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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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.


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

<table>
<thead>
<tr>
<th>National Missions</th>
<th>Brief overview</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Solar Mission</td>
<td>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.</td>
</tr>
<tr>
<td>2. Enhanced Energy Efficiency</td>
<td>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.</td>
</tr>
<tr>
<td>3. Sustainable Habitat</td>
<td>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.</td>
</tr>
<tr>
<td>4. Water Mission</td>
<td>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...</td>
</tr>
</tbody>
</table>
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\textsubscript{2} emission, India is already the third largest CO\textsubscript{2} emitter worldwide, behind only China (7955), and US (5287). India’s CO\textsubscript{2} 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 CO\textsubscript{2} emissions is estimated to reach two billion tonnes by 2030, the largest after China’s six billion tonnes (IEA reference scenario).

![Figure 1-1 CO\textsubscript{2} Emissions from Fuel Combustion](Source: IGES, based on IEA 2013 edition: CO\textsubscript{2} 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:

![Research flowchart](image)

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

Institute for Global Environmental Strategies (IGES) [Managing Entity]

Joint Research Agreement

The Energy and Resource Institute (TERI) [Counterpart]

Cooperation

Japanese Companies (Comp. Air Suppliers)

Indian Companies, Business Associations, Japanese Associated...
(5) Research schedule

As indicated 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.

<table>
<thead>
<tr>
<th>Activities</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build Promotion System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop Research Framework</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TERI-IGES Cooperation/Coordination</td>
<td><img src="image" alt="X" /></td>
<td><img src="image" alt="X" /></td>
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<tr>
<td>Site Investigations/Impact Estimation</td>
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<tr>
<td>Develop MRV methodology (Draft)</td>
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<tr>
<td>Kick Off/ Joint Seminar</td>
<td><img src="image" alt="X" /></td>
<td><img src="image" alt="X" /></td>
</tr>
<tr>
<td>Write Research Report</td>
<td></td>
<td><strong>Japan</strong> / <strong>India</strong></td>
</tr>
<tr>
<td>Communication</td>
<td><img src="image" alt="X" /></td>
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<tr>
<td>Meetings/Progress report</td>
<td><img src="image" alt="X" /></td>
<td><img src="image" alt="X" /></td>
</tr>
<tr>
<td>Business trips to India</td>
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<td><img src="image" alt="X" /></td>
</tr>
</tbody>
</table>
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](image)

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)](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

<table>
<thead>
<tr>
<th>Date</th>
<th>Company (industry sector)</th>
<th>Places</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct.6th</td>
<td>Kick off meeting with TERI</td>
<td>Nagpur</td>
</tr>
<tr>
<td></td>
<td>Feasibility study at Raymond Denim Pvt. Ltd. (Textile).</td>
<td></td>
</tr>
<tr>
<td>Oct. 7th</td>
<td>Feasibility study at Morarjee Textile Ltd. (Textile)</td>
<td>Nagpur</td>
</tr>
<tr>
<td>Oct. 8th</td>
<td>Feasibility study at Arvind Pvt. Ltd. (Textile)</td>
<td>Ahmedabad</td>
</tr>
<tr>
<td>Oct. 9th</td>
<td>Feasibility study to Bombay Dyeing Ltd. (Textile)</td>
<td>Pune</td>
</tr>
<tr>
<td>Oct. 10th</td>
<td>Feasibility study at Ahmednagar Ltd. (Forging)</td>
<td>Pune</td>
</tr>
<tr>
<td></td>
<td>Feasibility study at Mahindra Hinoday Ltd. (Casting)</td>
<td></td>
</tr>
<tr>
<td>Oct. 11th</td>
<td>Work shop</td>
<td>Pune</td>
</tr>
<tr>
<td></td>
<td>Wrap up meeting with TERI</td>
<td></td>
</tr>
</tbody>
</table>

(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 1 bar (from current end value of 7 bar 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.

➢ 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.

<table>
<thead>
<tr>
<th></th>
<th>75kW x 1 unit</th>
<th>75kW x 2 units</th>
<th>150kW x 1 unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input power kW</td>
<td>84.0</td>
<td>168.0</td>
<td>160.0</td>
</tr>
<tr>
<td>Discharge air m³/min</td>
<td>12.4</td>
<td>24.8</td>
<td>28.5</td>
</tr>
<tr>
<td>Power consumption kW/(m³/min)</td>
<td>6.53</td>
<td>6.53</td>
<td>5.61</td>
</tr>
</tbody>
</table>

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

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

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 draining 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 (9,800,000 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 (m³/min)
- **H**: Amount of heat produced per unit (MJ/h)
- **n**: Number of units installed
- **T**: Allowable temperature increase

(When outside temperature is 35 °C, compressor’s allowable maximum temperature is 45 °C; \( \Delta T = 45 - 35 = 10 °C \))

(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 corruptions?
- 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
Proposal of system of absorbing load fluctuation

Recommendation for CO2 reduction

- CENTRIFUGAL + Screw compressor

Installation of high-efficiency drain trap

Recommendation of high-efficiency drain trap

(Reduction of discharge air)

Cited from BEKOMAT website.
Drain discharge according to the actual drain amount is required in order to efficiently avoid unnecessary damage and cost associated with generating process of compressed air.
Intelligent electronic control system keeps the loss of compressed air and energy consumption to a minimum by BEKOMAT drain discharge equipped with capacity levelling sensor for this.
Therefore, comparing to the case when adopting an time-controlled type exhaust valve, it's possible to pay back the initial investment in half year

\[
Q = \frac{60Ca}{J} \sqrt{\frac{P1}{V1}}
\]

| Amount of air jetted out from hole (ø2mm) | 0.11m³/min (3.8cfm) | 0.18m³/min (6.3cfm) | 0.28m³/min (10cfm) |
| Amount of air jetted out from hole (ø3mm) | 0.24m³/min (8.4cfm) | 0.41m³/min (14cfm) | 0.65m³/min (23cfm) |

Q: Jetting out amount
C: Number of flowmeters
a: Area of the narrowest part of hole
J: Density of air
P1: Absolute pressure of the gas in front of the hole
V1: Volume ratio of the gas in front of the hole
[Recommendation: soft side]

- 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 1 bar 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 need 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.

---

- Stop of buried piping

### Important points for piping construction...Risks involved in buried piping

In buried piping, the casing is observed so that piping does not come above the ground; however, if the casing is used for long time then the corrosion occurs in piping and the large amount of air leakage is generated. Nevertheless, it is very difficult to find out such leakage and in addition, to that the maintenance also becomes very difficult.

In case of buried piping, 50% of compressed air leakage has been reported. As far as possible, it would be better if buried piping is changed to above the ground piping. If construction of buried piping is inevitable, adopting the method of insertion into a pit is recommended.

Changing the buried piping to the ground piping is recommended due to the high concern of the leakage from the buried piping.
Improvement of blow gun

Example of effective air blow improvement.....How much effect?

Air consumption is large when jetting with a cut long-copper pipe.

Pressure loss large = Air consumption large

When using air nozzle attached just before cutting edge, jet pressure can be taken out effectively.

Pressure loss small = Air consumption small

If squeezing just before blowing made high...

Air blow contacting pressure before and after improvement is same even in decompressing.

Reduction of 30% of air quantity can be expected.

The ideal area ratio of the size of the nozzle to piping is 3:1.

Comparison of pressure loss of air quantity between direct cutting edge of copper pipe and blow gun.

Jet air amount changes depending on shapes of nozzles.

Usage of energy saving coupler

Proposals for improvement of coupler
(Introduction of energy-saving coupler)

Since inside diameter of the present coupler is narrowed down, pressure loss occurs.

Since there is no change of inside diameter when introducing an energy-saving coupler, no pressure loss occurs.
Regular cleaning of pre-intake filter

Recommendation of oil smoke treatment

Air breathing of the Centrifugal machine is exhausted into the to the compressor room. When a compressor absorbs this oil smoke, it makes the quality of air deteriorated, and also leads to environmental degradation. Oil smoke treatment is required.

Simple checking of receiver tank

[Summary of feasibility study]

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Recommendation</th>
<th>Expected energy savings kWh per year</th>
<th>tCO₂ emission reduction per year</th>
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<tbody>
<tr>
<td>1</td>
<td>Use of inverter type of air compressor</td>
<td>660200</td>
<td>647</td>
</tr>
<tr>
<td>2</td>
<td>Install high efficiency drain trap</td>
<td>63200</td>
<td>62</td>
</tr>
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</table>

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.
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

[Recommendation: Hard side (related to compressor)]
❖ Installation of booster compressor

![Efficient Usage Example of local high pressurizing](image)
Lowering original pressure and boosting places where necessary

**Compressor:** Pressure setting 6 bar → 5 bar

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

Local pressurizing by oil-free booster babicon
Each high-pressure equipment, individual installation (booster valve change, safety and noise reduction)

**Energy-saving by local pressurizing**

1. Lowering original pressure 6 bar → 5 bar 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 5 bar and boosting the pressure to 7 bar.

