FY2014 Feasibility Studies on Joint Crediting Mechanism (JCM) Projects towards Environmentally Sustainable Cities in Asia

The feasibility study to promote Low Carbon Technology application in India

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Institute for Global Environmental Strategies

(IGES)

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Chapter1 Research Background and Framework

1.1 Research Background

(1) JCM scheme and the case of India

The new approach proposed by Japan, called Joint Crediting Mechanism (JCM) aims to contribute to global actions for emission reductions and removals by sinks undertaken by UNFCCC. Japan has conducted consultations on JCM with developing countries since 2011, and has shared its vision on JCM in various conference of the parties (COP) under UNFCCC, such as the one in Doha (COP18), in Warsaw (COP19), and lately in Cancun (COP20). The JCM provides opportunities for developed countries to meet their emission reduction targets by corresponding flexibly and quickly to national circumstances of developing countries and facilitating diffusion of greenhouse gas emission reduction technologies, products, systems, service, infrastructures, etc., as well as the implementation of mitigation actions in those countries, and making the measurement, reporting and verification (MRV) of those greenhouse gas emission reduction effects possible.

This study is carried under JCM scheme and targeting India. For instance, Japan has been discussing JCM with India for last few years but no agreement has been reached yet. An agreement on this regard would allow Japanese companies to install carbon-cutting technology in India and in return receive carbon credits under the JCM scheme that can be used to offset their own carbon footprint under the country's emissions target or be sold to the Japanese government.

In order to support in raising awareness about JCM, IGES, in collaboration with The Energy and Resource Institute (TERI), organized a workshop in Delhi, on Feb.5th, 2014. The ultimate objective of the workshop was to discuss “Financing of Low Carbon Technologies in Indian Industries” through discussing financing options for implementation of energy efficient technologies in Indian industries and the strategies to use existing mechanisms to accelerate the adoption of Japanese low carbon technologies. During the workshop, the JCM scheme as well as the credit line provided by JICA to Small Industries Development Bank (SIDBI) were introduced as potential options. Although the JCM scheme hasn’t been signed yet between Japan and India, but there was significant interest from Indian side in this scheme, and a strong hope that both countries move ahead for signing it.

(2) Indian initiatives regarding GHG emission reduction

India is already a global giant in terms of primary energy demand. By 2020, India’s primary energy demand is expected to surpass that of Russia to become the third largest in the world. Not to mention, India's CO2 emissions are expected to soar to even higher levels in accordance with the rapidly growing primary energy demand.

On June 30, 2008, India released its first National Action Plan on Climate Change (NAPCC) outlining existing and future policies and programs addressing climate mitigation and adaptation. The plan identifies eight core "national missions" running through 2017. 1) National Solar Mission; 2) National Mission for Enhanced Energy Efficiency; 3) National Mission on Sustainable Habitat; 4) National Water Mission; 5) National Mission for Sustaining the Himalayan Ecosystem; 6) National Mission for a "Green India"; 7) National Mission for Sustainable Agriculture; 8) National Mission on Strategic Knowledge for Climate Change.

Table 1-1 Indian's initiatives on GHG reduction (India National Action Plan on Climate Change)

National Missions	Brief overview
1. Solar Mission	Specific goals include increasing use of solar thermal technologies, increasing production of photovoltaics and deploying solar thermal power generation. Other objectives include the establishment of a solar research center, increased international collaboration on technology development, strengthening of domestic manufacturing capacity, and increased government funding and international support.
2. Enhanced Energy Efficiency	Mandating specific energy consumption decreases in large energy-consuming industries, with a system for companies to trade energy-savings certificates; Energy incentives, including reduced taxes on energy-efficient appliances; and Financing for public-private partnerships to reduce energy consumption through demand-side management programs in the municipal, buildings and agricultural sectors.
3. Sustainable Habitat	To promote energy efficiency as a core component of urban planning, the plan calls for extending the existing Energy Conservation Building Code; A greater emphasis on urban waste management and recycling, including power production from waste; Strengthening the enforcement of automotive fuel economy standards and using pricing measures to encourage the purchase of efficient vehicles; and Incentives for the use of public transportation.
4. Water Mission	With water scarcity projected to worsen as a result of climate change, the plan sets a goal of a 20% improvement in water use efficiency through

	pricing and other measures.
5. Sustaining the Himalayan Ecosystem	The plan aims to conserve biodiversity, forest cover, and other ecological values in the Himalayan region, where glaciers that are a major source of India's water supply are projected to recede as a result of global warming.
6. "Green India"	Goals include the afforestation of 6 million hectares of degraded forest lands and expanding forest cover from 23% to 33% of India's territory.
7. Sustainable Agriculture	The plan aims to support climate adaptation in agriculture through the development of climate-resilient crops, expansion of weather insurance mechanisms, and agricultural practices.
8. Strategic Knowledge for Climate Change	The plan envisions a new Climate Science Research Fund, improved climate modeling, and increased international collaboration. It also encourage private sector initiatives to develop adaptation and mitigation technologies through venture capital funds.

The Purchase Achieve and Trade (PAT) Mechanism is one of the initiatives under NMEEE programme. It is a market based mechanism to further accelerate as well as incentivize energy efficiency in the large energy-intensive industries. The scheme provides the option to trade any additional certified energy savings with other designated consumers to comply with the Specific Energy Consumption reduction targets. The Energy Savings Certificates (ESCerts) so issued will be tradable on special trading platforms to be created in the two power exchanges — Indian Energy Exchange and Power Exchange India.

The Government of India identified 478 industrial units to be targets under PAT and notified them under the Energy Conservation Act, 2001 on 30th March, 2012. These units are to achieve specific GHG emission targets up to 2014-15.The Ministry of Power and the Bureau of Energy Efficiency (BEE) have been in the vanguard of promoting the efficient use of energy and its conservation, including the operation of PAT scheme.

(3) India: Overview

The Republic of India occupies most of the subcontinent of India in southern Asia. Its total area is 3,287,590 sq. Km and it borders on China in the northeast. Other neighbors are Pakistan on the west, Nepal and Bhutan on the north, and Burma and Bangladesh on the east. India is a developing country and currently is the world's number two population giant next to China. India's population was 1.21 billion as of 2010, but is expected to continue on an increasing trend to surpass China in 2015, to become 1.48 billion in 2030 and 1.61 billion in 2050 (UN DESA, 2009). Despite large gaps existing in Indian society, where the population remaining in poverty (under 1.25 USD) is 44 percent in rural areas and 36 percent in urban areas, when examined as a whole, India is a major developing country undergoing rapid economic development.

Significant economic development has captured large interest of foreign businesses including those from Japan. However, the penetration of Japanese businesses in Indian market is relatively slow compared to other nearby Asian emerging markets and China.

Regarding CO_2 emission, India is already the third largest CO_2 emitter worldwide, behind only China (7955), and US (5287). India's CO2 emissions are expected to soar to even higher levels in accordance with the rapidly growing primary energy demand. India's CAGR (compound average annual growth rate) of primary energy demand from 2008 to 2035 is estimated to be 3.4%, which is significantly larger than other countries including even China (2.6%) . If technologies do not undergo a major change, India's increase in CO2 emissions is estimated to reach two billion tonnes by 2030, the largest after China's six billion tonnes(IEA reference scenario).

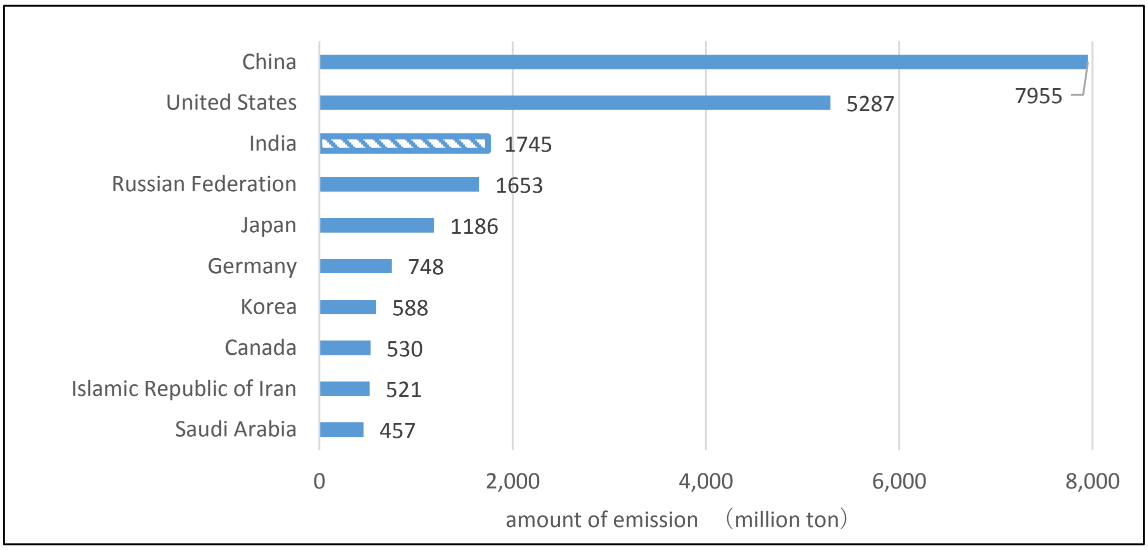


Figure 1-1 CO2 Emissions from Fuel Combustion

(Source: IGES, based on IEA 2013 edition: CO2 emissions: Sectorial Approach (2011))

(4) IGES experience on research activities in India

The institute for global environmental strategies (IGES), with collaboration of the Kyoto University, from Japan side, and The Energy and Research Institute (TERI), from Indian side, has jointly conducted a four years research project to promote the application of Japanese low carbon technologies in Indian SME. The project, titled ALCT project, has been just accomplished in Mar. 2014. It was funded by the JICA-JST Science and Technology Research Partnership for

Sustainable Development (SATREPS) scheme, and has been conducted under the supervision of Ministry of Environment and Forest in India, and with the collaboration of private sector from India and Japan. The project constituted a model of good and strong collaboration between research institutes, academia, government organizations and private sector to search about opportunities and challenges for low carbon technology application in Indian SME through various activities, including implementation of pilot projects as show cases. The ultimate aim of the project was to facilitate India–Japan collaboration at business-to-business (B2B) and government-to-government (G2G) levels to promote the deployment and diffusion of Japanese LCTs in the Indian SME sector through various existing national, bilateral, regional and international programs, as well as through possible new regulations and incentives in both countries.

Under ALCT project, several Japanese technologies have been identified as promising LCTs for application in Indian SMEs. Pilot projects have been implemented on four of them: namely, gas heat pump system (GHP), electric heat pump system (EHP), compressed air system (CA) and induction furnace system (IF). The pilot projects on GHP and EHP include implementation of 'hardware' (equipment), while the pilot projects on CA and IF include only 'soft' components (capacity building on best operating practices, improved management practices (Kaizen), etc.).

As for compressed air system, improving compressed air system could take place at various points of the system, such as upgrading the air compressor to inverter type, changing pressure setting, increasing piping size, using efficient filters, blowers, etc. For instance, inverter type air compressor technology has been widely deployed in Japan, but it was surprisingly enough that none of the sites which have been investigated under ALCT project, have installed it yet.

It was estimated that the impact of installing inverter type air compressor in Indian SME will result in energy saving and CO2 emission reduction in the range of 15-25%. This will result also in significant operation cost saving. Given that most of the cost of Air compressor is operation cost, then the saving in operation cost is tremendously important to motivate plants to install it.

1.2 Overview of the Study

(1) Objective of study

The objective of this research study is to investigate about the feasibility of applying technologies related to compressed air system in Indian industries.

(2) Period of study

This project was implemented from 5th Sep. 2014 to 20th Mar. 2015.

(3) Procedures of study

The project was implemented following the chart below:

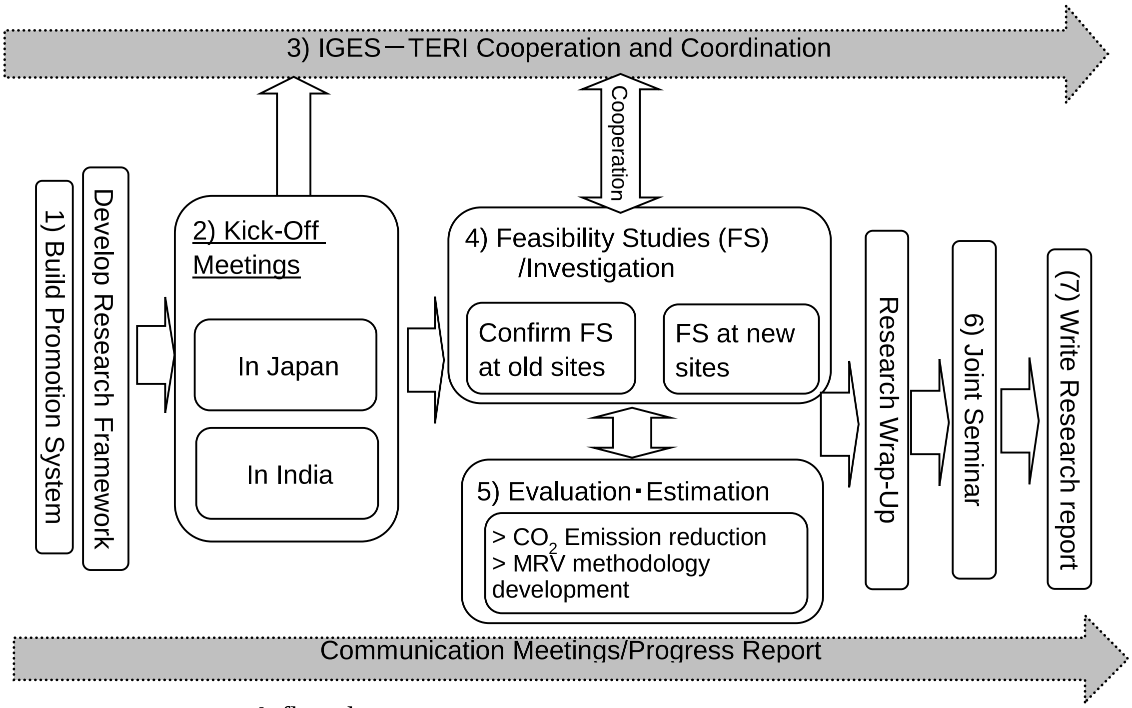


Figure 1-2 Research flowchart

More details about the component of the project are explained below:

1) Build Promotion System: In order to promote the application of technologies related to compressed air in India in general and to conduct the current JCM project in particular, IGES have made the necessary arrangements (through meetings, conferences, etc.) with relevant stakeholders from Japan, especially Japanese supplier, and from India, especially The Energy and Resource Institute (TERI).

2) Kick Off: A kick off meeting of the project was conducted first in Japan involving only IGES and technology supplier (namely HITACHI IES) and then in India involving IGES, TERI and Hitachi IES.

3) TERI-IGES Cooperation/Coordination: The cooperation/coordination between IGES and TERI was ongoing prior to the current JCM project. For instance, IGES and TERI jointly conducted successfully a four years research project (2010-2014) to promote the application of Japanese low carbon technologies in Indian SME. The project constituted a model of good and strong collaboration between research institutes, academia, government organizations and private sector to search about opportunities and challenges for low carbon

technology application in Indian SME through various activities, including implementation of pilot projects as show cases. Under JCM project, TERI and IGES jointly conducted a workshop to enhance the awareness among Indian industries about technologies and best practices regarding compressed air technology.

4) Feasibility Studies (FS)/Investigation

> Confirm FS at old sites/ Monitoring: The current project included confirmation of feasibility studies previously conducted, namely under ALCT project, at one site through additional investigation as well as necessary monitoring.

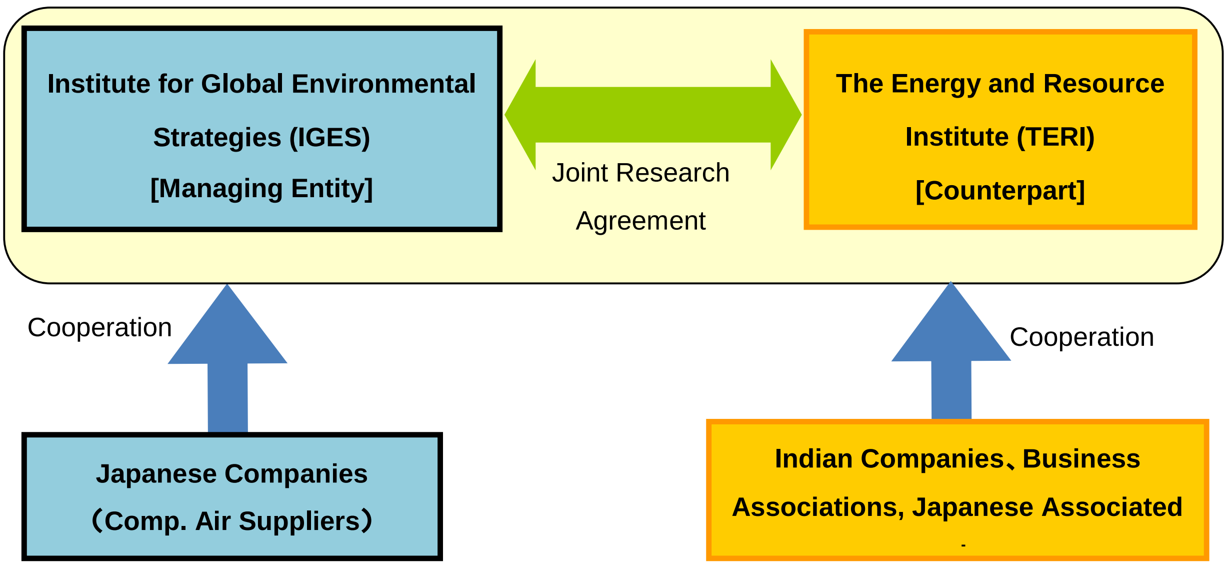
> FS at New Sites (Needs investigation): The project targeted new sites and conducted FS about the application of technologies related to compressed air in their sites, especially regarding inverter type air compressor. This is to understand their needs and to match their needs with technology available in Japan.

5) Develop MRV Methodology and PDD (draft): Under the project, a draft methodology on how to Monitor, Report and Verify (MRV) the impact of installing inverter type air compressor was developed, along with draft of PDD. They were developed according to JCM guidelines in order to be used later on if the JCM will be agreed between the two countries.

6) Joint Seminar: A wrap up meeting and joint seminar were conducted in Feb. 2015 in order to share the progress and to discuss the way forwards.

7) Writing Research Report: The findings from the research activities were summarized in the current research report in collaboration with experts and counterpart.

(4) Research partnership



(5) Research schedule

As indicted in the following project schedule, business trips to India were conducted on Oct. 2014 and on Feb. 2015. The first was to conduct the investigation and to organize workshop and the latter to wrap up and to conduct the joint seminar.

Activities	2014									2015		
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Build Promotion System					━━	━━						
Develop Research Framework					━━	━━						
TERI-IGES Cooperation/Coordination	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Site Investigations/Impact Estimation				- -	- -	- -	- -	- -	- -	- -	- -	
Develop MRV methodology (Draft)				- -	- -	- -	- -	- -	- -	- -	- -	
Kick Off/ Joint Seminar						● Japan	● India				● Japan/ India	
Write Research Report										━━	━━	●
Communication Meetings/Progress report							●	●	●		●	●
Business trips to India							●				●	

Chapter 2 Implementation of Feasibility Study

2.1 Feasibility Study for Low Carbonization of Compressed Air System

(1) Compressed air system

Compressed air is called the fourth utility of an industry, after electricity, gas and water. It is also the most inefficiently used energy, due to negligence and lack of good control and management. It is mainly used extensively as a source of power for tools, equipment and industrial processes. A typical compressed air system consists of compressors, coolers, filters, moisture traps, dryers, and receivers (Fig.2).

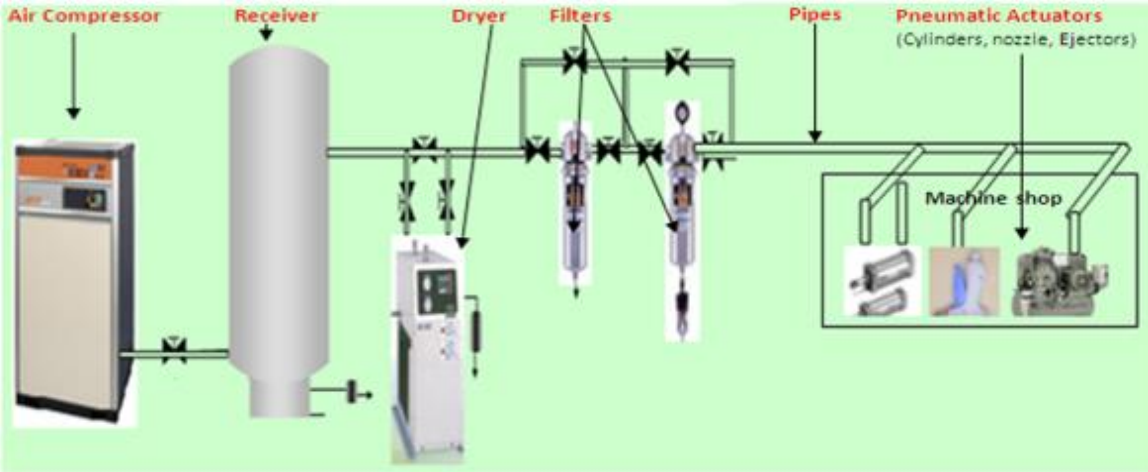


Figure 2-1 Compressed air system

Energy loss in compressed air system is caused by pressure loss in several points between the supply end (air compressor) and the demand end (use end), as shown in Figure 2-2. According to the performance analysis of standard compressed air system, it has been pointed out that the equivalent to around 20% of air is being waste due to leakage.

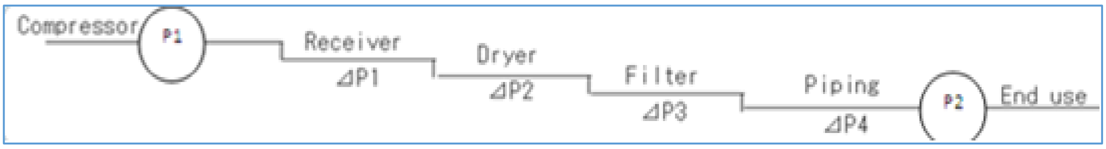


Figure 2-2 Energy loss regarding compressed air system (Image)

Other reasons for inefficiency of compressed air systems include inappropriate pressure setting, gap between the supply of and demand for compressed air; compressed air is supplied even to work places which are not in operation; use of air compressors rather than blowers when a blower is more appropriate; inappropriate piping size and design; inappropriate size of receiver tanks; inefficient equipment/devices (Air guns, valves, filters, dryers, etc.), etc.

(2) Important points to reduce CO2 for compressed air system.

Use energy should be reduced to CO2 reduction in compressor system, so the pressure and the consumption which become the power element need to be reduced. Also, effective energy can be used by reducing leakage and pressure loss.

Three biggest points for energy saving of pneumatic system are as follows.

1. Reduce the consumption (elimination of waste, reduction of leakage, etc.)
2. Reduce operating pressure (partial pressurization, reduction of pressure loss, etc.)
3. Optimize the compressor system (effectively use)

The details are shown in Figure 2-3.

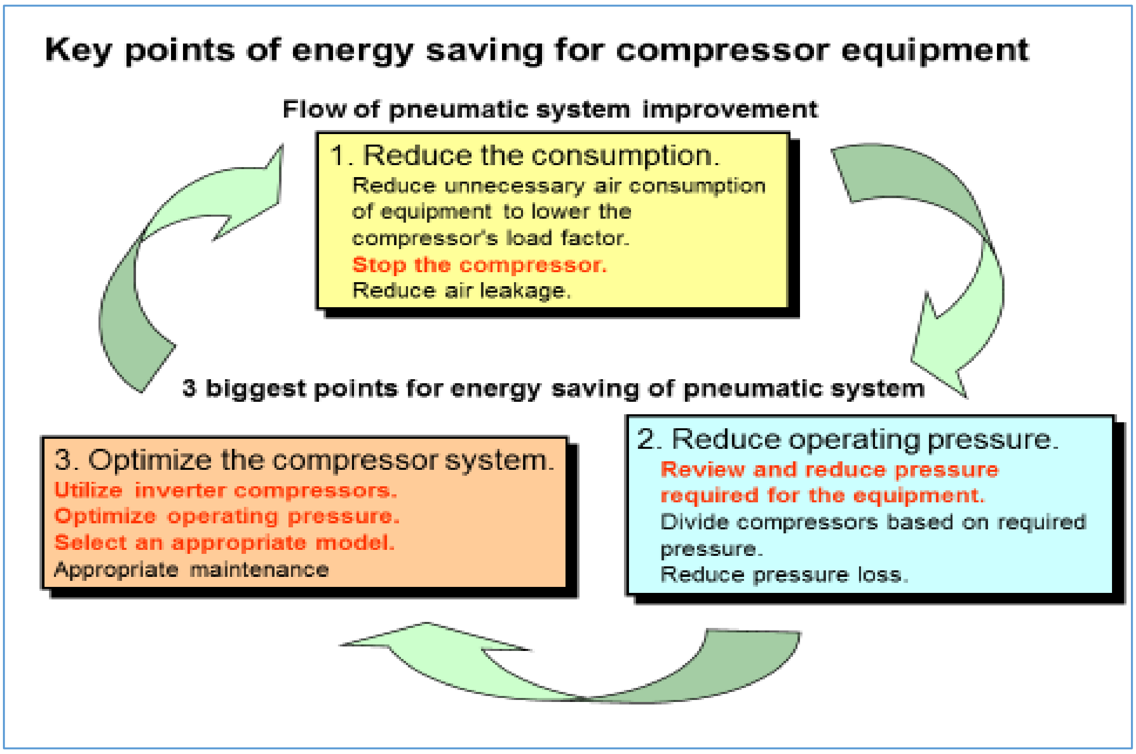


Figure 2-3 Three biggest points for energy saving of pneumatic system

(3) Electric power and cost of compressor

It's considered that motor-used equipment consumes most of the energy consumed at a factory, and specially the electric power consumed by a compressor accounts for about 15-25% of the whole. As for a compressor with average size (75kw equivalence), most of energy cost is spent to pay for electric power cost (about 84%), and only small part is paid for maintenance cost (about 9%), and for initial cost (7%; compressor, installation, etc.). So, in case of air compressor, it is important to control the power consumption, which can be obtained by the ratio of power and air volume, with installing watt meter and air flow meter. Details of the cost and control of power consumption is shown in Figure 2-4.

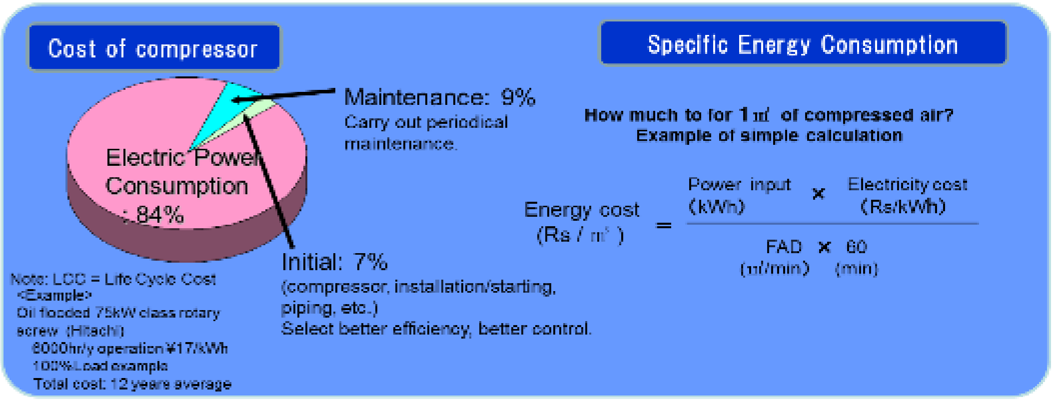


Figure 2-4　Cost of compressed air system

2.2 Results of Feasibility Studies (FS)

(1) Investigated sites (factories)

FS were implemented at 4 textile companies, one forging company, and one casting company. Since textile industry is one of nine industries selected under PAT scheme in India, the innovative energy saving for improvement of energy efficiency and the GHG emission reduction measures in the industry has been expected. Moreover, forging and casting industries were selected because these industries generally require lots of energy demand that IGES and TERI have investigated.

Table 2-1　Outline of investigation

Date	Company (industry sector)	Places
Oct.6th (Mon.)	Kick off meeting with TERI Feasibility study at Raymond Denim Pvt. Ltd. (Textile).	Nagpur
Oct. 7th (Tue.)	Feasibility study at Morarjee Textile Ltd. (Textile)	Nagpur
Oct. 8th (Wed.)	Feasibility study at Arvind Pvt. Ltd. (Textile)	Ahmedabad
Oct. 9th (Thu.)	Feasibility study to Bombay Dyeing Ltd. (Textile)	Pune
Oct. 10th (Fri.)	Feasibility study at Ahmednagar Ltd. (Forging) Feasibility study at Mahindra Hinoday Ltd. (Casting)	Pune
Oct. 11th (Sat.)	Work shop Wrap up meeting with TERI	Pune

(2) Proposals on CO2 reduction and environmental improvement

Based on site investigation several proposals and recommendations, about what measures could be taken, were raised by experts to improve the currently being used air compressor systems at the investigated sites. The cost to take such measures vary significantly from one to another, but significant benefit could still be generated with minimum cost, if they are taken successfully. The list of main proposed measures is given below:

1. Make efficient usage of compressor(s) through:
   - Reduction of discharge pressure
   - Effective utilization of inverter type air compressor
   - Combination of Centrifugal＋screw compressor
   - Usage of booster compressors
   - Usage of two-stage compressor(s)
2. Eliminate wasted energy through:
   - Reduction of leakage, by starting with investigation on existing leakage
   - Stop using buried piping ~ Taking it out from the ground
   - Stopping inter-cooler and after-cooler blows, and usage of high efficiency drain trap to reduce the air blow volume
   - Usage of effective blow gun and improvement of blow gun
   - Usage of air saving valve for actuator
   - Usage of energy-saving coupler
3. Adjust the environment
   - FRESH, COLD, DRY
   - Installation of drain water processor
   - Clean the pre-suction-filter regularly
4. Improve pressure loss in piping construction
5. Ventilation measures method to avoid rise in temperature in compressor room
6. Simple checking of receiver tank
7. Energy monitoring
   - Usage of monitoring system
8. Utilise measurement and diagnosis
9. Convert cooling water pumps to inverter-driven operation

(2)-1 Make efficient usage of compressor

➢ Reducing discharge pressure

As shown in Figure 2-5, 8% of energy saving is possible by lowering 1bar (from current end value of 7bar to 6 bar), in case of single-stage compressor.

Pneumatic equipment used in a factory does not necessarily need to be used at high pressure. If efforts are made to use it at the lowest possible pressure, energy consumption is reduced.

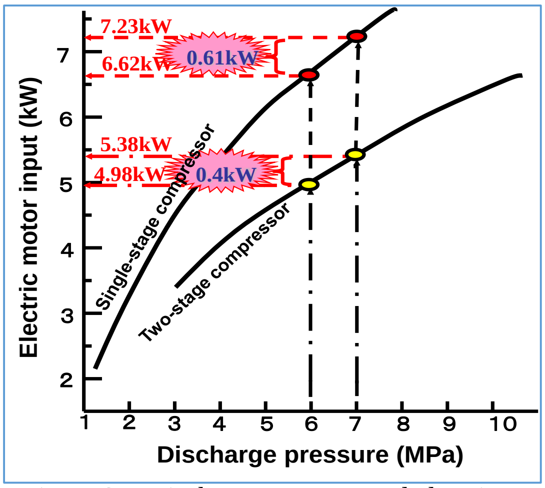


Figure 2-5 Discharge pressure and electric power

➢ Utilise inverter compressor effectively

Compressors work in response to the quantity of compressed air required by the user, and they are not always working at 100% capacity. The compressor controls its capacity according to the compressed air requirement, and how well it performs that control process has a significant impact on the amount of power consumed. In essence, compressors that have poor control consume excess energy even when they are not actually performing work. In this regards, Inverter screw compressors are designed to optimize capacity control by means of a pressure sensor that sends a signal to the inverter in response to the quantity of compressed air required, thereby changing the rotational speed accordingly. This method enables a compressor to operate with the lowest electricity consumption possible to obtain the required air quantity. Electricity costs can be reduced to an optimal level because, in the case of an inverter compressor, even if the rotational speed changes, the compressor's performance is unimpaired and it maintains a constant compressing pressure, so there is almost no ineffectual operation.

In India, it was observed that large number of centrifugal (turbo) compressors are being used in the textiles industry. Compression technologies vary according to the type of compressor used, requiring different measures to reduce energy consumption. It is therefore important to select machines that suit the particular characteristics of each factory.

Figure 2-6 shows types of compressors and their key features. For sites using centrifugal air compressors it was mainly recommended to use them in combination with Screw compressor(s) to control the level of load fluctuation.

CENTRIFUGAL (Turbo) compressor has the following features;

- High capacity machine is more energy-efficient than small capacity machine
- Larger the number of compression stages greater is the energy saving. Select three-stage type instead of two-stage type.
- Make sure to use it as a base load since load variation brings inefficiency.
- Care should be exercised when making the choice because energy saving cannot be obtained by reducing discharge pressure.
- Variations in performance due to temperature can be easily obtained (low temperature is advantageous)

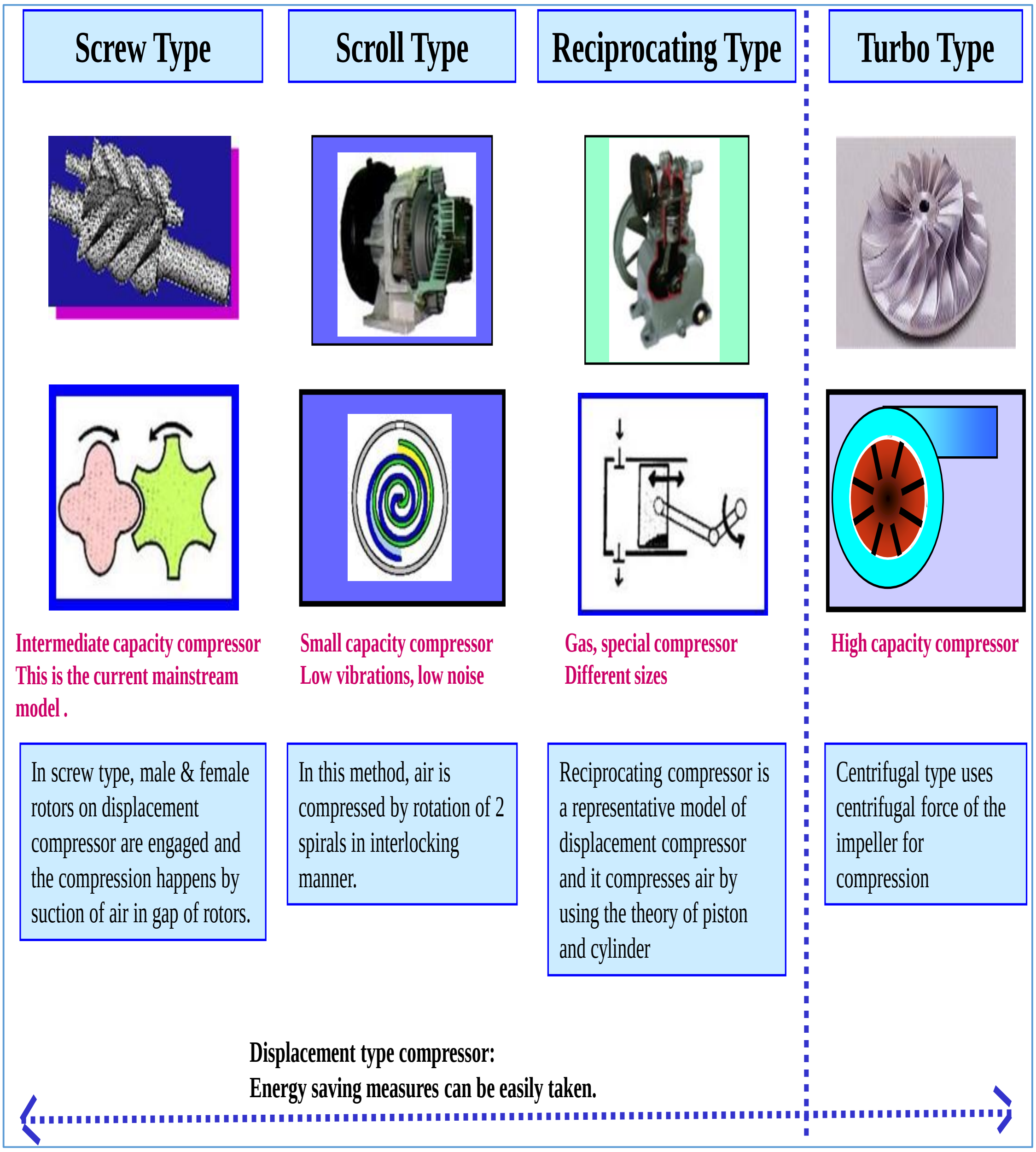


Figure 2-6 Types of compressors and measures to reduce energy consumption

As shown in Fig. 2-7, the most appropriate method is to use the centrifugal (turbo) compressor as the base load, with a displacement (screw) compressor to handle the load fluctuation, resulting in reduced energy requirement (lower specific energy consumption) overall.

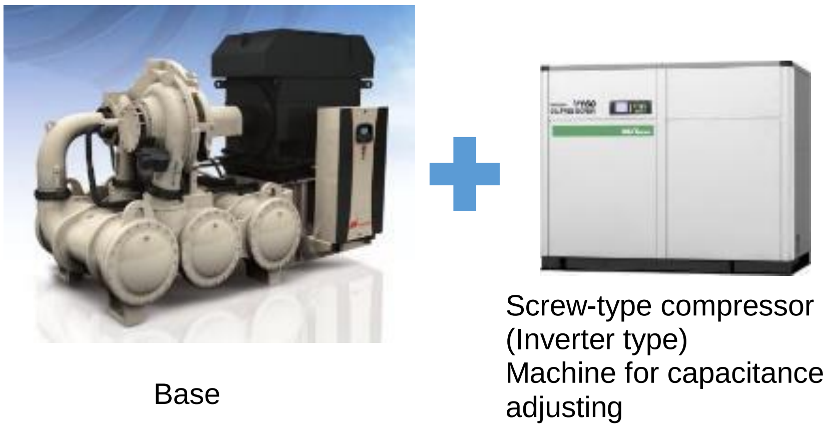


Figure 2-7 Combining compressors as a means of handling load fluctuations

➢ Use booster compressors

Compressed air used in a factory is not necessarily all being delivered at the same pressure. To save energy and reduce energy costs, energy consumption can be reduced significantly by lowering the overall pressure of the air supply in the factory as much as possible, and installing booster compressors in the specific locations where high-pressure air is required (as depicted in Figure 2-8).

If the pressure supplied to the factory as a whole is reduced by 1.5 bar, a reduction in energy consumption of approximately 10% can be achieved over the line as a whole, even if more power is required of the compressors from time to time. Meanwhile, only a limited amount of energy is needed for booster compression.

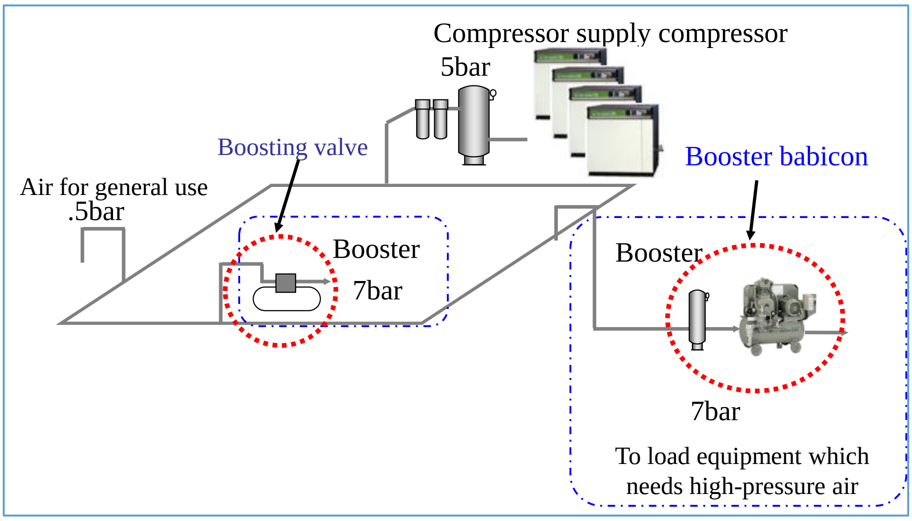


Figure 2-8 Example of local high pressurizing

➢ Use a two-stage compressor

Use of a two-stage compressor is recommended if several single-stage compressors are being operated. Single-stage reciprocating and screw compressors are in widespread use because they are cheaper and easier to use, but their energy efficiency is poor. From the energy efficiency point of view, cost benefits can be obtained by using a two-stage compressor when capacity of 110 kW or more is required.

As shown in Table 2-2, usage of a two-stage compressor rather than a single-stage compressor can potentially reduce energy consumption by as much as 15–18%. However, if a particular user's equipment has large load fluctuations, energy consumption may be more effectively reduced by operating separate single-stage compressors rather than using two stage compressor. Careful choice should be made.

	75kW x 1 unit	75kW x 2 units	150kW x 1 unit
Input power kW	84.0	168.0	160.0
Discharge air m^3/min	12.4	24.8	28.5
Power consumption kW/(m^3/min)	6.53	6.53	5.61

* Power consumption = Input power ÷ Discharge air

Table 2-2 Specific energy consumption of compressor

It is also possible to reduce energy consumption by integrating and increasing the size of equipment according to the following recommendations:

- Integrate and increase the size of compressors that are currently installed separately
- Improve energy efficiency by using two-stage compressors
- Install compressors in locations offering good environmental conditions to eliminate external causes of problems
- Use 150 mm (6B) piping for the main piping in each factory. Existing leakage will be eliminated
- Overall capacity can be optimised if one compressor is converted to an inverter compressor and the number of compressors in operation at any one time is controlled

(2)-2 Eliminate wasted energy

➢ Reduce leakage - Starting with investigation of existing leakage

A compressor's biggest waste of energy is the energy lost due to leakage. Empirical figures from the pneumatics industry indicate that compressed air leakage from an entire factory amounts to as much as 20% of the compressed air generated. This is an average amount, so in extreme cases it can be as much as 50%.

