

# **EXECUTIVE SUMMARY**

## **0.1 INTRODUCTION TO AIR & GAS COMPRESSORS**

A compressor is a machine which is capable of compressing air or gas thereby elevating its pressure from an initial low pressure to a higher final pressure. All compressors act as sources of energy.

Compressed air is a source of energy and finds application in virtually all sectors of industry. Some of the major industries which use compressed air are construction, cement, glass, plastic processing, chemicals and pharmaceuticals, foundries and forge shops, textiles and automotive manufacture. The air is typically used for control applications, etc. where it triggers, starts, stops, modulates or acts otherwise for controlling the motion or process.

Gas compressors find use in any industry where gases are handled as part of the manufacturing process, such as vanaspati, fertilizers, refineries, etc. apart from usage in gas purification and bottling plants including LPG bottling.

A compressor can be classified in many ways. Depending on the mobility factor, compressors are classified as Portable or Stationary. Depending on the technology used, they could be reciprocating, rotary vane, screw or centrifugal. And depending on the inputs used, they could be either air or gas compressors.

Reciprocating, Rotary vane and Screw compressors are based on the positive displacement principle while Centrifugal compressors are based on the dynamic principle. Depending on the requirements of the application, compressors can be further sub-classified as single or multistage, air-cooled or water-cooled, horizontal or balanced opposed, electric driven or diesel engine driven and lubricated or non-lubricated compressors.

The major raw-materials used for the manufacture of compressors are castings, aluminium and steel. The major finished and semi-finished

components used are bearings, crankshafts, switches, gauges, rotors and housings. The major bought-out items are motors, starters, control-panels, inter and after coolers and filters.

The major capital equipment used in the manufacture of compressors are horizontal boring machines, vertical boring machines, CNC machines, radial drilling machines, 3-D measuring units, ultrasonic cleaning equipment and dynamic balancing equipment.

## **0.2 STRUCTURE OF THE AIR & GAS COMPRESSOR INDUSTRY**

### **0.2.1 Manufacturers of Compressors**

Manufacture of compressors of power rating upto 5 hp is reserved for the small scale sector. It is estimated that there are around 35 - 40 manufacturers of these small compressors spread all over the country. These small compressors are mainly used for garage type applications and the technology involved is very simple and does not require sophisticated machinery. These type of compressors are not covered in this report. The total size of this market is around 60,000 to 70,000 units per annum valued between Rs. 50 to 60 crore. This estimate includes units upto 30hp manufactured by companies in the medium scale sector, which traditionally get clubbed with the small scale sector.

All the well-known manufacturers are in the medium scale sector. Many of the companies have a technical/equity tie-up with reputed manufacturers abroad. The total production in this sector is around 10,000 units per annum valued at around Rs.175 crore.

Bharat Heavy Electricals Limited (BHEL) and Bharat Pumps and Compressors Ltd. (BPCL) are two public sector units in the field of Centrifugal compressors. They manufacture large heavy duty compressors and compressors for customized/tailor-made applications. The value of output of this sector is Rs.100 to 120 crore, consisting of few units but of very high unit value.

### **0.2.2 Installed Capacity and its Utilisation**

The total installed capacity of Air & Gas compressors is about 59,375 units per annum. The capacity utilisation for the various manufacturers ranges from 23% to 86%. For the year 1992-93, the production of Air & Gas compressors was around 41,000 units. This includes the small air compressors manufactured by the organised sector.

There has been virtually no growth in the production of Air & Gas compressors over the last five years. It was 40,791 units in 1987-88 and 40,958 in 1992-93.

### **0.2.3 Exports**

In recent years, there has been a focused effort at exports by the compressor manufacturers. Ingersoll-Rand (I) has been a very successful manufacturer in their export efforts, mainly because of the support from the parent company. The total exports of Air & Gas compressors during the year 1991-92 was around Rs. 25 crore. USA, UK, erstwhile USSR, Belgium and Italy are the major countries to which compressors are exported. None of the manufacturers have got the ISO 9000 certificate, so far.

