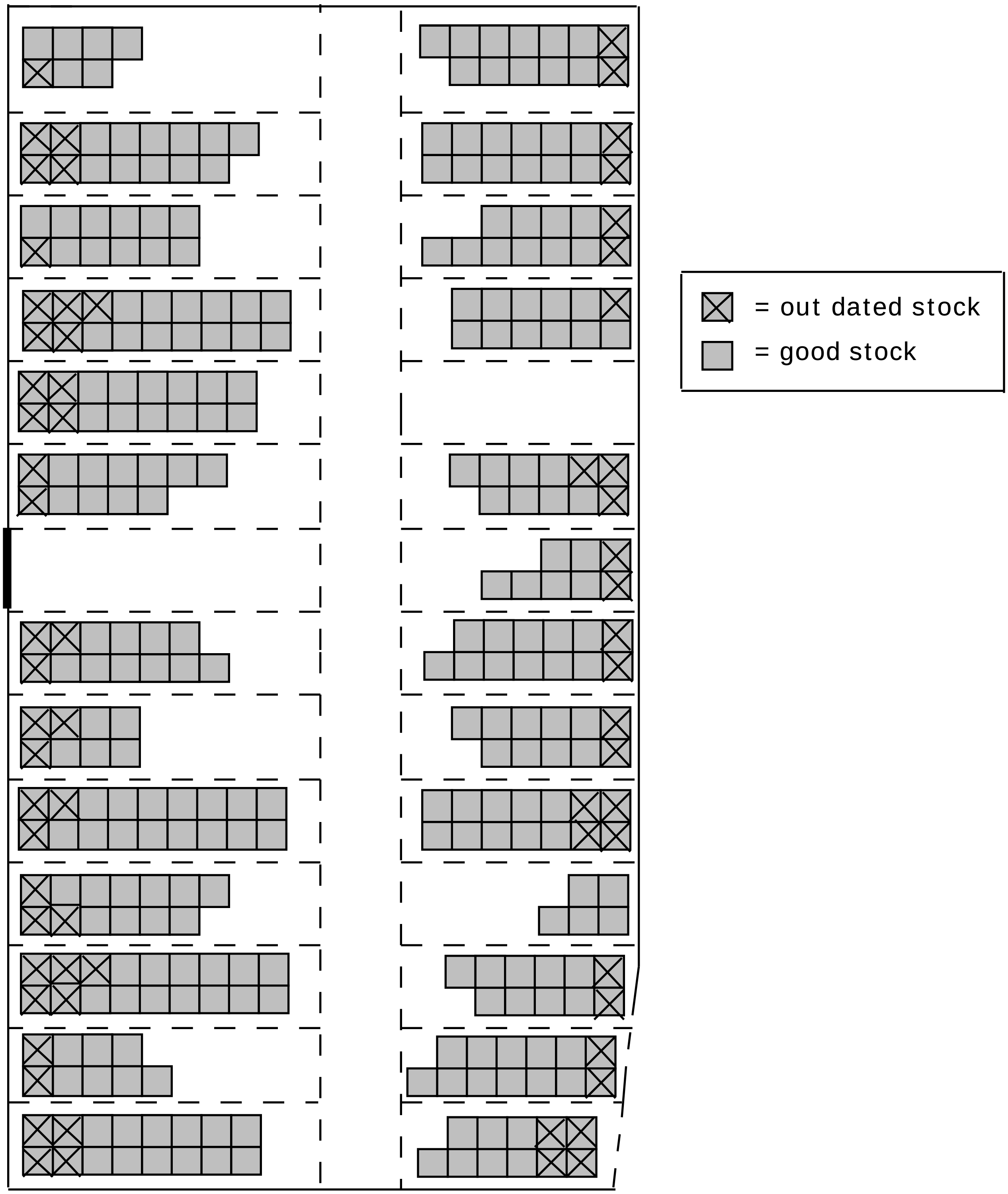
Simple Payback Period = 0.4 years (5 months)

Existing Practice and Observation

During our assessment, it was noticed that a large amount of the existing inventory is very old, or has been damaged. Boxes containing products as old as 8 years were found. Interviews with plant management revealed that a significant percentage of the existing inventory is not sellable because it is either out-of-date, damaged, or has become misplaced due to improper packaging which occurred when batch quantities were over-produced.

