# POLITECNICO DI TORINO

## Master of Science in Engineering and Management


Master's Degree Thesis

# ERP QM Module Implementation in an O-Ring Manufacturer Company

**Supervisor:**

Domenico Augusto Maisano

**Candidate:**

Yessela Agudelo

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# Abstract

The present work is about an implementation of the SAP QM module that was carried out in an important Italian company which produces O-Rings. In addition, this document exposes the problems and limitations that the company faces in terms of quality management and traceability of its production process. This company supplies a large share of the national market and has a strong overseas presence, therefore in the quest to achieve an effective standardization of quality processes during the manufacturing stages, it was made the choice to manage the quality of its processes and products through SAP.

This thesis will focus mainly on how both the quality structure of the company is composed and how the quality inspections take place in the productive process. The different elements which are involved in quality management will be defined and the way in which these are converted and entered into SAP will be explained, the individual QM procedures will be parameterized and then integrated with all the ERP modules, which together will be the final SAP system for the company.

The conclusive part of the present work will refer the aspects improved in the processes of the Quality Management in both the Laboratory and the production area of the company after implementing the QM module SAP.

# CONTENTS

## Acronyms and Abbreviations

QM: Quality Management

PP: Production Planning

MM: Materials Management.

WM: Warehouse Management.

ERP: Enterprise Resource Planning

S. *A.:* Anonymous society.

SAP: systems, applications and products.

ISO: International Organization for Standardization.

PLM: Product Lifecycle Management.

LSMW: Legacy System Migration Workbench.

# 1.Introduction

Nowadays, in a totally globalized world and with the accelerated development of new information technologies, the business world faces a highly competitive market, in which it becomes necessary to adapt both the business system and its different subsystems into advanced technologies. This, in order to meet the demands of the market, where it is a must for Managers to make decisions faster and provide accurate information to customers and stakeholders involved in the business. For this reason, companies must be able to achieve the highest possible efficiency when talking about information management and also do it in real-time throughout the entire value chain.

This study is focused on the implementation of the QM Module (Quality Management) and its integration with the other modules included in the ERP system (Enterprise Resource Planning) of SAP in a rubber O-Rings manufacturing company. This, in order to solve several criticalities that arise in the company.

Such problems are related to the management of data obtained in the quality controls of the company and the inability to access and store them in an orderly and entirely way due to their volume and complexity. Thus, making impossible further analysis and traceability at each stage of the supply chain. All the above can be solved by means of a complete computer system package such as an ERP (Enterprise Resource Planning) that interconnects the different areas of the company. Thereby, during the time that the ERP is being used, data will be accumulated on the actions carried out that will provide information on the performance of the company and in this way, there will be a database to analyze, allowing to determine which areas present the best performance and which need to be improved.

The thesis consists of 6 chapters, in the second the company is presented, focusing on the industry in what it is, the products that conform the company portfolio and the manufacturing processes. The third chapter describes the as-is situation of the productive processes in the organization, mainly focused in the management of the quality and its criticalities, later the solution is proposed, which corresponds to a project of implementation of SAP with their respective objectives, analysis and methodology, to close the content of this chapter my role in the project is presented. The fourth chapter shows in detail the methodology adopted and the deployment of each of its stages.

The fifth chapter is the most extensive, in this, the operation and structure of the quality department in the company are initially discussed and then the realization stage of the project is developed. This stage documents the key components and parameters to be entered into the system for the proper functioning of quality management in the company and its integration with other areas of the company. Finally, chapter six evidences the conclusions of the project.

# 2. The Environment

The thesis is based on the case of an O-ring producer company located in Italy, especially on the Quality management area. This chapter is dedicated to the company presentation, history and the industry in which it is positioned, besides there is a section mentioning the mission, vision and objectives of the corporation. Finally, the main information about the manufacturing processes and the product is provided.

## 2.1. Industry Overview

From a broader point of view, the rubber industry is in a stable environment without many changes, this happens because there are several sectors that globally demand these products. Global industrial rubber products market is expected to reach US$ 151 Billion by 2025 (Transparency Market Research, 2018). The following are the most important industries consuming rubber components: Automotive, Automation, Biomedicine, Hydraulics and Pneumatics, Electrical and Electronic Engineering, Refrigeration and Air Conditioning, Food, Processes, Nuclear Engineering, Petroleum, among others.

In the rubber seals market, the rivalry between competitors is relatively low in terms of differentiation, besidese each company usually covers a demand according to geographic location and the constant introduction of new products. It is also important to emphasize that some companies have an advantageous position, in case they have an airport or a port nearby. In order to be competitive in the production of rubber pieces or gaskets it is vital, first the economies of scale in the production and acquisition of raw materials; second a strong investment in infrastructure; and especially a recognized brand image and adequate access to distribution channels.

The rampant production of automobiles makes the Asia-Pacific excluding Japan (APEJ) region the world's largest industrial rubber market. With over one-third share of global revenues, industrial rubber sold across the APEJ region is expected to make US$ 55,939.3 Mn in revenues by 2026-end. Meanwhile, industrial rubber revenues in the Middle East & Africa region will witness an important growth by exhibiting a positive CAGR (Compound Annual Growth Rate) of 6.6%. (Freedonia Group, 2018).


*Figure 1. Key findings from gasket and seals market analysis (Technavio, 2015).*

The rubber industry is quite big and it is comprised by many sectors, this paper is going to focus on Gaskets & Seals, a rubber market Segmentation. The gasket and seals market size will grow by USD 11.29 billion during 2018-2022 according to the latest market research report by Technavio see Figure 1. The increasing adoption of seals and gaskets by the automotive industry is one of the major gaskets and seals market drivers. These elements are extensively used in the automotive industry to seal several automobile parts and assemblies that carry fluids and gases. Additionally, O-ring seals are used as shock absorbers to endure impacts. Since gaskets and seals can withstand harsh environments such as extreme temperature and pressure, they are also used in fuel injectors. Finally,

with the growth of the automotive industry across the globe, the need for gaskets and seals in the automotive industry will increase in the coming years, increasing the market's growth prospects, and despite that this channel has acquired greater relevance (motor vehicle output and auto component manufacturing) O-rings are still demanded from different relevant industries (such as industrial machinery, electrical, electronics and chemical) and their applications increase over time (Technavio, 2015).

From a local point of view, in Italy there is the so-called "Rubber Valley" of Sebino, which includes about ten municipalities in the province of Bergamo and one in the province of Brescia, Paratico, this "Valley" has specialized in the production of gaskets, rubber products and innovative polymeric and elastomeric materials. The district is confirmed as the largest national and European producer and supplier of rubber gaskets for construction, cars, agriculture, taps, household appliances, aerodynamics and the food industry. According to the latest Intesa Sanpaolo's report on the economy and finance of industrial districts, the rubber and plastic district is the one with the best performance and growth in Italy. Just to give a few figures, the mentioned production covers the entire supply chain, employs 4,500 people and has an aggregate turnover of about 2.5 billion euros, with exports worth more than 430 million.

In Italy, many companies in the industry are well known worldwide, there are leading companies that have always focused on innovation and cutting-edge technologies. One example is Argomm of Villongo, which has become a pocket-sized multinational with plants abroad, 51 million euros in revenues, net profits of 6 million and an acquisition of 4 million euros in Thailand which, in 2013, has ensured the verticalization of processes and the expansion of the product range. Onother example is Lanzagomma, founded in the 1970s but constantly evolving: during the crisis, for example, it expanded its market by taking care of the production of plastic material on behalf of third parties. A winning choice, given that this process, today, is worth 60-70% of its turnover.

But there is also the Company of study, one of the most successful companies in Europe specializing in the production of O-rings (rings used as seals) and technical rubber parts, or Ar-tex, founded in 1970 in Viadanica, a region with less than a thousand people in the north of Sarnico, and now world leader in the production of rubber seals for car engines (Borsa Italiana, 2017).

## 2.2. The Company

This company is specialized in the production of O-Rings, which are approved according to European directives for every kind of application and intended for the most varied uses in the world market. Additionally, the company is a member of the Sealcore group: a network characterized by constant interaction between the participating companies, active for many years in the world market and in many industrial sectors.

The company was founded in the early 2000s with the public contribution of 12 million euros, it produces O-rings, or rubber rings of 8,000 different sizes that are used as mechanical seals for various sectors, from the automotive industry to electronics, from telephony to the precision industry. This enterprise began with 6 employees who have now become 202 for an indefinite period, all Sardinian and all from the municipalities of the area.

Nowadays, the company processes 200 tons per month of rubber, from which millions of pieces are produced and nearly 70% of them are exported abroad, bringing a turnover of more than 12 million euros per year. This company that works in the heart of Sardinia is the largest in the sector in Italy. The plant covers an area of 27500 m2, of which 17000 m2 are covered. The production capacity is generated by 100 injection presses, is about 2,200 tons/year of rubber and is divided over a wide portfolio of items, with a range of sizes from a minimum internal diameter of 0.7 mm to a maximum of 800 mm.

The production capacity of the company is composed by two production plants, one in the north of Italy and the other one located in Sardinia. The headquarters are situated in the first mentioned region and includes the offices, the workshop for the production of molds, finishing, sorting and shipping of goods. In the Sardinia facilities there are the production department, the finishing and the first stage of sorting of the pieces. Once finished, the goods are then sent to the logistics centre in Chiuduno where they are finally sorted and then, sent to customers. The sorting process is carried out with the classic manual method or by using the automated optical machines.

### 2.2.1. Company Mission

To be the leading company in production and marketing specializing in a wide range of rubber components, which are principally O-rings seals. Bringing to the market products of quality, maintaining a permanent technological overcoming that allows to offer every time greater advantages in what refers to the use of rubber seal materials for the Industry, as well as to satisfy the requirements of the clients, contributing solutions of added value, generating fulfilment and trustfulness when meeting their needs and expectations. Starting from solid principles, maintaining high standards of quality and efficiency, through continuous improvement of all processes of the organization, aiming to be competitive in the market and to differentiate all company products and services. In addition, it is important to contribute significantly to the economic and social development of the community of Sardinia, through the individual commitment of all employees, promoting professional growth and being distinguished as a socially responsible company.

### 2.2.2. Company Vision

The company intends to consolidate its leadership in the design and production of O-Rings in order to eventually be recognized in the industry as the most competitive, dynamic and innovative leading organization at a national and international level in the manufacturing and commercialization of all types of O-rings with the highest quality, generating a permanent trust that satisfies the demands of customers. To this end, the objective is always to work with creativity, a sense of teamwork, simplicity and to be supported in the development of human talent with the commitment to continuously meliorate the production processes. Assuring in this way the reliability and the quality.

### 2.2.3. Company Products

Currently, the portfolio's company of finished products or materials exceeds 18000 references, of which the most part are O-rings. Those elements allow to seal in reliable form fluids and gases, in fact, O-rings are the most widely used adapted seals in the world due to their simplicity, low cost and easy installation. They are suitable for dynamic or static seals within material limit temperatures. O-rings can be produced by extrusion, injection molding, pressure molding or transfer molding.

Those O-rings are made of elastomeric material (rubber) of toroidal shape geometrically characterized by an internal and external diameter and a cross-section. The raw materials generally used are rubber elastomer compounds, mainly belonging to four families which are: NBR rubber, FKM rubber, EPDM rubber and EPDM PEROSIDICO rubber. **Appendix 1**

An elastomer is a polymer whose main characteristic is elasticity, being able to recover its shape after being subjected to the action of a force, it can stretch or deform without breaking and then, when the force ceases, recover its original shape. Due to their molecular structure, elastomers can be stretched up to 700% without suffering permanent deformation. This is since polymer chains can modify their position to achieve an efficient distribution of tension. When the force is no longer applied, the covalent bond allows the elastomer to return to its original condition. The chemical composition of an elastomer is the grouping of thousands of molecules called monomers, which join together to form enormous chains. These large chains of polymers are what give it elasticity since they are flexible and are interlaced in a very disordered way (The Shifting Research Frontiers , 1994).

The evolution of the compounds and of the production systems allows manufacturing O-rings with high and constant quality over time. The O-ring, imposing itself as the most widely used static (and in some cases dynamic) sealing element and one of the most commonly used sealing structures in mechanical systems due to their outstanding heat resistance and solvent resistance properties (Liao, Sun, Yan, Ren, & Zhang, 2017) (Kun , Zhou, Zhanga, Fenga, & Zhanga, 2019)

The variety of fields of application and the continual improvement in quality are prompted by a constant increase in the possible characteristic's combination since as time passes there is more variety in available materials, and this variety permits increase the offer of products which can be more reliable as well as fulfill more precise requirements. The company provides solutions for every kind of request: from the smallest O-ring, with an internal diameter of 0.7 mm, to the largest which, thanks to an innovative new production system, does not set limits on dimensions, see Figure 2.

*Figure 2. O- Rings in different sizes (Srl, s.d.).*

## 2.2.4. Company Manufacturing process

Since the company, currently offers a wide range of high quality and performance products, it requires firstly the use of superior quality elastomers. Those materials are stored according to rigorous procedures that use a sophisticated system to ensure the quality of the finished products. Besides, throughout the following procedures some quality control inspections are carried out.

Automatic machines receive and process the raw material to obtain a molding product directly. Otherwise compression processes are used, and the molding phase is performed after the raw material is prepared by extrudes. Once extruded, the elastomer is ready to be fed into the press where by the using of high pressure and high temperatures a circular molding product is obtained known as the O-ring.

Stages that follow the molding are finishing processes, such as deflashing and cryogenic deflashing, grinding barrels and heat treatment. All gaskets undergo an operation to remove the burr that normally forms during the molding process. After that, the O-rings are now ready for the last stage, which is the final quality control. Strict control procedures ensure top quality product that far exceeds normal standards offering the best solution to meet the needs of clients from a variety of sectors such as automotive, shipping, oil hydraulics, chemical and food processing. **See appendix 2**

# 3. Project Definition

This chapter is dedicated to present the current situation which is the problem the company is facing, next there is the proposed solution in order to solve the aforementioned problem, then there is a brief description of both the project's general objectives and specific objectives, and finally is explained the scope, the methodology and my role in the implementation of the QM module.

## 3.1. Current Situation

The quality inspection of raw materials is carried out at the time of goods receipt to ensure the quality of the products which are going to be used in the manufacturing processes. During the production process, quality inspections take place at different stages of the process to guarantee that quality standards are met.

