Energy Saving and Environmentally Friendliness of Air Compressors

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Trends in Global CO2 Emissions

Global CO2 emissions - Emission rate of each country -

- U.S. 21.1%
- China 20.6%
- Other 28.8%

2006
- Approx. 27.3 billion tons
- Converted to carbon dioxide (CO2) equivalent

2011 figures
- China 8,561
- US 5,271
- India 1,801
- Russia 1,677
- Japan 1,174

Other
- Mexico 1.6%
- South Korea 1.6%
- Canada 4.5%
- Italy 4.6%
- France 5.7%
- Germany 7.1%
- Japan 9.5%
- South America 9.6%

Published by International Energy Agency (IEA)

2011 figures
- China 26.9%
- U.S. 16.6%
- India 14.8%
- Russia 14.3%
- Other 38 billion tons worldwide

Source: 1997 Environmental White Paper by Oak Ridge National Laboratory (U.S.)
Source: 2011 Energy in Focus by Oak Ridge National Laboratory (U.S.)
Energy consumed for the industrial sector (factories) accounts for approximately 40% of the total energy consumption in Japan. It is considered that approximately a quarter of that amount is used by compressors. In addition, compressors are regarded as machines whose energy consumption can be reduced relatively easily. As a result, energy saving through rotation control and multiple unit control is strongly requested by the Ministry of Economy, Trade and Industry as well. Therefore energy saving for compressors needs to be addressed urgently.
Let’s check out energy cost - LCC and Specific Power Consumption

Most of compressor LCC is power consumption.

Electric Power Consumption: 84%

Initial: 7%
- (compressor, installation/starting, piping, etc.)
- Select better efficiency, better control.

Maintenance: 9%
- Carry out periodical maintenance.

Note: LCC = Life Cycle Cost

<Example>
Oil flooded 75kW class rotary screw (Hitachi)
6000hr/y operation ¥17/kWh
100% Load example
Total cost: 12 years average

If average air consumption decreased by 70%, electricity cost decreased by 70%.

Specific Energy Consumption

How much to for 1 m³ of compressed air? --- Example of quick calculation

\[
\text{Energy cost per m³} = \frac{\text{Power input (kWh)} \times \text{Electricity cost (¥/kWh)}}{\text{FAD (m³/min)} \times 60 \text{ (min)}}
\]

HOW MUCH?
Key points of energy saving for compressor equipment

Flow of pneumatic system improvement

1. Reduce the consumption.
   Reduce unnecessary air consumption of equipment to lower the compressor's load factor.
   **Stop the compressor.**
   Reduce air leakage.

2. Reduce operating pressure.
   Review and reduce pressure required for the equipment.
   Divide compressors based on required pressure.
   Reduce pressure loss.

3. Optimize the compressor system.
   Utilize inverter compressors.
   Optimize operating pressure.
   Select an appropriate model.
   Appropriate maintenance
What is the cost of air compressor?
CO₂ reduction = energy saving of the air system

Saving energy of compressed air system = Energy cost down

Energy cost (L kW) = pressure (P) x air consumption (V)

The policy for cost cuts useless
  - Lower useless pressure (P)
  - Reducing volume air consumption (V)
  - Improvement (pressure loss, leak) of the loss

The point of the energy saving is to get rid of waste how, and to perform the following
1. Making better capacity control (use the efficient machine)
2. Make efficient use of equipment
3. Appropriate pipe diameter and length = down compressed air speed
4. Counter measurement of leak
Remote Monitoring System (COSMOS II)

Easy monitoring on PC utilizing LAN (Local Area Network).
Easy communication with Service department.
Social needs for the remote monitoring is increasing together with Electric power monitoring.

LAN environment

**Internet**

COSMOS II has mail-send function for Warning/shutdown.
(Note: for this function, it is Necessary to install mail server or open an account of IPS (internet service provider).

Other monitoring system with WEB controller remote monitoring service for important equipment is also available.
Latest technique enable on-time insulation monitoring as well.

**LAN environment**

**Internet**

COSMOS II intranet

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Latest technique enable on-time insulation monitoring as well.
In this practice, we verify the importance of proper pressures design at positions in air supply lines.

1. **Piping system**
   - How pressure loss changes if size changed?
   - How pressure loss changes if valve structure differs?

2. **Air compressor**
   - How input power changes if compressor is driven by Inverter?
   - How pressure fluctuation changes if air tank is installed.

3. **Local pressurization**
   - What is “booster babicon”?
1. Pressure optimization by piping system redesign.

What is efficient way for local low pressure demand.  
Do you have similar cases like this in your factory?