---

**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 5 bar 500L/min is required at the suction pressure of 5 bar, 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 Charges 9 Yen/kWh, 3,000 hours/Year

Reduction in Electricity charge
or 118,000 Yen/year

Oil free booster BABICON is equivalent to 1.5 kW.
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.

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
[Recommendation: soft side]

**Reduction of discharge pressure**

**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 1 bar 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 your company's facility, total capacity is about 250kW. If 8% 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.

**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 1 bar 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.

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 89 Ton of CO2 emission can be expected by reducing leakage by half.
Improvement of blow gun

Example of effective air blow improvement......How much effect?

Usage of energy saving coupler
Simple checking of receiver tank

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

[Summary of feasibility study]

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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:  24Hrs/day
Total electricity consumption:  220,000 kWh/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

******

[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

**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 1 bar from the predetermined pressure. Since all of this leads to waste of energy, there is a necessity for quick measures.

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**The places where air leakage is likely to occur**

- Valve
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**Improvement of blow gun**

**Example of effective air blow improvement.....How much effect?**

Air consumption is large when jetting with a cut long-copper pipe.

- Direct cutting edge
  - Pressure loss large – Air consumption large

When using air nozzle attached just before cutting edge, jet pressure can be taken out effectively.

- Impingement pressure is KEY.
  - If squeezing just before blowing out
    - Pressure loss small – Air consumption small

If pressure just before blowing made high...

Air blow contacting pressure before and after improvement is same even in decompressing.

**Reduction of 30% of air quantity can be expected.**

The ideal area ratio of the size of the nozzle to piping is 3:1.

Jet air amount changes depending on shapes of nozzles.
Usage of energy saving coupler

**Proposals for improvement of coupler**
(Introduction of energy-saving coupler)

Since inside diameter of the present coupler is narrowed down, pressure loss occurs.

Since there is no change of inside diameter when introducing an energy-saving coupler, no pressure loss occurs.

Regular cleaning of pre-intake filter

**Energy saving and cleaning of absorption**

For compressor, clogging of absorption filter directly leads to deterioration of the performance. Since compressor has to be stopped for cleaning the absorption filter when clogging, the efficiency can be maintained and the operation can be stable by installing pre-filter and cleaning every day.
Simple checking of receiver tank

Inspection points of receiver tank ... Regulation of AIR VESSEL

- Corrosion, leakage, function set pressure, operation
- Crack, damage, galling, corrosion
- Display, dirt, function
- Periodic check of corrosion condition, measurement of tank thickness
- Internal carbon removal, prevention of fire or ignition accident
- Galling, corrosion, deformation, loose bolts, detaching

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

Replacing of cooling pump to inverter-type pump

Existing pump (16.5kW x 2 units)

Replacing of the pump to inverter-type pump is recommended to avoid waste, since the load factor is low, there is no connection with air compressor, and valve is being throttled.
Others (oil smoke treatment)

**Recommendation of oil smoke treatment**

Air breathing of the Centrifugal machine is exhausted into the to the compressor room. When a compressor absorbs this oil smoke, it makes the quality of air deteriorated, and also leads to environmental degradation. Oil smoke treatment is required.

---

[Summary of feasibility study]

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<tr>
<td>1</td>
<td>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</td>
<td>231000</td>
<td>226</td>
</tr>
<tr>
<td>2</td>
<td>Install inverter type air compressor</td>
<td>660200</td>
<td>647</td>
</tr>
<tr>
<td>3</td>
<td>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</td>
<td>261360</td>
<td>256</td>
</tr>
<tr>
<td></td>
<td>Installation of 15 traps for 5 units</td>
<td>158000</td>
<td>155</td>
</tr>
<tr>
<td>4</td>
<td>Adjust the environment - i) fresh, cold &amp; dry air intake, ii) regular cleaning of pre-intake filter</td>
<td>182160</td>
<td>179</td>
</tr>
</tbody>
</table>

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.
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

[Recommendation: Hard side (related to compressor)]
❖ Installation / Effective use of inverter compressor
[Recommendation: soft side]

Reduction of discharge pressure

Reduction of 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 1 bar from current value in case of single-stage compressor.

In case of your company’s facility, total capacity is about 120 kW.
If 8% reduction is possible, energy saving of 120 kW x 0.08 = 9.6 kW is expected.
If annual operating hours is 7200 hours, 9.6 kW x 7200 h = 69,120 kWh, and 64 Ton 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.

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 1 bar from the predetermined pressure.
Since all of this leads to waste of energy, there is a necessity for quick decision.
If in the above investigation, it is possible to calculate the amount of leakage, then leakage locations need 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 as high as 20% of the total average plants.
As the amount of leakage can be calculated by the formula in the last slide, 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.
Usage of effective blow gun

Example of effective air blow improvement.... How much effect?

- Air consumption is large when jetting with a cut long-copper pipe.
- When using air nozzle attached just before cutting edge, jet pressure can be taken out effectively.

Pressure loss large = Air consumption large
Pressure loss small = Air consumption small

If pressure just before blowing made high...
Air blow contacting pressure before and after improvement is same even in decompressing.

Reduction of 30% of air quantity can be expected.
The ideal area ratio of the size of the nozzle to piping is 3:1.

Comparison of pressure loss of air quantity between direct cutting edge of copper pipe and blow gun.

Jet air amount changes depending on shapes of nozzles.

Usage of energy saving coupler

Proposals for improvement of coupler
(Introduction of energy-saving coupler)

Since inside diameter of the present coupler is narrowed down, pressure loss occurs.
Since there is no change of inside diameter when introducing an energy-saving coupler, no pressure loss occurs.
Ventilation measures in compressor room

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

- 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.

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.

Smooth air flow
Proper cooling

Problem of rise in Temperature due to short cut

Make improvements in this method

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%.
Ventilation and Ventilating Fan Capacity --- Reference

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

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

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

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.

\[ Q = \frac{3.6 \times (30 \times 0.9 + 0.2) \text{kW} \times 3}{0.0753 \times 10} = 480 \text{M}^3/\text{min} \]

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.

Simple checking of receiver tank

Inspection points of receiver tank ... Regulation of AIR VESSEL

- Corrosion, leakage, function set pressure, operation
- Display, dirt, function
- Crack, damage, galling, corrosion
- Galling, corrosion, deformation, loose bolts, detaching
- Periodic check of corrosion condition
- Measurement of tank thickness
- Internal carbon removal
- Prevention of fire or ignition accident
Others (Installation of drain water processor)

**Drain water discharged from compressor, and suggestion for treatment**

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.

The drain water which oil mixed needs to be treated.

100 – 300PPM oil

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

### Summary of feasibility study

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Recommendation</th>
<th>Expected energy savings kWh per year</th>
<th>tCO₂ reduction per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Make efficient usage of air compressor - i) reduction of discharge pressure, ii) effective utilization inverter type air compressor</td>
<td>69120</td>
<td>68</td>
</tr>
<tr>
<td>2</td>
<td>Use of inverter type of air compressor</td>
<td>60830</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>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</td>
<td>42887</td>
<td>42</td>
</tr>
<tr>
<td>4</td>
<td>Adjust the environment - i) fresh, cold &amp; dry air intake, ii) regular cleaning of pre-intake filter</td>
<td>42887</td>
<td>42</td>
</tr>
</tbody>
</table>
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

[Recommendation: Hard side (related to compressor)]
.aspect: 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 in case of large load-variation equipment)

**Proposal**

**Adoption of two-stage compressor**

<table>
<thead>
<tr>
<th>160kW x 1 unit</th>
<th>160kW x 1 unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input power kW</td>
<td>168.0</td>
</tr>
<tr>
<td>Discharge air m³/min</td>
<td>25.9</td>
</tr>
<tr>
<td>Power consumption kW/m³/min</td>
<td>6.49</td>
</tr>
</tbody>
</table>

*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!!

Effective Utilization of Inverter Screw Compressor

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.
Proposal for energy saving by adopting two-stage compressor

Replacing the existing compressor to two-stage compressor is proposed. Energy saving of at least 10% can be obtained through base load. The following saving can be expected.