It is estimated that your company has the equivalent of one month's production in stock. Due to the long production line set-up times, glassware is often produced in lots much larger than the existing order with the hope that the customer will order another shipment of the same product in the future. Often, however, all of the products are *not* sold. Since there has been no established procedure for purging the inventory of out-of-date products, these items have accumulated over the years and now occupy a significant amount of warehousing space.

According to our observations and conversations with facility personnel, about one-quarter of the finished goods in the warehouse are out-of-date, damaged, or otherwise "spoiled." Much of this stock appears to have been grouped together when the newer inventory system was



AR#22, Figure #1: Outdated Inventory in Newer Warehouse

implemented, but some is also in the newer warehouse (shown in AR#22, Figure 1). Currently, inventory is tagged with customer and date and inventoried in "rows" in the warehouse. Only inventory to be shipped is pulled from rows, leaving out-of-date inventory in entire rows or especially at the back end of rows.

Recommended Action

Reduce inventory by immediately re-stocking or disposing of old, damaged, or otherwise “spoiled” inventory, and instituting new accounting methods for the inventory in the newer warehouse. A procedure should be established to identify inventoried products which have become out-dated and have no chance of being sold. Once the glassware becomes out-dated, it should be used as cullet (clear glass) or sold as scrap (colored glass).

The previous actions will result in approximately 9,000 ft^2 of cleared floor space which should be either:

1) leased to an outside organization to provide a new source of revenue, or
2) used to offset a portion of the construction costs for planned expansions.

Anticipated Savings

The existing inventory is estimated as the equivalent of one month’s production:

Existing Inventory = (Annual Production) / (12)
= [(31,851 tons) x (2000 lb./ton)]/12
= (63,702,000 lb.)/12 = 5,308,500 lb.

We estimate that one-quarter of the existing inventory is out-of-date and could be used as cullet. Using cullet to produce glass allows the avoided use of new raw materials, resulting in a cost savings on raw material purchases--***it requires 10% more virgin raw materials (by weight) to produce a pound of glass as compared to re-melting cullet.***[17] In addition, because it requires less heat to melt cullet than it does to make glass from virgin raw materials, energy savings will also result--***about 1,200 BTU per pound of glass produced is conserved by using cullet instead of raw materials.***[18]

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[17] National Cleaner Production Database
[18] Office of Technology Assessment. 1989. Facing America's Trash: What Next for Municipal Solid Waste

The amount of cullet obtained from out-of-date inventory is estimated as one-quarter of the existing stock, or 5,308,500 lb. / 4 = 1,327,125 lb., resulting in a raw material savings of: (1,327,125 lb. cullet) x (1.1 lb. raw mat'ls/lb. cullet) = 1,459,838 lb. The corresponding cost savings would be:

75% sand =	1,459,838 lb. x 0.75 x $12.60/ton x 1 ton/2000 lb = $6,898
15% lime =	1,459,838 lb. x 0.15 x $13.00/ton x 1 ton/2000 lb = $1,423
10% soda ash =	1,459,838 lb. x 0.10 x $68.00/ton x 1 ton/2000 lb = $4,963

Total Reduction in Raw Material Cost (RM) = $13,284

The energy savings would be:

Energy Savings = (1,327,125 lb.) x (1200 Btu/lb.) x (10^{-6} MMBtu/Btu)
Energy Savings = 1,593 MMBtu

Since about 15% of the heat for the furnaces is electric heat and 85% is from natural gas, the energy cost savings would be:

Energy Cost Savings = (Energy Savings) x (% Gas Heat) x (Cost of Gas) + . . .
. . . + (Energy Savings) x (% Electric) x (Cost of Electricity Usage)
= (1,593 MMBtu) x (0.85) x ($2.65/MMBtu) + . . .
. . . + (1,593 MMBtu) x (0.15) x ($9.02/MMBtu)
Energy Cost Savings = ($3,588) + ($2,155)
Energy Cost Savings = $5,743

Hence, the total one-time cost savings achieved by purging your inventory of out-of-date stock and using it as cullet would be:

Total One-time Savings = Raw Material Cost Savings + Energy Cost Savings
Total One-time Savings = $13,284 + $5,743 = $19,027

The above savings is thought of as a one-time savings because improved inventory methods will prevent future build-ups of out-of-date inventories. If one assumes that the existing out-of-date inventories were built up over a period of 8 years, then the estimated annual savings achieved by re-cycling out-of-date glassware would be about ($19,027)/(8 years) = $2,378/yr.

