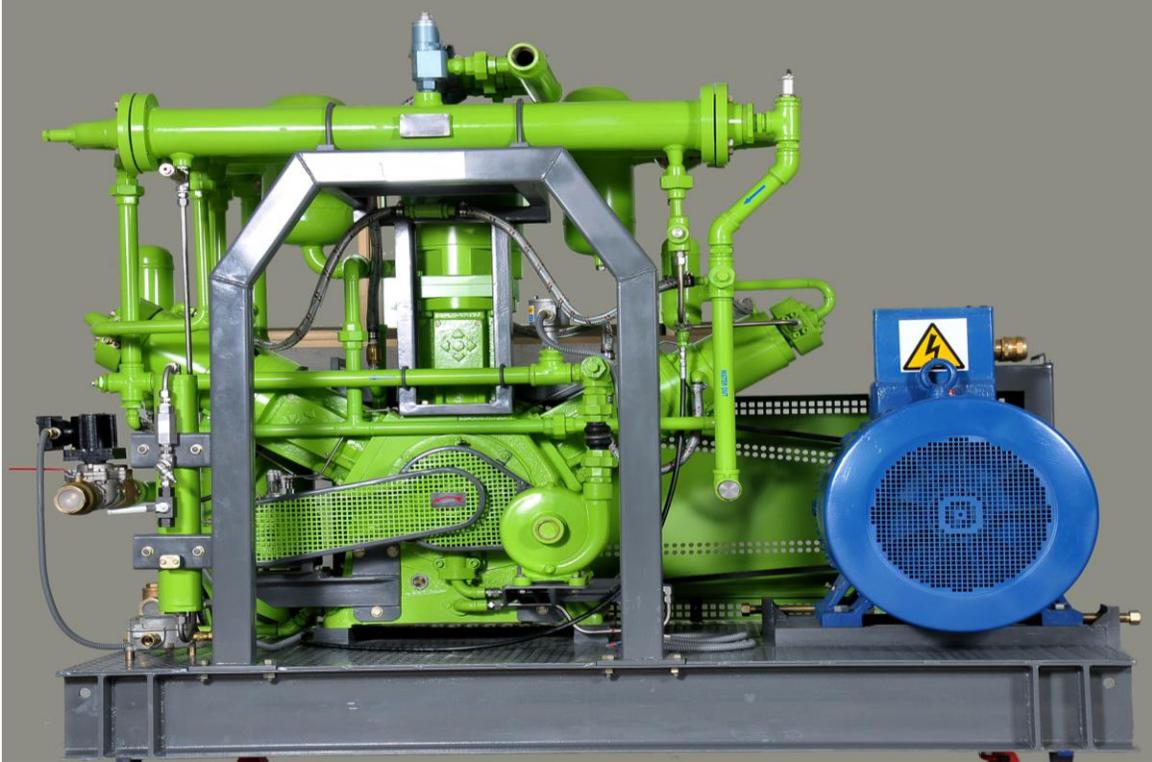


# INDIGENOUS DEVELOPMENT OF NATURAL GAS (CNG) COMPRESSOR

By

Engr. Muhammad Asim<sup>1</sup>



## INTRODUCTION

M/s Hypercomp (Pvt) Ltd successfully developed Natural Gas Compressor in Pakistan. The compressor was developed through reverse engineering for which indigenously available resources, including Material Evaluation, Testing, Inspection, Manufacturing and Expert Services were utilized. It is extremely encouraging that the concentrated effort of the resources has lead to the successful achievement of an uphill task. M/s Hypercomp (Pvt) Ltd acknowledge and appreciate the efforts of contribution of all human resources and support by the concerned industries to provide material.

## DEVELOPMENT OF CNG COMPRESSOR

After many unsuccessful attempts for having a joint venture or technical collaboration with the world's renowned manufacturers, **Reverse Engineering** had been the only choice for which a small but highly motivated and dedicated team of qualified engineers and consultants was formed based on available expertise.