Air leakage can occur anywhere. Hence, as first step, leakage amounts and locations must be investigated. All air leaks amount to wasted energy, so remedial measures are required immediately. Leakage checks should be performed at night time or during holidays, when the plant is not in operation. To measure the volume of leakage, first, a compressor has to be turned on and continue operating until it reaches the predetermined pressure (e.g., 7 bar). Then, it should be stopped and the time taken to reduce the pressure by 1 bar (perhaps from 7 bar to 6 bar) should

$$Q = \frac{(P1 - P2) \times V}{Po(1.0) \times T}$$

Original pressure･･･P1bar (gauge pressure ＋ 1bar)
Pressure after leaking･･･P2bar (gauge pressure ＋ 1bar)
Time taken to reduce pressure from P1 to P2･･･T(min)
Atmospheric pressure･･･Po bar
Piping capacity･･･V M3 (piping capacity in the factory
＋ tack capacity; M3）
Amount of leakage･･･Q M3/min

be identified. The amount of leakage from an entire compressing facility (or factory) is obtained using the following formula:

Once an air leak occurs, it tends to occur again in the same place, even if remedial measures have been taken. Leakage cannot be completely stopped with one-time measures; it is important to continuously monitor and take appropriate action.

There are a number of methods for investigating leaks, including checking for sounds or holding a hand over suspected leakage locations, but the surrounding conditions may make it difficult to determine leakage using these methods. As a quantitative means of diagnosis, therefore, we recommend investigation using a leak detector.

The leak detector provides a means of checking leakage by detecting the minute sounds of compressed air escaping. The laser pointer attached to it measures the amounts and locations of air leakage. The capabilities of the leak detector are described below, and can be put to practical use for various types of leakage.

Ultrasonic waves are generally produced whenever vapor or fluid is released into the atmosphere at some speed, or whenever bearings operate on a scratched surface, or without lubricating oil. Plant Walker Leak Detector Ⅱ can be used to detect ultrasonic wave near 40 kHz where is emitted notably by leakage of gas, and can be used for detection of air leakage from piping and gas leakage from various equipment, and diagnosis of bearing, etc. It can also be used in various fields as energy-saving measures, environmental preservation measures, and a safety-measures tool.

If the above investigation results in successful calculation of the amount of leakage, then the next step is to identify the leakage locations. Having identified the locations, remedial measures should be taken starting from the areas where they are likely to be most effective. Figure 2-9 shows locations where leaks are likely to occur. Compressed air leaks from locations such as piping couplings and regulators are reportedly common.

Figure 2-9 Example of places where air leakage is likely to occur

➢ Eliminate buried piping (bring piping aboveground)

Piping is sometimes buried to avoid it being exposed aboveground, but if the piping is used for a long time, corrosion always occurs, risking major leakage of compressed air.

Moreover, such leaks are difficult to detect, and therefore difficult to repair.

There are reports of cases in which 50% of the compressed air generated has leaked when buried piping is used. Buried piping should be eliminated wherever possible, with such piping brought aboveground. If it must be buried, insertion into a pit is recommended.

➢ Stop compressed air escaping from the intercooler/after cooler; use a drain trap

Condensate drained from intercoolers/after coolers is externally discharged through orifices. Along with the condensate, one orifice also releases approximately 200 liters of compressed air per minute, although the amount varies depending on the diameter and pressure of the orifice in question. Three orifices are used for centrifugal compressors, resulting in approximately 600 liters (21 CFM) per minute of compressed air escaping per machine. This results in 280,000m3 (9, 8000,000 CFM) of compressed air lost annually. We therefore recommend switching to a high-efficiency drain trap to reduce the amount of air released.

Unnecessary costs and damage during the generation of compressed air can only be avoided in an efficient way with amount-adjusted condensate drainage.

Therefore, BEKOMAT condensate drains operate with a capacitive sensor. The intelligent electronics prevent compressed air losses and minimize the energy demand. As a result, the BEKOMAT often pays itself off within half a year already, in contrast to devices with timed drain valves.

➢ Use blow guns effectively and improve their efficiency

Analysis of the purposes for which compressed air is used reveals that most compressed air is used for either (a) air blowing, or (b) actuators.

Of these two purposes, air blowing accounts for 70% of all compressed air generated, so efficient use of such air is called for.

① Air blowing

In a factory, most compressed air is used for air blowing. The continuous sound of compressed air use in a factory is often due to air blowing work, and sustained use results in a considerable amount of compressed air consumption.

One method of air blowing is use of a blow gun (air gun); the amount of compressed air consumed varies depending on the device used.

As for blow gun, a nozzle-type gun is energy saving.

【Checking point 】

Diameter of air blow outlet... (Consumption is "large", if the size is large)

Pressure of outlet (supply pressure) ... (consumption is "large", if the pressure is high)

② Time and frequency

Many air guns emit air from a tube of uniform internal diameter, but this is inefficient. The issue is how to maintain the pressure just before emission from the end of the tube, and tubes of uniform diameter cause a drop in pressure, leading to lower efficiency. To reduce the amount of compressed air consumed, a nozzle can be attached to the end of the tube to increase the pressure just before emission. By ensuring that the same amount of work is performed, even if the colliding pressure decreases, it is possible to reduce consumption of compressed air by 30%. The ideal ratio of tube size to nozzle size in terms of cross-sectional area is 3:1.

③ Actuators

The drives (air cylinders) of actuators do not use a large amount of compressed air, but they need to produce power, so a guaranteed minimum pressure is required. If an air-saving valve is attached to the air cylinder exhaust, the supply of compressed air can be cut by 30% while working at the same level of power.

The amount of compressed air consumed can also be reduced by checking the pressure gauge on the regulator to confirm whether the pressure can be lowered further, or by doing this in addition to using an air-saving valve.

➢Use energy-saving couplings

Almost all the couplings in common use today cause narrowing in the internal diameter of the piping they connect, and this narrowing and widening of internal diameter through the couplings causes loss of pressure. Energy-saving couplings provide a means of connecting pipes on the exterior so there is no change in internal diameter, resulting in minimal loss of pressure.

(2)-3 Adjust the environment

➢ FRESH, COLD, DRY

When operating a compressor, the conditions should be fresh, cold, and dry; these are the three elements that provide the most unfavorable environment. Plant and equipment such as compressors are easily affected by their surroundings, which has implications for energy conservation, making it necessary to adjust the environment.

Fresh: If the air at the installation site is not good, then the compressor cannot perform efficiently, for example:

- Harmful gases in surrounding area (corrosion, degradation, damage)
- Dust, foreign substances (early damage, impaired performance)
- Sealed room (reduced air volume, high temperature)
- Near the sea (salt damage, corrosion)

The above conditions cause clogging in the suction filter and the line filter, leading to impaired performance. If a compressor is installed in an unfavorable environment, it is perfectly natural for the loss in terms of performance to amount to 5–10%.

Cold: In a displacement (screw or reciprocating) compressor, if the intake temperature changes, the air volume in terms of intake hardly changes, but the density of the air generated in the compressor does change. As a result, therefore, temperature does cause the intake air volume to change.

One of the special characteristics of air is the fact that the lower the intake temperature, the less intake air is required to provide the same amount of discharge air. In other words, the lower density of hot air means that the volume discharged falls short when the intake air is hot (for each 1 °C increase in intake air temperature, efficiency drops by 0.3%).

Dry: Part of the moisture in the atmospheric intake air is condensed into condensate and then it is discharged. The higher the humidity, therefore, the lower the volume of compressed air released from the compressor outlet. Some compressors that maintain their pressure when the weather is fine can suffer deterioration in pressure when it rains (the air volume is reduced by 3–5% in rainy weather, as compared to fine weather).

➢ Installation of drain water processor

Drain water discharged from a compressor is discharged without any specific treatment at present.

However, given the environmental protection, it is not allowed to discharge the drain water directly. Generally, drain water from compressor contains 100 – 300PPM oil. Under the Water Pollution Control Law, there is the regulation that the PPM should be lowered to 5 PPM when discharging the water into a river. Since ISO140001 is based on this, drain water treatment is recommended.

➢ Clean the pre-suction-filter regularly

We have already described how a compressor’s performance can be adversely affected by its environment, and a reduction in the compressor’s intake pressure can also reduce its efficiency. However, in an environment where a compressor’s suction-filter is likely to become clogged, for instance, a pre-filter can be installed. The problem of clogging would be resolved if the suction-filter were cleaned regularly, but the compressor must be stopped every time maintenance is performed. Installing a pre-filter in front of the suction-filter allows maintenance to be performed without stopping the compressor. If this pre-filter is cleaned regularly, the compressor’s efficiency can be maintained over the long term.

Moreover, the air intake pressure can also decrease and impair efficiency if the compressor room is a sealed space. It is therefore necessary to address this by means such as monitoring the intake pressure within the compressor room.

(2)-4 Important points when constructing piping

We recommend upgrading piping to enhance air quality. When constructing piping it is important to bear in mind that large losses result from narrow piping, or piping with numerous bends or cut-offs such as valves, and these will require remedial measures. Piping can also be the cause of a range of problems, such as backflow of condensate that causes the compressor to break down. To avoid this, it is advisable to connect piping to the compressor from above.

1. Be sure to provide a drain release 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 release valve at the end of each pipe.

(2)-5 Ventilation methods

The air emitted from compressors and air dryers is accompanied by compression heat, which raises the temperature inside the compressor room. If this exhaust heat is raising the room temperature in an enclosed environment, it leads to impaired performance in the equipment. We therefore recommend constructing ducts and installing exhaust fans. If ducts are poorly constructed, however, they can cause problems such as abnormal stoppage in the compressor.

If the temperature inside the compressor room increases by 10 °C, it causes a 3% reduction in compressor efficiency. For this reason, ventilation inside the compressor room is an important point.

The amount of ventilating air required can be calculated using the following formula:

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

Q: **Required ventilation amount** (m^3/min)
H: **Amount of heat produced per unit** (MJ/h)
(1 kW = 3.6 MJ/h)
n: **Number of units installed**
T: **Allowable temperature increase**

(When outside temperature is 35 ℃, compressor's allowable maximum temperature is 45 ℃, $\Delta T = 45 - 35 = 10$ ℃)

(2)-6 Simple inspection of the receiver tank

Receiver tanks are generally placed outdoors, and if external corrosion is apparent, it can be assumed that internal corrosion has also occurred. This can lead to leakage of a large volume of compressed air. Consequently, regular observation becomes necessary.

Under Japanese regulations, pressure tanks with a capacity of 40 litres or more are designated as Class-2 pressure vessels. Voluntary inspections of such pressure tanks are required annually, and records of the inspections must be retained for three years.

Public regulations for receiver tanks require regular measurement of the tank's thickness, as well as inspection of each area detailed below.

- If there is any loose of bolts or/and nuts?
- If pressure gauge is functioning?
- If there is any leakage?
- If there is any corrosions ?
- If safety valve functions correctly?
- If base bolts are tight?
- If there is any modifications?

(2)-7 Energy monitoring

➢ Use a monitoring system

Reducing the amount of energy used in a factory first of all requires current usage to be ascertained. It is also necessary to monitor energy usage constantly in order to make continuous improvements.

Factory Energy Management System (FEMS) can:

- Support cost savings as a result of reduction in energy consumption

· Standardize the level of energy management for each production line or factory and combine energy management information

· FEMS is an overall energy management system for use in factories, designed with attention to potential scalability enabling future additions or upgrades to equipment or linkage with other systems.

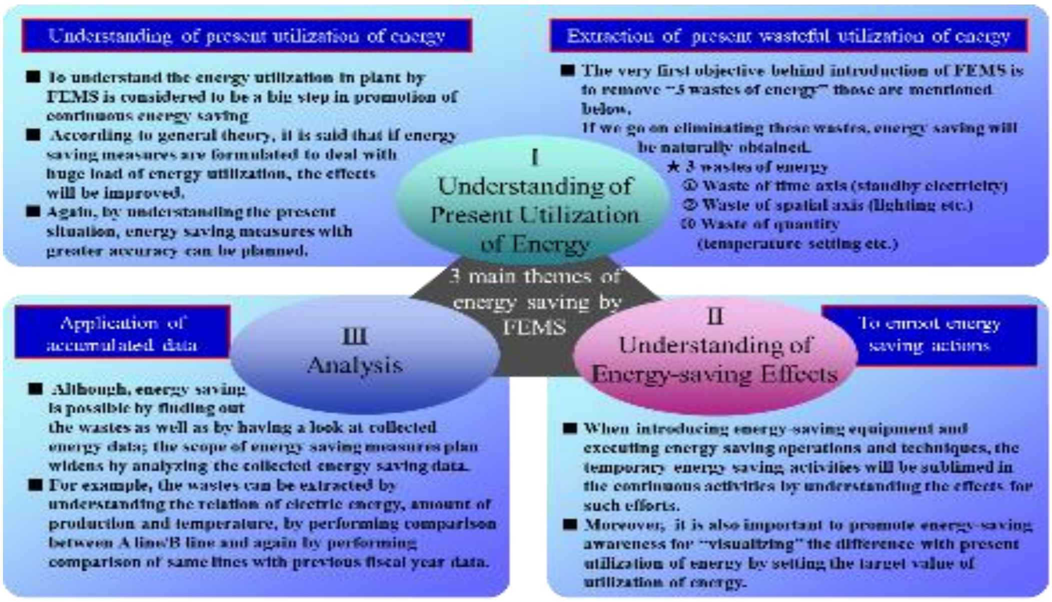


Figure 2-10 Overview of FEMS

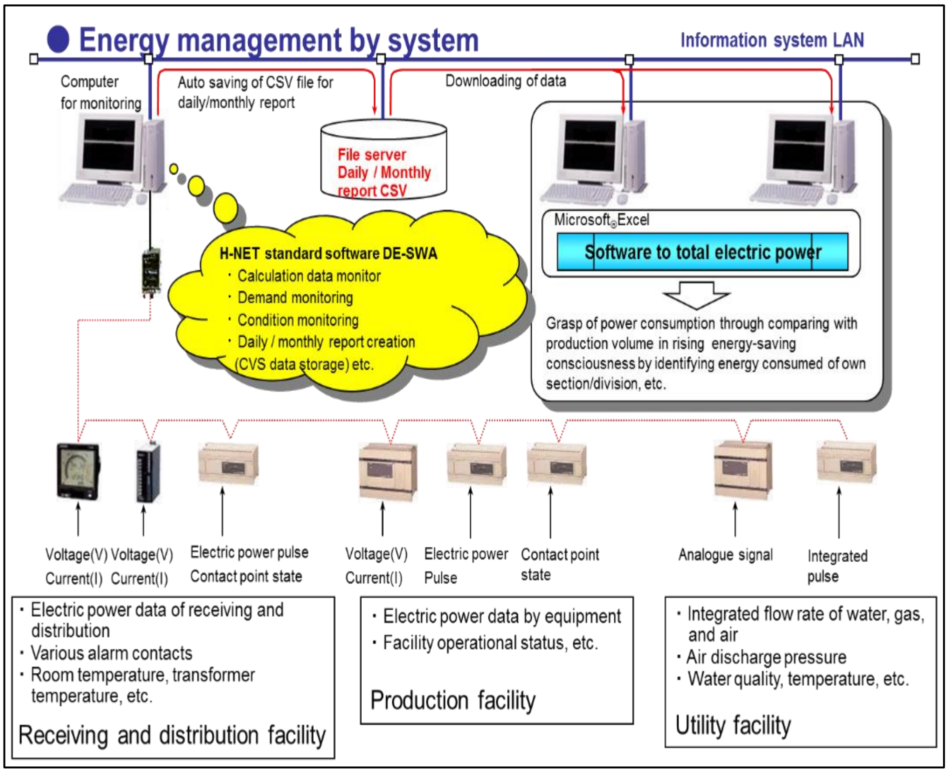


Figure 2-11 Example of electric power monitoring system

(2)-8 Utilize measurement and diagnosis

Our activities to date have primarily comprised feasibility studies, so we have not gone so far as to ascertain the amount of electricity consumed by each machine. However, if we conduct a full investigation, we will need to ascertain the situation regarding each individual compressor, so we took with us a measurement and diagnosis device and performed measurement for short periods. As a result we were able to obtain tangible figures to demonstrate the energy-saving benefits surmised during our walk-through investigation. On this occasion, our activities involved only short investigations, but introduction of FEMS as an energy management system will be essential if data are to be collected continuously over the long term. The advantage of introducing FEMS is that energy usage throughout a factory can be ascertained, and the information used to make improvements in terms of reduced energy consumption and CO2 emissions. Moreover, making such data visible can lead employees to become more aware of energy conservation issues.

(2)-9 Convert cooling water pumps to inverter-driven operation

In our investigations to date, we also paid attention to cooling water circulation pumps in water-cooled compressors. Although they are auxiliary to compressors, we occasionally found situations in which pumps were constantly working at a fixed speed, regardless of the number of compressors in operation. In the same way that converting compressors themselves to inverter-driven operation can yield significant energy saving benefits, such benefits can also be expected from using an inverter to control cooling water circulation pumps in response to the number of compressors in operation. The input power (electricity consumption) of a motor and pump is proportional to the rotational speed cubed. So, for example, if the rotational speed were halved, the input power (electricity consumption) of the motor and pump would theoretically be reduced to 12.5% of the original requirement, achieving an 87.5% reduction in energy consumption.

(3) Recommendations to reduce CO2 emissions and improve factory environments at factories investigated

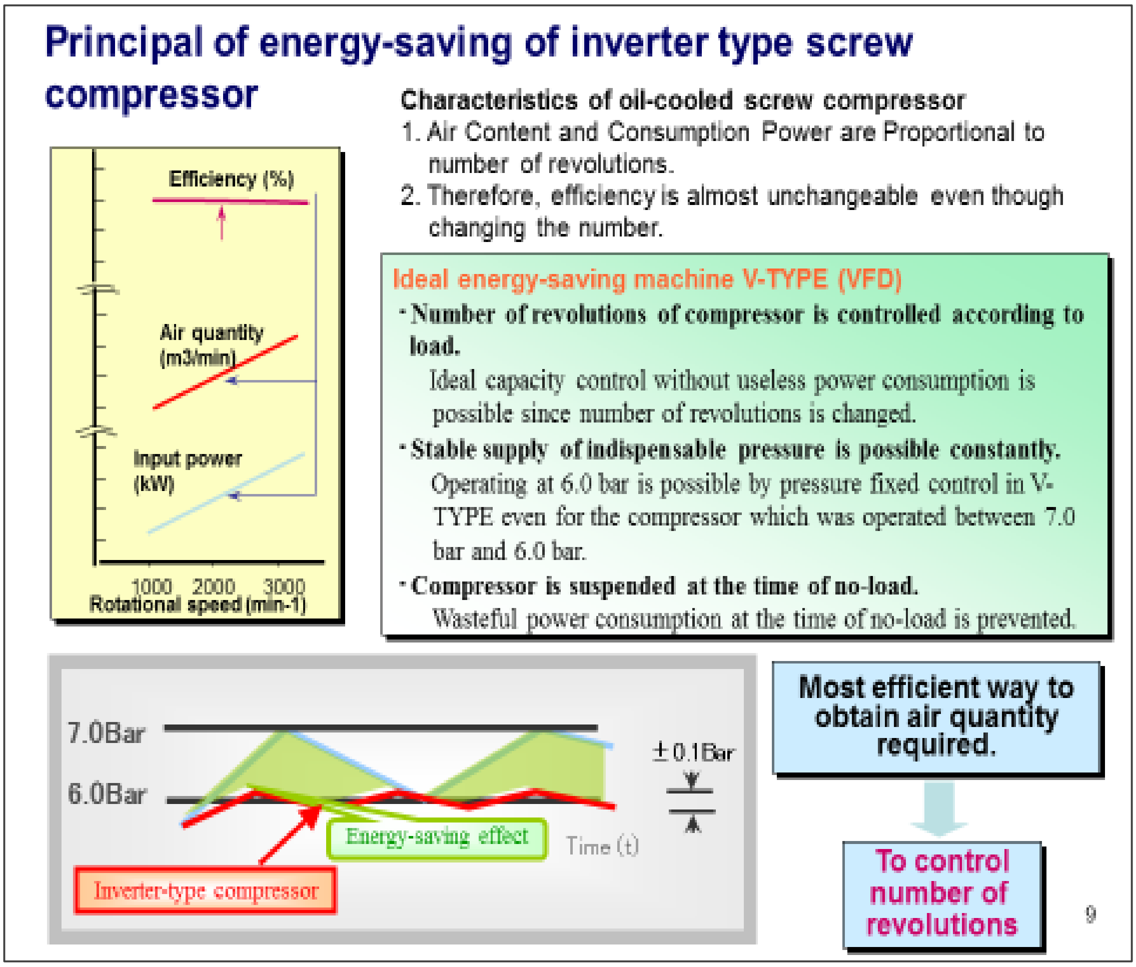
During the mission period allocated, feasibility studies (FS) for six companies were conducted, ascertaining the current situation, identifying issues, and suggesting remedial measures. In the FS reports, we addressed specific themes to recommend strategies for reducing energy consumption, remedial measures for factory environments, and other measures. Worthy of special mention is the fact that, of the six companies visited, three had already introduced inverter compressors. However, the inverters were of no use in reducing energy consumption. This was because of the way they were being used. It shows that however impressive the equipment itself may be, it is pointless if it is not being used appropriately. Technical support is therefore needed with regard to both equipment and the way it is used. Recommendations are given in the following sub-section.

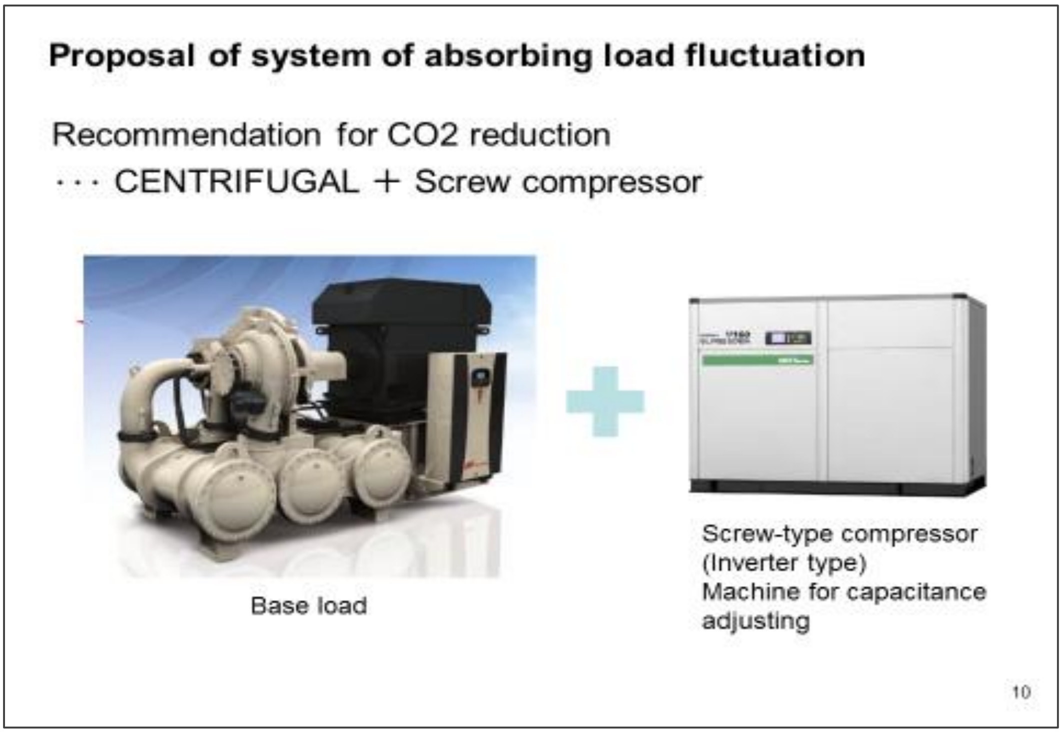
(3)-1 Raymond Denim Pvt. Ltd. (Textile)

Survey date: Oct. 6, 2014
Interviewee: Mr. Nitin K.Shrivastava
Mr. Suketu Shah
Sector/Industry: Textile
Operating hours: 24Hours/day
Total electricity consumption: 220,000kWh/day
Power required for compressor: Approx. 19%of total energy consumption
Electric power unit price (Rs/kwh): 5.5
Existing compressor: I/R C39MX3 x 2 units, ATLAS ZR250FF x 3 units
GA110 x 2 units, ELGI 250kW x 3 units
Supplemental equipment: Air dryer, air tank
Uses: For air jet machine, for spinning, for weaving

[Recommendation: Hard side (related to compressor)]

◈ Installation / Effective utilization of inverter compressor

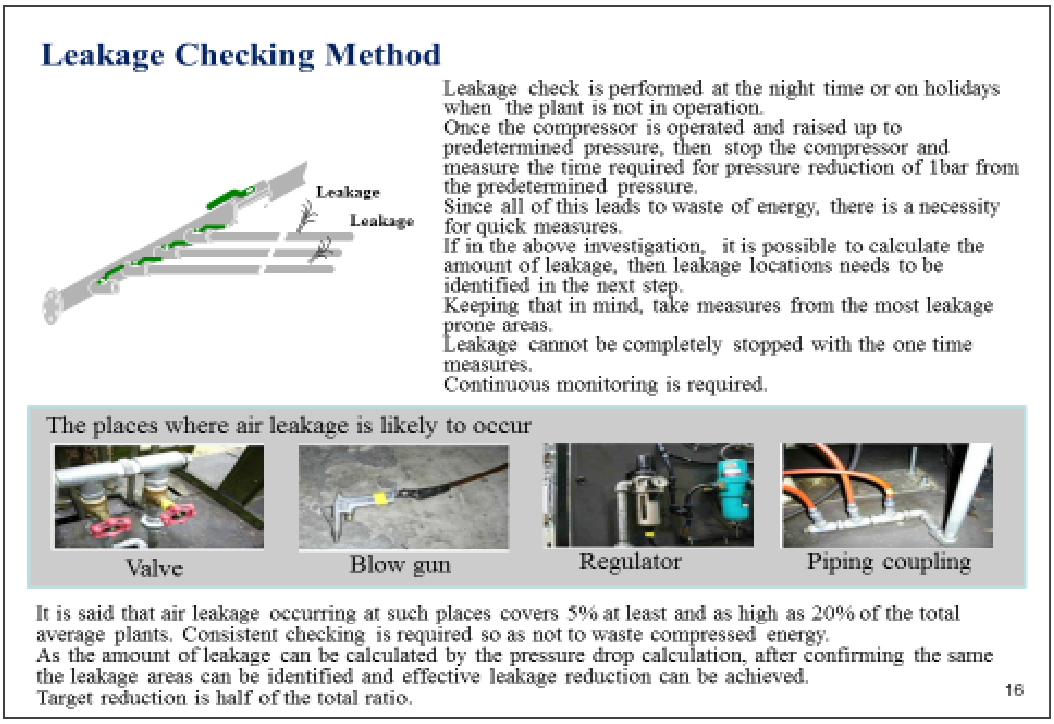




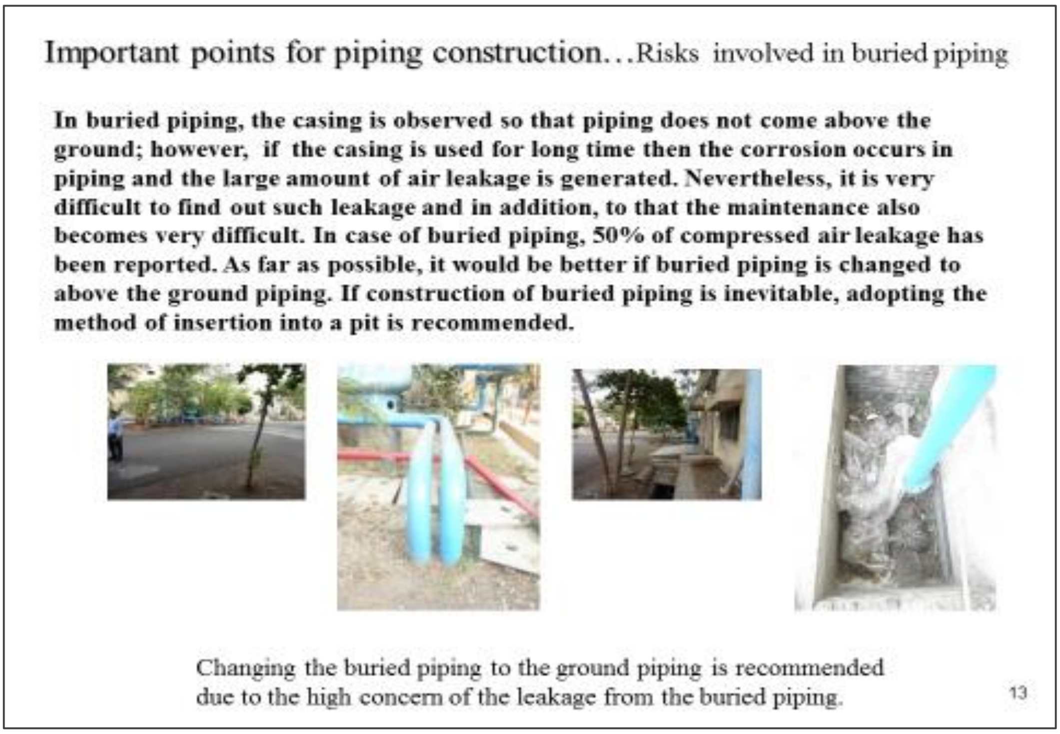
◈ Installation of high-efficiency drain trap

[Recommendation: soft side]

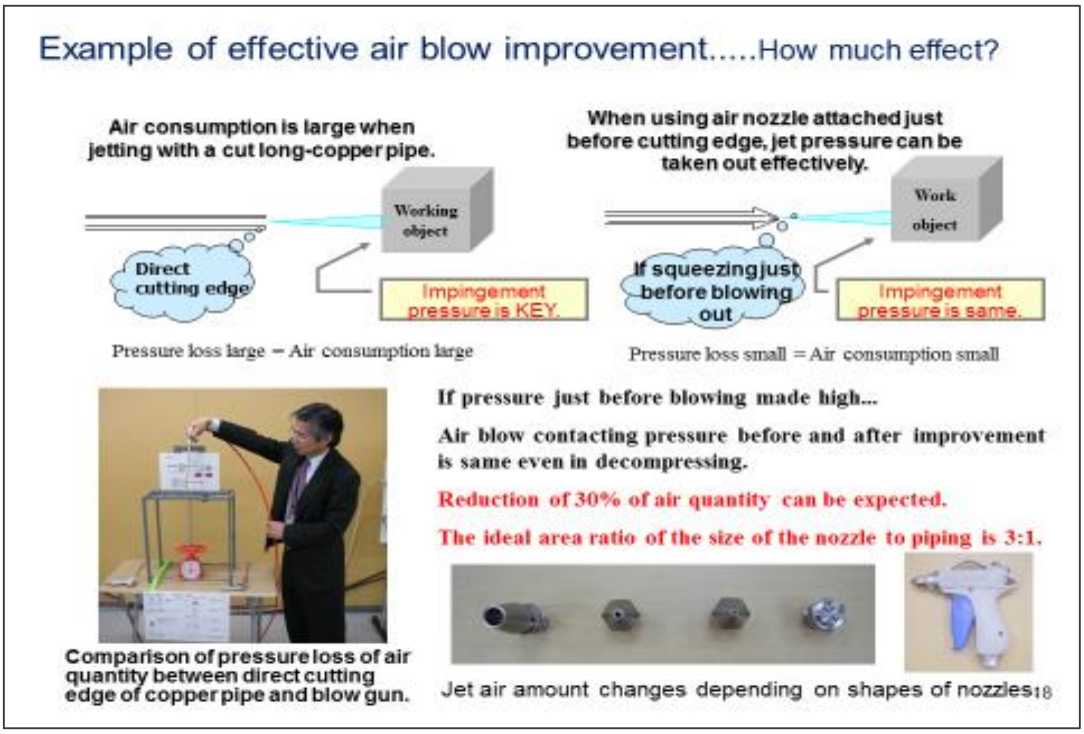
◈ Reduction of leakage ~ present status investigation



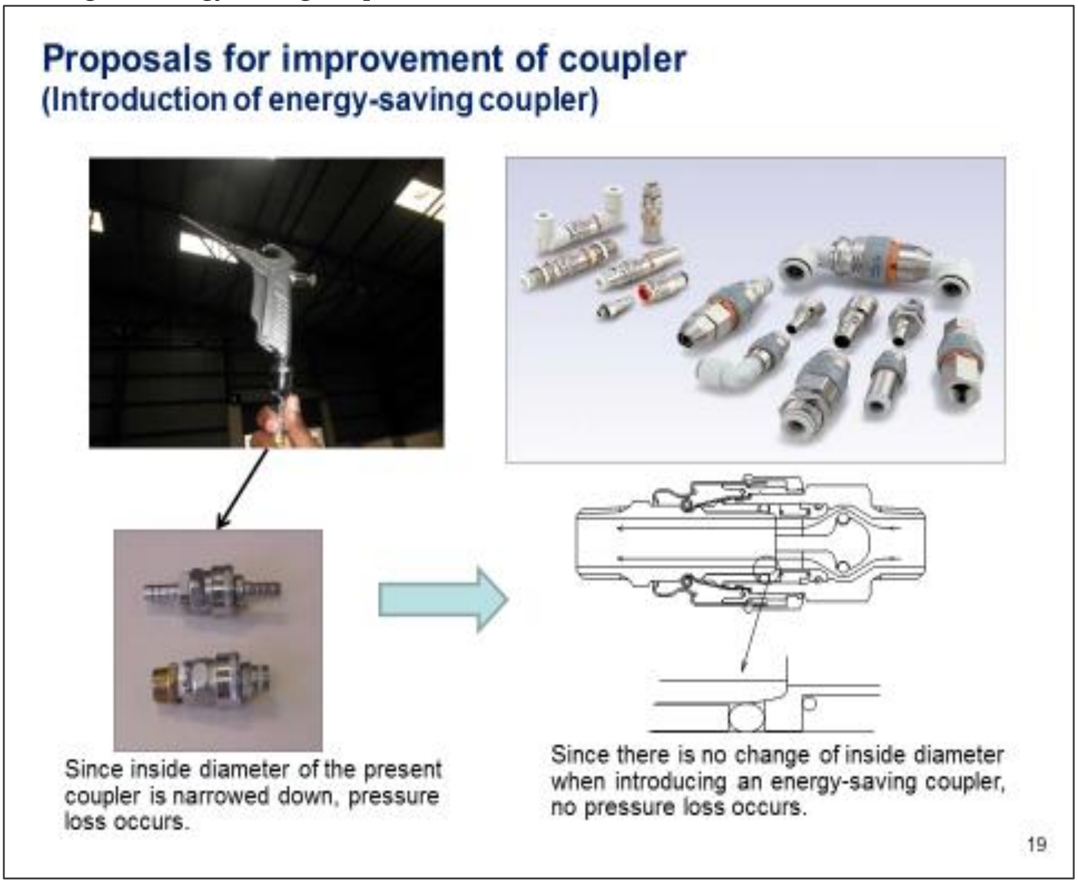
◈ Stop of buried piping



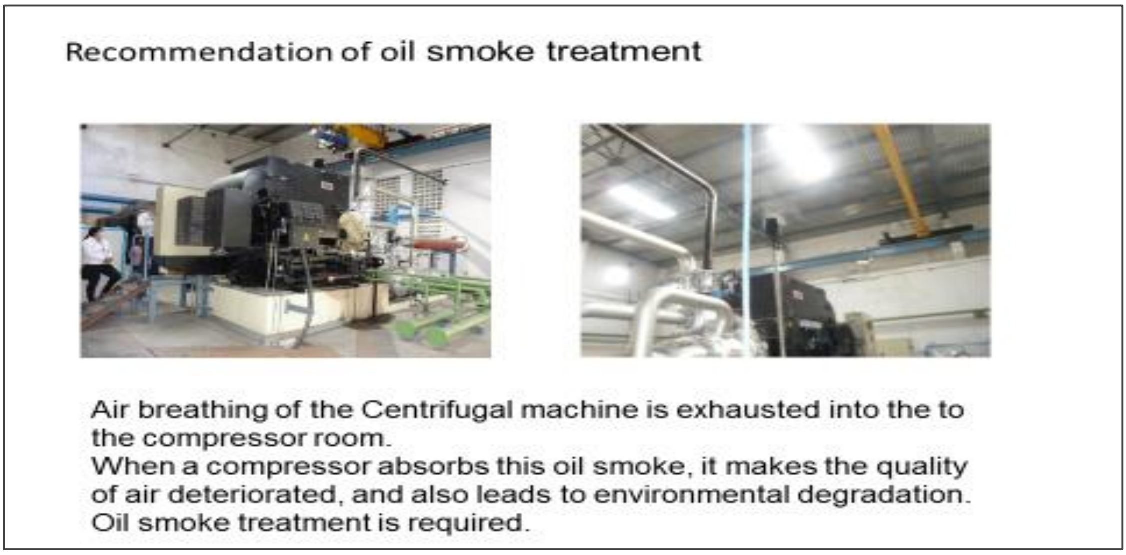
◈ Improvement of blow gun



◈ Usage of energy saving coupler



◈ Regular cleaning of pre-intake filter



◈ Simple checking of receiver tank

[Summary of feasibility study]

Sr. No.	Recommendation	Expected energy savings kWh per year	tCO_2 emission reduction per year
1	Use of inverter type of air compressor	660200	647
2	Install high efficiency drain trap	63200	62

In addition, other recommendations like visual inspection of the receiver tank and adoption of energy monitoring system were also made to the plant to improve the energy efficiency of their compressed air systems.

(3)-2 Morarjee Textile Ltd. (Textile)

Survey date: Oct. 7, 2104
Interviewee: Mr. Shripad Saraname, Mr. Ramesh Pokale
Mr. Mragank Nema
Sector/Industry: Textile
Operating hours: 24Hours/day
Total electricity consumption: 120,000kWh/day
Power required for compressor: 5% of total energy consumption
Electric power unit price (Rs/kwh): 6.0
Existing compressor: I/R reciprocating type x 2 units
ATLAS ZR250FF x 1 unit
Supplemental equipment: Air dryer, Air tank
Uses: For spinning, for weaving, for Delta

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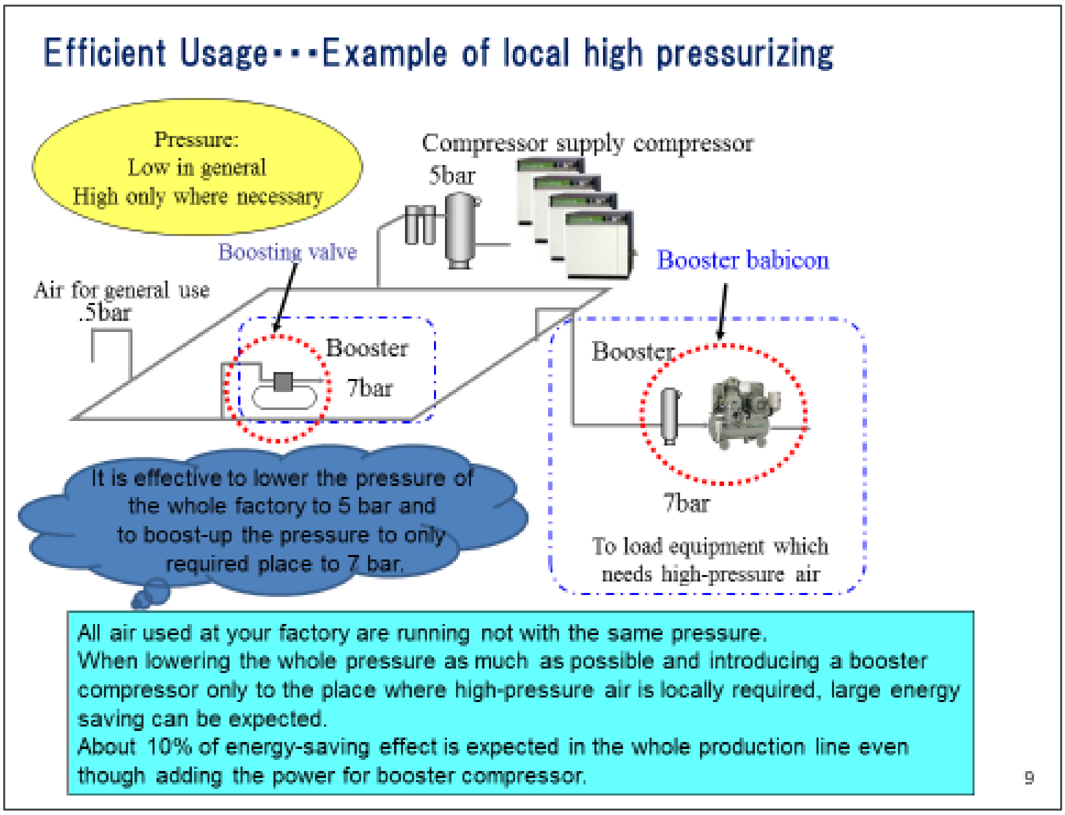
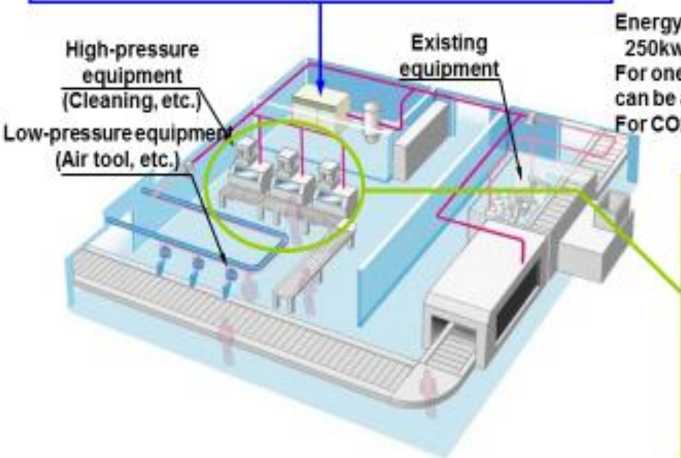
[Recommendation: Hard side (related to compressor)]

◈ Installation of booster compressor



Lowering original pressure and boosting places where necessary

Compressor: pressure setting 6bar ⇒ 5bar



Energy-saving at main supply line is;
250kw x 0.06 = 15kW
For one year; 115,500kWh
can be achieved.
For CO2 conversion; 107TON/year

Local pressurizing by oil-free booster babicon

Booster of 1.5kW

Each high-pressure equipment, individual installation (boosting valve change/safety and noise reduction)

【Energy-saving by local pressurizing】

① Lowering original pressure 6bar ⇒ 5bar to low-pressure equipment.
Power consumption of compressor can be reduced approx. 6.4%.