While sitting in inventory, the *value* of the out-of-date products can be viewed as “idle” capital. If invested elsewhere in the company, this capital would be worth (assuming a rate of return of 15%/yr):

Reclaimed Capital Earnings = (Value of Out-of-Date Inventory) x (15%/yr)

= (Raw Material Cost Savings + Energy Cost Savings) x (15%/yr)

= ($13,284 + $5,743) x (0.15/yr) = ($19,027) x (0.15/yr)

Reclaimed Capital Earnings = $2,854/yr

The warehousing space used to store out-of-date goods is essentially *wasted space* at the present time. Although this space may be viewed as having no value (because it is owned by the company), purging the out-of-date glassware will make the space available for other uses, such as expanded production operations or as leasable space. In this light, the space does have tangible value and should be considered as a significant benefit which will result from implementing this recommendation.

According to statistics published by the Society of Industrial and Office Realtors[19], ***gross lease prices*** in your company’s geographical area for warehousing spaces in the range of 5,000 to 20,000 ft^2 in size are in the range of $3.25-$4.50/ft^2/yr and are in *moderate shortage*. Using a leasing value of $3.75/$ft^2$/yr, this space has a revenue producing potential of (9,000 ft^2) x ($3.75/$ft^2$/yr) = $33,750/yr. Subtracting the annual operating costs for maintaining this space as a warehouse (shown below), ***the net earnings would be $33,750/yr - $12,636/yr = $21,114/yr.***

Operating Cost

It is estimated that it would require an additional 10 hours/week of manpower (warehouse person, shipping clerk, etc.) to perform the functions of the rental venture. It is not necessary to insure other client’s property, nor would there be any municipal tax consequences.

Labor = 10 hr/week x 52 weeks/yr x ($15.00/hr + 35% fringe)	=	$10,530/yr
Administrative Costs = 2 hr/wk x 52 wk/yr x ($15.00/hr + 35% fringe)	=	$2,106/yr
Total Costs	**=**	**$12,636/yr**

NOTE: The above costs may not be as high if the space is leased for non-warehousing purposes; however, there would probably be a one-time facility renovation cost in that case.

[19] *1996 Comparative Statistics of Industrial and Office Real Estate Markets*, Society of Industrial and Office Realtors, Washington, D.C., p.46.

Implementation Costs

The cost to implement this recommendation include:

1) clean-up of old inventory
2) modification of your present inventory system to identify out-of-date goods
3) preparing the reclaimed space for rental purposes

Cost to clear the area is estimated as using existing personnel and hiring outside help for two weeks. An alternative scheme would be to use present personnel, if job rules and available personnel allow.

labor = 2 inside people @ ($15.00/hr + 35%) for 80 hours = $3240
2 outside hires @ $40.00/hr for 80 hours = $6400
Total labor = $9,640

Simple Payback* = $9,640 / ($23,968/yr) = 0.4 years (5 months)

* NOTE: The above payback calculation neglects the one-time SAVINGS of $19,027.

Floor Layout

Introduction

Opportunities in modifying floor layout involve saving **time, space, inventory or labor**. This is accomplished by eliminating or reducing wasted motion, or non-value added operations. A common practice by plant management over the years has been to expand into all available space, even constructing or leasing new buildings rather than maximizing the existing floor layout. Most manufacturers did not design the layout you see today, but rather they "grew" into it. Typically, they do not assign any value to wasted space, particularly if it does not have a direct cost.

Floor layouts will vary depending on the number of different products made, and by the quantity produced. Low quantity producers, or job shops, produce small quantities of specialized and customized products. The equipment is general purpose, and the work force skilled. One type of small quantity layout is **process** oriented. The facility is laid out in departments, where equipment is consolidated by type; lathes are in one area, paint booths in another. The product is routed through departments in the order of the process required. While this layout allows for flexibility, *the disadvantage is much moving and handling.* If the product varieties are few, and the demand is predictable, the product can be produced in batches. This is characterized by longer production runs, frequently repeated. Equipment is somewhat specialized, and orders are usually made to replenish inventory, since equipment changeover is time consuming.