Cost saving:
- 160kw x 2units x 0.1 = 32.0kw
- 32kw x 7700h = 246,400kwh
- CO2 conversion:
  \[ 246,400 \text{kwh} \times 0.00093 = 229 \text{Ton/year} \]

Constant-speed compressor
Two-stage compressor

Depending on the case, inverter machine is desirable.

[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 your company's facility, total capacity is about 375kW.

If 8% reduction is possible, energy saving of 375kW x 0.08 = 30kW is expected.

If annual operating hours is 7700 hours, 30kW x 7700h = 231,000kWh (215Ton in CO2 conversion) is expected.

Please start an investigation first whether lowering pressure is possible or not.
Reduction of leakage ~ present status investigation

Stop of buried piping

Important Points at the time of Piping Construction …
Risk involved in Buried Piping

In buried piping, the casing is observed so that piping does not come above the ground; however, if the casing is used for long time then the corrosion occurs in piping and the large amount of air leakage is generated. Nevertheless, it is very difficult to find out such leakage and in addition, to that the maintenance also becomes very difficult. In case of buried piping, 50% of compressed air leakage has been reported. As far as possible, it would be better if buried piping is changed to above the ground piping. If construction of buried piping is inevitable, adopting the method of insertion into a pit is recommended.

Leakage Checking Method

The places where air leakage is likely to occur

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 5%. In your company, 375kW x 0.05 = 18.8kW is the target.
Simple checking of receiver tank

Inspection points of receiver tank ... Regulation of AIR VESSEL

- Corrosion, leakage, function
- Set pressure, operation

- Display, dirt, function
- Crack, damage, galling, corrosion

- Periodic check of corrosion condition
- Measurement of tank thickness
- Internal carbon removal
- Prevention of fire or ignition accident

- Galling, corrosion, deformation, loose bolts, detaching

Others (Installation of drain water processor)

Drain water discharged from a compressor, and Suggestion for treatment

- 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.

- Make a clean water to discharge
- Oil content concentration of 5ppm or less.

The drain water which oil mixed needs to be treated.
Oil content of 100-300PPM
## Summary of feasibility study

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Recommendation</th>
<th>Expected energy savings kWh per year</th>
<th>tCO₂ emission reduction per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>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</td>
<td>231000</td>
<td>226</td>
</tr>
<tr>
<td>2</td>
<td>Effective use of inverter type crew air compressor</td>
<td>350000</td>
<td>343</td>
</tr>
<tr>
<td>3</td>
<td>Use of two stage air compressor</td>
<td>130500</td>
<td>128</td>
</tr>
<tr>
<td>4</td>
<td>Use of new inverter type air compressor - replacing old ELGI air compressor</td>
<td>346680</td>
<td>340</td>
</tr>
<tr>
<td>5</td>
<td>i) reduction in leakage - 5% starting with the present status investigation, ii) stop of buried piping - taking it out of the ground</td>
<td>144835</td>
<td>142</td>
</tr>
<tr>
<td>6</td>
<td>Adjust the environment - i) fresh, cold &amp; dry air intake, ii) installation of drain water processor from the view point of environmental problem</td>
<td>86940</td>
<td>85</td>
</tr>
</tbody>
</table>

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
- ASD47
- ASD32（休日用）

Updating to V-M combination

Upgrading to inverter-type screw compressor 【NL-1】

NL-1
- DRYER
- DP171
- DRYER
- DP171

NL-1
- 90 KW Constant-speed model
- 90 KW Inverter-type

Updating to V-M combination
Upgrading to inverter-type screw compressor [NL-2]

- **NL-2**
  - DSP142
  - ASD37
  - ASD47
  - ASD47

- **NL-2**
  - DSP142
  - ASD37
  - ASD47
  - ASD47

Unify to 75kW x 1 unit

Inverter-type screw compressor (V-M Combination)

- **HISCREW**
  - V-M combination 2 units
  - DUAL type

**[Case 1: NL-0]**
Energy saving of approx. 40% is possible if assuming load factor to be 60%.
\[ \therefore \text{Energy saving} \rightarrow 90\text{kW} \div 0.9 \times 0.4 = 40\text{kW} \]

**[Case 2: NL-2]**
2 units of ASD47 and 1 unit of ASD37 are unified to 1 unit of 75kW.
Energy saving of approx. 40% is possible if assuming load factor to be 60%.
\[ \therefore \text{Energy saving} \rightarrow 75\text{kW} \div 0.9 \times 0.4 = 33.3\text{kW} \]

**[Case 3: NL-1]**
Energy saving of approx. 40% is possible if assuming load factor to be 60%.
\[ \therefore \text{Energy saving} \rightarrow 90\text{kW} \div 0.9 \times 0.4 = 40\text{kW} \]
Adopting booster compressor

Efficient Usage - Example of local high pressurizing

Pressure:
Low in general
High only where necessary

Compressor supply pressure 5bar

Boosting valve

Booster 7bar

Air for general use 5bar

It is effective to lower the pressure of the whole factory to 5 bar and to boost-up the pressure to only required place to 7 bar.

Booster babicon

To load equipment which needs high-pressure air

All air used at your factory are running not with the same pressure. When lowering the whole pressure as much as possible and introducing a booster compressor only to the place where high-pressure air is locally required, large energy saving can be expected. About 10% of energy-saving effect is expected in the whole production line even though adding the power for booster compressor.

Lowering original pressure and boosting places where necessary

Compressor: pressure setting 0.60MPa ⇒ 0.50MPa

Energy-saving at main supply line is:
480kW x 0.08 = 38.4kW, and 921kW/day at max.
For one year:
298,404kWh by multiplying 324 days by 921kW/day and 277TON/year in CO2 conversion

Local pressurizing by oil-free booster babicon

To prepare several boosters 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. 8%.
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.
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).

[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 1 bar 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 CO2 conversion) is expected. Please start an investigation first whether lowering pressure is possible or not.
Centralization and enlargement of compressor

**Proposal of centralization and enlargement**

**Ideas of centralization recommended**
- To enlarge and centralize the compressors currently installed separately.
- To adopt two-stage compressor to improve energy efficiency.
- To install compressors in a good environmental to prevent external factors from troubles.
- To set main piping as 150A (6B) and install it throughout each factory to avoid the existing leakage.
- To replace one compressor to inverter-type compressor to control compressor number for optimization.

**Recommended new equipment (centralization and enlargement)**

Make efficient usage of compressor

**Efficient Usage... Unifying compressor type**

- Easy control for the model composition with same capacity
- Also best for automatic operation

- Pressure is detected, and air quantity is increased when pressure is below set pressure.
- Compressor is given a command to reduce air quantity when pressure is more than set pressure.
- Compressor performs loading, unloading control, starting, and stopping by command.
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 1 bar 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 need 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 as high as 20% of the total average plants. As the amount of leakage can be calculated by the formula in the last slide, 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. 5% of leakage reduction will reduce 172 Ton of CO2 per annum.

Usage of effective blow gun

Example of effective air blow improvement. ....How much effect?

Air consumption is large when jetting with a cut long-copper pipe.

When using air nozzle attached just before cutting edge, jet pressure can be taken out effectively.

Pressure loss large = Air consumption large

If squeezing just before blowing out.

Pressure loss small = Air consumption small

Impingement pressure is KEY.

If pressure just before blowing made high...

Air blow contacting pressure before and after improvement is same even in decompressing.

Reduction of 30% of air quantity can be expected.

The ideal area ratio of the size of the nozzle to piping is 3:1.

Comparison of pressure loss of air quantity between direct cutting edge of copper pipe and blow gun.
Usage of energy saving coupler

**Proposals for improvement of coupler**
*(Introduction of energy-saving coupler)*

Since inside diameter of the present coupler is narrowed down, pressure loss occurs.

Since there is no change of inside diameter when introducing an energy-saving coupler, no pressure loss occurs.

Ventilation measures in compressor room

**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.

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%.
Simple checking of receiver tank
Others (Installation of drain water processor)

Drain water discharged from compressor, and suggestion for treatment

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 - 300 PPM 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 ISO 140001 is based on this, drain water treatment is recommended.

The drain water which oil mixed needs to be treated. Make a clean water to discharge

Discharging the drain water after lowering it to 5ppm or less.

