THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

Center for Advanced Energy Systems

Industrial Analysis Report No. 96-001

Prepared for:

A Generic Glass Company

Director: Professor Michael R. Muller

Office of Industrial Productivity and Energy Assessment
Department of Mechanical and Aerospace Engineering
Rutgers, The State University of New Jersey
Piscataway, NJ 08854

Assessment Date:
May 20, 1996

Report Date:
July 20, 2005

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy

Table of Contents

Preface

Rutgers University performed the work described in this report. The Industrial Assessment Center Program is funded by the United States Department of Energy's Industrial Technologies Program. Rutgers, The State University of New Jersey, serves as the Field Manager. The assessment team consists of faculty, and students from the school's IAC center. The students obtain valuable educational experience, and act as paid employees of the university.

The objectives of the IAC are to identify and evaluate selected opportunities for energy conservation, productivity improvement, and waste minimization. The recommendations developed are the result of analyses performed on client-supplied data and through a site visit, and are therefore restricted in detail due to limitations on available time at the site. When energy conservation or waste minimization opportunities involving engineering design and capital investment are found to be the recommended course of action, it is advisable to engage the services of a consulting engineering firm or other experts to do the detailed engineering work involved.

REQUIRED
- Introduction to the IAC Program
- Inclusion of students and faculty in the program

DISCLAIMER

The contents of this report are offered as guidance. The authors of this report, Rutgers University, The U.S. Department of Energy's Industrial Technologies Program, and all technical sources referenced in this report do not (a) make any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe on privately owned rights; (b) assume any liabilities with respect to the use of, for damages resulting from the use of, any information, apparatus, method or process disclosed in this report. This report does not reflect official views or policy of the above mentioned institutions. Mention of trade names or commercial products does not constitute endorsement or recommendation of use.

The disclaimer is a **Required** section of the report for legal reasons.

EXECUTIVE SUMMARY

Our energy analysis of your plant shows that from January, 1995 through December, 1995, your energy consumption consisted of:

35,186,000 kWh of electricity	(120,089 x 10^6 BTU/yr)
4,201,090 Therms of natural gas	(420,109 x 10^6 BTU/yr)

Combined natural gas and electricity consumption totaled to an equivalent of 540,198 million BTU's of energy. Total energy costs for the same period were $2,778,491 with unit energy costs averaging $0.0472/kWh for electricity and $0.266/Therm for natural gas.

The 3 energy conservation opportunities described in this report (considered independently) could provide a net savings of about $138,713 per year, or 5% of your annual energy consumption costs. Our estimated costs for implementing the recommended energy conservation measures translate into an average payback of less than 1.9 years. The 2 waste minimization opportunities can save $26,812 per year with an immediate payback due to their low cost of implementation. In addition, a one-time savings of $334,167 can be achieved by implementing recommendation number 4, *Remove and Sell Scrap Colored Glass*. Finally, the 8 productivity enhancement opportunities can save $3,620,171 per year with an overall payback of under 1.5 years. When compared to your company's gross annual sales of $45 million, implementation of the productivity enhancement recommendations would represent a financial gain of over 8%.

The recommended savings opportunities are summarized in Table 1 on the following page. Following a description of your facility and an analysis of your utility bills, each recommendation is fully described. Additional suggestions for savings opportunities are included in the final section of the report--these ideas were not analyzed fully because data was not available or it was felt that either the paybacks would be too long or the savings too low to warrant a more complete analysis.

Although the calculations contained in this report represent our best estimates of your potential savings and costs, you may want to consult other sources and verify these estimates before you decide to implement the recommendations with which they are associated. We welcome inquiries and further discussion of any information contained in this report.

AR #	Assessment Recommendation	Annual Resource Savings (kWh)	Annual Electric Demand Savings (kW)	Annual Resource Savings (hrs)	Annual Cost Savings	Net Imp. Cost	Simple Payback Period (Months)
Energy Recommendations							
1	**Install Adjustable Speed Drives**	**2,631,261 kWh**	-	-	**$81,043**	**$237,500**	**35**
2	**Install Energy Efficient Motors**	**480,462 kWh**	**686 kW**	-	**$21,926**	**$31,940**	**17**
3	**Repair Compressed Air Leaks**	**783,049 kWh**	-	-	**$35,744**	**$2,077**	**1**
Waste Management Opportunities							
4	**Remove and Sell Scrap Colored Glass**	-	-	-	**$11,122**	**$0**	**0**
5	**Reduce Flow of Quenching Water**	-	-	-	**$15,690**	**$0**	**0**
Productivity Enhancement Opportunities							
6	**Decrease Production Line Set- Up Times**	-	-	-	**$1,820,000**	**$3,040,000**	**20**
7	**Install Automatic Packers**	-	-	-	**$1,109,432**	**$1,600,000**	**17**
8	**Reduce Defects by Reducing Bottle Tipping**	-	-	**630**	**$398,160**	**$152,094**	**5**
	Totals	**3,894,772 kWh**	**686 kW**	**630 hrs/yr**	**$3,493,117**	**$5,063,611**	**11 months**

* This recommendation also includes a one-time cost savings of $334,167 which can be obtained by selling the EXISTING stock-pile of colored glass.

PLANT BACKGROUND

Company name and address are removed from report before sending to Field Manager.

Audit Data

Plant Location:	Baltimore, MD 21203
Audit Date:	May 20, 1996
Auditor:	Dr. Michael R. Muller
Temperature:	
Annual Average Temperature	54^{o} F
Heating Degree Days (65^{o} F base)	4821
Cooling Degree Days (65 ^{o}F base)	1344
Principal Products:	Glassware (bottles) for the cosmetics industry
SIC Codes:	3221
Number of Employees:	600
Annual Production:	31,851 tons/yr
Gross Annual Sales:	$45,000,000/yr
Annual Operating Hours:	8,400
Operating Schedule:	Production takes place 4 shifts/week, 7 days/week, 50 weeks/yr.
Energy Sources:	Electricity, Natural Gas

Facility Description

A diagram of the facility and the company property is shown in Figure 1. The facility is located adjacent to train tracks and has its own rail spur; hence, raw materials and finished goods may be transported via truck or rail. The combined floor space at the facility is about 300,000 ft^2. The usage breakdown of the space is approximately as follows:

Space Usage	Percent of Total Facility Space
Offices/Break rooms	3%
Manufacturing	30%
Warehousing/Storage	57%
Abandoned	10%

As shown in the table above, an unusual amount of space in the facility has been abandoned and is presently used as an equipment "graveyard." Over the years, these areas of the facility have become dilapidated and would require extensive repair and renovation before being considered useful. In addition, much of the land area on the site is covered by large piles of crushed colored glass (shown as the waste material fill in Figure 1) which are referred to by employees as the "Alps." Since colored glass cannot be re-melted and used as a raw material in the furnaces, the colored glass scrap has been stockpiled for years in the hopes that a buyer for the material will be found, or at least that another company will transport the glass from the facility at no charge. The land occupied by this scrap glass is said to be increasingly valuable to the company due to planned future expansions and great interest was expressed in removing the "Alps."

Offices are cooled via small window-mounted air conditioning units or packaged combination units with gas heat and electric cooling. No comfort cooling is provided in the manufacturing and warehousing areas, however heat is supplied by natural gas forced-convection space heaters. Due to the small size of the office spaces relative to the rest of the facility and the energy-intensive nature of the manufacturing process, space conditioning costs are considered negligible.

High efficiency lighting (mostly high pressure sodium and energy efficient fluorescent lamps and ballasts) is already in place throughout the facilities as a result of a recent lighting system upgrade which has resulted in a $160,000 per year reduction in electricity bills.

Process layout and description are suggested as it will both aid those writing the report, and indicate to the client your full understanding of the process.

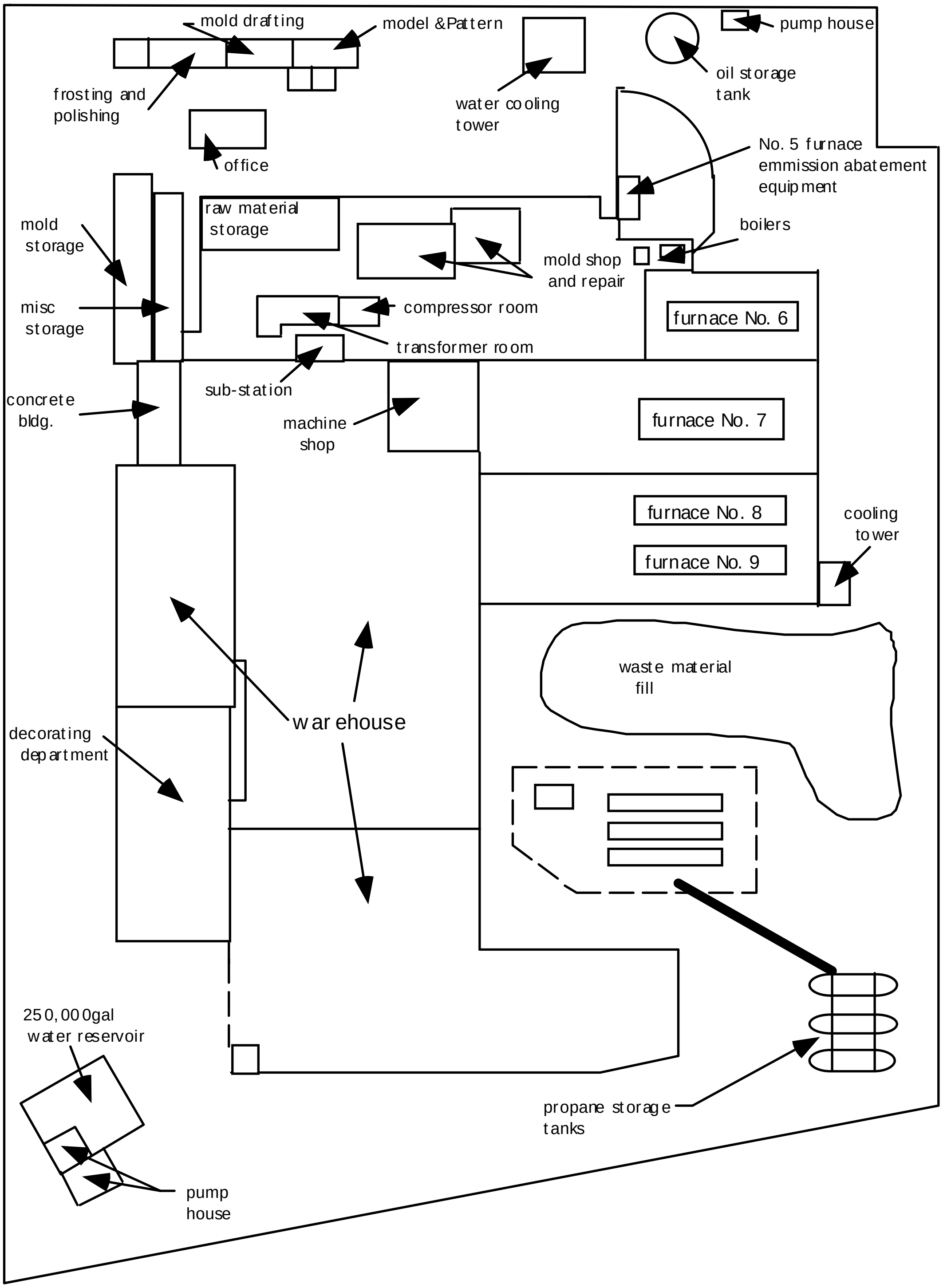


Figure 1: Facility Diagram

Process Description

Sand (silica), lime, and soda ash are stored in silos and mixed in 3,200 lb. batches along with other minor ingredients. The mixed batches are loaded into hoppers and transported to the furnace area using small propane-powered vehicles. The hoppers are hoisted onto a monorail system which hangs high above the production floor.

The material flow into the furnaces consists of the raw materials from the hoppers (70-75% of the total) and clear, crushed glass (referred to as “cullet”) obtained from rejected glassware. Cullet makes up 25%-30% of the material input to the furnace.

A typical furnace system is shown in Figure 2. Each of the three furnaces operates at about 2800˚F to melt the raw ingredients. The primary heat source for furnaces #7 and #8 is natural gas, while the #9 furnace is heated entirely by electric resistance. From the furnace, glass flows into a refiner which operates at about 2400˚F. Molten glass then flows from the refiner into several fore-hearths which contain electric booster heaters to maintain the glass at about 2200˚F. Each fore-hearth feeds one of the ten separate production lines, allowing different glass feed temperatures for each line. For about 10% of the products, coloring agents are added to the molten glass in the fore-hearth. Glass is fed from the fore-hearth to the molding stations by a plunger which pushes “gobs” of molten glass out of the fore-hearth in prescribed volumes.

Since one of the most important factors in extending the campaign life of the furnace refractory is maintaining a constant level of glass in the furnace, the raw material is fed into the furnace at the same rate at which glass is removed from the furnace. Presently, glass is removed from each furnace at a nearly constant rate (regardless of the actual process need for glass), so the rate of feed of raw materials into each furnace is also constant. When process requirements for molten glass are decreased (during mold changes, production line set-up, or during times of decreased production), excess “gobs” of molten glass (20 tons/day) are guided into a basement below the production floor where they are solidified by a continuous flow of water. Once solidified, the glass is crushed and stored for re-melting in the furnaces.