② Local pressurizing by using oil-free booster babicon for high-pressure equipment.
Compression efficiency can be increased to 9% by intaking the air with 5bar and boosting the pressure to 7 bar.

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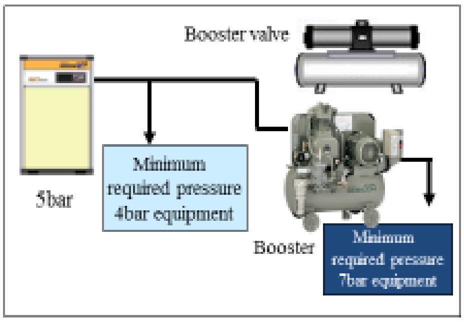
Energy Saving by using Booster Device

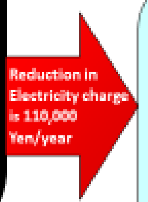
Energy saving by booster BABICON

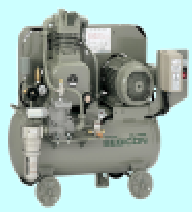
A booster device in which general auxiliary air is required, will not be able to boost the pressure unless it has the raw material air approximately **Double** of discharged air.
For example, if 8bar 500L/min is required at the suction pressure of 5bar, then 1,000L/min of air is necessary for booster device.
Out of that 500L/min is exhausted as auxiliary air for boosting .

If it is converted into electricity charges,
About 200,000 Yen/ year is wasted.

* Calculation condition:
Electricity Charges19Yen/kwh,
3,000 hours/year







Electricity Charges are 100,000 Yen/year

Oil free booster BABICON is equivalent to 1.5 kW.

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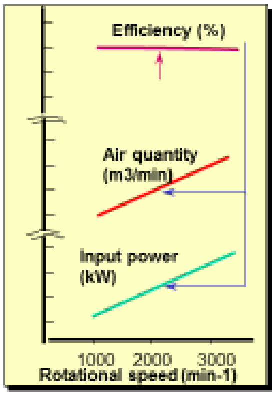
◈ Installation / Effective utilization of inverter compressor

Principal of energy-saving of inverter type screw compressor

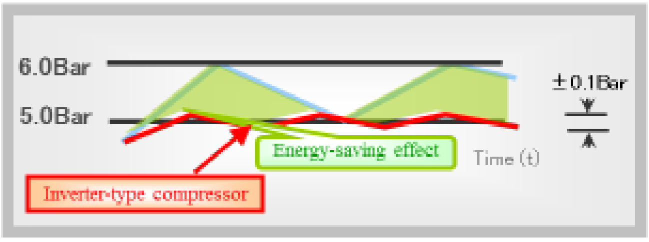


Characteristics of oil-cooled screw compressor

1. Air Content and Consumption Power are Proportional to number of revolutions.
2. Therefore, efficiency is almost unchangeable even though changing the number.

Ideal energy-saving machine V-TYPE (VFD)

- **Number of revolutions of compressor is controlled according to load.**
  Ideal capacity control without useless power consumption is possible since number of revolutions is changed.
- **Stable supply of indispensable pressure is possible constantly.**
  Operating at 5.0 bar is possible by pressure fixed control in V-TYPE even for the compressor which was operated between 6.0 bar and 5.0 bar.
- **Compressor is suspended at the time of no-load.**
  Wasteful power consumption at the time of no-load is prevented.



Most efficient way to obtain air quantity required.

To control number of revolutions

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Proposal of system of absorbing load fluctuation

Recommendation for CO2 reduction

・・・ CENTRIFUGAL ＋ Screw compressor

Base load

Screw-type compressor (Inverter type)
Machine for capacitance adjusting

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[Recommendation: soft side]

◈ Reduction of discharge pressure

Reducing discharge pressure for energy saving!

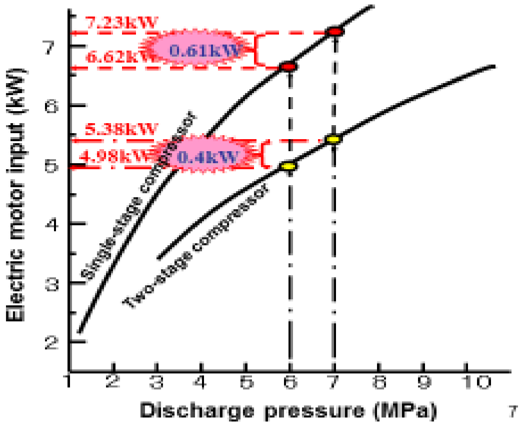
Expected impact of reducing a discharge pressure

Is 6bar needed at the end (edge)?
Let's try to reduce 1bar.
Reducing discharge pressure by 1bar results in about 8% energy saving for screw compressor.

Is discharge pressure of the compressor at your company higher than needed?
Reducing pressure is recommended for saving energy.
8% of energy saving is possible by lowering 1bar from current value.in case of single-stage compressor, and 7% of power saving is possible in case of two-stage compressor.

In case of you company's facility, total capacity is about 250kW.
If 6% reduction is possible, energy saving of 250kW x 0.06 = 15kW is expected.
If annual operating hours is 7700 hours, 15kW x 7700h = 115,500kWh (107Ton in CO2 conversion) is expected.
Please start an investigation first whether lowering pressure is possible or not.

Energy saving is attained by reducing discharge pressure.



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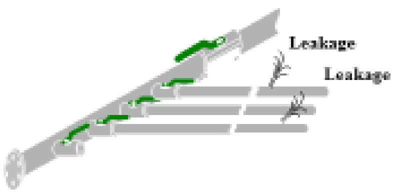
◈ Reduction of leakage ~ present status investigation

Leakage Checking Method

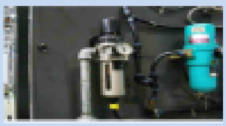


Leakage check is performed at the night time or on holidays when the plant is not in operation.
Once the compressor is operated and raised up to predetermined pressure, then stop the compressor and measure the time required for pressure reduction of 1bar from the predetermined pressure.
Since all of this leads to waste of energy, there is a necessity for quick measures.
If in the above investigation, it is possible to calculate the amount of leakage, then leakage locations needs to be identified in the next step.
Keeping that in mind, take measures from the most leakage prone areas.
Leakage cannot be completely stopped with the one time measures.
Continuous monitoring is required.

The places where air leakage is likely to occur

Valve

Blow gun



Regulator

Piping coupling

It is said that air leakage occurring at such places covers 5% at least and as high as 20% of the total average plants. Consistent checking is required so as not to waste compressed energy.
As the amount of leakage can be calculated by the pressure drop calculation, after confirming the same the leakage areas can be identified and effective leakage reduction can be achieved.
Target reduction is half of the total ratio. Reduction of 89Ton of CO_2 emission can be expected by reducing leakage by half.

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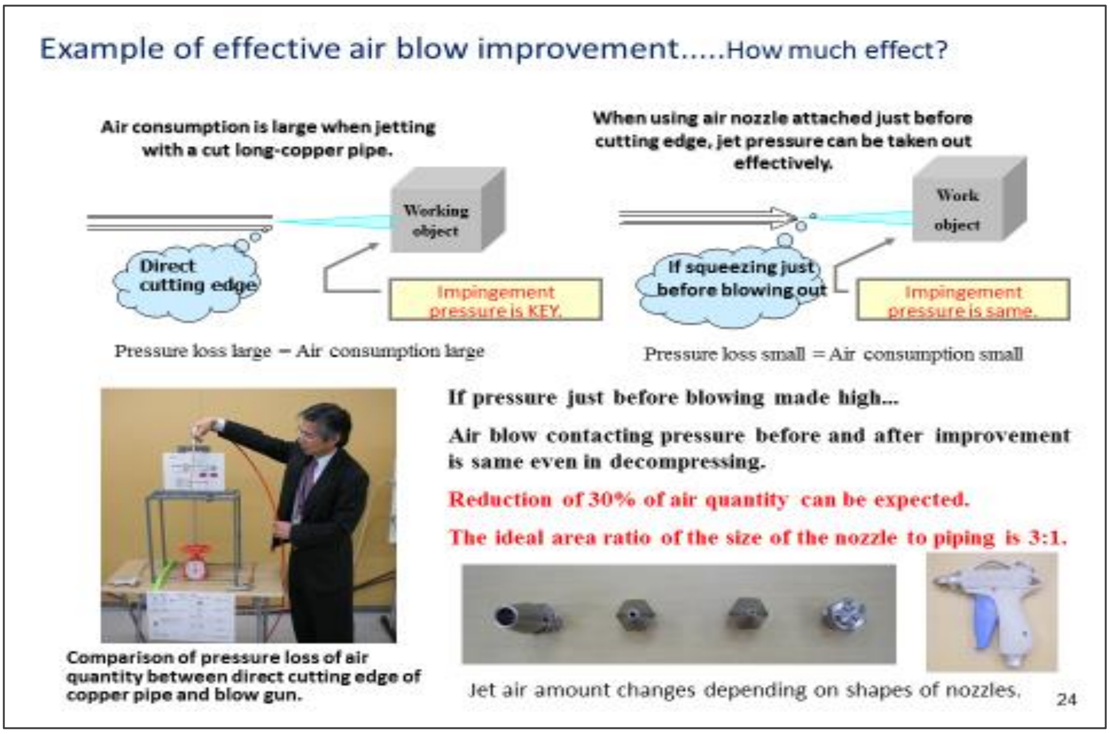
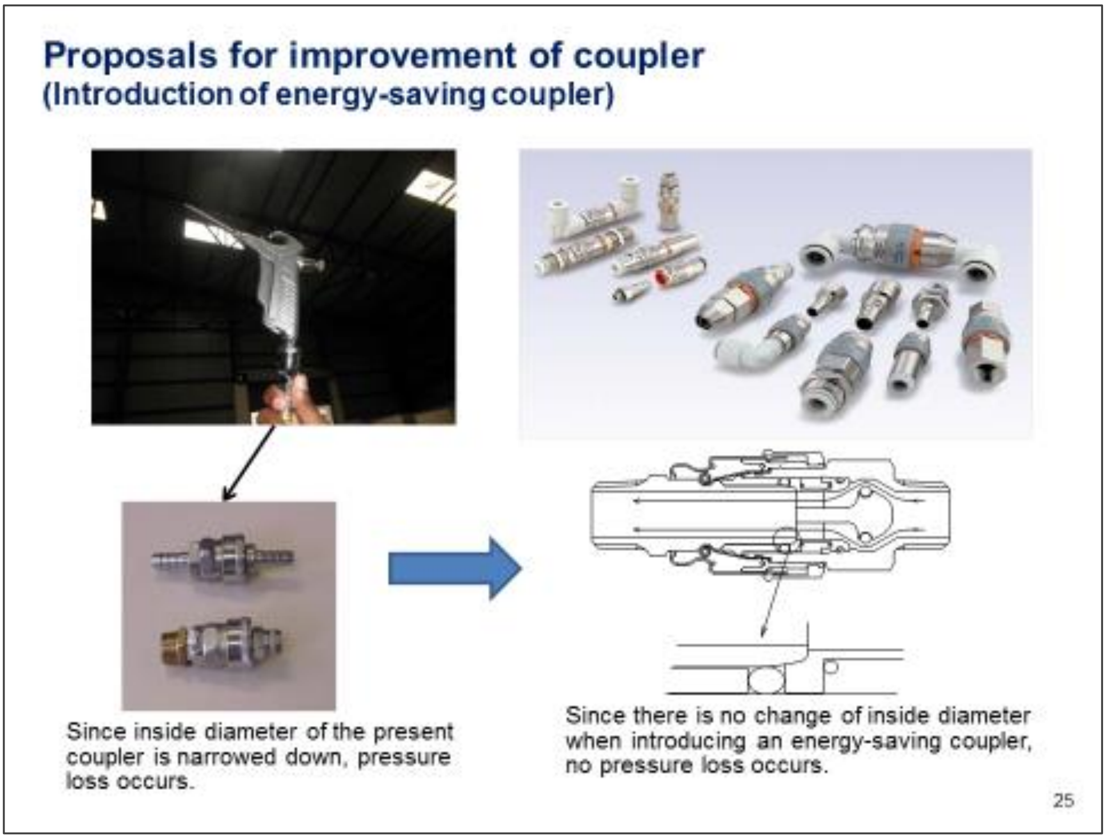
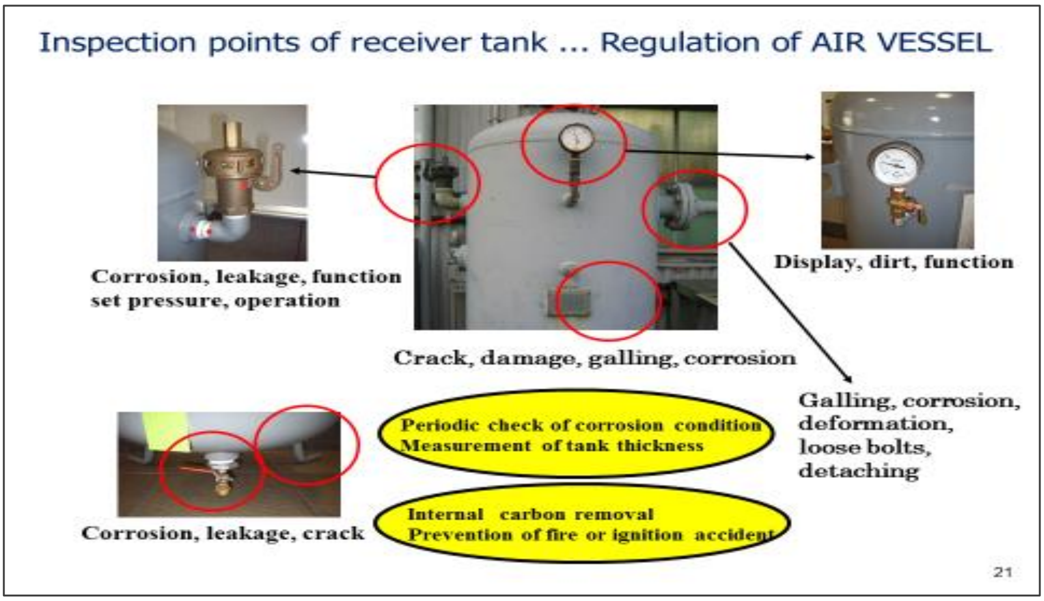
◈ Improvement of blow gun



◈ Usage of energy saving coupler



◈ Simple checking of receiver tank



◈ Others (Change of cooling pump to inverter-type pump)

[Summary of feasibility study]

Sr. No.	Recommendation	Expected energy savings kWh per year	tCO_2 emission reduction per year
1	Install inverter type air compressor	660200	647
2	Use of booster compressor	109000	107

In addition, other recommendations like visual inspection of the receiver tank and adoption of energy monitoring system were also made to the plant to improve the energy efficiency of their compressed air systems.

(3)-3 Arvind Pvt. Ltd. (Textile)

Survey date: Oct. 8, 2014
Interviewee: Mr. Kushal Triredi
Sector/Industry: Textile
Operating hours: 24Hours/day
Total electricity consumption: 220,000kWh/day
Power required for compressor: Approx. 30%of total energy consumption
Electric power unit price (Rs/kwh): 7.35
Existing compressor: I/R C1000 x 3 units, C700 x 2 units
ATLAS ZR630250 x 3 units, ZR250 x 2 units
Supplemental equipment: Air dryer, Air tank
Uses: For sir jet machine, for spinning, for weaving

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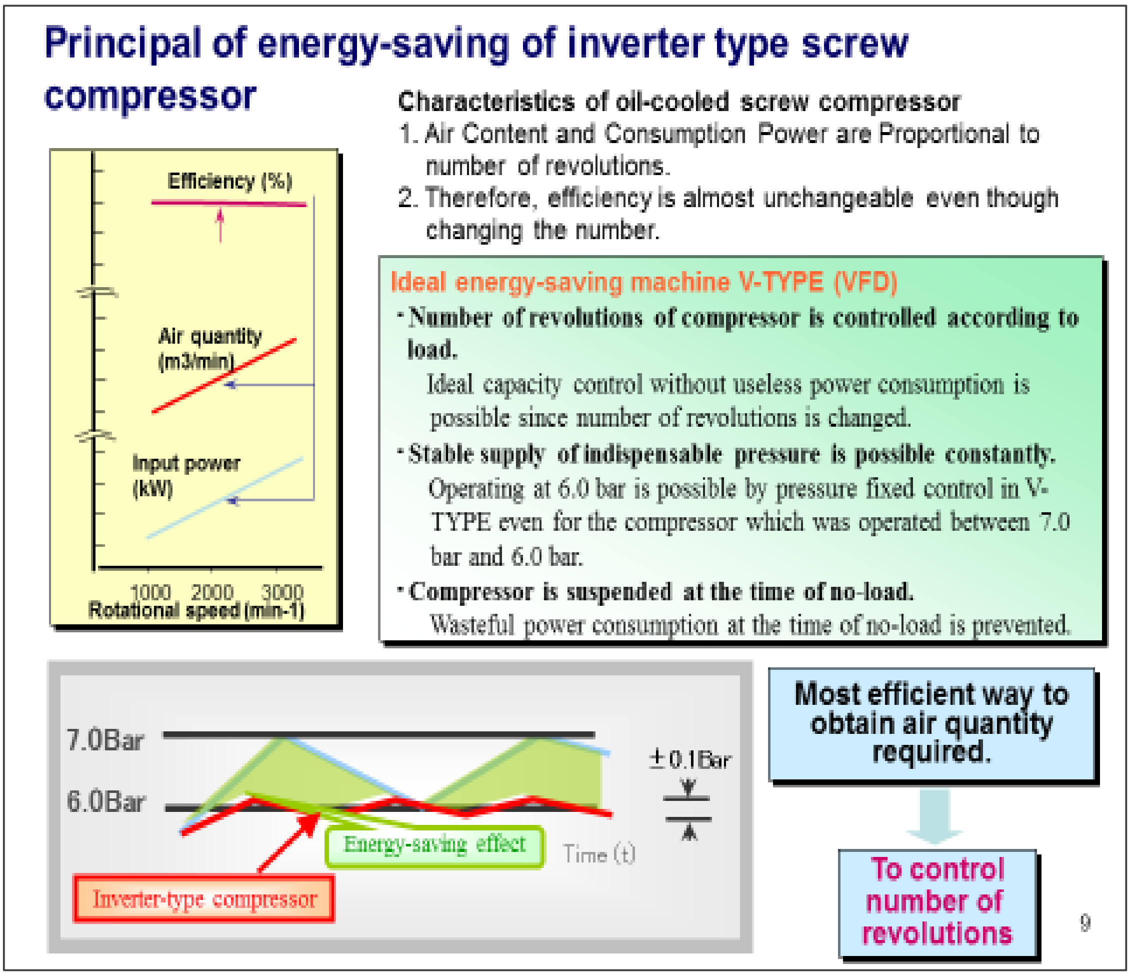
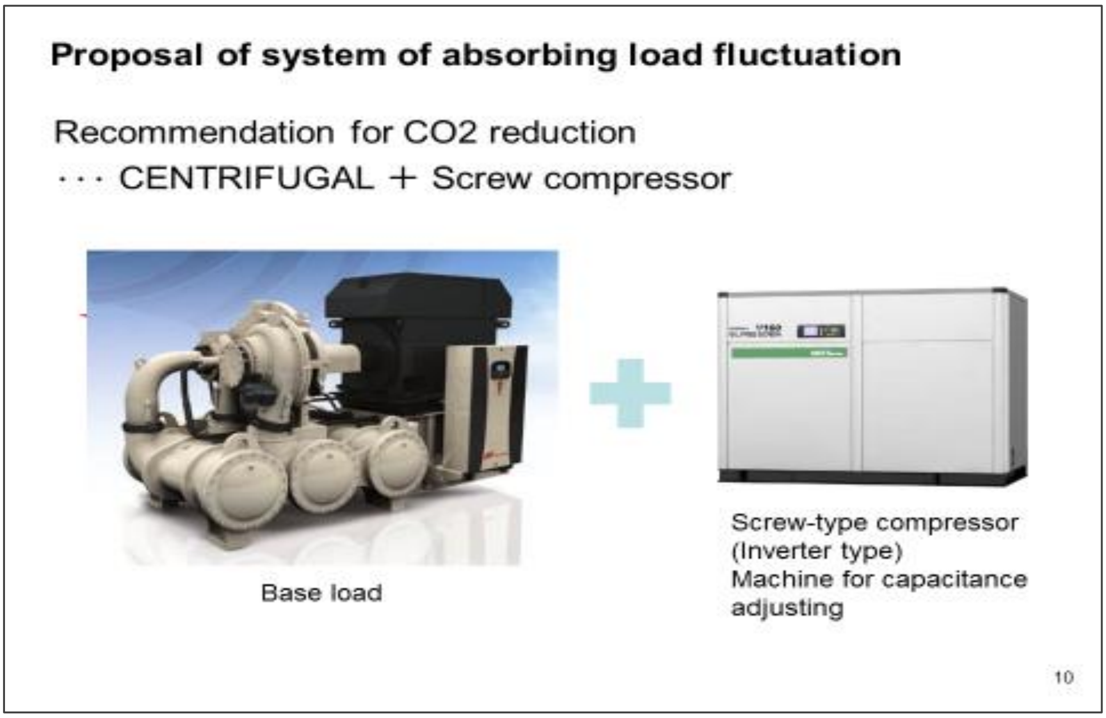
[Recommendation: Hard side (related to compressor)]

◈ Installation / Effective utilization of inverter compressor

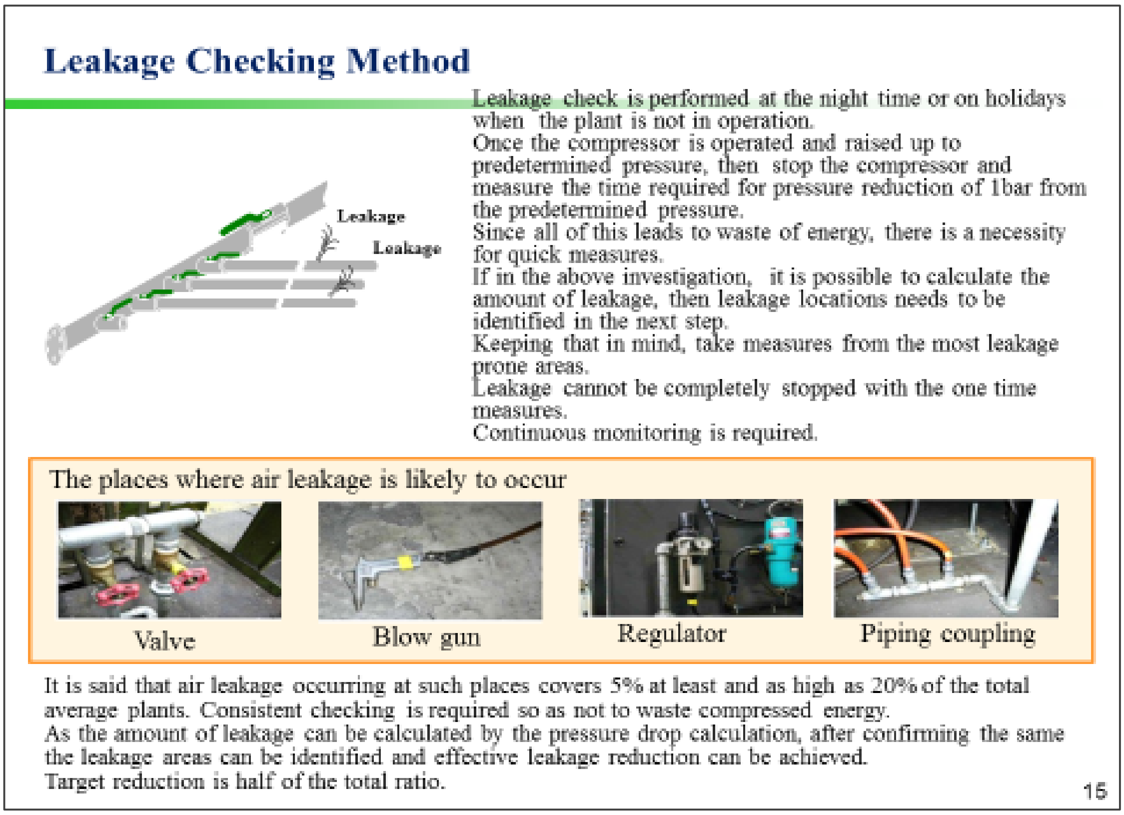




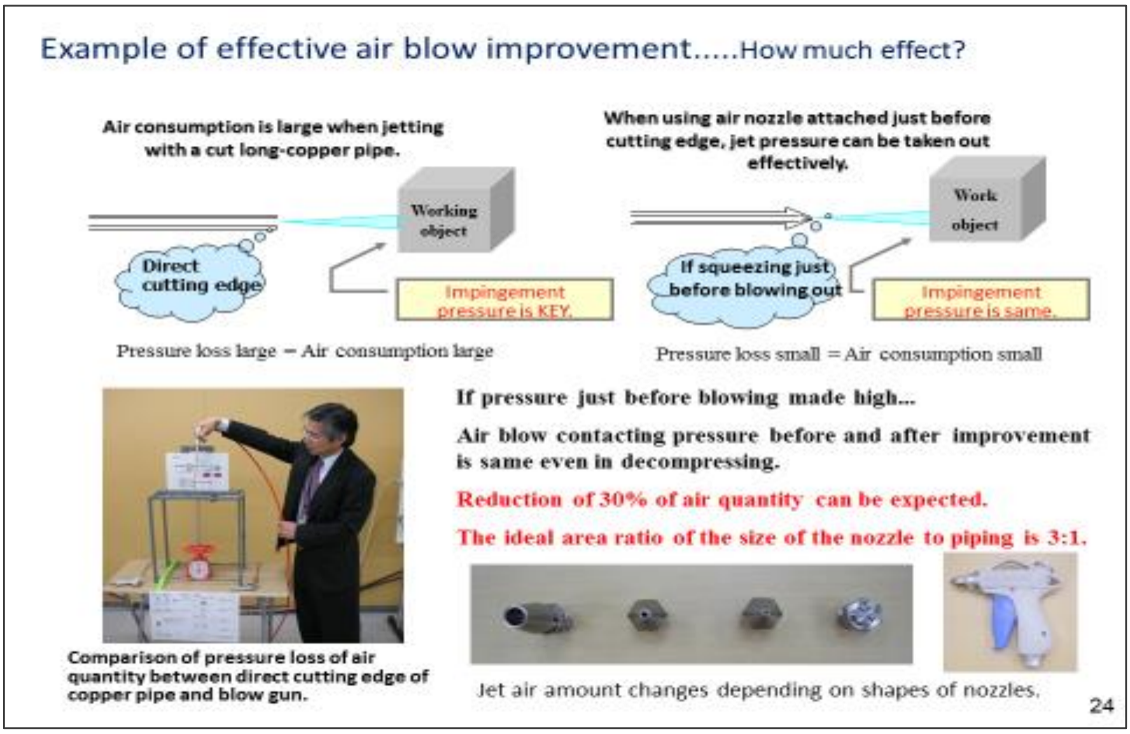
◈ Installation of high-efficiency drain trap

[Recommendation: soft side]

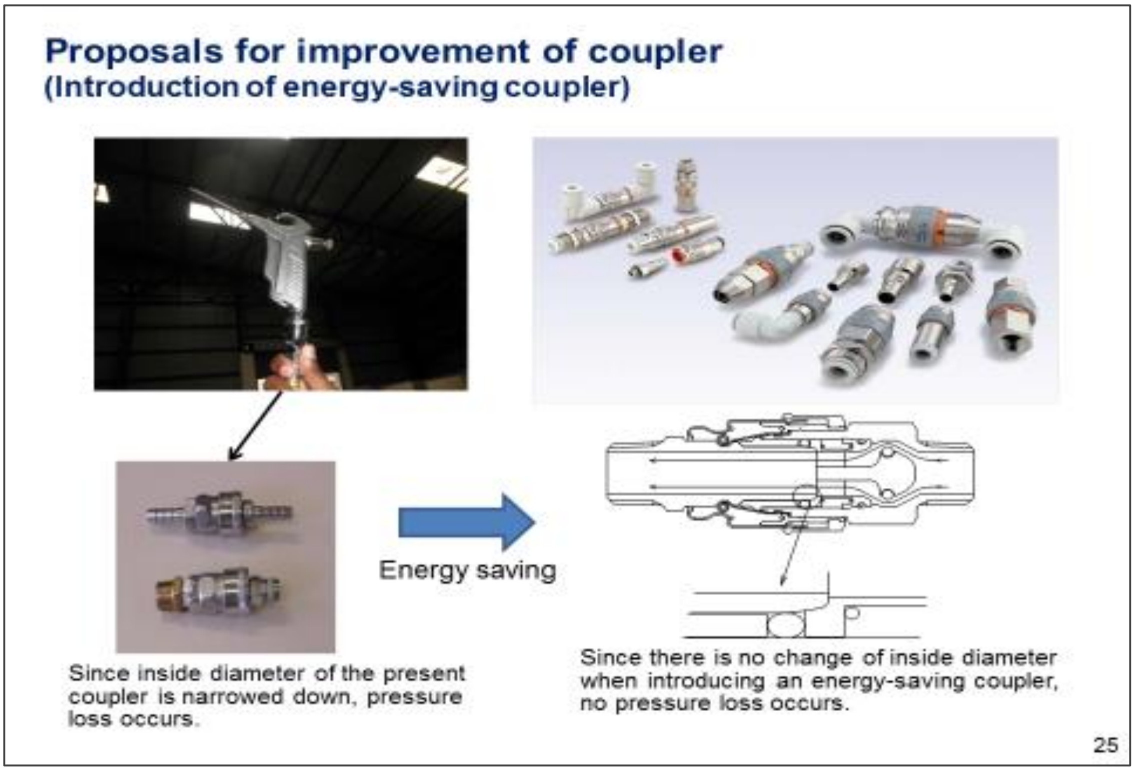
◈ Reduction of leakage ~ present status investigation



◈ Improvement of blow gun

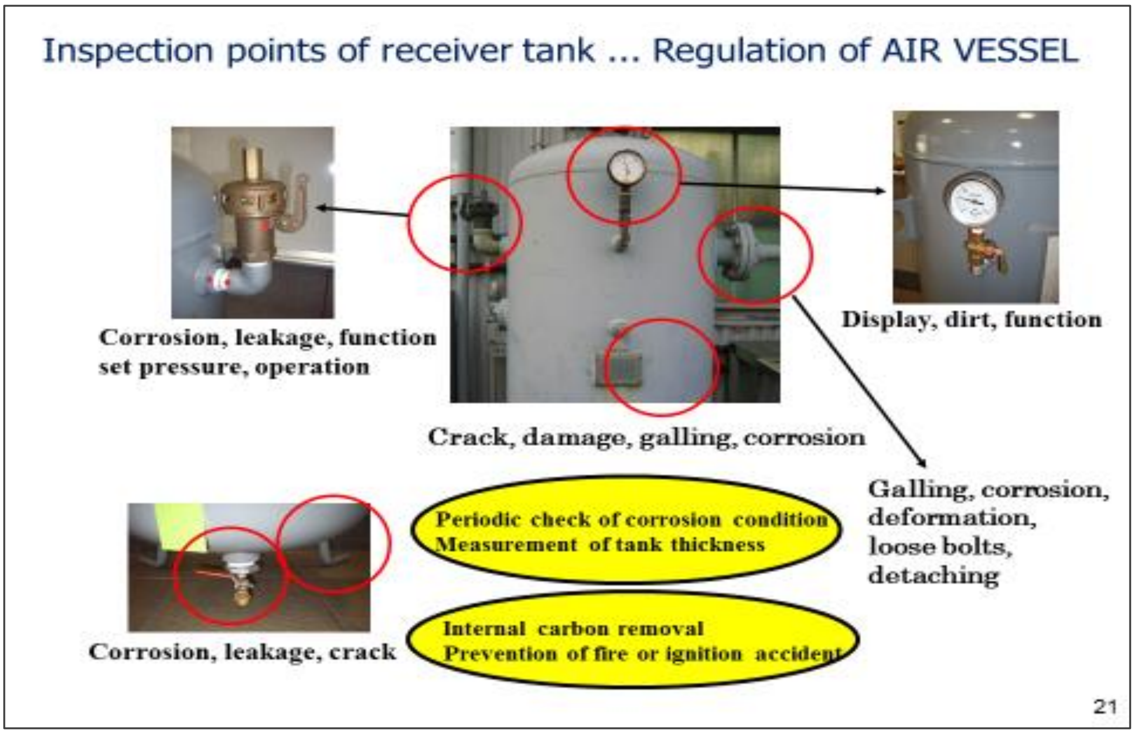


◈ Usage of energy saving coupler

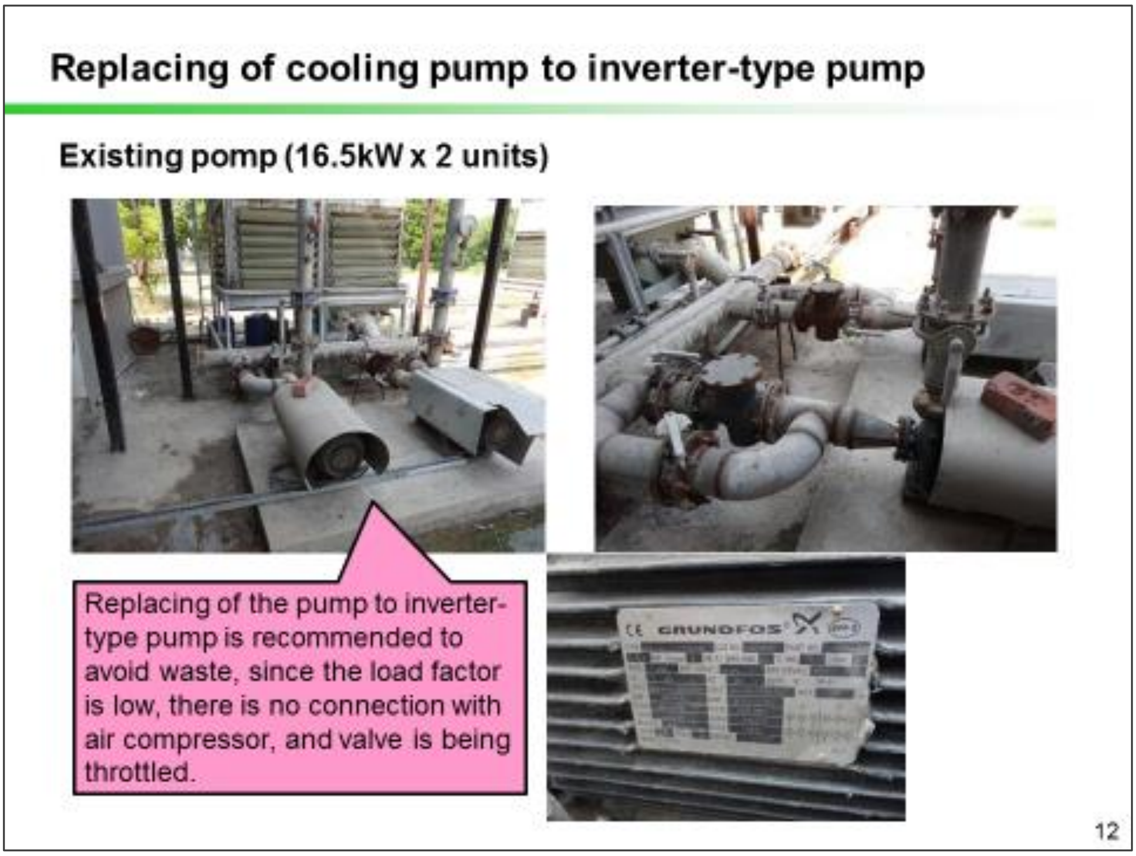


◈ Regular cleaning of pre-intake filter

◈ Simple checking of receiver tank



◈ Others (Change of cooling pump to inverter-type pump)



◈ Others (oil smoke treatment)

[Summary of feasibility study]

Sr. No.	Recommendation	Expected energy savings kWh per year	tCO_2 emission reduction per year
1	Make efficient usage of air compressor - i) use of efficient air compressor (if necessary upgrade to inverter type air compressor), ii) effective utilization with the combination of Centrifugal + Screw air compressor, iii) change of cooling pumps to inverter type pumps	231000	226
2	Install inverter type air compressor	660200	647
3	Get rid of the waste - i) reduction in leakage - 5% starting with the present status investigation, ii) stopping inter-cooler and after cooler blows, and use of drain trap, iii) improvement of blow guns, iv) use of energy savings couplers	261360	256
	Installation of 15 traps for 5 units	158000	155
4	Adjust the environment - i) fresh, cold & dry air intake, ii) regular cleaning of pre-intake filter	182160	179

In addition, other recommendations like visual inspection of receiver tank and adoption of energy monitoring system were also made to the plant to improve the energy efficiency of their compressed air systems.