Currently, physical sheets, spreadsheets or Excel templates (see Figure 3) are used in the organization to manually record the results of, firstly, the inspection plans for raw materials entering the warehouse, however, these ones are seldom performed since the company has a base of certified, qualified and validated suppliers. Secondly, of the tests carried out during the different stages of the manufacturing process and finally, the results of the tests performed on the final product in the laboratory by the quality inspectors following the specific standard norms of each industry to which the production batch is directed. These inspections also vary according to the production plant in which the production is taking place and even to the production line since sometimes the model of the equipment and machines in one work center differ from each other.

| SCHEDA DI PRODUZIONE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cliente: | | Ordine: | | | Quantità: | | | | |
| Lotto: | | Articolo: | | | Campione: | | | | |
| Lancio: | | Primo operatore: | | | | | | | |
| | | | | | | | | | |
| **Attività** | **Controlli** | **Specifiche** | **limite inf.** | **limite sup.** | **Resultati** | | | | |
| **1.STAMPAGGIO** | | | | | 1 | 2 | 3 | 4 | 5 |
| Impianto: | Diametro Interno (MIN) | 53,65 | 53,14 | 54,16 | | | | | |
| | Corda (MIN) | 2,62 | 2,53 | 2,71 | | | | | |
| | Durezza mIRHD (MIN) | 70 | 58 | 70 | | | | | |
| | Fuori Centro | 0 | 0 | 0,1 | | | | | |
| | Stampo consumato / Bava X | 0 | 0 | 0,1 | | | | | |
| | Stampo consumato / Bava Y | 0 | 0 | 0,1 | | | | | |
| | Peso Stampata | 122 | 115,9 | 128,1 | | | | | |
| | | | | | | | | | |
| **2.RETTIFICA DINAMICA** | Corda (MIN) | 2,62 | 2,53 | 2,71 | | | | | |
| Impianto: | | | | | | | | | |
| | | | | | | | | | |
| **3.Tolleranze CERNITA** | Spessore | 2,62 | 2,53 | 2,71 | | | | | |
| Impianto: | Fascia | 2,62 | 2,53 | 2,71 | | | | | |
| | Durezza mIRHD | 70 | 65 | 75 | | | | | |
| | | | | | | | | | |
| **4.CERNITA MANUALE** | Controllo Visivo | | | | | | | | |

*Figure 3. Example of sheet template used in a quality test (own elaboration).*

Next, the data are entered into a statistical program to visualize the results of the sampling in the form of graphs in order to make comparisons with target values and customer specifications, after graphically analyzing these data, getting some indicators and if the graphs do not show irregularities the quality manager makes the decision to send the batch to the finished product warehouse, an authorization is given to conclude with the inspection of the batch that was being processed and to continue with the quality inspection of a new batch. However, the problem with this methodology is that the data entry process can be very tedious and time-demanding, so in turn, the time to detect anomalies is quite high, making this method very low responsiveness.

The way in which quality is managed in the company shows serious problems when it comes to the analysis of the data, given that there is no full historic record of all samples and tests performed since the dimension of the production is quite

big (there are more than 18.000 different products), and this makes hard to store and handle all the information. The records are mainly recorded on physical paper sheets and excel sheets. Thus, it is only possible to get a full statistics report of the current period, but not previous periods given the complexity to handle the big number of files stored. Besides, just a few information is backed up on a server.

On the one hand, at the supply level, when quality inspections are carried out on the raw material, a record is kept of the results and the quality level of the goods received. However, due to the amount of data and the lack of robustness of the database, it is sometimes difficult to identify the suppliers of the raw material that coincide with problems that arise in production or communicated by customers. On the other hand, at the production level when there is a problem with the functionality of the O-rings sold by the company, the customer communicates to the company's quality and production managers how the product failed and what conditions it was being exposed to. However, in many cases the company does not have enough traceability data to know through which processes this product passed, which machines and work centers were used, what were the types of inspections performed with their respective results, the raw material used and many other data. Because of this, in those situations, it is difficult to identify which was the cause of the failure, i.e. if there was a failure in the machine used, if a defective material was used or if it was a mistake of the quality equipment or controllers. Therefore, it becomes almost impossible to determine if this failure affected other lots already produced and which are. That is why improve the traceability is critical to protect the reputation of the company, since it permits to take the necessary measures as soon as possible and these defective lots do not affect further production processes or the customers, what means a decrease of defective units and customer returns, increasing profits and the good image of the organization.

The lack of accuracy-detail that the company has in the management of the recording of production and quality data leads to slow and poor progress in

improvements since the lack of a robust and organized database makes it impossible to generate specific and detailed reports of each stage of production and quality for later analysis. SAP instead would permit to generate precise and detailed reports through which it could be possible to recognize patterns, trends and evaluate the performance of different processes, identifying which is more likely to fail and requires more attention. Finally, with this new information it would be possible to propose and execute improvements at both structural and process level, thus, the probability that any failure will take place would be reduced.

## 3.2. Proposed Solution

The quality management in the organization must improve and adapt the new trends in order to increase the level of performance to face the new challenges in the environment. The company currently has the SAP license, and this program on its turn is used in various departments such as production, accounting and finance, however the Quality Control module has not yet been implemented. Given the situation that the company already has a license of the program and it is familiarized with it, for the organization will not be so expensive, difficult or time demanding to both implement and start to work with the module of quality control and add it to those that are currently operating. Therefore, the proposed solution is to analyze, identify, define, model and transfer the quality test performed during the production process to the ERP system used in the company by preparing and deploying the module of quality control in the company.

Before going deeper, it is important to give a brief introduction to what an ERP system such as SAP offers. An ERP (Enterprise Resource Planning) is a program in charge of integrating all the existing and necessary processes to operate a company such as finance, accounting, production planning and maintenance, quality control, purchasing, and others. It means that SAP consists of several

blocks or vertical modules, each representing a process together with its functions, of a department of the organization. As shown in Figure 4, there are several departments integrated into a single system. By using an ERP, the flow of real and effective information is highly improved, which helps the management of the organization to make concrete decisions and increase productivity.

Once the database is fed, the information is available in the system and accessible from all the operating modules in the company. At any time and any department can have information in real-time, of the processes occurring in each of them. Each employee responsible for his area will take the daily management of his module and present their reports to management. Thus, by including the quality management module, it would be easy to handle the traceability of the products, raw material, and the responsiveness in case of failures increases when the production module is working along with quality control in the company.

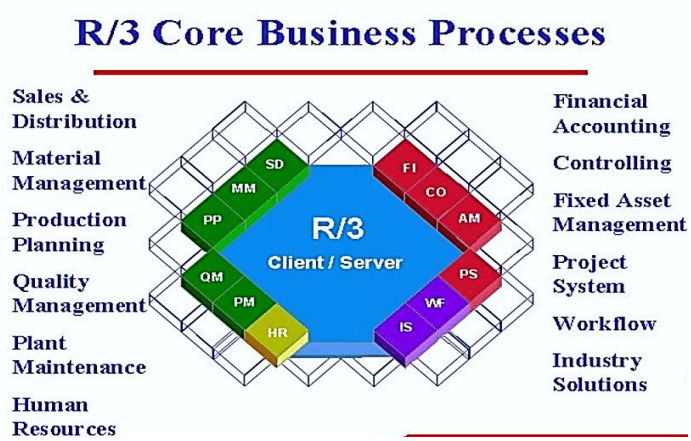


*Figure 4. SAP ERP components (SAP, 2014).*

## 3.3. Project Objectives

### 3.1.1 General Objective:

The general objective of the project will be the full implementation and deployment of the QM module for production, in the SAP system. Additionally, this implementation will be supported specifically through the configuration to integrate the QM module with the PP module (Production Planning). Although there are quality control tests for the entry of raw material, this work will focus on the quality management for production processes and final products of the company, since those are the most critical controls in the company.

### 3.3.2. Specific Objectives:

- To study the current situation of the Laboratory and Production area in the control of the manufactured product.
- Study the scope of the project with respect to those provided by SAP for the QM-PP module and carry out strategic planning for its development, including the definition of Master Data, manufacturing standards and variables to be sampled.
- Collect and analyze data from the company.
- Model and parametrize the current quality processes and transfer those models to the SAP system.
- Evaluate Software Test Results
- Planning of training adequately to the personnel of Quality (Laboratory) and the one of Production.
- Implementation and commissioning of the module linking QM and PP.
- Integrate the Quality Management module with the other SAP modules already implemented in the company generating a positive impact in the way in which the Quality control is carried out.

## 3.4. Scope and Methodology

The scope of the project spans the analysis, modeling and implementation of the QM module in the company as well as carry out its interlacing with other SAP modules already implemented in the company. The SAP Quality Management module is fully integrated with many key supply chain processes, so it is necessary to maintain and modify some modules related to QM, which primarily are the Materials Management (MM) and Production Planning (PP) modules.

Because it is integrated with the SAP Production Planning (PP) module, SAP QM adds two additional types of quality inspections: the in-process and finished product. During the production process, an in-process inspection checks the quality of the goods in production. In regards to the integration to (MM) module, SAP QM allows to add quality inspections for raw materials when the goods are received. Therefore, since the QM module oversees the carrying out of all those tasks that involve quality planning, control, inspections, and monitoring working along with other modules. It is also relevant to remark, and briefly explain the aforementioned modules which are directly linked to the QM module.

- PP module: Production Planning contains tools for the different phases, tasks and methodologies used for its operation. For instance, quantities and types of products or supply time of materials. In addition to the production process itself. The PP module is integrated with other modules such as SD (sales and distribution), MM (materials management), etc.

- MM module: Materials Management carries out the handling of materials; includes the planning of consumption, the planning of purchases, Invoice control, stock management, quality control and warehouse management.

The methodology to implement and deploy the QM module in the company will be the ASAP, a standard methodology that is proposed by SAP for the installation of this software and its modules. ASAP stands for Accelerated SAP. Its purpose is to help design SAP implementation in the most efficient manner possible. Its goal is to effectively optimize time, people, quality and other resources, using a proven methodology to implementation since ASAP has an implementation guide, which is feedbacked with the experiences in using these projects over the years. The Roadmap establishes a repeatable standard procedure for implementations, including project management, the configuration of business and technical processes, testing and training. (SAP, 2014)

The typical scheme of this methodology is as shown in Figure 5


*Figure 5. ASAP Roadmap (SAP, 2014).*

The roadmap steps are:

1. **Project preparation**: this phase provides initial planning and preparation for the project. Each project has its own unique objectives, scope, and priorities. The deliverables indicated in this phase assist in completing the initiation and planning steps in an efficient and effective manner – like the setup of project governance, project plan and project schedule are prepared at this stage.

2. **Scope validation**: its objectives are achieving a common understanding of how the company intends to run SAP to support their business. It focuses on the proper setup of environment that is available for validation workshop with business users to confirm scope and determine requirements that will be performed in the next phase.

3. **Realization** - The purpose of this phase is to implement all the business process requirements defined during the previous phase. The team configures, develops, tests and documents the solution in a series of time iterations. Before the solution is released to next phase it is fully end-to-end integration tested and accepted by end-users.

4. **Final preparation** – It is aimed to complete the cutover activities (including technical and load testing, end-user training, system management, and cutover rehearsal activities) to finalize readiness to go live. The Final Preparation phase also serves to resolve all remaining critical issues.

5. **Go-live support** - The purpose of this phase is to move from a project-oriented, pre-production environment to live production operation and provide sustained support to business users to aid their transition into the new environment.

6. **Operate** - The purpose of this phase is to fine-tune the application lifecycle standards, processes and procedures established during the project and align them with operational needs. The central operation platform is SAP Solution Manager, which leverages the documented solution for system operations (SAP, 2014).

## 3.5. My Role

My work at AdHocLogica S.R.L comprises several multidisciplinary activities, which require knowledge of quality, production, logistics, optimization, among many others. Adhoclogica is constantly developing and working on projects in conjunction with other companies in various sectors. Such projects are based on research, modeling, development and deployment of modules of an ERP system, seeking to improve and make more effective the processes within the organization.

I am involved in the management of the modules of Quality, Material Management and Production Planning, and in each project of the company I have as main activities to gather and to analyze the business processes of the company and to transfer them by means of the configuration or parameterization of the ERP system as well as its possible modifications and extensions. The job as a consultant is then to help companies to move and configure their business processes in the ERP system and even improve them. It is a function that is not limited only to the ERP system itself, but to all the documentation of the processes that is necessary.

My activities during this specific project, which took place in the O-rings manufacturing company were:

- Identify and define the necessary tests on the products.
- Model and parametrize current quality tests in SAP System.
- Track test progress and results.
- Validate and verify the quality of the system and the application.
- Generation of functional diagrams and test cases.

# 4. Project Preparation

This chapter explains everything concerning project planning based on the stages and deliverables needed to carry out the project. These, in turn, are composed of activities that are performed by the members of the teamwork according to their functions.

**Phases:** The project plan is characterized by the sequence of distinct macro implementation phases see Figure 6, this foreseen duration of eight months and include certain deliverables to be verified at the end of each phase.

