III.- PROLOGUE

The current world requires increasingly an efficient and less polluting industrial and energy processes which force us to look for increasingly advanced technology based on the performance and experiences recorded over decades in multiple industrial plants located worldwide, product of the lessons learned and the best engineering practices in each productive sector of each country, required in the most critical areas of the world economy, such as the oil, gas, petrochemical industry and in power generation.

In a world looking for more and more efficiency and less polluting energies, at the same time more safety, there is a focus on eliminating the energies producing high contaminants like the Carbon (CO, CO_2 greater pollutants) and to keep the economy in the countries using efficient industrial processes in order to avoid them through cleaner fuels such as natural gas and less polluting liquid fuels (such as clean gasolines and diesels with a low sulfur content), as well as now in these days, preparing to use in the near future, the hydrogen and other less polluting synthetic gases, while cleaner and renewable energies such as wind energy, solar energy, hydraulic energy can be developed and improved to benefit the pollution all over the world.

Nuclear energy is a separated issue, since although it is clean, it requires very risky and dangerous processes which have proven to be very harmful and danger to the worldwide due to the hazard effects caused by the presence of radioactivity during the process and the sequelae it produces on living beings humans and nature. This book tries to achieve the possible improvements at the level of the world industry, using the most efficient and the least polluting energy being available and cheap, which is derived from the fossils (i.e., not in the case of non-renewable energy being in development). The oil and natural gas industry has been developed since a century ago, exist a good infrastructure, improved performance, being more efficient and safer in industrial processes now in our days, improving the quality of human lives looking for minimize also any possible negative effects on nature.

These industrial processes in many Facilities around the world require to use highly efficient and reliable machinery through multiple chemical and thermodynamic processes in the treatment of raw fuels such as crude oil and natural gas. There are very important critical steps in the development and operation of these oil and gas treatment plants, where the correct design and selection of mechanical equipment (in this case applicable to rotating equipment) are vital to obtain the final products that the international market and economies require in order to maintain a satisfactory world economy and the best life standards for people in this world, not being in the highest and effective level in these days.

Among the rotating equipment that is required to be used in industrial plants to obtain the commercial fuels (liquid and gas) that move the economy around the world, some of them are as follow, the hydrocarbon pumps, air and gas compressors, gas and steam turbines, air and gas blowers, gearboxes, electric motors (fix speed or VFD), gas engines, and some others, where each one alone represents a variety of complex and critical designs and divers utility consumptions associated, that complement it in order to have a reliable and functional operation, reaching the objectives and goals with the final product demanded by the society.

Each of the different types of rotating equipment required in the world industry, have been developed through very complex and effective technical specifications, which for several decades have been continuously reviewed and improved through the good and bad experiences in the operation and maintenance of process plants and taking care about the lessons learned and through the advances in the newest and more reliable technologies developed by different engineering entities and manufacturers in the case of rotating equipment.

Some of them, that design the industrial plants for the processing of crude oil and natural gas (through the Licensors / Process Technologists), the owner/purchaser/user who operate and maintain these critical and complicated plants (by oil and gas companies, Power Generation, Petrochemical companies), and the periodically revision among the users, such as the owners operating plants and the world-class turbomachinery manufacturers, about this critical equipment in severe services sometimes.

In addition, we have the Contractor or Designer in this case applicable about Engineering, Procurement and Construction, and also through the Oil & Gas Institutions in charge, having the compromise to meet the best specialists and getting their field experiences and lessons learned, in periodically time (some of these institutions have carried out technical meetings every 5 to 10 years approximately), in order to improve the reliability, maintainability, availability, quality and safety in each mechanical equipment, in this case about the rotating equipment like the reciprocating compressors treated in this book.

All these technical specifications generated in those technical meetings, coordinated by important Institutions in charge, with senior specialists over the world, and with the experiences acquired in so many years (with their own "know how"), have been used in the industry for the technical development of this class of equipment and how to fight with their exigent processes, where the Contractor (in charge of Engineering-Procurement-Construction) is who finally applies it in new projects, where its own experience learned in the past and the knowledge of new tools and applications, based on the best technology being available (also known by turbomachinery manufacturers), can be applied in order to complete the planning and actions to execute any project.