[Summary of feasibility study]

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Recommendation</th>
<th>Expected energy savings kWh per year</th>
<th>tCO₂ emission reduction per year</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>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</td>
<td>295680</td>
<td>290</td>
</tr>
<tr>
<td>2</td>
<td>Use of booster compressor</td>
<td>108864</td>
<td>107</td>
</tr>
<tr>
<td>3</td>
<td>Inverter type air compressor NL-0 plant</td>
<td>308160</td>
<td>302</td>
</tr>
<tr>
<td>4</td>
<td>Inverter type air compressor NL-2 plant</td>
<td>256543</td>
<td>251</td>
</tr>
<tr>
<td>5</td>
<td>Inverter type air compressor NL-1 plant</td>
<td>308160</td>
<td>302</td>
</tr>
<tr>
<td>6</td>
<td>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</td>
<td>185477</td>
<td>182</td>
</tr>
</tbody>
</table>

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 Other recommendations on CO2 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 7.9 kW. The annual energy-saving effect was 60,830 kWh, and 56 Ton in CO2 conversion. The load fluctuation isn’t always right because it was measured in holiday.
Assumed impact of introduction of inverter-type machine based on the current usages

<table>
<thead>
<tr>
<th>Energy-saving effect</th>
<th>Machine at constant speed</th>
<th>Inverter-type machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.66 x 0.9 x 0.72 = 3.7 M³/min</td>
<td>3.7/6.6 = 56%</td>
<td>72%</td>
</tr>
</tbody>
</table>

60A

30A

Ahmednagar Ltd. (Forging)

Energy saving by using measurement and diagnosis

Current measurement

Pressure measurement in machine room

Terminal pressure measurement
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.

AHMEDNAGAR FORGINGS LIMITED
(ELGI current fluctuation)

Improving can be expected in this area.
Large potential for energy saving
AHMEDNAGAR FORGINGS LIMITED
(ELGI current fluctuation)

<table>
<thead>
<tr>
<th>Property</th>
<th>Measurement CH1</th>
<th>Measurement CH1</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Instantaneous</td>
<td>Instantaneous</td>
</tr>
<tr>
<td>Unit</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Average</td>
<td>185.6</td>
<td>229.8</td>
</tr>
<tr>
<td>Max.</td>
<td>968.8</td>
<td>247.3</td>
</tr>
<tr>
<td>Min.</td>
<td>0</td>
<td>217.8</td>
</tr>
</tbody>
</table>

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

Power consumption can be calculated from the average current.

- ELGI
  $185.6\times 400V \times 1.73 \times 0.89 \div 1000 = 115.6kW$
- SULLAIR
  $229.8\times 400V \times 1.73 \times 0.9 \div 1000 = 143.1kW$

---

Calculating Energy-saving Potential from Load Characteristics Diagram

<table>
<thead>
<tr>
<th>Load current</th>
<th>270A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine at constant speed</td>
<td></td>
</tr>
<tr>
<td>Ave. current</td>
<td>185A</td>
</tr>
<tr>
<td>(115.6kw)</td>
<td>69%</td>
</tr>
<tr>
<td>Inverter-type machine</td>
<td></td>
</tr>
<tr>
<td>Effect</td>
<td></td>
</tr>
<tr>
<td>Power of Inverter-type machine</td>
<td></td>
</tr>
<tr>
<td>$147 \times 0.48 = 70.6kw$</td>
<td></td>
</tr>
<tr>
<td>No-load current</td>
<td>120A</td>
</tr>
<tr>
<td>By changing the setting value,</td>
<td></td>
</tr>
<tr>
<td>Energy-saving effect</td>
<td>45.0kw</td>
</tr>
<tr>
<td>(Amount of air currently using)</td>
<td></td>
</tr>
<tr>
<td>Unit requirement; 1</td>
<td></td>
</tr>
<tr>
<td>$0.44 = 11.4 M3/min$</td>
<td></td>
</tr>
<tr>
<td>108kW/11.4M3/min = 9.5kW/m3/min</td>
<td></td>
</tr>
<tr>
<td>$11.4/26 = 44%$</td>
<td></td>
</tr>
</tbody>
</table>

44\%
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)

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>09:30 – 10:30 am</td>
<td>Registration &amp; Tea</td>
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</table>
| 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 – 11:30 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 – 13:30 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

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name</th>
<th>Organization</th>
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<tbody>
<tr>
<td>1.</td>
<td>Mr. Ramesh Shinde</td>
<td>Bombay Dyeing, Pune</td>
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<tr>
<td>2.</td>
<td>Mr. Sameer D Bold</td>
<td>Benteler Automotive, Pune</td>
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<tr>
<td>3.</td>
<td>Mr. Vivek Gore</td>
<td>Burckhardt Compression, Pune</td>
</tr>
<tr>
<td>4.</td>
<td>Mr. Atul S Kakad</td>
<td>Manchana Industries Ltd., Mumbai</td>
</tr>
<tr>
<td>5.</td>
<td>Mr. Subhash S Yewale</td>
<td>Bharat Forge Ltd, Pune</td>
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<tr>
<td>6.</td>
<td>Mr. M M Deepan</td>
<td>Kumars Autotech (Pune) Pvt Ltd, Pune</td>
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<tr>
<td>7.</td>
<td>Mr. Deepak Dhami</td>
<td>Ranvik Auto, Pune</td>
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<tr>
<td>8.</td>
<td>Mr. Mukesh F Chavan</td>
<td>Echjay Industries Pvt Ltd, Rajkot</td>
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<tr>
<td>9.</td>
<td>Mr. N M Bhairagond</td>
<td>Hightemp Furnaces Ltd, Pune</td>
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<tr>
<td>10.</td>
<td>Mr. S N Bancode</td>
<td>Indoace Engineers Pvt Ltd, Pune</td>
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<tr>
<td>11.</td>
<td>Mr. D T Patil</td>
<td>Indoace Engineers Pvt Ltd, Pune</td>
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<tr>
<td>12.</td>
<td>Mr. Jitendra Lakhodia</td>
<td>Aakar Foundry Pvt Ltd, Pune</td>
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<tr>
<td>13.</td>
<td>Mr. S M Nar</td>
<td>Aakar Foundry Pvt Ltd, Pune</td>
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<tr>
<td>14.</td>
<td>Mr. S R Rane</td>
<td>Mahindra Hinday Industries Ltd, Pune</td>
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<tr>
<td>15.</td>
<td>Mr. Sanjay S Bhandari</td>
<td>Aum Prasad Casting (P) Ltd, Pune</td>
</tr>
<tr>
<td>16.</td>
<td>Mr. Shalak Sandhi</td>
<td>MCCA (Deputy DG), Pune</td>
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<tr>
<td>18.</td>
<td>Mr Sham Jadhav</td>
<td>Mas Die Casting, Pune</td>
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<tr>
<td>19.</td>
<td>Mr Kisan Sagackar</td>
<td>Mas Die Casting, Pune</td>
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<tr>
<td>20.</td>
<td>Mr Raju Nagabandit</td>
<td>Subros Ltd., Pune</td>
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<tr>
<td>21.</td>
<td>Mr Shanilu Pothak</td>
<td>ENCON Pvt Ltd., Pune</td>
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<td>22.</td>
<td>Mr Nilesh Zaware</td>
<td>ENCON Pvt Ltd., Pune</td>
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<td>23.</td>
<td>Mr Kadam K G</td>
<td>Western India Forgings, Pune</td>
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<td>24.</td>
<td>Mr S P Ranade</td>
<td>S P Ranade Associates, Pune</td>
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<td>25.</td>
<td>Mr Swapnil Galikwad</td>
<td>Green Flame Pvt Ltd, Pune</td>
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<tr>
<td>26.</td>
<td>Mr Kaif Khan</td>
<td>Raymond UCO Denim Pvt Ltd, Yavatmal</td>
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<td>27.</td>
<td>Mr Yogesh Bondre</td>
<td>Raymond UCO Denim Pvt Ltd, Yavatmal</td>
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<td>28.</td>
<td>Mr Kushal Trivedi</td>
<td>Anvind Ltd, Ahmedabad</td>
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<td>29.</td>
<td>Mr Radhakar Chaudhary</td>
<td>Ponna Forge, Pune</td>
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<td>30.</td>
<td>Mr Abhijeet R Chavan</td>
<td>Kayseri Forge Ltd, Pune</td>
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<tr>
<td>31.</td>
<td>Mr Shashi Kant</td>
<td>The Word Bookshop, Pune</td>
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<td>32.</td>
<td>Mr Ashpakh Shaikh</td>
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<td>Hightemp Furnaces Ltd, Pune</td>
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<td>36.</td>
<td>Mr Prasun Pandy</td>
<td>Shakti Sustainable Energy Foundation, Delhi</td>
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<tr>
<td>37.</td>
<td>Mr Laxmane Panday</td>
<td>MEDA, Pune</td>
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<td>38.</td>
<td>Mr Inderjitsingh Rana</td>
<td>Orient Auto Pressings, Pune</td>
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<td>39.</td>
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<td>ACE Engineers</td>
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<td>40</td>
<td>Mr S A Patil</td>
<td>MEDA, Pune</td>
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<td>41</td>
<td>Mr Aril Javalkar</td>
<td>PFPL, Pune</td>
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<tr>
<td>42</td>
<td>Mr Shivaji B Patil</td>
<td>ITPL-Vesan Engg, Pune</td>
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<td>43</td>
<td>Mr I M Sayed</td>
<td>ITPL-Vesan Engg, Pune</td>
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<tr>
<td>44</td>
<td>Prafull Mokashi</td>
<td>Ex-AIFI secretary</td>
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<tr>
<td>45</td>
<td>Chetan kumar Sangole</td>
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<td>48</td>
<td>Prosanto Pal</td>
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<td>MEDA</td>
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<td>52</td>
<td>Dr AbdessamenRathi</td>
<td>IOES</td>
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<td>TsukasaGato</td>
<td>Hitachi-IGES</td>
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<tr>
<td>54</td>
<td>Atio Yoshizaki</td>
<td>Hitachi-IGES</td>
</tr>
<tr>
<td>55</td>
<td>Meghna Joglekar</td>
<td>Kalehashi Services Pvt Ltd</td>
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</tbody>
</table>
Energy Saving and Environmentally Friendliness of Air Compressors