**Team Work:** Below the teamwork composition and their main activities are presented:

1. Service manager: Evaluation and control of project delivery.
2. Project leader: Coordination of the project phases. Monitoring of progress. Interaction with the Company Client for verification and control of the activities in question.
3. The team leader of the QM module: Management of the solution design and coordination of the implementation in the various environments. Collection of additional requirements where required
4. Functional consultant: Drafting of the activities of preparation of the documentation related to training and testing. Execution of functional parameterization activities of the SAP systems involved
5. Senior technical consultant: Creation of custom programs based on the functional requirements outlined. Technical management of interfacing programs
6. Functional senior consultant: Execution of parameterization activities. Drafting of functional and technical analysis documents

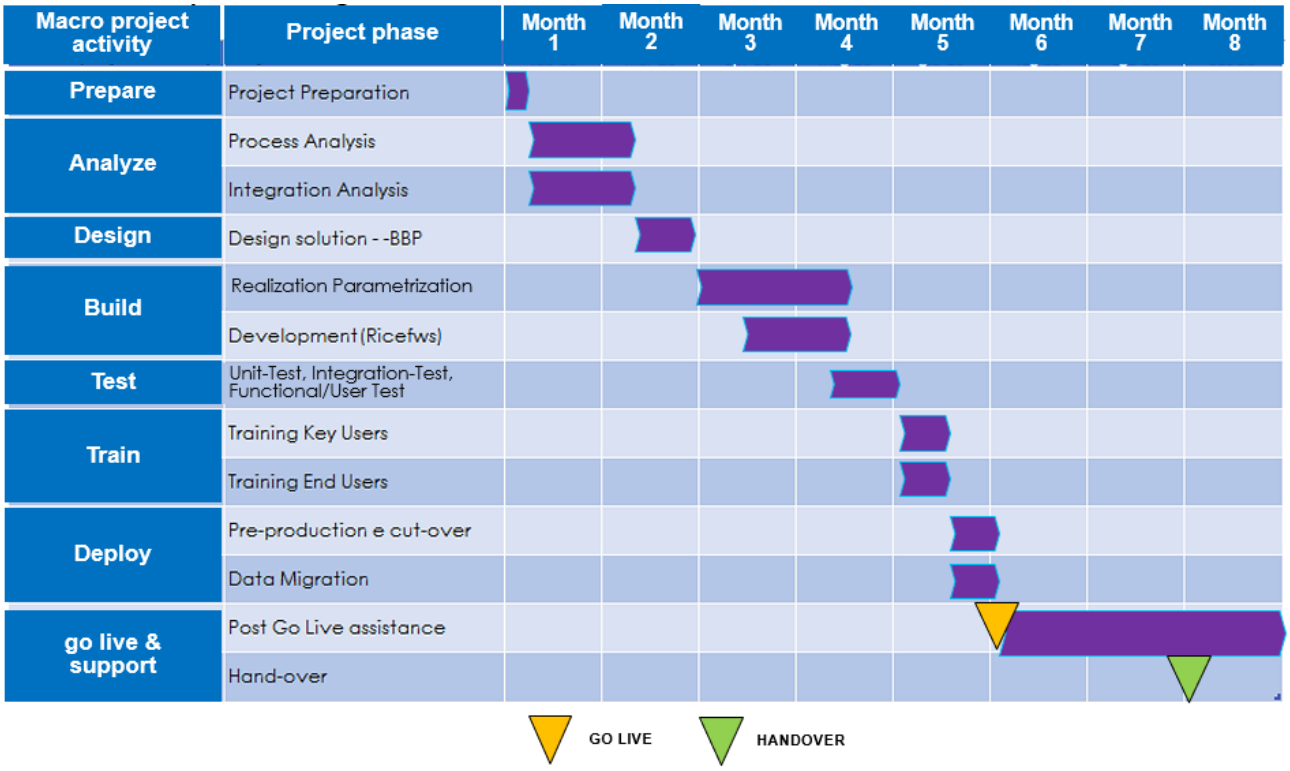


*Figure 6. Gantt chart project activities (own elaboration).*

## 4.1. Project Preparation

The project preparation is based on the Kickoff, which is the first meeting between the client of the implementation and the company responsible for it (partner). All the actors involved in the implementation participate in this meeting: Advanced users, managers, area managers, project directors and the consultants of the different modules to be implemented. In this phase, those people must clearly define the objectives of the project. The first general planning of the project is made, the project team and the working environment are defined.

The first step for the project managers is to establish the parameters, limits and general objectives of the implementation project. This kickoff is critical because it is here where the project team and the process owners (client) visualize together the objectives to be achieved and define the responsibilities of each one. In this

meeting is usually used a PowerPoint presentation which shows the needs to cover, the reasons for the choice of SAP and, finally, the members of Teamwork and those responsible for the project of the client company are introduced with each other.

At this point the implanting company offers a document, explaining which the objective of the implementation is. It is usually accompanied by brief presentations with the changes and improvements that will be carried out. The company is also presented with a first plan including the different milestones of the project.

## 4.2. Project Analysis

In this stage, the teams of consultants are in charge of obtaining a general overview of the company through meetings with those in charge of the area in the client company. With the help of the client, the current process map of the company is analyzed, identifying the key processes as well as possible improvements. At this point, the objective of the partner company presented in the kickoff will be specified.

The content of these meetings will be recorded in minutes that then will serve for the preparation of the (BBPs) Business Blue Prints (see section 4.4. Design solution: The Business Blueprint). These documents are drafted by the implementing company but must be ratified by both parties for the project to be approved. This document will set out the operating model for each of the functional areas. In addition, those responsible for the area and project directors will oversee that what is included in the document is complied with, as well as the times that are set out in the document.

Any deviation from the initial scope of the project, be it the implementation of modules not agreed in advance or the introduction of new functionalities not

included from the beginning, will have consequences for the project. These consequences are summarized in:

- Cost overruns: Any functionality not included in the BBP that the company requires, will be negotiated again with the implementing company (price not included in the initial project). The decision to hire another implementing company may mean the end of the project.
- Delays: New developments result in a greater effort on the part of the implementing company. In general, adding functionalities outside the contract means carrying out unplanned GAPs (see section 4.6. Development) that slow down the initial project.

## 4.3. Functional Analysis

Users are responsible for identifying and setting out the objectives of the implementation. It will also be their responsibility to adapt (whenever necessary) their way of working to the SAP solution. This can mean redesigning processes, new tasks and even increasing or eliminating jobs.

The functional analysis aims, on the one hand, to reflect the current situation of the different areas of the company and the procedures used in their management, and on the other, to carry out a detailed study of those aspects that could be improved or modified in the implementation of the integrated QM module. As a result of this functional analysis, some Functional Requirements will be obtained, and these will mark the detailed scope of the project.

## 4.4. Design solution: The Business Blueprint

The purpose of this phase is to create the Business Blueprint document which is the detailed documentation of how the requirements gathered during the review sessions of the processes to be implemented will be satisfied. The Business Blueprint is used to define the scope of the project and to refine the objectives, goals and schedule of the project. These review sessions will involve the project work team and the project responsible for the client company.

The document will be built through Business Blueprint Workshops. The team of functional consultants together with the client's project responsible must reach a common agreement on how the company will carry out the development of the implementation. During the sessions the organizational structures will be designed, and the master data to be converted or uploaded will be identified. Likewise, it will be identified the improvements or adjustments to be made, the necessary interfaces with the current systems, the necessary reports and the roles to be played by each one of the participants in the process. The objective for Business Blueprint is to document the company's processes in order to achieve a shared understanding of how these will be supported by the SAP solution.

Based on the resulting scope given by the processes to be implemented, and by the developments and improvements to be made, a detailed plan of the Realization, Cutover and Go Live phases will be elaborated.

It should be noted that since this is a detailed review of the functional scope required by the company to meet its requirements, it is usual to occur a variation of the implementation schedule, due to the differences required in effort and duration of each of the subsequent phases. This generally implies that more resources and budget may be required. Due to this, at the end of this phase, an executive meeting will be held where the proposed Business goals, the Organization and the designed Processes will be presented, as well as the estimated variations in scope, time and budget.

## 4.5. Realization: Parameterization

The objective of this phase is to configure and parametrize the QM module, in order to obtain an integrated and documented solution that fulfills all the previously defined requirements. During the realization phase, the SAP software system is configured and tested in several specific cycles.

All the development, including business services, interfaces of data modification and conversion programs (see section 4.6. Development), reports in general and the improvements that have to be developed are also documented in the SAP Solution Manager. For this, data conversion programs are created and tested in advance under a previous version. In this way, the system to be used is installed during the Realization phase.

The system parameterization is carried out in two stages, basic parameterization and final parameterization. First, the basic configuration is carried out in order to test and confirm its viability, this step consists in implementing around 80% of the daily quality transactions and completing the organizational structure and master data load, these represent the basic adjustments of the company's processes.

For its part, the final configuration is done cyclically, oriented to the processes as a whole, this solution is tested from start to finish by a test cycle that focuses on the total integration of the solution. This configuration has to be correctly developed and documented in the SAP Solution Manager.

The basic configuration is performed by functional consultants, while SAP senior undergoes more advanced and specialized tasks. This enables this team to begin to fully understand the operation of the processes already within the QM system. This team must be able to validate and test this basic parameterization, designing example scenarios to prove that all the requirements have been implemented

properly in the system. At least one base test scenario must be designed for each of the key processes.

The final configuration will be based on the previous one and is carried out by the technical consultants. In this way, by participating in the different areas of the company, it is possible to parameterize in an integrated way, identifying the real problems, since now not only the processes are considered, but also the integration with the rest of the company's areas.

## 4.6. Development

A template of necessary developments within a project is elaborated, known as RICEFW (Reports, Interface, Conversion, Enhancements, Forms and Workflow). At this stage, it is necessary to define which are the standard functionalities of the system that do not meet 100% of the requirements of the project. A typical example is the generation of commercial invoices that can have multiple variations of form and background such as the printing format, the inclusion of logos and commercial texts. Although some of them can be minimal changes others can incorporate several of them becoming true "GAP".

At this stage, the aim is to define how this GAP in functionality is going to be filled, which in most cases involves carrying out a development that completes or replaces the functionality with which the need is to be covered. Given that normally the person who carries out the developments is not the same person who identifies the need, it is then necessary for the consultant who identified the GAP to make a document that describes in detail the requirement and what is expected of it to cover the GAP.

The task of the developer, finally, is to fulfill the requirement by means of one of the following available tools:

Reports: A report in SAP is an executable program that obtains information from the database and generates an output based on filters and selection criteria provided by the user. SAP already has a set of standard reports that show typical information of the operation processes, however, there are needs that are not covered so usually, there must be a development.

Interfaces: In some organizations, some of the processes of the organization are executed or managed in external systems, either SAP or non-SAP, and within the ERP component. So, it is required an interface to link the external system to the SAP environment.

Conversion programs: These programs are typically needed when information needs to be standardized between different systems. In this way, when SAP is implemented, some or all legacy systems will be replaced, but the information must remain, so this information is extracted from the legacy systems and placed in some files to be uploaded to the SAP system by means of conversion programs intended for this purpose, thus loading errors are avoided in the go-live phase.

Enhancements: The enhancements are programs through which existing functionalities will be added or modified to the standard SAP module applications, that is to say, the standard functionality does not cover the requirement in its entirety, or does not contain all the information that is required for a certain process, so by means of enhancements such as user-exits, customer-exits or BAdIs, the system code can be accessed and modified to adapt it completely to what it is required.

Forms: Forms are printouts that contain information extracted from SAP, such as purchase orders, invoices or batch printing certificates, to name a few. Generally, the forms provided by SAP usually are tailored to the needs of the customer or company, since there is data that is required and not included in it, as well as printing logos or barcodes.

Workflow: Workflows are a sequence of connected activities resulting in the exchange and propagation of information. In each one of the below types of development, it is essential that the functional team specifies to the developers the characteristics of the requirements, such as:

- The columns that each report should contain.
- The mapping of the fields that are susceptible to conversions.
- The list of points to improve the standard system.
- The information that must be contained in the forms.
- Information flow diagrams.

## 4.7. Testing

Once the setting up and developing the system stages are finished, a series of tests that are integrated into the system are planned. These tests validate that the project is on the path agreed by both parties. These tests are similar to those carried out at the parametrization phase, but instead they are carried out with the end-users and in a more global way. The tests are already carried out with the real data of the client trying to reflect reliably how they will behave after implementation.

Once the initial tests have been successfully completed, the integral tests must continue, which consist of testing the integration of the QM module with the other modules (mainly PP and MM). Scenarios that are defined with key users are tested. In the case of this project for these tests, it is necessary the collaboration of the key users of the PP and MM modules so that the integration of the modules can be tested. For example, the planning department forecasts for the following month. This order request must be attended by the logistics area through both the production module and quality management. This flow must be validated as well by both the quality area and the production area.

Next, it is time to correct and redefine, in some cases, the direction of the project given that this phase is usually close to the start date, it is the most conflictive point, since there could be needs that were not expressed well, developments not ordered before, failures in the system and other inconveniences are generally presented. These changes must be evaluated to measure the impact they would have and decide if they are feasible. The changes must be made in this phase to be ready for the next movement. If everything evolves correctly and the users validate the different integration tests, the project is ready for the next movement.

## 4.8. Training

It is not common for end-users to have an understanding of SAP. That is why to ensure the success of the implementation of the project and its maintenance over time users must be trained. There are increasingly more companies specialized in SAP training, however, the training is usually assigned to the company that implemented the system rather than outsourcing it for practical reasons.

To train end-users, the project team will train key users using the "train-the-trainer" method (method by which a key user is trained, who then will be responsible for training end-users). This method facilitates training and feedback from end-users, and also builds the knowledge base for self-support and future system improvements. The final step of this phase is to test the system and verify that the organization is ready to officially 'turn on' SAP.

## 4.9. Cutover

Documenting the plan to migrate the system and organization to the new SAP environment is what is called a cutover plan. This plan should concentrate on the activities, tasks and synchronization of the last days of the project, whose main benefit is to ensure an optimal transition to the new environment. Referring to this plan in case of difficulties serves as a guide for action since it includes a checklist that revises the preparation points and provides the basis for approval of the progress of the activities.

The cutover planning should cover the procedures for closing legacy systems and entering information into the new system, in addition, it should include a pause in activities between the start of operations and the tuning off of the production system, because it may be needed to solve last-minute problems, and should last between 12 and 24 hours.

The cutover plan should include:

- Information conversions.
- Estimated times of when the conversions will be made.
- Team leaders for cutover, both functional and technical.
- Roles and responsibilities of the core project team, key users, users, etc.
- Team assignments and work schedules and availability.
- Involve company management and designate who will make decisions.
- Procedures for shutting down legacy systems.
- Reconciliation processes to ensure that company transactions are entered into new systems.
- Reconciliation processes to ensure that information is converted to new system formats.

The cutover plan must be reviewed and approved by the project leader, team leaders, and company management.

## 4.10. Go-live

The purpose of this phase is to move the pre-final system to the final system of the organization. A supporting environment must be in a place that allows the organization's processes to flow smoothly during the first critical days of system use. During this phase, users generally require permanent advice from project people for questions and problem-solving.

After finally entering into operation, the system should be checked and refined to ensure the support to the correct company’s environment, where there may be cases of adjustments to the configuration and its detection and correction should be made by the organization's team assisted by the implementing company SAP consultant team.

This point usually has a high criticality, since it is the moment of transition between two systems and inconsistencies and errors may occur. Just the opposite of what it might seem, it is recommended that the transition between systems be made abruptly (a maximum of one week) and not gradually. The reason for this is that if the systems coexist, undesirable duplicities can be generated and the obtaining of data could be very complicated. Habitually stages of inactivity are used to carry out these starts (non-working days, scheduled production stops, etc.). For the implementing company, the effort in those days is usually enormous and the journeys are usually long.

The start date is usually determined at the analysis stage and may vary throughout the project. An unjustified advance or delay may lead to financial penalties for the responsible party.