A country wide survey was then conducted to source, assess and evaluate the required resources in the fields of material testing, pattern making, drafting, casting, welding etc. It was quite encouraging to know that although the available resources and technical know- how are hidden and scattered but are more than enough for the project.

## SELECTED DESIGN and TECHNICAL SPECIFICATIONS

After a detailed study of the CNG market nationally, internationally and the requirements of end users, the following design and technical specifications were selected.

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1. PEC(MECH/17864) (Development Engineer) Hypercomp (Pvt) Ltd.

Make and Model	Hypercomp, 3W815
Compressor Configuration	W- 120°
Compressor Design	Cross Head design, Atmospheric Crankcase
No. of Cylinders	03 No.
No. of Stages	03 No.
Gas Inlet Pressure (min-max)	08-15 Psig
Gas Discharge Pressure	3625 Psig
Gas Discharge Capacity@ 15 Psig	270 m <sup>3</sup> /hr ± 5% (at 30°C)
Gas Discharge Capacity@ 08 Psig	225 m <sup>3</sup> /hr ± 5% (at 30°C)
Compressor Speed	795-900 RPM
Piston Stroke	127 mm
Piston Mean Speed	3.36 m/s @ 795 RPM
	3.81 m/s @ 900 RPM
Cylinder Jacket Cooling	Water
Inter Stage Gas Cooling	Water
Cooling System	Cooling Tower (70RT min.) Closed Circuit Optional
Electric Motor Size	75KW (100hp)
Oil Capacity (Crankcase)	13 Liters
Oil Capacity (Lubricator)	1.5 Liters
Ambient Temperature Range	Up to 50°C
Overall Dimensions (LXWXH)	2135 X 1190 X 1730 (mm)
Weight (without motor)	Approx. 1750Kg
Overall Weight	Approx.2400Kg

## FEATURES

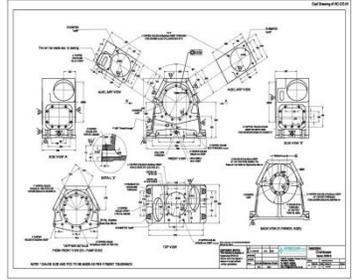
Based on Technical Specifications the following features in the Compressor were aimed.

1.	Dedicated natural gas compressor design
2.	W type cylinder arrangement utilizing gas load balancing
3.	Specifically designed Heat Exchangers for high ambient conditions
4.	High quality Relief valves for sure safety
5.	Full flow filtered pressurized lubrication
6.	Very low vibration does not require any specific foundation
7.	Lowest maintenance cost due to low RPMS and piston speed
8.	Accessible for easy and quick maintenance
9.	No special tooling required for any maintenance operation
10.	100% parts availability round the clock

## DEVELOPMENT PROCESS THROUGH REVERSE ENGINEERING

For reverse engineering complete evaluation of all the parts was done by **PSQCA Laboratories**. Evaluation reports include Chemical, Physical and Metallographic analysis.

Comprehensive and detailed machining and pattern drawings for each and every part were developed and patterns on German Standard were produced by expert pattern makers.