It’s also important to have in mind the reliability since the original concept or vision till its final execution being reached when the machine is built (i.e., passing through the conceptual engineering, basic engineering for design, detailed engineering, procurement, manufacturing, assembly, inspection, testing (in factory and in site), shipment, preservation, installation, commissioning, start-up, reviewing any issue such as planned in order to comply with the expected guarantees / warranties in the future operation in the process plant, as minimum).

In addition (but not less important) in the design and new technology application, it’s made by the mechanical equipment manufacturer, who design the equipment depending on the service type in order to comply with a minimum warranty and guarantee conditions as required in most of the chemical and thermodynamic process used to transform the raw fuels (usually to get a useful life cycle of the equipment and the industrial plants of 30 years), in clean and less contaminated fuels, in the best reliable and safe possible way, but always following the best engineering procedures, technical specifications, which are based in international codes/regulations being available all around the world.

As mentioned, those codes / regulations are constantly in revision and improvements based in new knowledge, studies, simulations, and technology to be applied in the equipment by the manufactures world-class level, where the focus is to produce cleaner fuels or derivates of them, as required by the end user, who through scheduling periodical technical meetings (with serious and specialized engineering Institutes and manufacturers through its specialists) in order to increase the benefits economically, generating the most appropriate technical specifications for the mechanical equipment already mentioned (in this case the rotating case). This has been used in industrial plants with the highest world-class level in quality (oil and gas companies, petrochemical, power generation, among others).

Due to the extensive technical specifications that allow a reliable and safe design of rotating equipment in industrial plants, they would be separated into independent sections, depending on each specific type of reciprocating compressors, also in rotating equipment (requiring different books or volumes to clarify technically on each particular case), where the intention is to give the maximum possible technical details about how to design and manufacture in these days, and how each equipment can be operated and maintained, so we can increase the performance in efficiency, safety and also reducing the environment impact and pollution that could cause the fuels produced in process plants like oil, gas and petrochemical companies, using this class of equipment. Besides, is important to mention about to improve the auxiliary parts involved in the compressor operation and the utility consumptions, which together form what is called the equipment package. This implies to have a single responsible or coordinator in the entire engineering and manufacturing process (on each side, by Owner, Contractor & Manufacturer), so we can get reach the minimum guarantees and performance being required to comply with the service for which it has been destined within the industrial plant.

The compressor package, in addition to its complexity in design and manufacture, most be integrated with advanced control systems and complex auxiliary systems included as part of the package. This means, we require the presence of different engineering disciplines for its adequate completion with a high quality standard. In this case, engineering disciplines such as, Process, Mechanical, Piping, Civil, Structural, Flexibility and Stress Piping, Electrical, Instrumentation and Control Systems, Industrial Safety, Fire & Gas Metallurgical and Corrosion, Welding, Architecture, Quality Assurance (especially during the Certification, Inspection and Testing), Installation, Commissioning, Start-up, Construction on site, as well as those about the Procurement and Project Control. In addition, it is needed to interchange the technical issues during the project with their respective responsible counterparts (by disciplines) as planned for the project by the Client/ Purchaser to whom in the project must carried out.

The best intention with my contribution in knowledge and experiences in this technical book (or others related with rotating equipment in the future), is to share the lessons learned in these 4 decades (since the early 80s till now), in the conceptual design, basic and detailed engineering for the selection, design, procurement, installation, operation and maintenance about the compressors through its useful life cycle in the plant.
My technical contribution has been shared in 50% of the time (20 years) in the phase of the design and selection engineering, and the rest 50% (20 years) assisting and coordinating in the facilities at field in the process plants directly, directly in contact with the operators and maintainers in the aspects related with the reliability, maintainability, availability and safety in the correct operation and maintenance, in order to recommend the best to reach an operational and mechanical performance, and also reaching the longest possible useful life in that class of equipment over the process plants.

The book includes also information in text, different diagrams, drawings, photos, in order to facilitate the understanding of the technical issues being addressed, to make easier and as a reference or clarification for the reader.

It also should be noted that in addition to the technical specifications being applied in these days by world class level companies, there are sections where the reliability, maintainability, quality and safety can be better followed based in a comparative review of the specifications for reciprocating compressors between those used by the Purchaser and the main recommended by API Institute Specification (American Petroleum Institute) regarding the basis to design and select the machinery.