Trends in Global CO2 Emissions

- 2006 figures
- 1997 figures

China: 8,561
US: 5,271
India: 1,801
Russia: 1,677
Japan: 1,174

Published by International Energy Agency (IEA)

2011 figures
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.

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

Maintenance: 9%  
Carry out periodical maintenance.

Electric Power Consumption: 84%

Specific Energy Consumption

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

Energy cost (¥/㎥)

Power input (kWh) x Electricity cost (¥/kWh) by
FAD x 60 (㎥/min) (min)

Note: LCC = Life Cycle Cost

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

If average air consumption decreased by 70%, electricity cost decreased by 70%.
Key points of energy saving for compressor equipment

Flow of pneumatic system improvement

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

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

3. Optimize the compressor system.
   Utilize inverter compressors.
   Optimize operating pressure.
   Select an appropriate model.
   Appropriate maintenance

What is cost of air compressor?

Pressure
Loss
Unload/load
Leakage
loss
Number of
Running
machine unit
Useless usage
running
hours
A year
Quantity
Vm3/h
Power
collection
kWh
Pressure
MPa

77
**CO2 reduction=energy saving of the air system**

Saving energy of compressed air system=Energy cost down

Energy cost (J, 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
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 piping (size, route, valves).

What kind of improvement in this case?

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

In case piping diameter is 8mm, upper stream pressure is increased because pressure loss is big. As a result, air compressor commands unload operation. Therefore, bottom stream pressure is much decreased.

Pressure Loss through Pipe and Internal Flow Rate

General flow of compressed air

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 HICREW NEXT (Discharge pressure: 0.69 MPa, discharge air volume: 13.2 M3/min), size of discharge air pipe: 50mm

\[
V = \frac{13.2 \times 0.101}{(0.101 + 0.69) + 0.05} = 0.105 = 3.14 / 4 = 60
\]

\[
V = 14.31 \text{ m/sec} \quad \text{(This is a very high speed.) The energy-saving effect is low.}
\]
Pressure loss depends on valve types and shapes

Big loss...

7 pcs of glovevalve(*** 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 pipenarrowed 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 pipe in a pit.

Reduce internal pipe resistance for energy saving

Example of piping improvement

Narrow piping
Complicated piping
Many partition piping

Review this piping!! Easy for energy saving?

Energy saving effect 11%

405,000kwh → 346,450kwh (Improvement)

OSP-75D5AI
Piping diameter 2D → 3D
Size up capacity for air dryer
Size up for air filter
Replacement, construction fee: 3,600kV
Investment recovered in 4.5 years
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.

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Changing air velocity through internal pipe - loop piping

Necessary air velocity is about 5m/s

Load

Load

Load

Load

Pressure loss is two times higher of air velocity in proportion

Pressure loss is minimized to one quarter, only to make 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 a 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.

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 23,000kWh

- Detail of improvement
  - 37kW inverter compressor x 1 unit
  - Powersaving: 24%

- Investment and effectiveness
  - Apply to new 37kW Inverter compressor
  - Efficiency of energy saving: 1106kW

- Other effectiveness
  - CO2 reduction ▲34% for environment protection
  - Periodical overhaul and parts durability last longer (per 8 years)
  - Maintenance cost is reduced 3%
    (our company calculation)
Effect of receiver tank if pressure fluctuation is frequently

![Diagram showing effect of receiver tank on pressure fluctuations](image1)

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 \( (MJ/h) \)
  
  \( (1 \text{ kW} = 3.6 \text{ MJ/h}) \)
- **n**: Number of units installed
- **T**: Allowable temperature increase

Notes:

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

Install the compressor in the direction so that a hermetically-closed room or intake of contaminated air (oil, gas, etc.) is avoided.

Prevent the air discharged from the compressor room from being sent back into the room and circulating.

Discharge air in compressor room

Install the fan high on the wall of the compressor room.

When using a rain hood, take resistance into consideration when selecting a ventilating fan.
Notes for Duct Installation Work

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

Be careful that the discharge port and suction port are placed on the same side. In such a case, the room will not be ventilated at all.

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

Air will not be discharged properly, leading to a failure.
The same rule applies when air is discharged through a duct using a blower or ventilator.
Even with forced exhaust, if ducts are combined into a single duct, balance will not be maintained.
Overflowing discharge air may be taken into the neighbor machine.

3. Improvement local pressurizing

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

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

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

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

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

If you replace the intensifier with Booster Babicon, you will have the following advantage
1. Reduce air consumption.
   - Booster babicon take compressed air and pressurize efficiently.
2. Long maintenance cycle
   - 0000 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.

Effective Usage — local high pressurize

Pressure: Low in general.
High only where necessary.

Compressor supply air 0.5MPa

Pressure valve

Regulating system

Low pressure equipment
Reduce to 0.3MPa

Boosted Babicon

Supply high pressure line by pressurize from low pressure line, (pressurize valve, booster)

All the equipment in a factory are running set 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 babicon works as multi-compression causing more energy saving.
Effective utilization - Energy saving between pressurize valve and booster bicon

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

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

Booster Compressor
Booster Compressor is an 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, electrical cost is also very little.
Cost saving for 1.5kW power up to 1100/year.
(Cost calculation: Electric power cost 15yen/kWh, 0.008yen/kWh)

---

Characteristics of Air Compressor (positive displacement compressor)

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.

---

89
Example of effective air blow • • • How much effect?

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

Working object

Air impact pressure is atC

Direct cutting

Pressure loss big = Air consumption big

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

Working object

Air squeezed before blowing out

Pressure loss small = Air consumption small

When air blow pressure made high

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

Brow gun

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

Shapes of nozzle promote air blow different

leakage

Recommendation: determine total leakage and reduce it

Leakage Checking Method

Pneumatic tool

10%

Air leakage

17-20%

Blow air

70%

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

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

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

With:
- \( Q \) = Volume of leakage (M3/min)
- \( P_1 \) = Predetermined pressure (kg/cm2) (gauge pressure + 1.033 kg/cm2)
- \( P_2 \) = Pressure after leakage (kg/cm2) (gauge pressure + 1.033 kg/cm2)
- \( T \) = Time taken to reduce pressure from \( P_1 \) to \( P_2 \) (min)
- \( P_0 \) = Atmospheric air pressure (kg/cm2)
- \( V \) = Piping capacity (M3) (in case of your company; 72.31 m3)
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 m³ = 1.8 yen)

\[
\text{Cost} = \frac{200}{1000} \times 80 \times 8000 \text{hrs/yr} \times 1.8 \text{ yen/kWh} = 172,800 \text{ yen/yr.}
\]

Understand the difference between external leakage and internal leakage

Check the leakage point example and leakage amount.

<table>
<thead>
<tr>
<th>Leakage from a pipe</th>
<th>Leakage from a coupler</th>
<th>Leakage from an internal component of a device</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Note that a leakage often occurs at valves and joints.