<p style="text-align: center;">GOVERNMENT OF PAKISTAN MINISTRY OF SCIENCE &amp; TECHNOLOGY <b>PAKISTAN STANDARDS AND QUALITY CONTROL AUTHORITY</b> TECHNICAL SERVICES CENTRE (FORMER MIRDIC)</p> <p>Job No: 24842      Date: 26.02.2007</p> <p style="text-align: center;"><b>EVALUATION OF CYLINDER LINER</b></p> <p><b>Client:</b> M/s. Hera International, 28-Services Plaza, The Mall, Rawalpindi.</p> <p><b>Job Description:</b> The client submitted a sample of cylinder liner of CNG Compressor for evaluation, for which following tests were performed at TSC Labs:</p> <ol style="list-style-type: none"> <li>1. Chemical Analysis;</li> <li>2. Metallography;</li> <li>3. Hardness Testing.</li> </ol> <p>Results and observations regarding above mentioned tests are as follows:</p> <p><b>Chemical Analysis Results:</b></p> <table border="1"> <thead> <tr> <th>Elements</th> <th>Percentages</th> </tr> </thead> <tbody> <tr><td>Carbon(C)</td><td>= 2.50%</td></tr> <tr><td>Manganese(Mn)</td><td>= 0.89%</td></tr> <tr><td>Silicon(Si)</td><td>= 1.88%</td></tr> <tr><td>Sulphur(S)</td><td>= 0.039%</td></tr> <tr><td>Phosphorus(P)</td><td>= 0.16%</td></tr> <tr><td>Nickel (Ni)</td><td>= 0.14%</td></tr> <tr><td>Chromium(Cr)</td><td>= 0.38%</td></tr> <tr><td>Molybdenum(Mo)</td><td>= Traces</td></tr> <tr><td>Copper(Cu)</td><td>= 0.20%</td></tr> </tbody> </table> <p><b>Metallography:</b> One suitable cross-section cut specimen was prepared and observed in Unetched and etched conditions.</p> <p><b>Unetched:</b> The specimen shows B Type distribution of graphite flakes in grey iron characterized by matrix grouping random orientation (Fig.1) and uniform distribution.</p> <p style="text-align: right;">RE-VIEWED 3/4</p>	Elements	Percentages	Carbon(C)	= 2.50%	Manganese(Mn)	= 0.89%	Silicon(Si)	= 1.88%	Sulphur(S)	= 0.039%	Phosphorus(P)	= 0.16%	Nickel (Ni)	= 0.14%	Chromium(Cr)	= 0.38%	Molybdenum(Mo)	= Traces	Copper(Cu)	= 0.20%	<p style="text-align: center;">PHOTOMICROGRAPHS J-24842</p>  <p>Fig. 1 Unetched 100X</p>  <p>Fig. 2 Etched 200X</p> <p style="text-align: right;">3/4</p>	 <p style="text-align: center;"><b>Patterns</b></p>  <p style="text-align: center;"><b>Drawings</b></p>
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## CODES and STANDARDS FOLLOWED

### 1. For Overall Design

I. Reciprocating compressors for petroleum, chemical and gas industry services **API (American Petroleum Institute) Standard 618**, Fourth Edition, June 1995.

II. Pakistan **CNG Rules 1992**

### 2. For Heat Exchanger's Design

TEMA Class R, ASME Section VIII Div. I

### 3. For Welding and Fabrication of Heat Exchangers, Piping and Pressure Vessels

ASME Section VIII, IX and B31.3

## MATERIALS USED

The materials used for different parts were proven which were very carefully selected through our consultants in accordance with API-618.

ITEM DESCRIPTION	MATERIAL	FORM
Crankcase	Gray Cast Iron BS Grade 260	Cast
Crankshaft	SG Iron BS 700/3	Cast
Connecting Rods	SG Iron BS 700/3	Cast
Piston Pins	AISI-8620	Forged
Cross Head Pistons and Cylinders	Gray Cast Iron BS Grade 260	Cast
Compression Cylinder 1 <sup>st</sup> Stage	Gray Cast Iron BS Grade 260	Cast
Compression Cylinders 2 <sup>nd</sup> and 3 <sup>rd</sup> Stage	AISI-1045	Forged
Cylinder Liners	Gray Cast Iron BS Grade 260	Cast
Cylinder Head 1 <sup>st</sup> Stage	Gray Cast Iron BS Grade 260	Cast

Cylinder Heads 2 <sup>nd</sup> and 3 <sup>rd</sup> Stage	AISI-1045	Forged
Compression Piston 1 <sup>st</sup> Stage	Aluminum-8620	Extruded Bar
Compression Piston 2 <sup>nd</sup> Stage	Aluminum-7075	Extruded Bar
Compression Piston 3 <sup>rd</sup> Stage	AISI-4140	Bar Stock
Piston Rods	AISI-4140	Bar Stock
Valve Seats and Guards	Carbon Steel	Plate
Valve Plates	Stainless Steel AISI-304	Plate
Valve Springs	Stainless Steel AISI-304	Plate
Packing Cases	AISI-1045	Forged
Piston Rings, Rider Rings, Rod Seals	PTFE, PEEK	Bar Stock
Shell for Heat Exchangers	ASTM 106, Grade: B	Extruded Bar
Tubes for Heat Exchangers	AISI-304L	Extruded Bar
Tube sheets for Heat Exchangers	AISI-304L	Extruded Bar

## VENDORS

The International manufacturing method was adopted i.e. subcontracting and vendorization. Here are some vendors which are very renowned and professional in their concerned fields.