Besides, there are other important technical documents (related with the operating conditions, material details, manufacturing process, accessories, auxiliary and control systems as required, scope of procedures for inspections and testing, the new technology available in turbomachinery in these days, and some others about how to apply the scope and how to analyze the failures and typical damage in compressors affecting the reliability, and some technical tools about how to improve the reliability in compressor through a risk analysis).

Utility consumables are critical in these reciprocating compressors such as the cooling water system, air / gas or purge for sealing and nitrogen barriers in seal systems, steam water system and oil seal systems (when applicable), electrical consumption for the main drivers and for devices and actuators (also pneumatics devices through air where be applicable) regarding the compressor package, gas / oil heater systems (electrical or steam water), instrument air for pneumatic action in auxiliary systems, oil lubrication / oil control systems for bearings and in operational control systems, and on each auxiliary service and in accessories being part of the package.

In addition, it is necessary at the beginning of the project, to define the instrumentation and piping diagrams (P&ID) for the correct operation of the compressor package, as well as the drawings for general arrangement about the compressor package, besides is important to review the foundations diagrams as required, in order to adapt the physical spaces available in the process plant (the size and spaces inside the plant are defined prior to the selection of the rotating equipment to be installed).

It is also relevant to have since the beginning the procedures and acceptance criteria as required for the inspection and test plans (required for the Factory acceptance test FAT, and those required for the Site acceptance test – SAT) applicable for the major components in the rotating equipment (compressor package), and approved by each part in project before to install the compressor in the plant. It's also required to receive memories of calculus and different technical studies, operational and mechanical simulations (including rotodynamic studies), in order to get finally a reliable design and performance in the reciprocating compressor being selected.

On the other hand, the control architecture and the philosophy about operation and control must be clearly defined during the execution and development phase in the project. The whole technical documentation must be reviewed in the first 6 to 8 months of starting the detailed engineering in the project, so the Contractor can accept to start the manufacturing process and the assembly in the Factory about the major and critical parts in the reciprocating compressor.

In the phase prior to provide the purchase order, before to buy the compressor with the final selected Supplier/ Manufacturer (through a technical comparative evaluation about different bidders), and after to have multiple technical meetings for the clarification related with aspects such as the scope of supply, optional items, mechanical and operational performance, inspection and testing procedures, control systems architecture, about the compressor package, is when it is decided about the scope of the supply as agreed to be provided by the Supplier/Manufacturer of the equipment, and when be agreed the delivery time expected to complete the engineering and manufacturing project according to the project schedule, related with the time when to move the compressor package from the Factory to the process plant at site (reception / preservation at site before the installation).

It is worth mentioning that the integrity and compromise by my side, about all the information as presented and commented in this book, is not related with any particular Oil Company or Compressor Manufacturer, so I clarify the intention is to look for the best way to get reliability, availability, maintainability and safety issues, so this means to use information coming from different technical subjects, I have consulted before, information being available in technical papers, technical magazines, proceedings in technical meetings, Conferences or Symposiums, etc., in order to get a better explanation or understanding how to collect, analyze, evaluate and detect the causes or reasons affecting the compressor, so we can take the best actions to avoid the severe or critical failures and the consequences of the damage in reciprocating compressors (even in case when the failure be considered not severe such as deterioration fails or incipient fails).

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The material in this book, includes different aspects based in the Manufacturing experience and technology available at the project moment by Manufacturers, and as agreed among the parts before to assign the purchase requisition in order to comply with all the Quality issues, about the experiences and lesson learned by each technologist or licensor involved in the Process, related with the compressor operators in the Oil, Gas and Petrochemical Plants, regarding the different national or international standards, codes or regulations that could be agreed in each project and that must be applied in a good manner by the EPC (project contractor). The idea is to comply with the goals in quality assurance in the different phases since the beginning of the project till the final installation, commissioning and start-up of them, expecting to cover the minimum and maximum operational and mechanical guarantees as requested for which they have been designed.

It is my intention that all this knowledge in the area of rotating equipment could serve as a reference for turbomachinery engineers in actual and future generations in the industrial world, and that will also be the basis for the improvements and technological changes that will surely occur in the future about the compressors, due to the conditions of the world economy and the infrastructure existing today.