The other type of small production uses a **cell** layout. This strategy is used when there is a lot of variety in the product and/or the demand is unpredictable. Equipment is designed so that similar products can be made (or assembled) on the same machinery without significant modification to the machines. Workstations are arranged to manufacture a "family" of products simply by adding or eliminating steps, or changing sizes. This economizes on the amount of in-process inventory, and minimizes handling by reducing lead time. The final products or assemblies are often made to order.

High quantity production is generally set up in flow line layout, with the products moving through the factory, usually on conveyors, and the workstations and workers located next to the line. Many factories will be a mixture of these three types of layouts.

One example of modifying a floor layout to reduce in-process inventory involved a manufacturer of plastic parts that moved batches of 10,000 parts at a time to the printing area.

Printing took only one minute; a manufacturing lead time of 10,000 to one. It was possible to move the extruder next to the printer, reducing the **lead time** to less than 5 to one. This layout modification also eliminated the expense of movement by forklift.

Questions to Ask

- Do you rent, lease or own the facility (or another)? (cost $/ft^2/yr)
- Do you have any plans for expansion?
- How do you account for the cost of space? (cost $/ft^2/yr)
- How many different products do you make?
- What is the **lead time** of the product/process?

Indicators / Symptoms

- Excess Inventory (raw material, in-process, finished goods)
- Unnecessary motion
- Excessive transportation within the plant
- Duplication (two conveyors where one would do)

Related ARs

- MODIFY EQUIPMENT LAYOUT TO REDUCE MOTION OR TRANSPORTATION
- RELOCATE DEPARTMENT (REPAIR SHOP, SHIPPING) TO REDUCE TRANSPORTATION TIME
- VERTICALLY WAREHOUSE THE FINISHED PRODUCT (OR USE ROBOTICS) TO REDUCE TRANSPORTATION AND/OR MAXIMIZE FLOOR SPACE
- INSTALL DISTRIBUTION SYSTEM TO MOVE RAW MATERIALS (OR WASTE) TO REDUCE TIME ASSOCIATED WITH INDIVIDUAL PICK-UP AREAS
- DISTRIBUTE UTILITIES (AIR, WATER, ELECTRICITY) TO REDUCE TIME SPENT MOVING PRODUCT OR TOOLS
- CLEAR EQUIPMENT GRAVEYARD TO MAKE USEFUL SPACE
- CONSOLIDATE PRODUCTION AREA TO CREATE WAREHOUSE SPACE

Assessment Recommendation No. 23
Clear and Rent an Existing Warehouse

Assessment Recommendation Summary

Estimated Cost Savings = $125,400/yr.

Estimated Implementation Cost = $38,000

Simple Payback Period = 0.3 years (4 months)

Existing Practice and Observation

Warehouse #3 is presently being used for the storage of out-of-date machinery and unusable material. A large portion of the machinery in the warehouse is no longer worth repairing and is considered unsalvageable. It is believed, by management, that more than three-quarters of the objects that are presently being stored in the warehouse are of no future use. The warehouse has approximately 26,400 ft^2 of usable space and a private entrance. Presently it is insured and annual taxes are paid on the original assessed value of the building. These are costs that your company is absorbing and little to no benefits are received. There is ample room in other warehouses to store the machinery and materials that are still valuable to the company.

Recommended Action

Clear warehouse #3 and rent it to an outside organization, separating all machinery or materials that are salvageable and moving them to other warehouses. The rest of the equipment and materials that have no value can be hauled to the dump. It is important that a large portion of what is presently in the warehouse be permanently disposed of in order to avoid this problem from occurring in another place.

Anticipated Benefits

According to statistics published by the Society of Industrial and Office Realtors[20], ***gross lease prices*** in your company's geographical area for warehousing spaces in the range of 20,000 to 60,000 ft^2 in size are in the range of $\$4.00$-$\$5.50/ft^2/yr$ and are in *moderate shortage*. Using a leasing value of $\$4.75/ft^2/yr$, this space has a revenue producing potential of $(26{,}400\ ft^2) \times (\$4.75/ft^2/yr) = \$125{,}400/yr$.

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[20] *1996 Comparative Statistics of Industrial and Office Real Estate Markets*, Society of Industrial and Office Realtors, Washington, D.C., p.46.

Implementation

Implementation requires the removal of the unusable materials and salvage of the scrap machines. The rubbish will have to be loaded, hauled, and dumped at the nearest trash site. The loading and hauling will cost \$46.50 per yd^3 of rubbish while the dump charge will be \$30 per yd^3 at the trash facility. This will result in a total disposal cost of \$76.50 per yd^3 of rubbish[21]. It is estimated that 500 yd^3 of rubbish will need to be removed, resulting in a total removal cost of \$38,250.

