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Energy Saving in A Glass Bottle Manufacturing Plant

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Abstract: - Energy saving is very essential in the present scenario for all industries. Global warming and higher carbon footprint is resulting in climatic changes across the world. In a glass bottle manufacturing plant, compressed air system is very critical for getting good quality bottles. Leakages and pressure drop are the main cause for energy loss in compressed air system and it increases the percentage of defective bottles. The objective of this work is to save the energy by reducing the pressure drop and thus reducing the percentage of defective bottles manufactured due to insufficient pressure. In a glass bottle manufacturing plant in Pondicherry, high-pressure lines and low-pressure lines are used for forming various size bottles. Annual energy consumption, leakage percentage and the energy loss of the existing arrangement of compressed air system were calculated with the measured data. The pressure drop in the system was reduced by modifying this system by adding a secondary air receiver. The annual energy consumption leakage percentage and energy loss are calculated for modified arrangement at the same operating pressure and increased operating pressure. On analysis, it is found that energy loss is reduced by 18.1 % in the modified compressed air system.

Keywords: - Glass industry, Compressed Air System, Energy saving.

I. INTRODUCTION

In most industrial facilities, compressed air is necessary for manufacturing. Compressed-air generation is energy intensive, and for most industrial operations, energy cost for compressed air is significant compared with overall energy costs. Annual operating costs of air compressors, dryers, and supporting equipment’s is high; so energy saving is important in increasing the efficiency of manufacturing companies. In the glass bottle manufacturing process defects are formed due to improper compressed air and pressure drop occurring in the pressure line. Some of the common defects due to improper air pressure are choke neck, heel tap, thin ware and bird swing. The energy utilized for manufacturing these defective bottles is wasted. The main objective of this work is to identify the energy saving options in a glass bottle manufacturing plant and to implement corrective measures to minimize the energy consumption and cost.

II. RELATED WORK

Compressed air is typically one of the most expensive utilities in an industrial facility and potential savings opportunities must be aggressively sought out and identified [1]. Energy audit helps in collecting data that is important for estimating compressed-air energy use [2]. The energy loss in compressed air systems can be minimized by repairing air leaks, installing high-efficiency motors, reducing the average air inlet temperature by using outside air and reducing compressor air pressure [3].

III. EXISTING COMPRESSED AIR SYSTEM

A detailed study of the existing pressure line layout and compressed air requirement of the glass bottle manufacturing plant is done. The company has a separate compressed air system for high pressure (3.45 bar) and low pressure (2.85 bar) requirements in the bottling line. High pressure line is mainly used for manufacturing of large and medium size bottles and low pressure line is mainly used for manufacturing of small size bottle. The layout of the compressed air system is shown in Fig 1.