This allows us to predict, this infrastructure will be in force for at least 25-30 more years (i.e., till 2050 as I have estimated could be) since the world's reserves of crude oil and natural gas, and fossil fuels statistically reflect this scenario. In this period of time, the minimum infrastructure to use renewable energy and non-polluting energy such as hydro, wind, solar, nuclear (not so reliable in these times) and some others in development process (hydrogen, capture and collection of CO_2 through underground wells, synthetic gas, among some others) will be developed satisfactory in next decades in order to be cheaper and safety and reliable compared with the energy being now derived from the fossil fuels.

Technological advances have been the key in the rotating equipment going from control components issues, passing the mechanical to pneumatic, then the hydraulic and currently to electronic systems, which are proven to be increasingly efficient, effective and reliable as well as safe for the current world economy, significantly reducing the possible risks and dangers could be caused by fossil fuels and their processing, to human beings themselves and the impact about the environment such as they have occurred before in the facilities.

Besides, the useful life cycle of the equipment and its most critical components have been significantly increased with new studies simulations and technologies, and with the increasingly resistant and lightweight materials used today. In summary, the machinery has been improved compared to past few decades, since it is lighter, more efficient, more reliable in requirements with more critical services and process, with higher or lower pressures, temperatures, flows, capacity, composition in gases (affecting the gas sealing systems in compressors, speed control systems (such as in steam or gas turbines, synchronous or induction motors, VFD), improvements in metallurgy and materials in direct contact with the process gas, improvement in the analysis and studies about rotodynamic or piping pulsation and vibration, being applied to smaller or bigger gear running in reciprocating air or gas compressors, among some others issues).

All this can be measured through the level of reliability in the compressor (occurring fewer and less severe failures during operating time), availability (increasing the operating time), maintainability (improvement in repair time), and in the safety and quality issues about the personnel, equipment and facilities (i.e., less severe and fewer unforeseen or unscheduled shutdowns, less fires, less spills, less explosions, or production loss time, etc.).

These factors and improvements related to rotating equipment, have also been developed and applied for other types of mechanical equipment such as static parts (among others, pressure vessels, heat exchangers with cooling by water or by air, treatment towers, columns, in direct fire equipment (such as burners, process furnaces, steam boilers, etc.), surface condensers, systems with ejectors, for injection of chemicals (corrosion inhibitors, etc.), as well as many others that are part of the facilities in the Process plants. However, they are not part of this book since it is up to the static technical specialists in this type of mechanical equipment to describe, evaluate and analyze the technology available and recent improvements being made in last decades in that kind of equipment.

I close this prologue with the illusion in mind, that these 4 decades of learning and knowledge acquired in rotating equipment, with the experience accumulated in this time, and with the supports as received from the great companies that I have had the opportunity to face the challenges day by day, both in the Facilities in process plant and in the phase about the design, selection and during the execution of small and big projects, it could be part of the knowledge and learning that can be consulted by engineers who are now being responsible to provide good engineering in rotating equipment, those specialists requiring actualization about knowledge, an first at all, to those engineers starting in this area of knowledge and those who will enter soon in the industry and for future generations. To all of them, I wish you reach your goals in this complex area, such as I think have met my own goals and objectives in this regard being supported by great companies, clients, institutions and manufacturers.

Alberto Mtz Llaurado, 2022

IV.- OBJECTIVES AND GOALS IN RELIABILITY FOR RECIPROCATING COMPRESSORS

The main objective to achieve the highest profitability for an industrial company that aspires to be world class level, is to have the highest levels in reliability, availability, safety, maintainability, among other aspects of value, which are achieved based in the experiences and lessons learned about the design, manufacture, installation, operation and maintenance of rotating equipment, and in this case that applies to us here, in reciprocating compressors.

Among the different existing tools for this purpose, we must mention (among others), the application of continuous improvements in the development of the technical specifications of the equipment and its facilities, the contributions accumulated by various studies and cases analyzed from the analysis of the failures and the correct diagnosis in said analyzes for each case, as well as the collection of statistical and probabilistic data of the different type of failures being analyzed through the few decades by the specialists and technicians present in the industry worldwide.

The profitability of industrial companies that want to reach a world-class level, must comply with strict protocols and standards that are part of the specifications of the final product as it is in this case for the compressors, being the objective the achievement of continuous operations without failures or unforeseen or unscheduled shutdowns, operating in the widest range of design and production capacity (for greater productivity), and without affecting the environmental and community environment where the industrial activity is carried out or developed.