**Excel Engineering- Lahore** : Supported in the production castings of crankcases, cross head cylinders and cylinder heads.

**Qadri Brothers – Lahore** : Supported in the development of crankshafts in SG Iron Grades under supervision of

**Mr. Munir Ahmad** : It has higher strengths and is more economical than the original one which was made of forged 1045.QBL also casted flywheels which weighs **330kg** each.

Crankshafts and flywheels were balanced dynamically at 795 RPM at **KSB Pumps - Hassanabdal**. Since each and every rotating part of compressor is dynamically balanced not statically, so machine's vibrations are very low.

**PSQCA - LHR (Pakistan Standard and Quality Control Authority)** : Supported throughout in material testing and development of crucial castings like connecting Rods again under supervision of **Mr. Munir Ahmad**. This part was developed in **SG Iron** instead of forged Steel 1045 and its results are quite satisfactory.

**Shahsons Engineering – Multan** : Supported in the manufacturing of cylinder liners according to our given specifications.

**GM Engineering – Lahore** : Casted miscellaneous small but critical parts. Different special processes to enhance the performance and service life of different parts.

**Hercules Engineering - Lahore** developed **special PTFE coatings** for cross head pistons through which friction was reduced and saved electricity load. They are also engaged in hard anodizing of Aluminum pistons.

**PMO (Pakistan Management Organization)'s** state of the art machining centers provided machining services for critical parts.

**Precision Engineered parts – USA** : Manufactured Piston rings, rods and rod seals on specific sizes and requirements.

**Petrocon Engineering – Islamabad** : Provided services in the field of fabrication and welding of heat exchangers, pressure vessels piping and structures in accordance with international

applicable welding codes like **ASME section VIII and IX**. Radiography carried out by **Jiaco Pakistan** and inspection of fabrication/piping done by **Dynamic Inspection Services**.

**Hamid Traders – Islamabad** : Got developed special high temperature resistant paints from **ICI** for our special requirement.

Our vendors/sub contractors have always been very supportive and we expect the same response in the future also.

			
<b>Rastgar Engineering- ISB</b>	<b>Excel Engineering - LHR.</b>	<b>Qadri Brothers - LHR.</b>	<b>KSB Pumps- Hasanabdal</b>
			
<b>PSQCA - LHR.</b>	<b>Shahsons - Multan</b>	<b>GM Engineering - LHR.</b>	<b>Hercules Eng. LHR.</b>
			
<b>PMO Khanpur - Taxila</b>	<b>Indigenous Developed Parts</b>	<b>Precision Engineered Parts, USA</b>	<b>Imported Items</b>
			
<b>Petrocon Engineering - ISB.</b>		<b>Dynamic Inspection Services</b>	<b>Hamid Traders - ISB.</b>

### IN-HOUSE ACTIVITIES

These are some in-house activities associated in manufacturing of CNG Compressors.

All the parts received have to go through strict quality checks. Each and every part has its own acceptance criteria. All quality and inspection procedures were developed by Hypercomp (Pvt) Ltd an **ISO 9001 : 2008** certified company.

To ensure the precision and accuracy of all parts, calibrated instruments were used from reputable resources. For this the services from **PCSIR, Inspectest, and KSB** etc were hired.

All the pressure containing parts are **hydrostatically** tested at **1.5 times** of their design pressure for 24 hrs as per international codes. This includes compression cylinders, heads, heat exchangers and all piping spools.

Parts are then assembled according to their predefined fitments and tolerances. The assembly procedures and fixtures for each and every part were developed at M/s, Hypercomp. It also reduced the assembly time.