1. Unstabilized factory air.  
   [status]  pressure far side from compressor unstable.  
   Pressure down when other system ON.

2. Due to budget allowance, no uniformity on air system such as devices, pipings (size, route, valves).

What kind of improvement in this case?

- Many glove valves in many locations through air piping system.
- Pipings are too narrow.
- Pressure lowered in far side from the compressor.
- Too much air blow make other devices hit the lower pressure limit.

How loop piping, size, bend and valves effect proper pressure in system?
Discharge pipe diameter and pressure loss

How much difference if piping diameter is changed?

In case piping diameter is 8mm, upper stream pressure is increased because pressure loss is big. As a result, air compressor commands unload operation. Therefore, bottom stream pressure is much decreased.
The flow rate in the pipe. = \( V (m/s) = \frac{Q_s \times \frac{Ps}{Pd} \times 60}{A \times \frac{Ps}{Pd}} \)

The flow rate in the pipe is desirably 4 to 5 m/s. - Economic speed

The smaller the pipe size, the higher the flow rate, causing a larger loss in the pipe. Accordingly an energy loss is generated, reducing the energy-saving effect.

* Example of 75-kW HISCREW NEXT (Discharge pressure: 0.69 MPa, discharge air volume: 13.2 M3/min), size of discharge air pipe: 50mm

\[ V = 13.2 \times 0.101 / (0.101 + 0.69) \div 0.05 \div 0.05 \div 3.14 / 4 \div 60 \]

= 14.31 m/sec (This is a very high speed.) The energy-saving effect is low.
Pressure loss depends on valve types and shapes

Big loss

7 pcs of glove valve (*** Valve)

Pressure loss caused by different types of valve
Example of pipes having many valves or bends. All of these generate resistance, causing pressure loss. Change the type of the valves (to the one with low resistance) or reduce bends as much as possible.

A pipe narrowed immediately after the air dryer. Generates resistance, causing pressure loss.
A riser pipe. Causes a backward flow of condensate, leading to an increasing number of mechanical troubles.
Examples of problematic piping

Drain trap attached just behind the compressor. Clogging of the pipe may be caused. Also, it increases the resistance at the immediate back of the compressor, which not only causes energy loss but also makes control difficult.

Rust of receiver tank and internal corrosion may be caused. Internal resistance increases. It is recommended that a receiver tank with internal treatment with epoxy or similar be selected.

Rubber hose connected from the compressor to the discharge pipe. It causes a large internal resistance and is inappropriate in terms of energy saving. Rubber hoses generate resistance higher by 20% or more than steel pipes and are not inappropriate.
Examples of recommended piping

Provide a drain plug for a riser pipe.

Recommended collecting pipe

Riser pipe installed from above

Large-bore pipe and receiver tank with adequate capacity

Recommended equipment and pipe flow
Notes for Piping Work

1. Be sure to provide a drain connection for a riser pipe. Installation to a collecting pipe must be made from above to prevent backflow. (Similarly, branch pipes must be installed from above.)

2. For a collecting pipe, give an inclination (1/100) from the upstream to the downstream. Attach a drain plug at the end of each pipe.

3. Buried piping makes it difficult not only to detect air leakage but also to repair. Therefore above-ground piping must be adopted. If buried piping is inevitable, install the pipes in a pit.
Reduce internal pipe resistance for energy saving

Example of piping improvement

Narrow piping
Complicated piping
Many partition piping

Review this piping !! Easy for energy saving!!

Energy saving effect 11%

405,000kwh => 360,450kwh (improvement)

OSP-75D5ALI
Piping diameter 2B => 3B
Size up capacity for air dryer
Size up for air filter
Replacement, construction fee: 3,000k¥
Investment recovered : 4.5year
Pressure loss:
0.2MPa => 0.5MPa (improvement)
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Changing air velocity through internal pipe ... loop piping

Pressure loss is two times higher of air velocity in proportion

Pressure loss is minimized to one quarter, only to make loop piping!

Necessary air velocity is about 5m/s

How much improvement can be made with loop piping?

Pressure loss become one quarter, only to make loop piping if there is imbalance among load.
Improvement with air compressor and air receiver tank

Ideal and effective operation by variable speed control compressor with air receiver tank

Do you have any familiar situation like below?

There are many possibilities to reduce extra power by changing into air compressor’s control operation with air receiver tank.

1. Air compressor’s control commands unload operation frequently.
2. There are big gap of air consumption in specific period, and facilities run all day.
3. Air pressure is fluctuating frequently even if small amount of air is used. (unstable)

Improve on air compressor with variable speed control operation (inverter).