## 4.11. Support

Once started there is a period of stabilization until the system is considered to be at its best performance. During this period, support will be offered for a certain period. This stage of the project is determined entirely by the contractual conditions defined at the beginning of the project. The objective of this support is to assist users in both the resolution of errors and providing information about doubts that may arise.

Due to the conditions of the project, a base consulting team is expected to attend, fine-tune the requirements and give support to the on-site operation, following these steps:

- The base consulting team is created.

- transfer to the site, i.e. work from the offices where the operation is carried out, if necessary, the consulting team is divided geographically.

- The consultants will be verifying that the operation is carried out properly if there are errors, or modification upon request of the client, it must be corrected.

- It is the responsibility of the consultants to ensure the best strategy for implementing the system, and if a point of improvement is found, an appropriate solution must be provided meeting the needs of the company.

In this way, a seamless operation is guaranteed with the support of the consulting team integrated with the end-users.

# 5. Project Realization

This chapter describes how the quality structure of the company is composed and the productive process including the inspection points as well as the components of the SAP QM module are explained. The different elements which are involved in quality management are collected, converted and finally entered into SAP, the individual QM instruments are parametrized and then integrated with all the modules, which together will be the final SAP system for the company.

This document will focus on the parametrization since it is in this phase where each one of the objects of the QM module is defined, it is here where the initial model is created taking into account the special requirements of the customer for the system. Is with this model where it can really be appreciated whether the elements are working properly, and the parametrization is correct.

## 5.1. Understanding the Company's Quality Structure

### 5.1.1. Parts involved

The Quality Management department presents a solid structure and reliable processes to fulfill the specifications of the client, such structure is comprised by 12 people in charge of the control of quality and the handling of measurement tools. 8 of those people work in the laboratory following procedures designed and analyzed by the Laboratory manager. Besides, there are two supervisors of the area of quality, and there is one person responsible for them with the position of Quality Manager. Below the QM staff and their functions are presented.

**Quality manager:**

1. Review customer requirements and make sure they are met.
2. Make sure that manufacturing or production processes meet international and national standards.
3. Review existing quality policies and make suggestions for changes and improvements and how to implement them.

**Quality Supervisor:**

1. Ensure compliance with process and product quality specifications.
2. Manage quality programs.
3. Define quality procedures in conjunction with operating staff.

**Laboratory manager:**

1. Review and approve testing procedures in accordance with the established requirements of the Quality Manager.
2. Researches, analyzes, modifies and approves the Standard Operating Procedures performed in the laboratory.
3. Manages the training of the laboratory team members.

**Process Controller (qualified workers):**

1. Carry out sampling during production.
2. Analysis of the data obtained.
3. Perform quality control of the finished product.
4. Enter results into the system.

### 5.1.2. Process Flow

The steps of the manufacturing process of O-rings along with the quality control points are presented using a flow diagram, whose nomenclature can be seen in Table 1.

| Symbol | Description |
|---|---|
|  | Start/End, determines the start or end of the process. |
|  | Activity that is part of the manufacturing process. |
|  | Decision node. It represents a decision of the process in which, depending on its status, a route of activities will be taken. |
|  | Document or list, usually arises from some activity. |
|  | Logical or physical flow of information between process activities. |
|  | It represents that the previous activity is a quality control point or that there is one at the end of the mentioned activity |

*Table 1. Diagramming methodology (own elaboration).*

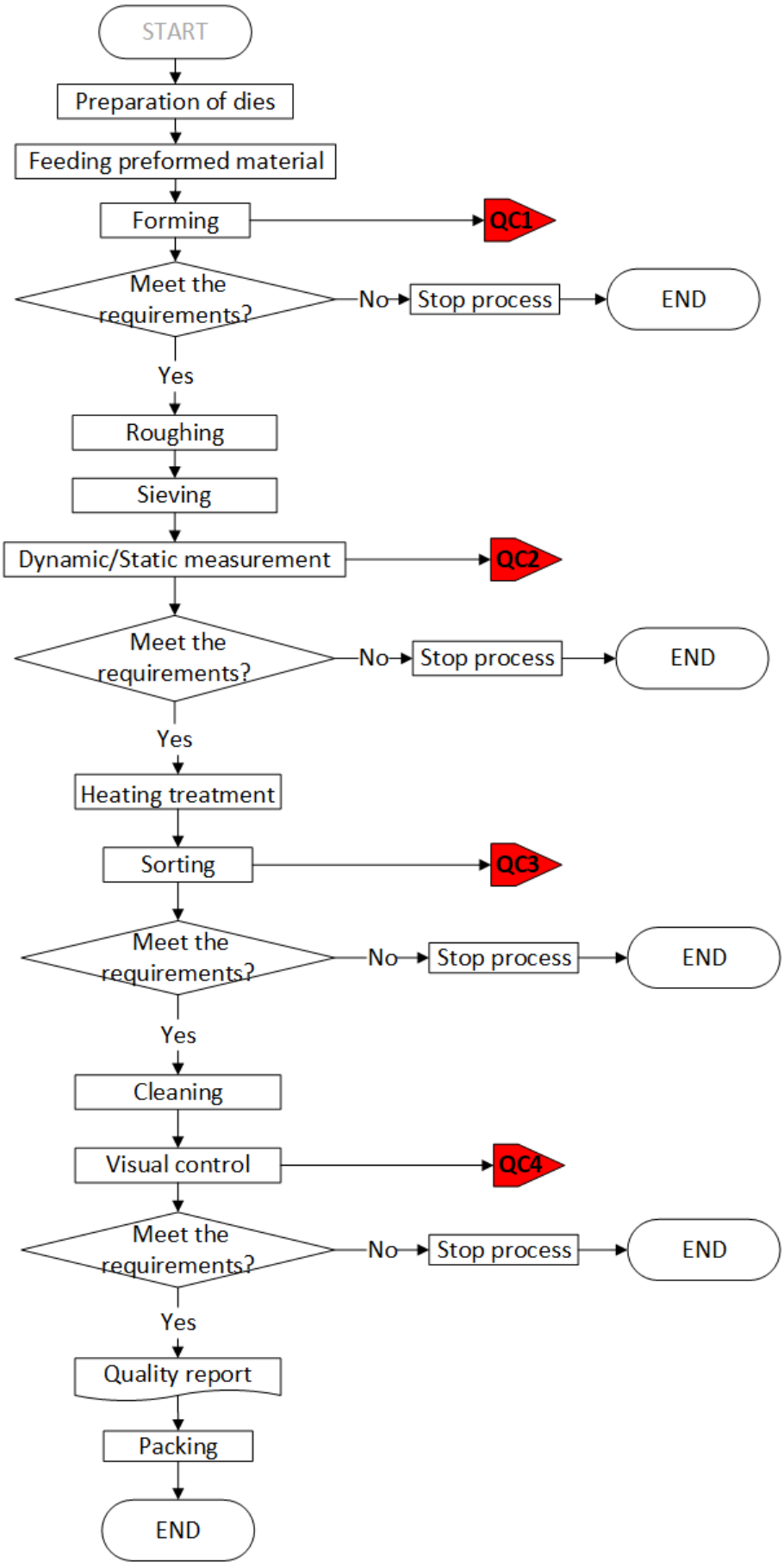


*Figure 7. Rubber O-ring manufacturing process (own elaboration)*

### 5.1.3. General Production and Quality Processes

The manufacturing process of O-rings is similar for all the references offered by the company and it is represented in a general way in Figure 7. The first activity is the preparation of dies, whose reference must correspond to that indicated in the production order, in addition the dies must be in good condition (clean and without bumps). Next, the forming machine is fed with elastomer in the shape of sheets, then the consequent forming process can be carried out in three ways and these vary according to the classification of the O-ring that will be produced, see Table 2. If the reference of the O-ring to be produced corresponds to a small classification, the production of these is carried out by means of compression molding, a process in which a single stamping can produce up to 1000 pieces of O-rings, on the other hand, if the O-ring is of medium size, it is usually used an injection molding machine, see **Appendix 2**. Finally, the formation of large O-rings is divided into 2 steps, the first feeds the extruder with raw material, where it is heated to reduce viscosity and forced to come out through a mold in order to produce rubber cord, in the second step this cord is cut to size and placed in a mold in order to join the ends and shape the O-ring in the compression process.

| **O-ring classification** | **Range Internal diameter (mm)** | **Most likely Manufacturing process** |
|---|---|---|
| Small size | From 2 to 49 | Compression molding |
| Medium size | From 50 to 299 | Injection molding |
| Big size | Bigger than 300 | Extrusion process and compression molding |

*Table 2. O-ring classification by size (Own elaboration).*

Once the forming step has been completed, from any of the manufacturing processes mentioned in Table 2, the quality control 1 is initiated and an inspection lot is created using sampling procedure C2 (see Table 3), which corresponds to a sample of fixed size previously established by the organization depending on the reference and also containing the limit number of defective units to accept the lot and also to continue the process. However, both the size of the sample and the acceptance limit can be modified. After the inspection, the lot is finally confirmed by the Quality Supervisor. Considering that the objective of the first quality control is to verify that the progress of the production process is adequate to meet the specifications of the product, it requires a series of quantitative measures which are taken manually to the pieces, such as weight, hardness, thickness, diameter, compression, among others. The values of the results of every unit are compared with the target value and if these do not go beyond the specification limits the manufacturing process can continue as planned. Otherwise, either the Quality Supervisor or the Quality Manager analyses the results based on the characteristics measured, the criticality of the defects found (minor, major or critical) and makes the decision to interrupt production or to continue, but in any case it is necessary to generate a document which evidences what happened and the reason why production was or was not interrupted.

After the first quality control, the roughing process takes place, in this process the excess of flash is removed from the O-ring, making it perfectly round. This stage can be done in two different ways, the first one is a manual technique called buffing for O-rings of medium/large size see Figure 8, the second is an automatic method for small O-rings using a grit blasting process, drumming or cryogenic deflashing process see **Appendix 2**. Once the roughing process is finished, the sieving process is started to separate the excess material from the product and thus, only the O-Rings continue in the production process.

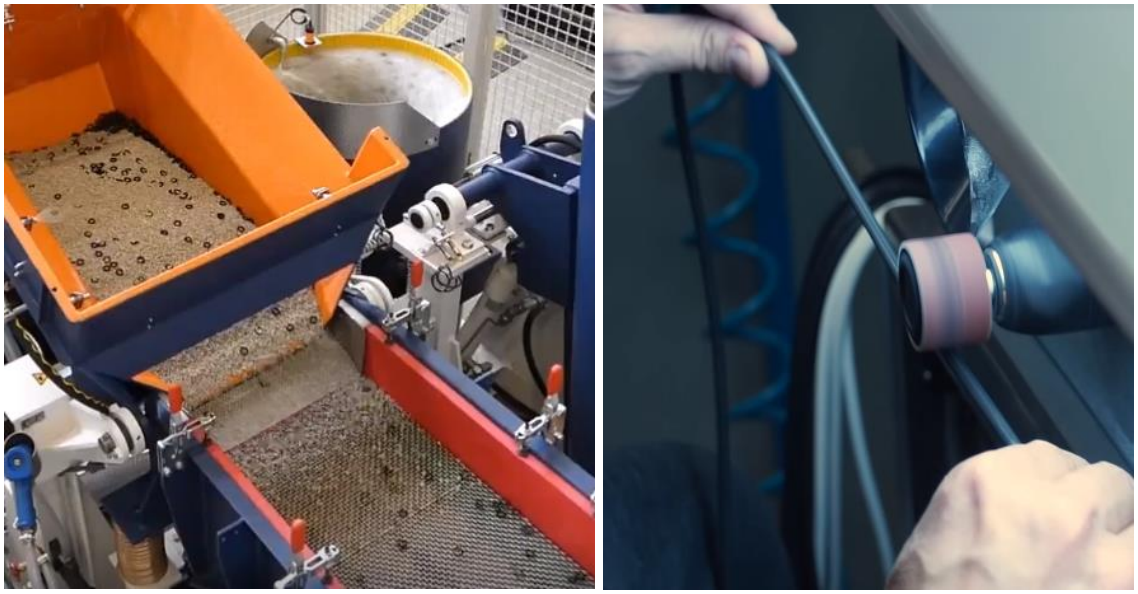

*Figure 8. Grit blasting and buffer processes (Precision Polymer Engineering Ltd, 2018).*

In quality control 2, an inspection lot is generated using sampling procedure C4. As in quality control 1, the sample size is fixed and depends on the reference that is produced, the characteristics to be checked are the same as in the first quality control but stricter, additionally, there are more specific ones and most of them are measured manually. In this stage, for the first time the quality control takes into consideration the type of sealing for which the O-Ring is going to be used, this can be static (absence of relative movement between the parts of machinery to be sealed) or dynamic (relative movement between the parts of machinery to be sealed), in this last one the seals present greater strain and to measure them it is required the use of precise measurement tools which then transfer those results to a computer, see Figure 9, for example in the control of the surface and in the resistance to high temperatures (see **Appendix 1**). At the end of this stage it is necessary to make a verification of the results and a confirmation on the part of the head of shift and quality supervisor to continue with the productive process.

*Figure 9. The characteristic measure of dynamic sealing O-rings (BER-PA SRL, 2014).*

In the next step, the O-rings are placed in an oven to be exposed to carefully controlled high temperatures for hours (ranging from 3 to 18 depending on the reference) in order to remove excess water and volatile additives. Consequently, the Sorting process (which is a quality control procedure) is performed by means of an advanced machine, equipped with a conveyor belt, a blower and cameras that take pictures from different angles that can accurately measure the dimensions of the pieces and if any of these differs from those specified for the batch, this is immediately separated (blown) without being able to continue in the remaining steps of the manufacturing process. It should be noted that in the stage of sorting the sampling procedure used is C0 and this corresponds to an inspection of 100% of the batch, in Figure 10 the sorting process can be observed. Depending on the reference being produced the company has a certain parameter to this step (AQL), so if the percentage of the production does not meet the acceptable limit the entire lot is rejected, otherwise it is accepted and continue in the next step. Once the lot passes the just mentioned quality inspection control 3, the parts are

entered into a cleaning area where any contaminating particles present on the surface of the O-Rings are removed with ultrapure deionized water (UPDI).