Going into more detail, in the development of the book, the different technical tools and processes most appropriate for the achievement of these objectives will be indicated that make companies leaders to follow worldwide, in an increasingly competitive and demanding world in these times where aspects such as climate change and its consequences force us to implement increasingly demanding and challenging rules and procedures in this decade and in the rest of XXI century.

A primary tool for the achievement of these objectives and goals is the application of technical specifications in the design phase in any industrial project, since it is the moment when they are reviewed and decided based on the experiences lived and the learning in the area of rotating equipment and in this particular case of reciprocating compressors, based on the particular operating conditions required in the process to which the equipment will be subjected during its useful life cycle, which is estimated around 30 years.

In general, it is expected that, during that stage or life cycle, there will be no unforeseen or severe failures or stops, while operating at the highest possible capacity (or according to the criteria or strategy conceived in this regard), always with the highest possible levels of efficiency to have the highest business profitability.

The scope of the technical specifications for reciprocating compressors is generated through different entities and technical institutions based on their own criteria and experiences lived during the operation in the different industrial plants where they are required, taking into account that their scope may vary depending on the type of service, the physical conditions of the plant site, the regulatory limitations of the country or by Purchaser, the technology developed or available to the current date, as well as other factors (tangible or intangible) derived from the available budget and the strategies of the government in this regard, the specifications required in the final product of the plant, the degree or level of minimum acceptable quality in the process, which must comply with the minimum standards of any class company worldwide, where the installation, operational and maintenance risks are as low as possible.

The scope of the technical design specifications are generated by institutions such as the technologist or licensor of the process that is required to be applied, the standards and codes of the client or user of the plant or facilities, the EPC-ist (project designer) who will develop the project, as well as some of the existing international institutions that are recognized for this purpose, that depending on the location of the plant, may vary (in the case of projects at the American level, standards such as APIs, ASME, ASTM, NFPA, ISO, AWS, among others), taking into account the rules and regulations of the country where these equipment would operate.

An appropriate method to achieve this goal is to see over time, the technological advances or changes made, as well as the experiences seen and lessons learned along the way (from the last 30 years, if possible) regarding the installation, operation and maintenance of this equipment in existing facilities.

In this case, the text includes particular cases of the different technical improvements made in the specifications, with the aim of having a greater degree of reliability, safety, availability, maintainability and operational efficiency of both the equipment and its facilities.

Given how extensive the particular specifications of reciprocating compressors are, in this case we consider the most relevant or critical aspects that may affect these factors (especially reliability and safety) to achieve the highest possible operational capacity with the best possible efficiency.

Among the cases to be analyzed, we could highlight the following:

- Specifications of the technologist /process licensor.
  In this particular, the different standards generated for reciprocating compressors and those of their auxiliary lubrication, control and sealing systems are taken into account, as they are the most important in the design and reliability of this type of equipment.
- Technical specifications of the user or client of the physical facilities where this equipment will be installed.
- Technical specifications of the designer (EPC-ist) applied to compressors.
- Technical specifications developed by international institutions applied to compressors (cases such as API, ISO, etc.).
- Technical specifications developed by world-class private companies in projects for reciprocating compressors, especially for the oil, gas and petrochemical industry (Fluor, Shell, BP, ADNOC, etc.).

- Particular technical complements that apply as improvements in the area of reciprocating compressors.

In addition to the technical specifications, another way to improve the issue of reliability in this equipment is by applying statistical and probabilistic studies according to the different failure patterns seen for the area of compressors, studies carried out by serious institutions created for this purpose, as it is in one of the cases, OREDA (Offshore and Onshore Reliability Data) among others. In our case, data and analysis carried out by OREDA are taken to have a good base reference in this regard.

There are other technical tools used to achieve the goal of increased reliability, which includes failure mode analysis and fault diagnosis related to reciprocating compressors (with procedures such as RCA, FMEA, FMECA, Hazop, SIS, brainstorms, fishbones, statistics tools, etc., among some others).

Another important aspect to improve the reliability of the equipment is the application of risk-based management applied to compressors. In this case API have developed some documents recommended practices being associated with this aspect, so we can refer or review about this in the book.

