Compressed Air System Optimization: Case Study Food Industry in Indonesia

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Abstract. Compressors and compressed air systems was one of the most important utilities in industries or factories. Approximately 10% of the cost of electricity in the industry was used to produce compressed air. Therefore the potential for energy savings in the compressors and compressed air systems had a big challenge. This field was conducted especially in Indonesia food industry or factory. Compressed air system optimization was a technique approach to determine the optimal conditions for the operation of compressors and compressed air systems that included evaluation of the energy needs, supply adjustment, eliminating or reconfiguring the use and operation of inefficient, changing and complementing some equipment and improving operating efficiencies. This technique gave the significant impact for energy saving and costs. The potential savings based on this study through measurement and optimization e.g. system that lowers the pressure of 7.5 barg to 6.8 barg would reduce energy consumption and running costs approximately 4.2 %, switch off the compressor GA110 and GA75 was obtained annual savings of USD 52,947 ≈ 455,714 kWh, running GA75 light load or unloaded then obtained annual savings of USD 31,841 ≈ 270,685 kWh, install new compressor 2x132 kW and 1x 132 kW VSD obtained annual savings of USD 108,325 ≈ 928,500 kWh. Furthermore it was needed to conduct study of technical aspect of energy saving potential (Investment Grade Audit) and performed Cost Benefit Analysis. This study was one of best practice solutions how to save energy and improve energy performance in compressors and compressed air system.

Keywords: compressor, compressed air system optimization, efficiency, energy saving, running cost, light load, unloaded
1. Introduction

1.1. Background
Energy has a very important role and becomes a basic necessity in sustainable national economic development. Energy demand grew at an average of 7% per year (DESDM, 2009). On the supply side, the growth rate of energy supply could not keep up the pace of growth in energy demand. This condition was increasingly gap between demand and supply. Therefore, energy conservation was an importance throughout the world, including Indonesia. There were strong indications that the use of energy in all sectors which includes households, industry, buildings (public and private) and transportation was inefficient (Warent, Ernest et.al, 2010).

Almost all industries use compressed air system/compressed air (Thumman & Younger, 2007). Compressed air systems were often as significant energy users in industry/factory. Industrial/plant used compressed air for process or production. Generally the compressed air generated by the compressed air unit with ranged from 5 to 50,000 Hp (Harding & Moore, 2012). Approximately 70-90% of compressed air was lost in the form of heat that could not be used, friction, misuse and noise. This was why efforts to increase the energy efficiency of the compressors and compressed air systems become an important target area in industry/plant (Warent, Ernest et.al, 2010). Based on these facts it was necessary to investigate the energy efficiency improvement in compressors and compressed air system through this study.

The results of this study were expected to be used as reference/benchmark for industry/factory to increase the efficiency of the compressors and compressed air systems and also provided reference support for industrial energy audit training in our training center.

1.2. Problem Identification
Generally about 10% of the cost of electricity in industry is used to produce compressed air. So far, the management considers that the compressed air was cheap because air or fluida to be compressed was available and free of charge. Otherwise indicated that the compressed air was an expensive resource therefore that must be used efficiently. Besides the energy losses - in the compressed air system was large enough so that the potential savings of about 30% was high enough (Kane & Medaris, 2003). How does the solution to the problem so that the compressor and compressed air systems could be optimized in order to save energy and costs?

Compressed air system optimization was the method how to approach the compressed air system as a whole system in order to save energy and cost. Energy savings in the compressors and compressed air systems had considerable potential (Kazuhide Konitoku, 2014). However, the techniques and the study of it is not widely practiced, especially in the industry/factory in Indonesia. In industry/factory compressed air is generally provided based on users request. If the compressed air demand of users are fulfilled it mean that compressor and compressed air system in a good condition although the users request or compressed air demand over, waste energy and cost.

1.3. Study Purpose
This study aimed is to obtain the potential energy savings in compressed air systems in industry/factory so that it could provide a solution to the problems of energy supply, especially in the energy performance improvement. The results of this research could be used for industry/factory as benchmark for energy performance of the compressor and compressed air systems.