The savings for salvaged scrap metal is the amount of money that can be collected from the salvage of the machinery in the warehouse. The price that is paid for the metal varies from \$2.50 to \$4.00 per one hundred pounds and mainly depends on the condition and type of metal. Assuming the worst price to allow for improvements, the 5 tons of scrap will return:

(5 tons) x (2000 lb/ton) x [(\$2.50 /100 lb.)] = \$250

The total implementation costs will be \$38,000.

The simple payback period can be calculated with the following equation:

Payback Period = (Implementation Cost) / ACS
= (\$38,000) / (\$125,400 /yr.)
Payback Period = 0.3 years (4 months)

[21]Means Repair and Remodeling Cost Data 15th Annual Edition, R.S. Means Construction Company, Kingston, MA.

Assessment Recommendation No. 24
Re-arrange Equipment Layout to Reduce Labor Costs

Assessment Recommendation Summary

Estimated Cost Savings = $135,000/yr
Estimated Implementation Cost = $5,038
Simple Payback Period = less than one month

Existing Practice and Observation

Part of the existing floor layout is shown in Figure 1. Both manual and automated packing machines are used to package finished products (cups). The automated machines can package cups from two production lines at once and are used where the same product is manufactured on two adjacent lines. The manual machines are only capable of packaging product from one line at a time and are used on the lower volume cup lines, where the ordered volume of cups doesn't merit the use of two simultaneous production lines.

Presently, one operator is used for each type of packing machine and there are four production shifts per week.. The operators on the two automatic packing machines were observed to be underutilized, spending well over half of their time waiting for something to do. Since these machines are presently located at least 50 feet apart, two operators are required. According to management, aside from the packing machines the only difference between production lines for different products are the molds and the process set-up (timing, etc.). A full product changeover, including the process set-up, takes approximately 6 hours (on average).

Recommended Action

Re-arrange the production equipment as shown in Figure 2, placing the two automatic packaging machines side by side. This will allow one operator (instead of two) to monitor both machines. This will require four complete production line changeovers and the movement and set-up of one automatic packing machine and two manual packers.

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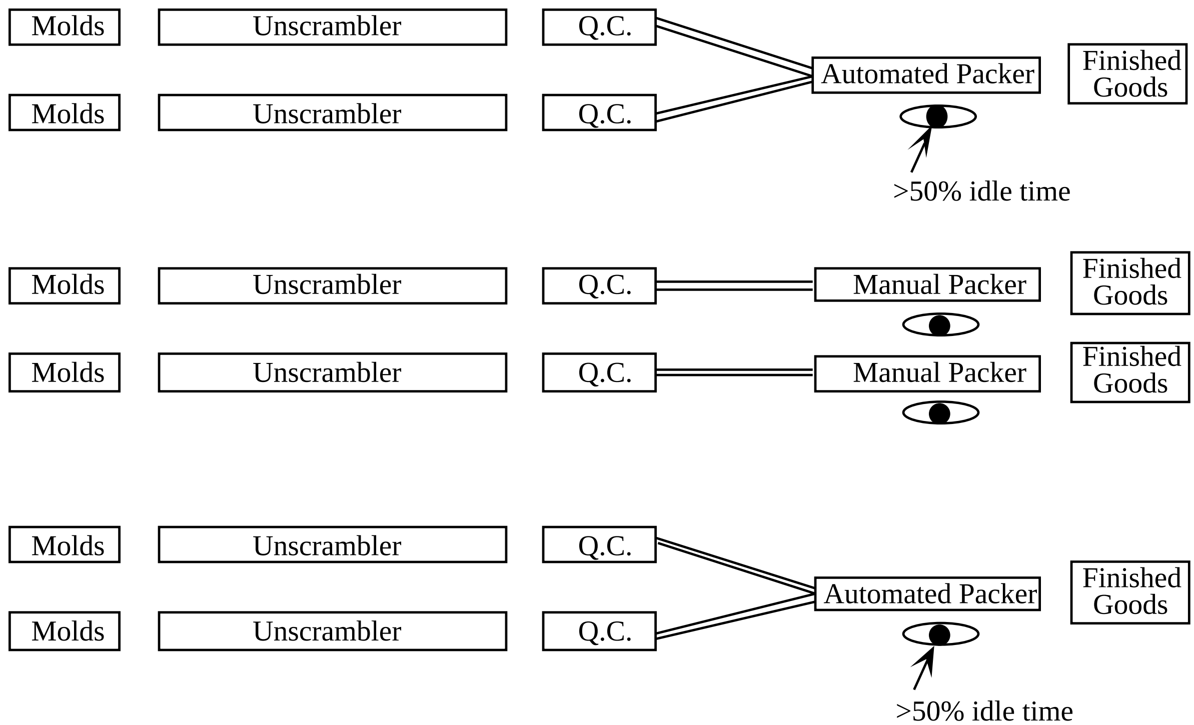