When the “gob” of molten glass is pushed out of the bottom of the fore-hearth, a scissor-like shearing device cuts the “gob” and it drops onto a chute which guides it into the first of two molds. In the first mold, the neck and threads of the bottle are formed. The first mold opens and the glass is removed by mechanical clamping arms. Next, the glass is placed in the second mold where compressed air is used to blow the hot glass into the mold cavity and the body of the

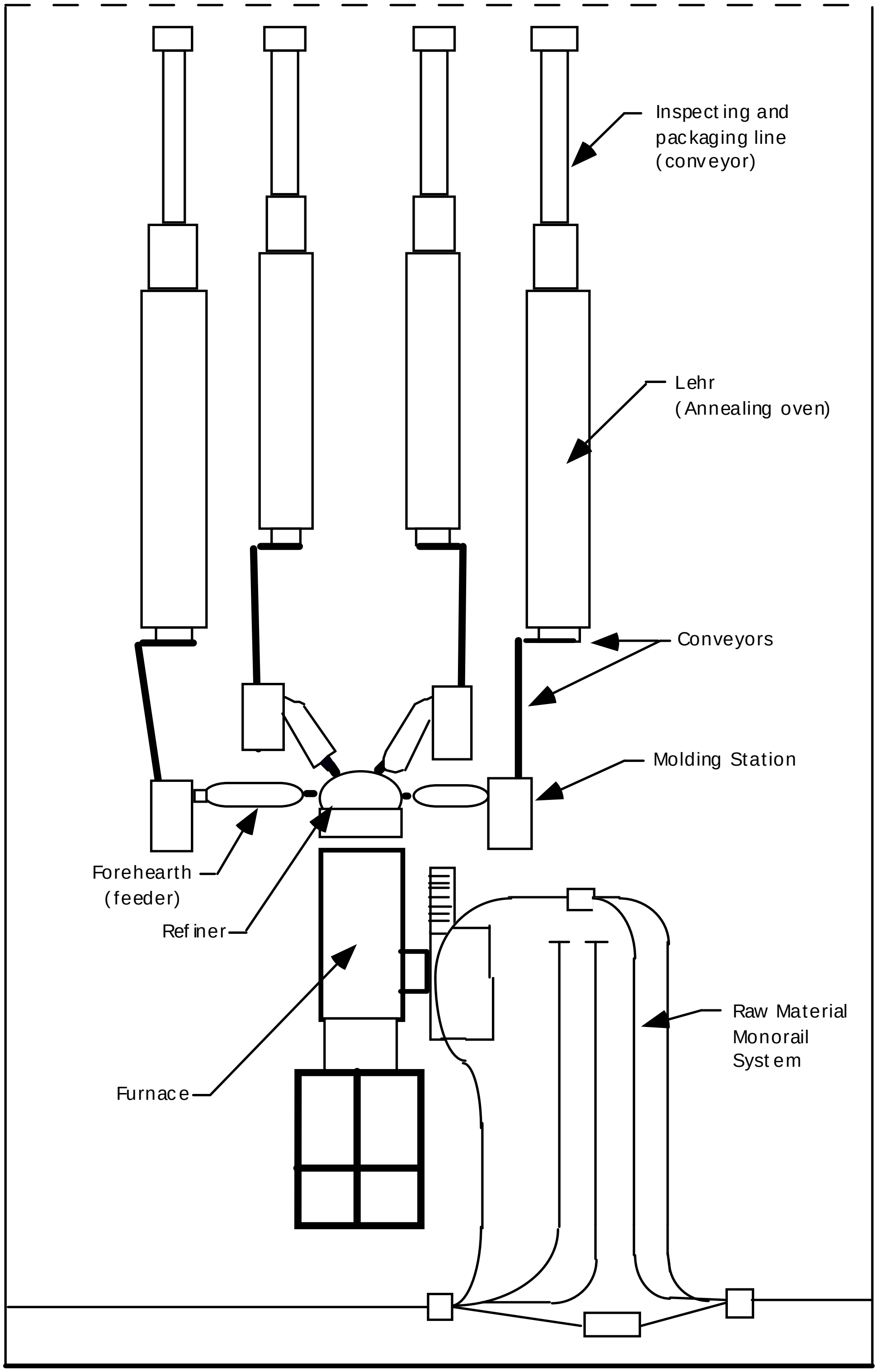


Figure 2: Production Line Diagram

container is formed. While in the molds, cooling is achieved using air delivered by a 75 hp fan and compressed air. One 75 hp cooling air fan serves each of the ten molding stations. Once the glass has been sufficiently cooled, the second mold opens and the fully-molded container is removed from the mold by mechanical clamping arms and placed on a conveyor. When placed on the conveyor, the temperature of the glass is approximately 1000˚F.

Next, the glassware is pushed from the initial conveyor onto another which travels through annealing ovens, or “Lehrs.” While in the Lehrs, the temperature of the glass is slowly decreased to the exit temperature of 150˚F to 300˚F. Upon exit from the Lehrs, each piece is hand inspected. Pieces which pass inspection are manually packaged, while rejects are placed back onto the conveyor line and drop into the basement to be used as cullet.

The most common rejects include: surface scoring, cracks, wrinkles, and improper glass distribution. Most rejected products are caused by improperly adjusted, or worn and dirty mechanical equipment. Common examples are mold misalignment or problems with temperature or mechanical timing.

After packaging, 10% of the glassware is sent to the decorating or frosting departments and the remainder is transported to the finished goods warehouse. Once in the decorating or frosting departments, the glassware is manually taken out of the boxes prior to further processing. In the decorating department, pigment is "impregnated" with very fine glass and screened onto the bottles. The bottles are then annealed again (to about 800˚F) to allow the coloring and decoration to melt into the skin of the glass. In the frosting department, the bottles are dipped in a series of baths for about 30 seconds each: first HFl acid, then HCl acid, then water. After being removed from the water bath, the glass is hosed off with city water, then inspected and repackaged. The acids are drained into a pit where they are neutralized.

A flow diagram for the plant’s materials and processes is shown in Figure 3.

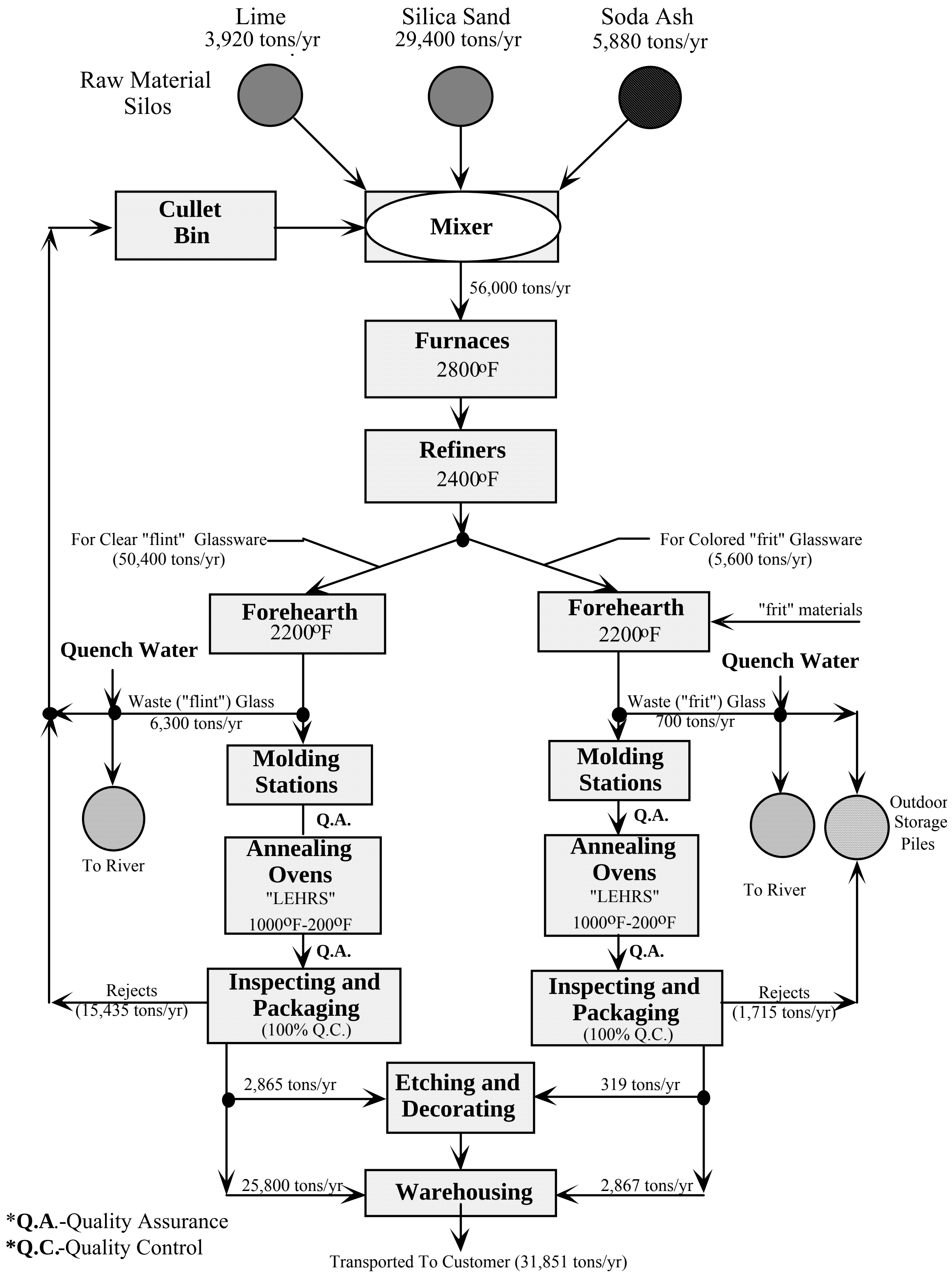


Figure 3: Material and Process Flow Diagram

Informational Summary

Principal products:

- Clear and colored glass bottles

Materials or components used:

- Silica Sand
- Soda Ash
- Lime (calcium carbonate)
- Feldspar
- Coloring agents

Manufacturing operations:

- Mixing
- Melting
- Molding
- Annealing
- Etching
- Decorating
- Packaging

Major Plant Energy Consuming Equipment

Electricity

A. Air Compressors

High Pressure System (100 psig)	*Low Pressure System (50 psig)*
1-120 HP rotary screw	2-800 HP centrifugal
1 - 75 HP reciprocating	2-250 HP centrifugal
1 - 60 HP rotary screw	
1 - 40 HP rotary screw	

B. Heating/Cooling/Ventilating Equipment

Packaged Office Cooling Units (about 25 tons combined cooling capacity)
2 Small cooling towers

C. Production Equipment

Furnace #9, 1500 kW
Furnace #7 & #8 Boosters, 900 kW
10 - 75 hp motors (mold cooling fans)
2 - 100 hp motors (furnace air supply fans)

Natural Gas

A. Heating/Cooling/Ventilating Equipment

Gas fired space heaters

B. Production Equipment

Furnace #7, 15.5 Mcf per hour
Furnace #8, 11.5 Mcf per hour
10 Feeders (Fore hearths), 1.54 Mcf per hour
10 Annealing ovens (Lehrs), 0.83 Mcf per hour

General Material, Labor, and Production Cost Data

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.

Labor Costs:

Production Worker:	$30,000/man-year ($19.47/man-hour)
Skilled Technician:	$40,000/man-year ($25.96/man-hour)
Engineering (contracted):	$100/engineer-hour

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

Raw Material Costs:

Silica Sand:	$13.43/ton
Soda Ash:	$68.00/ton
Lime:	$13.00/ton
Water:	$2.50/hcf (1 hcf = 100 ft^3)

The average raw material mixture is assumed to consist of 30% cullet and 70% virgin materials. The virgin material is assumed to be 75% silica sand, 15% soda ash, and 10% lime.

Cost of Lost Production:

Since this plant operates continuously (24 hr/day) throughout the year (except during planned down-times) and there are plans to expand the production capacity of furnace #7, it has been assumed that any time saved due to a reduction in production line down-time or product defect rate can be used to make other products. The glassware produced during this "saved" time would hold the following value to the company per hour of production line time saved (see Assessment Recommendation No. 6 for calculation):

Cost of Lost Production (or Value of Production Time Gained):$632/hr/prod. line

Inventory and Floor space:

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

Inventory Carrying Cost: 10%

Production Lead Time: 13 weeks

Best Practices

- **Safety Conscious** – Before we walked through the plant, we were given explicit safety instructions by the plant environmental safety manager. Holding safety as paramount is an important plant operating practice.
- **High-bay Fluorescent Light Fixtures** – Management has replaced many metal halide (MH) fixtures with high-bay fluorescent (HBF) fixtures, and plan to replace more in the future. Compared to MH fixtures, HBF fixtures provide more light to working areas, have a higher color rendering index (CRI), and consume less electricity. Management conducted a study that compares plant foot-candle readings before and after the HBF retrofit, and results clearly show that HBF fixtures provide the greater amount of light.
- **Space Heat with Air Compressor Exhaust Heat** – During the winter, air compressor exhaust heat is directed to the plant for space heating. This offsets natural gas heating costs.