(3)-4 Bombay Dyeing Ltd. (Textile)

Survey date: Oct. 9, 2014
Interviewee: Mr. Ramesh Shinde
Sector/Industry: Textile
Operating hours: 24Hours/day,
Total electricity consumption: 220,000kWh/day
Power required for compressor: 19% of total power consumption
Electric power unit price (Rs/kwh): 5.5
Existing compressor: KAESER BSD62 x 3 units, KAESER BSD62 x 3 units
Supplemental equipment: Air dryer, air tank
Uses: For spinning, for weaving

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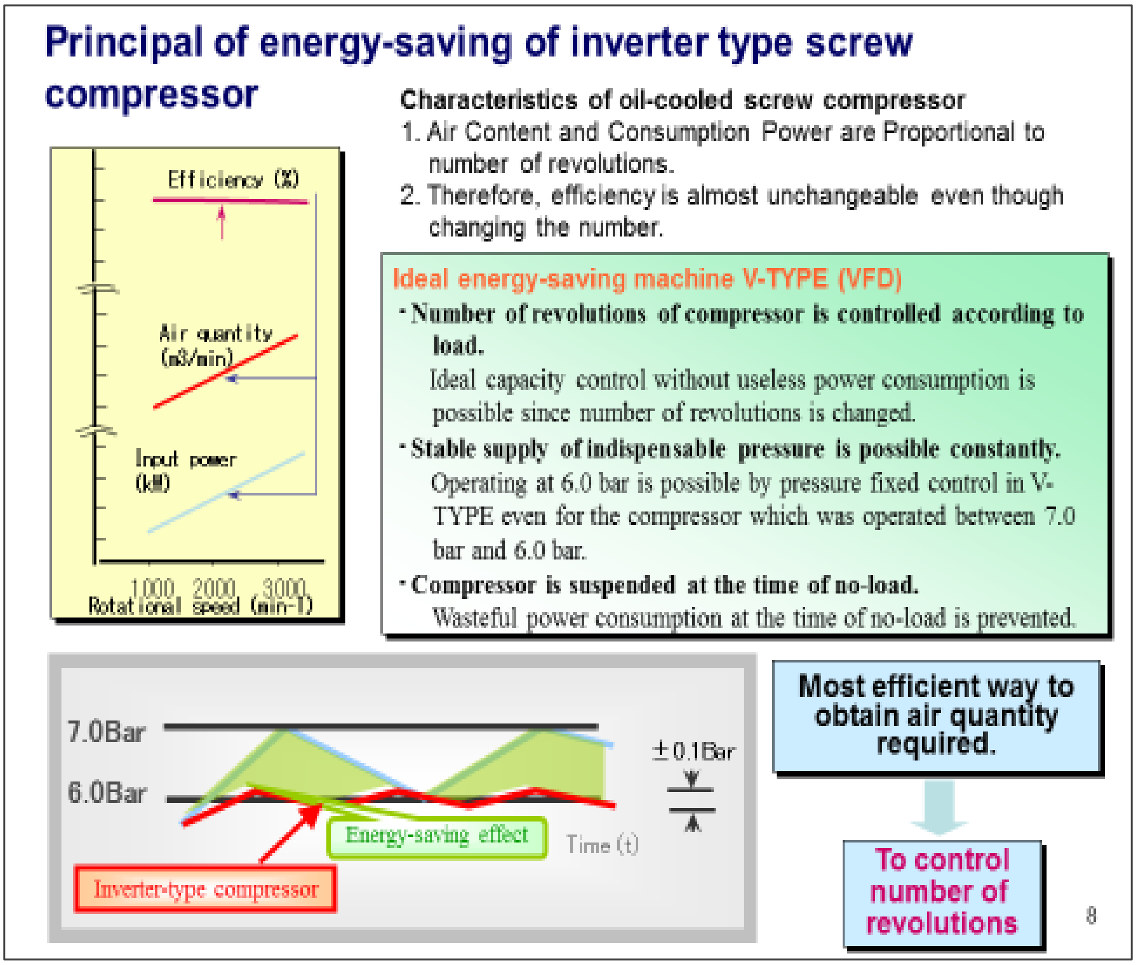
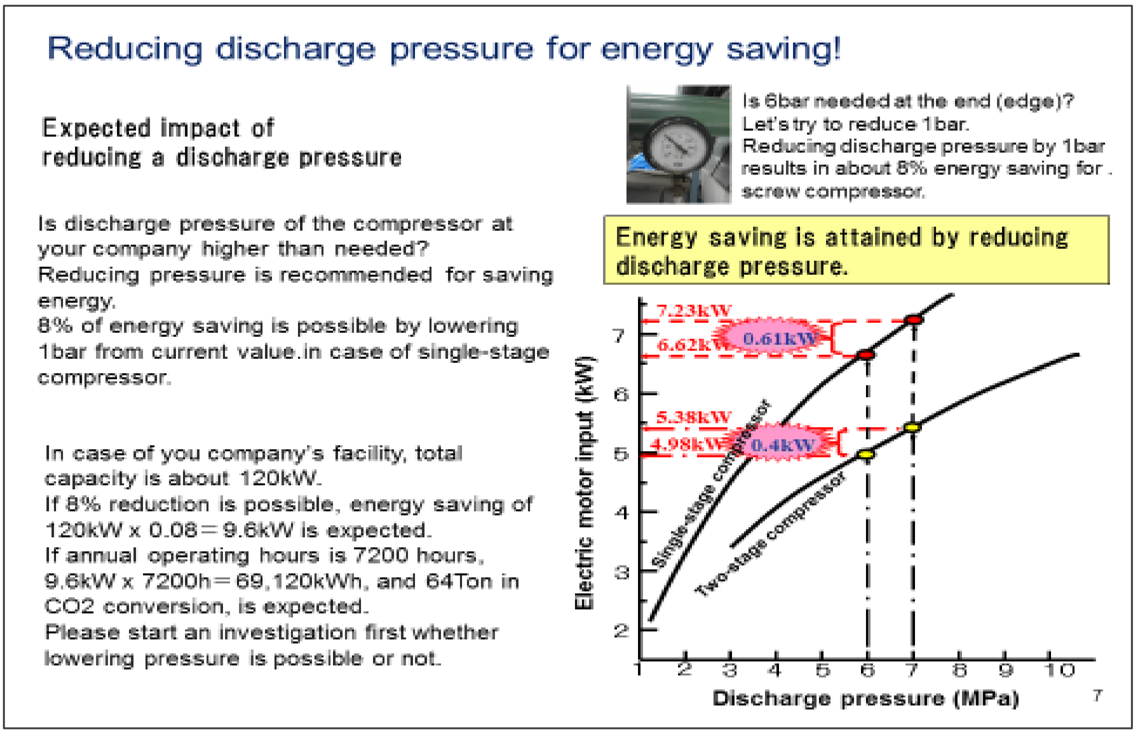
[Recommendation: Hard side (related to compressor)]

◈ Installation / Effective use of inverter compressor

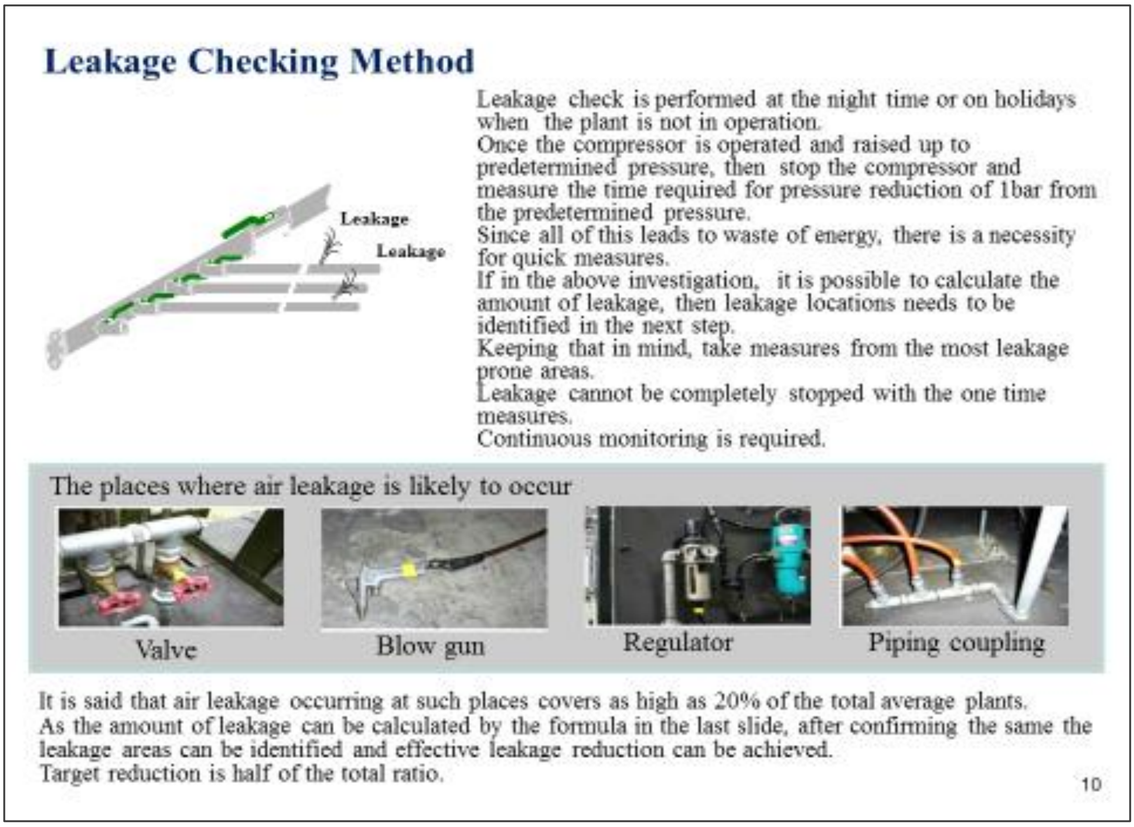


[Recommendation: soft side]

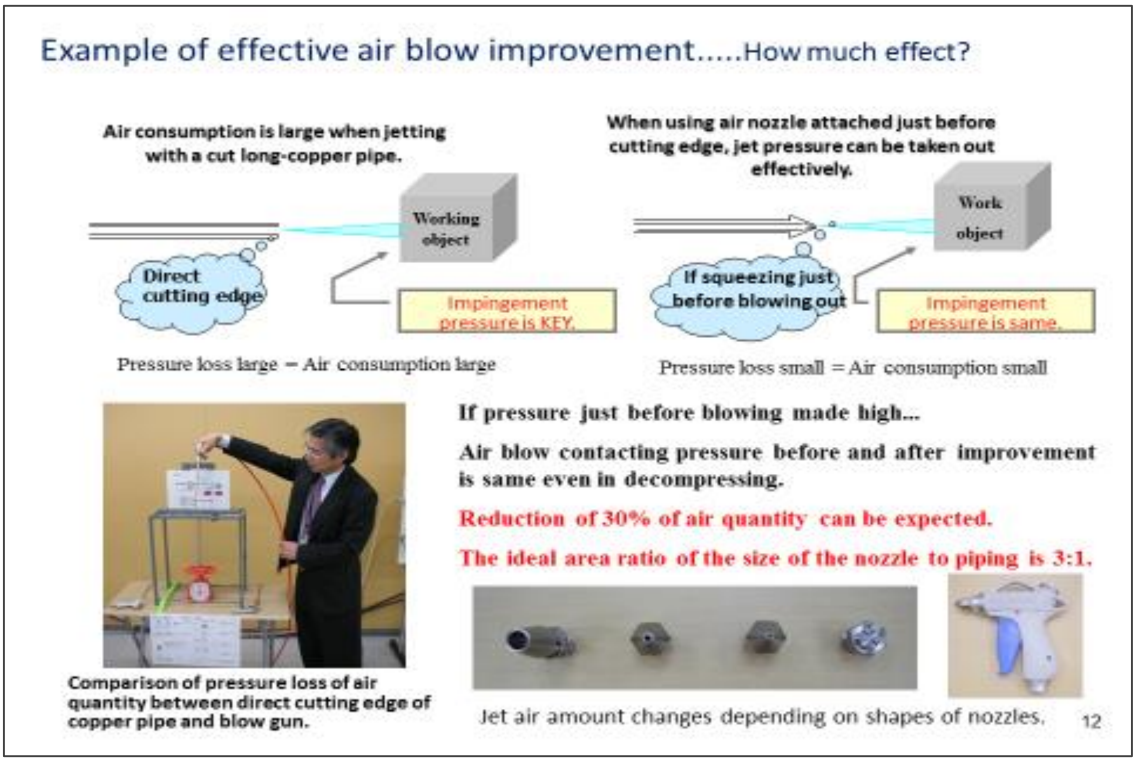
◈ Reduction of discharge pressure



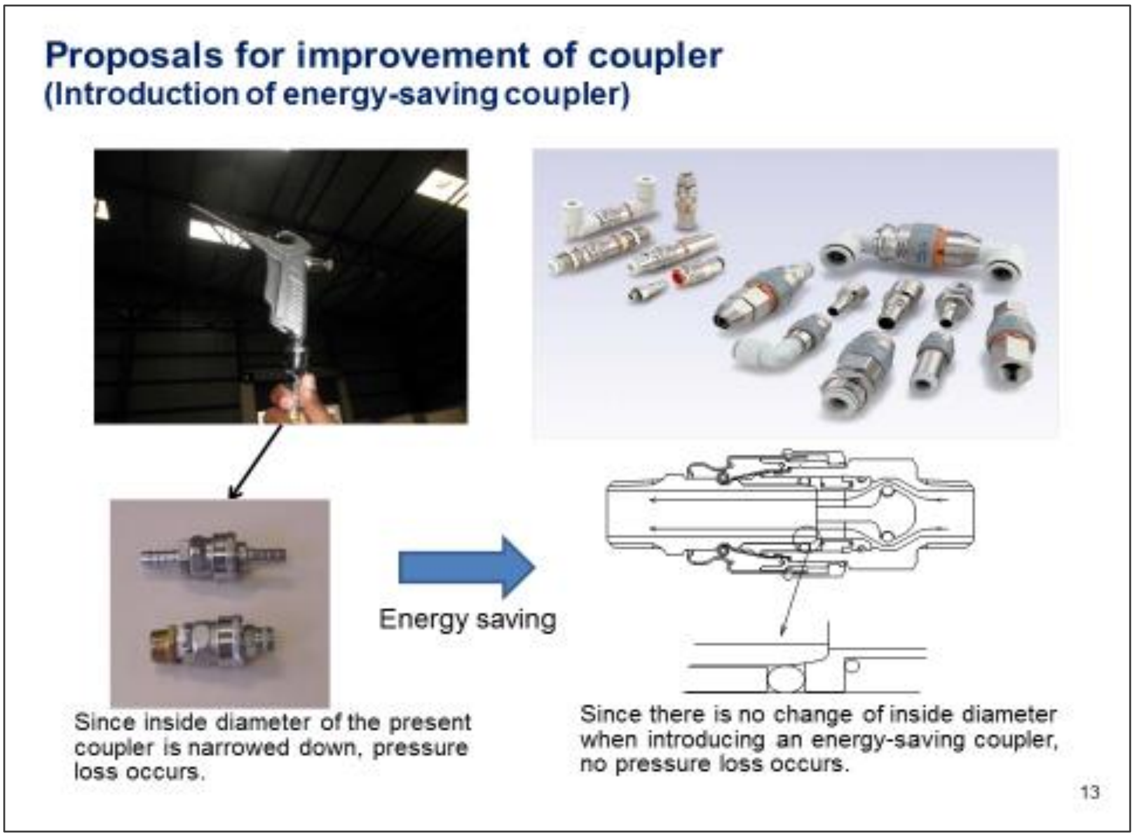
◈ Reduction of leakage ~ present status investigation



◈ Usage of effective blow gun



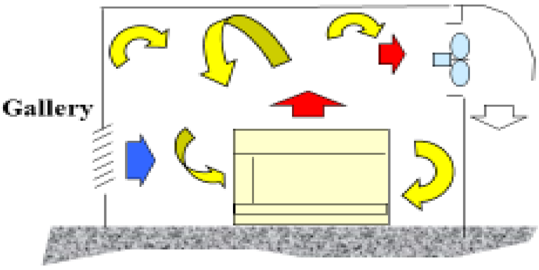
◈ Usage of energy saving coupler



◈ Ventilation measures in compressor room

Favorable Environment for Compressor… Room Temperature and Pressure Control by providing Ventilation

Rise in temperature inside compressor room



If there is rise in temperature inside the compressor room,

・Degradation in the performance of compressor. At 3°C, the performance is degraded by 1%.

Moreover, even if suction pressure of the compressor decreases,

・The compressor efficiency deteriorates.

General Instructions

Air intake to compressor room

Since the compressor room is situated at a place having hardly any ventilation, air intake temperature is likely to rise in summer.

Air intake resistance improvement in compressor room

Since the compressor room is a sealed room, the efficiency can be worsened due to reduction in suction pressure. Therefore, monitoring intake pressure inside the compressor room is recommended.

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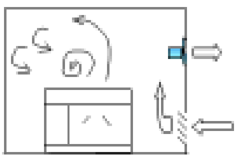
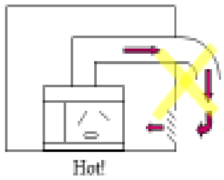
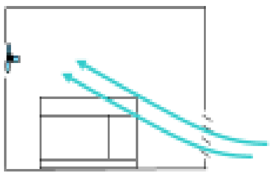
Ventilation Inside Compressor Room

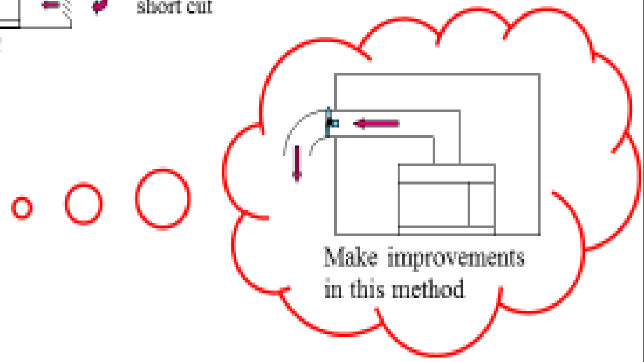
Air inlet should be situated at the diagonal lower surface of exhaust port.
Make sure that exhaust side and air intake side are not in the same plane.
Indoor ventilation is not at all done.







Warm air has been in-taken since the gas has been exhausted in the room without exhaust ducts.



Presently the compressor exhaust and air dryer exhaust are confined in the compressor room and increasing the room temperature.
Because of which the performance of equipment is degrading.
Construction of duct and installation of exhaust fan is recommended.
With 10°C rise in temperature, the compressor efficiency is reduced by 3%.

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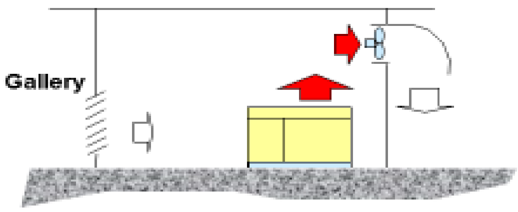
Ventilation and Ventilating Fan Capacity --- Reference

Required ventilation amount for general ventilation



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

Q: Required ventilation amount (m^3/min)
H: Amount of heat produced per unit (MJ/h)
(1 kW = 3.6 MJ/h)
n: Number of units installed
T: Allowable temperature increase

(When outside temperature is 35 ℃, compressor's allowable maximum temperature is 45 ℃, ΔT = 45 - 35 = 10 ℃)

Required ventilation amount in your company

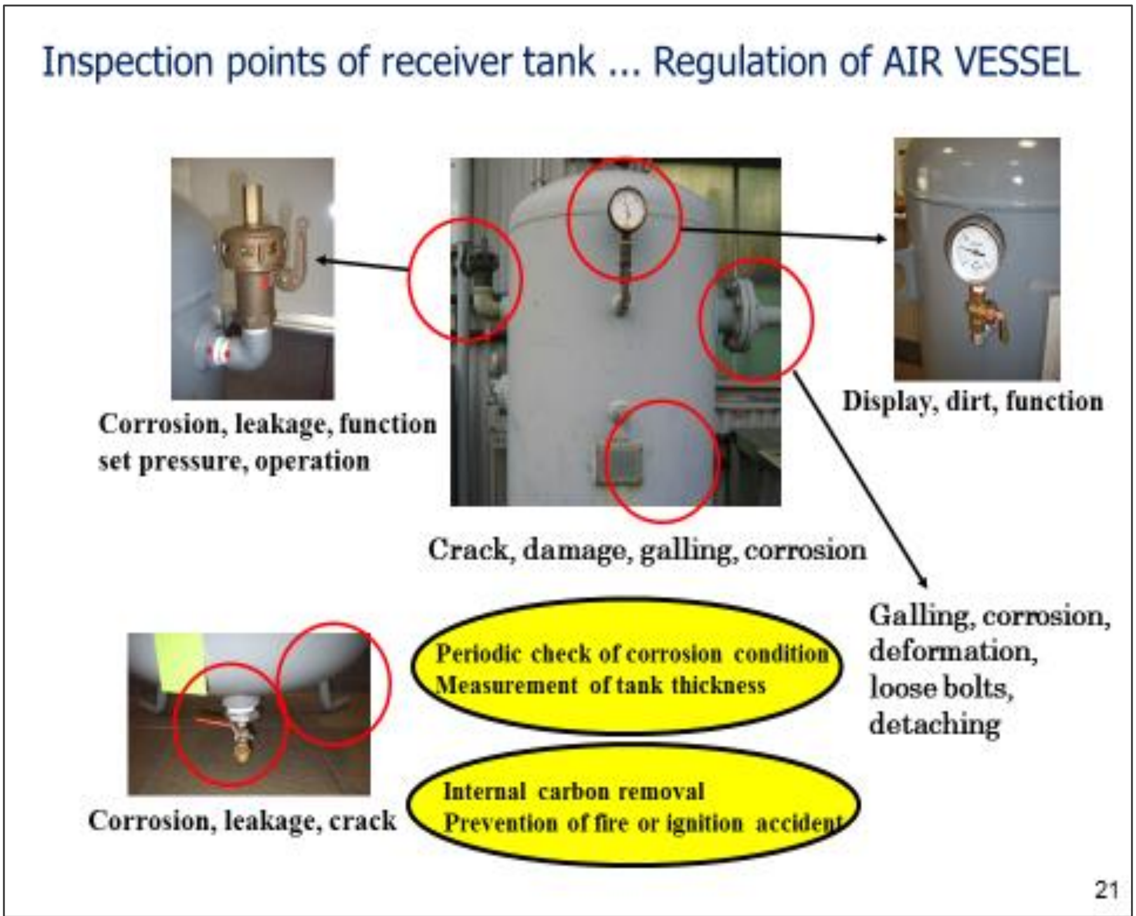
Required air amount is calculated on condition of operating three 30kW compressors.
The heat generated of air drier is set to 800W as input value.

$$Q = \frac{3.6 \times (30/0.9 + 0.2)kW \times 3}{0.0753 \times 10} = 480M3/min$$

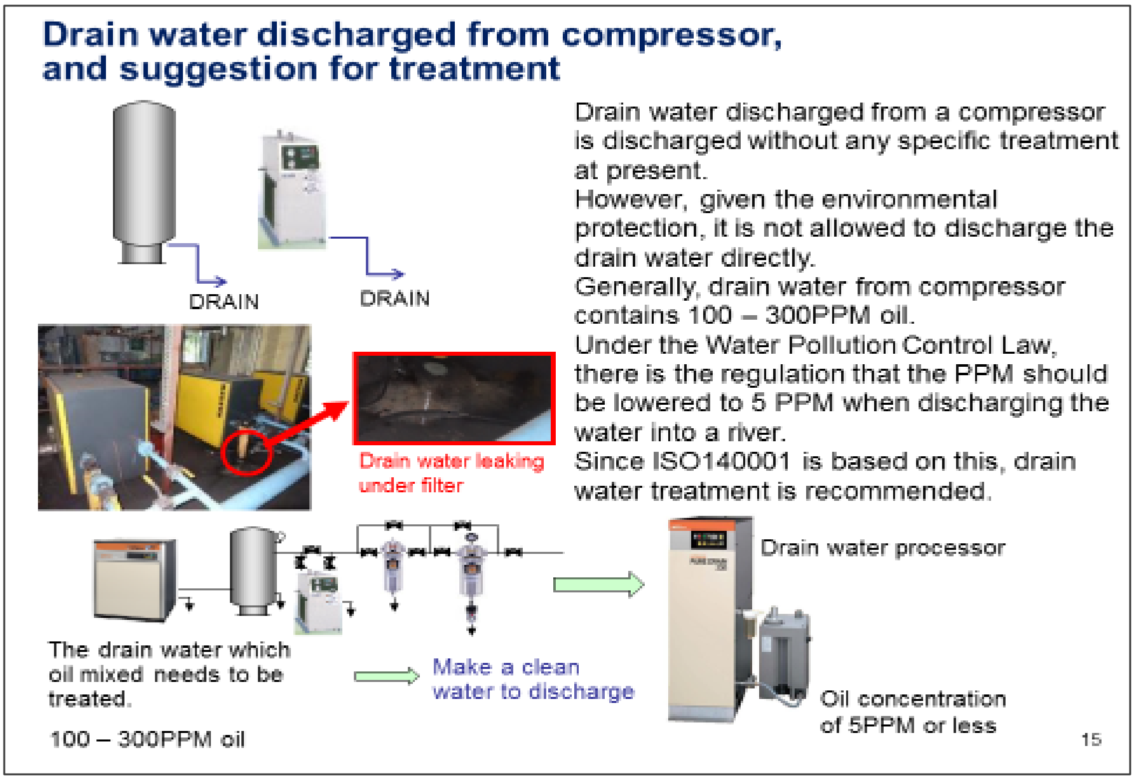
That is, it is in a desirable situation to install five pressure ventilation fans with 100M3/min under the present conditions.
In reality, it is impossible, please constructing a duct and controlling the temperature are required.
When constructing a duct, the current ventilation fan capacity is enough.

19

◈ Simple checking of receiver tank



◈ Others (Installation of drain water processor)



[Summary of feasibility study]

Sr. No.	Recommendation	Expected energy savings kWh per year	tCO_2 emission reduction per year
1	Make efficient usage of air compressor - i) reduction of discharge pressure, ii) effective utilization inverter type air compressor	69120	68
2	Use of inverter type of air compressor	60830	60
3	Get rid of the waste - i) reduction in leakage - 5% starting with the present status investigation, ii) improvement and use of effective blow guns, iii) use of energy savings couplers	42887	42
4	Adjust the environment - i) fresh, cold & dry air intake, ii) regular cleaning of pre-intake filter	42887	42

In addition, other recommendations were made to the plant to improve the energy efficiency of their compressed air systems. These recommendations are summarised below.

- Improved ventilation measures
- Improvements in piping construction and layout
- Visual checking of the receiver tank
- Energy monitoring system

(3)-5 Ahmednagar Ltd. (Forging)

Survey date: Oct. 10, 2014
Interviewee: MR. AHHASAHEB GHAMAT
Sector/Industry: Forging
Operating hours: 24Hours/day
Total electricity consumption: 7,000,000kWh/month
Power required for compressor: 15~20%of total energy consumption
Electric power unit price (Rs/kwh): 6.75
Existing compressor: ATLAS GA160 x 3 units, GI 160kw 54215 x 2 units,
ELGI 132kW E132 x 1 unit, GODREJ 150kw LS20S (INVERTER)
Supplemental equipment: Air dryer, Air tank, Unit control panels
Uses: For press forging, for cleaning

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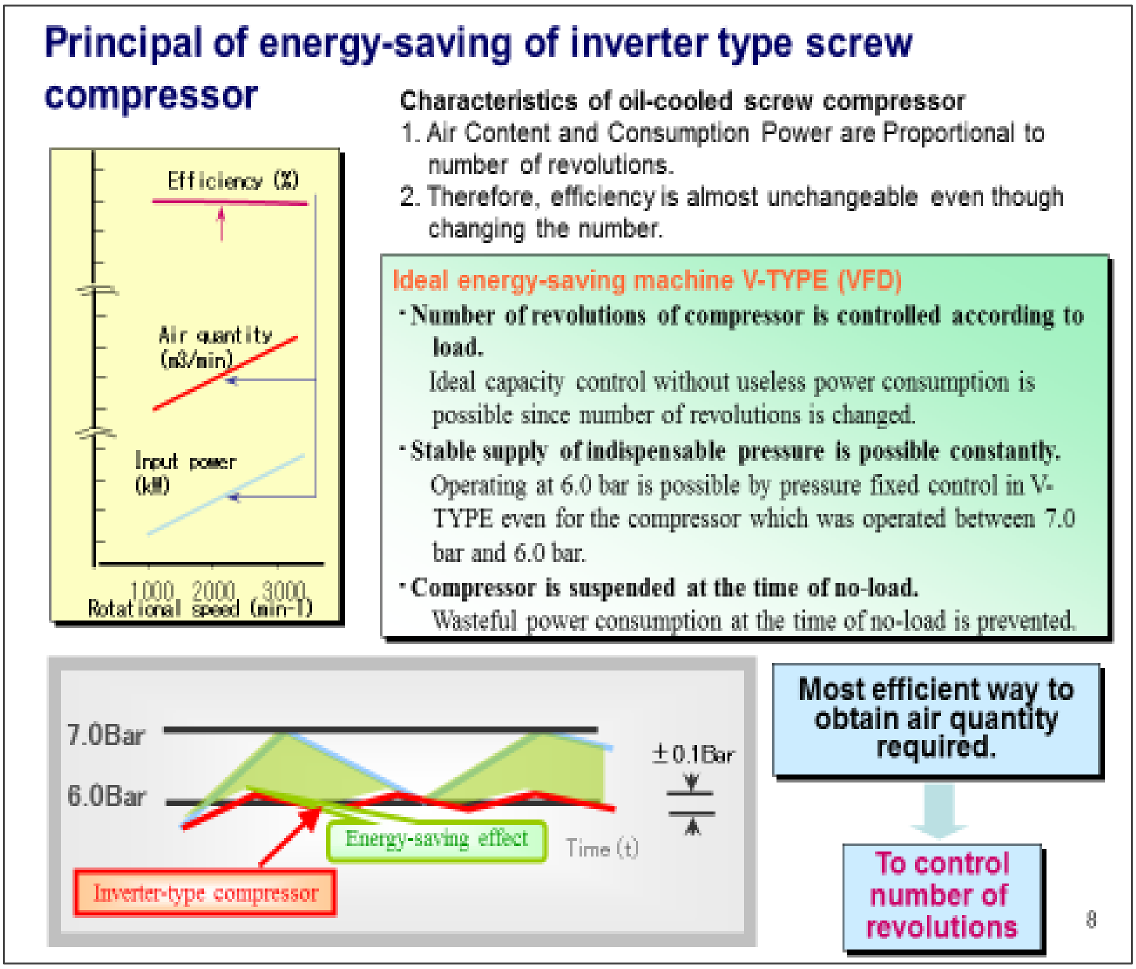
[Recommendation: Hard side (related to compressor)]

◈ Installation / Effective use of inverter compressor



◈ Adopting two-stage compressor

Energy saving by adopting two-stage compressor

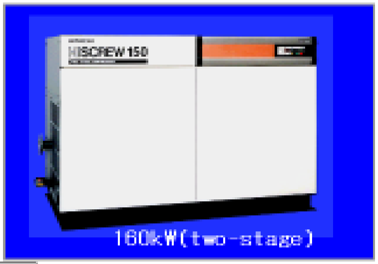
Two-stage compressor is recommended if operating several single-stage compressors.
Power consumption at 15 - 18% can be improved if adopting two-stage compressor.
(However, better energy-saving can be expected by separate operation incase of large load-variation equipment)

ELGI1,2

160kW
(single-stage)

Proposal

Adoption of two-stage compressor



	160kW x 1 unit	160kW x 1 unit
Input power kW	168.0	174.0
Discharge air m^3/min	25.9	30.0
Power consumption kW/(m^3/min)	6.49	5.8

* Power consumption = Input power ÷ Discharge air

It is judged that this value seems about 5% lower. If so, power consumption will be 6.8.

15% improvement in power consumption !!

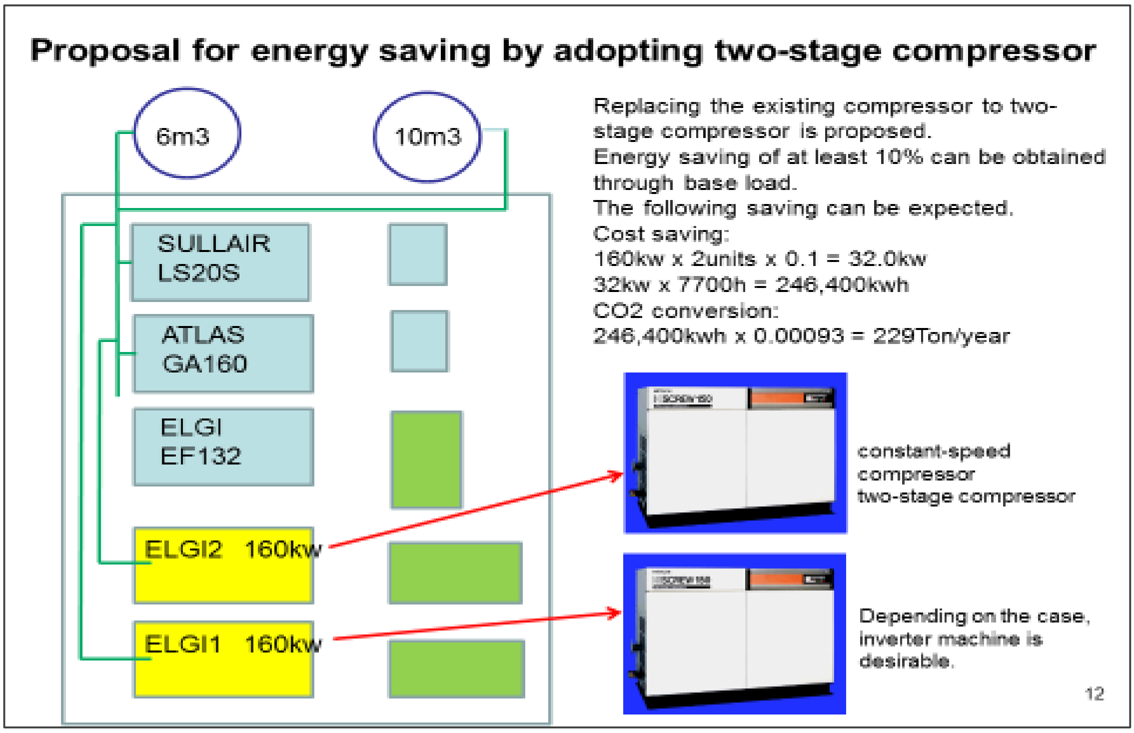
10

Effective Utilization of Inverter Screw Compressor

Indicating 137.4kW
Average 143.1kW by measurement diagnosis

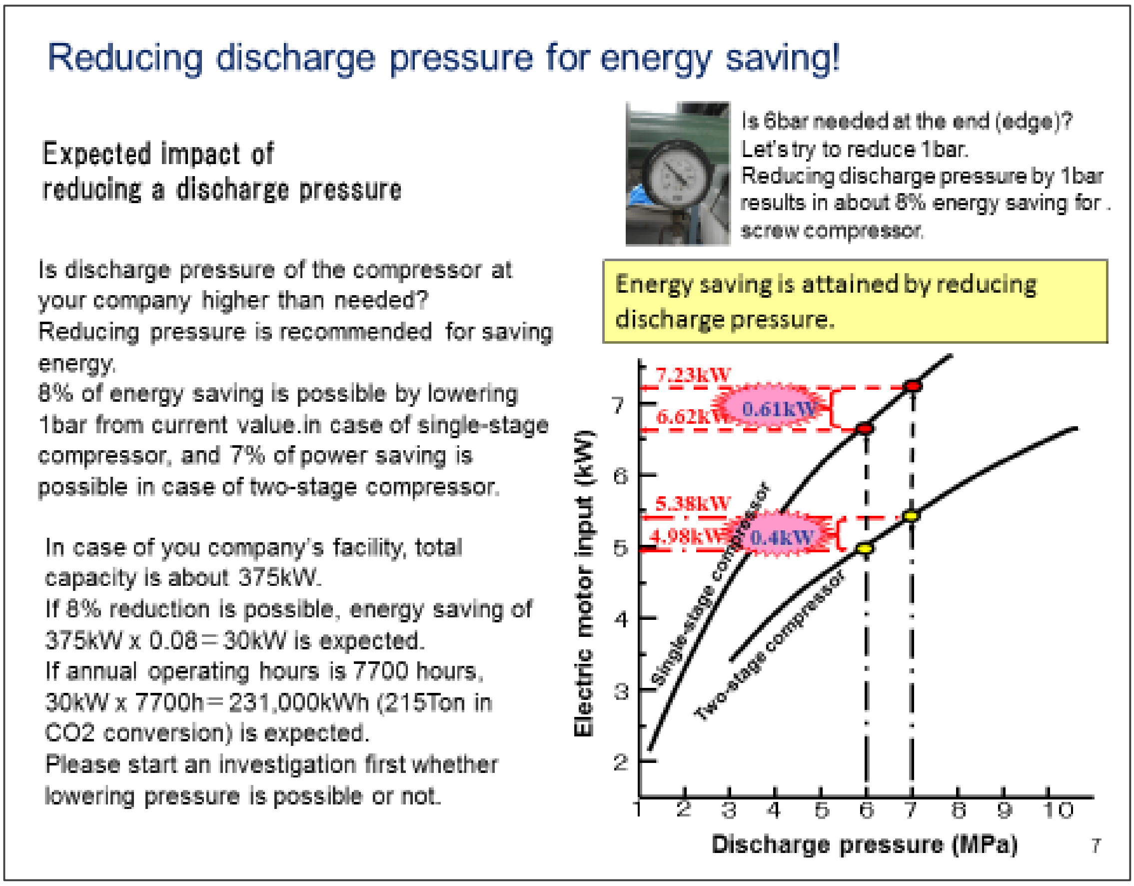
Inverter machine is not functioning properly.
It has not responded to load variations.
As per the measurement diagnosis, the waste of 45.0kw was confirmed. Essentially one compressor needs to be stopped.
If one compressor is stopped, energy saving of 115kW will be possible.
First of all, it is important to change the settings so that inverter machine will properly respond.
If retrofit compressor does not bring that much effect, then the purchase of new inverter type compressor can serve the purpose of energy saving.
Energy saving of 45kW is 342,000 kw per annum. CO2 conversion (emission reduction) of 318 ton and saving of 2,308,500 Rs per annum can be achieved.
Also, with the new machinery investment, the investment payback is possible within the span of 2.5 years.

9



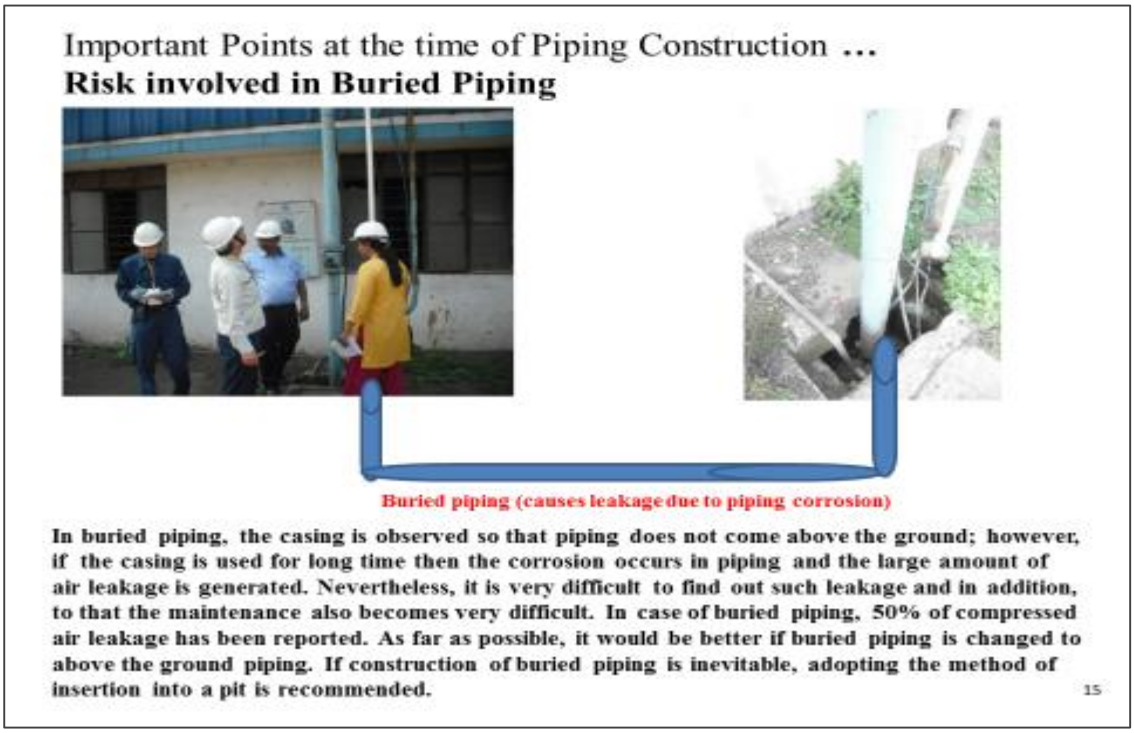
[Recommendation: soft side]

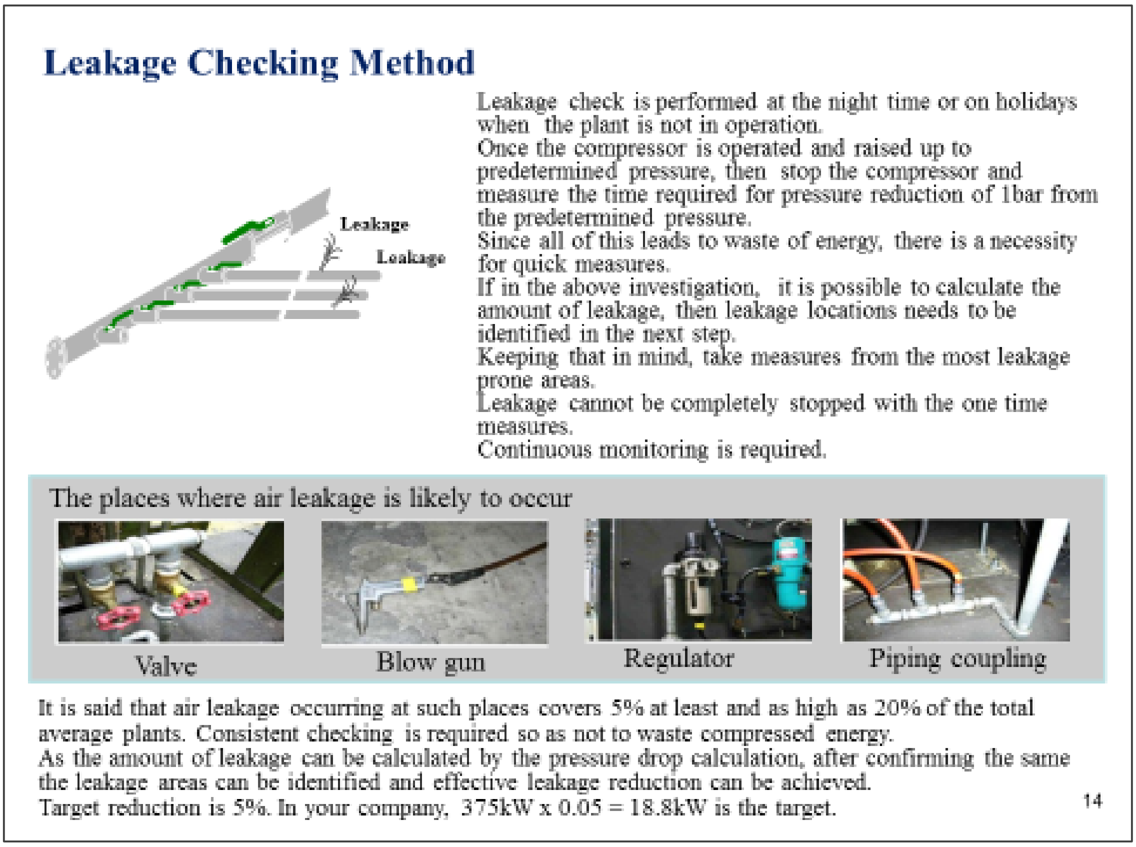
◈ Reduction of discharge pressure



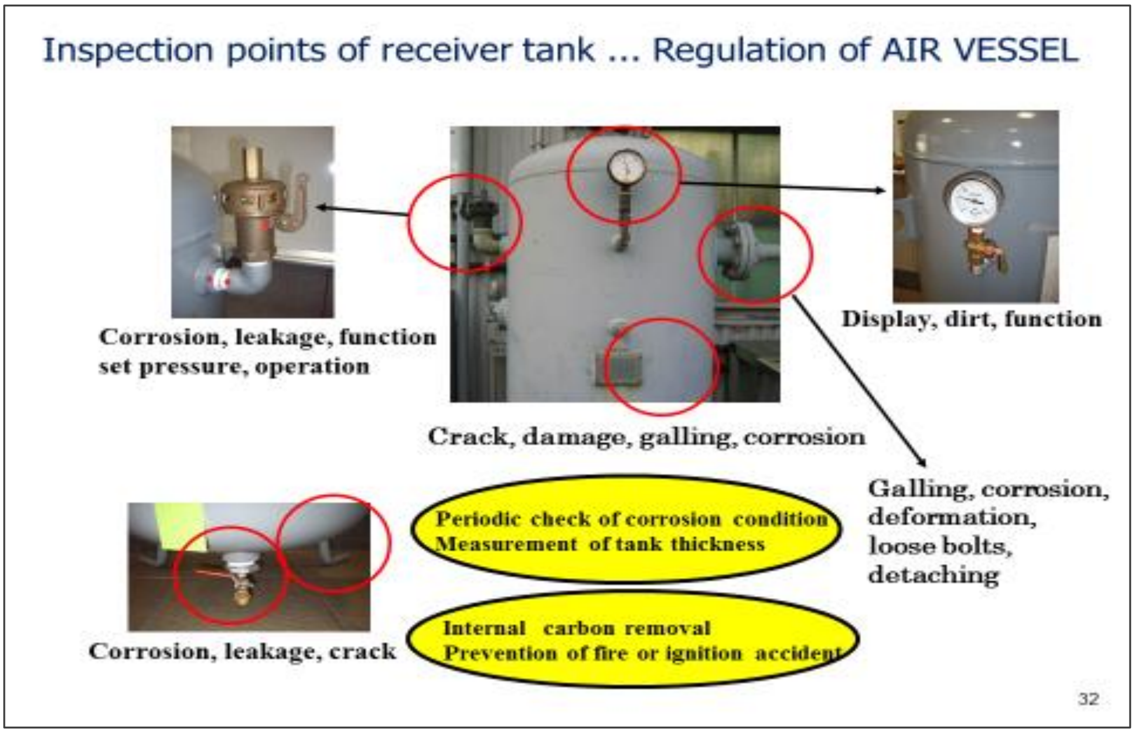
◈ Reduction of leakage ~ present status investigation

◈ Stop of buried piping

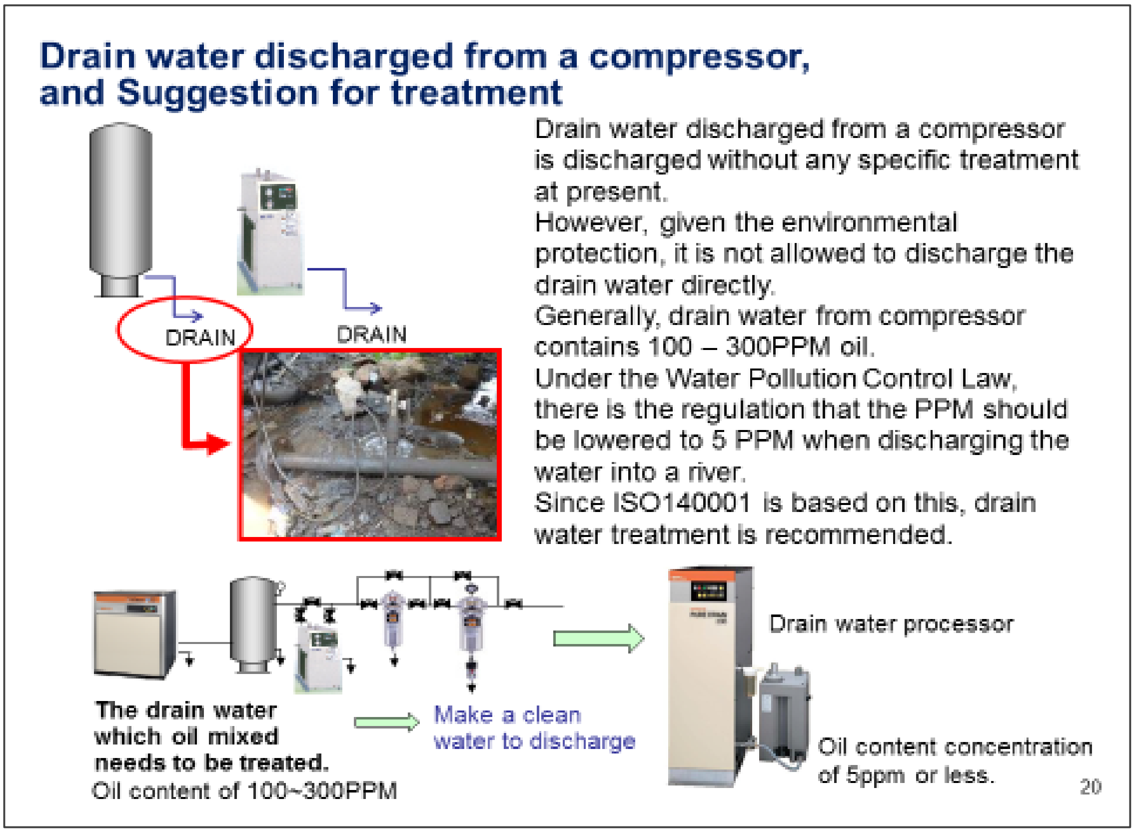




◈ Simple checking of receiver tank



◈ Others (Installation of drain water processor)



[Summary of feasibility study]

Sr. No.	Recommendation	Expected energy savings kWh per year	tCO_2 emission reduction per year
1	Make efficient usage of air compressor - i) reduction in discharge pressure, ii) effective utilization of inverter type air compressor, iii) use of two stage compressor	231000	226
2	Effective use of inverter type crew air compressor	350000	343
3	Use of two stage air compressor	130500	128
4	Use of new inverter type air compressor - replacing old ELGI air compressor	346680	340
5	i) reduction in leakage - 5% starting with the present status investigation, ii) stop of buried piping - taking it out of the ground	144835	142
6	Adjust the environment - i) fresh, cold & dry air intake, ii) installation of drain water processor from the view point of environmental problem	86940	85

In addition, other recommendations like visual inspection of the receiver tank and adoption of energy monitoring system were made to the plant to improve the energy efficiency of their compressed air systems.