The exporters are facing problems in the following areas :

- meeting rigid delivery schedules
- quality of peripherals
- high volume of documentation involved
- spare parts exports

### **0.2.4 Imports**

The total imports of Air & Gas compressors was around Rs. 24 crore for the year 1991-92. More than 50% of the value of the compressors

imported were Centrifugal gas compressors. Only one manufacturer, (BHEL), has got the manufacturing facility for Centrifugal air/gas compressors in India.

Though BHEL has adequate technology, due to their extended delivery periods, Centrifugal air/gas compressors are imported to some extent. Integral gear type compressors, which are not manufactured in India, are also imported. The major sources of imports are USA, UK, Sweden, Germany, Japan and France.

#### **0.2.5 Financial Status**

Most manufacturers are multi-product companies. They have diversified into allied areas. It has been observed that all companies, except K.G. Khosla, are making profits. The Net profit margin, Operating profit margin and Gross profit margin for the industry are 3.8%, 11.7% and 7.7% respectively.

#### **0.2.6 Demand**

The demand for Portable and Stationary compressors are estimated separately. Portable compressors are mainly used in Mining and Construction activities. Stationary compressors find use in most of the industries.

Demand for portable compressors and stationary compressors due to the increase in the capacity of the end-user industries has been estimated for the period upto 1995. This has been achieved by developing norms for the requirement of compressed air/gas from compressors of different capacity ranges for each end-user industry. In most cases, the norm has been established as CFM per unit of installed capacity. Where this has not been possible, a norm based on turnover has been established.

The estimates of the additional capacity in most of the end-user industries are based on the seventh and eighth plan projections and discussions with the experts in the industry.

Based on the usage norms (as given in Annexure - 5) and the projected additional capacities in the end-user industries (as given in Annexure - 6), the demand for Air & Gas compressors upto 1995 has been estimated. The demand for portable and stationary air compressors has been estimated to be around 9150 units and 5724 units respectively. Demand for stationary gas compressors is estimated to be around 580 units. The total replacement demand is estimated to be around 20,000 units.

Thus the total domestic demand is estimated to be 35,000 units for the years 1990-95. This amounts to an average annual demand of 7000 units. For the past few years the average annual production has also been 7000 units. It is expected that the past trend of nil growth in domestic demand will continue. The growth in demand would have to be from exports.

### **0.3 TECHNOLOGY STATUS OF INDIAN INDUSTRY**

#### **0.3.1 Sources of Technology**

Since the beginning of the establishment of the compressor industry in India, Air and Gas compressors have been manufactured with foreign technical collaboration. Even today, most of the established manufacturers continue to enter into fresh foreign collaborations for producing new types of compressors or for updating and expanding the present range.

There is no instance of technology transfer among Indian manufacturers. Moreover, collaborations with the same foreign companies have been concluded at different times for updating or manufacturing new types of compressors. It may hence be derived that there is little original design and development work undertaken in India and whatever has been attempted so far has not met with much success.

#### **0.3.2 Research and Development Activities**

The R&D effort in India is mainly aimed at indigenisation of the compressors as per the collaborator's specifications and according to a

phased manufacturing programme. R & D activities, where reported by multiproduct companies are common for all the products. So separate R & D expenditure on compressor development has not been available in most cases.

#### **0.4 INTERNATIONAL SCENARIO**

##### **0.4.1 Major International Manufacturers**

The major international manufacturers in the field of Air & Gas compressors are :

- \* Kobe Steels, Japan
- \* Joy Compressors, USA
- \* MAN GHH Sterkrade, Germany
- \* Atlas Copco, Sweden
- \* Ingersoll-Rand, USA
- \* Sundyne Compressors, USA
- \* Hokuetsu Industries, Japan
- \* Fives Cail Babcock, France
- \* Elliot, USA
- \* Nuovo Pignone, Italy
- \* Dresser-Rand, USA
- \* Demag, Germany
- \* MHI, Japan

- \* Ebara, Japan
- \* Borsig, Germany
- \* Hitachi, Japan
- \* Sullair Corporation, USA
- \* Sulzer, Germany

Ingersoll-Rand, USA and Atlas Copco, Sweden have a presence in India through their subsidiaries, Ingersoll-Rand (I) and Atlas Copco (I) respectively. Hokuetsu Industries and Fives Cail Babcock have technical collaborations with C.P. Tools and Sullair with Elgi Equipments.