A Best Practices section is included to show positive aspects of a client's facility.

ENERGY MANAGEMENT

Rising energy costs and repeated energy shortages will determine the future of many companies. To meet this challenge, a successful company must have an energy conservation management program to consistently take advantage of every energy conservation opportunity. Several basic steps are required for effective energy management:

- Management Commitment
- Data Analysis
- Analysis of Conservation Opportunities
- Implementation of Conservation Techniques
- Continued Feedback and Analysis

The Energy Management program must have the commitment of management for it to produce a long term increase in energy efficiency. A brief, early show of support will only result in small, temporary improvements. Management must design the conservation program as part of its regular, overall company management system. Also, energy costs and consequence of future energy shortages should be widely disseminated to create overall energy awareness.

Accounting for energy and its cost is an essential component of an energy management program. It can best be done by keeping up-to-date bar graphs of energy consumption and associated costs on a monthly basis. When the utility bills are received each month it is recommended that the energy used is plotted immediately on the bar graphs. A graph will be required for each type of energy used. The value of the bar graphs can best be understood by examining those plotted for your company on the following pages. It is simple to detect trends and anomalies from these graphs, and much easier to assess the value of energy conserving actions.

Data analysis will be greatly aided if the records use a standard format for all the company's divisions and if the different energy units (such as kilowatt-hours of electricity, gallons of oil etc.) are converted to a common energy unit, the BTU (British Thermal Unit). One BTU is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit. By comparing the cost of various fuels on the basis of cost per million BTU's

($/MMBtu), the true cost of each fuel can be determined. The conversion factors required are shown on the following page.

ENERGY UNIT	ENERGY EQUIVALENT
1 kWh	3,412 BTU
1 Therm	100,000 BTU
1 Cu. Ft. of Natural Gas	1,000 BTU*
1 gallon #2 Oil	140,000 BTU*
1 gallon #4 Oil	144,000 BTU*
1 gallon #6 Oil	152,000 BTU*
1 gallon propane	91,600 BTU*
1 ton coal	28,000,000 BTU*
1 boiler horsepower	9.81 kW
1 horsepower	0.746 kW
1 ton refrigeration	12,000 BTU/hr

*Varies slightly with supplier

On a regular basis, whether monthly or annually, progress toward conservation goals should be examined and a new set of goals defined. All goal setting will depend on the opportunities for energy conservation which data analysis have uncovered. More detailed information on specific mechanisms may be required as the program continues the search for energy waste. Data listings and plots such as those presented in the following section should be used as a minimum to aid in the measurement and analysis of energy conservation efforts.

In addition, pie charts of specific energy and production related costs can be helpful in identifying areas which may offer large cost saving potential. Examples of these pie charts for your facility are also shown in the following section.

PLANT ENERGY CONSUMPTION

Period Considered: January 1995 to December 1995

An analysis of one year of a client's Energy bills is suggested to note any trends for the client and aid in developing Assessment Recommendations (ARs).

TOTAL USAGE & COST SUMMARY	
Energy Usage	540,198 MMBtu/yr
Energy Cost	$2,778,491 /yr

ELECTRICITY

Month	Electric Usage (kWh)	Usage Cost ($)	On-Peak Demand (kW)	Demand Cost ($)	Electric Fees ($)	Total Electric Cost
January	3,469,000	100,806	5,193	43,206	1,270	145,283
February	3,923,000	113,999	5,193	43,206	1,338	158,544
March	3,670,000	108,347	6,077	50,561	1,301	160,208
April	2,450,000	70,414	3,964	32,980	1,118	104,512
May	2,526,000	73,763	3,873	32,044	1,129	106,936
June	2,403,000	84,731	3,986	57,478	1,110	143,319
July	2,689,000	98,857	4,281	61,732	1,153	161,742
August	2,989,000	111,739	4,447	64,126	1,198	177,063
September	2,629,000	94,506	4,248	61,398	1,144	157,048
October	2,946,000	82,522	4,248	35,343	1,192	119,058
November	2,930,000	82,099	4,384	36,475	1,190	119,764
December	2,562,000	61,034	4,536	46,857	1,076	108,967
TOTALS	**35,186,000**	**1,082,818**	**54,430**	**565,406**	**14,220**	**1,662,443**

Usage Cost = $0.0308/kWh; Demand Cost = $10.39/kW-month ; Average Cost = $0.0472/kWh

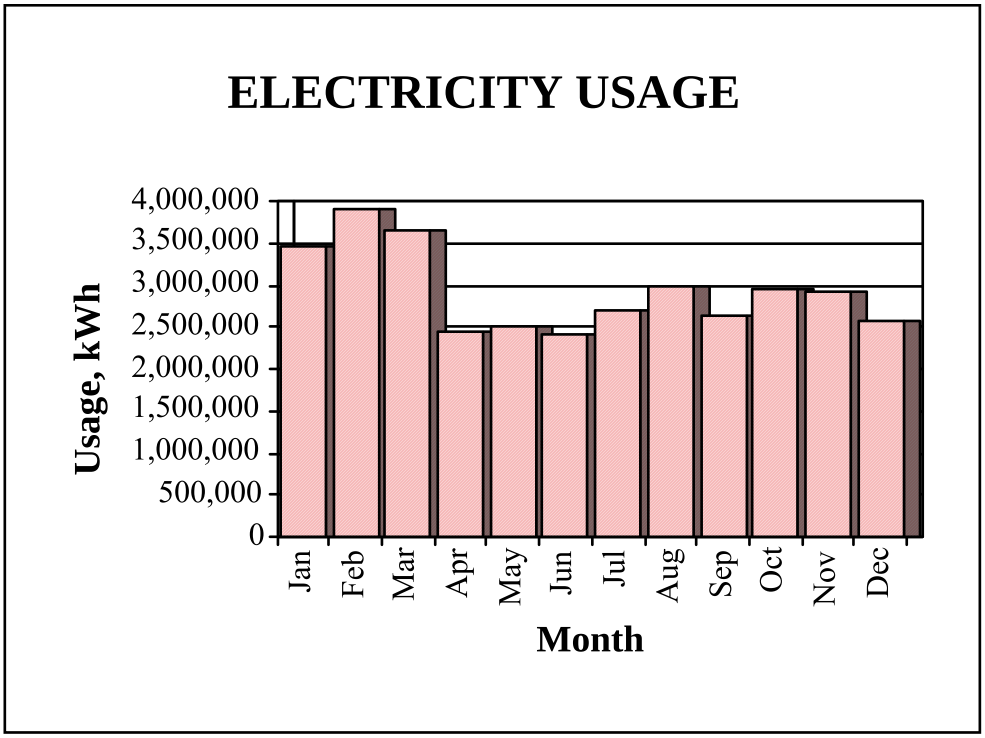
NATURAL GAS

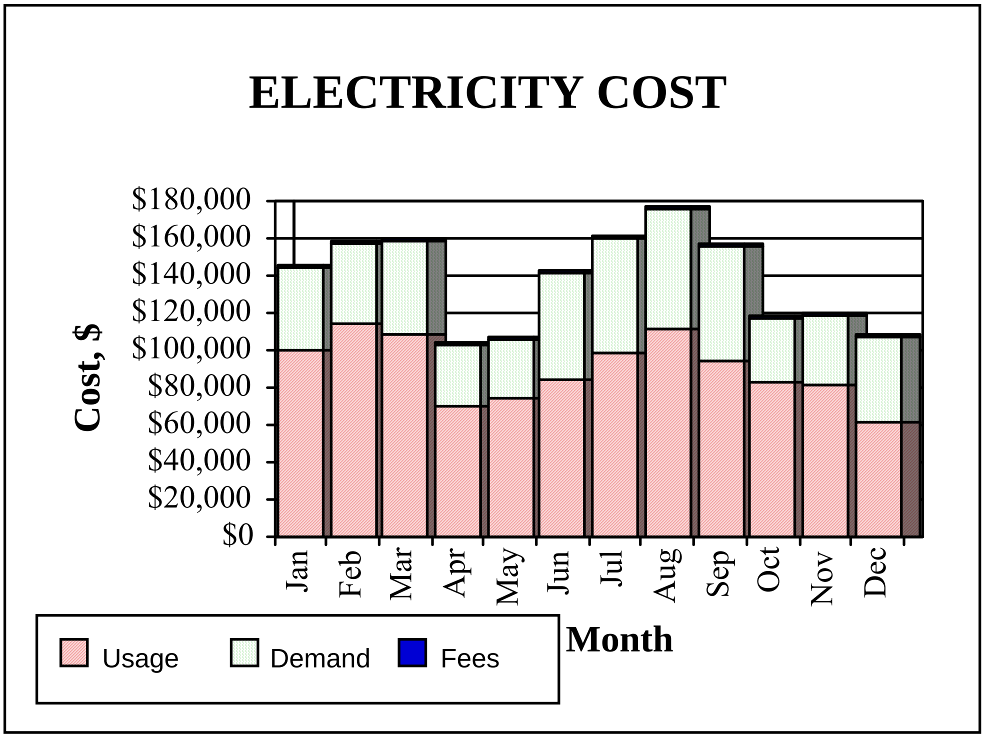
Month & Year	Mcf	MMBtu	Total Cost
January	28,252	29,665	84,782
February	22,162	23,270	87,091
March	39,059	41,012	98,094
April	35,059	36,812	88,515
May	35,617	37,398	91,351
June	35,705	37,490	88,183
July	35,397	37,167	71,976
August	30,691	32,226	74,265
September	33,947	35,644	81,823
October	32,918	34,564	86,271
November	35,110	36,866	112,623
December	36,187	37,996	151,074
TOTALS	**400,104**	**420,109**	**1,116,048**