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

The air leak point

**Leakage cases**

- Point: valves
  - 17.4 L/min
- Point: air gun
  - 49.2 L/min
- Point: hoses
  - 59.4 L/min
- Point: hose joint
  - 69.4 L/min
- Point: regulator
  - 71.7 L/min
- Point: coupler
  - 27.7 L/min

20% of leakage exists in a plant on average.
Adopt 2 stage compressor with higher efficiency

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

<table>
<thead>
<tr>
<th></th>
<th>75kW x 1 unit</th>
<th>75kW x 2 unit</th>
<th>150kW x 1 unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input power kW</td>
<td>81.0</td>
<td>162.0</td>
<td>180.0</td>
</tr>
<tr>
<td>Air Delivery m³/min</td>
<td>12.4</td>
<td>24.8</td>
<td>28.5</td>
</tr>
<tr>
<td>Specific power kW/m³/min</td>
<td>8.53</td>
<td>6.53</td>
<td>5.61</td>
</tr>
</tbody>
</table>

※ 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

160kW class

Energy saving 17.8%

Combination with OSP-65VA + OSP-65VA x2 unit
- Much reduction of maintenance fee
- Improvement in vibration troubles
- Reduction of labor cost
- Environment protection
  (Improvement for oil leakage, drain troubles)

Power consumption per year: 110,600kWh => 264,000kWh (Improvement)
Energy saving: about 0.6m/kWh (energy saving 17.0%)

Example of separate operation

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

125kW and 160kW were controlled individually by manual.
Choose suitable compressor, calculating from load ratio and necessary oil consumption.

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

Power consumption per year: 585,140kWh => 375,012kWh (Improvement)
Energy saving: about 600kWh/year
Centralized operation for energy saving... From decentralized operation to centralized operation (power saving at sight shift)

- Power consumption per year 303,020kWh \(\Rightarrow\) 169,600kWh (improvement)
- Energy saving about 200kWh/year

- Only few air is discharged from 3 units of compressor

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

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.

160kW 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)
Closed all windows except exhaust side of fan to make wind flow direction.

- Power consumption per year: 165kW x 2 units x 1.1 x 8900h = $2,516,000/kW
  - Energy efficiency 3% = half of $4,480/kW (months)
  - ($1 kWh = 10 yen: 516,000 yen improvement)

- 35°C
- 45°C

Energy saving 3%

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-CO2)/kWh

CO2 coefficient is different from each electric power generation method.

<Eg>

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

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

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

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

Control progress by reporting, notice, thoroughness of improvement.

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

\[
CF_{\text{output}} = (P_{\text{output}} - R_{\text{output}}) / P_{\text{output}}
\]

\[CF_{\text{output}}: \text{Correction coefficient}\]
\( P_{\text{output}} \): Project output

\( R_{\text{output}} \): Reference output

\[ CRE_y = CF_{\text{output}} \times RE_y \]

\( CRE_y \): 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.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 1</td>
<td>The project consists of improving existing compressed air system through upgrading existing air compressor to inverter type air compressor.</td>
<td>☐</td>
</tr>
<tr>
<td>Condition 2</td>
<td>The old air compressor(s), which is being replaced with inverter type</td>
<td>☐</td>
</tr>
</tbody>
</table>
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 and/or 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 method 1 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:

$$RE_y = AEI_{yNC} \cdot EEF$$

$$PE_y = AEI_{yIC} \cdot EEF$$

Then,

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

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 CO2 Emission Factor (t-CO2/kWh).

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

<table>
<thead>
<tr>
<th>Description of Data</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Electricity Input to Non inverter air compressor (NC)</td>
<td></td>
<td>kWh/year</td>
</tr>
<tr>
<td>Annual Electricity Input to Inverter type air compressor (IC)</td>
<td></td>
<td>kWh/year</td>
</tr>
<tr>
<td>Electricity CO2 Emission Factor</td>
<td></td>
<td>t-CO2/kWh</td>
</tr>
</tbody>
</table>
Note: While data about Annual Electricity Input to Non inverter type air compressor, \( AEI_{\text{\(\gamma\)NC}} \), and the Annual Electricity Input to Inverter type air compressor, \( AEI_{\text{\(\gamma\)IC}} \), 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Measurement procedure (e.g.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( AEI_{\text{(\gamma)NC}} )</td>
<td>Annual Electricity Input to Non inverter type air compressor (NC)</td>
<td>Dedicated electric meter</td>
</tr>
<tr>
<td>( AEI_{\text{(\gamma)IC}} )</td>
<td>Annual Electricity Input to Inverter type air compressor (IC)</td>
<td>Dedicated electric meter</td>
</tr>
<tr>
<td>( EEF )</td>
<td>Electricity CO(_2) Emission Factor</td>
<td>Public and default value of host electric utility companies</td>
</tr>
</tbody>
</table>

(5)-5-1-2 Calculation sheet

1. Calculation of CO\(_2\) Emission Reduction

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Energy type</th>
<th>Value</th>
<th>Units</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 Emission Reduction</td>
<td></td>
<td></td>
<td>t(\cdot)CO(_2)</td>
<td>( ER_y )</td>
<td></td>
</tr>
</tbody>
</table>

2. Default values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Units</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity CO(_2) emission factor</td>
<td></td>
<td></td>
<td>t(\cdot)CO(_2)/kWh</td>
<td>( EEF )</td>
</tr>
</tbody>
</table>

3. Calculation of Reference Emission

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Energy type</th>
<th>Value</th>
<th>Units</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference CO2 Emission</td>
<td></td>
<td></td>
<td>t(\cdot)CO(_2)</td>
<td>( RE_y )</td>
<td></td>
</tr>
<tr>
<td>Annual Electricity Input to Non inverter type air compressor (NC)</td>
<td>Electricity</td>
<td></td>
<td>KWh/year</td>
<td>( AEI_{\text{(\gamma)NC}} )</td>
<td></td>
</tr>
</tbody>
</table>

4. Calculation of Project Emission

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Energy type</th>
<th>Value</th>
<th>Units</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project CO2 Emission</td>
<td></td>
<td></td>
<td>t(\cdot)CO(_2)</td>
<td>( PE_y )</td>
<td></td>
</tr>
<tr>
<td>Annual Electricity Input to Inverter air compressor (IC)</td>
<td>Electricity</td>
<td></td>
<td>KWh/year</td>
<td>( AEI_{\text{(\gamma)IC}} )</td>
<td></td>
</tr>
</tbody>
</table>
(5)-5-2 Calculation method 2

The calculation method 2 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 method 1 and method 2 will be only in the measurement procedure of power consumption in reference scenario and project scenario given below:

Monitoring parameters to calculate reference emission

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Measurement procedure (e.g.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$AEI_{\text{yNC}}$</td>
<td>Annual Electricity Input to Non inverter type air compressor (NC)</td>
<td>Catalogue/nameplate data tag, and schematic figure</td>
</tr>
<tr>
<td>$AEI_{\text{yIC}}$</td>
<td>Annual Electricity Input to Inverter type air compressor (IC)</td>
<td>Catalogue/nameplate data tag, and schematic figure</td>
</tr>
<tr>
<td>$EEF$</td>
<td>Electricity CO$_2$ Emission Factor</td>
<td>Public and default value of host electric utility companies</td>
</tr>
</tbody>
</table>

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

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

  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.

  $$AEI_{\text{yNC}} = \sqrt{3}[OV * FLA] \times 0.85 / 1000 / AOH$$

  With

  $OV$ : Operational voltage
  $FLA$ : Full load amperage
  $AOH$ : Annual Operation hours
Instruction to calculate Annual Electricity Input to Non inverter type air compressor $AEI_{NC}$:

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 $240V \times 50A = 12,000$ watts.

4) Divide 12,000 watts by 1,000 to find the kilowatt (KW) consumption of the air compressor. The result is 12KW, and $12,000 \times (1.73 \times 0.85)/1,000 = 17.612$ KW in case of three-phase AC.

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 54,597.2 KWH.

In this case, $AEI_{NC} = 54,597$ 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%.

---

1In case of three-phase AC, $12000 \times (1.73 \times 0.85)/1,000$. (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, $AEI_{\text{IC}}$.