2. Literature Review

2.1. Compressor
Compressor was a utility to increase the air pressure by compressing the gas or air. Compressor worked by sucking in atmospheric air (Abels & Kisscook, 2011). If the compressor worked at a higher pressure than the atmospheric pressure then called a booster compressor (booster), and if the compressor was working under atmospheric pressure, it is called a vacuum compressor (Abels & Kisscook, 2011). Low-powered compressor used single phase electric motor or gasoline engine while large power compressors required 3 phase electric motors, diesel engines or gas turbines.

2.2. Compressed Air System

Compressed air system consisted of supply and demand side. Supply side included compressors and air treatment while the demand side such as distribution, storage and end-use equipments (Harding & Moore, 2012). Main component compressed air system consisted of intake air filters, inter-stage coolers, after-coolers, air-dryers, moisture drain traps, receivers, piping network, filters, regulators and lubricators. It was described in Figure 1.

![Figure 1. Compressed Air System (Harding & Moore, 2012)](image)

2.3. Compressed Air

Compressed air was a gas fluid/compressed air. Compressed air had a great ability to store energy per unit volume. At the time of the expansion of the stored energy was released as work (Beals, CE, 2009). In these cases applied equation:

\[ WP = \frac{F}{A} \]  

(1)

\[ \frac{P_0 V_0}{T_0} = \frac{P_1 V_1}{T_1} = R = \text{constant} \]  

(2)

2.4. Compressed Air System Optimization
Compressed air system optimization is an engineering approach to determine the potential for energy savings in the compressed air system which included evaluation of energy needs in industrial plant/factory, adjustment of the supply, eliminating or reconfiguring the use and operation of inefficient, converting and equipping equipment to fit the needs and improve the efficiency of operations. In this case, boundary need to be set in advance as an initial step in the study of air compressed system optimization (Harding & Moore, 2012).

2.5. Energy Consumption in Compressor
It was only about 10-20% from total energy consumption in compressed air system had been using to compress the air (Kazuhide Konitoku, 2014) as described in Figure 3.
3. Research Methodology

3.1. Methodology
The methodology used in this study was a qualitative and quantitative methods with steps as follows:
- Preparation,
- Collecting secondary data,
- Field observation and measurement,
- Data verification and
- Data analysis

4. Result of Study

4.1. Overview of Energy Use
Types of energy and enery use in this plant (locus of study) was as follow:
- Electricity;
- Coal (steam
- Liquid Petroleum Gas
- Diesel oil
The electrical energy generated by the Power Plant with coal fuel. The type of power plant was co-
geneneration with 70% of the steam produced to generate electricity and 30% steam for process.

4.2. Investigation and Compressed Air System Optimization
The compressor was one of the most important utilities and compressed air (CA) was needed in the production process as well as operations in this study. CA system used to meet the demand site consists of 8 (eight) compressors with 1 (one) main system and local instrument air system.

### 4.2.1 Compressor Performance

Compressors performance had been described in Figure 4.

![Figure 4. Compressor Performance](image)

The performance in the figure 4. based on specific energy consumption (kwh/cfm). It was necessary able to compare the performance of each compressor, as shown in Table 1.

| Compressor   | Bauer 1 | Bauer2 | Bauer3 | M45   | GA75  | M160  | M110  | GA110 |
|--------------|---------|--------|--------|-------|-------|-------|-------|-------|
| Rated (scfm) | 671     | 671    | 671    | 261   | 449   | 869   | 665   | 637   |
| Actual (scfm)| 670.6   | 167.5  | 437.2  | 235.1 | 408.1 | 772.1 | 699.7 | 626.3 |
| % Rated      | 100     | 25     | 65     | 90    | 91    | 89    | 105   | 98    |
| SEC (kWh/100 cfm) | 0.3 | 4.0 | 0.6 | 0.4 | 0.4 | 0.5 | 0.3 | 0.3 |

Based on the figure 4 and table 1 as well as visual observation in the field, it could be compared compressor performance for each compressor was as follows:
- Bauer 1, very good (efficient): 0.3 kWh/100 cfm
- Bauer 2, very bad (very energy wasteful): 4.0 kWh/100 cfm
- Bauer 3, bad (energy wasteful): 0.6 kWh/100 cfm
- M45, good (efficient): 0.4 kWh/100 cfm
- GA75, good (efficient): 0.4 kWh/100 cfm

### 4.2.2 Compressed Air Demand Profile
To obtain the compressed air demand profile was conducted by measuring the flow rate (flowmetering) in GA75 Line 1, Line 2 and Line1-Main. Measurement results could be seen in the graph Figure 5.