Average Cost = $2.79/Mcf = $0.266/Therm = $2.66/MMBtu

ELECTRICITY

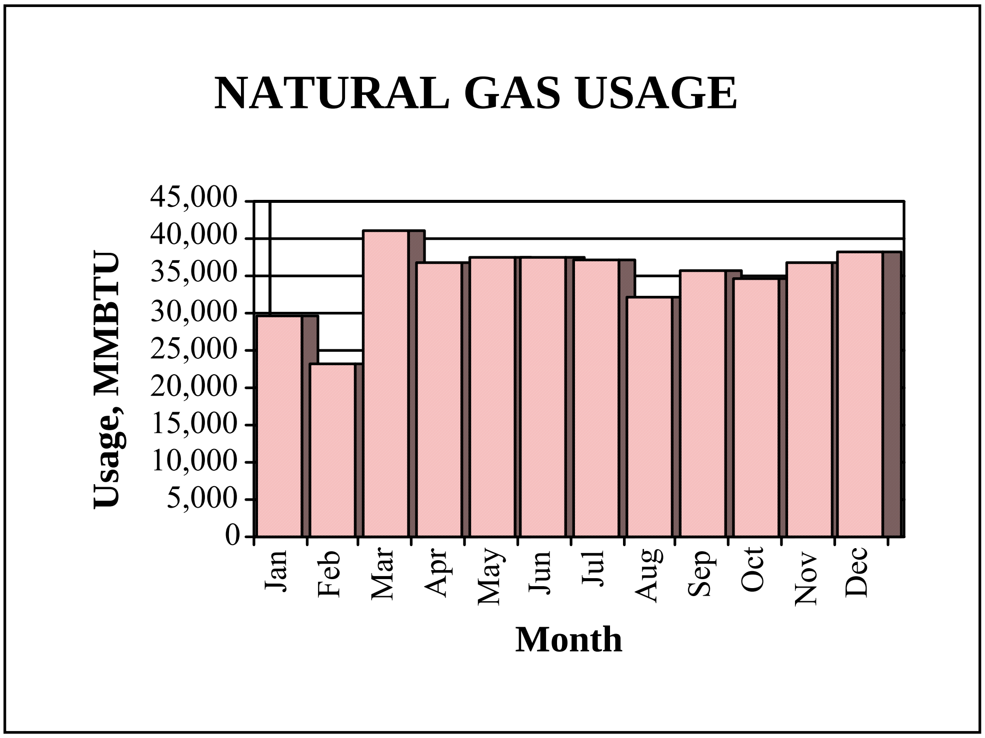
Monthly Usage and Cost

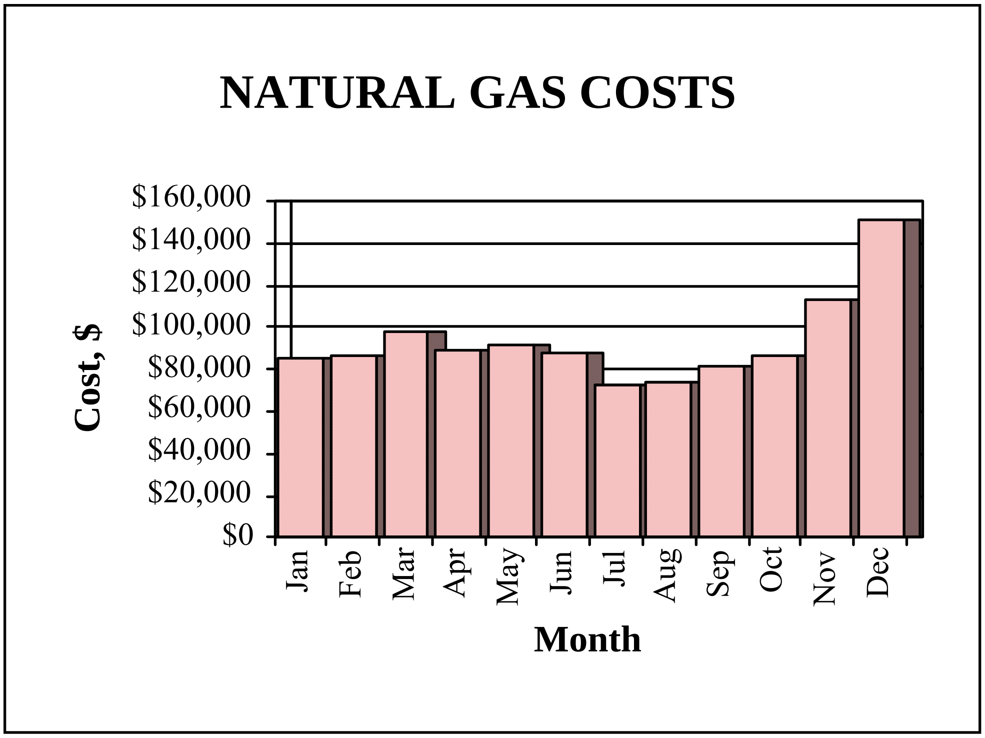




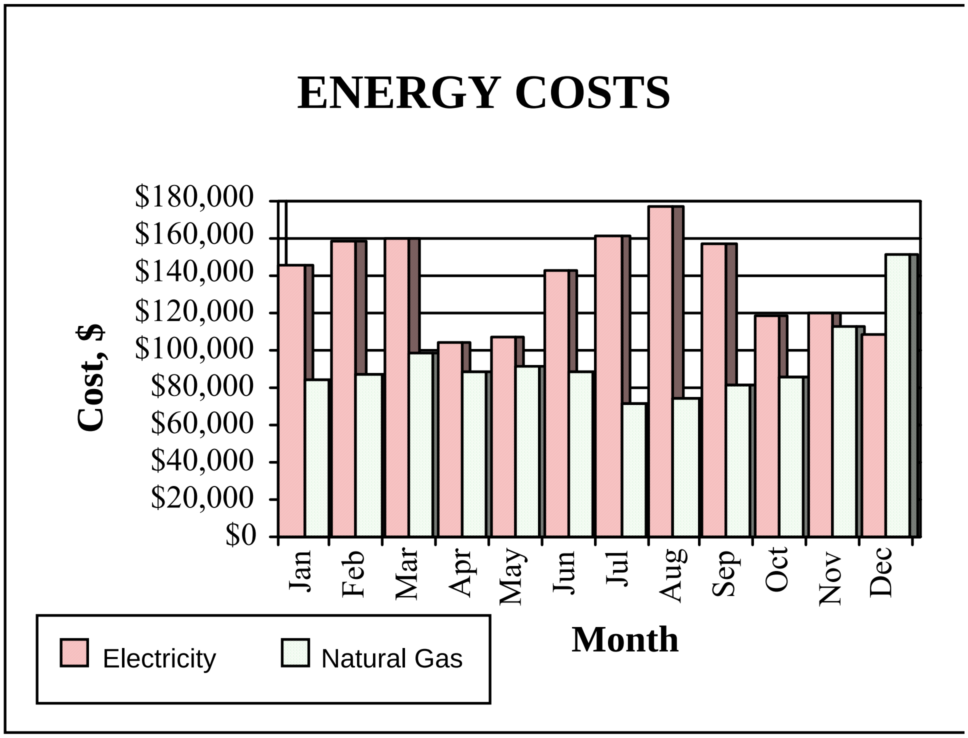
NATURAL GAS

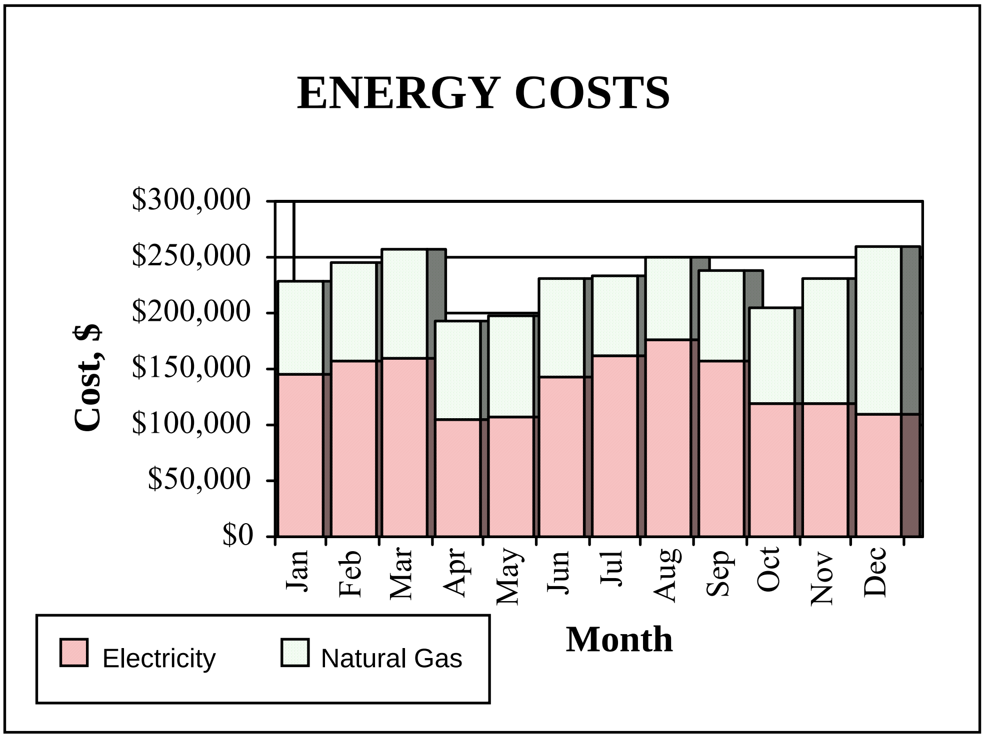
Monthly Usage and Cost



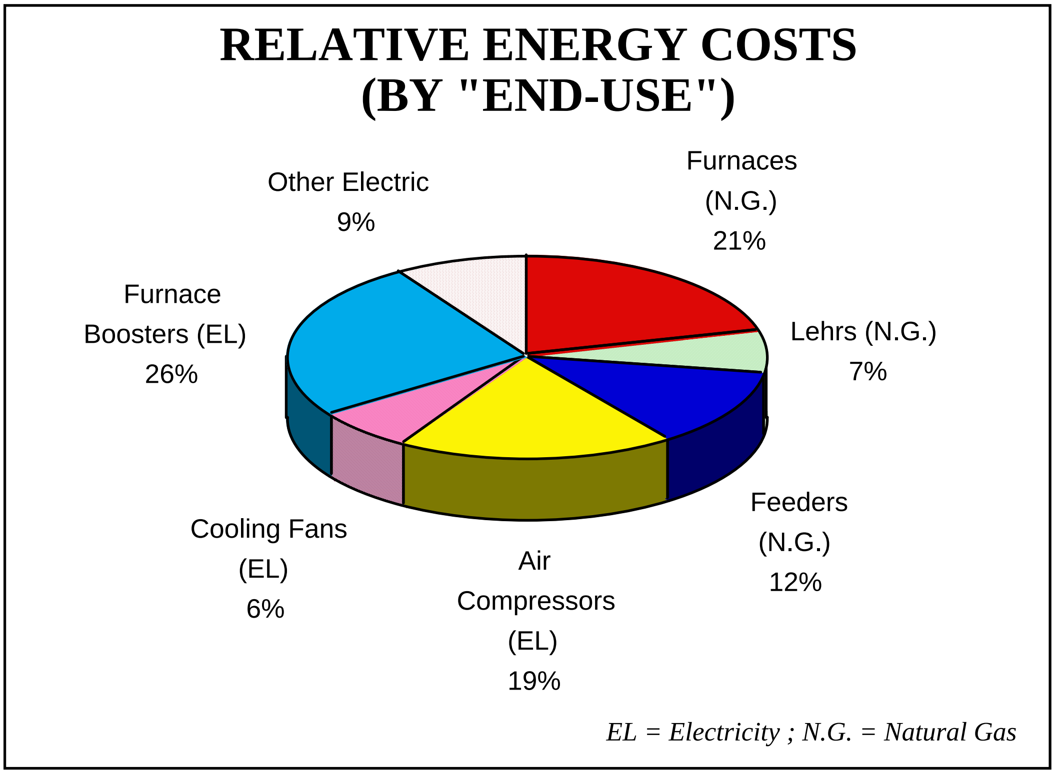


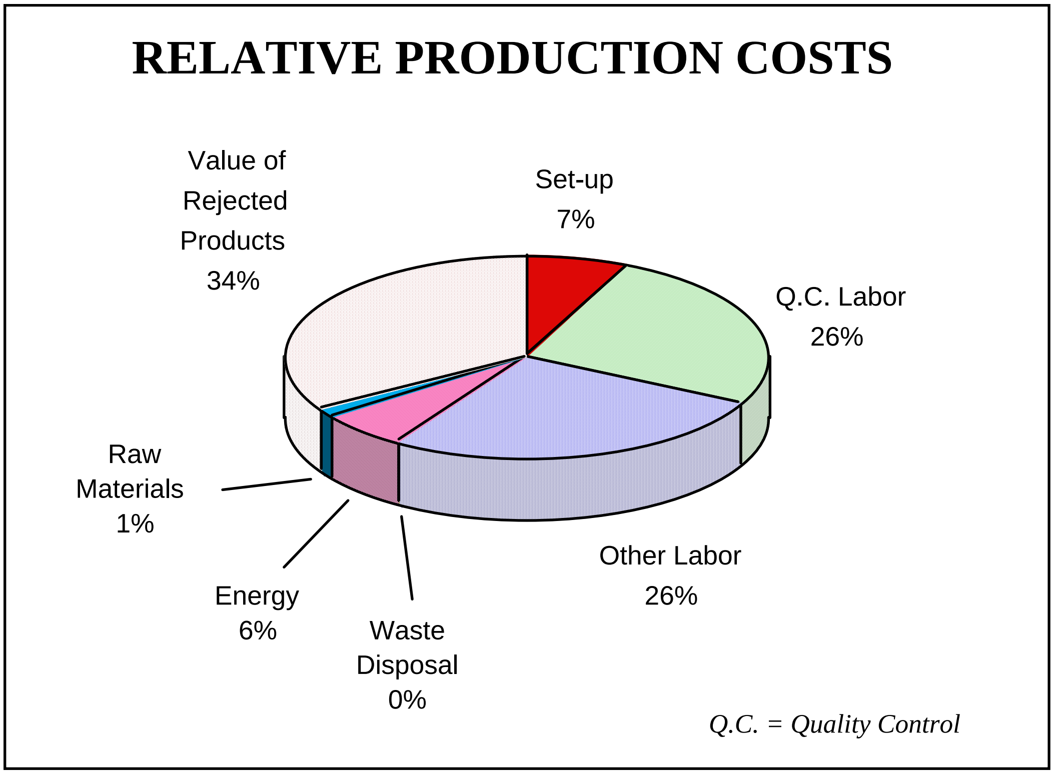
COMBINED ENERGY COSTS




ENERGY COSTS
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Cost, $
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Electricity
Natural Gas

ENERGY & PRODUCTIVITY COST PIE CHARTS





RELATIVE PRODUCTION COSTS

Q.C. = Quality Control

All Recommendations should include Current Practices, Recommendation, Anticipated Resource and Cost savings with calculations, implementation cost and simple payback. The IAC program does not endorse any vendor.

ENERGY CONSERVATION OPPORTUNITIES

AR No. 1

INSTALL ADJUSTABLE SPEED DRIVES ON FORMING DEPARTMENT COOLING FANS AND FURNACE AIR SUPPLY MOTORS

Assessment Recommendation Summary

Estimated Electricity Usage Savings = 2,631,261 kWh/yr
Estimated Cost Savings = $81,043/yr
Estimated Implementation Cost = $237,500
Simple Payback Period = 2.9 years

Existing Practice and Observation

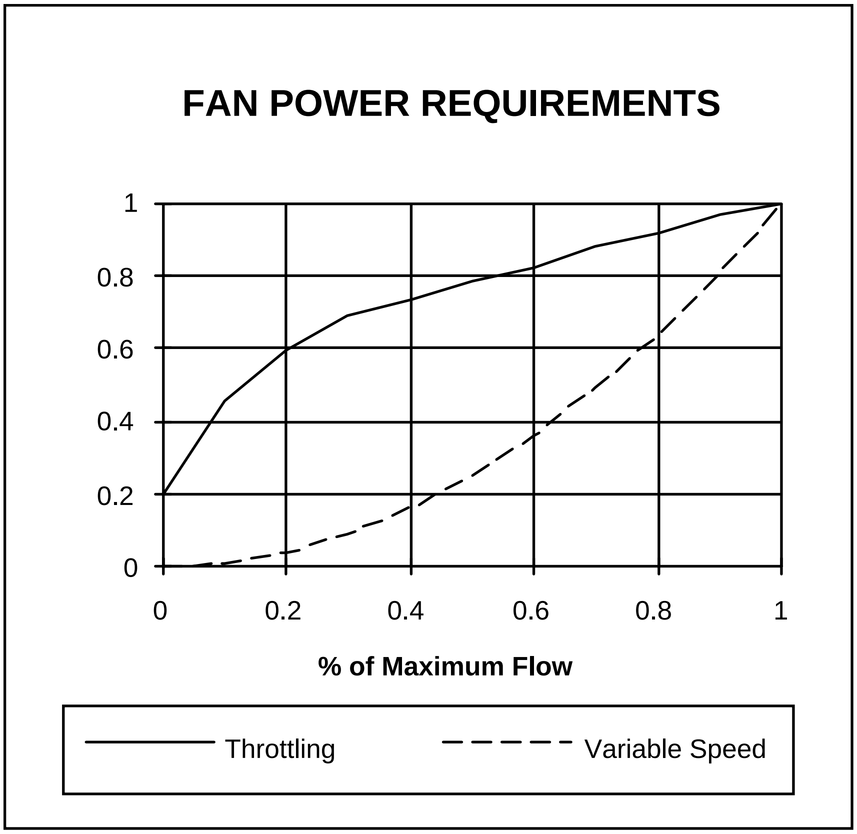
Ten fans are used to provide cooling to the production lines. The fans utilize 75 hp standard-efficiency, single-speed motors. Ambient air is delivered to the mold "shops" via ductwork from the mezzanine level to the production floor. Flow through these fans is presently modulated using dampers on the outlets of the ducts.