(3)-6 Mahindra Hinoday Ltd. (Casting)

Survey date: Oct. 10, 2014

Interviewee: Mr. Mahindra Hinoday

Sector/Industry: Casting

Operating hours: 24Hours/day

Total electricity consumption: 6,480,680kWh/month

Power required for compressor: 10~15%of total energy consumption

Electric power unit price (Rs/kwh): 6.0

Existing compressor: ATLAS GA907 x 2 units 90kW, GA37 x 1 unit 37kW, KAESER ASD47 x 3 units 25kW, KAESER ASD37 x 3 units 18.5～22kW, KAESER DSD141x3 units 75kW～90kW

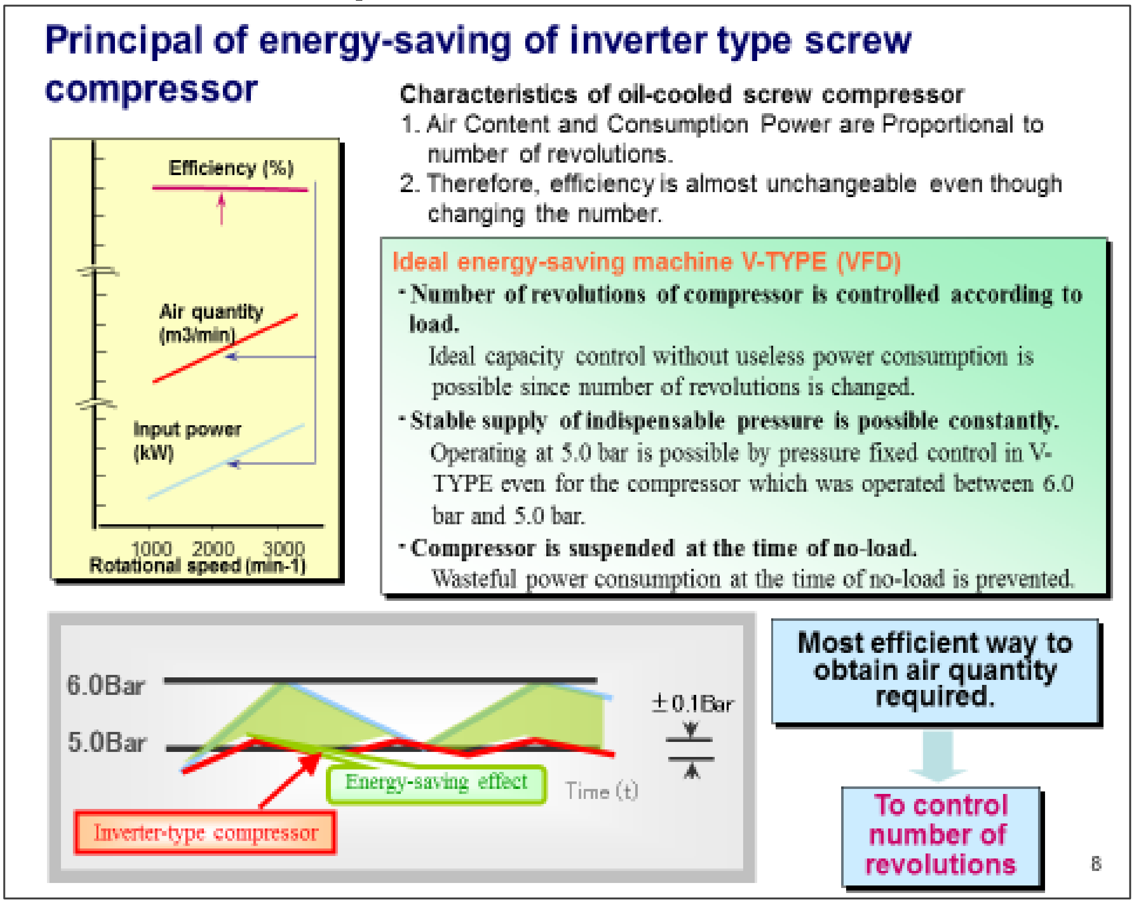
Supplemental equipment: Air dryer, Air tank,

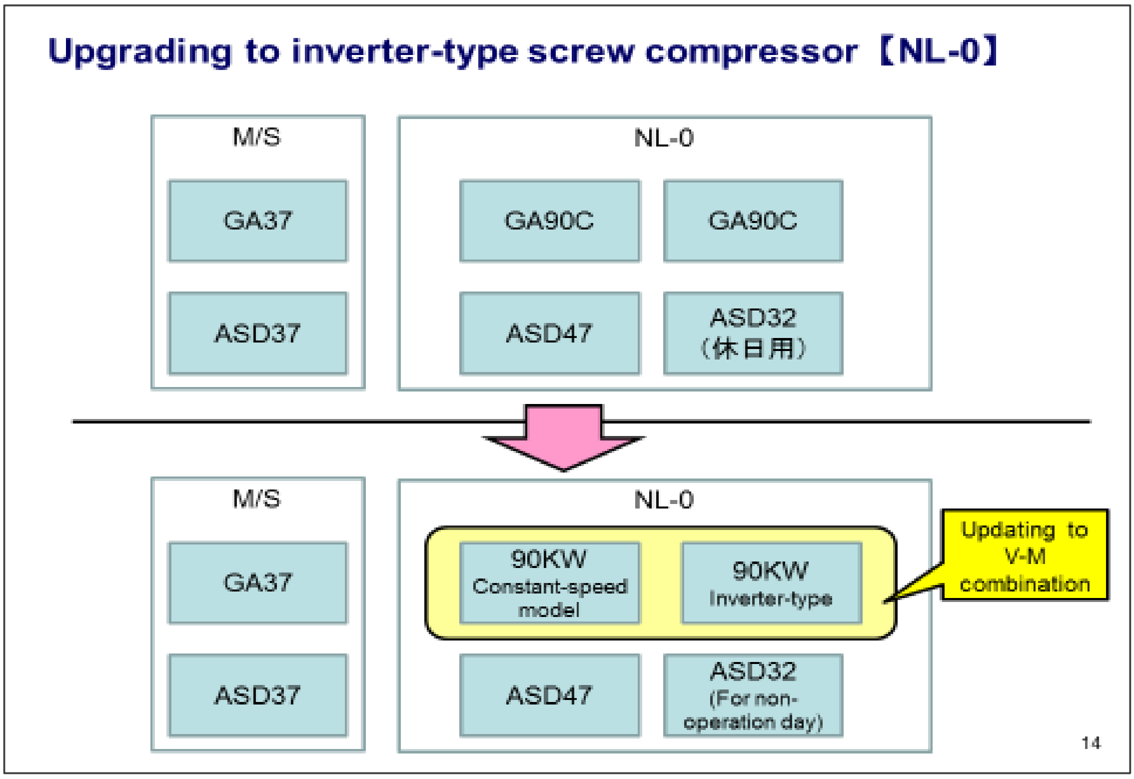
Uses: For molding machine, for cleaning, etc.

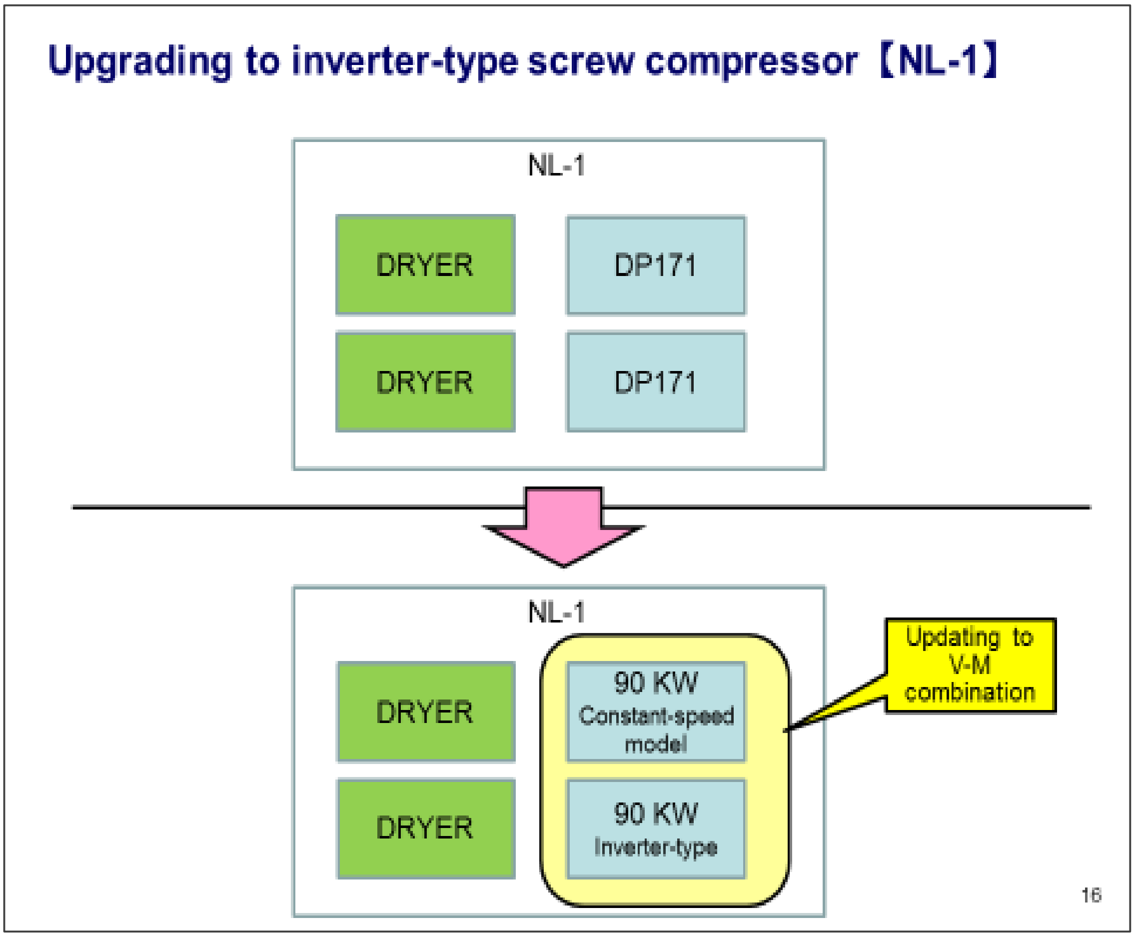
******

[Recommendation: Hard side (related to compressor)]

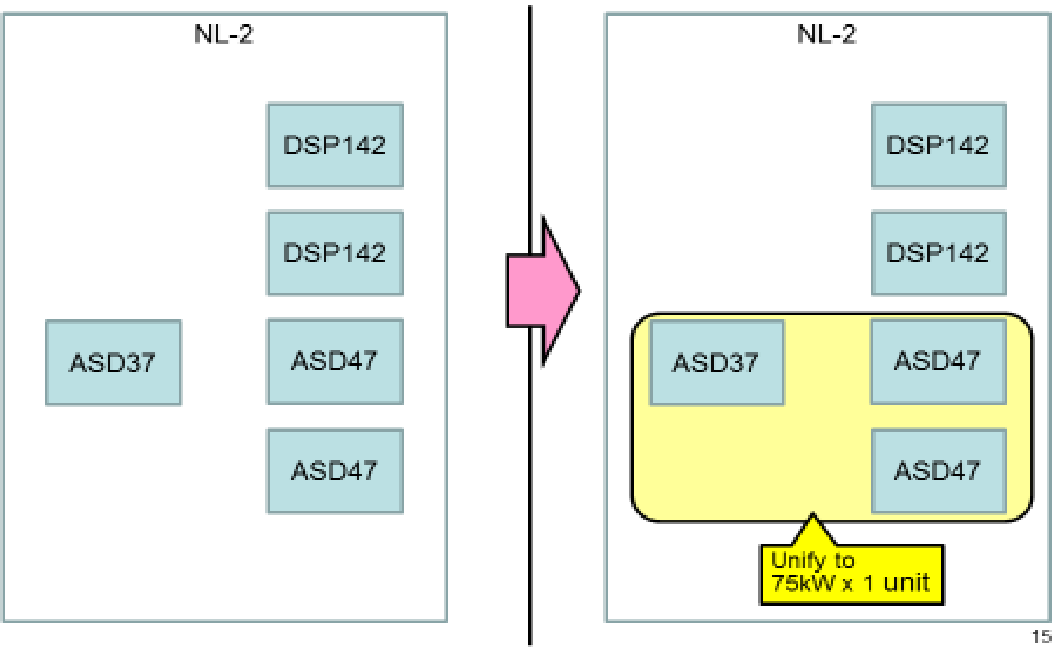
◈ Installation of inverter compressor




Upgrading to inverter-type screw compressor【NL-0】
M/S
GA37
ASD37
NL-0
GA90C
GA90C
ASD47
ASD32
（休日用）
M/S
GA37
ASD37
NL-0
90KW
Constant-speed model
90KW
Inverter-type
ASD47
ASD32
(For non-operation day)
Updating to V-M combination
14

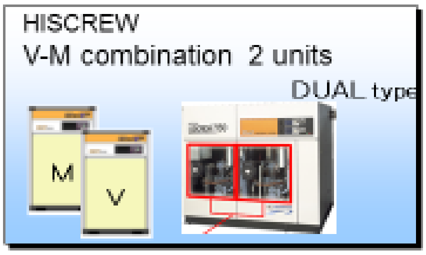

Upgrading to inverter-type screw compressor【NL-1】
NL-1
DRYER
DP171
DRYER
DP171
NL-1
DRYER
90 KW
Constant-speed model
DRYER
90 KW
Inverter-type
Updating to V-M combination
16

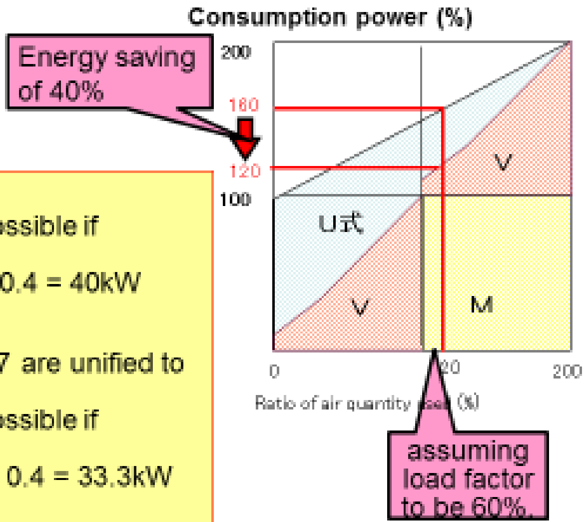
Upgrading to inverter-type screw compressor【NL-2】



15

Inverter-type screw compressor (V-M Combination)





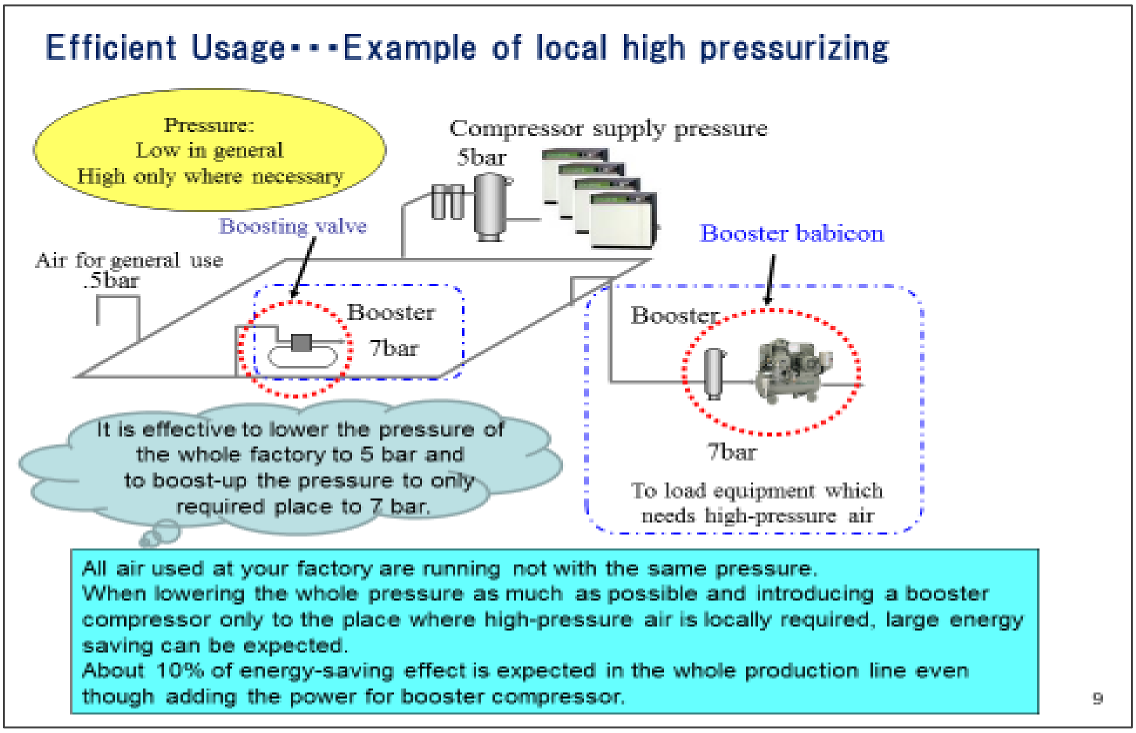
【Case 1: NL-0】
Energy saving of approx. 40% is possible if assuming load factor to be 60%.
∴ Energy saving -> 90kw÷0.9 x 0.4 = 40kW

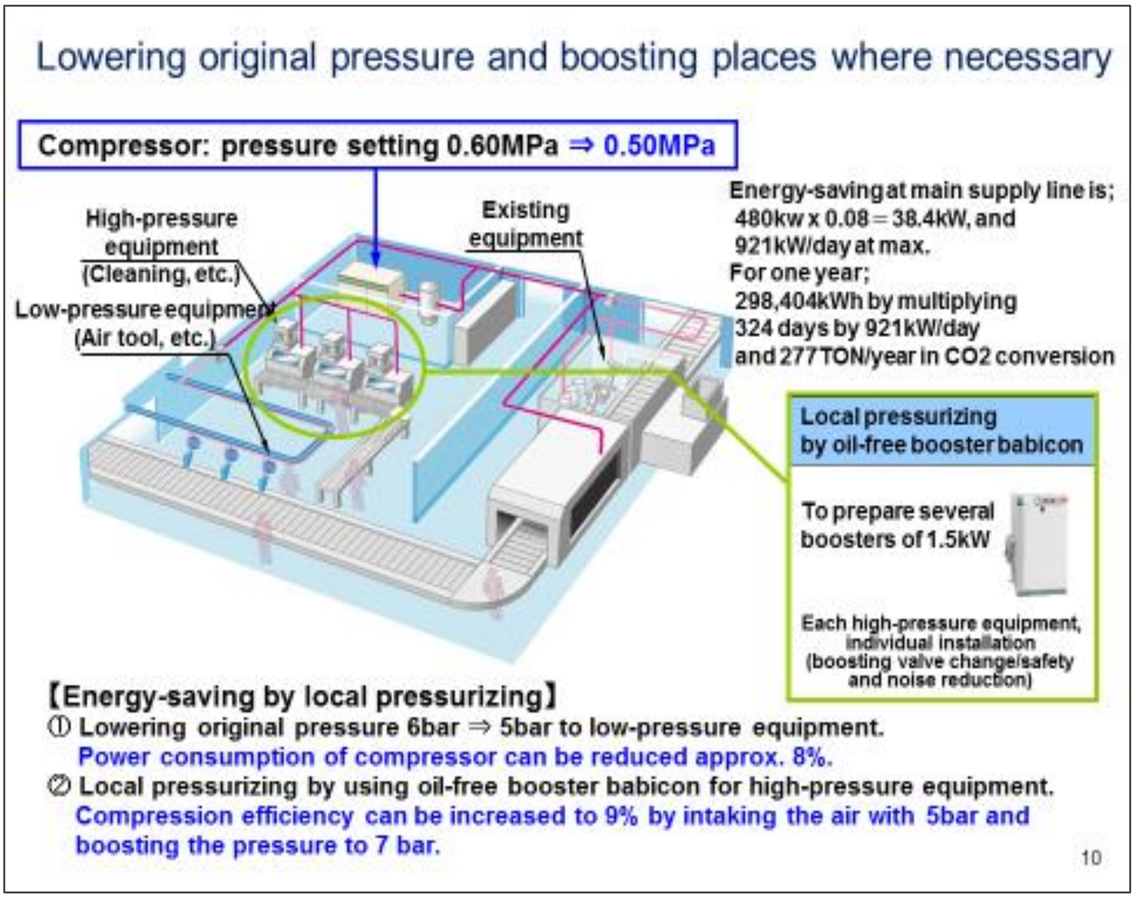
【Case 2: NL-2】
2 units of ASD47and1 unit of ASD37 are unified to 1 unit of 75kW.
Energy saving of approx. 40% is possible if assuming load factor to be 60%.
∴ Energy saving -> 75kw÷0.9 x 0.4 = 33.3kW

【Case 3: NL-1】
Energy saving of approx. 40% is possible if assuming load factor to be 60%.
∴ Energy saving -> 90kw÷0.9 x 0.4 = 40kW

17

◈ Adopting booster compressor

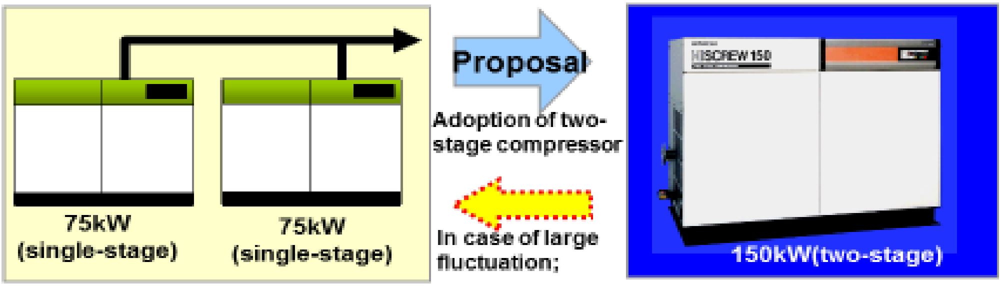




◈ Adopting two-stage compressor

Energy saving by adopting two-stage compressor

Two-stage compressor is recommended if operating several single-stage compressors.
Power consumption at 15 - 18% can be improved if adopting two-stage compressor.
(However, better energy-saving can be expected by separate operation incase of large load-variation equipment)



	75kW x 1 unit	75kW x 2 units	150kW x 1 unit
Input power kW	84.0	168.0	160.0
Discharge air m^3/min	12.4	24.8	28.5
Power consumption kW/(m^3/min)	6.53	6.53	5.61

16% improvement in power consumption !!

* Power consumption = Input power ÷ Discharge air

11

[Recommendation: soft side]

◈ Reduction of discharge pressure

Reducing discharge pressure for energy saving!

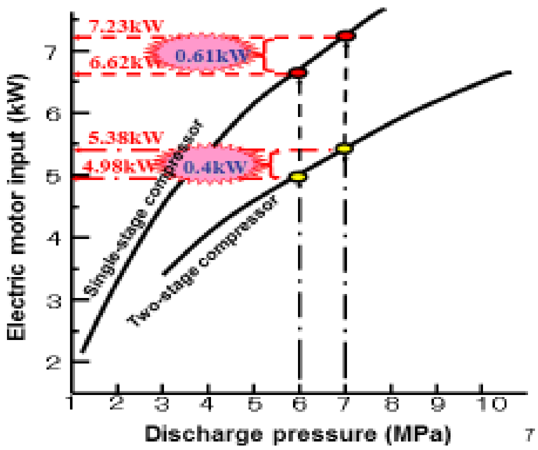
Expected impact of reducing a discharge pressure

Is discharge pressure of the compressor at your company higher than needed?
Reducing pressure is recommended for saving energy.
8% of energy saving is possible by lowering 1bar from current value.in case of single-stage compressor, and 7% of power saving is possible in case of two-stage compressor.

In case of you company's facility, total capacity is about 480kW.
If 8% reduction is possible, energy saving of 480kW x 0.08 = 38.4kW is expected.
If annual operating hours is 7700 hours, 38.4kW x 7700h = 295,680kWh (275Ton in CO_2 conversion) is expected.
Please start an investigation first whether lowering pressure is possible or not.

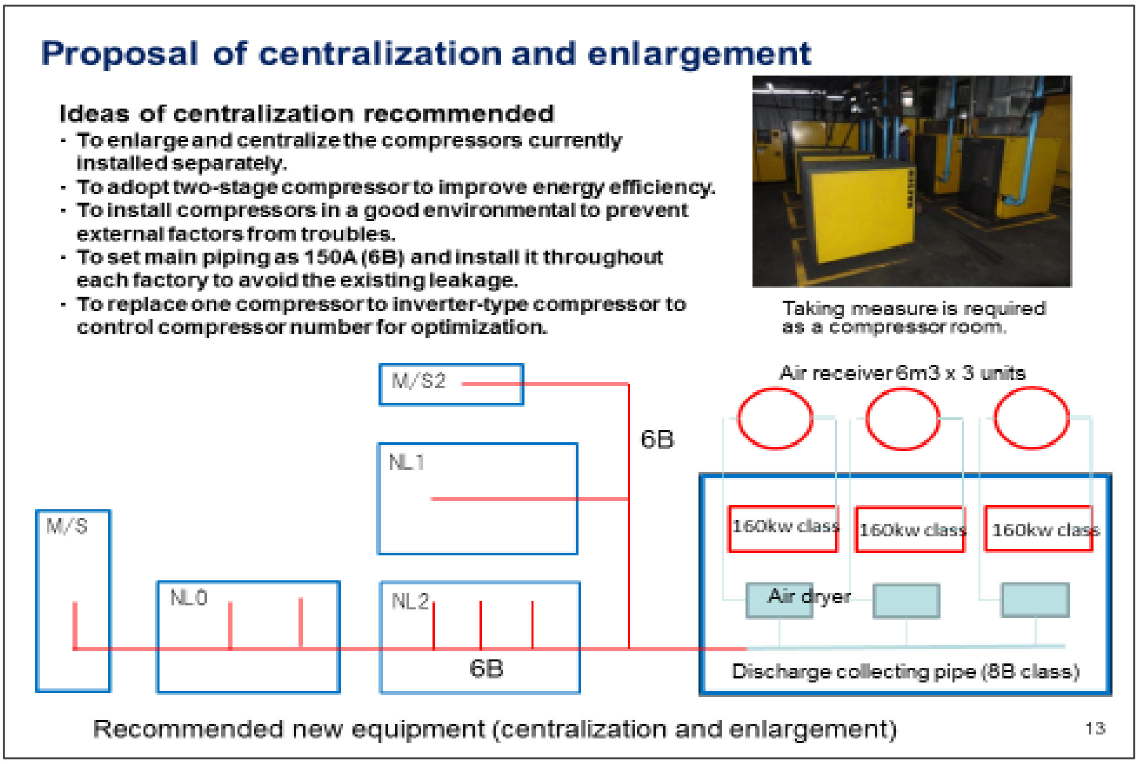
Is 6bar needed at the end (edge)?
Let's try to reduce 1bar.
Reducing discharge pressure by 1bar results in about 8% energy saving for screw compressor.

Energy saving is attained by reducing discharge pressure.

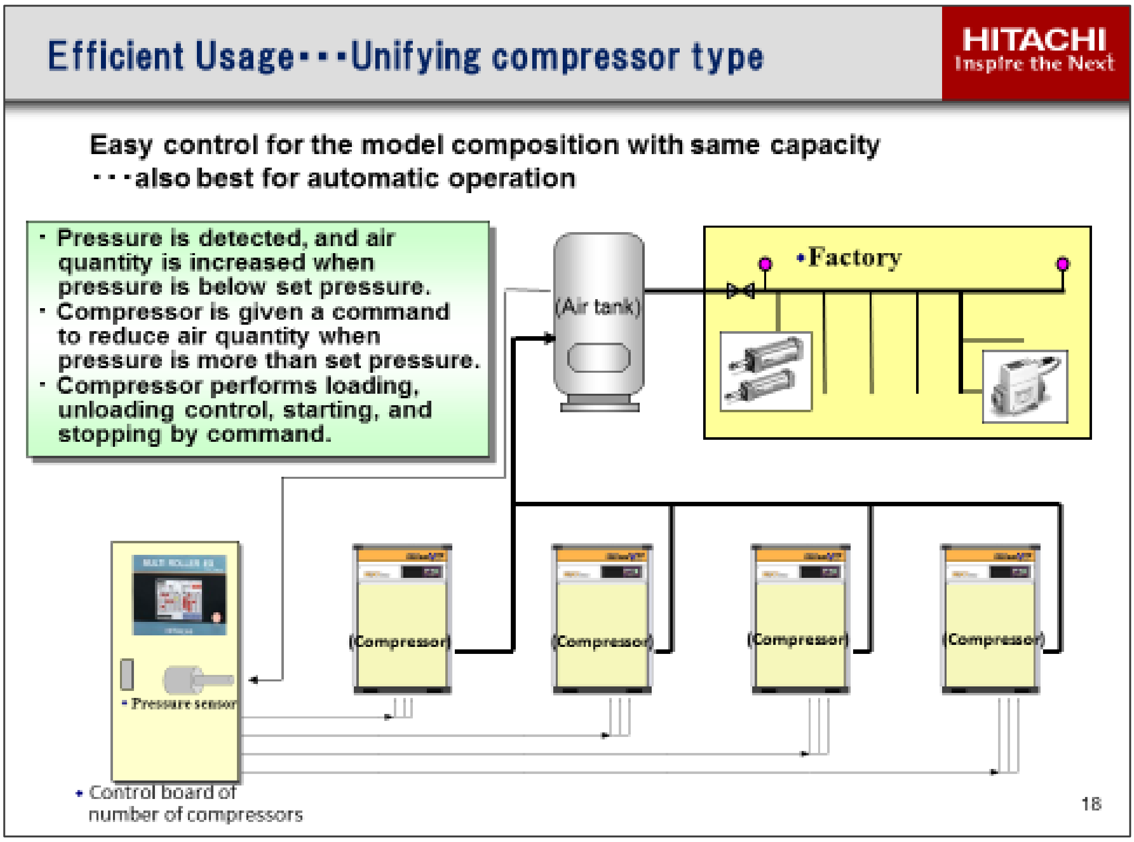


7

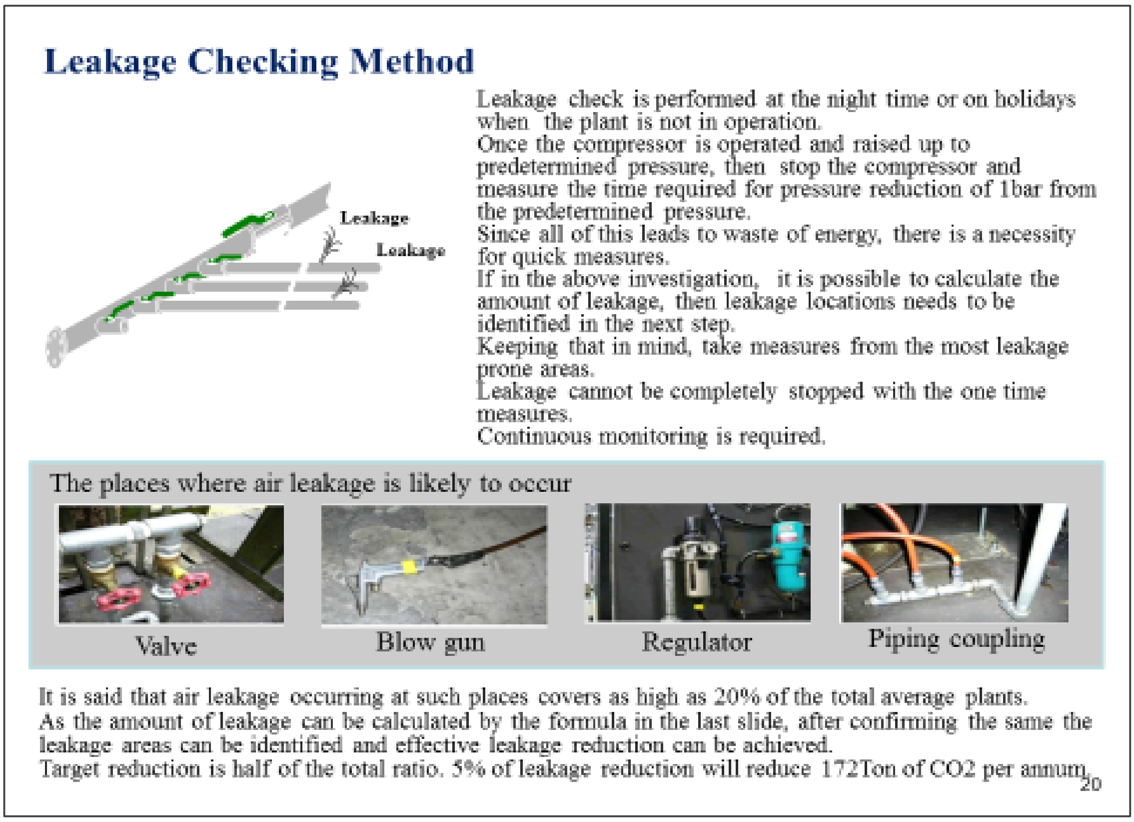
◈ Centralization and enlargement of compressor



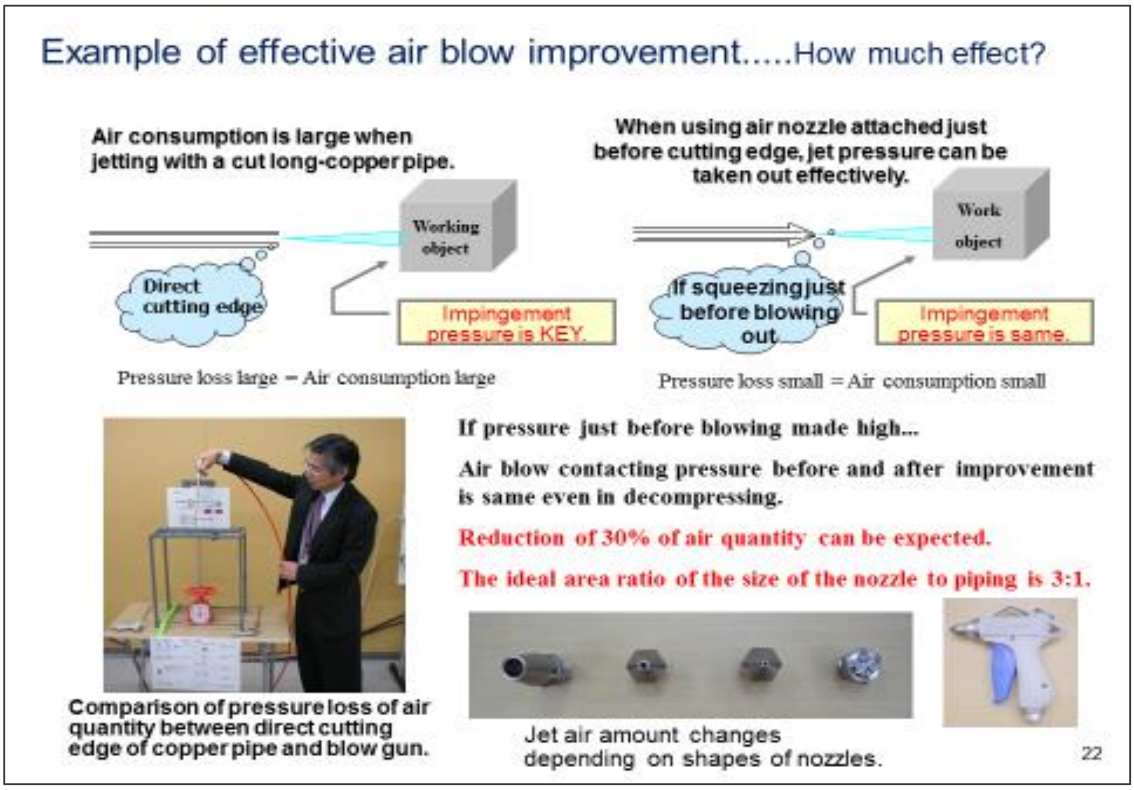
◈ Make efficient usage of compressor



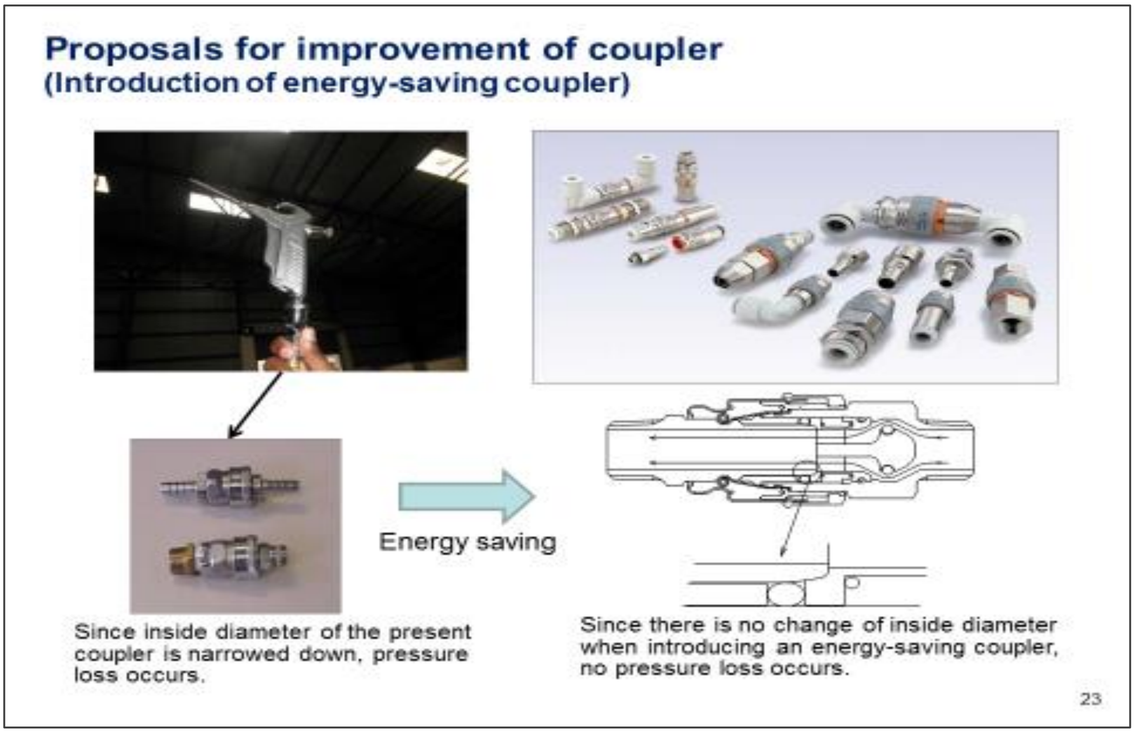
◈ Reduction of leakage ~ present status investigation