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

$$AEI_{\text{IC}} = (100\% - X\%) \cdot AEI_{\text{NC}}$$
With

\[ X \% = \text{the percentage of power consumption reduction that could be generated by upgrading the non inverter type air compressor to inverter type one (the power load factor of the current state - the power load factor after inverter machine introduction)} \]

(5)-5-2-1 Emission reduction

Similar to Method 1, the

\[ ER_y = [AEI_{yNC} - AEI_{yIC}] \times EEF \]

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).

\[ ER_y = [AEI_{yNC} - AEI_{yIC}] \times EEF \]

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

\[ ER_y = [(X\% \times AEI_{yNC})] \times EEF \]

(5)-5-2-2 Calculation sheet

<table>
<thead>
<tr>
<th>1. Calculation of CO2 Emission Reduction</th>
<th>Energy type</th>
<th>Value</th>
<th>Units</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 Emission Reduction</td>
<td></td>
<td></td>
<td>t-CO2</td>
<td>( ER_y )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Default values</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity CO2 emission factor</td>
<td>t-CO2/kWh</td>
<td></td>
<td>( EEF )</td>
<td></td>
</tr>
<tr>
<td>Operational voltage</td>
<td>V</td>
<td></td>
<td>( OV )</td>
<td></td>
</tr>
<tr>
<td>Full load amperage</td>
<td>A</td>
<td></td>
<td>( FLA )</td>
<td></td>
</tr>
<tr>
<td>Three-phase circuit (AC)</td>
<td>1.73</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power factor</td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual operation hours</td>
<td>Hr/year</td>
<td></td>
<td>( AOH )</td>
<td></td>
</tr>
<tr>
<td>percentage of power consumption reduction that could be generated by upgrading the non inverter type air</td>
<td>%</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 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

<table>
<thead>
<tr>
<th>Country</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region/State/Province</td>
<td>Maharashtra</td>
</tr>
<tr>
<td>City/Town/Community</td>
<td>Pune</td>
</tr>
<tr>
<td>Complete address</td>
<td>Gat No. 318, Gaon Urse, Tal. Maval, Pune – 410 506. India</td>
</tr>
</tbody>
</table>

Figure 1 Map of location of project site

A.4. Name of project participants

<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>Mahindra Hinoday Ind. Ltd.</td>
</tr>
<tr>
<td>Japan</td>
<td>Hitachi Industrial Equipment Systems Co. Ltd. (and other To be confirmed later)</td>
</tr>
</tbody>
</table>

A.5. Duration

<table>
<thead>
<tr>
<th>Starting date of project operation</th>
<th>To be decided later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected operational lifetime of project</td>
<td>15 years</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Selected approved methodology No.</th>
<th>JCM-JP.**.**** (Currently being developed as first draft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version number</td>
<td>Ver. ** (still draft)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Eligibility criteria</th>
<th>Descriptions specified in the methodology</th>
<th>Project information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criterion 1</td>
<td>The project consists of improving existing compressed air system through upgrading existing air compressor to inverter type air compressor.</td>
<td>The proposal consider to upgrade the currently used screw compressor into inverter type air compressor.</td>
</tr>
<tr>
<td>Criterion 2</td>
<td>The old air compressor(s), which is being replaced with inverter type air compressor, will not be used anywhere else in the site.</td>
<td>The old screw air compressor(s), which is being replaced with inverter type air compressor, will not be used anywhere else in the site.</td>
</tr>
<tr>
<td>Criterion 3</td>
<td>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.</td>
<td>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.</td>
</tr>
<tr>
<td>Criterion 4</td>
<td>The energy inputs to air compressor(s) are measurable and/or based on catalogues. So catalogues of all air compressors are available.</td>
<td>The energy inputs to air compressor(s) are measurable using instruments from the site.</td>
</tr>
<tr>
<td>Criterion 5</td>
<td>Electricity in the reference and project scenarios shall be supplied by a connected grid.</td>
<td>Electricity is supplied by the grid connected.</td>
</tr>
</tbody>
</table>

C. Calculation of emission reductions

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

<table>
<thead>
<tr>
<th>Reference emissions</th>
<th>GHG type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission sources</td>
<td></td>
</tr>
</tbody>
</table>
C.2. Figure of all emission sources and monitoring points relevant to the JCM project

C.3. Estimated emissions reductions in each year

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimated Reference emissions (tCO2e)</th>
<th>Estimated Project Emissions (tCO2e)</th>
<th>Estimated Emission Reductions (tCO2e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1\textsuperscript{st} year</td>
<td>755</td>
<td>453</td>
<td>302</td>
</tr>
<tr>
<td>2\textsuperscript{nd} year</td>
<td>755</td>
<td>453</td>
<td>302</td>
</tr>
<tr>
<td>3\textsuperscript{rd} year</td>
<td>755</td>
<td>453</td>
<td>302</td>
</tr>
<tr>
<td>4\textsuperscript{th} year</td>
<td>755</td>
<td>453</td>
<td>302</td>
</tr>
<tr>
<td>5\textsuperscript{th} year</td>
<td>755</td>
<td>453</td>
<td>302</td>
</tr>
<tr>
<td>Total (e.g. in 5 years) (t-CO2e)</td>
<td>3,775</td>
<td>2,265</td>
<td>1,510</td>
</tr>
</tbody>
</table>

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 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

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Contents revised</th>
</tr>
</thead>
<tbody>
<tr>
<td>01.0</td>
<td>6th Feb. 2015</td>
<td>First Edition</td>
</tr>
</tbody>
</table>
Annex (1): Monitoring Plan Sheets (Input sheet) [attachment to PDD for Mahindra Hinoday Co. Ltd]

<table>
<thead>
<tr>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
<th>(f)</th>
<th>(g)</th>
<th>(h)</th>
<th>(i)</th>
<th>(j)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring parameter</td>
<td>Parameter</td>
<td>Description of data</td>
<td>Estimated Values</td>
<td>Units</td>
<td>Monitoring option</td>
<td>Source of data</td>
<td>Measurement methods and procedures</td>
<td>Monitoring frequency</td>
<td>Other comments</td>
</tr>
<tr>
<td>2.1</td>
<td>EFF</td>
<td>Electricity CO2 emission factor</td>
<td>0.05</td>
<td>t-CO2/kWh</td>
<td>Option A</td>
<td>Public and default value of host electricity companies</td>
<td>Carbon emissions data</td>
<td>Every verification</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>COV</td>
<td>Operational lifetime</td>
<td>220</td>
<td>hours</td>
<td>Option B</td>
<td>Carbon emissions data</td>
<td>Carbon emissions data</td>
<td>Every verification</td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>FLA</td>
<td>Fullload operating hours</td>
<td>200</td>
<td>hours</td>
<td>Option B</td>
<td>Carbon emissions data</td>
<td>Carbon emissions data</td>
<td>Every verification</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>P</td>
<td>Power Factor</td>
<td>0.99</td>
<td></td>
<td>Option A</td>
<td>Public and default value of host electricity companies</td>
<td>Public and default value of host electricity companies</td>
<td>Every verification</td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>K</td>
<td>Annual operation hours</td>
<td>7400</td>
<td>Hours</td>
<td>Option C</td>
<td>From the site</td>
<td>Monitored data or hours</td>
<td>Continuous</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Project-specific parameters to calculate project emission

<table>
<thead>
<tr>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
<th>(f)</th>
<th>(g)</th>
<th>(h)</th>
<th>(i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>Description of data</td>
<td>Estimated Values</td>
<td>Units</td>
<td>Source of data</td>
<td>Other comments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>X</td>
<td>Percentage of power consumption reduction that could be generated by upgrading the non-inverter type air compressor to inverters</td>
<td>40%</td>
<td>Option B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Ex-ante estimation of CO2 emission reductions

<table>
<thead>
<tr>
<th>CO2</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>302</td>
<td>t-CO2/kWh</td>
</tr>
</tbody>
</table>

Monitoring option

<table>
<thead>
<tr>
<th>Option</th>
<th>Based on</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option A</td>
<td>Public data which is measured by entities other than the project participants. (Data used: publicly recognized data such as statistical data and specifications)</td>
<td></td>
</tr>
<tr>
<td>Option B</td>
<td>Catalogs, brochures, and source of data.</td>
<td></td>
</tr>
<tr>
<td>Option C</td>
<td>Verification of data by the project participants.</td>
<td></td>
</tr>
</tbody>
</table>
Annex (2): Monitoring Plan Sheets (Calculation process sheet) [attachment to PDD for Mahindra Hinoday Co. Ltd]