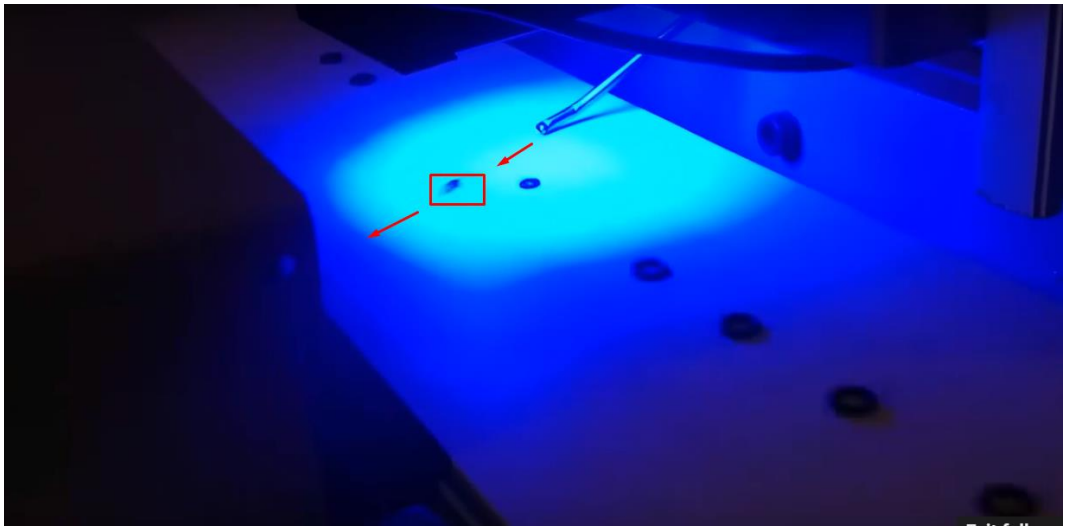

*Figure 10. Sorting phase.*

After cleaning, the final quality control test takes place, in this the sample size is determined by the sampling procedure C5, which corresponds to a percentage of the lot that has reached this final inspection stage. For this last revision, a laboratory that is operated by trained quality experts is used, where the experts initially use magnification tools to visualize possible identifiable errors in O-rings see Figure 11 and then high precision equipment including hardness testers, thickness gauges, calipers, thermostatic baths, and ovens are employed to perform the inspection. If the results meet the quality requirements, it is made the decision to conclude with the final stage of packaging and then the entry of production into the finished product warehouse. The final quality results are stored in the system with the production batch number as the final quality test report.

*Figure 11. Quality expert using magnification tools (Precision Polymer Engineering Ltd, 2018).*

## 5.2. Understanding SAP Quality Management Components

To carry out the project, some Quality Management Components must be established in the system. Namely, to create all the inspection characteristics that are used to asses the quality of O-rings. Also, the way in which inspection lots are generated must be defined, likewise how the results are entered into the system and the usage decision is made and the management of the non-conformities is handled. Therefore, data collection and conversion of information is necessary to ensure the compatibility and proper functioning of SAP.

The QM module covers three distinct areas:

1.Planning

2.Notifications

3. Quality Inspections

**The Quality Management Components**

The planning area corresponds to the first component of quality management (see Figure 12) that permits the planning of inspections of work in progress and finished products. This, in turn, has several associated subcomponents that make its correct functioning possible. The quality notification refers to component 5 and is the mean through which the system registers the problems related to failures that arise during the production and are detected by quality control inspections. The quality inspection is the physical inspection, which is composed by components 2, 3 and 4 mentioned in Figure 12, those components, in turn, are using the specifications defined in the quality planning, i.e. in component 1.


*Figure 12. Quality management components (own elaboration).*

The components of the QM processes could be understood as stages and are explained in the following way:

Inspection Plan defines where and how samples are obtained in the productive process in execution. Throughout the production processes, several lots of inspection are generated, which are entered by the quality department into the system. When the production is in process, samples of the products are tested in both the production area and the laboratory, in this way inspection results are obtained and reported in SAP. At the end of all the quality controls the usage decision is made, If the product meets requirements it is sent to the warehouse of finished material, whereas in the event that any defect is detected, the system generates a non-conformity notification that is managed by the quality and production departments, then depending on the severity classification of the failure defined in the inspection plan, established procedures take place, which range from accepting the lot but pointing out that it does not meet some specifications to rejecting the lot. In any case, the quality process is closed by a non-conformity notification in which it is specified the results obtained, the quality level reached and when, where and which the problems took place.

**1.Inspection Plan:** In SAP, quality inspection plans define how an article must be inspected. The plan also establishes where the inspection will be carried out, and for this, a sampling procedure is assigned to a work center or material, see **Appendix 3**. It is also required to define which will be the characteristics of the article to be inspected in each operation and all the resources required for the inspection; these could be human resources, work centers or tools.

**Sub-components used in inspection plans:**

- **Sampling procedure:** A sampling procedure defines the rules that specify how the system calculates the sample size, it also contains information

about the valuation of the inspection characteristic (attributive, variable, manual, etc.). The rules for determining the sample are stored in the sampling type. The sampling type and valuation mode are combined for the inspection characteristics. This combination forms the structure of the sampling procedure. Below there is a brief description of both (SAP, s.d.).

- **Sampling Type:** The sampling type defines how a sample is calculated (fixed sample, 100% inspection, use sampling scheme, percentage sample or AQL based sample). Together with the valuation mode, the sampling type defines the parameters for sample determination. Using the sampling type, the system proposes a list of rules for sample determination.

- **Valuation Mode:** The valuation mode specifies the rules for accepting and rejecting a characteristic or sample (for example, attributive inspection on the basis of nonconforming units, variable inspection according to Statistical Process Control inspection). Below there is a brief description of the types of valuation mode.

  - Attributive inspection nonconf. Units: for a sampling procedure with this valuation mode, valuation depends on sample size and an acceptance number. The acceptance number and the number of nonconforming or defects units of the inspection results are compared. If the number of defects or nonconforming units does not exceed the acceptance number, the characteristic is accepted. In an attributive inspection, the characteristics assessed are qualitative.

  - Manual Valuation Used in Valuation: For a sampling procedure with this valuation mode, valuation occurs manually. That is, during the results recording of an inspection characteristic or a sample, it is

manually set to "Accept" or "Reject". A person has to manually decide if the characteristic passes or not.

- Inspection by Tolerance Used in Valuation: Inspection Against Specification Limits.

- Sampling Schemas: activity allows to set parameters for company-specific sampling schemes. These are a collection of sampling instructions that define the sample size and the criteria for acceptance and rejection. It considers the lot quantity to be inspected, the inspection severity, and the AQL.

- **Inspection characteristic:** It is created as a record. This characteristic is intended for frequent use in inspection plans and serves to describe the inspection criteria for materials, parts and products, these define what needs to be inspected and can be either quantitative or qualitative.

- **Catalogs**: Catalogs correspond to information stored and classified in the system to manage, uniformly define, and standardize information arising from the production process (for example, defect types, causes, activities, or characteristic attributes) of the customer or plant. Catalogs can help to record and then evaluate qualitative data and describe problems.

- **Work Center**: They are the physical place in which each one of the operations of a production order is carried out. They can be Machines, tools or a group of these, it is possible, also, to assign human resources to a work center and these are indispensable not only for the management of the quality but also for the planning of the production.

- **Production resources and tools (PRTs)**: unlike the work center these are mobile operational resources that are indispensable to perform activities and are used repeatedly. For example, PRTs include documents, engineering drawings and measurement instruments. Production resources and tools can be assigned to productive activities and the use of these is specified in terms of quantity, times and dates.

- **QM material master view:** Information related to QM management is stored in the QM view of the material master record, besides the basic settings for the process flow of the quality inspection is defined in the inspection setup (which is in the QM master view) and there are several indicators to set depending on the material being parametrized.

- **Assignments**: In this case, it is not related to the creation of a quality management component itself, but to the assignment of that component to an existing record in SAP. This record refers to a material (it can be elements that are consumed in production activities or final products, arising from productive processes) or to a routing (operations necessary to manufacture a product) see **APPENDIX 3**.

  The assignment of inspection characteristics to materials, from catalogs to inspection characteristics and finally, from sampling procedures, work center, and production resources tools to routings are indispensable not only for product inspection but also for total traceability.

**2.Inspection lot generation:** The in-process inspection has as reference a production order, at the moment in which a production order is created, an inspection lot is automatically generated, and it is shaped according to its corresponding sampling procedure. To carry out this process, it is required a

special set-up in the system for the materials to be produced (see section 5.3.1.1. Material Management Set-Up).

**3.input inspection results:** In this component, results are recorded and processed for the inspection characteristics. The inspection lot is the reference object in results recording. The recorded inspection results evidence the quality of the inspected product and can be used to make quality inspection evaluations.

**4.Usage decision:** Once an inspection has been completed, the usage decision is made for the inspection lot. The system proposes a decision according to the results entered, however, the quality supervisor is the one who confirms whether the inspected goods are accepted or rejected.

**5.Non-conformity management:** This component describes the management of defects and nonconformities. If there is a failure in the production process the quality controller creates a defect record and adds all the information required (pictures, list of results, signed documents). The Quality Supervisor further processes the defect record by documenting or defining immediate, corrective, and preventive actions. The quality controller executes the defined corrective actions and then checks whether the system is working properly. After defect resolution, the quality supervisor closes the defect record.

The notifications to implement are of the type of internal problems and will be linked to problems related to internal operations, machines, delays in production times, among others. The internal problem will be linked to a production order and this, in turn, will be linked to a defect generated within the inspection lot having complete traceability from its origin.

## 5.3. Parametrization

In this phase the elements of the QM module are modeled, defined and created, in addition, it is possible to test the new instruments that the company now has at its disposal with SAP to improve its processes, elements such as control charts and the impeccable traceability of products in each stage of the logistics supply chain.

Finally, a basis of confidence about the ability of the system to manage the company is provided since the daily behavior of the company's quality processes can be examined by performing several tests using the model with the parametrizations and tools offered by SAP to manage quality.

In this project, it will be used 2 methodologies of data transfer, which are individual configuration and massive migration.

Manual creation: Usually in projects, there is a need to create master data in small quantities and it also requires accurate and detailed information. In this case, the creation of this data is carried out by means of the creation transactions that correspond to each one of the master data in the system, by means of which the functional consultants fill in the necessary fields and add the information as detailed as required. The individual configuration will be used for the sampling procedure and quality management view creation in the material masters whose steps will be explained later.

Massive Migration: Legacy System Migration Workbench (LSMW). In large projects, there may be a team dedicated only to master data loading, however, in some cases like this one, it is the responsibility of the functional team to massively load this information, such as objects, the configuration of existing records or transfer fixed assets from several databases. LSMW is a standard SAP tool that, step by step, takes the information to be uploaded from source files and enters it into the system by filling in structures specific to each master data. Massive migration will be used for the objects mentioned in Table 4.

### 5.3.1. Manual Configuration

#### 5.3.1.1. Material Management Set-Up

**Individual Creation:** It is used to configure the material masters after having created just one material, for instance, a new material whose characteristics are different from the rest of existing materials in the company currently. Below it is presented the individual creation of a quality management view in a master material for illustrative purposes.

**Create a "Quality Management" view in the material master:**

The individual creation of this view can be done through transaction code MM01 where the parameters would be set manually in the views corresponding to Quality management as shown in Figure 13

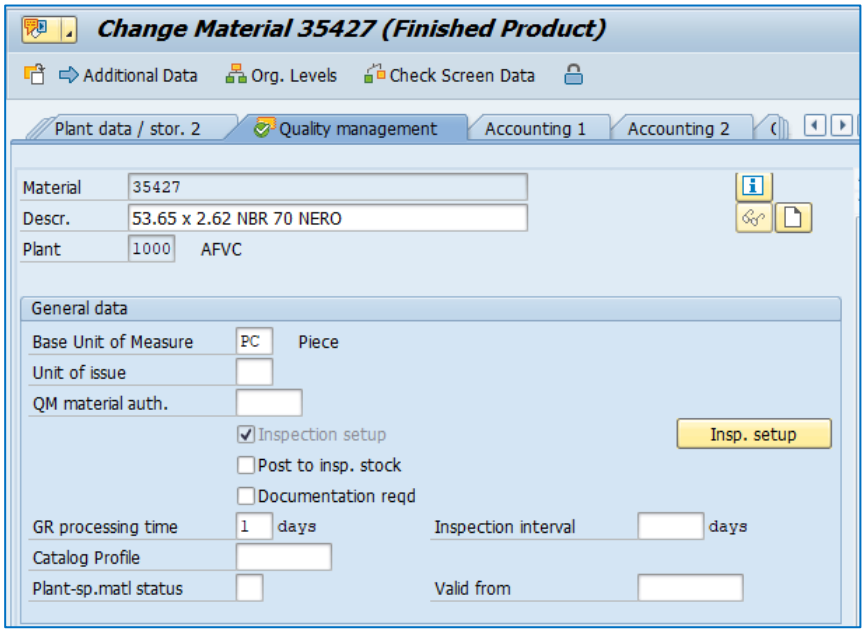


*Figure 13. Material Master QM view (taken from SAP).*

For the inspection setup configuration, it is necessary first to assign an inspection type to the material from all the options offered by SAP shown in Figure 15, in this case, the inspection type 3 is chosen, which means that the system will create inspection lots during the manufacturing process. Then the fields of inspection with task list, skips allowed, and check characteristics are marked. The Q-score procedure is entered as 06- from usage decision see Figure 14 (All these fields will be explained in the massive migration of data section).