Kobe Steel produces compressors, from raw materials to finished products. It manufactures a complete line of compressors, which includes reciprocating, centrifugal and axial compressors. Kobe Steel has established a market niche for their compressors in Petrochemical industry applications.

Joy Compressors is specialised in the field of centrifugal compressors. They manufacture a wide range of centrifugal air and gas compressors. Kirloskar Pneumatics are their agent in India.

MAN GHH has manufactured compressors since 1904. The company is able to offer a complete package for any application. MAN GHH has established a market niche for their Ammonia compressors.

## **0.4.2 LATEST DEVELOPMENTS AT INTERNATIONAL LEVEL**

### **0.4.2.1 Integral Gear Type Compressors**

The latest developments in the field of Air & Gas compressors are taking place in Dynamic compressor technology. Several developments have been adapted to the integral gear type centrifugal compressor, formerly used mainly for air applications requiring pressures below 1.5 MPa and its applicable range has consequently been expanded. Adopting a barrel-

type construction for the casing, the maximum operating pressure of this compressor has been raised up to 5.0 MPa, and the maximum number of stages has been increased from four to six by use of a three-pinion type speed increasing gear. In addition, a special arrangement with an expansion turbine connected to a one pinion shaft has been developed.

#### **0.4.2.2 Flexible Metallic Couplings**

When torque is transmitted from one piece of machinery to another, the coupling used will take up the inevitable misalignment which will exist between the shafts of the driving and driven machinery. Recently a group of couplings having flexible elements made up of banks of thin membranes, have been developed. These couplings were developed in order to supply industry's need for non-lubricated, and therefore maintenance free couplings, capable of absorbing shaft misalignments which may be angular or lateral, or a combination of both.

#### **0.4.2.3 Optical Alignment Techniques**

The general principle of optical alignment, sometimes referred to as optical tooling, utilizes powerful precision telescopes and jig transits, rather than mechanical tools, to determine straightness, flatness and squareness. The heart of the technique is the optical alignment telescope and jig transit with built-in optical micrometers graduated in 0.001 inch increments. The micrometers allow for precise measurement of any displacement from a precise and referenced line of sight in both vertical and horizontal planes.

#### **0.4.2.4 High Speed Centrifugal Compressors**

The Offshore oil and gas industry has created a requirement for fluid handling machinery that has high output to weight and space ratios, coupled with reliability and ease of maintenance. High speed machines have been developed which could meet these requirements. A range of single stage high speed compressors are available with flow capacity upto 2000 CFM and driver HP upto 400. Impeller speeds for machines of this type currently in use vary from 5800 to 35,000 RPM.



## **0.5.0 TECHNOLOGY GAPS**

The technology gaps existing in the Indian compressor industry are discussed in terms of compressor design, ranges of compressors, raw material & components, peripherals and manufacturing process.

### **0.5.1 COMPRESSOR DESIGN**

#### **0.5.1.1 Integral Gear Type Centrifugal Compressors**

API 672 based Integral geared compressors are not manufactured in India. These units are imported into India from some of the major international manufacturers, namely Kobe Steels, MAN GHH, Elliot, Demag etc.

#### **0.5.1.2 Oil-free Screw compressors**

Oil-free Screw compressors are not manufactured in India. Atlas Copco (India) imports the core units, namely the male and female rotors, from the parent company, packs it and sells it in India.

The main reason for this technology gap is low demand for oil-free screw compressors in India and since the parent companies of the Indian subsidiaries have already built the manufacturing facility elsewhere in the world, the core units are imported and assembled in India.