Two fans, *assumed to each have a 100 hp motor*, are used to supply air for combustion in the furnaces. Inlet vanes and outlet dampers are presently used to control this air flow.

Recommended Action

Install adjustable speed drives on the cooling fans and the furnace air supply fans. For flow systems which operate for significant periods of time at part load (i.e., with less than the maximum possible flow rate), lower operating costs can be achieved by using adjustable speed drives to vary flow rates instead of using throttling devices such as valves, inlet vanes, or dampers which impose losses or inefficiencies in the flow system.

The losses caused by throttling devices result in a waste of the electricity used to drive the fan motor. On the other hand, by varying the speed of the fan and opening the throttling devices these losses are avoided. There can be as much as a cubic relationship between flow (and speed) reduction and input power reduction when modulating flow rates by varying the motor speed. That is, if flow is reduced to 50% of the original flow, the power required could be as low as (0.50)(0.50)(0.50) = 0.125, or 12.5% of the original power. To be conservative, we have assumed a square relationship between flow and power reduction. Figure #1, AR#1 shows the percent of maximum power demand for both throttled and ASD systems for various flow rates. On the graph, notice the significant drop in power requirement of an ASD with a decrease in the rate of air flow.



Anticipated Savings

The annual energy savings as a result of the adjustable speed drives, AES, is the difference in the power requirement for the throttled case and the variable speed case. Hence, AES can be calculated as follows:

$$AES = N \times HP \times HRS \times D \times (PDR_E - PDR_{ASD}) \times C$$

where

N = number of motors

HP = motor horsepower

PDR_C = existing power demand ratio (from Figure #1, AR#1)

PDR_{ASD} = power demand ratio if the ASDs are installed (from Figure #1, AR#1)

C = conversion constant, 0.746 kW/hp

HRS = annual hours of operation, 8,400 hrs/yr
D = duty cycle (% of time)

For the cooling fans operating at 75% load, the savings are calculated as follows using Figure #1, AR#1:

N = 10 motors
HP = 75 hp
PDR_C = 0.75 (from the throttling curve, at Power = 75%, Flow = 43%)
PDR_{ASD} = 0.20 (from the variable speed curve, at Flow = 43% , Power = 20%)
D = 0.20

thus, the annual energy savings of the cooling fans, AES_{CF}, at 75% load is

$$AES_{CF} = (10)(75)(8,400)(0.20)(0.75 - 0.20)(0.746)$$
$$= 516,978 \text{ kWh/yr}$$

For the air supply fans,

N = 2 motors
HP = 100 motors
PDR_C = 0.75
PDR_{ASD} = 0.20
D = 0.20

and the annual energy savings for the air supply fans, AES_{ASF}, will be,

$$AES_{ASF} = (2)(100)(8,400)(0.20)(0.75 - 0.20)(0.746)$$
$$= 137,861 \text{ kWh/yr}$$

The total annual energy savings, AES_{ASD}, at 75% load by installing adjustable speed drives will be,

$$AES_{ASD} = AES_{CF} + AES_{ASF}$$
$$= 516,978 + 137,861$$
$$= 654,839 \text{ kWh/yr}$$

Based on power measurements taken during our site visit and interviews with facility personnel, it is assumed that the fan motors are not presently operating at less than 50% load. *It is also assumed that 20% of the motor operating hours are presently spent operating in each of* *the following load ranges: 50 to 60%, 60 to 70%, 70 to 80%, 80 to 90%, and 90 to 100%. As shown in the following table, the savings provided by installing adjustable speed drives is highly dependent on the existing load profile of the motors (load profile = percent time operating at each load). Hence,* ***before implementing this recommendation, the load profile assumed in our calculations should be closely scrutinized and adjusted if necessary. Extended field monitoring of the power consumption of the fans would ensure that the anticipated results are achieved.***

Since motors operate poorly at speeds of less than 30%, the minimum percent load for the ASD should correspond to the minimum speed of 30%; i.e., the minimum load using an ASD would be about 10% (from Figure #1, AR#1). If flows less than 30% are needed, throttling devices could be used *in combination* with the adjustable speed drive. This has been taken into account in the following table.

The table below shows the combined energy savings for the cooling fan motors and the furnace air supply motors at varying percentages of the existing motor loads:

% Maximum Load, Existing	% Maximum Load, ASD	Duty Cycle (% of time)	Throttled Flow Energy Usage, kWh/yr	Variable Speed Flow Energy Usage, kWh/yr	Savings, kWh/yr
50-60%	10%	20%	654,839	119,062	535,777
60-70%	10%	20%	773,900	119,062	654,839
70-80%	20%	20%	892,962	238,123	654,839
80-90%	42%	20%	1,012,024	500,059	511,965
90-100%	72%	20%	1,131,085	857,244	273,842
	Totals	100%	4,464,810	1,833,549	2,631,261

The annual cost savings resulting from the ASDs, ACS_{ASD}, can be calculated with the following equation:

$$ACS_{ASD} = AES_{ASD} \times EC$$

where

EC = cost of electricity usage, \$0.0308/kWh

Thus,

$$ACS_{ASD} = (2,631,261)(0.0308)$$

= \$81,043/yr

Savings on peak electric demand costs may also result and could be as high as:
[(2,631,261 kWh/yr) / (8400 hr/yr)] x (12 month/yr) x (\$10.39/kW/month) = \$39,055/yr. Again, to be conservative, these savings have been neglected.

Implementation

Implementation of this recommendation would call for installation of the adjustable speed drives. The adjustable speed drives can be installed for approximately \$250 per hp which equates to a total of \$237,500. This results in a simple payback of 2.9 years.

AR No. 2

INSTALL ENERGY EFFICIENT MOTORS ON FORMING DEPARTMENT COOLING FANS, FURNACE AIR SUPPLY FANS, AND COMPRESSORS

Assessment Recommendation Summary

Estimated Electricity Usage Savings = 480,462 kWh/yr
Estimated Peak Electric Demand Savings = 686 kW-months/yr
Estimated Cost Savings = $21,926/yr
Estimated Net Implementation Cost = $31,940
Simple Payback Period = 1.5 years

Background

Depending on the horsepower rating, the operating efficiency of a given high efficiency (HE) motor may be from 1% to 10% higher than that of a standard motor currently being used in the facility. In general, the larger the motor, the smaller the efficiency increase. When a standard motor fails, the cheapest initial cost approach is to rewind it. However, because high efficiency motors are significantly cheaper to operate than standard motors, it is often cost-effective to purchase a new high efficiency motor instead of rewinding the failed standard motor.

Also, studies have shown that the rewinding process itself, as well as the thermal shock suffered by the motor during failure decreases the motor efficiency by about 2% (on average). This makes upgrading to high efficiency motors even more economically attractive. The cost premium (or cost differential) involved in making such an upgrade would be the difference between the purchase price of the new high efficiency motor and the cost of rewinding the failed one.

Recommended Action

Install high efficiency electric motors to replace the existing standard motors currently used at this facility as the existing motors fail (i.e. only on a replacement basis). High efficiency motors are cheaper to operate and provide significant savings on electric bills.

The motors examined for this recommendation are listed in the following table:

Area	Horse- power	Number of Motors	Load Factor	Annual Operating Hours	Standard Eff.	Rewind Efficiency	EE Efficiency
Cooling Fans	75	10	0.75	8400	91.8%	89.8%	95.2%
Air Supply Fans	100	2	0.75	8400	92.0%	90.0%	95.3%
Compressor Room	250	2	0.75	8400	93.5%	91.5%	95.7%
Compressor Room	125	1	0.75	8400	92.2%	90.2%	95.2%
Compressor Room	40	1	0.75	8400	90.7%	88.7%	94.5%
Compressor Room	60	1	0.75	8400	91.7%	89.7%	95.0%
Compressor Room	75	1	0.75	8400	91.8%	89.8%	95.2%

Anticipated Savings

The annual energy savings as a result of the energy efficient motors, AES_{EEM}, is based on the difference in efficiencies if the failed motor is rewound as compared to replacement with an energy efficient motor. AES_{EEM} can be calculated as follows:

$$AES_{EEM} = CEU - PEU$$

where

CEU = the current energy usage with the standard efficiency motors
PEU = the proposed energy usage as a result of the energy efficient motors

CEU can be obtained using the following equation:

$$CEU = N \times HP \times LF \times HRS \times 1/(Eff_{STD} - RWL) \times C$$

where

N = number of motors
HP = motor horsepower
LF = load factor of the motors
HRS = annual operating hours, 8,400 hrs
Eff_{STD} = motor efficiency of the standard model
RWL = motor rewind losses, 2%
C = conversion factor, 0.746 kW/hp

As an example, data for the forming department cooling fans is,

N = 10 motors

HP = 75 hp

EFF_{STD} = 0.918

LF = 0.75

Therefore,

CEU = (10)(75)(0.75)(8400)(1/(0.918-0.02))(0.746)

= 3,925,223 kWh/yr

PEU can be calculated in the same manner:

$$PEU = N \times HP \times LF \times HRS \times 1/Eff_{EEM} \times C$$

Thus, for the forming department cooling fans,

N = 10 motors

HP = 75 hp

Eff_{EEM} = motor efficiency of the energy efficient model, 0.952

Therefore,

PEU = (10)(75)(0.75)(8400)(1/0.952)(0.746)

= 3,702,574 kWh/yr

Therefore, the annual energy savings by installing energy efficient motors rather than rewinding is:

AES_{EEM} = 3,925,223 - 3,702,574

= 222,649 kWh/yr

The above calculation can be performed in one step using the following equation:

$$AES_{EEM} = CEU - PEU = N \times HP \times LF \times HRS \times [1/(Eff_{STD}-RWL) - (1/Eff_{EEM})] \times C$$

The annual demand reduction as a result of the energy efficient motors would be:

$$ADR_{EEM} = AES_{EEM}/HRS \times 12 \text{ months/year}$$

$= (222{,}649)/(8400) \times 12$

$= 318$ kW-month/yr

The following table outlines the results of switching to energy efficient motors:

Area	Current Energy Usage, kWh/yr	Proposed Energy Usage, kWh/yr	Savings, kWh/yr	Demand Reduction, kW-months/yr
Cooling Fans	3,925,223	3,702,574	222,649	318
Air Supply Fans	1,044,400	986,317	58,083	83
250 hp Compressor	2,568,197	2,455,486	112,711	161
125 hp Compressor	651,303	617,096	34,207	49
40 hp Compressor	211,941	198,933	13,008	19
60 hp Compressor	314,368	296,829	17,538	25
75 hp Compressor	392,522	370,257	22,265	32
Totals	9,107,954	8,627,492	480,462	686

The annual cost savings resulting from the energy efficient motors, ACS_{EEM}, can be calculated with the following equation:

$$ACS_{EEM} = AES_{EEM} \times EC + ADR_{EEM} \times DC$$

Where:

EC = cost of electricity, \$0.0308/kWh

DC = cost of demand, \$10.39/kW-month

Thus,

$$ACS_{EEM} = (480{,}462)(0.0308) + (686)(10.39)$$

$$= \$21{,}926/\text{yr}$$

Motor Selection and Application

In comparison to standard motors, energy efficient motors tend to run at a slightly higher speed due to their decreased losses. ***Since the loads experienced by pumps and fans increase significantly as rotational speed increases, care must be taken to select a high efficiency motor with the same rotational speed as the standard motor it replaces.*** A general rule of thumb is: a 1/3% increase in rotational speed will negate a 1% gain in motor efficiency. If it is difficult to match the speed of a high efficiency motor to that of an existing standard motor, adjusting the sheaves or changing pulleys are the suggested methods of maintaining the same fan speed.