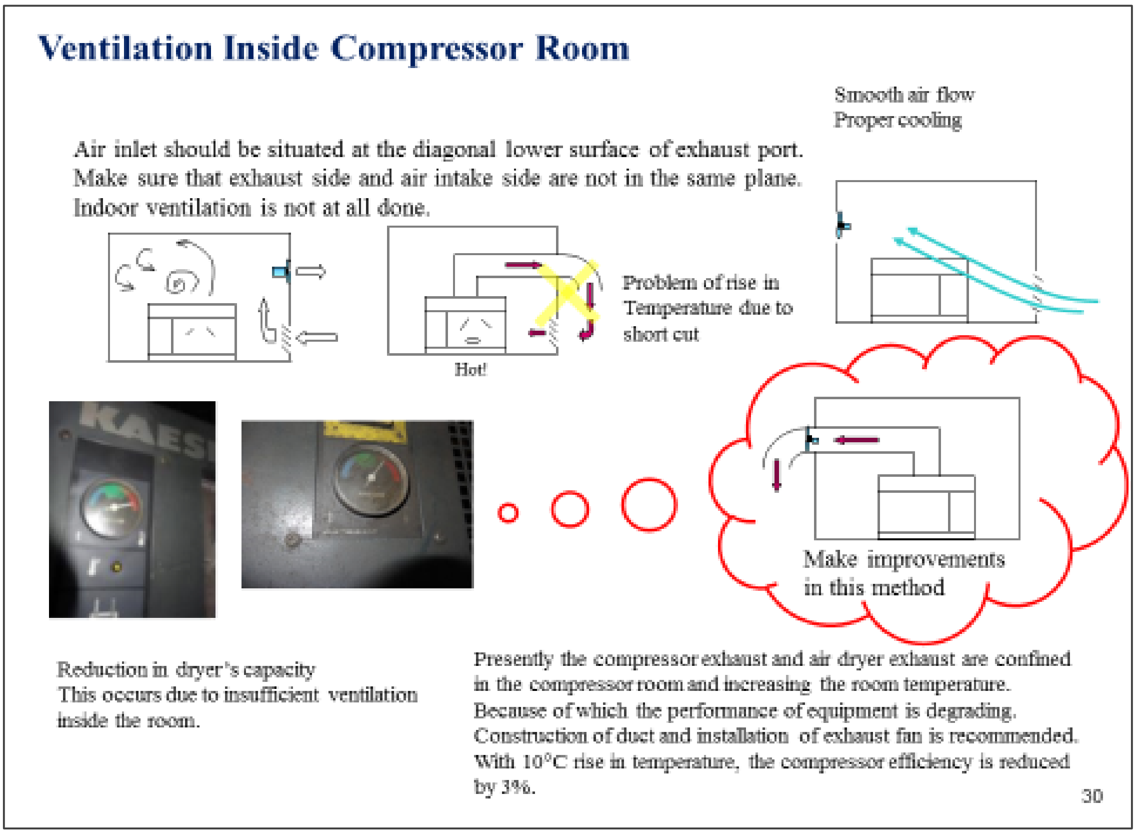
◈ Usage of effective blow gun

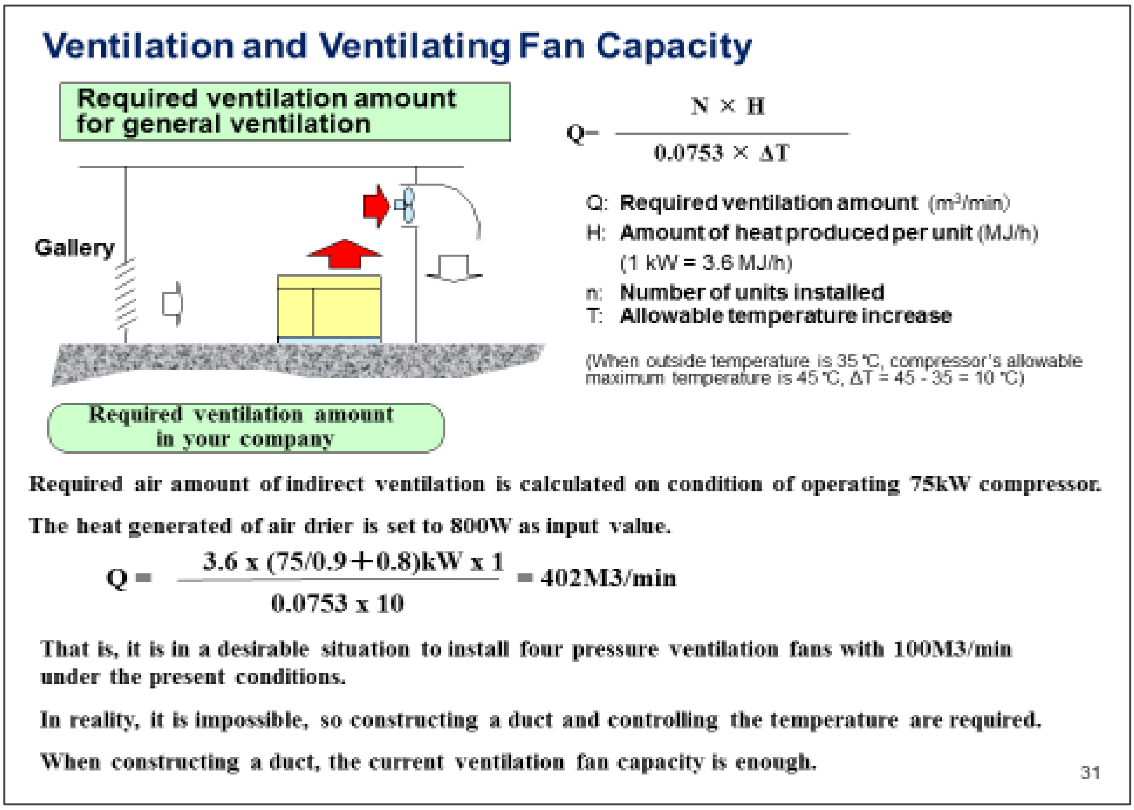


◈ Usage of energy saving coupler

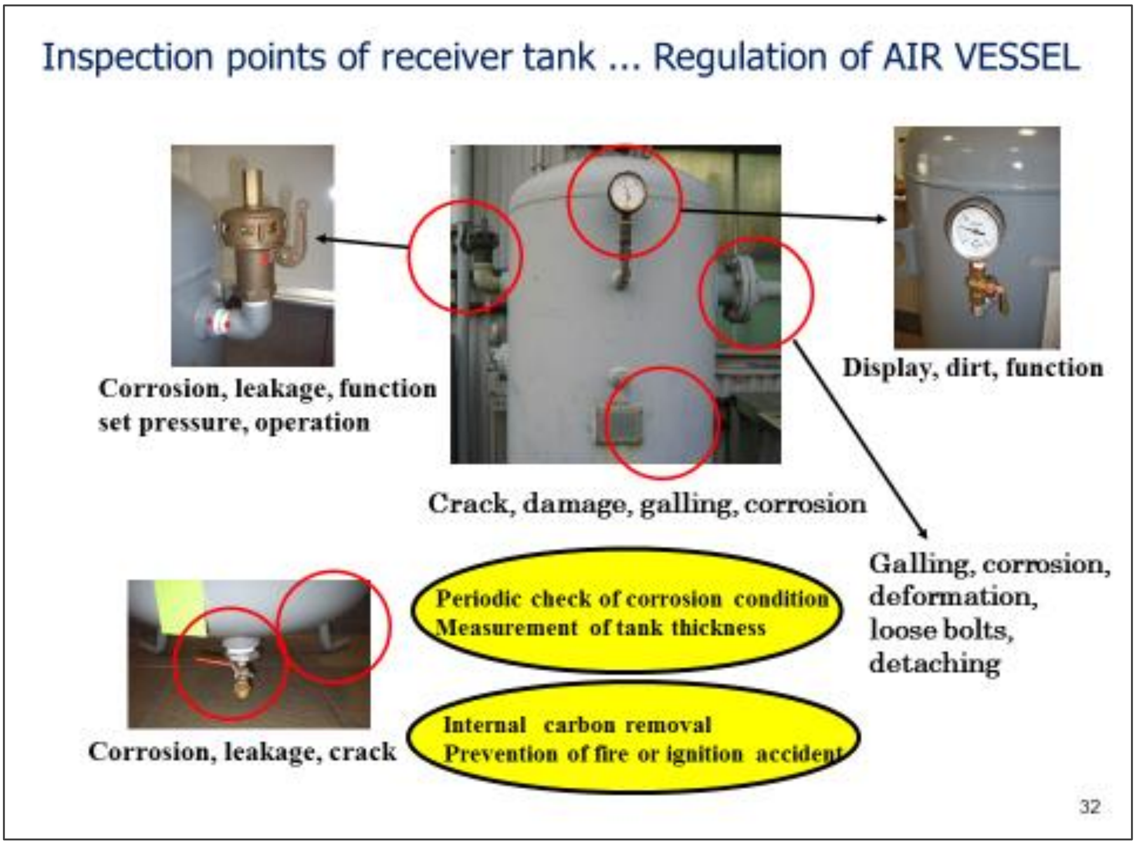


◈ Ventilation measures in compressor room





◈ Simple checking of receiver tank



◈ Others (Installation of drain water processor)

[Summary of feasibility study]

Sr. No.	Recommendation	Expected energy savings kWh per year	tCO_2 emission reduction per year
1	Make efficient usage of air compressor - i) reduction in discharge pressure, ii) effective utilization of inverter type air compressor, iii) Use of booster compressor, iv) use of two stage compressor	295680	290
2	Use of booster compressor	108864	107
3	Inverter type air compressor NL-0 plant	308160	302
4	Inverter type air compressor NL-2 plant	256543	251
5	Inverter type air compressor NL-1 plant	308160	302
6	Get rid of the waste - i) reduction in leakage - 5% starting with the present status investigation, ii) use of effective blow gun, iii) use of energy savings coupler	185477	182

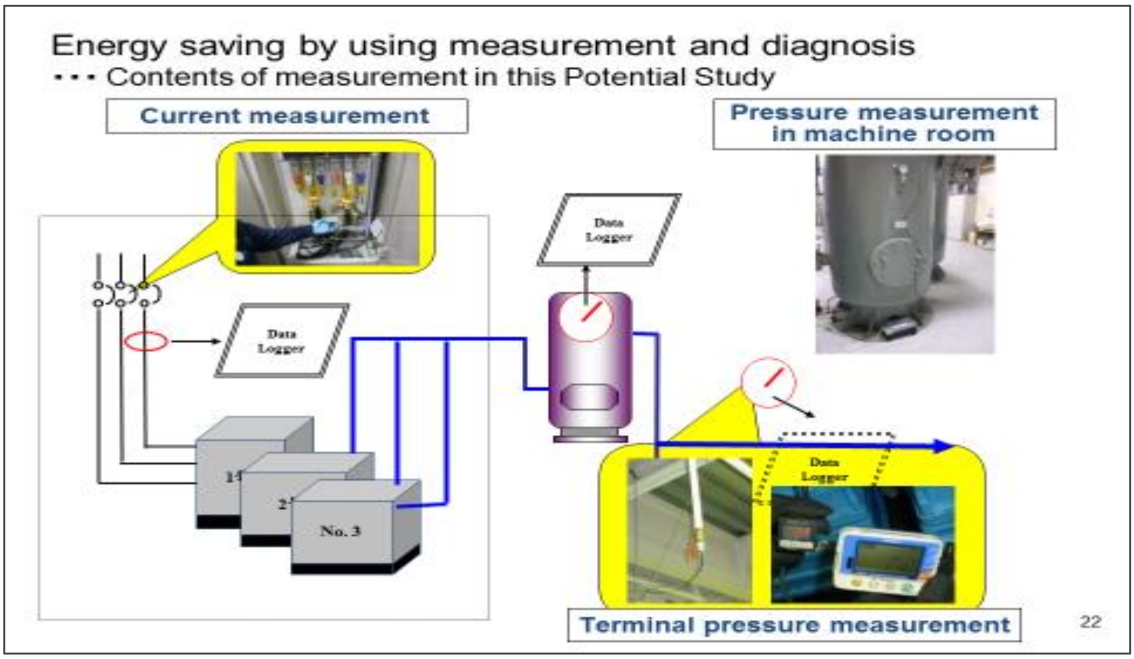
In addition, other recommendations were made to the plant to improve the energy efficiency of their compressed air systems. These recommendations are summarised below.

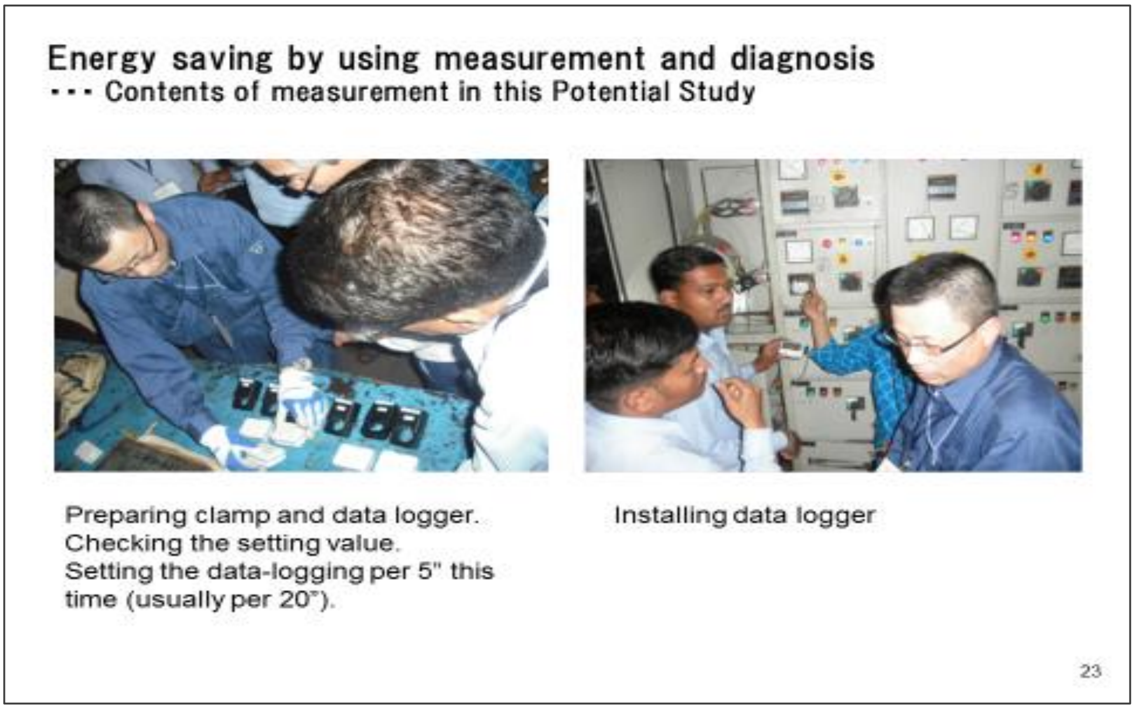
- Adjust the environment – (i) fresh, cold & dry air intake, (ii) installation of drain water processor
- Improvements in piping layout
- Implementation of ventilation measures
- Visual inspection of the receiver tank
- Energy monitoring system

(3)-7 Otherrecommendations on CO_2 reduction through energy monitoring

Necessity of monitoring energy usage state constantly for the continuous improvement with the amount of use energy in the factory has already described in (2)-7. This is recommended to all six investigation sites as a common issue. The example cases of energy saving proposal which utilised measurement and diagnosis are introduced.

［Case ① : Bombay Dyeing Ltd. (Textile)］

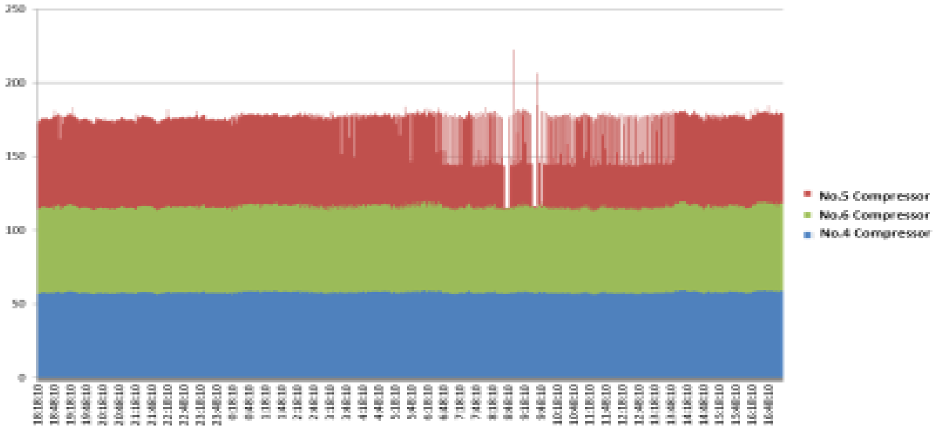




Energy saving by using measurement and diagnosis

・・・Contents of measurement in this Potential Study

The following graph indicates piling of the current values of 3 compressors.
A load has become higher which is different from the one of last year.
The load fluctuation time is also clear.
The calculation result of the effect by introducing the inverter-type compressor was 7.9kW.
The annual energy-saving effect was 60,830kWh, and 56Ton in CO_2 conversion.
The load fluctuation isn't always right because it was measured in holiday.



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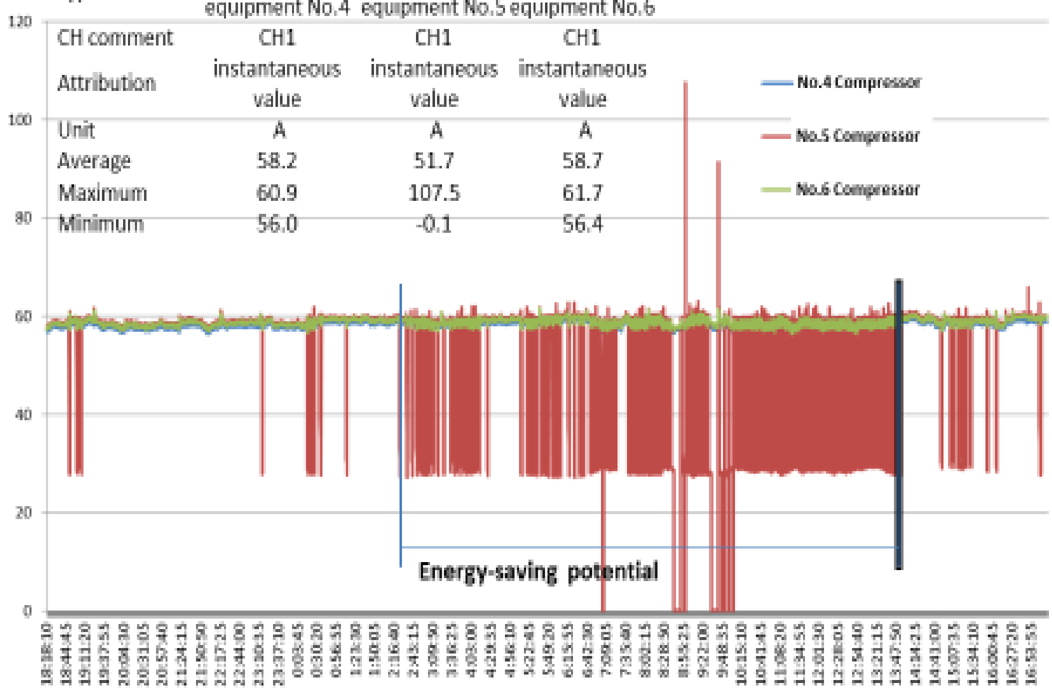
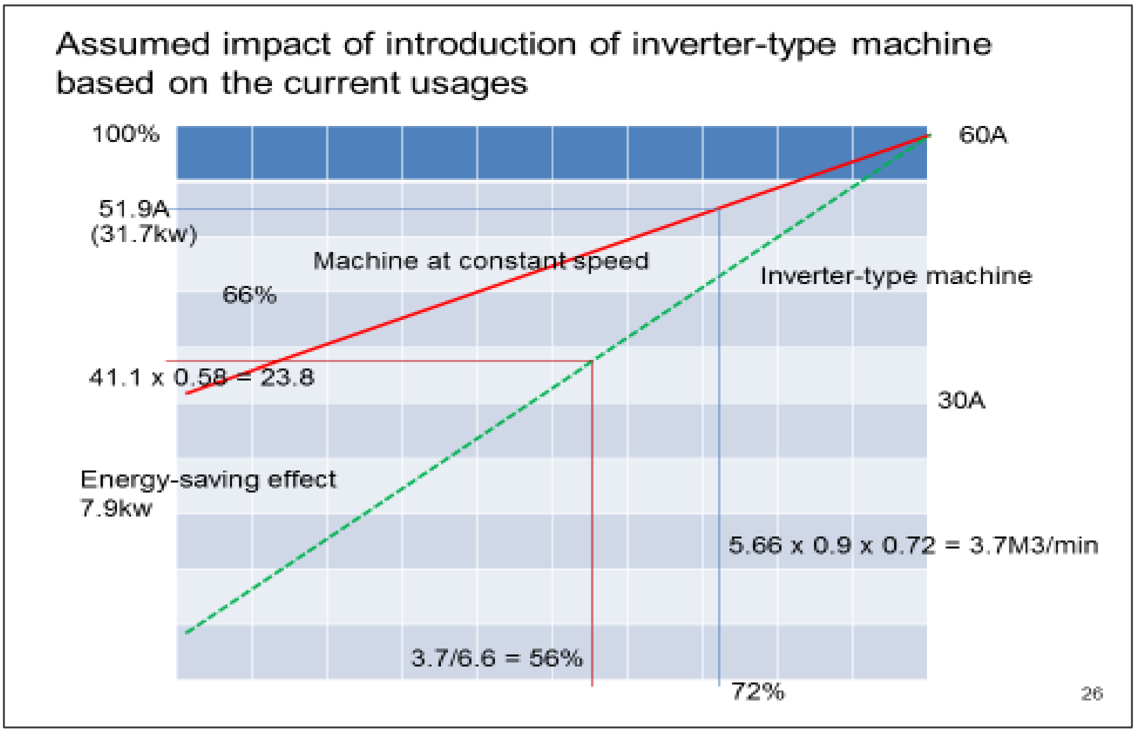
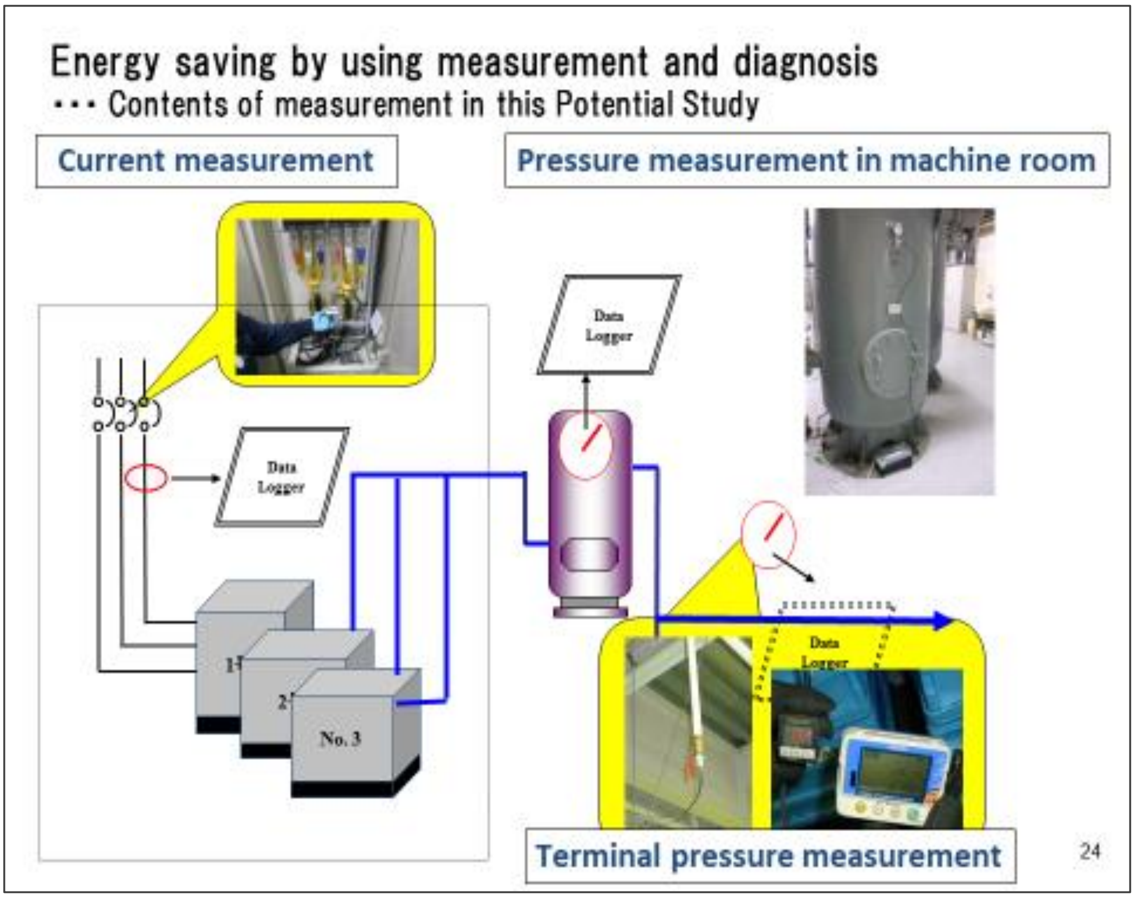


Type comment	Measuring equipment No.4	Measuring equipment No.5	Measuring equipment No.6
CH comment	CH1	CH1	CH1
Attribution	instantaneous value	instantaneous value	instantaneous value
Unit	A	A	A
Average	58.2	51.7	58.7
Maximum	60.9	107.5	61.7
Minimum	56.0	-0.1	56.4

25



［事例②：　Ahmednagar Ltd. (Forging)］



Energy saving by using measurement and diagnosis
・・・Contents of measurement in this Potential Study

Retrofitted SULLAIR LS-20S
No support for load variation
There is a problem with setting and the response of the pressure.
Load factor remains around 80% in the measurement.

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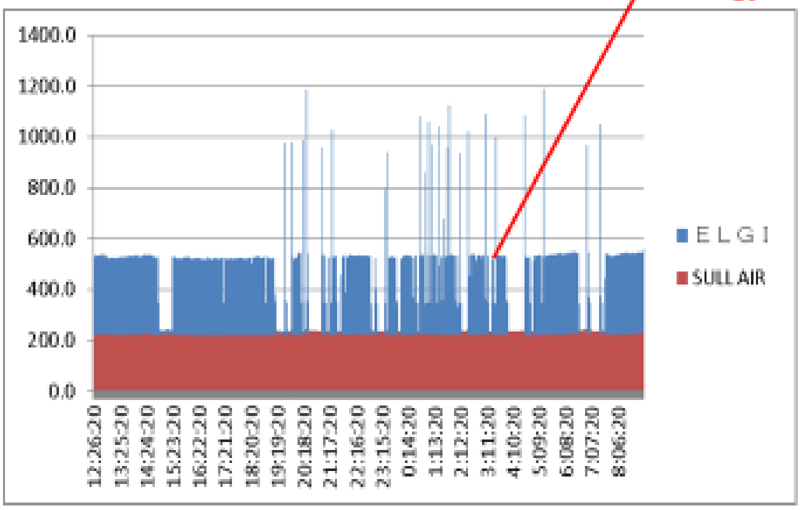
AHMEDNAGAR FORGINGS LIMITED
(ELGI current fluctuation)

Improving can be expected in this area.
Large potential for energy saving



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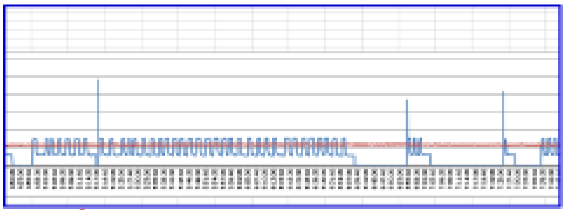
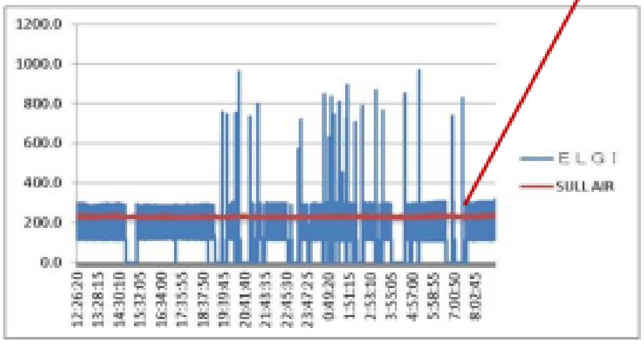
AHMEDNAGAR FORGINGS LIMITED
(ELGI current fluctuation)

Model comment	Measurement Devise No.1	Measurement Devise No.2
CH comment	CH1	CH1
Property	Instantaneous value	Instantaneous value
Unit	A	A
Average	185.6	229.8
Max.	968.8	247.3
Min.	0	217.8





It is not loaded state, just switching "ON-OFF". Unnecessary operation.

Power consumption can be calculated from the average current.

・ELGI2
185.6A x 400V x 1.73 x 0.89 ÷ 1000
= 115.6kW

・SULLAIR
229.8A x 400V x 1.73 x 0.9 ÷ 1000
= 143.1kW

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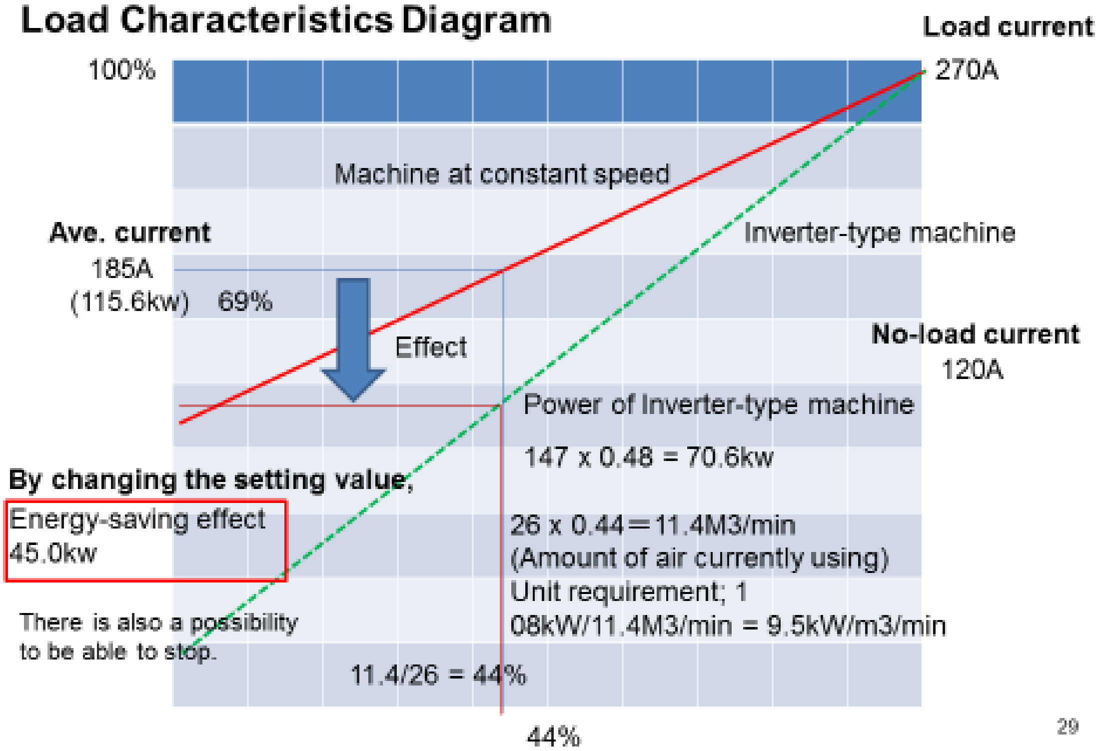
Calculating Energy-saving Potential from Load Characteristics Diagram



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(4) Workshop

Date & Time	October 11th, 2014　9:30 ~ 15:00
Place	Pune, Maharashtra state, India
Host organizer	IGES・TERI (Co-host)
Cooperated by	Maharashtra Energy Development Agency (MEDA), India
Number of participants	55

An awareness workshop on 'Energy Efficient Japanese Technologies and Best Practices in Compressed Air System' was organised on 11th October 2014, at Courtyard Marriott, Pune by TERI and Institute for Global Environmental Strategies (IGES), Japan in collaboration with Maharashtra Energy Development Agency (MEDA). About 45 participants from government, industry, consultancy agencies and donor organisations attended the event. A summary of the deliberations at the workshop is presented below.

Mr. Chetankumar Sangole, TERI welcomed the Japanese compressed air experts and other delegates to the event. He also gave an overview of the activities being undertaken by TERI and IGES to disseminate Japanese energy efficient technologies among industry in India.

Mr. Hemant Patil, MEDA gave the inaugural address. He mentioned that Japan is well known for energy efficient technologies and hence such bilateral cooperation will be of great mutual benefit. MEDA provides support for energy audit studies and also gives financial assistance for implementation of energy efficiency projects. He urged the units to conduct energy audits and take the help of organisations like TERI for energy efficiency improvements.

Mr. Prosanto Pal, TERI gave an overview of the proposed bilateral 'Joint Crediting Mechanism (JCM)', between India and Japan and mentioned that the mechanism would provide a good opportunity for financing of new energy efficient Japanese technologies for adoption in India. He also mentioned about TERI’s activities among forging units in Pune cluster under the World Bank-GEF program.

Dr. Rabhi Abdessalem, IGES made a presentation on the ALCT project, undertaken by IGES and TERI with support from JICA/JST. Under the project, hard technologies like Gas Heat Pump (GHP) and Electric Heat Pump (EHP) and soft technologies in compressed air and induction furnaces were demonstrated among SMEs in India. In future, the JCM scheme can be used to implement low carbon Japanese technologies in India and support under Climate Technology Centre and Network (CTCN) of UNFCCC can also be explored.

Mr. Tsukasa Saito, Hitachi Industrial Equipment System, Japan made a presentation on ‘Best Practices in Compressed Air Systems’. He mentioned that the air compressor consumes between 20-40% of the total energy in many industries. Typically, in an air compressor’s life cycle, cost of operation (energy) is 84%, capital cost is 7% and maintenance cost is 9%. He highlighted the need to reduce the consumption of compressed air and reduce the compressed air generation pressure wherever possible before optimizing the air compressor itself. He emphasised various areas which are important for efficient operation of air compressors such as pipe sizing, reducing unloading time, reducing the use of valves, epoxy coating of air receiver, providing drain valves, proper sizing of filter and air dryer, closed loop system, use of two stage compressor, use of invertor compressor, proper sizing of air receiver, use of exhaust ventilation ducts, use of nozzles and many such measures.

[Workshop Agenda]

Awareness Workshop
Energy efficient Japanese technologies and best practices in Compressed Air System

Venue:
Courtyard Marriott, Pune

Date:
October 11, 2014 (Duration: 9:30 am – 3:00 pm)

Tentative Agenda

09:30 – 10:30 am	**Registration & Tea**	
10:30 – 10:45 am	**Welcome Address**	**Mr. Chetankumar Sangole,** The Energy and Resources Institute (TERI), India
10:45 – 11:15 am	**Overview of TERI-IGES Project**	**Mr. Prosanto Pal,** The Energy and Resources Institute (TERI), India **Dr Abdessalem RABHI,** Institute for Global Environmental Strategies (IGES), Japan
11:15 – 11:25 am	**Inaugural Remarks**	**Mr. Hemant H Patil,** Manager, Environmental & Energy Efficiency, Maharashtra Energy Development Agency (MEDA), India
11:25 – 13:00 pm	**'Energy efficiency in Compressed Air System' – Japanese Experience**	**Mr. Tsukasa SAITO,** Senior Engineer, Air Compressor System Division, Hitachi Industrial Equipment System Co. Ltd, Japan
13:00 – 13:25 pm	**Discussion/Q & A**	
13:25 – 13:30 pm	**Vote of Thanks**	**Mr. Kailash Tarde,** The Energy and Resources Institute (TERI), India
13:30 pm	**Lunch**	

[List of participants]

Awareness Workshop
Energy efficient Japanese technologies and best in Compressed Air System

Hotel Courtyard Marriott, Pune
11th October 2014, 9:30 am – 3:00 pm

S. No.	*Name*	*Organization*
1.	Mr Ramesh Shinde	Bombay Dyeing, Pune
2.	MrSameer D Boid	Benteler Automotive, Pune
3.	Mr Vivek Gore	Burckhardt Compression, Pune
4.	Mr Atul S Kakad	Mandhana Industries Ltd, Mumbai
5.	Mr Subhash S Yewale	Bharat Forge Ltd, Pune
6.	Mr M M Deepan	Kumars Autotech (Pune) Pvt Ltd, Pune
7.	Mr Adinath Funde	University of Pune
8.	Mr Deepak Dhami	Ranvik Auto, Pune
9.	Mr Mukesh F Chavan	Echjay Industries Pvt Ltd, Rajkot
10.	Mr N M Bhairagond	Hightemp Furnaces Ltd, Pune
11.	Mr S N Bansode	Indoswe Engineers Pvt Ltd, Pune
12.	Mr D T Patil	Indoswe Engineers Pvt Ltd, Pune
13.	Mr Jitendra Lakhotia	Aakar Foundry Pvt Ltd, Pune
14.	Mr Sunilkumar Nair	Aakar Foundry Pvt Ltd, Pune
15.	Mr S R Rane	Mahindra Hinoday Industries Ltd, Pune
16.	Mr Sanjay S Bhandari	Aum Prasad Casting (P) Ltd, Pune
17.	Mr Shalak Gandhi	MCCIA (Deputy DG), Pune

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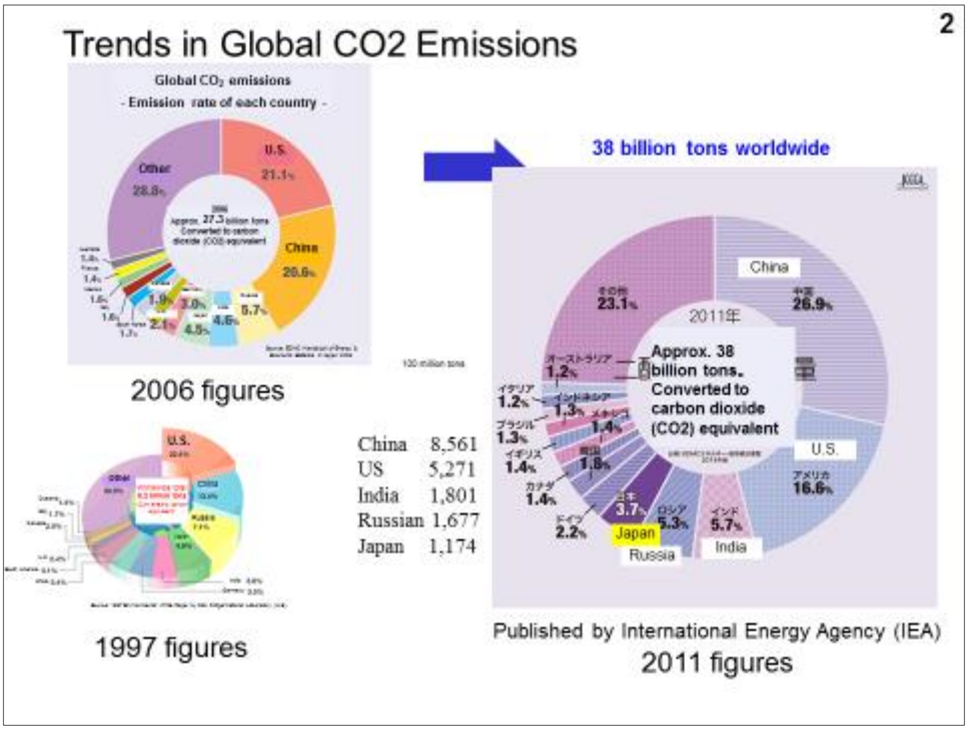
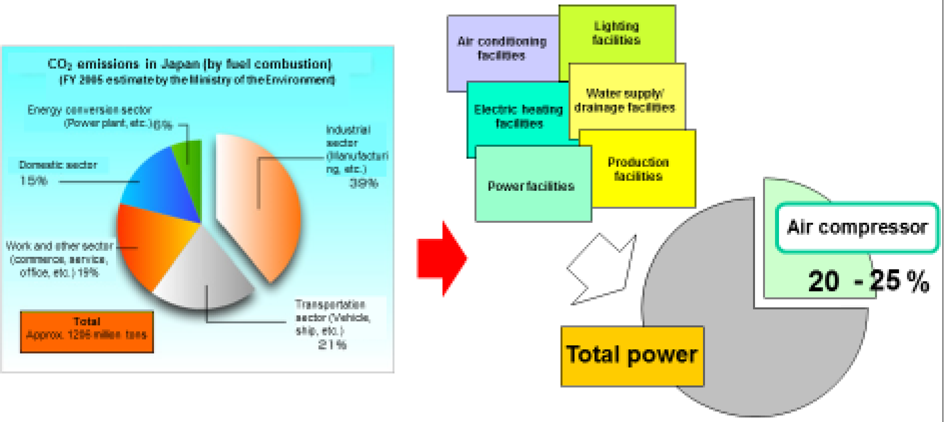
S. No.	*Name*	*Organization*
18.	Mr Sham Jadhav	Mas Die Casting, Pune
19.	Mr Kisan Sagaokar	Mas Die Casting, Pune
20.	Mr Raju Nagabandi	Subros Ltd., Pune
21.	Mr Shantanu Pathak	ENCON Pvt Ltd, Pune
22.	Mr Nilesh Zaware	ENCON Pvt Ltd, Pune
23.	Mr Kadam K G	Western India Forgings, Pune
24.	Mr S P Ranade	S P Ranade Associates, Pune
25.	Mr Swapnil Gaikwad	Green Flame Pvt Ltd, Pune
26.	Mr Kalim Khan	Raymond UCO Denim Pvt Ltd, Yavatmal
27.	Mr Yogesh Bondre	Raymond UCO Denim Pvt Ltd, Yavatmal
28.	Mr Kushal Trivedi	Arvind Ltd, Ahmedabad
29.	Mr Ratnakar Chaudhari	Poona Forge, Pune
30.	Mr Abhijeet R Chavan	Kalyani Forge Ltd, Pune
31.	Mr Shashi Kant	The Word Bookshop, Pune
32.	Mr Ashpak Shaikh	The Word Bookshop, Pune
33.	Mr VishweshKhadilkar	Bombay Dyeing, Pune
34.	Mr Sumant Naik	Amtek, Pune
35.	Mr Arif S Shaikh	Hightemp Furnaces Ltd, Pune
36.	Mr PrasunPandy	Shakti Sustainable Energy Foundation, Delhi
37.	Mr Umakant Pande	MEDA, Pune
38.	Mr Inderjitsingh Rana	Orient Auto Pressings, Pune
39.	Mr Sunil Checker	ACE Engineers

S. No.	*Name*	*Organization*
40.	Mr S A Patil	MEDA, Pune
41.	Mr Anil Javalkar	PFPL, Pune
42.	Mr Shivaji B Patil	ITPL-Vesan Engg, Pune
43.	Mr I M Sayad	ITPL-Vesan Engg, Pune
44.	Prafull Mokashi	Ex-AIFI secretary
45.	Chetan kumar Sangole	TERI
46.	Prosanto Pal	TERI
47.	Vivek Sharma	TERI
48.	KailashTarde	TERI
49.	Nilesh Shedge	TERI
50.	AshishSakhare	TERI
51.	HemantPatil	MEDA
52.	Dr.AbdessalemRabhi	IGES
53.	TsukasaSaito	Hitachi-IGES
54.	Akio Yoshizaki	Hitachi-IGES
55.	Meghna Joglekar	Kakehashi Services Pvt Ltd

[Presentation (Compressed air system)]



Energy Consumption in Japan



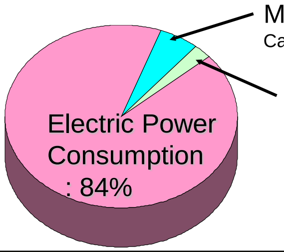
Energy consumed for the industrial sector (factories) accounts for approximately 40% of the total energy consumption in Japan.
It is considered that approximately a quarter of that amount is used by compressors.
In addition, compressors are regarded as machines whose energy consumption can be reduced 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.