### **0.5.2 RANGE OF COMPRESSORS**

Table 1 gives the ranges of compressors in which there are technology gaps in India.

**TABLE - 1****TECHNOLOGY GAPS**

Type of Compressor	Technology Gaps			
	Capacity		Maxm. Discharge Pressure	
	m <sup>3</sup> /min	(cfm)	kg/sq. cm.	(psig)
Air compressors				
- Reciprocating	141-420	(5,000 - 14,600)	168-1005	(2,400 - 14,300)
- Screw	127-1331	(4,500 - 47,000)	24-60	(350 - 850)
- Centrifugal	5945-9910	(210,000 - 350,000)	350-605	(5,000 - 8,600)
Gas compressors	5945-9910	(210,000 - 350,000)	350-605	(5,000 - 8,600)

However, the demand for Air & Gas compressors in these ranges is very low in India.

Reciprocating and Screw technology is available with most of the manufacturers in India. They offer a wide range of compressors upto 141 m<sup>3</sup>/min. (5,000 cfm) and 168 kg/sq. cm. (2,400 psig).

Reciprocating air compressors above 141 m<sup>3</sup>/min. (5,000 cfm) capacity and 168 kg/sq cm (2400 psig) discharge pressure and Screw compressors above 127 m<sup>3</sup>/min (4,500 cfm) capacity and 24 kg/sq cm. (350 psig) discharge pressure are not manufactured in India. Worldwide, reciprocating air compressors are available upto 420 m<sup>3</sup>/min. (14,600 cfm) capacity with discharge pressure upto 1005 kg/sq cm (14,300 psig) and screw compressors are available upto 1331 m<sup>3</sup>/min. (47,000 cfm) capacity with discharge pressure upto 60 kg/sq cm (850 psig). However, in India, the demand for these ranges of reciprocating and screw compressors is very low.

Reciprocating gas compressors are mainly used in the lower operating ranges less than 85 m<sup>3</sup>/min. (3000 cfm). Only Ingersoll-Rand (I) seems to have a firm foothold in this category. Atlas Copco (I), K.G. Khosla and BPCL also manufacture reciprocating gas compressors but their presence is very limited.

Centrifugal gas compressors are mainly used in the higher operating ranges above 85 m<sup>3</sup>/min. (3000 cfm.) BHEL is the only manufacturer of Centrifugal gas compressors in India. They manufacture centrifugal gas compressors of 85 m<sup>3</sup>/min. to 5945 m<sup>3</sup>/min. (3,000 cfm to 210,000 cfm) capacity.

Though BHEL has an adequate level of technology, due to their extended delivery periods, Centrifugal air/gas compressors are imported to some extent. Integral gear type compressors, which are not manufactured in India, are also imported. The major sources of imports are USA, UK, Sweden, Germany, Japan and France.

Apart from BHEL, upto 708 m<sup>3</sup>/min. (25,000 cfm) capacity centrifugal air compressors are sold by Ingersoll-Rand (I) and Atlas Copco (I) — both Indian subsidiaries of foreign companies. However, both these companies do not have the facility to manufacture Centrifugal compressors. They import the core unit from their parent companies, assemble it according to the users' requirements and sell it in India. Kirloskar Pneumatics are the agents for U.S. based Joy Centrifugal compressors in India.

## **RAW MATERIALS AND COMPONENTS**

### **3-D Impellers**

Impellers are the most stressed components of the centrifugal compressors demanding high precision manufacturing techniques. 3D impellers are the latest designs in high efficiency impellers for higher flow coefficient and machine numbers. 5-axis Numerically Controlled milling machine centres are required to manufacture 3D impellers. This facility is not available in India.

### **Oil-free Screw Rotors**

The core elements of Oil free screw compressors, male and female rotors, are imported by the manufacturers. However, the decision to import these components is mainly on commercial considerations.

### **Mechanical Seals**

Gas seals and High speed oil seals are not available in India and are largely imported. Usage of Dry-seals is a recent development in this area.