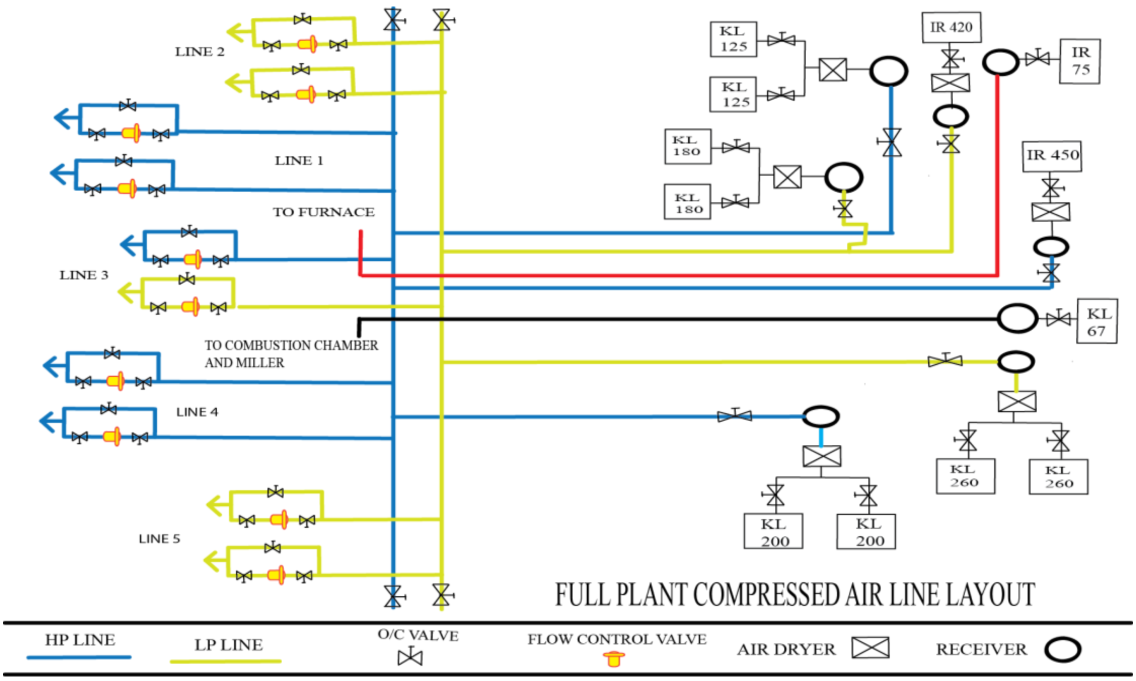

Fig 1. Layout of compressed air system

In the manufacturing plant, 5 compressors are used for the high pressure line and 5 compressors are used for the low pressure line. Before collecting the loading and unloading time of the receiver, the dryer

TABLE 1

	HIGH PRESSURE LINE 450 kW	LOW PRESSURE LINE 420 kW	HIGH PRESSURE LINE 125 kW + 125 kW	LOW PRESSURE LINE 260 kW + 260 kW	HIGH PRESSURE LINE 125 kW + 125 kW	LOW PRESSURE LINE 180 kW + 180 kW
POWER (loading)	Voltage: 440 V Amp: 24.5 A PF : 0.8	Voltage: 440 V Amp: 27.4 A PF : 0.8	Voltage: 440 V Amp: 34.3 A PF : 0.8	Voltage: 440 V Amp: 30.1 A PF : 0.8	Voltage: 440 V Amp: 30.4 A PF : 0.8	Voltage: 440 V Amp: 31.2 A PF : 0.8
Time (loading)	3.4 min	3.6 min	3.4 min	3.2 min	4.5 min	5.4 min
Pressure initial	2 bar	1.9 bar	1.9 bar	2 bar	2 bar	1.8 bar
Pressure final	7 bar	7.1 bar	7.2 bar	7.2 bar	7 bar	6.9 bar
Dryer temperature	40° C	40° C	40° C	40° C	40° C	40° C
Atmosphere temperature	32° C	32° C	30° C	30° C	29° C	29° C
Volume of the cylinder	500 L	500 L	500 L	500 L	500 L	500 L
Power (unloading)	Voltage: 440 V Amp: 11 V PF : 0.8	Voltage: 440 V Amp: 13.2 V PF : 0.8	Voltage: 440 V Amp: 22.1 V PF : 0.8	Voltage: 440 V Amp: 17.1 V PF : 0.8	Voltage: 440 V Amp: 19.2 V PF : 0.8	Voltage: 440 V Amp: 20.5 V PF : 0.8
Time (unloading)	10.5 min	11.2 min	10.5 min	10.1 min	12.4 min	14.2 min

temperature is set to be stable at 40°C. The data is given in Table 1.

A. ENERGY LOSS CALCULATIONS

The annual energy costs for the existing compressed air system is calculated using the method described in [2]. The average power draw (P_A) is determined using the equation:

$$P_A = \frac{P_L \times t_L \times P_{UL} \times t_{UL}}{t_L + t_{UL}} \quad (1)$$

where: P_A – average power draw (kW), P_L – power consumption during loading (kW), P_{UL} – power consumption during unloading (kW), t_L – total time while loaded (hrs), t_{UL} – total time unloaded (hrs).
The free air delivery (q_{FAD}) is determined as

$$q_{FAD} = \frac{V\,(P_2 - P_1)}{P_N\, t} \times \frac{T_1}{T_2} \quad (2)$$

where: V – storage volume m^3, P_N –normal pressure in kPa, P_1 – initial pressure after bleeding in kPa, P_2 – final pressure after filling in kPa, T_1 – initial temperature in K, T_2 – final temperature in K, t – time taken to build up pressure from P_1 to P_2 in hours.
The specific energy consumption (SEC) is determined as

$$SEC = \frac{P_A}{q_{FAD}} \quad (3)$$

Annual energy costs are calculated using the following equations:

