Energy Conservation Opportunities in Carbonated Soft Drink Canning/Bottling Facilities

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Industrial Energy Technology Conference
Houston, TX, April 16-19, 2002

Abstract

The processes in carbonated soft drink production are discussed with an emphasis on energy consumption, current prevalent practices in the industry are outlined, and potential measures for energy use and cost savings are elaborated. The results from detailed energy audits of a few large soft drink plants in California are presented.

Major savings identified are in process modification, lighting, refrigeration, compressed air and most importantly combined heat and power. Although each facility has its own unique features, the measures identified can have applications in most plants.

Introduction

Based on 1997 US Census Bureau, there are 606 soft drink manufacturing facilities in the country, from which slightly over 500 are carbonated soft drink manufacturers. The value of shipments for the soft drink industry is about 31.2 billion dollars.

Carbonated soft drink production is among the most energy intensive processes in food industry. Significant levels of refrigeration and heating are needed in the carbonation and bottling/canning processes. Refrigeration is required for lowering the drink mixture to a temperature low enough to absorb the necessary amount of carbon dioxide. Heating is required to bring the cold cans/bottles to a temperature high enough to prevent condensate from collecting on the containers after packaging and storage. Being a food product, significant energy is consumed in sanitation processes. In addition to cooling and heating, traditionally the processes use a significant amount of compressed air.

Manufacturing Process

A typical process flow diagram for manufacturing of carbonated soft drink is presented in Figure 1. Some variation from plant to plant should be expected.

Major processes involved in the production are:

- Water purification and dearation
- Mixing of water, flavor concentrates and sweeteners such as high fructose corn syrup. This happens in large mixing tanks.
- Addition of carbon dioxide to the drink mixture is performed in a “carbo-cooler”. The drink mixture is cooled to under 40 F, often using ammonia refrigeration, and then the pressurized carbon dioxide is injected into the liquid to near saturation level, Fuller (1973).
- Bottles or cans are then filled under pressure and sealed.

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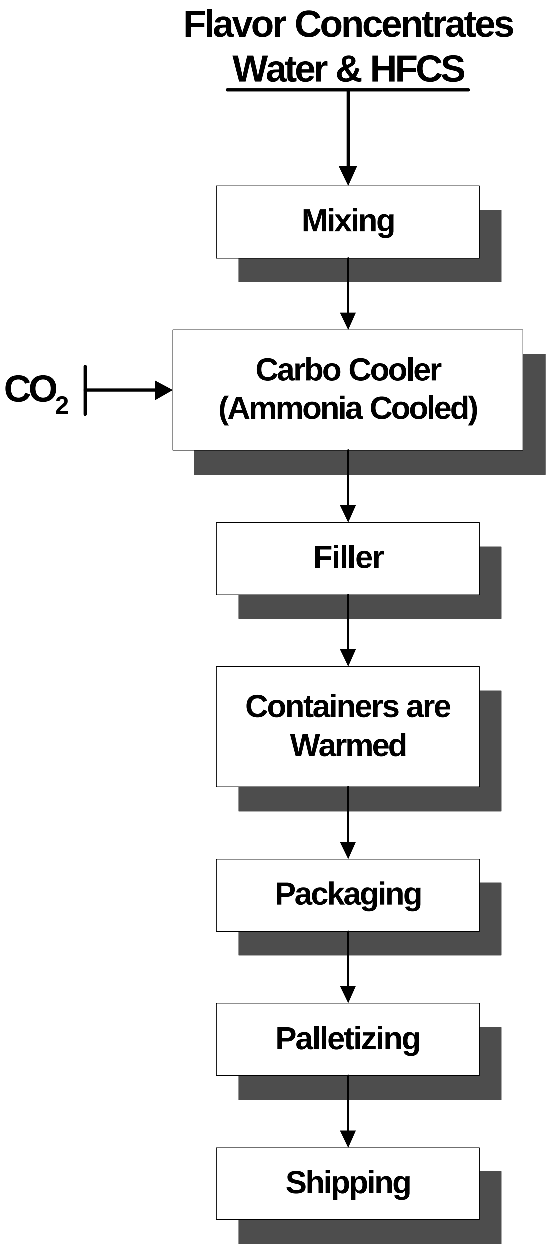

Figure 1 – A Typical Process Flow Diagram of a Soft Drink Bottling Facility

- Containers are then warmed to above the dew point of the ambient air to avoid condensation in the packaging. Warming usually happens through spraying or immersion in hot water bath at a temperature of about 130- 140 F.
- Containers are then packaged, palletized, stored, and shipped.