### **Bearings**

Certain special Bearings required for the manufacture of compressors are imported. Some of these bearings are pinion shaft bearings (tilting pad type) and wheel shaft bearings (split sleeve type).

### **High Speed Couplings**

High speed couplings are used for driver shaft - compressor shaft coupling . These couplings are imported.

### **Cartridge Filter**

The secondary oil filter used in Reciprocating compressors are called Cartridge filters which uses very thin filter paper. These filters are not available in India of the required quality.

### **Heat Exchangers**

Heat exchangers are basically Inter-coolers and After-coolers and in the lower ranges the quality of heat exchangers available in India is poor and it is imported to some extent.

### **Piston Rings**

In non-lubricating compressors, where the presence of lubricating oil in

the gas cannot be tolerated, piston rings are made of filled PTFE material. PTFE is a self-lubricating material. This material is imported.

### **Valves**

Suction valves which are attached in the front-end and Discharge valves which are attached in the discharge-end of a compressor which are manufactured in India are not of good quality, perhaps, because of the sophisticated technology involved. These items are therefore imported by the compressor manufacturers.

A new valve is being developed by Ingersoll-Rand (India) in association with their parent company which would increase the efficiency of a compressor. But this is still in the experimental stage

## **0.5.4 PERIPHERALS**

The Air-filter available domestically is poor in quality. It requires frequent replacement. Since manufacturers find it difficult to export spare parts because of the difficult documentation requirements, they import Air filters for manufacturing compressors for export purposes.

## **0.5.5 MANUFACTURING PROCESS**

### **Analog Study**

A reciprocating compressor produces pressure pulsations which, if not kept under control, can generate dangerous vibrations. Controlling these vibrations and reducing them to pre-established limits provides assurance of optimum operation of the system. Pressure pulsations can negatively affect compressor performance and can generate vibrations in the piping system. Only a careful study of pulsations and of the interaction between the compressor and piping system can provide an adequate solution to the problem. Analog study is used for this purpose which gives the best results and it is used by some major international players.

Presently this study technique is not available in India. Instead Digital study is used for this purpose.

#### **0.5.6 THRUST AREAS FOR THE INDIGENOUS TECHNOLOGY**

##### **Design Thrust Area**

The 3-D impeller used in the centrifugal compressors is more efficient than other types of impellers. In India none of the companies have the necessary manufacturing facility. Five axis milling machine centre would be necessary to manufacture 3-D impellers.

The Integral gear type centrifugal compressors (based on API 672) are not manufactured in India and these represent the latest development in Compressors. This can be one of the thrust areas for development by Indian companies.

Another thrust area is compressor noise control and reduction by looking directly at the noise sources. Efforts should also be made to reduce internal losses in the compressor. The technological needs are changing fast in India and in the years to come a distinct need is perceived for developing a mini compact air compressor which gives high portability especially for applications like portable oxygen concentrators and other health care applications.

The other thrust areas to improve the performance of compressors are Thermodynamics, Fluid Flow and Manufacturing technology based on CNC machining.

##### **Component Thrust Areas**

The thrust areas for the components used in the Air & Gas compressors are Mechanical seals, Tilting pad bearings, and Cartridge filters. Substantial investments have to be made to modernise the technology to improve the quality of these components.

## **0.6 CONCLUSIONS AND RECOMMENDATIONS**

### **0.6.1 Conclusions**

In India, reciprocating and screw air compressors are manufactured by most of the manufacturers. Few of them also manufacture reciprocating gas compressors. The total capacity range manufactured in India is limited as compared to manufacturers worldwide. Though this could be termed as a technology gap, this is not a gap in the true sense, because it is 'market-related'. In India, the demand for these ranges of reciprocating and screw compressors is not enough to provide the necessary economies of scale for domestic manufacture.

In terms of compressor design, technology gaps exist in the following types of compressors.

- Integral gear type centrifugal compressors.
- Oil-free screw compressors (the core unit is imported and assembled in India).