$$EC = P_A \times H \quad (4)$$

$$AEC = EC \times ER \quad (5)$$

where: EC – annual energy consumption (kWh/yr), PA – average power draw (kW), H – annual operating hours (hrs/yr), EC - annual energy costs (INR/yr), ER - energy rate (INR/kWh).
The volumetric leak flow rate is determined as

$$q_L = \frac{V\,(P_1 - P_2)}{P_a \times t} \times k \quad (6)$$

where: V – reservoir volume in m^3, p_1 – normal operating pressure in kPa, p_2 – lower pressure in kPa, p_a – atmospheric pressure in kPa, t – time in hours, k – corrects leakage to normal system pressure, k=1.25 (constant)
The power loss (P_{LOS}) is determined as

$$P_{LOS} = q_L \times SEC \quad (7)$$

Annual energy loss is determined as

$$EL = P_{LOS} \times H_L \quad (8)$$

$$CEL = EL \times ER \quad (9)$$

where: H_L – annual leakage in hours.

Using the above equations, the annual energy consumption for the plant is found as 11,55,514 kWh/ yr and the annual energy loss is found to be 2,69,200 kWh/ yr. Hence the cost of annual energy loss is Rs. 14,13,305/-.

B. MODIFICATION IN THE COMPRESSED AIR SYSTEM

A secondary receiver is fitted with the help of bypass pipeline to the high pressure and low pressure lines. Valves are fitted to the lines to actuate the new system. The modified layout is shown in Fig 2 and 3.

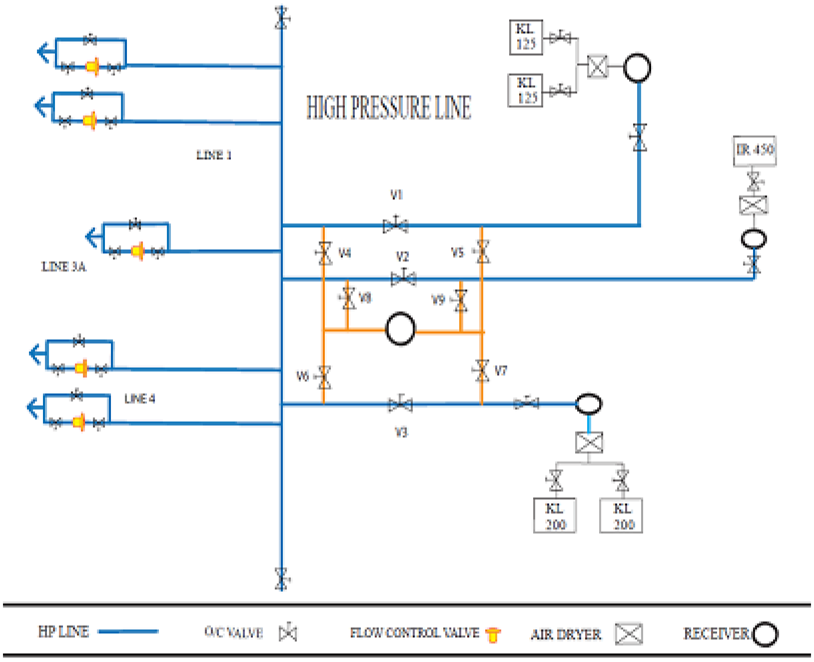

Fig 2 Modified high pressure line arrangement

The data collected in the modified system is given in Table 2.

Table 2. Compressor performance data of modified system

	HIGH PRESSURE LINE 450 kW	**LOW PRESSURE LINE 420 kW**	**HIGH PRESSURE LINE 125 kW + 125 kW**	**LOW PRESSURE LINE 260 kW + 260 kW**	**HIGH PRESSURE LINE 125 kW + 125 kW**	**LOW PRESSURE LINE 180 kW + 180 kW**
POWER (loading)	Voltage: 440 V Amp: 24.5 A PF : 0.8	Voltage: 440 V Amp: 27.4 A PF : 0.8	Voltage: 440 V Amp: 34.3 A PF : 0.8	Voltage: 440 V Amp: 30.1 A PF : 0.8	Voltage: 440 V Amp: 30.4 A PF : 0.8	Voltage: 440 V Amp: 31.2 A PF : 0.8
Time (loading)	3.4 min	3.6 min	6.4 min	3.2 min	5.4 min	4.3 min
Pressure initial	2 bar	1.9 bar	1.9 bar	2 bar	1.8 bar	2 bar
Pressure final	7 bar	7.1 bar	7.2 bar	7.2 bar	6.9 bar	7 bar
Dryer temperature	40° C	40° C	40° C	40° C	40° C	40° C
Atmosphere temperature	34° C	32° C	33° C	29° C	30° C	33° C
Volume of the cylinder	500 L + 500L	500 L+ 500L	500 L+ 500L	500 L+ 500L	500 L+ 500L	500 L+ 500L
Power (unloading)	Voltage: 440 V Amp: 11 V PF : 0.8	Voltage: 440 V Amp: 13.2 V PF : 0.8	Voltage: 440 V Amp: 22.1 V PF : 0.8	Voltage: 440 V Amp: 17.1 V PF : 0.8	Voltage: 440 V Amp: 19.2 V PF : 0.8	Voltage: 440 V Amp: 20.5 V PF : 0.8
Time (unloading)	23.4 min	25.7 min	33.1 min	21.3 min	27.2 min	25.9 min