Soft drink manufacturing facilities have significant electric and natural gas (or other fossil fuels) usage. Major energy users include,

- A significant amount of lighting energy, mostly for warehouse storage spaces.
- Various blowers, and pumps for pumping water and product.
- Significant level of refrigeration (usually ammonia) for cooling the product for carbonization
- Various hydraulic pumps for palletizers
- Significant level of compressed air for blowing, drying, pneumatics, etc.
- Significant level of heating (usually from natural gas) for warming the containers to avoid condensation.
- Shrink wrap tunnels when plastic wrapping is utilized

Figure 2 shows a typical electrical energy distribution pie chart of a soft drink plant.

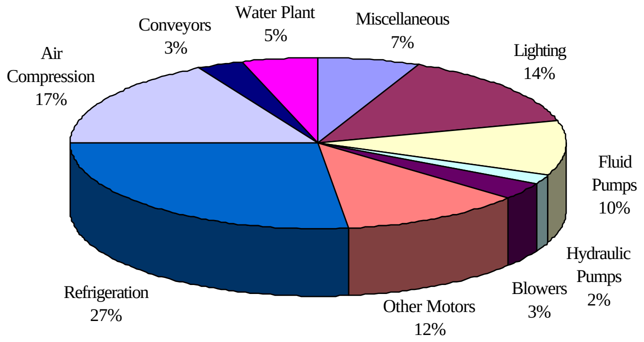

Figure 2 – Annual Electrical Energy Pie Chart for a Large Soft Drink Manufacturing Plant

Major Opportunities for Energy Efficiency

Our experience in detailed audits of soft drink manufacturing facilities has resulted in identification of numerous energy saving opportunities. Summaries of major energy efficiency opportunities are briefly described below.

Production Process

Cooling the Product to Optimum Level

The product is usually cooled to above freezing (e.g. 36 F) for dissolving carbon dioxide under high pressure. The desired absorbed level of carbon dioxide depends on the carbonation pressure and temperature. Optimizing the carbo-cooler temperature (e.g. raising it from 34 F to 40 F) will result in significant savings in refrigeration energy. Additionally increasing the temperature in carbo-cooler will result in heating energy saving in the warmer. An important point, raising the temperature beyond an optimum level can result in foaming which is undesirable.

Heating the Containers to Optimum Level

After the containers (cans or bottles) are filled, they are usually heated to 20 to 30 F above the dew point of the ambient air, in order to raise the drink temperature to prevent condensate from collecting on the containers when they are stored. The container exit temperature is 20 to 30 F above the dew point of the ambient air, which may be excessive depending on the length of time the container spends in the warmer. A simple heat transfer model (see for example Holman, 1990) can show the temperature distribution inside the container when it exits the warmer, and as a result the container surface temperature as a function of time. The surface temperature at equilibrium should be greater that the dew point temperature of the ambient air. For most applications heating the containers to 10 F above ambient will be sufficient. Measurement of the ambient dew point temperature and controlling the warmer temperature can result in significant heating energy savings.

Buildings and grounds

High Efficiency Lighting

Soft drink manufacturers usually have very large high bay warehouses that are usually illuminated with high intensity discharge (HID) lamps, such as metal halide and high-pressure sodium. These types of lamps can not be turned on and off on demand, but they can be dimmed on demand, with an energy saving of 50 to 60%. Major savings can be attained by installing bi-level lighting control systems that are activated by occupancy sensors upon detection of a person or a forklift in an aisle and shifting to full brightness.