Since motor failure usually occurs unexpectedly, replacement motors are often selected on a "first available" basis without consideration of improving motor efficiency. Hence, the most effective method of ensuring the implementation of high efficiency motors and achieving the resulting savings is to pre-select the replacement high efficiency motors. Further, many manufacturers purchase replacement motors before existing motors fail. Others make arrangements with their motor supplier to ensure that the desired motor is in stock when needed. These preparations can shorten downtime and ensure optimum motor selection.

Implementation

Implementation of this recommendation would call for a replacement of the existing motors as the motors fail. A motor rewind costs approximately $1,000 for each motor. The cost premium (the difference between a new energy efficient motor and a rewind) for the motors can be seen in the following table:

Size, hp	Cost Premium
40	$750
60	$1,900
75	$2,500
100	$2,800
125	$3,500
250	$6,800

Rebates exist from Baltimore Gas and Electric which would help offset the cost of the new motors. This rebate schedule can be seen in the table on the following page. The rated nameplate efficiency of the new motors must be at least that in the "Minimum Required Efficiency" column to be eligible for a rebate.

Before any rebate is applied, the total implementation cost for installation of the energy efficient motors is $52,850. Using the rebates, the total money returned from BG&E is $20,910. The resulting net implementation cost is $31,940. Based on the savings estimate of $21,926 per year, the simple payback period would be 1.5 years.

Size, hp	Minimum Required Efficiency	REBATE		
		TEFC		ODP
		Replacement Motors	Plant Expansion Motors	Plant Expansion & Replacement Motors
1	82.5%	$40		$40
1.5	84.0%	$50		$50
2	84.0%	$50		$50
3	87.5%	$70		$70
5	87.5%	$70		$70
7.5	89.5%	$90		$90
10	89.5%	$110		$110
15	91.0%	$150		$150
20	91.0%	$170		$170
25	92.4%	$220		$220
30	92.4%	$260		$260
40	93.0%	$360		$360
50	93.0%	$470		$470
60	93.6%	$550	$490	$300
75	94.1%	$800	$550	$320
100	94.5%	$1,100	$890	$400
125	94.5%	$2,200	$1,500	$530
150	95.0%	$3,000	$1,600	$730
200	95.0%	$3,200	$2,000	$1,050
250	95.0%	$3,400	$2,200	$2,300

AR No. 3
REPAIR LEAKS IN COMPRESSED AIR LINES

Assessment Recommendation Summary

Estimated Electricity Usage Savings = 783,049 kWh/yr

Estimated Cost Savings = $35,744/yr

Estimated Implementation Cost = $2,077

Simple Payback Period = less than 1 month

Background

The facility uses both high pressure and low pressure compressors to supply the necessary air to the molding machines and other equipment. The compressed air system consists of a total of eight compressors. Their sizes and average loads are listed below:

Number	Type	Horsepower	Average Load
2	Centrifugal	800	60%
2	Centrifugal	250	100%
1	Screw	125	100%
1	Reciprocating	75	100%
1	Screw	60	100%
1	Screw	40	100%

Based on the facility annual operating hours, the compressor operating hours are considered to be 8,400 hrs/yr. This recommendation considers air being lost as a result of leaks in and around the air lines and fittings. Therefore, these savings account for losses resulting strictly from "unplanned" leaks.

Anticipated Savings

Based on the load factors and horsepower ratings, an average of 1,760 hp is used to produce compressed air in the plant. This equates to 11,028,864 kWh in energy consumption each year. Previous surveys of the compressed air system at this facility have indicated that 15-20% of the compressed air is lost through leaks. After discussion with plant personnel, it has been estimated that by repairing air leaks in the plant, a reduction of 10% of the existing air production can be achieved.

The capacity control method of an air compressor can significantly effect the power consumption of the compressor at part-load operating conditions. Ideally, a 1% reduction in compressed air usage would result in a 1% reduction in input power to the compressor. However, some control methods (such as inlet throttling) are inefficient and require as much as a 3.6% reduction in flow to achieve a 1% reduction in input power[1]. For the compressors at this plant, it is estimated that a 1.4% reduction in flow will result in a 1% reduction in input power. Hence, a 10% flow reduction results in a 7.1% reduction in input power. The annual energy savings is calculated by:

ES = HP x C x HRS x PR

Where

HP = total average horsepower used to compress air, 1,760 hp
C = conversion constant, 0.746 kW/hp
HRS = annual operating hours, 8,400 hrs/yr
PR = power reduction due to repairing leaks, 7.1% = 0.071

Thus

ES = (1760)(0.746)(8400)(0.071)
= 783,049 kWh/yr

The cost savings is calculated by

CS = ES x EC + (ES / HRS) x (12 months/yr) x DC

Where

EC = cost of electricity usage, $0.0308/kWh
DC = cost of electric demand, $10.39/kW-month

Thus

CS = (783,049)(0.0308) + (783,049 / 8400)(12)(10.39)
= (783,049 kWh/yr)($0.0308/kWh) + (1119 kW-months/yr)($10.39/kW-month)
= ($24,118/yr) + ($11,646/yr)

---

[1] Marks' Standard Handbook for Mechanical Engineers, McGraw-Hill Inc., 1987, pp.14-37 to 14-43.

= $35,744/yr

Implementation

Most air leaks occur at fittings, hose clamps, couplings, or at any junction. Once the general area of the leak has been found, the exact location and size of the leak can be determined using a bottle of soapy water. Implementation of this recommendation involves:

1) replacement of couplings and/or hoses
2) replacement of seals around filters
3) repairing breaks in lines, etc.

It is assumed that the air leaks can be repaired by facility maintenance personnel with minimal material costs. Based solely on labor, $25.96 per man-hour, 80 hours of work, the estimated cost for repairs is $2,077. The cost savings of $35,744/yr would pay for the repairs in less than 1 month. Because the air lines are not always easily accessible, a large number of man-hours were allocated to repair the leaks. Since this facility normally operates 24 hours/day, 7 days/week, it is recommended that the leaks be repaired during planned maintenance down-times when noise from the leaks will be most noticeable.

WASTE MINIMIZATION OPPORTUNITIES

AR No. 4

REMOVE AND SELL SCRAP COLORED GLASS

Assessment Recommendation Summary

Estimated One Time Savings = $334,167
Estimated Cost Savings = $11,122/yr
Estimated Implementation Cost = none
Simple Payback Period = immediate

Existing Practice and Observation

Ten percent of the company’s production is made of colored glass. Unfortunately, the colored scrap glass cannot be reused in the process of making new glass. All broken colored ware and other scrap colored glass (including colored glass from the gobs) are presently piled up on the outdoor property of the company. Based on physical observation of stockpiles on the property, we estimate that the existing stockpile of colored scrap glass weighs at least 60,000 tons. In addition, based on the information given about the production, about 2,000 tons/year of new colored glass scrap is generated and added to the stockpiles.

Efforts to sell this glass (or have it removed at no cost) have been made in the past; however, no interested parties were located. Colored glass is not easy to get rid of because the market seems to be saturated to a point that almost all recycling companies simply refuse to take any colored glass waste. Through the use of the internet, we contacted several recycling service companies (identified below) who are potential buyers. The calculations introduced are based on the information we received from *Dlubak's Glass Company* because they seem to be the only one capable of absorbing all of the available glass colors in large quantities. We encourage contacting each of the companies to ensure that the best deal is obtained.

Dlubak's Glass Company
Box 274 Saxonburg Road
Natrona Heights, PA 15065
(412) 224-6611
(419) 294-4466

G & L Recycling
222 N. Calverton Road
Baltimore, MD 21223
(410) 233-1197

Modern Junk and Salvage Company
1423 N. Fremont Ave
Baltimore, MD 21217
(410) 668-8290

The Owl Corporation
1936 Rettman Lane
Dundalk, MD 21222
(410) 282-0066

Recommended Action

Based on our investigation, we recommend selling the scrap colored glass to Dlubak's Glass Company in Pennsylvania[2]. Since there is easy access to the railroad at the buyer and seller locations, and rail transportation costs are considerably cheaper than trucking, rail is the recommended means of delivery.

The buyer requires a minimum purchase of 5,000 tons of glass per year[3]. This volume is much less than is presently stockpiled. In order to take advantage of the present favorable sale and transportation prices, and to obtain the resulting capital as soon as possible (so it can be invested as soon as possible), we recommend an aggressive effort to sell the existing stockpile. The glass should be sold as quickly as the recycling company is capable of accepting it and your company is capable of delivering it. Once the existing stockpile is gone, sale of the newly generated colored scrap should be performed as soon as enough scrap to fill a rail car has been generated.

Anticipated Savings

The average price per ton for colored glass which is *delivered by the seller to the buyer* (i.e., the seller pays for the delivery) is $25. This price may vary depending on the exact content and type of the coloring agents. We are introducing this average because the exact composition of the colored glass was not known.

Loading and delivery costs are estimated using the following information:

- We estimate that scheduling and loading of one freight car would take 8 hours, at a labor rate of $25.96/hr.

---

[2] We recommend this vendor strictly on the basis of price and encourage separate inquiries.

[3] Based on a conversation with the buyer, it seems that there is considerable flexibility on their part and the annual production of colored glass scrap at this plant is enough for the buyer to be interested even after all of the stockpiled scrap is sold.

- The freight rate is \$17.13 per ton for cullet delivered from Baltimore to Natrona Heights in Pennsylvania, including a rail switch in Potomac Yard in Virginia.

One rail car can haul 180,000 lbf (90 tons) of cullet. Hence, the number of cars needed to remove the entire existing stockpile is (60,000 tons) / (90 tons/car) = 667 cars. After the existing stockpile has been sold, the number of cars delivered per year would be (2,000 ton/yr) / (90 tons/car) = 22.2 cars/yr. The sale price for one car of colored cullet would be (\$25/ton) x (90 tons/car) = \$2,250/car. The estimated labor costs for loading and scheduling of one railroad car is (\$25.96/hr) x (8 hr/car) = \$208/car. The railroad delivery charges are (\$17.13/ton) x (90 tons/car) = \$1,541/car.

The net cost benefit for selling the scrap colored glass is:

Cost Benefit = Sale Price - Loading and Scheduling Costs - Transportation Costs

Hence, the cost benefit for selling the existing stockpile, CB_{esp}, would be:

$$CB_{esp} = [\ (\$2{,}250/\text{car}) - (\$208/\text{car}) - (\$1{,}541/\text{car})\ ] \times 667 \text{ cars}$$
$$CB_{esp} = [\ (\$501/\text{car})\ ] \times 667 \text{ cars}$$
$$CB_{esp} = \$334{,}167$$

Note that the net cost benefit per rail car is \$501, or \$5.57/ton.

Similarly, the annual cost benefit for selling the newly generated colored scrap, CB_{new}, would be:

$$CB_{new} = [\ (\$501/\text{car})\ ] \times (22.2 \text{ cars/yr})$$
$$CB_{new} = \$11{,}122/\text{yr}$$

NOTE: *In addition to the immediate cash benefits of selling the glass, the freeing of space around the factory was mentioned by company management as being valuable for possible future expansions or restructuring of production.*

Implementation

Implementation will require proper scheduling of railroad cars for loading, and an available loading vehicle and laborer. Since the loading and scheduling costs were considered above (as operating costs) and a suitable loading vehicle is already available at the site, no immediate implementation costs will be incurred. Hence, the simple payback period will be immediate.

It should be noted that the recycling company was concerned about leaching of contaminants into the piles of glass lying on the ground. Should this become a problem, the construction of a concrete pad may be necessary to prevent contamination of newly generated scrap glass.

AR No. 5

REDUCE FLOW OF QUENCHING WATER

Assessment Recommendation Summary

Estimated Cost Savings = $15,690/yr
Estimated Implementation Cost = none
Simple Payback Period = immediate

Existing Practice and Observation

The company must keep the glass production in the furnace nearly constant. As a consequence, molten “gobs” of glass drip from the fore hearths continuously. When the dies are not operating (repair, exchange etc.), the glass is dumped into the basement through metal shoots. These shoots have to be cooled in order to extend their useful life. The cooling is accomplished by streams of water which flow through the shoots and into the basement where the water also helps to solidify the piles of molten glass. The streams of water presently flow continuously, even when gobs are not being dripped into the basement.

Recommended Action

We recommend shutting off the water supply for cooling the shoots when the glass is not being dumped into the basement, thereby reducing water usage and costs.

Anticipated Savings

The amount of time that cooling water presently flows and is not needed, WT, is:

$$WT = HRS - TMS \times (12 \text{ months/yr}) \times AST / NPL$$

where

HRS = facility’s annual production hours, hrs/yr/line
TMS = total number of monthly production change-overs (“set-ups”), no units
AST = average duration of a set-up period, hrs
NPL = number of production lines in the facility, no units

Thus,

WT = (8400 hrs/yr/line) - (60 set-up/month)(12 months/yr)(8 hrs/set-up)/(10 lines)
= (8,400 hrs/yr/line) - (576 hrs/yr/line)
WT = 7,824 hrs/yr/line

The water flow is estimated at 1 gallon per minute per shoot, or 60 gallons per hour per shoot. The annual volume of water saved by only using the water when it is needed will be:

Volume of Water Saved = Production Lines x Flow Rate per Line x Hours Saved per Line
Volume of Water Saved = (10 lines) x (60 gal./hr) x (7,824 hrs/yr/line) = 4,694,400 gal./yr
or
Volume of Water Saved = (4,694,400 gal./yr) / (7.48 gal./ft^3) = 627,594 ft^3/yr

Based on a water consumption charge of \$2.50/100 ft^3, the cost savings will be:

Cost Savings = Volume of Water Saved x Water Consumption Charge
Cost Savings = (627,594 ft^3/yr) x (\$2.50/100 ft^3)
Cost Savings = \$15,690/yr[4]

Implementation

Implementation requires only a procedural modification. While glassware is being produced, the operator should shut off the water valve to the supply line for the shoots. The simple payback period will be immediate.