Unnecessary power is consumed when low load operation, If conventional type capacity control (U type) and Integral operation (I type). Easy to reduce unnecessary power, only to adopt inverter control.

[Diagram showing power and air consumption with different control types (U type, I type, and inverter)]
Example of energy saving for inverter compressor

Application procedure

Carry out energy consumption analysis for air compressor (37kW conventional model x 1 unit evaluation)

Analysis result

- Average load ratio: 52%
- Power consumption 23,600kwh/m

Details of improvement

- 37kwh inverter compressor x 1 unit
- Power saving: 34%

Investment and effectiveness

- Apply to new 37kw Inverter compressor
- Efficiency of energy saving 110M¥/Y

Other effectiveness

- CO2 reduction (▲34%) for environment protection
- Periodical overhaul and parts durability last long (per 8 years)
- Maintenance cost is reduced 30%
  (our company calculation)
Effect of receiver tank if pressure fluctuation is frequently

Air receiver tank & bypass valve

Unnecessary fluctuation affect safety valve open

Min. pressure setting

Suitable capacity

Pressure fluctuation affect other comp. run unnecessarily

Energy saving

Power

load

unload
time

Without receiver tank

With receiver tank

Air pressure (Unstable)

Air pressure (Stable)

Air consumption is fluctuated frequently
normal: 0.5m³/min, max: 1.3m³/min
Compressor performance 1.0m³/min

Any difference with / without air receiver tank?
Ventilation and Ventilating Fan Capacity

**Required ventilation amount for general ventilation**

\[
Q = \frac{n \times H}{0.0753 \times \Delta T}
\]

- **Q**: Required ventilation amount (m³/min)
- **H**: Amount of heat produced per unit (MJ/h)
  
  \(1 \text{ kW} = 3.6 \text{ MJ/h}\)
- **n**: Number of units installed
- **T**: Allowable temperature increase

(When outside temperature is 35 °C, compressor's allowable maximum temperature is 40 °C, \(\Delta T = 40 - 35 = 5 °C\))

**Notes**

Air intake into the compressor room. (Pay attention to the gallery design - effective area.)

- Install the compressor in the direction so that a hermetically-closed room or intake of contaminated air (oil, gas, etc.) is avoided.
- Prevent the air discharged from the compressor room from being sent back into the room and circulating.

Discharge air in compressor room

- Install the fan high on the wall of the compressor room.
- When using a rain hood, take resistance into consideration when selecting a ventilating fan.
Notes for Duct Installation Work

Basically, provide a suction port low on the wall on the opposite side of the discharge port.

Be careful that the discharge port and suction port are placed on the same side.

In such a case, the room will not be ventilated at all.

Be sure to provide a separate discharge duct for each compressor. Do not share a discharge duct for 2 or 3 compressors.

Air will not be discharged properly, leading to a failure.

The same rule applies when air is discharged through a duct using a blower or ventilator.

Even with forced exhaust, if ducts are combined into a single duct, balance will not be maintained.

Overflowing discharge air may be taken into the neighbor machine.
3. Improvement local pressurizing

What is efficient way to pressurize higher locally within the air supply system.
Do you have similar cases in below?

1. Many pressure intensifier installed.
   [because:]
   - There are quite a lot of equipment requiring high pressure.
   - Capacity utilization raises in certain hours, causing pressure down.

2. Keep high pressure in whole system just because only a part of piping needs higher pressure.
Characteristics of pressure intensifier

[Advantage]
- Installation is easier for local pressure raising.
- No need for electricity.

[Disadvantage]
- About half amount of air is wasted to atmosphere. (the wasted air was originally compressed by using electricity.)
- Shorter overhauling. (in general, 1 Million cycles).
  In certain case, only 3000 hr may be maintenance cycle.

If you replace the intensifier with Booster Babicon, you will have the following advantage

1. Reduce air consumption.
   - Booster babicon in-take compressed air and pressurize efficiently.

2. Long maintenance cycle
   - 6000 Hr is overhauling maintenance period, which is quite long!

Let’s feel it! How small the required air if the pressure intensifier is replaced with booster babicon.
Supply high pressure line by pressurize from low pressure line. (pressurize valve, booster)

Effective Usage --- local high pressurize

Pressure:
Low in general. High only where necessary.

Compressor supply air
0.6MPa

Pressurize valve

Pressurize system

General use
0.55MPa

Low pressure equipment
Reduce to 0.3MPa.

Boosters
Bebicon

Pressurize system

0.8 ~ 1.0MPa

To equipment which need high pressure air.