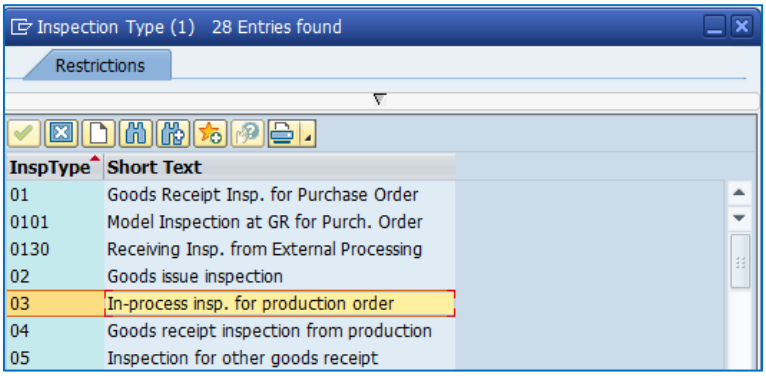


*Figure 15. Inspection types available in SAP (taken from SAP).*

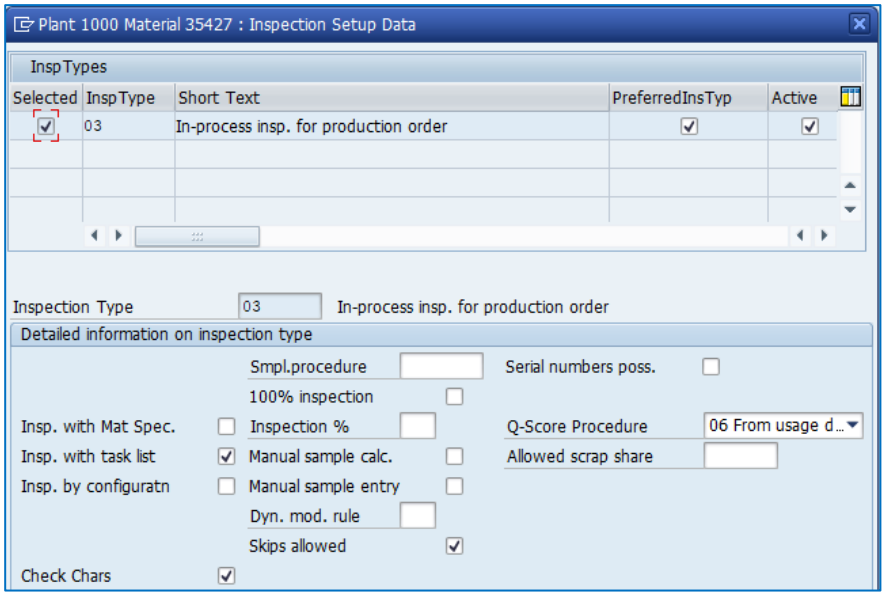


*Figure 14. Inspection setup data for QM view (taken from SAP).*

**Massive creation:** It is used to activate at the same time the quality management view of several materials at the same time. Since the company is already using SAP, most of the materials present in the software database must be extended, that is, the "Quality Management" view must be created for more than 16,000 materials. In light of that, the most convenient way is to carry out the creation of the quality management view in the material master of the desired materials in a massive way and to do this, it is necessary to execute the transaction MM17, once executed, the next step is to select MARA (this is the main table used in the material management module) in the tab tables as can be seen in Figure 16.

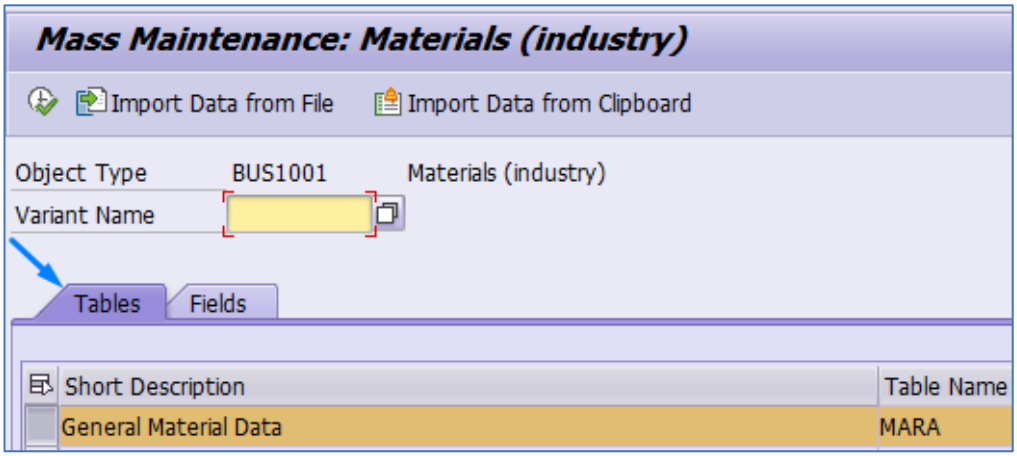


*Figure 16. Transaction MM17 tables tab (Taken from SAP).*

After having chosen the table, now it is necessary to choose the field to be changed in a massive way. To do so, it is required to move to the fields tab, there is chosen the field name QMPUR which corresponds to the QM procurement see Figure 17. Click on execute to continue to the next window.

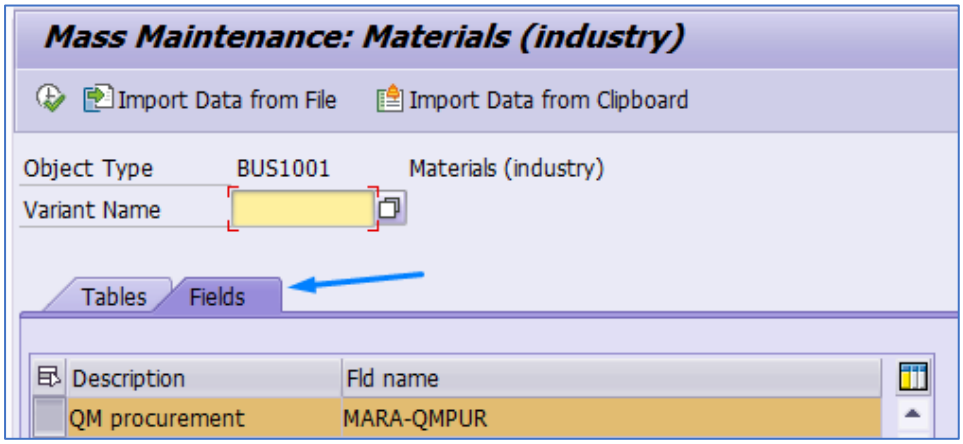


*Figure 17. Transaction MM17 fields tab (taken from SAP)*

In the new screen shown in Figure 18 are entered as many material codes as desired to be changed, then click again in execute.

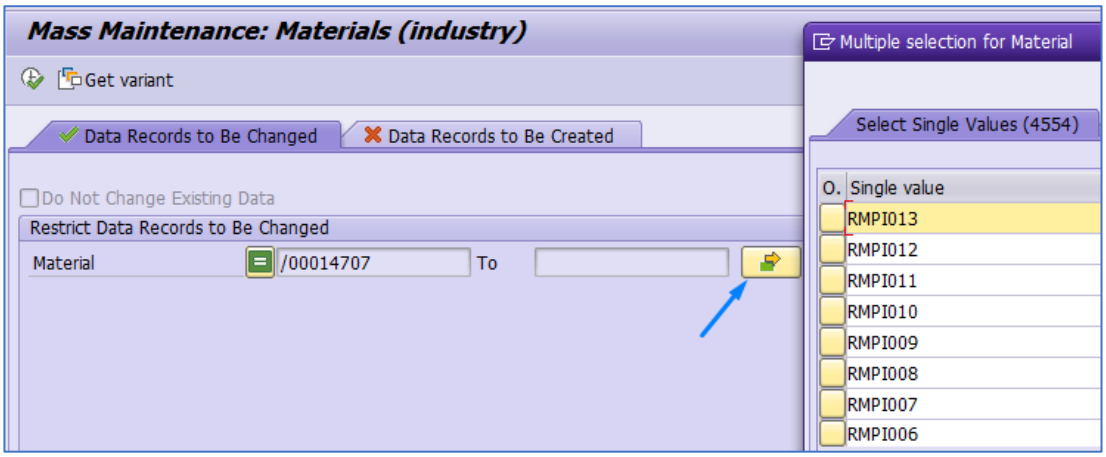


*Figure 18. Multiple selection for materials MM17 transaction (taken from SAP).*

The last screen is divided in two, in the upper part it is assigned the new value for the field that will be changed which in this case is the checkbox related to QM procedure, this would change indicating now that QM is active, so once clicked the button mass change for all materials selected in the bottom part their respective checkbox changes its status to active (see Figure 19).

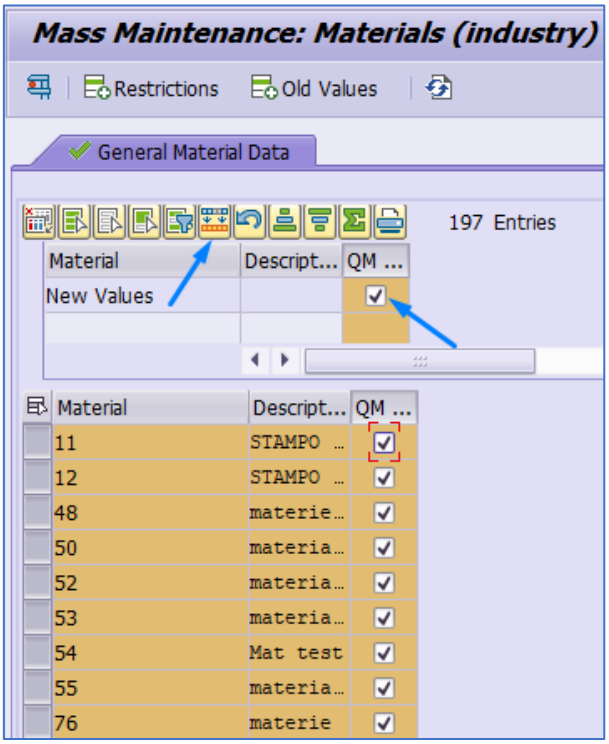


*Figure 19. Mass change for Materials (Taken from SAP).*

Now, all the materials which have been modified have active the QM view in the material masters record, however, it is still necessary to perform several configurations in the system, that is, to assign an inspection type and some parameters which will be explained later in the massive migration procedure.

#### 5.3.1.2. Sampling Procedure

Sampling is a process or technique of choosing a sub-group from a population to observe and this may estimate something about the whole population (K. Thompson, 2012). In SAP QM module the sample size is determined using the sampling procedure. The sampling type defined in the sampling procedure defines how the sample is determined, while the valuation mode defines rules for accepting or rejecting a characteristic or sample (see Figure 22).

In the company, there are 6 sampling procedures (see Table 3) parameterized according to the characteristics (Qualitative, Quantitative) of the process for the final product. With a type of sampling that could be a fixed sample, a percentage of production, a 100% inspection or use a sampling scheme, the latter is mainly used to Goods receipt and it consists of tables with sampling plans which depend on the lot size and use parameters such as AQL (acceptable quality level).

| **Sampling procedure** | **Sampling type** | **Valuation mode** | **Description** |
|---|---|---|---|
| C0 | Fixed Sample | Manual Valuation | Dimensional control |
| C1 | Sampling Scheme | Attributive Inspection non-conforming units | Sample size based on AQL – Goods Receipt |
| C2 | Sampling Scheme | Mean Value within tolerance range | Fixed sample size |
| C3 | Sampling Scheme | Mean Value within tolerance range | Fixed sample size |
| C4 | 100% Inspection | Attributive Inspection non-conforming units | 100% Lot inspection |
| C5 | Percentage Sample | Manual Valuation | Percentage of total production - |

*Table 3.Sampling procedures created in the company (own elaboration).*

Hereunder, the sampling procedure creation in QM Sap module is illustrated, with its respective steps. The example to be created has a sampling procedure with a fixed sample, this type of procedure is used in materials whose production is managed in fixed lot size as is the case of the most part of the products within the company. Therefore, for the majority references it is known what is the quantity to sample in a production lot.

To start the creation of a sampling procedure, it is necessary to execute the transaction QDV1. Figure 21 shows the navigation tree to search for the transaction through which a sampling procedure is created.

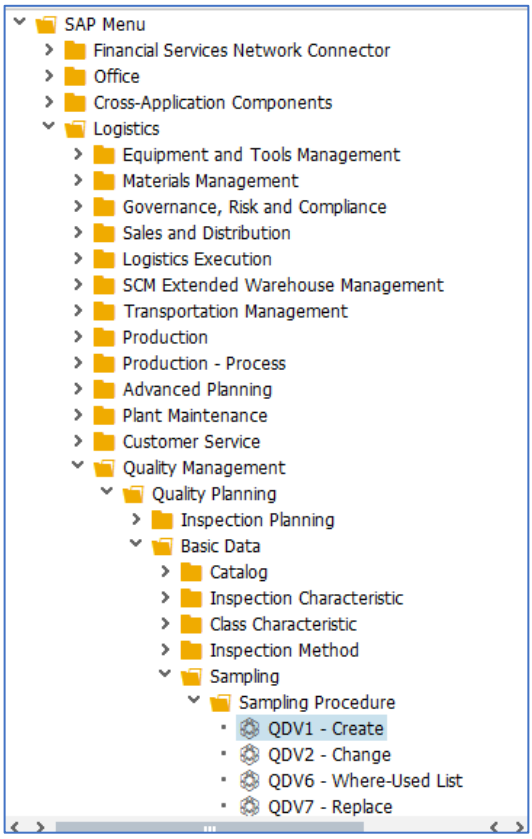


*Figure 21. Navigation tree for sampling procedure (taken from SAP).*

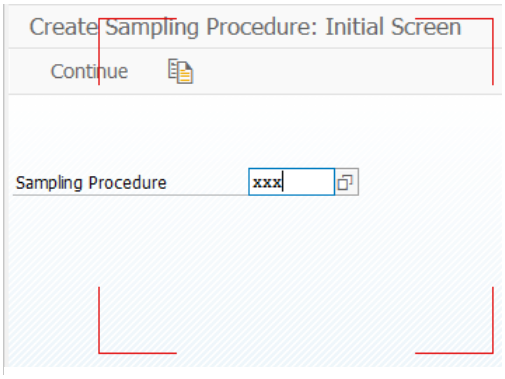


*Figure 20. Naming sampling procedure (taken from SAP).*

Once executed and after having entered the name of the sampling procedure to be created as shown in Figure 20, a fixed sample and a valuation mode manual are set in this example, however, it could have been attributive inspection, mean value within tolerance range or valuation according to characteristics (see Figure 22).