<table>
<thead>
<tr>
<th>1. Calculation of CO2 Emission Reduction</th>
<th>Energy type</th>
<th>Value</th>
<th>Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 CO2 Emission Reduction Volume</td>
<td></td>
<td>302</td>
<td>t·CO2</td>
<td>$ER_ν$</td>
</tr>
<tr>
<td>2. Default values</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Electricity CO2 emission factor</td>
<td></td>
<td>0.98</td>
<td>t·CO2/kWh</td>
<td>$EEF$</td>
</tr>
<tr>
<td>2.1 Operational voltage</td>
<td></td>
<td>220</td>
<td>V</td>
<td>$OV$</td>
</tr>
<tr>
<td>2.3 Full load amperage</td>
<td></td>
<td>290</td>
<td>A</td>
<td>$FLA$</td>
</tr>
<tr>
<td>2.4 Three phase</td>
<td></td>
<td>1.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5 Power Factor</td>
<td></td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6 Annual operation hours</td>
<td></td>
<td>7,704</td>
<td>Hr/year</td>
<td>$AOH$</td>
</tr>
<tr>
<td>2.7 Percentage of power consumption</td>
<td></td>
<td>40</td>
<td>%</td>
<td>$χ$</td>
</tr>
<tr>
<td>reduction that could be generated by</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>upgrading the non inverter type air</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>compressor to inverter type one</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Calculation of Reference emission

| 3.1 Reference CO2 emission volume        |             | 754.1499574 | CO₂ トン | $RE_ν$ |
| 3.2 Annual Electricity Input to Non      | Electricity | 769540.7729 | KWh/year | $AEI_{NC}$ |
| inverter type air compressor (NC)        |             |           |        |        |

4. Calculation of Project Emission

| 4.1 Project CO2 Emission Volume          |             | 452.4899745 | t·CO2 | $PE_ν$ |
| 4.2 Annual Electricity Input to Inverter| Electricity | 461724.4637 | KWh/year | $AEI_{IC}$ |
| type air compressor (IC)                |             |           |        |        |
Annex (3): Monitoring Structure sheet [attachment to PDD for Mahindra Hinoday Co. Ltd]

<table>
<thead>
<tr>
<th>Responsible personnel</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factory Director</td>
<td>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.</td>
</tr>
<tr>
<td>Chief supervisor</td>
<td>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.</td>
</tr>
<tr>
<td>Operators</td>
<td>Appointed to be in charge of checking and collecting raw data from monitoring devices. Monitored data is archived and recorded on monthly basis.</td>
</tr>
</tbody>
</table>
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)

<table>
<thead>
<tr>
<th>Sites</th>
<th>Proposals for hardware/equipments installation</th>
<th>Estimated emission reduction (kWh/year)</th>
<th>Estimated emission reduction (Ton/year)</th>
<th>Estimated operation cost saving (Rs/year)</th>
<th>Initial cost (in Japan market) (1000 JPY)</th>
<th>Estimated Pay back period (Year)</th>
<th>Estimated cost of reducing 1 ton of CO2 (1000 JPY/ton of reduced CO2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahindra Hinoday Co. Ltd.</td>
<td>Install Inverter A.C (NL-0)</td>
<td>308,160</td>
<td>302</td>
<td>1,848,960</td>
<td>7,000</td>
<td>1.9</td>
<td>23.2</td>
</tr>
<tr>
<td></td>
<td>Install Inverter A.C (NL-1)</td>
<td>308,160</td>
<td>302</td>
<td>1,848,960</td>
<td>7,000</td>
<td>1.9</td>
<td>23.2</td>
</tr>
<tr>
<td></td>
<td>Install Inverter A.C (NL-2)</td>
<td>256,543</td>
<td>251</td>
<td>1,539,259</td>
<td>5,000</td>
<td>1.6</td>
<td>19.9</td>
</tr>
<tr>
<td></td>
<td>Install two stages A.C</td>
<td>391,500</td>
<td>384</td>
<td>2,349,000</td>
<td>30,000</td>
<td>6.4</td>
<td>78.1</td>
</tr>
<tr>
<td></td>
<td>Install Booster</td>
<td>108,864</td>
<td>106</td>
<td>653,184</td>
<td>3,000</td>
<td>2.3</td>
<td>28.3</td>
</tr>
<tr>
<td>Ahmednagar Forging Co. Ltd.</td>
<td>Install Inverter A.C</td>
<td>350,000</td>
<td>343</td>
<td>2,362,500</td>
<td>10,000</td>
<td>2.1</td>
<td>23.2</td>
</tr>
<tr>
<td></td>
<td>Install 2 stage A.C</td>
<td>130,500</td>
<td>126</td>
<td>880,875</td>
<td>10,000</td>
<td>5.7</td>
<td>78.1</td>
</tr>
<tr>
<td>Bombay Dyeing Co. Ltd.</td>
<td>Install Inverter A.C</td>
<td>60,830</td>
<td>56</td>
<td>334565</td>
<td>3,000</td>
<td>4.5</td>
<td>53.6</td>
</tr>
<tr>
<td>Arvind Textile Co. Ltd.</td>
<td>Install Inverter A.C</td>
<td>660,200</td>
<td>647</td>
<td>4852470</td>
<td>12,000</td>
<td>1.2</td>
<td>18.5</td>
</tr>
<tr>
<td></td>
<td>Install high-efficiency drain trap</td>
<td>158,000</td>
<td>155</td>
<td>1161300</td>
<td>4500</td>
<td>1.9</td>
<td>29.0</td>
</tr>
<tr>
<td>Morarjee Textile Co. Ltd.</td>
<td>Install Inverter A.C</td>
<td>660,200</td>
<td>647</td>
<td>3961200</td>
<td>12,000</td>
<td>1.5</td>
<td>18.5</td>
</tr>
<tr>
<td></td>
<td>Install Booster</td>
<td>109,000</td>
<td>107</td>
<td>654000</td>
<td>1,400</td>
<td>1.1</td>
<td>13.1</td>
</tr>
<tr>
<td>Raymond UCO textile</td>
<td>Install Inverter A.C</td>
<td>660,200</td>
<td>647</td>
<td>3631100</td>
<td>12,000</td>
<td>1.7</td>
<td>18.5</td>
</tr>
<tr>
<td></td>
<td>Install high-efficiency drain trap</td>
<td>63,200</td>
<td>62</td>
<td>347600</td>
<td>1,800</td>
<td>2.6</td>
<td>29.0</td>
</tr>
</tbody>
</table>
【Reference】


Reference data]

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

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

#### 2)-1 Feasibility study (FS)

<table>
<thead>
<tr>
<th>Period</th>
<th>October 5 ~ 12th, 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Venue</strong></td>
<td>Nagpur &amp; Pune (Maharashtra state), Ahmedabad (Gujarat state), India</td>
</tr>
<tr>
<td><strong>Member</strong></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><strong>Investigation site</strong></td>
<td>Nagpur: 2 sites (Textile) Ahmedabad: 1 site (Textile) Pune: 3 sites (Textile, Forging, Casting)</td>
</tr>
</tbody>
</table>

(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)
Ahmedabad (Arvind: Textile)

Pune 1 (Bombay Dyeing: Textile)
Pune 2 (Ahmednagar: Textile)

Pune 3 (Mahindra: Forging)
(2)-2 Workshop

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>October 11th, 2014  9:30 ~ 15:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place</td>
<td>Pune, Karnataka state, India</td>
</tr>
<tr>
<td>Host organizer</td>
<td>IGES・TERI (Co-host)</td>
</tr>
<tr>
<td>Cooperated by</td>
<td>Maharashtra Energy Development Agency (MEDA), India</td>
</tr>
<tr>
<td>Number of participants</td>
<td>55</td>
</tr>
</tbody>
</table>

* 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)

<table>
<thead>
<tr>
<th>Data&amp;Time</th>
<th>February 3rd, 2015 10:00 ~ 13:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venue</td>
<td>New Delhi, India (TERI office)</td>
</tr>
<tr>
<td>Attendees</td>
<td>(IGES) Dr. Rabhi Abdessalem</td>
</tr>
<tr>
<td></td>
<td>(TERI) Mr. Girish Sethi, Mr. Prosant Pal</td>
</tr>
<tr>
<td></td>
<td>Mr. Mohan Ghosh, Mr. Chetankumar Sangole</td>
</tr>
<tr>
<td>Agenda</td>
<td>* Confirmation of overall activity and review of this fiscal year's project</td>
</tr>
<tr>
<td></td>
<td>* Check and discussion about result of the on-site feasibility study</td>
</tr>
<tr>
<td></td>
<td>* Content check and fix of the TERI's activities and the report</td>
</tr>
<tr>
<td></td>
<td>* Exchange of opinions about the future activities for the next fiscal year onwards</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Data&amp;Time</th>
<th>February 6th, 2015 9:00 ~ 10:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venue</td>
<td>New Delhi, India (Taj Palace Hotel)</td>
</tr>
<tr>
<td>Attendees</td>
<td>IGES: Prof. Hironori Hamanaka, Dr. Rabhi Abdessalem, R K Pachauri, Rabindra N Mallik, Girish Sethi, Prosanto Pal, Chetankumar Sangole (TERI)</td>
</tr>
<tr>
<td></td>
<td>Shakti: Krishan Dhawan, Shashank Jain, Prasun Pandey</td>
</tr>
</tbody>
</table>
| 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 |