All the equipment in a factory are running not at the same pressure. It is effective for energy saving to install pressure reduction system for low pressure line and high pressurize system for high pressure line. For local high pressurization, pressurize valve, booster is good, especially, booster bebicon works as multi-compression causing more energy saving.
Effective utilization • • • Energy saving between pressurize valve and booster bebicon

In order to make intensive pressure, there are two methods of compression:
- Pressurize valve and Booster compression

Pressurize Valve

Pressurize valve does not require electricity, so it is easy to install and use. However, twice as much air is required from source air. For example, if 500L/min of 0.8MPa air is necessary, it means 1,000L/min of source air is required. 500L/min out of 1,000L/min is exhausted as working air for pressurization. • • • wasting air

Booster Compressor

Booster Compressor is all air compressed and discharged by itself without any air loss. Air loss is almost zero during compression process. Since only little power is used for compression, electric cost is also very little.

Cost saving for 1.5kW power => 110k¥/year.
(Cost calculation: Electric power cost 15yen/kwh, 6,000hr/year)

Calculation • • • Which is one is better for energy saving?
Characteristics of Air Compressor (positive displacement compressor)

- Motor input (kW)
- Discharge pressure (MPa)

Two-stage compressors can compress air with lower power.

Power consumption when 1 m³/min of air is compressed:

- Single-stage compressor:
  - Motor input: 0.61 kW
  - Discharge pressure: 0.61 MPa

- Two-stage compressor:
  - Motor input: 0.4 kW
  - Discharge pressure: 0.61 MPa

The lower the discharge pressure, the lower the power required for compression.

Calculations:

- Single-stage compressor:
  - Motor input: 6.62 kW
  - Discharge pressure: 0.7 MPa
  - Relative power consumption: 6.62 / 7.23 = 0.915
  - Approx. Δ8%

- Two-stage compressor:
  - Motor input: 4.98 kW
  - Discharge pressure: 0.5 MPa
  - Relative power consumption: 4.98 / 5.38 = 0.925
  - Approx. Δ8%
Example of effective air blow... How much effect?

Air consumption is big for air blow when using direct cutting edge of long pipe.

Air blow is much effective when using air nozzle attached just before cutting edge.

Direct cutting edge

Air consumption is big for air blow when using direct cutting edge of long pipe.

Pressure loss big = Air consumption big

Air impact pressure is a KEY

Air squeeze before blowing out

Pressure loss small = Air consumption small

Air impact pressure is same

Working object

When air blow pressure made high...

Even if pressure reduction is made, air blow contacting pressure is the same as before and after.

Comparison of pressure loss between direct cutting edge of pipe and blow gun

Shapes of nozzle promote air blow different

Brow gun
leakage
Recommendation: determine total leakage and reduce it

Leakage Checking Method

1) Operate compressor at night, or holiday, and shut it down when achieving a predetermined pressure value.
2) When the compressor is shut down, due to the leakage, the pressure will automatically decrease. The amount of leakage can be known by measuring the time (T) taken to decrease the pressure by 1 bar.

The formula to determine the leakage (Q) is given below:

\[ Q = \frac{(P_1 - P_2) \times V}{P_0(1.033) \times T} \]

With:
- Q = Volume of leakage (M3/min)
- P1 = Predetermined pressure (kg/cm2) (gauge pressure + 1.033kg/cm2)
- P2 = Pressure after leakage (kg/cm2) (gauge pressure + 1.033kg/cm2)
- T = Time taken to reduce pressure from P1 to P2 (min)
- P0 = Atmospheric air pressure (kg/cm2)
- V = Piping capacity (Mm3) (In case of your company: 72.31m3)
Air Leakage at Various Areas and Energy Loss

There is a report that as much as 20% of leakage exists in a plant on average. Since leakage directly leads to energy loss, it is the highest priority issue for air systems.

Be aware that leakage may occur anywhere.

If there is a leakage of 200 liters per minute, the annual loss cost is: (assuming $1 \text{ M}^3 = 1.8$ yen)

$$\frac{200}{1000} \times 60 \times 8000 \text{ hrs/yr} \times 1.8 \text{ yen/kWh} = 172,800 \text{ yen/yr}.$$

Understand the difference between external leakage and internal leakage

Check the leakage point example and leakage amount.

(1) Leakage from a pipe

(2) Leakage from a coupler

(3) Leakage from an internal component of a device

Note that a leakage often occurs at valves and joints.