Implementation Cost = none
Payback Period = immediate

If the manual shut-off method is impractical, solenoid valves could be installed and wired with a time delay relay within easy reach of the operator's station. The solenoid valves for 1" NPT cost about \$150[5]. If ten are required, including installation costs, the project is estimated at approximately \$2500. The payback period would then be 0.16 years (about 2 months).

---

[4] Since the water is also used for cooling the gobs in the basement, it is possible that the time of required water flow would be somewhat greater than indicated.

[5] See *Grainger* Catalogue.

PRODUCTIVITY ENHANCEMENT OPPORTUNITIES

AR No. 6
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 change-overs (“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.[6]

---

[6] 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 change-overs 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.[7]

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

---

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

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[8], based on a labor rate of $25.96/hr.

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)

---

[8] 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.

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.

AR No. 7

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:

$$ACS = NP \times [\, LE \times NS \times CPL - MSC \times (12\ \text{months/yr}) \times ST \times THR - MOC]$$

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:

$$MEC = [KW \times UF + V_f \times HP \times K\,] \times [\, EDR \times (12\ \text{months/yr}) + HRS \times EUR\,]$$

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)] x [(10.39)(12) + (8400)(0.0308)]

= [(163 kW-month/yr)(\$10.39/kW-month) + (114,064 kWh/yr)(\$0.0308/kWh)]

= [(\$1,694/yr) + (\$3,513/yr)]

MEC = \$5,207/yr

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

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

= (4)[(2 - 0.25)(4)(40,500) - (6)(12)(0.5)(25.96) - (5,207)]

= (4)[(\$283,500/yr) - (\$935/yr) - (\$5,207/yr)]

= (4)[(\$277,358/yr)]

ACS = \$1,109,432/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.

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.

Manufacturers of case packers and conveyor systems 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.

AR 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)

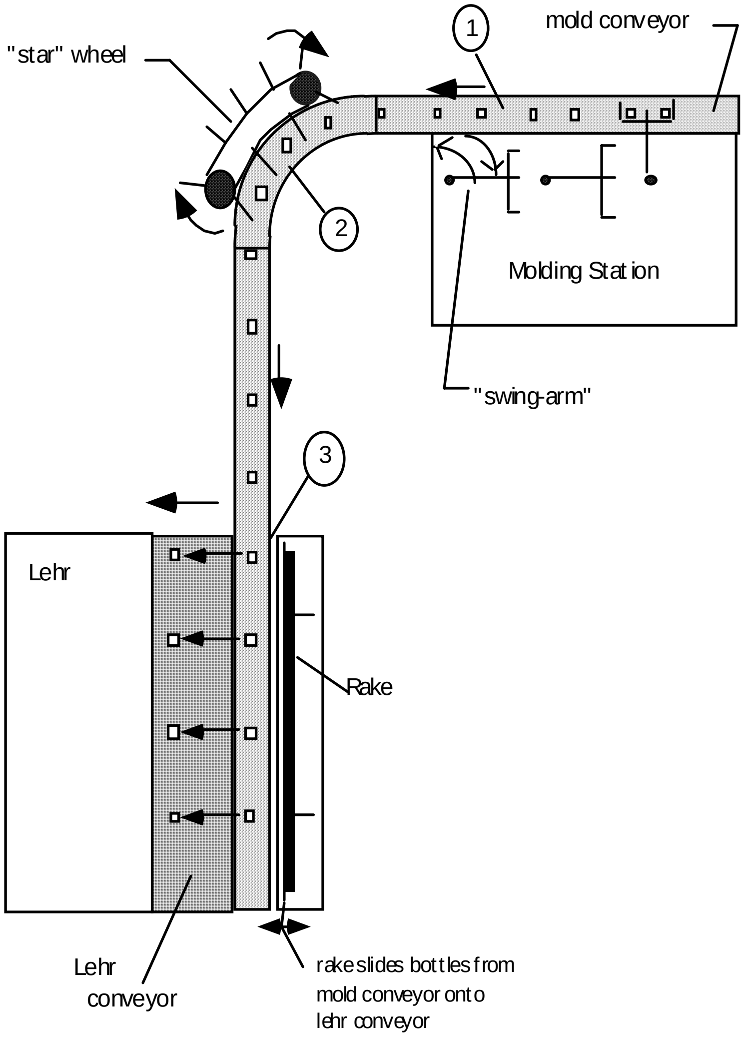
Existing Practice and Observation

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



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

"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.

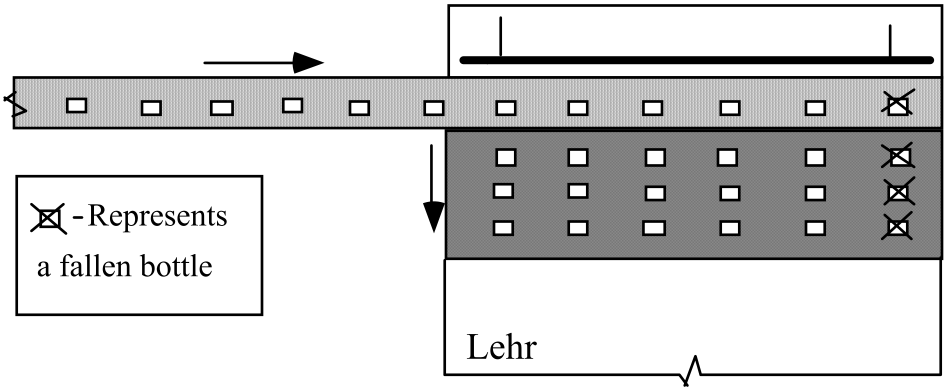
The rake at the Lehr entrance moves back and forth across the molding station conveyor to (and from) the Lehr conveyor. On the forward stroke (from the molding station conveyor to the Lehr conveyor), the rake pushes glassware onto the Lehr conveyor. On the reverse stroke for several of the production 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.

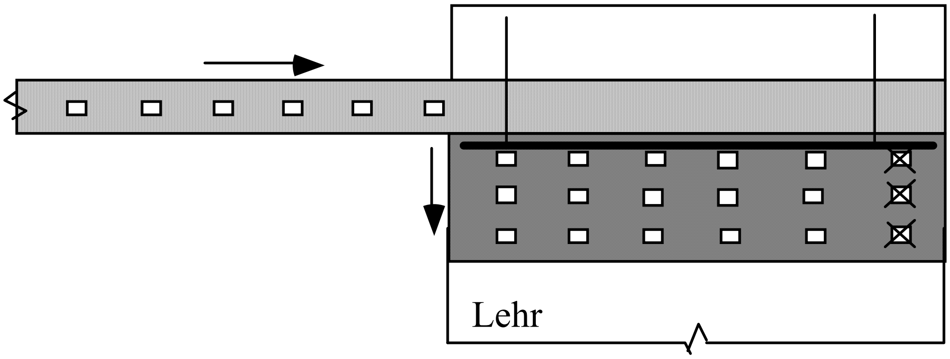
Recommended Action

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.

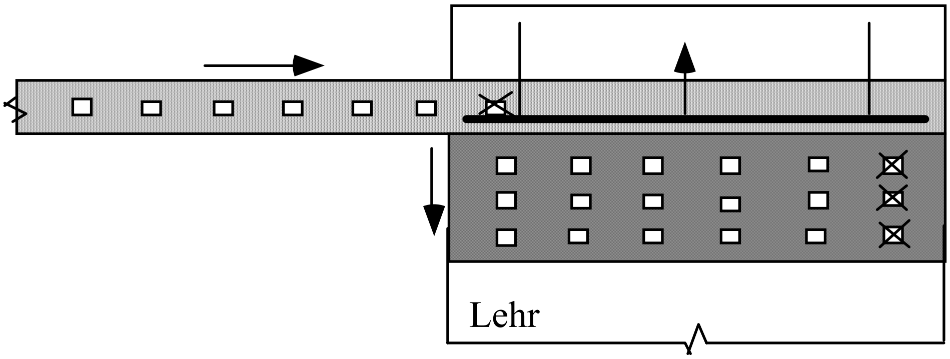
Since there is a wide degree of variance between product sizes and shapes, and some shapes are more prone than others to being knocked over, design changes which may reduce the knock-over rate for small glassware may not work for large glassware (and vice-versa). Hence, it may also help reduce the amount 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

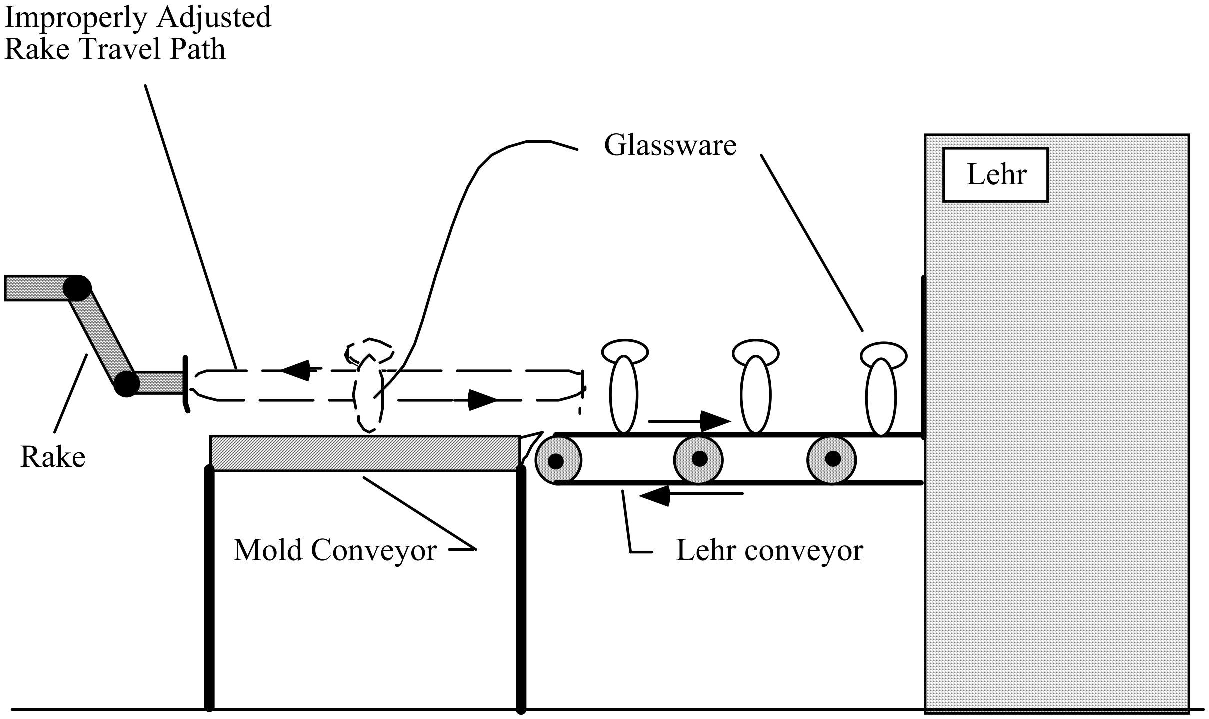


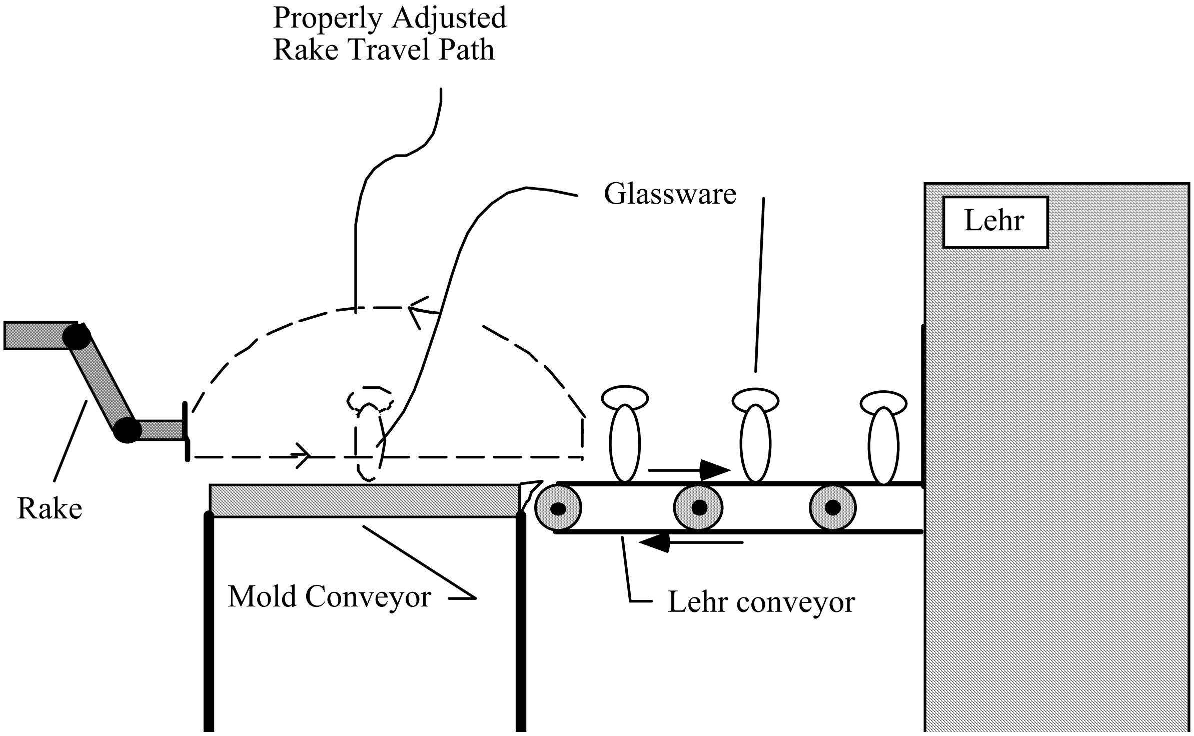
Position #2 - Rake Forward



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:

$$\text{APH} = \text{FPH} - \text{TMS} \times (12 \text{ months/yr}) \times \text{AST} / \text{TNPL}$$

where;

FPH = facility's annual production hours, hrs/yr
TMS = total number of monthly production change-overs ("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,

$$\begin{aligned}\text{APH} &= (8400 \text{ hrs/yr}) - (60 \text{ set-ups/month})(12 \text{ months/yr})(20 \text{ hrs/set-up}) / (10)\\ &= (8400 \text{ hrs/yr}) - (1440 \text{ hrs/yr})\\ \text{APH} &= 6{,}960 \text{ hrs/yr}\end{aligned}$$

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.