Figure 1: Existing Process Flow / Floor Layout

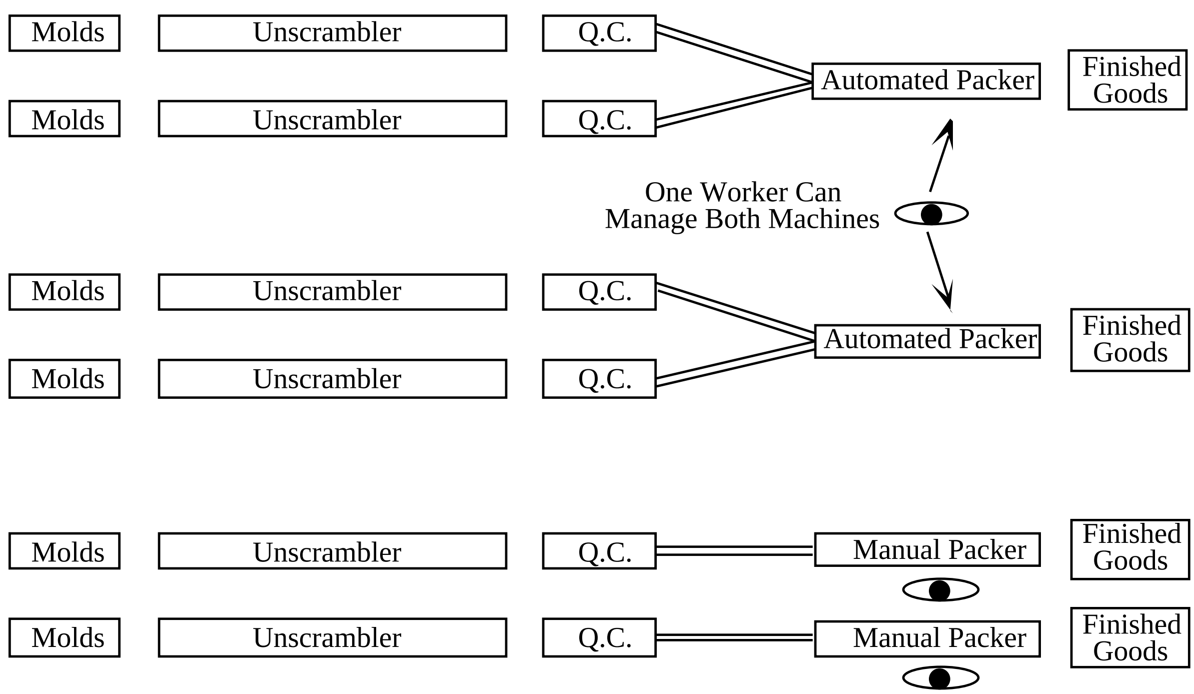

Figure 2: Proposed Process Flow / Floor Layout

Anticipated Savings

The equipment re-arrangement will reduce the labor requirements for the packaging operation by one person per shift for 4 shifts:

Cost Savings = (1 operator/shift) x (4 shifts) x ($25,000/yr/operator) x (1.35 fringe)

Cost Savings = $135,000/yr

Implementation

Implementation of this recommendation will require:

In-house Labor		
4 technicians/changeover (@ $19.47/hr incl. fringe)		
6 hours/changeover		
4 changeovers are required		
(4) x ($19.47/hr) x (6 hr/chg.) x (4 chg.)	=	$1,869
Plant Foreman (5 days)		
(@ $33.75/hr incl. fringe)	=	$1,350
Trades		
Electrician 16 hr. @ $27.50/hr		$440
Moving Equipment / Operators (1 day)		
Laborers 2 @ $32.00/hr		$512
Hydraulic Crane (25 ton) @ $541/day		$541
Equipment Operator (Crane) @ $40.75/hr		$326
Total Implementation Cost		**$5,038**

Simple Payback = $5,038 / ($135,000/yr) = less than one month

Note: Labor values taken from Means Repair & Remodeling Cost Data, 15th Annual Edition.