Internal leakage may occur at a solenoid valve, air cylinder, or other components.
The air leak point

Leakage cases

20% of leakage exists in a plant on average

point: valves
17.4 L/min

point: air gun
49.2 L/min

point: hoses
59.4 L/min

point: hose joint
59.4 L/min

point: regulator
71.7 L/min

point: coupler
27.7 L/min
Adopt 2 stage compressor with higher efficiency

If compressors are almost all the time running at full load, larger size would be better. (Note: in case the fluctuation is dominant, decentral system is better.)

<table>
<thead>
<tr>
<th></th>
<th>75kW x 1 unit</th>
<th>75kW x 2 unit</th>
<th>150kW x 1 unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input power kW</td>
<td>81.0</td>
<td>162.0</td>
<td>160.0</td>
</tr>
<tr>
<td>Air Delivery m³/min</td>
<td>12.4</td>
<td>24.8</td>
<td>28.5</td>
</tr>
<tr>
<td>Specific power kW/(m³/min)</td>
<td>6.53</td>
<td>6.53</td>
<td>5.61</td>
</tr>
</tbody>
</table>

※ Specific power = Input power ÷ Air delivery

16% improvement in Specific power!!!
Example of Ending Up with Increased Energy Consumption

One of 2 old machines was replaced with the latest model. Because the latest model machine has a higher discharge air volume, it was operated as a base machine. As a result, energy consumption increased approximately 10%.

Cause: The older machine was operated with capacity control. Because naturally it did not have good control characteristics, power consumption increased.
Action taken: Make the latest model machine dedicated for capacity control. As a result, approximately 20% energy saving was achieved.

There was a need of energy saving.
The highly-efficient inverter was operated as a base machine.
Energy saving by combination operation ...

Replacement of reciprocating compressor

Combination with OSP-55VA + OSP-55SA x2 unit
Much reduction of maintenance fee
Improvement in vibration troubles
Reduction of labor cost
Environment protection (improvement for oil leakage, drain troubles)

Energy saving 17.6%

Replacement of reciprocating compressor
150kW class

Power consumption per year : 319,500kWh => 264,000lWh (improvement)
Energy saving : about 0.5m¥/year (energy saving 17.6%)
Example of separate operation

100kW electric power was kept consuming
=> Average 54kW of power is saved

125kW and 160kW was controlled individually by manual.
Chose suitable compressor, calculating from load ratio and necessary air consumption.

OSP-75VW x 2 units are improved to control by lead lag operation (2 units will run in a peak power)

Power consumption per year : 685,140kWh => 370,032kWh (improvement)
Energy saving : about 400M¥/year
Centralized operation for energy saving...
From
decentralized operation to centralized operation (power saving at night shift)

Power consumption per year 303,920kWh => 169,600kWh (improvement)
Energy saving about 200M¥/year

Only few air is discharged from 3 units of compressor

In press process facility
(37kW + 22kW + 15kW)

- Replacement of air compressor
- Size up of piping diameter
- Install electric solenoid valve

In heat treatment process facility
(37kW + 22kW)

Centralization for press process facility
(37kW X 2 units + inverter 1 unit)
Environment protection ...replacement of reciprocating compressor

Low vibration, low noise level products

Environment protection is necessary!
The sound level is minimized as we can have talk easily.

150kW balanced type compressor
Improvement of power consumption in compressor room with humid environment.

Illustration of wind flow

Wind flow was not good for ventilation in the compressor room, so improved wind direction in one way. (figure below)

Close all windows except exhaust side of fan to make wind flow direction.

Inner compressor temperature reduced from 45°C to 35°C

Energy saving 3%

Power consumption per year: 160kW x 2 units x 1.1 x 8000h = 2,816,000kW
Energy efficiency 3% => half of 84,480kW (6 months)
(1kWh = 15 yen 633,600 yen improvement)
Reduction of environment load
--- Verification of reduction effect of CO2 emission

Verify how much of reduction of environment load by Compressor energy saving.

Electricity reduction per year x Coefficient of CO2 emission = ton/year
Here adopt Default CO2 coefficient = 0.00093 (ton-C02)/kWh

CO2 coefficient is different from each electric power generation method.

<Eg>
15kW energy saving and 4000Hr running operation per year, then CO2 cut-out is:

\[
15 \text{ kW} \times 4000 \text{h} \times 0.00093 \text{(t-CO2/kWh)} = 55 \text{ ton of CO2 is reduced.}
\]
Plan and procedure of energy saving improvement

- Environmental protection
- Energy saving act
- Control energy cost
  Measure, Record Log
  Maintenance, service
- Adopt Improvement plan,
  New process

Through above cycle, verify result of energy saving.
How much of CO2 reduction?
What for environmental protection.

Control progress by reporting, notice, thoroughness of improvement.

After achievement, make it standard, then try to improve more.
Target higher stage.