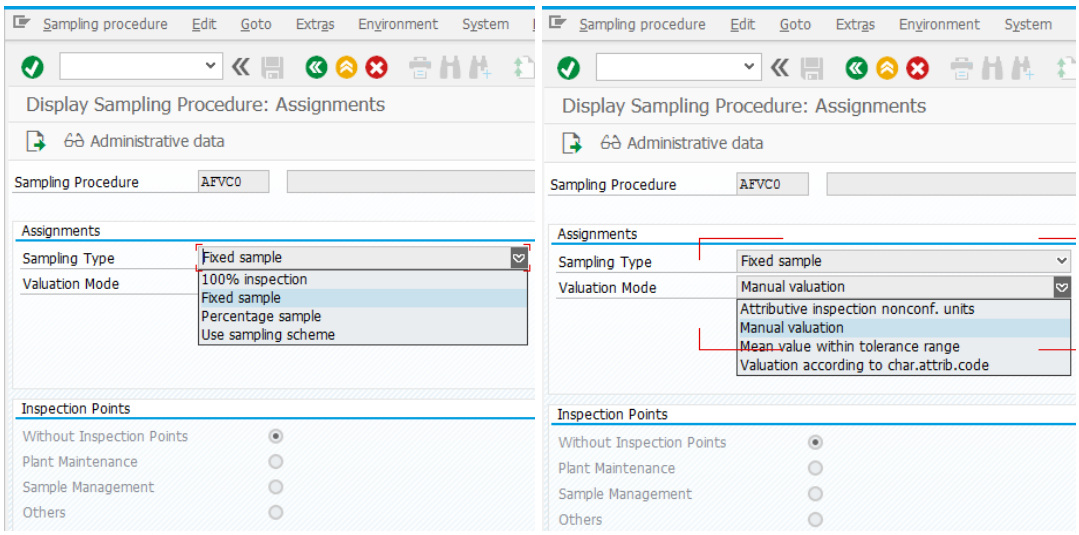


*Figure 22. Possible settings of a sampling procedures (taken from SAP).*

### 5.3.1.3. Catalogs

Catalogs can help when it is necessary to record and then to evaluate qualitative data, for instance, describe problems, defect items, tasks, activities, and causes in quality notifications and finally to make usage decisions during inspection lot completion (using catalog type 3). Catalogs are used to simplify and improve the recording of data, inspection results, defects, default locations during inspection lot and to describe problems that occur and to standardize the evaluation of this information. These catalogs can be directly assigned to master inspection characteristics and can store information at characteristic level in task lists (Routing or master recipe, these are defined in **Appendix 3**).

| C | Short text for the catalog | Keyword |
|---|---|---|
| 0 | Action Reasons | Action |
| 1 | Characteristic attributes | Attribute |
| 2 | Tasks | Task |
| 3 | Usage decisions | Decision |
| 4 | Events | Event |
| 5 | Causes | Cause |
| 6 | Results of defects | Results(def) |
| 7 | Hold Codes | Hold |
| 8 | Activities (QM) | Activity QM |
| 9 | Defect types | Defect type |
| A | Activities (PM) | Activity PM |
| B | Object parts | Object part |
| C | Overview of damage | Damage |
| D | Coding | Coding |
| E | Defect Locations | Defect loc. |
| F | Decision - SPM Returns | Dec. SPM |
| G | Defect - SPM Returns | Defect - SPM |
| H | Effort - SPM Returns | Effort - SPM |
| I | Follow-Up Activity - SPM Returns | Activity SPM |
| J | Functions | Function |

*Figure 23. Catalogs by default (taken from SAP)*

Catalogs contain several content-related codes which are qualitative descriptions of problems in text form. In the catalogs, each information unit is assigned to a unique alphanumeric code and a long text, typical contents of a catalog include: characteristic attributes, usage decisions, tasks, measures, causes, actions, defect classes, coding, defect locations and defect types, see Figure 23. Some of the codes can be freely combined or grouped into code groups in a catalog. The aforementioned catalogs are established in SAP by default from 0 to 9 and from A to O, but if required, it is possible to create and customize others and assign them any letter from P to Z. The catalog type defines the use of a catalog (for example, for defects recording, tasks, and so on). Code groups and selected sets can be directly assigned to inspection characteristics. Coding for the general documentation of events that have been triggered is also available (errors in result recording or errors as part of notification processing).

The more carefully these catalogs are planned, the greater the chance of being able to analyze the information collected in the form of FMECA. SAP offers FMECA (Failure Mode and Effects Analysis) as a tool of the QM module, which is designed to construct an FMECA on a long-term basis with the retained data of the failures that occurred in the process in a considerable period of time. (see **Appendix 1**). For instance, a notification itself is triggered by an occurrence, if the catalog of defect types that are used for quality notifications relates to the catalog of causes, it is easy to understand and classify the failure that will be recorded in the system database. Besides, the connection with tasks catalog type is extremely important, since tasks could be defined for a notification and immediately a responsible is assigned to perform the work steps that are necessary to solve the problem, multiple objects can be assigned in a quality notification. This enables the company to better document problems and faults, while at the same time reducing the required processing effort and number of quality notifications since all these are connected see Figure 24.

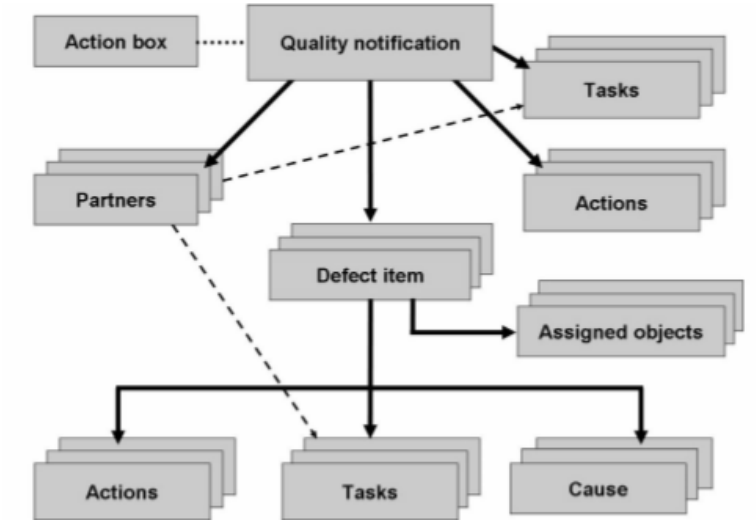


*Figure 24. Quality notification structure (SAP, 2011).*

### Code group and codes creation

The creation of a code group requires to access the transaction QS41. First, the catalog type code in which is wanted to record the data have to be specified (in this case 5, this corresponds to causes catalog), then in the code group a unique name must be given (in this example ENVIRONM) see Figure 25.

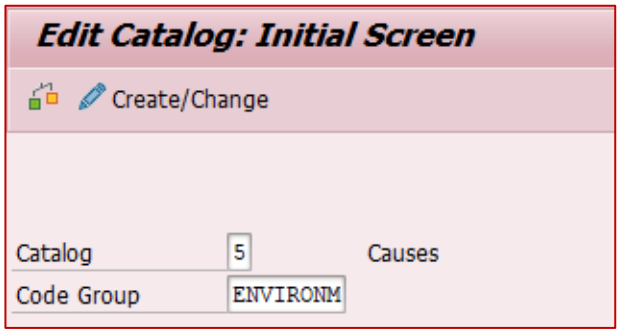


*Figure 25.Cataloge cration (taken from SAP).*

In the following screen, a short description for the code group must be given, in this case the status code group proposed by SAP is 1. being created. If desired a document could be attached pressing the button  see Figure 26.

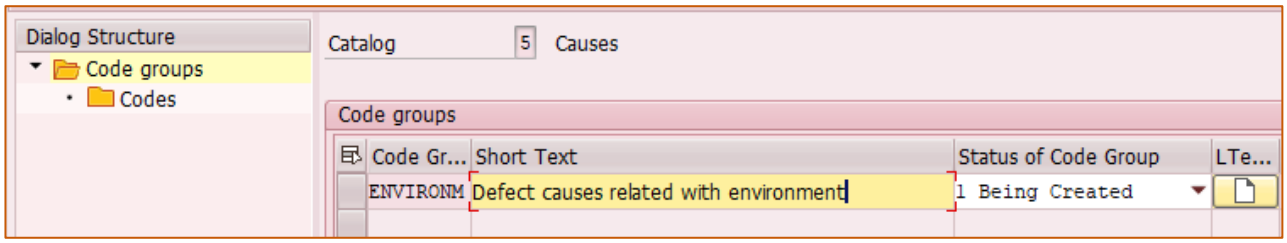


*Figure 26. Code group creation (taken from SAP).*

Then, to add the causes codes that the ENVORINM code group will contain, the row Codes must be selected in order to open the codes folder see Figure 27.

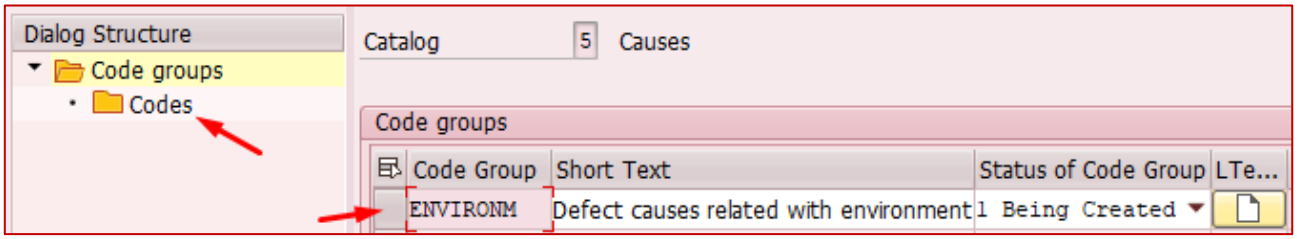


*Figure 27. Opening code group (taken from SAP).*

In the following window, new entries could be added, in the first column a unique code for the cause is given, in the second one brief description of the cause and finally a document can be attached see Figure 28. Now this causes(codes) could be linked with any problem in production.

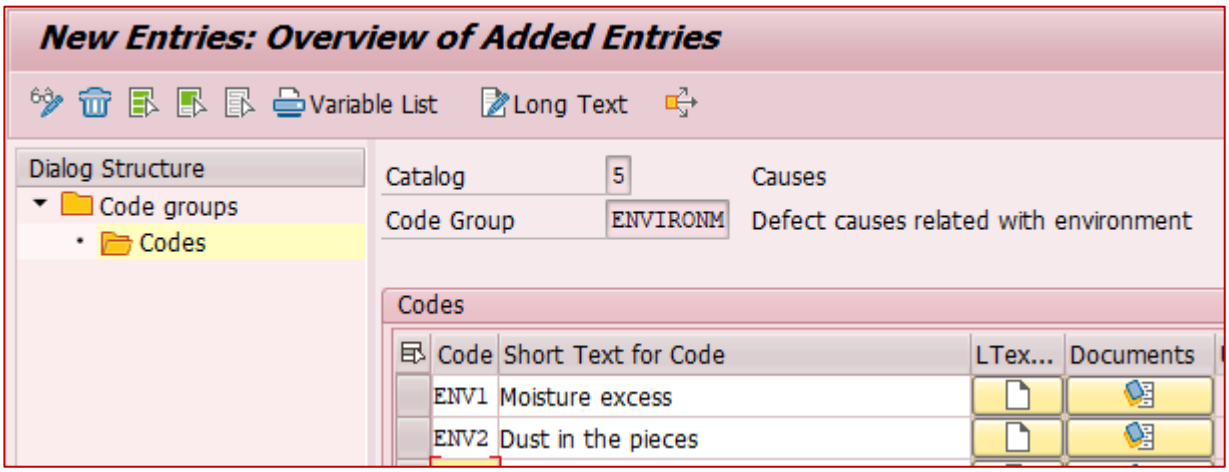


*Figure 28. Codes creation (taken from SAP).*

Once entered the entries in the code section, in order to make the catalog ready to be used, it is necessary to go back to the first window and then change the status of the catalog to released see Figure 29.

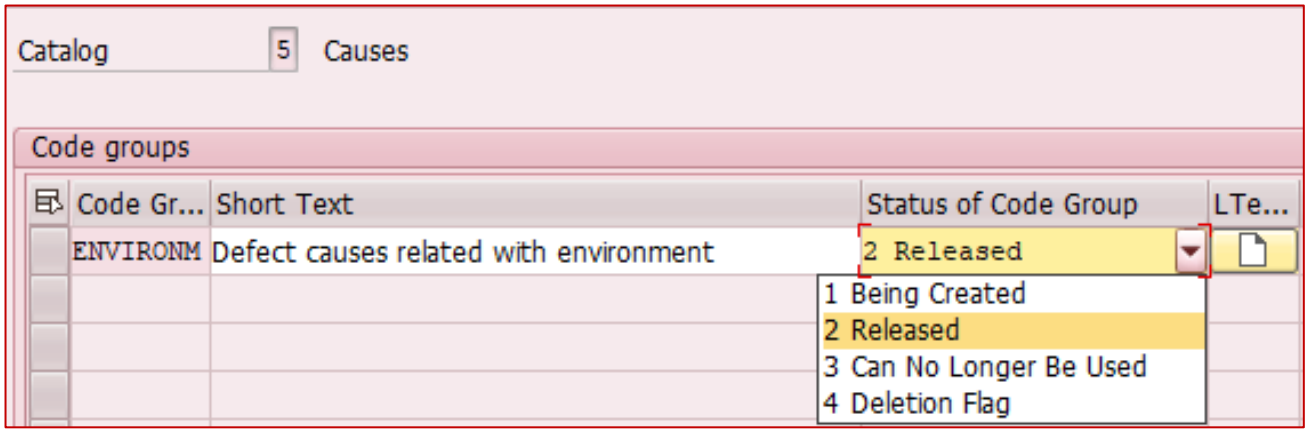


*Figure 29. Changing code group status (Taken from SAP).*

Now the catalog is ready, and the only missing step is to assign this catalog to an inspection characteristic. To do this, it is required to execute the transaction QS22, then enter the name of the inspection characteristic and the production plant as shown in Figure 30.