![Figure 5. Compressed Air Demand Profile](image)

From the figure 5, it was obtained the average demand in 2100 scfm.

4.2.3 System Pressure
Measurement of the compressed air system pressure was conducted by using a pressure transducer and the results could be seen from the graph Figure 6. Based on Figure 6 illustrated that the system pressure of 7.2 barg with a range between 6.5 – 7.5 barg. This indicated that the pressure could be reduced up to 6.8 barg. It meant that with a pressure of 6.8 barg pressure system had been insufficient and had also considered the margin for the safety factor. Reducing the pressure of 1 barg would reduce energy costs 6-7% (Harding & Moore, 2012).
Figure 6. System Pressure

4.2.4 Annual Generation Cost
Compressed air generation costs per year was estimated based on the average demand by simulation. The simulation results verified based on secondary data, energy costs for compressors and compressed air systems. Estimation of annual costs generation could be seen in Figure 7. From Figure 7, obtained cost estimation for the annual generation average demand (2100 scfm) was 396,666 USD which consist of 366,400 USD Main System and 30,266 USD Class Screen System. The result was verified with the real costs 400,712 USD; which consisted of 4,310,600 kWh Main System and 356,300 kWh class screen System. The difference between estimation and real cost was about 4,046 USD or about 1.02%, so that the annual cost estimation compressed air generation could be accepted.
4.3. Determination of Energy Saving

In this study, in order to determine the potential for energy saving was conducted by optimization of compressed air system/compressed air system optimization, among others, by adjusting supply, eliminating or reconfiguring the use of operation inefficient, transform and equip equipment that fit the needs and improving efficiency operation. The approach was based on thus scenarios, among others:

- Optimization of existing compressors, among others, performed with switched off GA75 and GA110, running Bauer2 as last backup, running Bauer3 as penultimate backup, M160 as backup running at rated capacity.
- Installing new equipment, this was done partly by installing 2x132 kW fixed speed compressor and 1 x 132 kW VSD compressor.

Estimation of annual generation cost from scenarios illustrated in figure 8. From figure 8 it could be seen that if GA110 and GA75 off, the obtained annual saving of USD 52,947 or around 455,714 kWh. If GA75 running light load or unloaded then obtained annual savings of USD 31,841 or around 270,685 kWh. If install new compressor 2x132 kW and 1x132 kW VSD obtained annual saving of USD 108,325 or around 928,500 kWh.

![Figure 7. Annual Compressed Air Generation Cost](image-url)
5. Conclusion and Recommendation

5.1. Conclusion
The study of compressed air system optimization was a step in the effort to save energy and cost savings on utility compressor and compressed air system. Compressed air system optimization approach included adjustment supply, removing or reconfiguring the use and operation of inefficient, transform and equip equipment that fit the needs and improve the efficiency of utility operations more effective because of this method that could be seen as a system included; energy, cost and safety factors.

Based on the locus of study there were 3 (three) potential opportunities e.g. optimization of system pressure, reconfiguring equipment operation and adjustment of supply to demand. Estimation of cost and energy saving based on the study was 52,947 around 455,714 kWh or USD 31,841 around 270,685 kWh.

5.2. Recommendation
Some recommendations that could be delivered from the results of this study which aims to save energy or reduce the consumption of energy were:
   a. Lowering system pressure of 7.5 barg to 6.8 barg will reduce energy consumption and running costs approximately 4.2%;
   b. GA110 and GA75 off, the obtained energy and cost savings of electricity that was USD $ 52,947; 455,714 kWh;
   c. GA75 running light load or unloaded then obtained electrical energy and cost savings was USD 31,841; 270,685 kWh;
d. Install new compressor 2x132 kW and 1x132 kW VSD acquired electrical energy and cost savings was USD 108,325; 928,500 kWh;
e. The results of this study needed further research such as carried out detailed audits and perform Cost Benefit Analysis or Investment Grade Audit (IGA).

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