Only one manufacturer, BHEL - a public sector unit, has the manufacturing base for centrifugal air/gas compressors. Atlas Copco (I) and Ingersoll-Rand (I) are the other two companies in India which sell Centrifugal Air compressors. However, neither of these companies has the facility to manufacture these compressors. They import the core units of the centrifugal air compressors from their parent companies and assemble them with features according to the users' requirements and sell them in the country.

More than 50 % of the value of the compressors imported are centrifugal gas compressors. The reasons for imports are as follow:

- \* Only BHEL manufactures heavy duty centrifugal gas compressors in India.

- \* Usually the lead time/delivery period taken by BHEL is quite high compared to foreign suppliers.
- \* Integral gear type centrifugal compressors are not manufactured in India and are totally imported.

Technology gaps exist in the following components of Air & Gas compressors.

- \* 3-D Impellers
- \* Oil-free screw rotors
- \* Mechanical seals
- \* Bearings
- \* High speed couplings
- \* Cartridge filter
- \* Heat exchangers
- \* Piston rings
- \* Valves

Some of the international manufacturers use Analog Study to study the pressure pulsations produced in reciprocating compressors. But this study technique is not available in India; instead, Digital study techniques are used for the purpose.

The thrust of research and development efforts of various Indian manufacturers is not towards developing new types of compressors (basic research & design) but more towards indigenisation of the collaborator's design. The main reasons for this state of affairs are :



the low volume of turnover of business does not permit sizable investment in research and design

globally India is not viewed as a source of basic research and design

it is faster to update technology through collaboration than through indigenous research

## **0.6.2 RECOMMENDATIONS**

0.6.2.1 Given the present situation, it is unlikely that the subsidiaries of the foreign companies in India would be in a position to invest in the latest technology; namely, centrifugal technology as their parent companies have already built up the manufacturing base elsewhere in the world. Also it is unlikely that the other Indian companies (without foreign equity participation) would be investing in the centrifugal technology in the coming years. BHEL, which already has a manufacturing base for centrifugal air/gas compressors, should explore possibilities for extending its product range (especially API 672 based Integral gear type centrifugal compressors, compressors with 3-D Impellers etc.) by entering into a technical/equity tie-up with one of the world leaders in these fields if necessary. The demand in India for these type of compressors is low, yet it is necessary to become globally competitive. BHEL would be in a position to do this because of the following reasons :

- BHEL has been in this field since 1971
- BHEL has already supplied many compressors under international competitive bidding

0.6.2.2 Research & Development in the field of materials science is necessary to improve the efficiency and performance of compressors. Industry should work along with the National Laboratories/Institutes in this direction. The thrust areas are the following :

- \* reducing internal losses

- \* noise control
- \* miniaturisation of compressors
- \* thermodynamics
- \* fluid flow

0.6.2.3 Indian manufacturers need to consider catering to the global market. They should not feel restricted, by low domestic demand, in investing in new technology. They should take necessary steps such that they possess state-of-the-art technology.

0.6.2.4 One of the reasons for the existing technology gap in certain areas like Oil-free screw compressors, Integral gear type centrifugal compressors etc., is low domestic demand. Indian manufacturers should try to become globally competitive to overcome this problem of low domestic demand. They may have to face foreign competition in the domestic market itself. They should therefore take necessary measures to meet the challenge.

0.6.2.5 The following export promotion measures need to be taken to facilitate exports of compressors :

- \* restrictions on delivery of spare parts to clients abroad need to be rationalised which would help manufacturers in their export efforts.
- \* as ISO 9000 certificate is fast becoming an essential export requirement in some parts of the world, Indian manufacturers should work to get the ISO 9000 certificate.

0.6.2.6 The technology for making special bearings required by the compressor manufacturers, should be procured/developed by them.

- 0.6.2.7 The technology for making suction and discharge valves used in the compressors, should be procured/developed by them.
- 0.6.2.8 In order to facilitate availability of quality spares for all types of compressors, manufacturers need take suitable action and cultivate such ancillaries as are capable of manufacturing good quality spares.