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



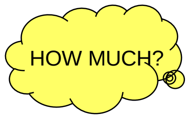
Maintenance: 9%
Carry out periodical maintenance.

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

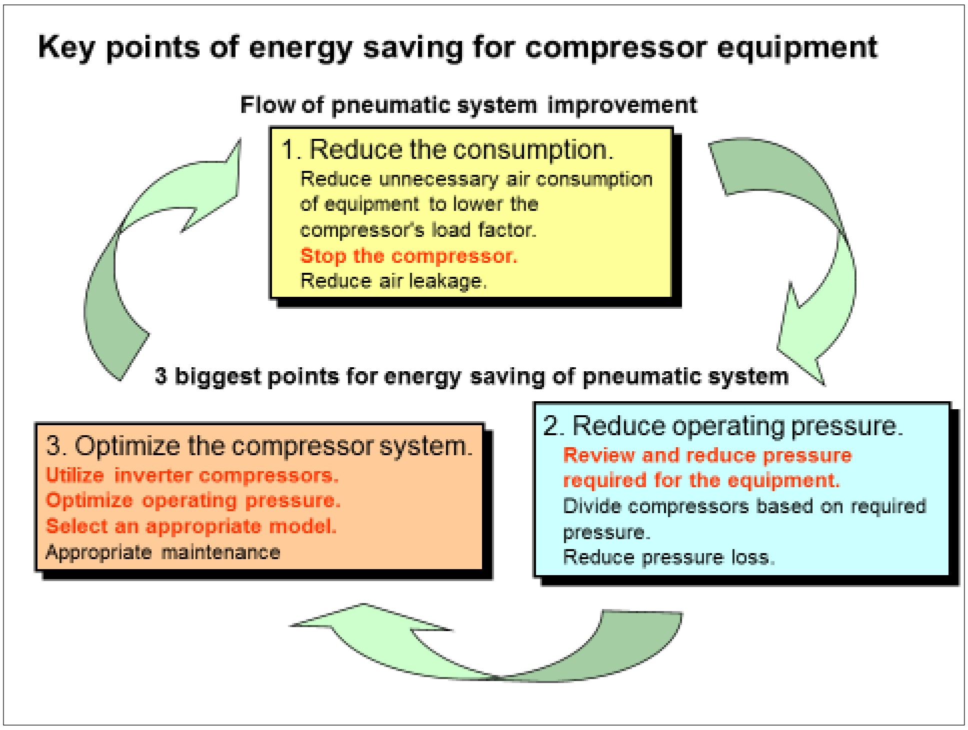
If average air consumption decreased by 70%, electricity cost decreased by 70%.

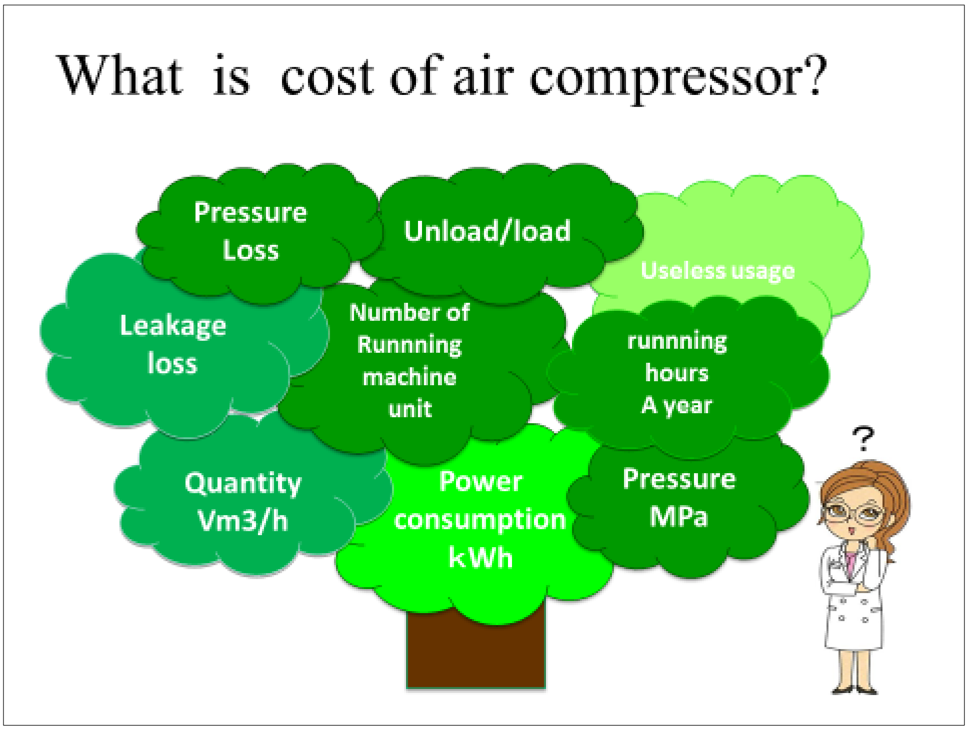
Specific Energy Consumption

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



$$\text{Energy cost } (\text{¥/m}^3) = \frac{\text{Power input (kWh)} \times \text{Electricity cost (¥/kWh)}}{\text{FAD (m}^3\text{/min)} \times 60 \text{ (min)}}$$


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.
3 biggest points for energy saving of pneumatic system
3. Optimize the compressor system.
Utilize inverter compressors.
Optimize operating pressure.
Select an appropriate model.
Appropriate maintenance
2. Reduce operating pressure.
Review and reduce pressure required for the equipment.
Divide compressors based on required pressure.
Reduce pressure loss.


What is cost of air compressor?
Pressure Loss
Unload/load
Useless usage
Leakage loss
Number of Runnning machine unit
runnning hours A year
Quantity Vm3/h
Power consumption kWh
Pressure MPa
?

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

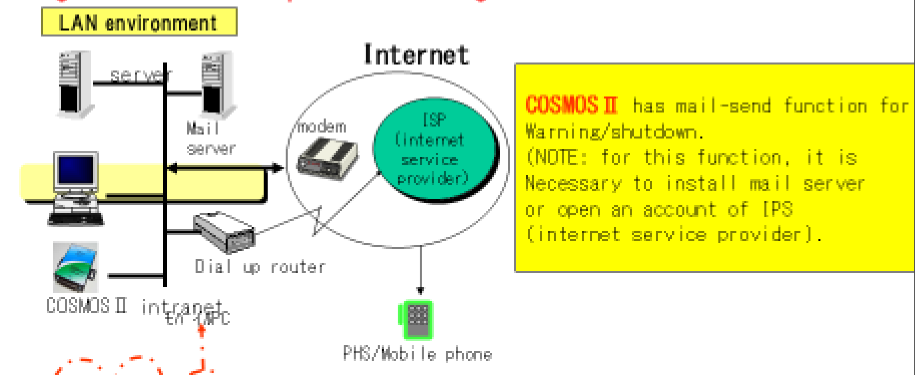
1. Making better capacity control (use the efficient machine)
2. Make efficient use of equipment
3. Appropriate pipe diameter and length=down compressed air speed
4. Counter measurement of leak

7

8

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.



Other monitoring system with WEB controller remote monitoring service for important equipment is also available. 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.

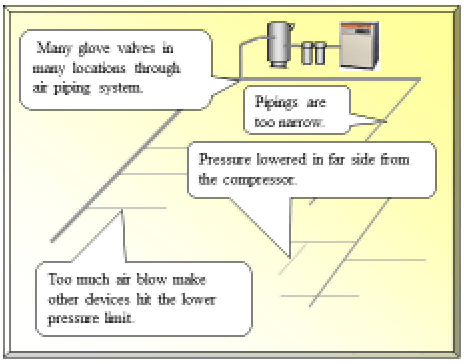
3. **Local pressurization**
   What is "booster babicon"?

1. Pressure optimization by piping system redesign.

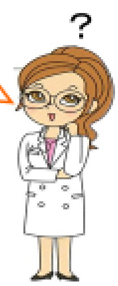
What is efficient way for local low pressure demand.
Do you have similar cases like this in your factory?

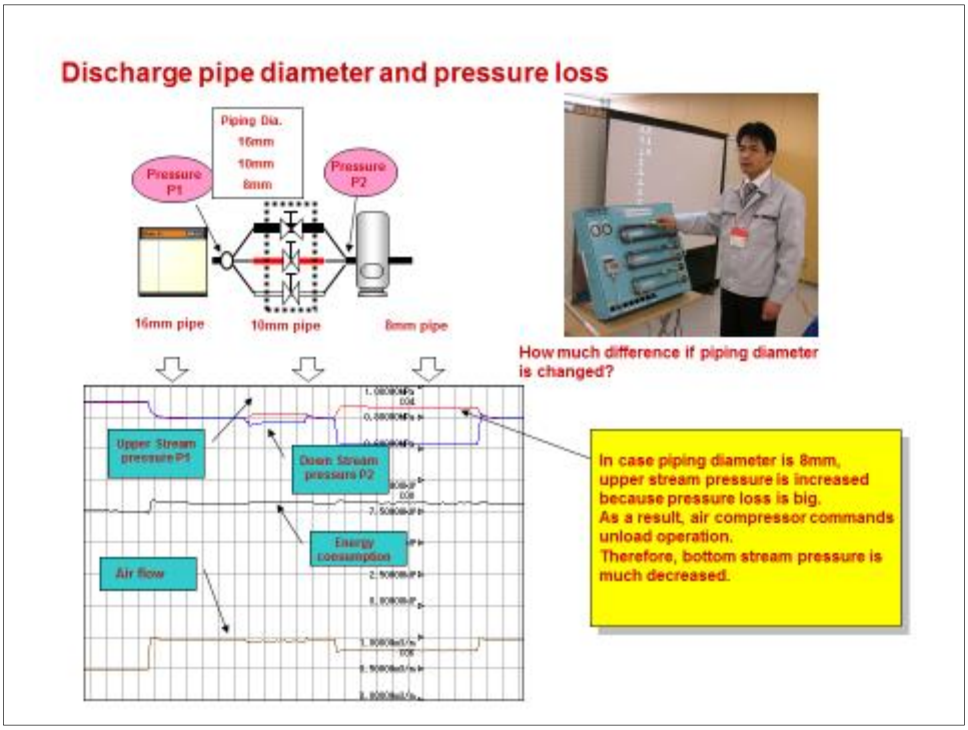
1. **Unstabilized factory air.**
   [status] pressure far side from compressor unstable.
   Pressure down when other system ON.
2. **Due to budget allowance, no uniformity on air system such as devices, pipings (size, route, valves).**

What kind of improvement in this case?



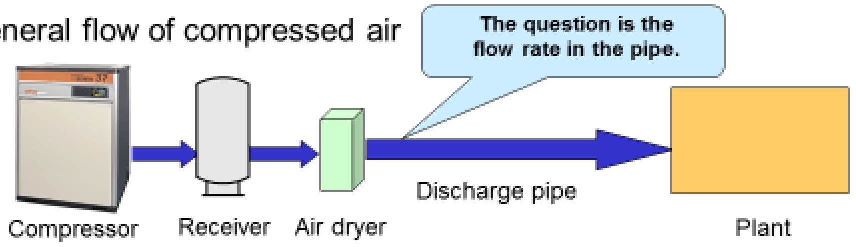
How loop piping, size, bend and valves effect proper pressure in system?





Pressure Loss through Pipe and Internal Flow Rate

General flow of compressed air



$$\text{Flow rate in the pipe. } V\ (m/s) = \frac{Qs \text{ Compressor's discharge air volume} \times Ps/Pd}{A \text{ Sectional area of discharge pipe} \times 60}$$

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

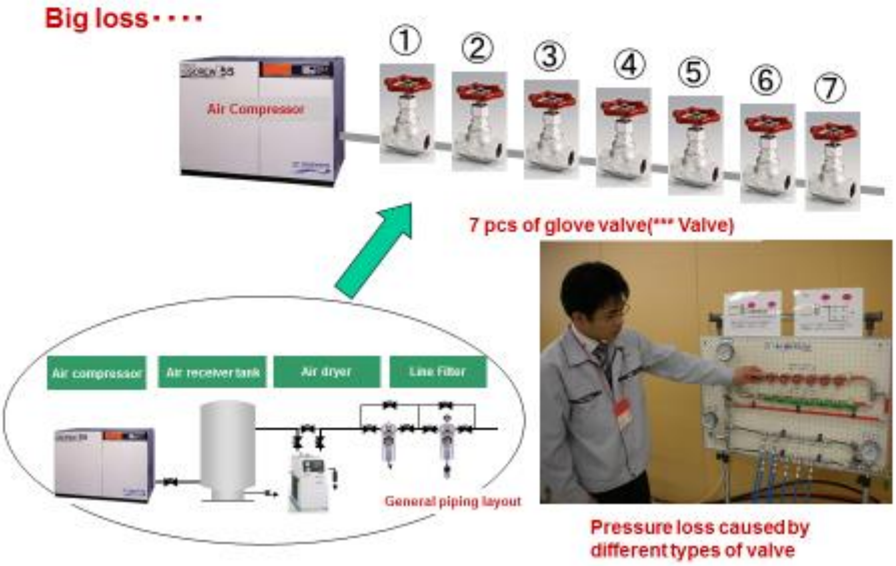
The smaller the pipe size, the higher the flow rate, causing a larger loss in the pipe. Accordingly an energy loss is generated, reducing the energy-saving effect.

* 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 x 0.101 / (0.101 + 0.69) ÷ 0.05 ÷ 0.05 ÷ 3.14 / 4 ÷ 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



Pressure loss caused by different types of valve

Contents of Improvement Measures - Examination of Piping Work

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.

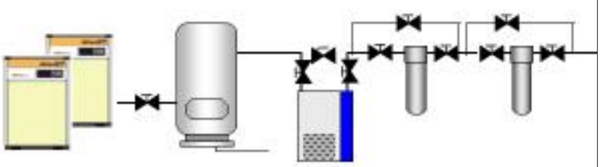
Examples of recommended piping

Provide a drain plug for a riser pipe.

Recommended collecting pipe

Riser pipe installed from above

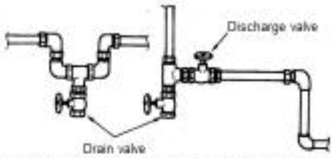
Large-bore pipe and receiver tank with adequate capacity

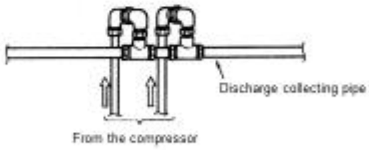


Recommended equipment and pipe flow

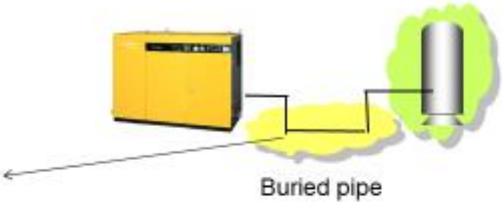
Notes for Piping Work

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

Review this piping !! Easy for energy saving!!

Narrow piping
Complicated piping
Many partition piping

Energy saving effect 11%

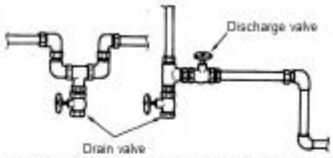
405,000kwh => 360,450kwh (improvement)

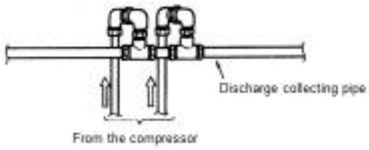
OSP-75D5ALI

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)

Notes for Piping Work

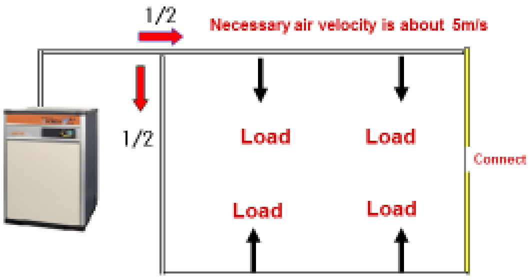
1. Be sure to provide a drain connection for a riser pipe. Installation to a collecting pipe must be made from above to prevent backflow. (Similarly, branch pipes must be installed from above.)
2. For a collecting pipe, give an inclination (1/100) from the upstream to the downstream. Attach a drain plug at the end of each pipe.





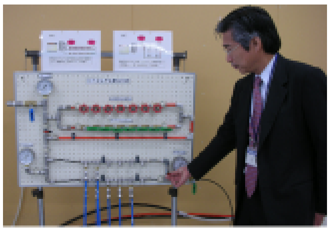
3. Buried piping makes it difficult not only to detect air leakage but also to repair. Therefore above-ground piping must be adopted. If buried piping is inevitable, install the pipes in a pit.

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!



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.

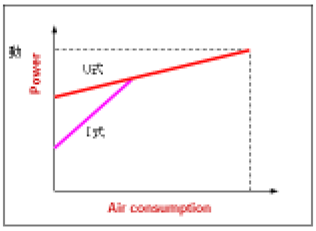
1.Air compressor's control commands unload operation frequently.

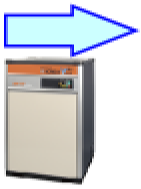
2.There are big gap of air consumption in specific period, and facilities run all day.

3.Air pressure is fluctuating frequently even if small amount of air is used. (unstable)

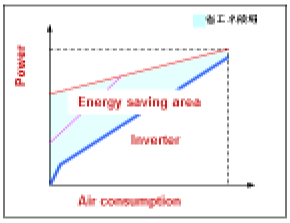
Improve on air compressor with variable speed control operation (inverter).

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.





Apply to variable speed control (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 110MW/y

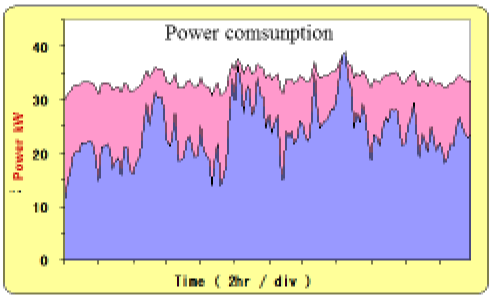
■Other effectiveness

・CO2 reduction (▲34%) for environment protection

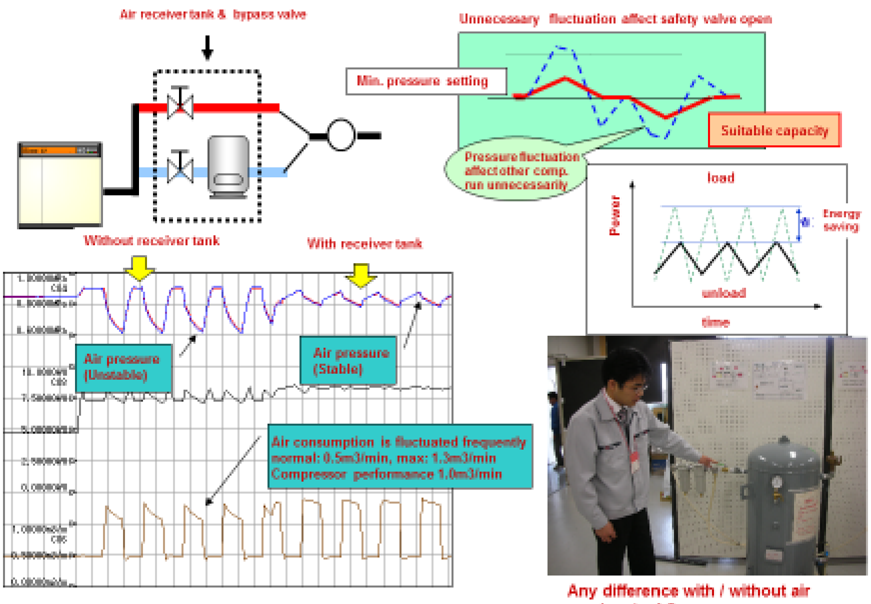
・Peoridical overhaul and parts durability last long (per 8 years)

・Maintenance cost is reduced 30%

(our company calculation)



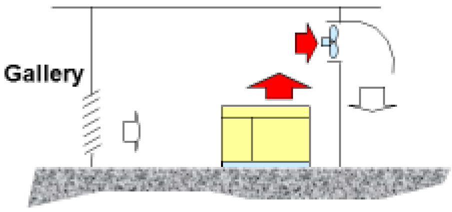
Effect of receiver tank if pressure fluctuation is frequently



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** (m^3/min)

H: **Amount of heat produced per unit** (MJ/h)

(1 kW = 3.6 MJ/h)

n: **Number of units installed**

T: **Allowable temperature increase**

(When outside temperature is 35 ℃, compressor's allowable maximum temperature is 40 ℃, ΔT = 40 - 35 = 5 ℃)

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

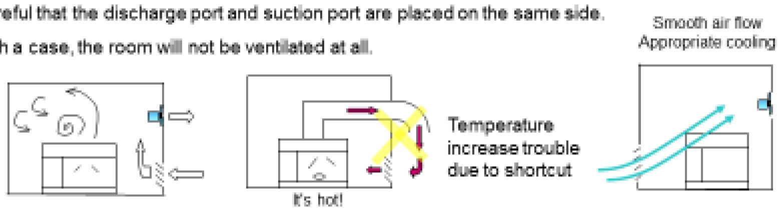
- Install the fan high on the wall of the compressor room.
- When using a rain hood, take resistance into consideration when selecting a ventilating fan.

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.

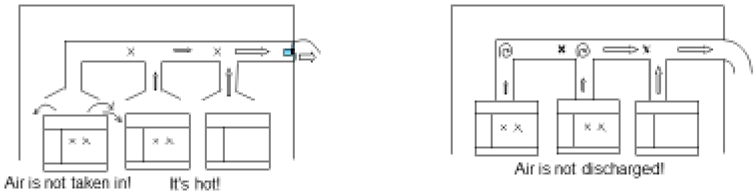


Be sure to provide a separate discharge duct for each compressor. Do not share a discharge duct for 2 or 3 compressors.

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.

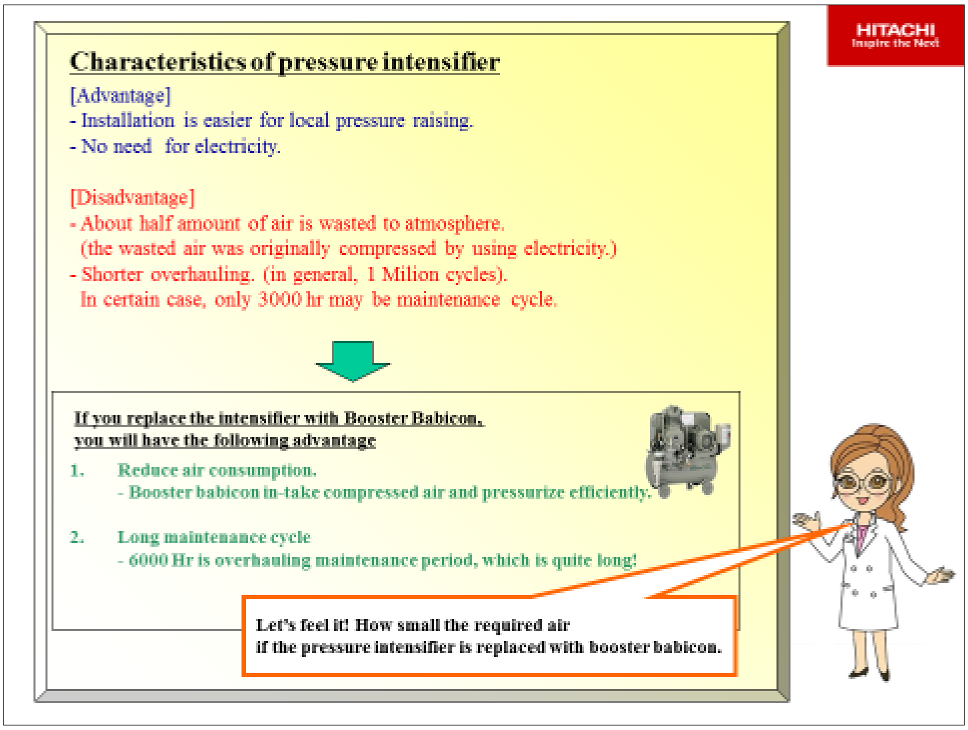


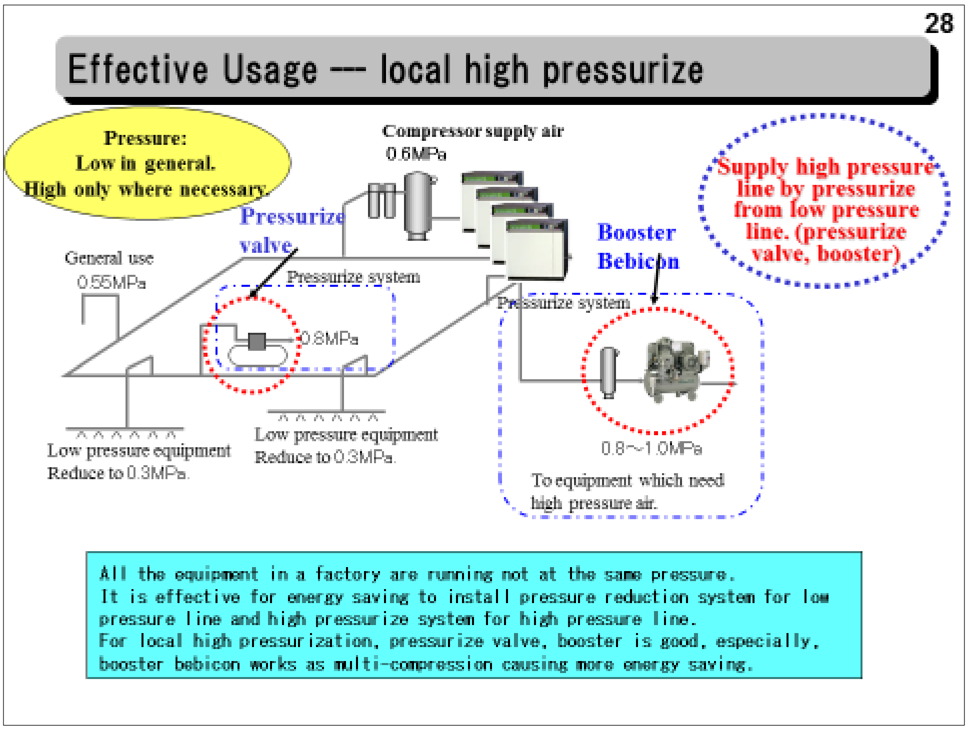
3. Improvement local pressurizing

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.**


HITACHI
Inspire the Next
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 Milion 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.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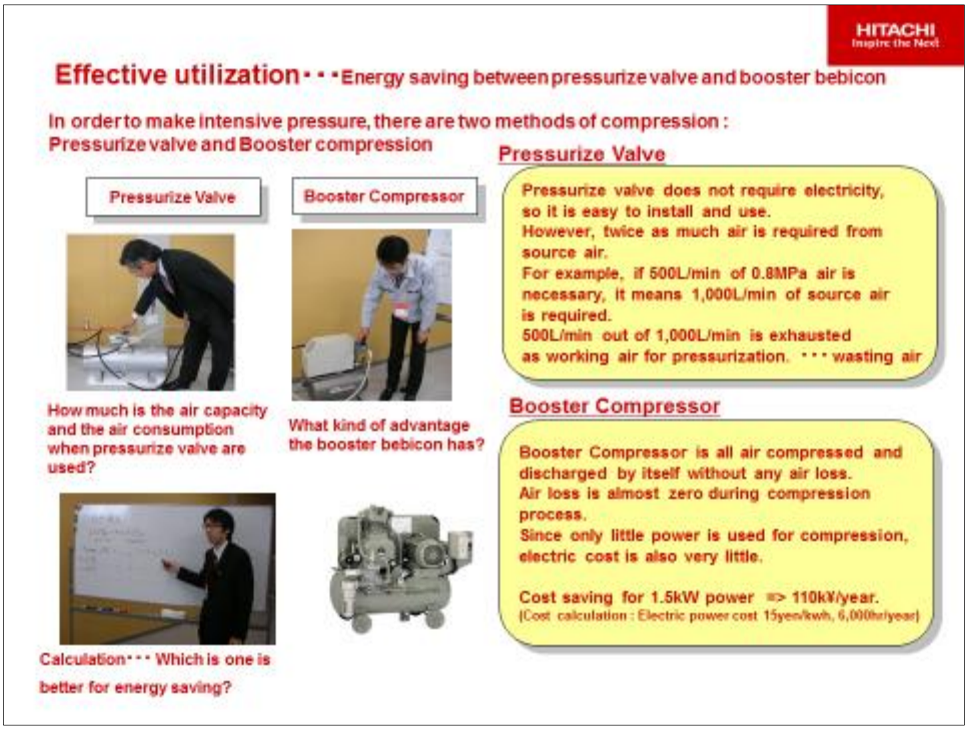
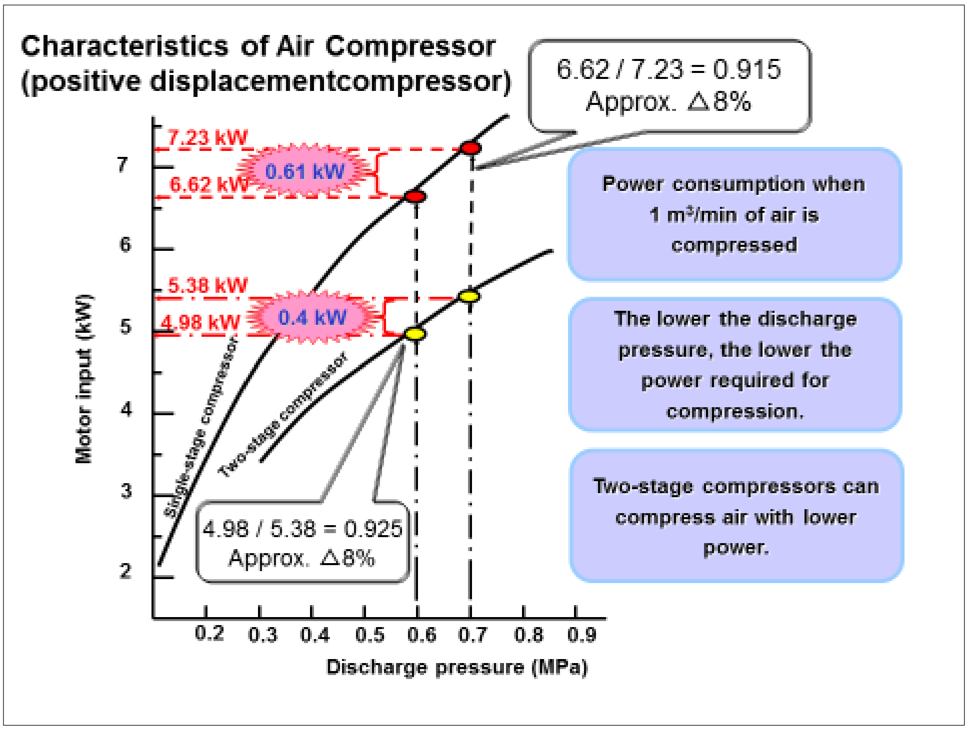
Effective Usage --- local high pressurize
Pressure:
Low in general.
High only where necessary.
Compressor supply air
0.6MPa
Pressurize
valve
Booster
Bebicon
Supply high pressure
line by pressurize
from low pressure
line. (pressurize
valve, booster)
General use
0.55MPa
Pressurize system
0.8MPa
Pressurize system
0.8~1.0MPa
Low pressure equipment
Reduce to 0.3MPa
Low pressure equipment
Reduce to 0.3MPa
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.


HITACHI
Inspire the Next
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
Booster Compressor
How much is the air capacity and the air consumption when pressurize valve are used?
What kind of advantage the booster bebicon has?
Calculation・・・Which is one is better for energy saving?
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)


Characteristics of Air Compressor
(positive displacementcompressor)
6.62 / 7.23 = 0.915
Approx. △8%
7.23 kW
6.62 kW
0.61 kW
5.38 kW
4.98 kW
0.4 kW
Single-stage compressor
Two-stage compressor
4.98 / 5.38 = 0.925
Approx. △8%
Motor input (kW)
7
6
5
4
3
2
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Discharge pressure (MPa)
Power consumption when 1 m³/min of air is compressed
The lower the discharge pressure, the lower the power required for compression.
Two-stage compressors can compress air with lower power.

Example of effective air blow・・・・How much effect?

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

Brow gun

When air blow pressure made high・・・・

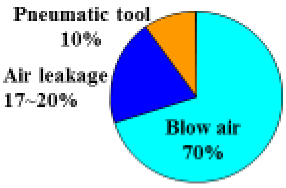
Even if pressure reduction is made, air blow contacting pressure is the same as before and after.

Shapes of nozzle promote air blow different

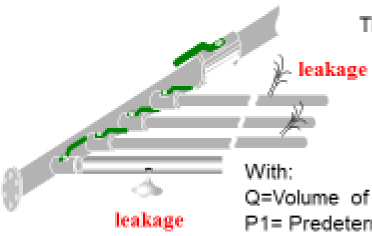
leakage

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:

$$Q = \frac{(P1 - P2) \times V}{Po(1.033) \times T}$$

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)
Po= 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 M^3 = 1.8 yen)
200 ÷ 1000 x 60 x 8000 hrs/yr x 1.8 yen/kWh = 172, 800 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

Note that a leakage often occurs at valves and joints.

(3) Leakage from an internal component of a device

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. 4L/min

point:air gun
49. 2L/min

point:hoses
59. 4L/min

point:hose joint
59. 4L/min

point:regulator
71. 7L/min

point:coupler
27. 7L/min

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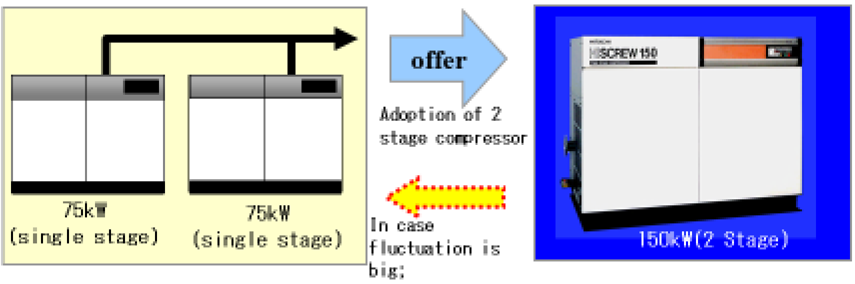
Adopt 2 stage compressor with higher efficiency

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.)



	75kW x 1 unit	75kW x 2 unit	150kW x 1 unit
Input power kW	81.0	162.0	160.0
Air Delivery m³/min	12.4	24.8	28.5
Specific power kW/(m³/min)	6.53	6.53	5.61

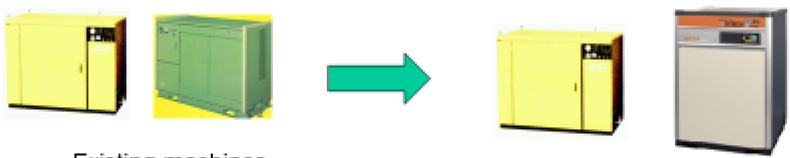
16% improvement in Specific power!!!

※ Specific power = Input power ÷ Air delivery

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.

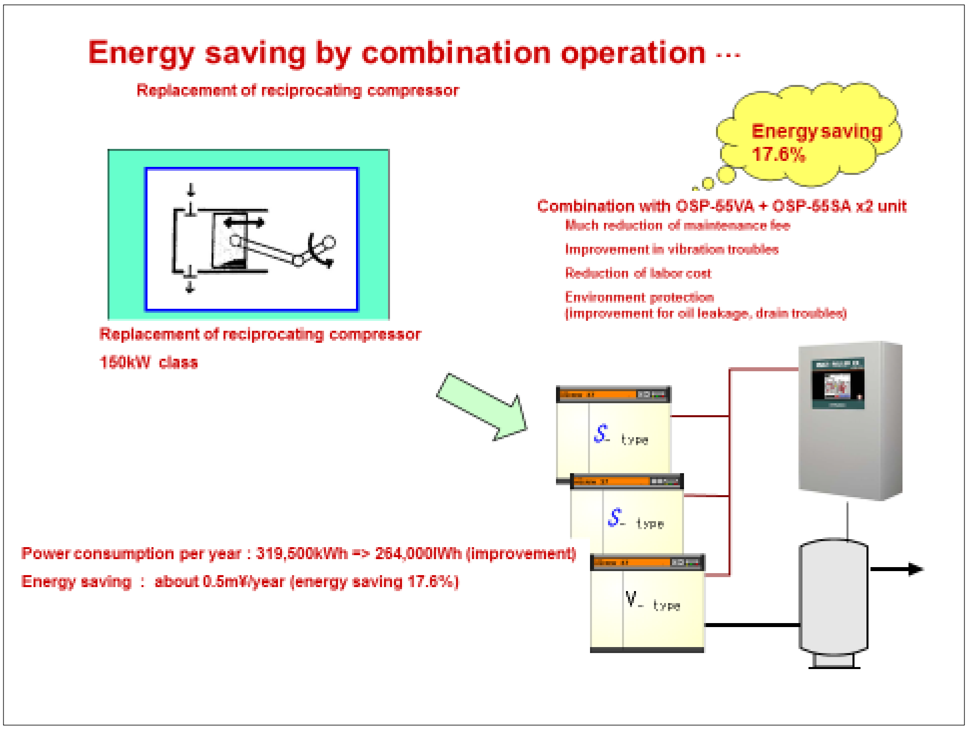


Existing machines

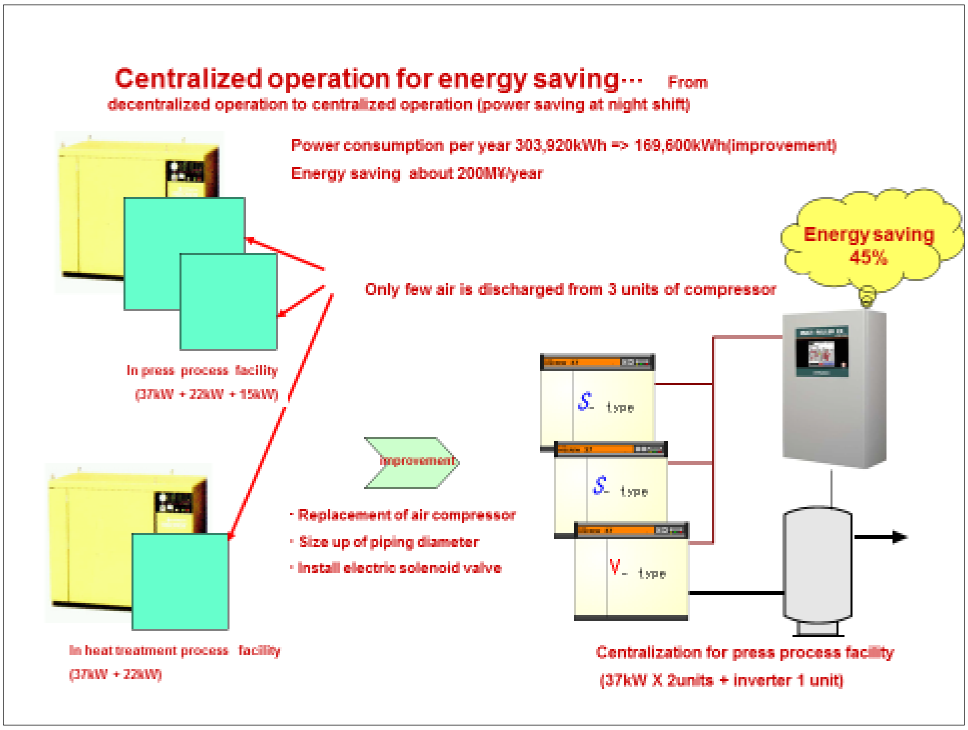
There was a need of energy saving.

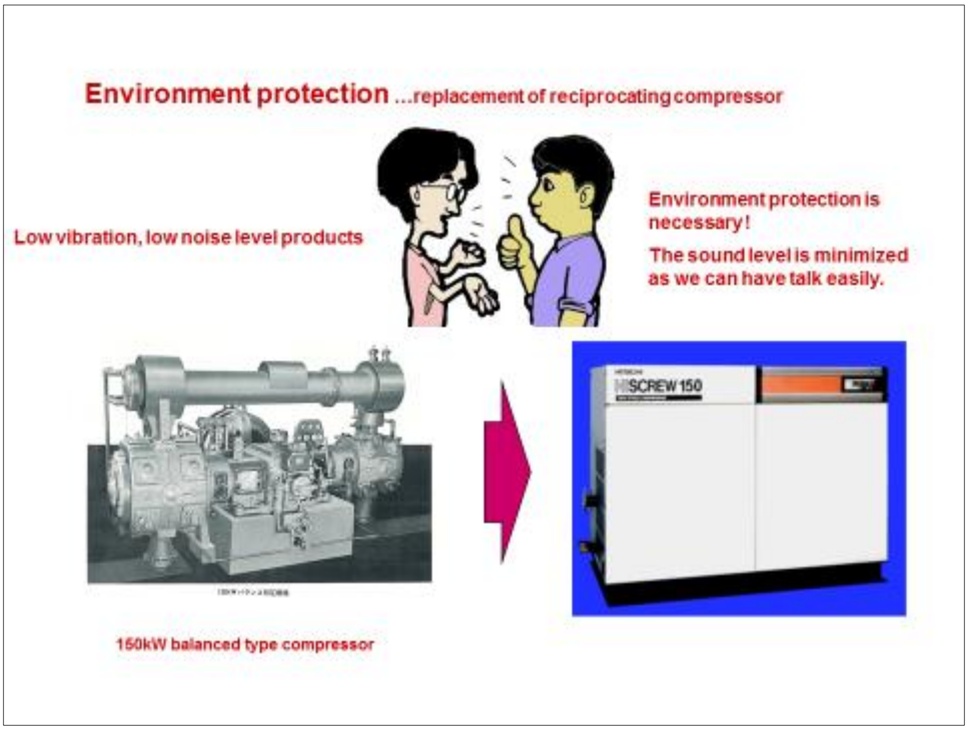
Replacement machines

The highly-efficient inverter was operated as a base machine.