After the completion of bare shaft compressor, piping and heat exchangers were installed on the main skid.

The **Performance and Endurance** testing activity was the most crucial part and for that an In-house test bench and duplicated environment of CNG Stations have been designed. Compressor had to undergo through harsh endurance testing to prove the set parameters.

Once compressor passed its performance test it is then shifted to paint shop where a proper painting procedure is applied in accordance with international standards. The paints used are comprised of **Epoxy Primer, PU Primer and 2K Paints** which are corrosion and high temperature resistant. A paint thickness report is generated for all painted parts before final assembling with all external gadgets.

Third party inspection and performance testing, which is a compulsory requirement from **OGRA (Oil and Gas Regulatory Authority)**, has been conducted by M/s **Bureau Veritas**, an international inspection company.

The **Final Manufacturing Data report** (MDR) was submitted to **OGRA** for its evaluation and approval in 2008. OGRA then formed a high level technical committee comprised of **OGRA itself, HDIP, BV and IMTech**.

As this was the first high pressure gas compressor ever made in Pakistan so every member of TEC was extra conscious and reluctant.

They later physically visited the facilities and witnessed the performance of compressor. They asked numerous questions which were answered with documented evidences. This gave them enough confidence to finally approve the CNG compressor and issued the letter for production in **Feb 2010**.

			
<b>Parts Inspection</b>	<b>Instrument Calibration</b>	<b>Hydrostatic Testing</b>	<b>Bare shaft Compressor</b>

			
<b>Welded Parts install.</b>	<b>Performance Testing</b>	<b>Painting</b>	<b>Assembly after Paint</b>
			
<b>3<sup>rd</sup> Party Inspection</b>	<b>OGRA's TEC Inspection</b>	<b>OGRA's Approval Letter</b>	<b>ISO9001:2008 Cert.</b>

### FUTURE TARGETS

With present available resources, expertise and professional casting and machining centers, M/s Hypercomp is in a position to manufacture any range of compressors for different pressure and flow rates.

1.	CNG compressors range from 200m <sup>3</sup> /hr to 600m <sup>3</sup> /hr for local and international market
2.	40 bar compressors for PET bottling industry
3.	Oxygen, Nitrogen and CO <sub>2</sub> compressor for industrial use
4.	High pressure Air compressors for defense forces

### ACKNOWLEDGEMENTS

Dedicated efforts, Vision and hard work of **Mr. Hamid Mahmood –CEO, M/s, Hypercomp**, who with limited resources but with tremendous courage, belief and dedication made the indigenous manufacturing of Natural Gas Compressor possible in the country.

### THE PFA (PAKISTAN FOUNDRY ASSOCIATION) ROLE

Thanks to **Pakistan Foundry Association**, who organized **International Foundry Congress and Exhibition (IFCE -2006)** at Lahore. It was a great opportunity for the team of Engineers where they found almost everything under one roof required to materialize for the project which is a ground reality now.

### CONSULTANTS

It is worth mentioning few names of consultants who encouraged technical staff in the development of Natural Gas Compressor. There is no doubt that without their support and extra ordinary help, the achievements could not have been possible.

**Mr. Munir Ahmad** : (Ex-DDG of PSQCA) who guided in the selection, sourcing and development of materials and parts.

**Mr. Imtiaz A. Rastgar** : (CEO Rastgar Engineering – Islamabad) provided first prototype casting of crankcase. It was casted by their German consultant Mr. Becker.

**Mr. Rick Tyma** : (Technical Manager Precision Engineered Parts, USA) for the selection, development and supply of the most crucial composite material parts like Piston Rings, Bearings and Rod seals etc.

**Mr. Reza Ahmad Malik** : (ASME Level 3 inspector, CEO of Dynamic Inspection Services Co.) for his valued contribution in laying welding procedures, overall inspection and technical guidance.

**Abdul Majid** : (Design Engineer, Darul Riaz-Saudi Arabia) who designed heat exchangers for the specific requirement.

The team involved in the project of Natural Gas Compressor is highly obliged and thankful to all those who extended their support in the development of this special Project.