Other sources of lighting energy savings include:

- Replacing other types of HID lamps (e.g. mercury vapor) with high pressure sodium lamps
- Installation of skylights, which are particularly attractive in mild climates such as California.
- Replacing T-12 lamps with magnetic ballast with T-8 or T-5 lamps with electronic ballast
- Use of light sensors in the areas that receive enough natural lighting
- Use of occupancy sensors in areas that are infrequently occupied

HVAC System

Although HVAC is often not a significant part of energy consumption in a soft drink manufacturing plants, it can be a major energy user in the administration part of the facilities. Major sources of energy savings in HVAC systems are:

- Controlling the HVAC system to heat and cool when needed by programmable thermostat or better with an energy management system.
- Proper zoning the HVAC air supply and return.
- Use of high EER package units with the minimum requirements of ASHRAE Standard 90.1.
- Use of variable frequency drive (VFD) controllers on air handlers in place of dampers

Refrigeration System

In production of carbonated soft drinks, the refrigeration system and its accessories such as cooling towers/evaporative coolers use a significant amount of energy. The refrigeration systems mostly use ammonia as the refrigerant. In the plants we have audited, between 25% to 35% of plant's electrical energy is used for refrigeration. Significant levels of energy savings can be achieved through:

- Sequencing the compressors
- Use of high efficiency refrigeration compressors with VFD controllers

- Heat recovery from the ammonia vapor at the compressor exit to pre-heat the boiler feed water. This measure also results in energy savings in the cooling tower/ evaporative cooler system because it reduces the heat load.
- Use of VFD on cooling tower fans, using sump temperature for feedback.
- Use of VFD on cooling tower supply water pumps, using return water temperature or chiller condenser pressure for feedback.
- Modification of refrigeration parameters (e.g. suction pressure, head pressure) to conform to process requirements

Heating System

Heating is needed to warm the containers before they are packaged in order to prevent condensation on container surface. Hot water for heating the containers is usually heated to about 130-140 F.

Two types of heating systems are used for this purpose, steam from steam boiler or hot water from hot water boiler that in turn heats the warming water through heat exchangers. Use of hot water boilers is much more efficient because small hot water boilers can be installed near the points of application (rather than installation of steam boilers in a more remote area). Installation of a central hot water boiler is also an option.

Main advantages using local hot water boilers are:

- Use of lengthy piping can be avoided
- Redundancy is built into the system, due to multiple hot water boilers rather than one or two large steam boilers
- Modern hot water boilers are much more efficient than steam boilers.
- The issue of maintaining steam traps are totally avoided

Compressed Air Systems

As Figure 2 shows, air compression can be a significant portion of the electrical energy consumption in these facilities. Major sources of air consumption include air jets used for directing cans and bottles along the conveyor lines, air jets for drying the containers after various stages of washing, air leaks and pneumatic actuators.

Significant saving can be achieved by using blowers in place of air jets for drying applications, and wherever possible for moving the containers. Table 1 compares the power consumption of a compressor versus blowers of various pressures. For majority of drying applications and some displacing applications, blowers can easily replace the compressed air. Refer to Compressed Air Challenge, 1998 for other energy efficiency measures for compressed air systems.

Combined Heat and Power

Carbonated soft drink facilities are ideal cases where distributed generation in the form of combine heat and power (CHP, the same as cogeneration) can be used. This is due to the fact that both heating and electrical energy are required simultaneously. In the plants we have audited, the ratio of electrical energy usage to heating energy usage have been 70% to 83%, which are in the bulk part range of electrical to thermal ratio of natural gas reciprocating engine cogeneration systems. Natural gas fueled reciprocating engines are suitable for this type of facility because,

- Low pressure steam or hot water production capability of these engines
- Suitability of the size of these engines to carbonated soft drink facilities, a few hundred kW to a few MW.
- Air pollution control technology is readily available for these engines even in a stringent air pollution control environment such as South Coast Air Quality Management District in California.
- Several percentage points of higher efficiency compared to gas turbines of the similar capacity.

Other Energy Efficiency Measures

The other energy efficiency measures we have been able to identify in carbonated soft drink manufacturing facilities are:

- Insulation of hot surfaces including condensate return lines.

- Avoid using shrink-wrap tunnels by converting the line to carton packaging if acceptable to the market. Shrink-wrap tunnels are significant energy users in these facilities.
- Interlocking blower or drying air jets to the flow of containers, i.e. with production
- Installation of high efficiency motors

For details on some other measures in manufacturing facilities refer to Ganji (1999).

Some Specific Case

In order to indicate the level of savings in these types of facilities one comprehensive case study and the case of CHP recommendation are presented here. Table 2 shows the summary of savings and costs for a plant in California. Total recommended measures amount to over 20% cost savings for the plant.