Energy saving by combination operation …
Replacement of reciprocating compressor
Energy saving
17.6%
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)
Replacement of reciprocating compressor
150kW class
S- type
S- type
V- type
Power consumption per year : 319,500kWh => 264,000lWh (improvement)
Energy saving : about 0.5m¥/year (energy saving 17.6%)


Example of separate operation
OS-160U5
100kW electric power was kept consuming
=> Average 54kW of power is saved
Energy saving
45%
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
Energy saving 45%
Only few air is discharged from 3 units of compressor
In press process facility
(37kW + 22kW + 15kW)
improvement
S type
S type
V type
・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 2units + 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.
HISCREW 150
150kW balanced type compressor

Improvement of power consumption in compressor room with humid environment.

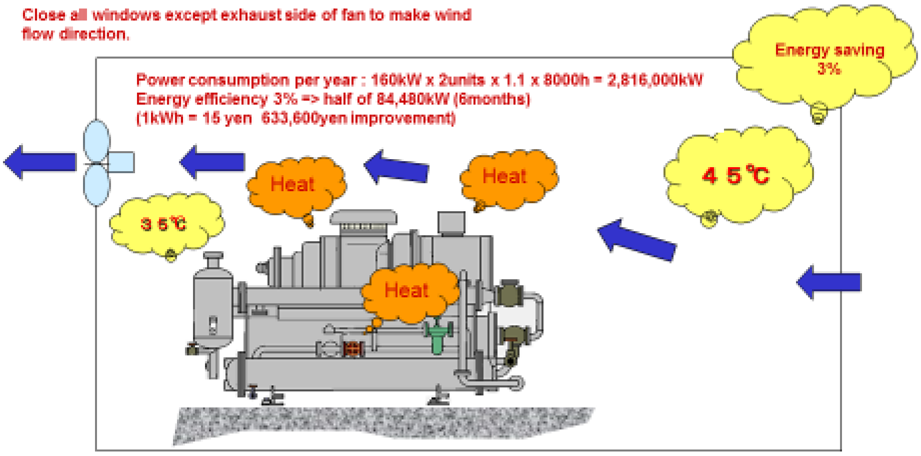
Illustration of wind flow

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℃ to 35℃

Energy saving 3%



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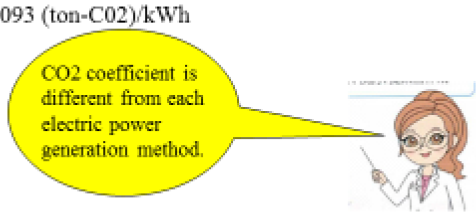
Reduction of environment load --- Verification of reduction effect of CO2 emission

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



<Eg>

15kW energy saving and 4000Hr running operation per year, then CO2 cut-out is;

15 kW x 4000h x 0.00093 (t-CO2/kWh)
= 55 ton of CO2 is reduced.

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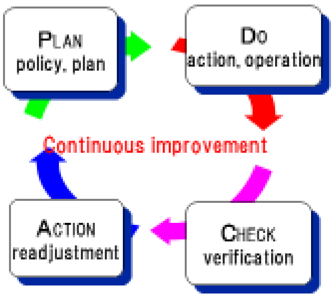
Plan and procedure of energy saving improvement

- 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 CO_2 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.

(5) MRV methodology and Project Design Document (PDD)

The energy efficient inverter based air compressor is a promising low carbon technology with good potential for uptake among Indian industries. Development of a robust MRV methodology for the technology would help in estimating the emission reduction by adoption of the technology on a case-to-case basis. Accurate MRV of carbon emissions is also useful in developing bilateral/multilateral funded projects on carbon reduction by the project participants and hence enhance the deployment and diffusion of such technologies in India.

Relevant inputs were provided to IGES on data and information related to the development of a MRV methodology. Inputs were provided by TERI, specifically with regard to the default CO2 emission factor for grid electricity in India. A default CO2 emission factor of 0.00098 has been suggested for grid electricity in India, based on “User guide” version 9.0 January 2014, CO2 baseline database for the Indian Power Sector.

(5)-1 Title of the methodology

“Monitoring, Reporting, and Verification of improving compressed air system”. Here after, CA MRV methodology.

(5)-2 Summary of the methodology

CA MRV methodology is applicable to projects that reduce GHG emissions in the reference scenario through improving existing compressed air system. While improving compressed air system could be through various measures, in this CA MRV methodology, the focus will be only on upgrading existing air compressor to inverter type air compressor.

(5)-3 Definitions of terms used in the methodology

- Reference scenario refers to the continuous use of the existing compressed air system as it is, Business as Usual (BAU).

It is assumed that the project does not involve expansion of production capacity. However; in the case of a project involving expansion of production capacity, its reference emission shall be corrected in proportion to the output or capacity expansion as indicated below.

$$CF_{output} = (P_{output} - R_{output}) / P_{output}$$

CF_{output}: Correction coefficient

P_{output}: Project output

R_{output}: Reference output

$$CRE_y = CF_{output} * RE_y$$

CRE_y : Corrected Reference Emission

RE_y : Reference emission during year y

In case of project involving expansion of production, emission reduction is calculated as follow:

$$ER_y = CRE_y - PE_y(-L_y)$$

- Project scenario refers to improving compressed air system through upgrading existing air compressor to inverter type air compressor.
- Project boundary
  The project boundary refers to:
  In order to determine GHG emission in reference scenario as well as in project scenario, the following emission sources shall be included:
  ➢Power generation plant(s) at the project site and/or the electric grid with which the site is connected.
  ➢Power consuming equipment(s).
  ➢Rooms where compressed air system is being used.
- Leakage emission
  It is assumed that the replaced old air compressor will not be used anywhere else in the site, hence, it is estimated that there is no leakage emission.

(5)-4 Eligibility Criteria

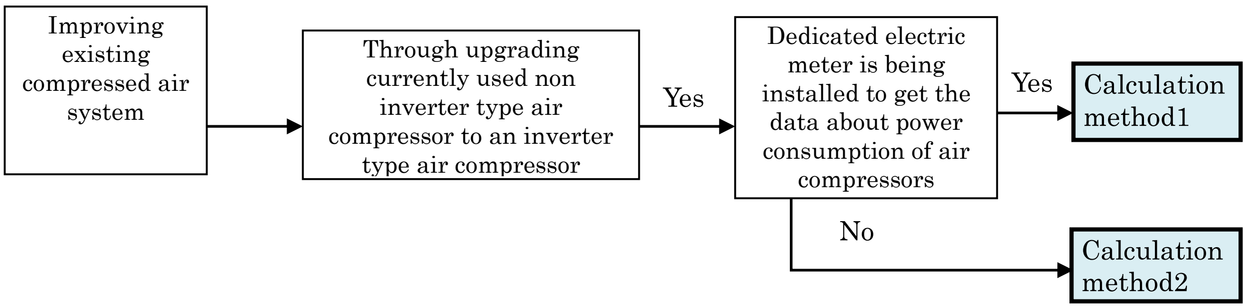
This methodology is applicable to projects that fully satisfy the following conditions.

		Check
Condition 1	The project consists of improving existing compressed air system through upgrading existing air compressor to inverter type air compressor.	☐
Condition 2	The old air compressor(s), which is being replaced with inverter type	☐

	air compressor, will not be used anywhere else in the site.	
Condition 3	Compressed air system is an important source of energy consumption in the site, hence improving it through one of the mentioned three measures results in energy saving and CO2 emission reduction (excluding retrofit).	☐
Condition 4	The energy inputs to air compressor(s) are measurable **<u>and/or</u>** based on catalogues. So catalogues of all air compressors are available.	☐
Criterion 5	Electricity in the reference and project scenarios shall be supplied by a connected grid.	☐

(5)-5 Selecting a Calculation Method

To calculate the emission reduction, project developer can select the best-suited calculation method for his/her project using the flow chart below.



More details about the calculation methodologies in the above flow chart and about the items which have to be considered in the calculation are given in the sections below.

(5)-5-1 Calculation method 1

The calculation method1 is required in the case when the currently used air compressor is being upgraded to an inverter type air compressor. The reference scenario refers to the case of using non inverter type air compressor; and the project scenario refers to the case of using inverter type air compressor. In both cases the energy inputs is assumed to be electricity. Hence the appropriate measurement tool is a dedicated electric meter.

(5)-5-1-1 Emission reduction

Emission reduction is generally calculated as follow:

$$ER_y = RE_y - PE_y(-L_y)$$

ER_y : CO2 Emission Reduction during year y (t-CO2/y).

RE_y : Reference CO2 Emission during year y (t-CO2/y).

PE_y : Project CO2 Emission during year y (t-CO2/y).

L_y : Leakage emission during year y (t-CO2/y).

In the current CA MRV methodology, the leakage emission is estimated to be null, thus, the emission reduction is calculated as follow:

$$ER_y = RE_y - PE_y$$

Given that:

$$RE_y = AEI_{yNC} * EEF$$

$$PE_y = AEI_{yIC} * EEF$$

Then,

$$ER_y = [AEI_{yNC} - AEI_{yIC}] * EEF$$

With,

AEI_{yNC} : Annual Electricity Input to existing non inverter air compressor (NC), during year y (kWh/year).

AEI_{yIC} : Annual Electricity Input to Inverter type air compressor (IC), during year y (KWh/year).

EEF : Electricity CO_2 Emission Factor (t-CO_2/kWh).

Based on the above, the monitoring and input data to calculate reference emission and project emission are given in table below:

Monitoring and input data to calculate reference emission and project emission

Description of Data	Value	Unit
Annual Electricity Input to Non inverter type air compressor (NC)		kWh/year
Annual Electricity Input to Inverter type air compressor (IC)		kWh/year
Electricity CO_2 Emission Factor		t-CO_2/kWh

Note: While data about Annual Electricity Input to Non inverter type air compressor, AEI_{yNC}, and the Annual Electricity Input to Inverter type air compressor, AEI_{yIC}, are collected using dedicated electric meter, the data about Electricity CO_2 Emission Factor, EEF, is a default value based on Indian conditions, and more specifically on the region where the project is installed in India. It can be collected from electric utility companies and/or from public values.

Monitoring parameters to calculate reference emission

Parameter	Description	Measurement procedure (e.g.)
AEI_{yNC}	Annual Electricity Input to Non inverter type air compressor (NC)	Dedicated electric meter
AEI_{yIC}	Annual Electricity Input to Inverter type air compressor (IC)	Dedicated electric meter
EEF	Electricity CO_2 Emission Factor	Public and default value of host electric utility companies

(5)-5-1-2 Calculation sheet

1. Calculation of CO2 Emission Reduction	Energy type	Value	Units	Symbol
CO2 Emission Reduction			t-CO2	ER_y
2. Default values				
Electricity CO2 emission factor			t-CO_2/kWh	EEF
3. Calculation of Reference Emission				
Reference CO2 Emission			t-CO2	RE_y
Annual Electricity Input to Non inverter type air compressor (NC)	Electricity		KWh/year	AEI_{yNC}
4. Calculation of Project Emission				
Project CO2 Emission			t-CO2	PE_y
Annual Electricity Input to Inverter air compressor (IC)	Electricity		KWh/year	AEI_{yIC}

(5)-5-2 Calculation method 2

The calculation method2 is also required in the case when the currently used non inverter type air compressor is being upgraded to an inverter type air compressor. The difference between method 1 and method 2 is only the fact that a dedicated electric meter is not being installed to concretely measure power consumption of air compressors in the reference scenario and project scenario. Power consumption of air compressors is being estimated based on catalogues/nameplate data tag, and schematic figure (default values). Thus, the difference between method1 and method2 will be only in the measurement procedure of power consumption in reference scenario and project scenario given below:

Monitoring parameters to calculate reference emission

Parameter	Description	Measurement procedure (e.g.)
AEI_{yNC}	Annual Electricity Input to Non inverter type air compressor (NC)	Catalogue/nameplate data tag, and schematic figure
AEI_{yIC}	Annual Electricity Input to Inverter type air compressor (IC)	Catalogue/nameplate data tag, and schematic figure
EEF	Electricity CO_2 Emission Factor	Public and default value of host electric utility companies

More details about how to measure Annual Electricity Input to Non inverter type air compressor, AEI_{yNC}, and Annual Electricity Input to Inverter type air compressor, AEI_{yIC}, are given below:

- Annual Electricity Input to Non inverter type air compressor, AEI_{yNC}

The power consumption of an air compressor involves several variables. The air compressor may not run under a full load of electrical power at all times. The compressor may shut off when not calling for required air pressure. The power consumption of all electrical devices is the product of voltage and amperage. Multiplying these two factors yields wattage. The third factor is time. All electric bills are calculated by kilowatt-hours (KWH), where kilo is equal to 1,000; wattage is power consumed and hours measure the duration under a given electrical load.

$$AEI_{yNC} = \sqrt{3}[OV * FLA]x0.85/1000 * AOH$$

With

OV : Operational voltage

FLA: Full load amperage

AOH : Annual Operation hours

Instruction to calculate Annual Electricity Input to Non inverter type air compressor AEI_{yNC}:

1) Install an operational hour meter into the non inverter air compressor's electrical control system. The hour meter must be connected in such a way so it will record the total amount of time the air compressor is under electrical operation. The amount of time the air compressor is under electrical operation could be also through recording it in a logbook data sheets.
2) Find the non inverter air compressor's nameplate data tag (or refer to relevant catalogue). The metal identification plate provides electrical information about the air compressor motor. Find the operational voltage and full load amperage. The full load amperage is the total amperes consumed by the motor when under a full operational or mechanical load.
3) Multiply the voltage and amperage together to find the wattage. As an example, the voltage may be 240 volts with full load amperage rating of 50 amperes. The total full load power consumption is equal to 240V x 50A x = 12,000 watts.
4) Divide 12,000 watts by 1,000 to find the kilowatt (KW) consumption of the air compressor. The result is 12KW, and 12,000 * (1.73 * 0.85)/1,000 = 17.612 KW in case of three-phase AC[1].
5) Record the amount of time in one day the non inverter compressor operates in average load factor from the hour meter, or from the logbook data sheet. Again as an example, the hour meter (or the logbook) records 10 hours of operation in full load per day. Multiply 17.612 KW times 10 hours, which equals 176.12 KWH per day.
6) Determine how many days per year the non inverter air compressor is under operation. If for example it runs for 176.12 KWH a day for a total of 310 days; then, total annual power consumption is 54,597.2KWH.

   In this case,
   AEI_{yNC} = 54,597 KWH

7) Determine the ratio of load/unload time of the non inverter air compressor in one cycle, through hearing or through using clamps.
8) Use one from the following methods.

   Method 1:
   Use the below schematic figures to determine the percentage of power consumption reduction that could be generated by upgrading the non inverter type air compressor to inverter type one, by projecting the ratio of unload time being used (horizontal axe) to ratio of power consumption (vertical axe) in both cases (non inverter type and inverter type). The results is "X%". Assuming that the ratio of unload time of non inverter type air compressor is 30%, then according to the schematic figure, the difference between power consumed by the non inverter type air compressor (reference scenario) and inverter type air compressor (project scenario) of the same capacity is 17%.

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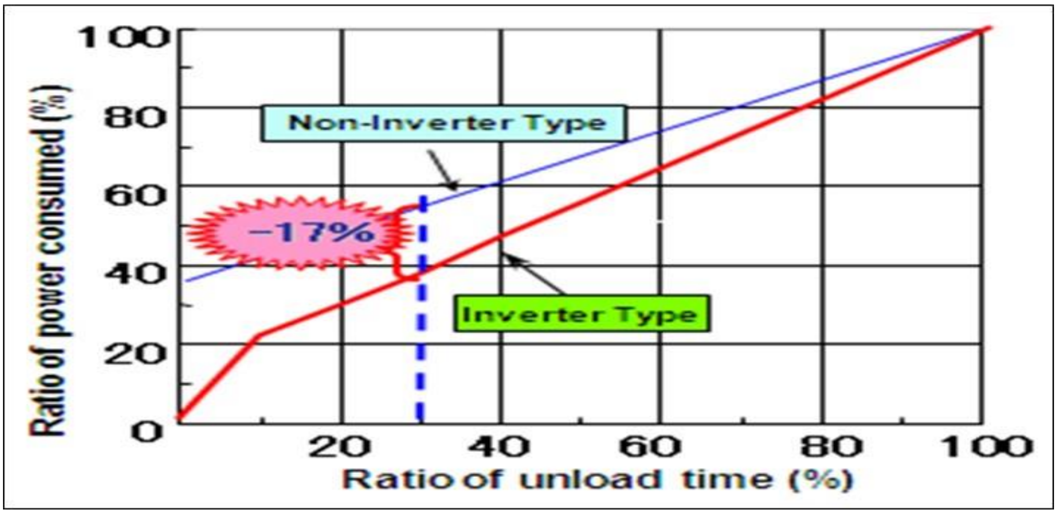
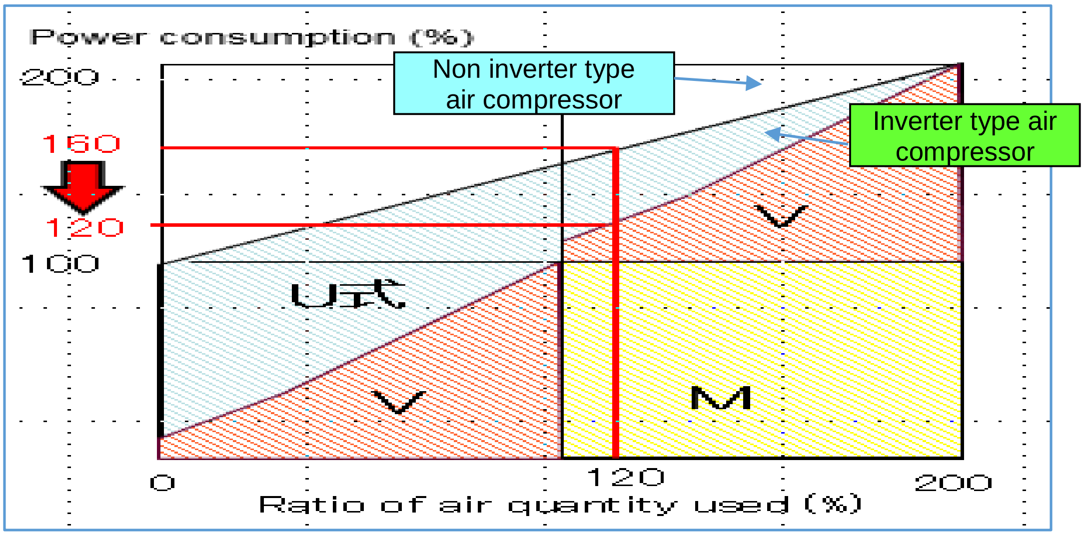
[1]In case of three-phase AC, 12000 X (1.73 X 0.85)/1,000. (0.85 = Power factor)



Method 2:

In case of combination of 2 kinds of inverter type air compressors (V-M), the energy saving ratio "X" can be assumed from the air volume ratio (horizontal axe) and the power consumption ratio (vertical axis) which are used in both curve lines for non inverter type air compressor and inverter type air compressor. The results is “X%”. Assuming that the amount of air used is 60%, then according to the schematic figure below, 40% of power consumption reduction can be achieved.



- Annual Electricity Input to Inverter type air compressor, AEI_{yIC} ,

The Annual Electricity Input to Inverter type air compressor could be calculated as follow:

$$AEI_{yIC} = (100\% - X\%) * AEI_{yNC}$$

With

X %= <u>the percentage of power consumption reduction that could be generated by upgrading the non inverter type air compressor to inverter type one (the power load factor of the current state - the power load factor after inverter machine introduction)</u>

(5)-5-2-1 Emission reduction

Similar to Method1, the $ER_y = [AEI_{yNC} - AEI_{yIC}] * EEF$

With

AEI_{yNC} : Annual Electricity Input to existing non inverter air compressor (NC), during year y (kWh/year).

AEI_{yIC} : Annual Electricity Input to Inverter type air compressor (IC), during year y (KWh/year).

EEF : Electricity CO_2 Emission Factor (Kg-CO_2/kWh).

$$ER_y = [AEI_{yNC} - AEI_{yIC}] * EEF$$

Given that $AEI_{yIC} = (100\% - X\%) * AEI_{yNC}$, then,

$$ER_y = [(X\% * AEI_{yNC}] * EEF$$

(5)-5-2-2 Calculation sheet

1. Calculation of CO2 Emission Reduction		Energy type	Value	Units	Symbol
	CO2 Emission Reduction			t-CO2	ER_y
2. Default values					
	Electricity CO2 emission factor			t-CO_2/kWh	EEF
	Operational voltage			V	OV
	Full load amperage			A	FLA
	Three-phase circuit (AC)			1.73	
	Power factor			0.85	
	Annual operation hours			Hr/year	AOH
	percentage of power consumption reduction that could be generated by upgrading the non inverter type air			%	X

	compressor to inverter type one				
3. Calculation of Reference Emission					
	Reference CO2 Emission			t-CO2	RE_y
	Annual Electricity Input to Non inverter type air compressor (NC)	Electricity		KWh/year	AEI_{yNC}
4. Calculation of Project Emission					
	Project CO2 Emission			t-CO2	PE_y
	Annual Electricity Input to Inverter type air compressor (IC)	Electricity		KWh/year	AEI_{yIC}

(5)-6 Project Design Document (Draft)

A. Project description

A.1. Title of the JCM project

Introducing Inverter Type Air compressor to a foundry plant in India

A.2. General Description of project and applied technologies and/or measures

Improving compressed air system could be through various measures. In this project, the focus will be only on upgrading existing air compressor(s) to inverter type air compressor (hardware). More specifically, the proposal considers to install a dual type (V-M combination) inverter air compressor of 90kW instead of the currently used constant speed air compressor of 90kW. This will certainly result in energy saving, CO2 emission reduction, and significant operation cost saving.

In addition, other recommendations which could be considered along with installing the inverter type air compressor include: Reduction in leakage, stopping inter-cooler and after cooler blows, use of drain trap, Use more efficient blow guns, use of energy savings couplers, Make visual inspection of receiver tank, and adoption of energy monitoring system. Experts from technology supplier will provide all necessary capacity building and training on how to uptake these recommendations if necessary.

A.3. Location of project, including coordinates

Country	India
Region/State/Province	Maharashtra
City/Town/Community	Pune
Complete address	Gat No. 318, Gaon Urse, Tal. Maval, Pune – 410 506. India

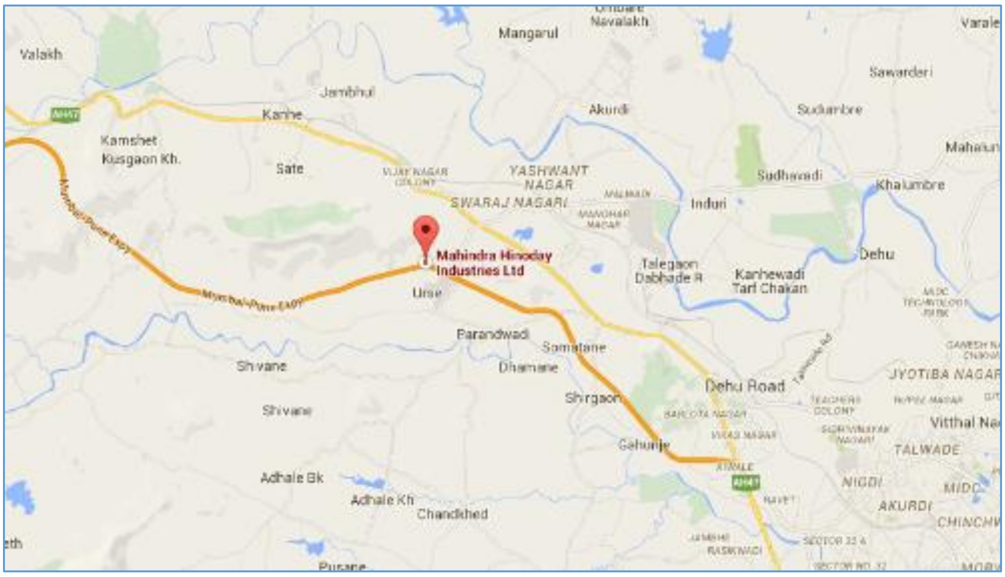


Figure 1 Map of location of project site

A.4. Name of project participants

India	Mahindra Hinoday Ind. Ltd.
Japan	Hitachi Industrial Equipment Systems Co. Ltd. (and other To be confirmed later

A.5. Duration

Starting date of project operation	To be decided later
Expected operational lifetime of project	15 years

A.6. Contribution from developed countries

The proposed project will contribute to a technology transfer of the state-of-the-art inverter type air compressor technology from Japan. Hitachi Industrial Equipment System (IES) Co. Ltd. will provide trainings to local staff members as part of their efforts to complete the transfer of technical know-how in its operation.

B. Application of an approved methodology (ies)

B.1. Selection of methodology (ies)

Selected approved methodology No.	JCM-JP-**-**** (Currently being developed as first draft)
Version number	Ver. ** (still draft)

B.2. Explanation of how the project meets eligibility criteria of the approved methodology

Eligibility criteria	Descriptions specified in the methodology	Project information
Criterion 1	The project consists of improving existing compressed air system through upgrading existing air compressor to inverter type air compressor.	The proposal consider to upgrade the currently used screw compressor into inverter type air compressor.
Criterion 2	The old air compressor(s), which is being replaced with inverter type air compressor, will not be used anywhere else in the site.	The old screw air compressor(s), which is being replaced with inverter type air compressor, will not be used anywhere else in the site.
Criterion 3	Compressed air system is an important source of energy consumption in the site, hence installing inverter type will results in energy saving and CO2 emission reduction.	The plant total's electricity consumption is 6,480 MWh/month, and compressed air power consumption consists of 10% - 20% of total consumption. Installing inverter type air compressor is expected to result in 302 tCO2.
Criterion 4	The energy inputs to air compressor(s) are measurable and/or based on catalogues. So catalogues of all air compressors are available.	The energy inputs to air compressor(s) are measurable using instruments from the site.
Criterion 5	Electricity in the reference and project scenarios shall be supplied by a connected grid.	Electricity is supplied by the grid connected.

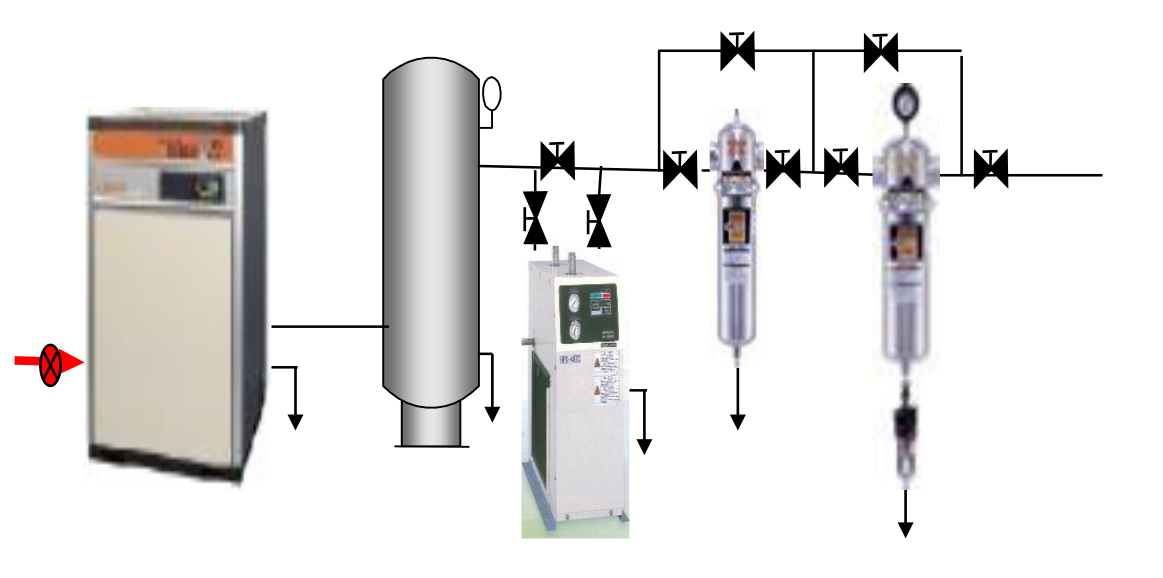
C. Calculation of emission reductions

C.1. All emission sources and their associated greenhouse gases relevant to the JCM project

Reference emissions	
Emission sources	GHG type

Electricity consumption by screw Type Air compressor	CO_2
Project emissions	
Electricity consumption by Inverter Type Air compressor	CO_2

C.2. Figure of all emission sources and monitoring points relevant to the JCM project



C.3. Estimated emissions reductions in each year

Year	Estimated Reference emissions (tCO2e)	Estimated Project Emissions (tCO2e)	Estimated Emission Reductions (tCO2e)
1st year	755	453	302
2nd year	755	453	302
3rd year	755	453	302
4th year	755	453	302
5th year	755	453	302
Total (e.g. in 5 years) (t-CO2e)	3,775	2,265	1,510

D. Environmental impact assessment

Legal requirement of environmental impact assessment for the proposed project	NA

E. Local stakeholder consultation

E.1. Solicitation of comments from local stakeholders

IGES, TERI along with experts from Hitachi IES, have conducted a site visit to investigate about the feasibility of installing inverter type air compressor at Mahindra Hinoday Ind. Ltd on Oct. 10th 2014. Along with the investigation, they conducted an interview was with Dr. Pradeep Panigrahi, General Manager, who has expressed significant interest in the technology and looking forwards to receive the results of the study. As a matter of cooperation, they were ready to conduct a monitoring of the current system for two weeks. The data has been collected and analyzed, however the collected data wasn't accurate so doesn't give enough picture about the total impact of installing inverter type air compressor.

E.2. Summary of comments received and their consideration

Comments from the sites are awaited since the report has just been shared with the site

F. References

Catalogue of compressed air equipment

Annex

(1) Monitoring Plan Sheets (Input sheet) (2) Monitoring Plan Sheets (Calculation process sheet) (3) Monitoring Structure sheet

Revision history of PDD

Version	Date	Contents revised
01.0	6th Feb. 2015	First Edition

(5)-6-1 Annex

Annex (1): Monitoring Plan Sheets (Input sheet) [attachment to PDD for Mahindra Hinoday Co. Ltd]

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Monitoring point No.	Parameters	Description of data	Estimated Values	Units	Monitoring option	Source of data	Measurement methods and procedures	Monitoring frequency	Other comments
2.1	*EEF*	Electricity CO2 emission factor	0.98	t-CO2/kWh	Option A	Public and default value of host electric utility companies	Public and default value of host electric utility companies	Every verification	
2.2	*OV*	Operational voltage	220	V	Option B	Catalogue/nameplate data tag	Catalogue/nameplate data tag	Every verification	
2.3	*FLA*	Full load amperage	290	A	Option B	Catalogue/nameplate data tag	Catalogue/nameplate data tag	Every verification	
2.5		Power Factor	0.90		Option A	Public and default value of host electric utility companies	Public and default value of host electric utility companies	Every verification	
2.6	*AOH*	Annual operation hours	7,740	Hr/year	Option C	From the site	Monitored data or hearing	contunious	

Table 2: Project-specific parameters to calculate project emission

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Parameters	Description of data		Estimated Values	Units	Source of data			Other comments	
2.7	X	Percentage of power consumption reduction that could be generated by upgrading the non inverter type air compressor to inverter	40	%	Option B	scematic figure	scematic figure	Every verification	

Table3: *Ex-ante* estimation of CO_2 emission reductions

CO_2	Units
302	t-CO2/Y

Monitoring option

Option A	Based on public data which is measured by entities other than the project participants (Data used: publicly recognized data such as statistical data and specifications)
Option B	Based on catalogues, Information plates, and/or hearing
Option C	Based on the actual measurement using measuring equipments (Data used: measured values) or hearing

Annex (2): Monitoring Plan Sheets (Calculation process sheet) [attachment to PDD for Mahindra Hinoday Co. Ltd]

1. Calculation of CO2 Emission Reduction		Energy type	Value	Unit	Symbol
1.1	CO2 Emission Reduction Volume		302	t-CO2	ER_y
2. Default values					
2.1	Electricity CO2 emission factor		0.98	t-CO2/kWh	EEF
2.1	Operational voltage		220	V	OV
2.3	Full load amperage		290	A	FLA
2.4	Three phase		1.73		
2.5	Power Factor		0.9		
2.6	Annual operation hours		7,704	Hr/year	AOH
2.7	Percentage of power consumption reduction that could be generated by upgrading the non inverter type air compressor to inverter type one		40	%	X
3. Calculation of Reference emission					
3.1	Reference CO2 emission volume		754.1499574	CO_2トン	RE_y
3.2	Annual Electricity Input to Non inverter type air compressor (NC)	Electricity	769540.7729	KWh/year	$AEI_{y,NC}$
4.Calculation of Project Emission					
4.1	Project CO2 Emission Volume		452.4899745	t-CO2	PE_y
4.2	Annual Electricity Input to Inverter type air compressor (IC)	Electricity	461724.4637	KWh/year	$AEI_{y,IC}$

Annex (3): Monitoring Structure sheet [attachment to PDD for Mahindra Hinoday Co. Ltd]

Responsible personnel	Role
Factory Director	Responsible for project planning, implementation, monitoring results and reporting. It is also in charge of supervise overall operation and maintenance coordinated by the chief supervisor.
Chief supervisor	Appointed to be in charge of reviewing the archived data after being checked and corrected when necessary. It is also in charge of implementation of monitoring-related operations under the supervision of the Factory Director.
Operators	Appointed to be in charge of checking and collecting raw data from monitoring devices. Monitored data is archived and recorded on monthly basis.

2.3 Conclusion and way forward

Over last 5 years, IGES have successively collaborate with local Indian partners, academia, and private sector to conduct researches on low carbon technology application in India. As reported in this report, feasibility studies conducted under JCM in FY.2014 showed that technologies related to compressed air, especially inverter type air-compressor, are promising in term of GHG emission reduction and cost saving; Hence, it is highly recommended to continue follow up activities to those feasibility studies, otherwise the efforts made in FY.2014 will be vain.

In FY.2015, IGES intends to conduct detailed studies, at the sites where potential have been found to introduce those technologies at factory level and/or at utility level. In addition it was noted that Japanese related companies located in India could undertake the proposals faster than those being targeted in FY2014, hence in FY. 2015 FS could be extended to be conducted at one or two sites from those Japanese related companies.

Given that CA related technologies are promising in term of cost saving, they could be deployed without waiting for JCM scheme to be signed between Japan and India. What is mainly required is to raise the awareness among Indian industries about them and to support them to identify projects. Large industries have the financial capacity to install such technologies if they are aware of the concept of the technology (capacity building and awareness creation), as well as if they know about the actual benefits (project identification). In the case of SMEs, given their limited financial capacity, they could approach to JICA-SIDBI (Small Industries Development Bank of India) credit line and/or other programmes supported by Indian government such as TEQUAP (Technology and Quality Upgradation Support to Micro, Small and Medium Enterprises) program to implement such technologies. Hence what is required is project identification to those SMEs and large industries as well as conduct awareness creation and capacity building activities.

Given that JCM hasn't been agreed yet between Japan and India, perhaps for the moment the following could be done: Project identification (through FS/DS etc.) and awareness creation/capacity building activities could be conducted using JCM scheme, whereas actual project implementation will be undertaken using other existing schemes from Indian side such as those under SIDBI, EESL (Energy Efficiency Services Limited), etc. or from Japan side such as those supported by JICA, JBIC (Japan Bank for International Cooperation), etc.

Table: Summary of proposals and expected impacts regarding installation of hardware at each selected site for Feasibility Study (FS)

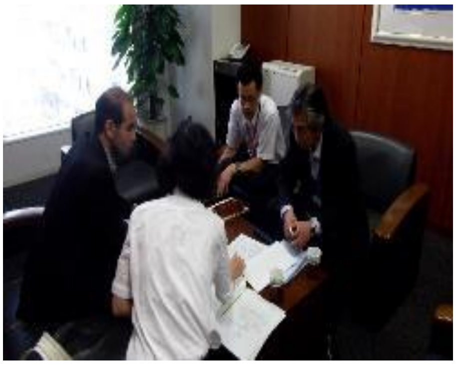
Sites	Proposals for hardware/equipements installation	Estimated emission reduction (kWh/year)	Estimated emission reduction (Ton/year)	Estimated operation cost saving (Rs/year)	Initial cost (in Japan market) (1000JPY)	Estimated Pay back period (Year)	Estimated cost of reducing 1 ton of CO2 (1000JPY/ton of reduced CO2)
Mahindra Hinoday Co. Ltd	Install Inverter A.C (NL-0)	308,160	302	1,848,960	7,000	1.9	**23.2**
	Install Inverter A.C (NL-1)	308,160	302	1,848,960	7,000	1.9	**23.2**
	Install Inverter A.C (NL-2)	256,543	251	1,539,259	5,000	1.6	**19.9**
	Install two stages A.C	391,500	384	2,349,000	30,000	6.4	**78.1**
	Install Booster	108,864	106	653,184	3,000	2.3	**28.3**
Ahmednagar Forging Co. Ltd.	Install Inverter A.C	350,000	343	2,362,500	10,000	2.1	**29.2**
	Install 2 stage A.C	130,500	128	880,875	10,000	5.7	**78.1**
Bombay Dyeing Co. Ltd.	Install Inverter A.C	60,830	56	334565	3,000	4.5	**53.6**
Arvind Textile Co. Ltd.	Install Inverter A.C	660,200	647	4852470	12,000	1.2	**18.5**
	Install high-efficiency drain trap	158,000	155	1161300	4500	1.9	**29.0**
Morarjee Textile Co. Ltd.	Install Inverter A.C	660,200	647	3961200	12,000	1.5	**18.5**
	Install Booster	109,000	107	654000	1,400	1.1	**13.1**
Raymond UCO textile	Install Inverter A.C	660,200	647	3631100	12,000	1.7	**18.5**
	Install high-efficiency drain trap	63,200	62	347600	1,800	2.6	**29.0**

【Reference】

UN DESA, 2009. World Population Prospects: The 2008 Revision.

Reference data】

(1) 1st Conference (Kick-off meeting)

Data&Time	September 9th, 2014 15:00 ~ 16:30
Venue	Tokyo (Meeting room at Hitachi Industrial Equipment System Co., Ltd., Japan
Attendees	Dr. Rabhi Abdessale, Ms. Mihoko Yoshida Mr. Tsukasa Saito (Expert), Mr. Akio Yoshizaki (Expert)
Agenda	* Confirm about whole project activities and schedule * Check of the contents of Feasibility Study (FS) * Check of the contents about workshop with presentation material
Others	(Kick-off meeting: discussion among domestic stakeholders)    

(2) Feasibility study (FS) and workshop

(2)-1 Feasibility study (FS)

<table>
<tr><td>Period</td><td>October 5 ~ 12th, 2014</td></tr>
<tr><td>Venue</td><td>Nagpur & Pune (Maharashtra state), Ahmedabad (Gujarat state), India</td></tr>
<tr><td>Member</td><td>(Japan) Dr. Rabhi Abdessalem,
Mr. Tsukasa Saito (Expert), Mr. Akio Yoshizaki (Expert)
(India) Mr. Chetankumar Sangole, Mr. Vivek Sharma</td></tr>
<tr><td>Investigation site</td><td>Nagpur: 2 sites (Textile)
Ahmedabad: 1 site (Textile)
Pune：3 sites (Textile, Forging, Casting)</td></tr>
<tr><td></td><td>

(Feasibility study (FS))

* Please refer to the main report for details of feasibility study report including the contents and the proposals for improvement.

Nagpur 1 (Raymond: Textile)

Nagpur 2 (Morarjee: Textile)

</td></tr>
</table>


Ahamedabad (Arvind: Textile)




Pune 1 (Bombay Dyeing: Textile)


Pune 2 (Ahmednagar: Textile)

Pune 3（Mahindra: Forging）

(2)-2 Workshop

Date & Time	October 11th, 2014 9:30 ~ 15:00
Place	Pune, Karnataka state, India
Host organizer	IGES・TERI (Co-host)
Cooperated by	Maharashtra Energy Development Agency (MEDA), India
Number of participants	55
	* Please refer to the main report for details of workshop including the report, the agenda, and the list of participants.

(3) 2nd Conference (Wrap-up meeting)

Data&Time	February 3rd, 2015　10:00 ~ 13:00
Venue	New Delhi, India (TERI office)
Attendees	(IGES) Dr. Rabhi Abdessalem (TERI) Mr. Girish Sethi, Mr. Prosant Pal Mr. Mohan Ghosh, Mr. Chetankumar Sangole
Agenda	* Confirmation of overall activity and review of this fiscal year's project * Check and discussion about result of the on-site feasibility study * Content check and fix of the TERI’s activities and the report * Exchange of opinions about the future activities for the next fiscal year onwards
	・Prior to the wrap-up meeting, the domestic meeting to discuss about the wrap-up meeting agenda and the way forward, etc. was held among Japanese stakeholders in January 14, 2015. Based on the above discussion, the wrap-up meeting between IGES and TERI was held.  

(4) Joint seminar

Data&Time	February 6th, 2015 9:00 ~ 10:00
Venue	New Delhi, India (Taj Palace Hotel)
Attendees	(IGES) Prof. Hironori Hamanaka Dr. Rabhi Abdessalem (TERI) R K Pachauri Rabindra N Mallik Girish Sethi Prosanto Pal Chetankumar Sangole (Shakti) Krishan Dhawan Shashank Jain Prasun Pandey
Agenda	* Sharing the overall research project activities and reviewing them. * Sharing of research project findings and achievements and exchanging opinions and views regarding their dissemination and development. * Exchange of opinions about the future activities and collaboration for the next fiscal year onwards.
	＝Common understanding＝ 1)Project identification regarding technologies which have been studied so far (detailed studies and cooperation with funding agencies for their implementation) 2)Expand the focus to include new technologies 3)Collaborate with local governments, from India and Japan, to disseminate the findings and to facilitate the matchmaking among business to business (B2B) and business to funding agencies (B2F) from India and Japan