Different technical studies and papers about compressor failures that affect the reliability are also included, as well as particular cases occurred in world-class projects in the area of reciprocating compressors, especially for the oil, gas and petrochemical industries.

Some serious studies are also analyzed, concluded and recommendations to be applied, taking care of different technical aspects that improve the reliability and safety of equipment.

There is a section with information about the manufacturers in reciprocating compressors, which highlights the latest in technology as developed by each one, as well as the technical and operational characteristics in each new design.

As a starting point, a brief basic theoretical description of the types and classes of existing compressor it's available in the world, and of course in the case of reciprocating compressors and about the industrial applicability is also shown and commented.

V.- INTRODUCTION & HISTORY

As an introduction in the area of reciprocating compressors, it is important to understand that this family of equipment, represents a critical component in crude oil processing plants and other processing plants of natural gas or other related gases, due to the gas service of high level of risk and criticality.

The first time when the reciprocating machines were used could be estimated to be in **1650**, based in the studies about the invention as done by the German scientist Otto von Guericke, where he devised an air pump consisting of a single piston and cylinder to compress the air with a mechanical device.

Reciprocating compressors have been widely used for over 200 years ever since gases needed to be compressed. In the last 50 years however their dominance as the compressor type of choice has been eroded as other compressor types have been developed. Reciprocating compressors can be used in almost any compression application, but other compressor types are generally preferred for certain applications. Centrifugal compressors tend to be preferred when the power is above 2 MW, the mole weight (MW) is greater than 10, and the discharge pressure below 100 MPa. Screw compressors are preferred when the power is in the range 10–500 kW and the discharge pressure is below 30 bar. Roots blowers are used for discharge pressures below 0.1 MPa gage. Power levels below 100 kW tend to be the province of diaphragms, vanes, etc.

Process where the requirements strictly need to reach high pressures in order to get the gas as per specifications is one of the main reasons to use reciprocating compressors in years before. Subsequently, the ammonia synthesis process was developed by reducing the final pressure and today's values are around 32 MPa (4640 psi). Other applications such as Urea production required pressure up to 35 MPa (5075 psi), but today, due to improvement in the process, reaction can be obtained at pressures of 15 to 20 MPa (2175-2900 psi). The storage and reinjection of natural gas also use high pressures ranging between 15 and 60 MPa (2175 to 8700 psi). Each application has particular difficulties connected to gas compression, liquid carry over, lubrication and corrosion.

The use of high pressure processes increased after World War II with industrial demand for low density polyethylene (LDPE),1 whose polymerization is achieved by bringing the gas up to 350 MPa (50750 psi) by using special types of reciprocating compressors (Fig. 7.1). Compressors in this service have been given the name *hyper-compressor*.

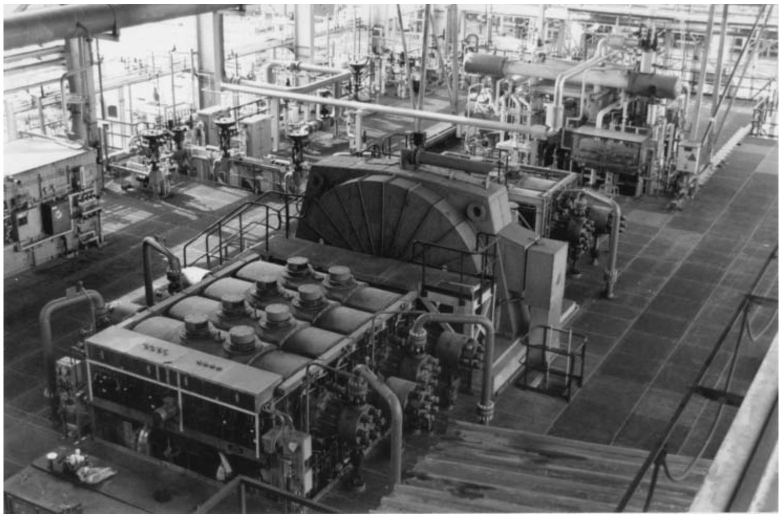

FIGURE 7.1 12 cylinder compressor for very high pressures (*courtesy of Nuovo Pignone*).