Using the above data, the annual energy consumption for the plant is found as 14,28,887 kWh/ yr and the annual energy loss is found to be 76,860 kWh/ yr. Hence the cost of annual energy loss is Rs. 4,03,516/-.

C. MODIFIED ARRANGEMENT WITH INCREASED OPERATING PRESSURE RESULTS

In the new arrangement, the high pressure line primary receiver operating pressure is kept at 4.45 bar and the secondary receiver operating pressure is kept at 3.45 bar. The low pressure line primary receiver operating pressure is kept at 3.85 bar and the secondary receiver is kept at 2.85 bar. The primary receiver is first filled with air and maintained before starting the bottling machine. Valves are used to restrict and divert the flow in the pressure line.

Data collected at this working pressure in the new pressure line arrangement is shown in Table 3.

Table 3. Compressor performance data of modified system operating at higher pressure

	HIGH PRESSURE LINE 450 kW	LOW PRESSURE LINE 420 Kw	HIGH PRESSURE LINE 125 kW + 125 kW	LOW PRESSURE LINE 260 kW + 260 kW	LOW PRESSURE LINE 180 kW + 180 kW	HIGH PRESSURE LINE 200 kW + 200 kW
POWER (loading)	Voltage: 440 V Amp: 24.5 A PF : 0.8	Voltage: 440 V Amp: 27.4 A PF : 0.8	Voltage: 440 V Amp: 34.3 A PF : 0.8	Voltage: 440 V Amp: 30.1 A PF : 0.8	Voltage: 440 V Amp: 31.2 A PF : 0.8	Voltage: 440 V Amp: 30.4 A PF : 0.8
Time (loading)	2.3 min	2.7 min	5.1 min	2.1 min	5.4 min	3.1 min
Pressure initial	2 bar	1.9 bar	1.9 bar	2 bar	1.8 bar	2 bar
Pressure final	7 bar	7.1 bar	7.2 bar	7.2 bar	6.9 bar	7 bar
Dryer temperature	40° C	40° C	40° C	40° C	40° C	40° C
Atmosphere temperature	34° C	32° C	34° C	34° C	33° C	34° C
Volume of the cylinder	1000 L	1000 L	1000 L	1000 L	1000 L	1000 L
Power (unloading)	Voltage: 440 V Amp: 8.4 V PF : 0.8	Voltage: 440 V Amp: 9.9 V PF : 0.8	Voltage: 440 V Amp: 12.5 V PF : 0.8	Voltage: 440 V Amp: 9.1 V PF : 0.8	Voltage: 440 V Amp: 13.1 V PF : 0.8	Voltage: 440 V Amp: 11.8 V PF : 0.8
Time (unloading)	18.4 min	20.2 min	29.5 min	18.3 min	22.4 min	21.3

IV. CONCLUSION

The objective of this work is to reduce the energy consumption in the compressed air system of glass bottle manufacturing plant. The annual energy consumption, leakage percentage and energy losses of the existing compressed air system are calculated. Based on this data, the compressed air line layout is modified and secondary air receivers are installed. Data is collected for new modified arrangement at same working pressure and increased operating pressure. Energy consumption for the modified system is calculated using the data. The annual energy consumption of the existing system, modified system operating at same pressure and modified system operating at increased operating pressure are 11,55,514 kWh/yr, 14,28,887 kWh/yr and 6,95,517 kWh/yr respectively. Comparing with the previous results, annual energy loss in the modified system with increased operating procedure is reduced by 18 %.

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