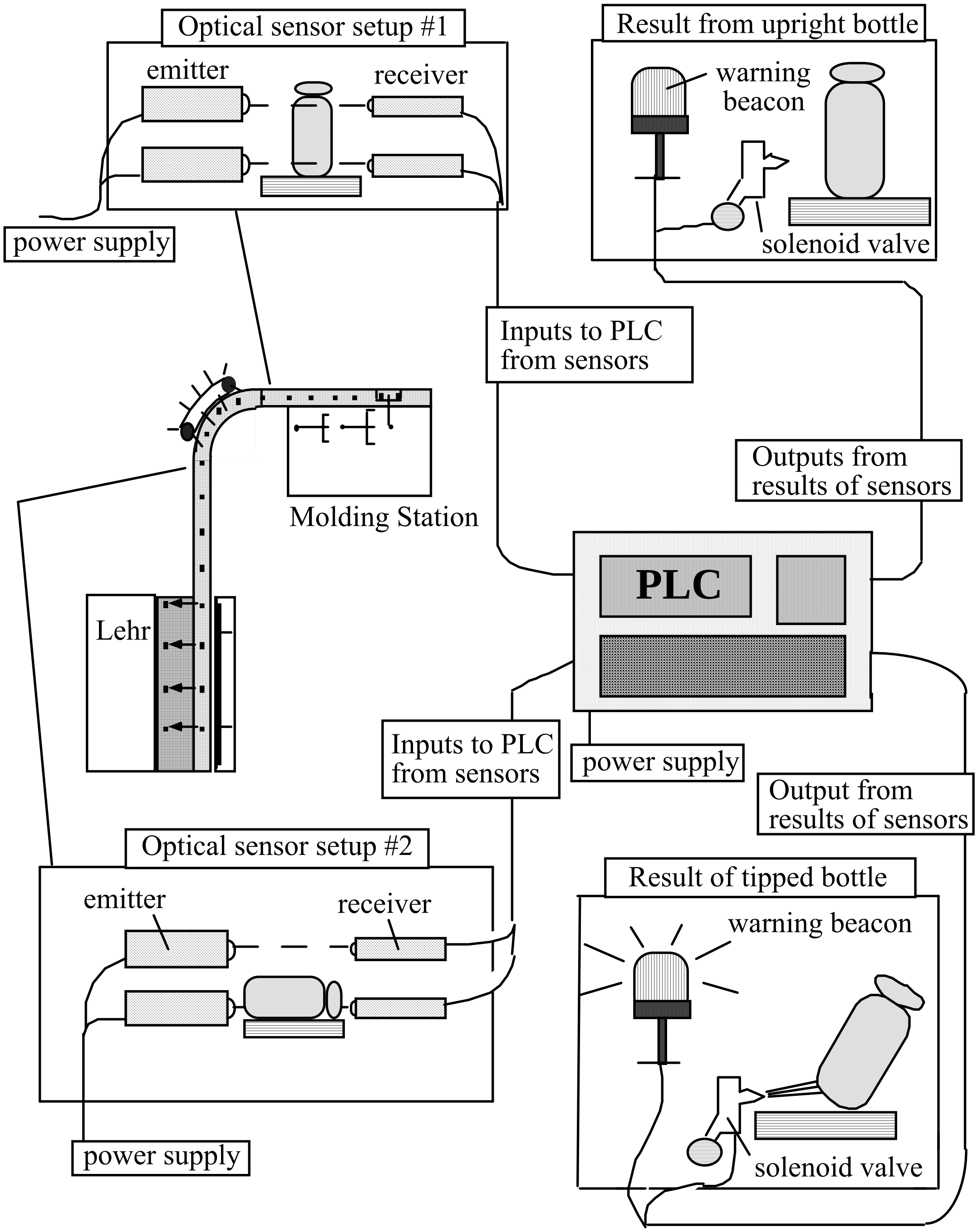
Implementation

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)

Other Potential Cost Saving Measures

These Additional Recommendations are included as there was not enough information to complete calculations, or the anticipated savings were not very high.

This section contains a list of additional opportunities for savings which were not analyzed fully because either data was not available or it was felt that the paybacks would be too long or the savings too low to warrant a more complete analysis. However, some attention to these ideas could result in additional savings.

1. Replace Existing Electric High Pressure Air Compressors with a Natural Gas Engine-Driven Unit

Analysis of the plant's utility bills showed a large difference between the costs of natural gas and electricity. On average, electricity costs $13.84/MMBtu ($0.0472/kWh, including demand costs) while natural gas is purchased for $2.66/MMBtu. Electricity is more than 5 times as expensive as natural gas at this plant.

A recommendation calling for the replacement of the existing electric air compressors with natural gas driven units was considered. Since no rebates are given by Baltimore Gas and Electric for this change, the payback was not economically favorable.

2. Use Oxygen-Enriched Combustion in Furnaces

Energy is wasted when ambient air is used in the combustion of fossil fuels. When a fossil fuel such as oil or natural gas is burned, oxygen in the combustion air reacts with hydrogen and carbon in the fuel to form water and carbon dioxide, releasing valuable heat in the process. Air is composed of approximately 21% oxygen, 78% nitrogen, and 1% various other gases. During air-fuel combustion, the chemically inert nitrogen dilutes the reactive oxygen and carries away some of the energy in the hot combustion exhaust gas. Compared to combustion using pure oxygen, or oxygen-enriched air, combustion using ambient air is therefore less efficient.

In addition to saving fuel (typically natural gas) and reducing emissions of harmful pollutants, the use of oxygen-enriched combustion reduces the need for a heat recovery system because of the large reduction in exhaust gas volume. It can also reduce defects in the glass because of improved furnace control. These benefits make oxygen-enriched combustion a very attractive option for glass producers.

Praxair, Inc. in conjunction with the U.S. Department of Energy's Office of Industrial Technologies, conducted a study in 1990 at this plant to experiment with oxygen-enriched combustion. NO_X emissions dropped from 21.6 lbs/ton of glass to 2.1 lbs/ton of glass. As a secondary result, natural gas usage dropped 15%.

A supply of oxygen is currently delivered to the plant by Praxair. In weighing the economic benefits of using oxygen-enriched combustion, the cost of oxygen was much greater than the annual cost savings on the natural gas bills. Unless there are *significant* changes in one or a combination of the following three items, use of oxygen-enriched combustion is not recommended:

- The price of natural gas increases
- The price of obtaining oxygen decreases
- The cost benefit for reducing NO_X emissions increases

3. Hire and Train New Mold Change Technicians for 2nd, 3rd, & 4th Shifts (or Train Existing Personnel to Perform Mold Changes):

During our visit, it was mentioned that only the first shift is staffed with technicians who are trained to perform production line change-overs. If the planned batch (number of bottles) is finished during a time *other* than the first shift, one of three things happens: 1) the production of the bottles is continued until the first shift change-out technicians are available, 2) production of glassware on that line is discontinued until the first shift change-out technicians are available, or 3) the first shift technicians work overtime (at an increased pay rate) to perform the change-over. All of these cases can be wasteful.

If the batch is continued, more than the ordered quantity of glassware is produced and the excess must be stored on-site in hopes of selling it in the future. The excess glassware takes up valuable warehousing space, can become damaged or obsolete, and represents a capital investment by the company which, as long as it remains in inventory, makes no money for the company.

If the production on a line is discontinued until the change-out technicians arrive, valuable production time and resources are wasted. According to our estimates, this lost production time costs about $632/hr per production line.

Adding change-out technicians could reduce the costs described above but may also be expensive. A cheaper and more efficient alternative may be to train *existing* personnel on the late shifts to perform the production line change-outs. The information needed to estimate the cost benefits of these actions was not available to our assessment team but should exist in your company's production scheduling department. A more detailed in-house investigation may prove worthwhile.

4. Install a Surge Tank to Reduce Compressed Air Pressure Fluctuations and Resulting Product Defects:

During the assessment, it was mentioned that fluctuations in the compressed air supply pressure at the production machines sometimes causes defects in the glassware, however no data existed as to what percentage of the defects were cause by these fluctuations, or why these fluctuations cause defects. During further telephone inquiries after the on-site inspection, we were told that this was *not* a problem (or that the personnel in charge of maintaining the compressed air system had not been informed that this was a production problem). Due to the lack of information and conflicting stories, we did not further pursue upgrades which would reduce these pressure fluctuations. As demonstrated in AR#8, a defect reduction of only 1.5% will result in a cost benefit of about $400,000/yr. Information obtained from the quality control department indicated that 75% of the defects (“heel taps,” “posted sides,” and “check finishes”) occur in the molding department as a result of equipment malfunctions or mis-adjustment, some of which could be the result of fluctuations in compressed air pressure. Due to the savings potential, further investigation is recommended.

5. Hire Industrial Engineer(s) to Reduce Prohibitive Costs of Technical Projects and Accelerate Productivity Enhancement

There are many potential areas for improvement in the manufacturing-related operations of your company. Some improvements are already underway and several other opportunities are discussed in this report. It seems as if your company is headed in the right direction in pursuing such improvements, however in talking with existing personnel it was mentioned that the implementation costs for many of the considered improvements have been prohibitive due to high engineering costs. Hiring one or several industrial engineers should greatly reduce these costs by bringing the engineering costs in-house and avoiding the consulting engineering rate which will include overhead and profit for the engineering firm. In addition, it would accelerate the rate at which productivity enhancements could be implemented. Further investigation into this idea is strongly recommended.

6. Upon Failure of Existing Cooling Fan Motors, Replace with Down-sized E.E. Motors

Motor power measurements on the day of our assessment indicated that the cooling fan motors may be oversized. Our power measurements indicated that the power input to the motor was only 52% of the rated input power. Since the efficiency of a motor is diminished at low loads, we investigated the option of downsizing the cooling fan motors upon failure of the existing motors. Our investigation indicated that the efficiency benefits of downsizing the motors would *not* warrant the action (the efficiency of an energy-efficient 75 hp motor at 52% load is slightly *higher* than that of a 50 or 60 hp motor for the same *output* load), especially when considering the mentioned plans for future expansion which may require more than the existing amount of air flow from the cooling fans. It was also mentioned that on the day of our assessment the cooling fan motors were operating under an unusually low load. For all of the reasons mentioned above, these motors should NOT be down-sized.

7. Focus Initial Defect Reduction Efforts on Colored Glass Production Lines to Reduce Scrap Glass Generation

Efforts are already underway to reduce the defect rate of the process. Assessment Recommendation No. 8 in this report is an example of a potential defect reduction opportunity. The existing high defect rate (≈35%) indicates that there is a great deal of opportunity for improvement and that defect reduction efforts should be a *major* focus of future productivity enhancement efforts at your facility. Since these efforts may involve some trial-and-error testing on a few production lines prior to implementation throughout the whole plant, we recommend that the first efforts for decreasing defects be performed on the production lines which are used to produce *colored* glassware. Since the colored glassware rejects can not be re-used in the furnaces as cullet, they are more costly per pound of glass as compared to the clear rejects (because the raw materials in the colored glass can not be reclaimed). For this reason, your company will receive the greatest initial return on its defect reduction efforts by focusing on the colored glass production lines.

THE STATE UNIVERSITY OF NEW JERSEY

[redacted]

Center for Advanced Energy Systems
640 Bartholomew Road
Piscataway • NJ 08854• tel: (732) 445-5540 • fax: (732) 445-0730
email: muller@caes.rutgers.edu