Assessment Recommendation No. 25
Re-arrange Equipment Layout to Reduce Handling Costs

Assessment Recommendation Summary

Estimated Cost Savings = $4,056/yr
Estimated Additional Income = $44,790/yr
Estimated Implementation Cost = $6343
Simple Payback Period = 2 months

Existing Practice and Observation

The process of manufacturing cereal feeds is divided into two lines each running in the same direction in the facility. In the first line, the grains are weighed, mixed, milled, cooked with steam and starches, extruded, dried, ground, and loaded into bins.

These bins are then moved by forklift truck to the beginning of the second line, where other ingredients such as minerals and vitamins are added. The product is then pelletized, packaged and moved to shipping.

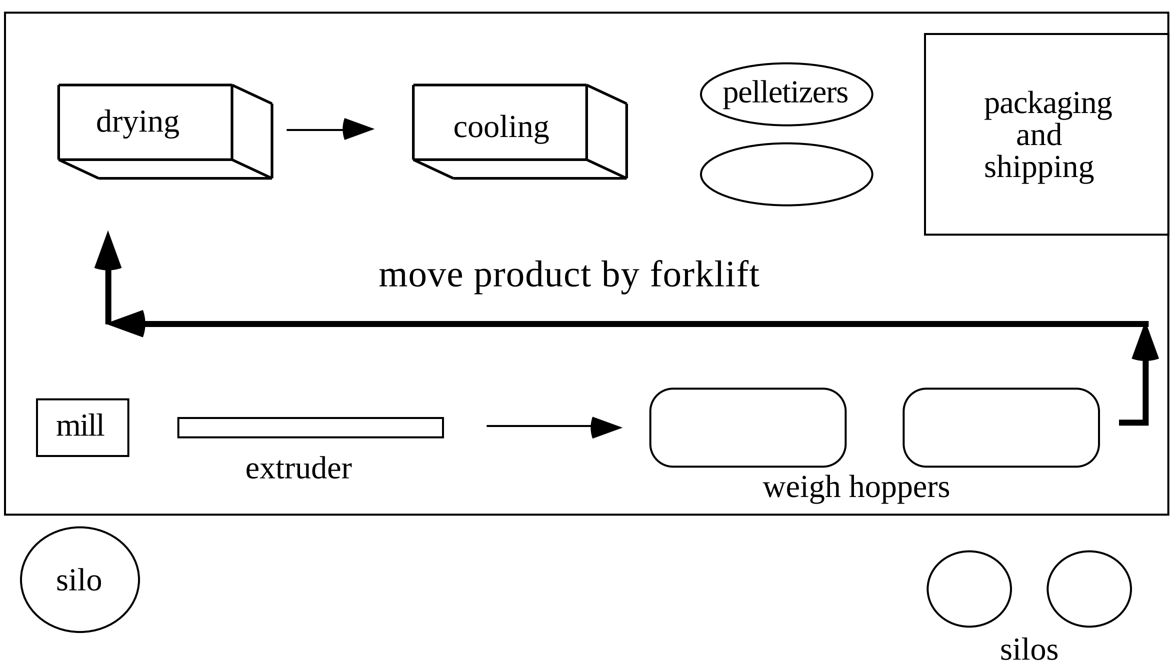

Figure 1: Existing Process Flow / Floor Layout

Recommended Action

Re-arrange the production equipment into a continuous line and install a conveyor system to deliver in-process materials from the weigh hoppers to the dryer, eliminating the need to move the product by fork-lift. Since your company has a planned shutdown for one week, it is recommended that this move be made during that time. Since there are loading doors on both ends of the facility, little or no inconvenience will be caused by moving the location of the shipping operations.