Plant capacities have considerably increased. In the early 1960s, the normal production per single line was on the order of 7,000 *tonn*/yr, while lines producing 200,000 *tonn*/yr LDPE are now typical in operation. These plants are dangerous in case of erroneous or unsafe operation, because of the high flammability of the gas and the very high pressures involved in the production process.

One of the sources of risk is to be found in the secondary hyper-compressor, where two main areas called for special care in the design and manufacturing stages: parts subjected to pressure and the crank-gear. The cylinders are subject to pressure fluctuations, which can cause fatigue failure if design, manufacture and material selection are not adequate. The crank mechanism, driving the plungers, must perform its task with great accuracy, because any misalignment might cause failures with possible risk of fire. Plungers are in fact brittle items owing to the very hard metal used, generally solid tungsten carbide. As a consequence, the design of these machines must be based on sound fundamental choices3 and supported by the most up to date analysis methods and experimental techniques. The mechanical difficulties connected with high pressures were encountered by compressor manufacturers during the development of ammonia synthesis processes after 1920, as pressures of about 100 MPa (14500 psi) were reached.

Because of the high technology and complexity being required to develop its engineering, it’s critical to get a reliable and safe design, procurement, manufacturing, inspection and testing in the factory, as well as in its subsequent process of preservation and storage on site, also due to the very demanding procedures of installation, very complex commissioning and to comply with exigent operational guarantees with severe penalties in cost for the manufacturer.

This makes reciprocating compressors very expensive equipment, with a long delivery time and that, if they present failures in their design and selection, generate high impacts on the production of the plants where they operate, with high risks of affectations in personnel and facilities, due to risks of leaks with fires, toxic spills, explosions, severe environmental impact, among others, which demand the greatest possible attention when it comes to their operation and maintenance.

The complex of maintenance activities, methodologies and tools aim to obtain the continuity of the productive process; traditionally, this objective was achieved by reviewing and substituting the critical systems or through operational and functional surplus in order to guarantee an excess of productive capacity. All these approaches have partially shown inefficiencies: redundant systems and excess capacity immobilise capitals that could be used more profitably for the production activities, while carrying out revision policies very careful means to support a rather expensive method to obtain the demand standards.

The complex of maintenance activities is transformed from a simple reparation activity to a complex managerial task which main aim is the prevention of failure.
An optimal maintenance approach is a key support to industrial production in the contemporary process industry and many tools have been developed for improving and optimising this task.
The evaluation of components reliability is a fundamental aspect for proper maintenance execution; existing reliability evaluation methods are based on the availability of knowledge about component states. However, component states are often uncertain or unknown, especially during the early stages of the development of new systems. In such cases, it is important to understand how uncertainties will affect system reliability assessment.
Reliability of systems often depends on their age, intrinsic factors (dimensioning, quality of components, material, etc.) and conditions of use (environment, load rate, stress, etc.).

In this context, RAM factors constitute a strategic approach for integrating reliability, availability and maintainability, by using methods, tools and engineering techniques (such as Mean Time to Failure, Equipment down Time and System Availability values) to identify and quantify equipment and system failures that prevent the achievement of its objectives.
The majority of industrial systems have a high level of complexity, nevertheless, in many cases, they can be repaired. Moreover historical and or benchmarking data, related to systems failure and repair patterns, are difficult to obtain and often they are not enough reliable due to various practical constraints. In such circumstances, it is evident that a good RAM analysis can play a key role in the design phase and in any modification required for achieving the optimized performance of such systems.

However, it is difficult to estimate the RAM parameters of these systems up to a desired degree of accuracy by utilizing available information and uncertain data.
Reciprocating Compressor are very sophisticated systems that go beyond traditional RAM analysis due to specific capabilities needed for performing a range of working operations that can ensure the required production efficiency and reliability in the Oil and Gas industry.

The main aim of this research work was to assess the availability of reciprocating compressors plant designed, configured, and eventually compared against End User Site Project that should be as minimum > of 96% during normal production. Another important goal was the identification and ranking of the equipment and subsystems which are major contributors towards unavailability. Ranking is based on the estimated equipment and sub-system contribution towards unavailability. The final objective was to propose and assess potential cost-effective optimization options to ensure the achievement of the target availability, where appropriate, and perform Equipment Criticality Assessment for the systems and equipment assessed as part of the RAM study.