In another plant in addition to other measures, we recommended the installation of a CHP (cogeneration) system. Table 3 shows the results of this evaluation for an approximate average electrical usage cost of $0.057/kWh, average demand cost of $13.5/kW and natural gas cost of $0.415/therm.

Conclusions

Significant opportunities exist for energy and cost savings in carbonated soft drink manufacturing facilities. Major savings identified are in process modification, lighting, ammonia refrigeration, compressed air and most importantly combined heat and power. Although each facility has its own unique features, the measures identified can have applications in most plants.

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Acknowledgment

The authors would like to thank the Southern California Gas Company, particularly Mr. Tony Hesam for providing BASE Energy, Inc. with the opportunity to audit numerous manufacturing facilities in the past few years. All authors have also greatly benefited from the experience at San Francisco State University Industrial Assessment Center.

Table 1 – Power Difference of Production of Compressed Air and Blower Air

	Compressor	Blower				
Pressure (psig)	100	3	6	9	12	15
HP/SCFM	0.238	0.0233	0.0439	0.0624	0.0794	0.0950

TABLE 2 SUMMARY OF SAVINGS AND COSTS

EEO No. Description	**Potential Energy Conserved**	**Demand Savings** (kW)	**Potential Savings** ($/yr)	**Resource Conserved**	**Implem. Cost** ($)	**Simple Payback** (years)
No or Low Term Measures						
1 Control the Temperature of the Filled Cans	63,108 therms/yr	N/A	27,004	Natural Gas	0	immediate
2 Raise the Temperature of the Carbo Coolers	351,404 kWh/yr	84.47	51,916	Electricity	0	immediate
3 Turn-Off the Two Suction Blowers on the Washer of Line #1	50,332 kWh/yr	11.52	7,343	Electricity	0	immediate
4 Tune and Adjust the Air-to-Fuel Ratio of the Steam Boilers	15,759 therms/yr	N/A	7,879	Natural Gas	500	0.1
5 Replace the Standard V-Belts with Cog-Type V-Belts	82,397 kWh/yr	18.82	12,024	Electricity	2,463	0.2
6 Use a Smaller Air Compressor for Weekend Operations	48,180 kWh/yr	0.00	5,256	Electricity	2,000	0.4
7 Insulate the Hot Surfaces in the Boiler Area and Line #2 Heat Exchanger	9,515 therms/yr	N/A	4,757	Natural Gas	2,490	0.5
8 Use a Blower to Produce Air for the Air Jets	16,448 kWh/yr	3.95	2,429	Electricity	1,500	0.6
9 Install Light Sensors on Lamps in the Loading Dock	5,192 kWh/yr	1.25	767	Electricity	480	0.6
10 Install Higher Efficiency Motors *	44,071 kWh/yr	6.43	6,360	Electricity	4,740	0.7
11 Recover Waste Heat from the Ammonia Refrigeration System	29,234 kWh/yr 82,900 therms/yr	0.00	44,639	Electricity Natural Gas	39,050	0.9
Short Term Measures						
12 Install Bi-Level Lighting Control on the HID Lights in the Warehouses	169,318 kWh/yr	24.67	22,437	Electricity	49,500	2.2
13 Install High Efficiency T8 Fluorescent Lighting	67,058 kWh/yr	17.18	10,077	Electricity	25,950	2.6
Total Energy Savings (Electricity)	**863,634 kWh/yr**					
(Natural Gas)	**171,282 therms/yr**					
Total Demand Savings		**168.3 kW**				
Total Cost Savings			**$202,888/yr**			
Total Implementation Cost					**$128,673**	
Simple Payback Period						**0.6 years**

* Two year figures. See EEO for details.

TABLE 3 SUMMARY OF SAVINGS AND COSTS						
EEO No. Description	**Potential Energy Conserved**	**Demand Savings** (kW)	**Potential Savings** ($/yr)	**Resource Conserved**	**Implem. Cost** ($)	**Simple Payback** (years)
1 Install a Combined Heat and Power System	4,632,900 kWh/yr -254,947 Therms/yr	900	245,408	Electricity Natural Gas	920,986	3.8