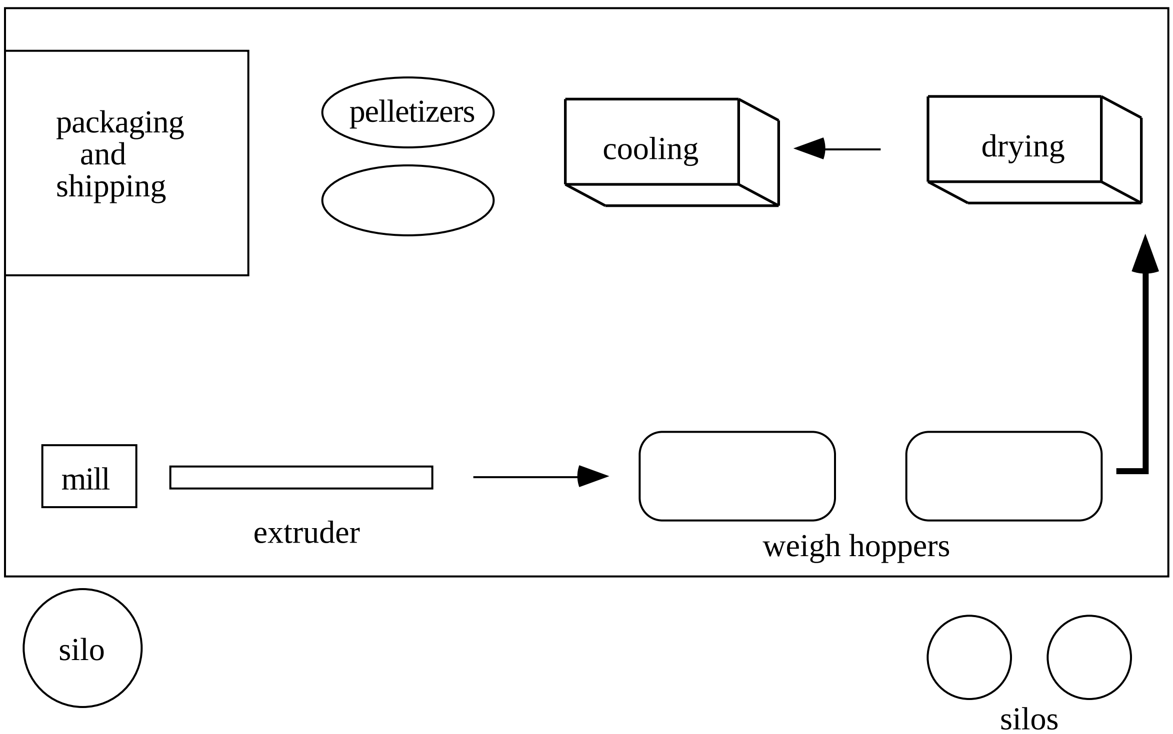

Figure 2: Proposed Process Flow / Floor Layout

Anticipated Savings

The product is moved 10 times each day (one shift). Each movement of the product takes 5 minutes. Re-arrangement of the equipment will save:

5 min. x 1 hr/60 min. x 10 times/day x 250 days/yr = 208 hrs/yr
Labor Saved = (208 hrs/yr) x ($15.00/hr) x (1.30 fringe) = $4,056/yr
Increased Production =(7200 tons/yr) / (2000 hrs/yr) x 208 hrs/yr = 749 tons/yr
Increased Sales = 749 tons/yr x $598/ton = $447,902/yr @ 10% profit = $44,790/yr
Total = $48,896/yr

Implementation

Implementation of this recommendation will require :

Conveyor System (installed)		$60,000
Trades		
Electrician 16 hr. @ $27.50/hr		$440
Plumber 16 hr. @ $28.30/hr		$453
Laborers (40 hr)		
Skilled 2 @ $24.65/hr	$1,972	
Helpers 2 @ 18.60/hr	$1,488	
Plant Foreman @ ($25/hr + $7.50/hr fringe)		$1,300
Trash Removal		
Construction 10 yd^3 @ $35.00/$yd^3$ =		$350
Rubbish 20 yd^3 @ $30.00/$yd^3$ =		$600
Moving Equipment / Operators		
Laborers 2 @ $32.00/hr		$1,536
Hydraulic Crane (25 ton) @ $541/day		$1,623
Equipment Operator (Crane) @ $40.75/hr		$978
Total Implementation Cost		**$70,740**

Simple Payback = $70,740 / $48,896/yr = 1.45 yrs (approx. 17 months)

Note: Labor values taken from Means Repair & Remodeling Cost Data, 15th Annual Edition.