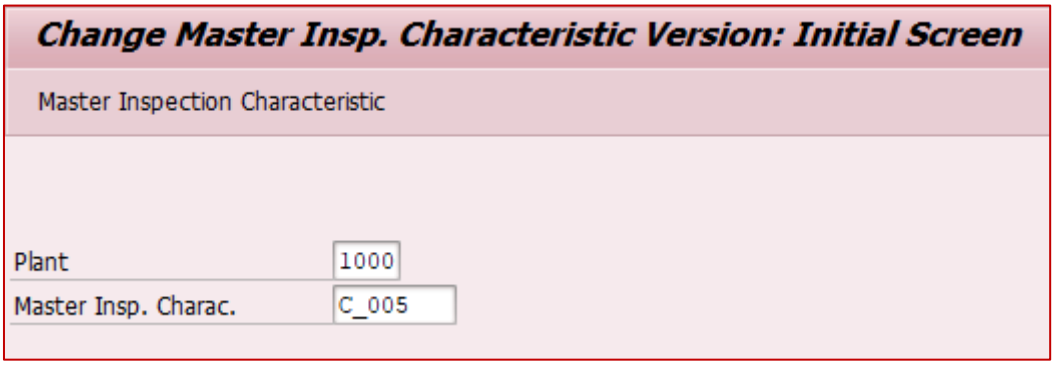


*Figure 30. QS22 Transaction, change Inspection characteristic (Taken from SAP).*

Finally, it is needed to select the checkbox catalogs, then click on the button and assign the code of the catalog created see Figure 31

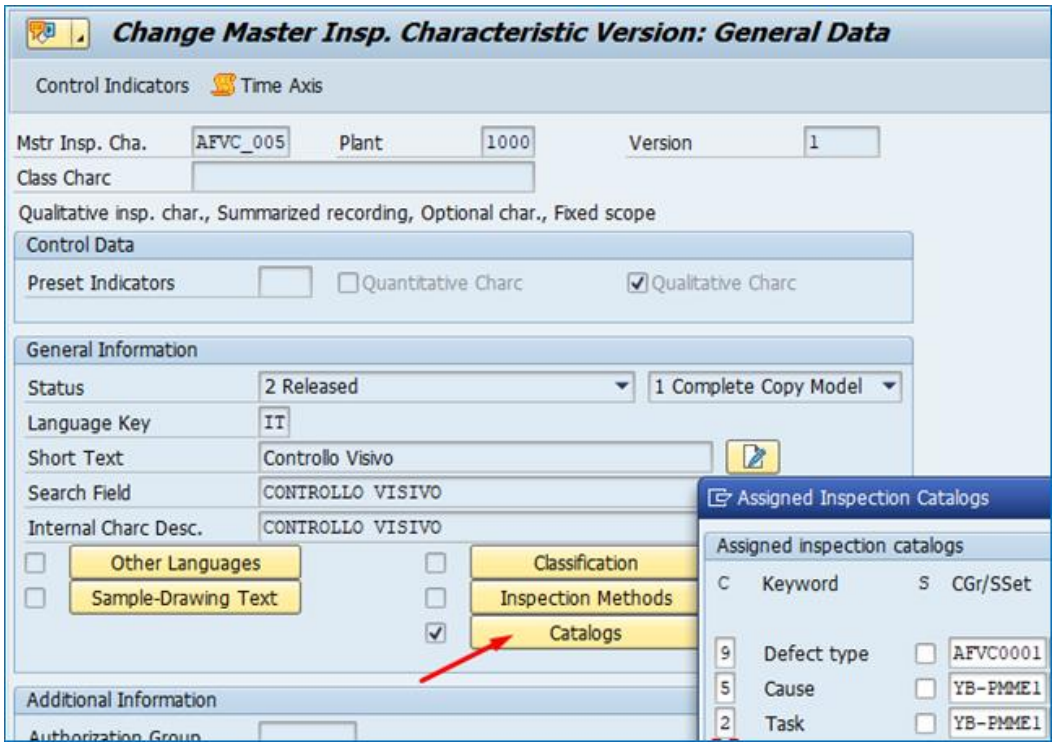


*Figure 31. Assigning catalogs to an inspection characteristic (taken from SAP)*

.

The following are some Group codes belonging to the most important catalogs used in the quality management area of the company, which are: defect type, causes and activities, those catalogs are the most used since they can be linked to an inspection characteristic. In this way, at the moment in which the mentioned inspection characteristic presents an irregularity, the usage decision for in-process inspection (see Figure 34) is used to assign a rejection to the characteristic and immediately the system asks for a defect type (i.e. Figure 33), its cause(i.e. Figure 32) and possibly a corrective activity (i.e. Figure 35) to perform.

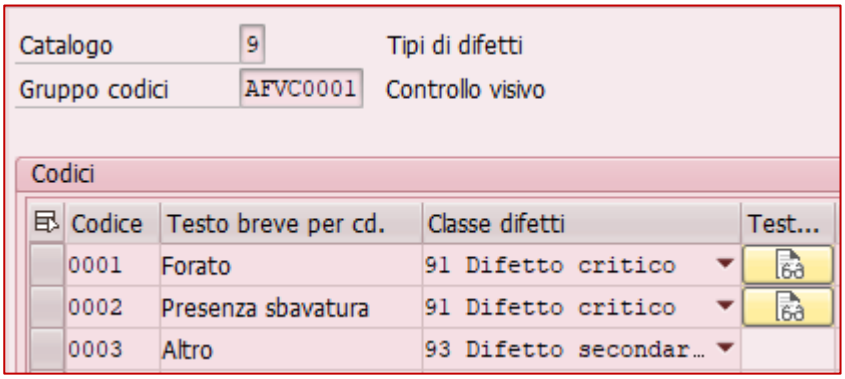


*Figure 33. "Controllo visivo" code group belonging to catalog 9. Defect type (taken from SAP).*

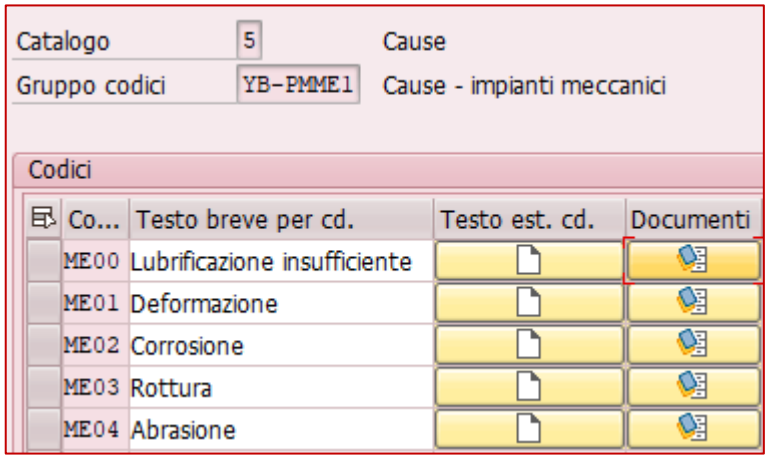


*Figure 32. "Impianti meccanici" code group belonging to catalog 5. causes (taken from SAP).*

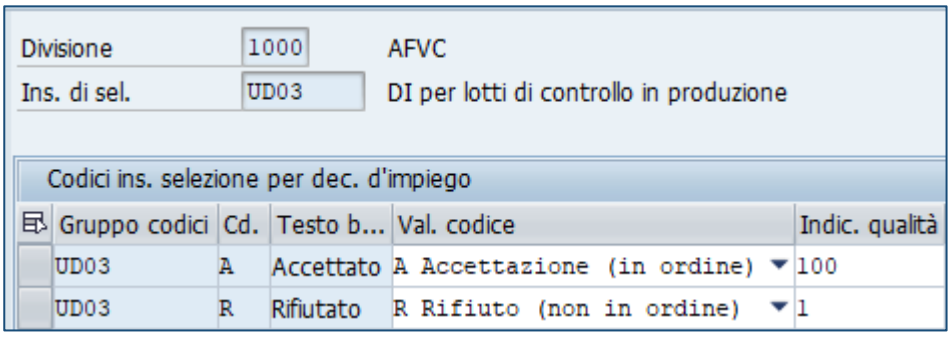


*Figure 34. "DI per lotti di controllo in produzione" code group belonging to catalog 3. Usage decisions (taken from SAP).*

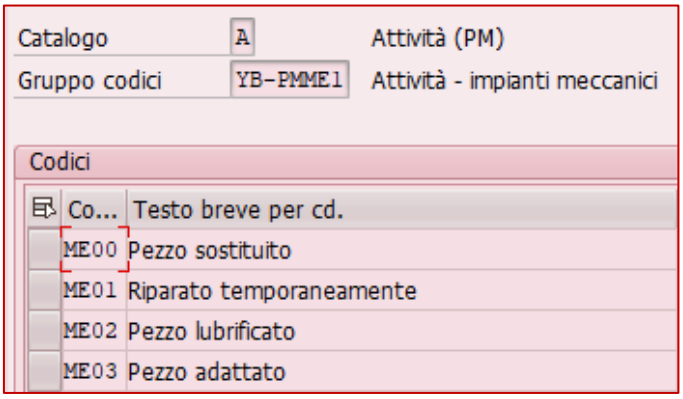


*Figure 35. "Impianti meccanici" code group belonging to catalog A. Activities (taken from SAP).*

### 5.3.2. Massive Migration

Data migration is the process by which a data transfer is performed from the current data storage system to the new system to be implemented, also refers to the conversion of some data formats to others.

The LSMW (Legacy System Migration Workbench) is a transaction that is used to load data into SAP massively from an external file (usually Excel). Data of the following types can be migrated to SAP via LSMW:

1. Master data: customers, suppliers, accounts, materials, work centers.

2.Transactional data: financial entries, orders.

In this case, data of the first type will be migrated. From the LSMW tool it is possible to download a standard template associated with the master data to be migrated, this can be customized according to the specific requirements of each project. That is to say, each template has obligatory fields, the optional fields and the transfer rules of these fields, that means, which type of data is valid and the what is maximum number of characters for each field.

The objects which will be transferred through data migration with the LSMW transaction are identified and described in Table 4.

| Object | Activity | Comments |
|---|---|---|
| Inspection Characteristics | Create features | Creation of qualitative and quantitative characteristics |
| Work Centers | Creates work centers | A work center must be loaded for each product |
| Assignment | Assignment of Characteristics to Material | assign inspection characteristics to material masters and routings. |
| QM material master view | Parametrize QM view material master parameters | set the quality inspection processes for materials. |
| Production Resources/Tools | Create measurement tools for the characteristics. | A measuring tool must be loaded for each characteristic. |

*Table 4. The objects which will be transfer by means of data migration (own elaboration).*

#### 5.3.2.1. Qualitative Inspection Characteristics

The loading program (LSMW) is entered into transaction QS21 and the following fields need to be filled, the first line corresponds to the fields of the database table that must be filled see figure Table 5.

1. Plant: Corresponds to the plant where the data are being loaded, it is a form of unique identification.

2. Characteristic ID: is the nomenclature used for each of the inspection characteristics univocally within a plant.

3. Start date: corresponds to the date when the characteristics will be active.

4. Qualitative characteristic: it is selected with an X. In this way, it is specified the relevant control indicators for the inspection characteristic. Inspection results are recorded in classes as inspection catalog codes, with the valuation OK/not OK, or as a quantity of the results determined. It does not define any tolerance limits and any theoretical values. Therefore, no measured value can be recorded in the result of confirmation as an example.

5. Status: Corresponds to a status in the master record, in this case, it is Released. The following statuses are allowed:

- **In creation**: When the master record is being created, the system proposes the status of "being created". However, there is the option of changing the status proposed by the system.
- **Released**: Before the master record is referenced, it must first be released by setting the status "released".
- **No longer usable**: If a master record is not going to be used anymore, the status "no longer usable" must be set.
- **Deletion Flag**: To delete a master record the next time a file is executed, the status "deletion flag" must be set. A background processing program then checks whether the master record is referenced. However, if there is a reference to this master record, it can only be deleted if the usages have already been deleted.

6.Description: Corresponds to a short description text for the characteristic, up to 40 characters.

7.Search field: corresponds to a short text field for searching. This field should improve the search possibilities for master data records using the search help.

8.Parameter 1: Corresponds to the properties of the characteristic. If this indicator is set, the inspection characteristic is marked as an attributive characteristic whose value range is specified as a selected set from catalog 1 (characteristic attributes).

If this indicator is not set, the inspection characteristic is marked as an alternative characteristic and can only adopt the values "accepted" or "rejected".

9.Parameter 2: Corresponds to the required sampling procedures. If this indicator is set, it is required to assign a sampling procedure in the task list to this inspection characteristic.

10.Parameter 3: Corresponds to the additional samples in the process.

11.Parameter 4: Corresponds to the result entry, which in this case is the single result of the inspection characteristic.

12.Parameter 5: corresponds to the notification of results, which in this case is Optional, since it is not necessary to verify the inspection characteristics, therefore, it is possible to enter results, but it is not mandatory to enter all results.

13.Parameter 6: corresponds to the fixed size, determines the number of inspected units.

14.Parameter 7: corresponds to the documentation which in this case is NOT required, it should not record any additional text as documentation for this inspection characteristic during the result entry.

15.Parameter 8: Corresponds to the printout of the inspection characteristic.

16.Catalog: Corresponds to the selected set assigned (Catalogue class) to the inspection characteristic.

| WERKS | MKMNR | GUELTIGAB | QUALITAET | LOEKZ | KURZTEXT | SORTFELD |
|---|---|---|---|---|---|---|
| **Plant** | **ID Characteristic** | **Valid from** | **Qualitative characteristic** | **Status** | **description** | **Search field** |
| 1000 | C_005 | 01.01.2012 | X | 2 | Visual control | Visual control |
| 1000 | C_011 | 01.01.2012 | X | 2 | Stampo consumato / BAVA X | Stampo consumato / BAVA X |

| PRUEFKAT | STICHPR | ADDPRO | ESTUKZ3 | RZWANG1 | DOKUKZ1 | PUMFKZ4 | DRUCK1 | USWMENGE1 |
|---|---|---|---|---|---|---|---|---|
| **Paramet.1** | **Paramet.2** | **Paramet.3** | **Paramet.4** | **Paramet.5** | **Paramet.6** | **Paramet.7** | **Paramet.8** | **CATALOGUE** |
| X | X | X | X | X | X | X | X | Defect |
| X | X | X | X | X | X | X | X | Damage |

*Table 5. Qualitative Characteristics Load Sheet (own elaboration).*

#### 5.3.2.2. Quantitative Inspection Characteristics

The loading program (LSMW) is entered into transaction QS21 it is required to fill out the same fields (from 1 to 7) already mentioned for the previous characteristic, except for the one corresponding to the number 4 (Qualitative characteristic) since in this case this field would correspond to quantitative characteristic and this is the one that is selected with an X Table 6. Then the other fields are defined.

1. Parameter 1: corresponds to the lower tolerance limit, if this option is selected, a lower tolerance limit must be specified for the inspection characteristic.

2. Parameter 2: Corresponds to the upper tolerance limit; if this option is selected, an upper tolerance limit must be entered for the inspection characteristic.

3. Parameter 3: corresponds to the theoretical value, if this option is selected, the system checks whether the theoretical value is within the lower and upper tolerance limits.

4. Parameter 4: corresponds to the required sampling procedure, if this option is selected, it must be assigned a sampling procedure in

the task list to this inspection characteristic. (See section 5.4.2.5 for more details on sampling procedures).

5. Parameter 5: corresponds to the additional samples of the process.

6. Parameter 6: corresponds to the SPC (Statistical Control Process) characteristics, if this option is selected a quality control chart will be made for this inspection characteristic.

7. Parameter 7: Corresponds to the result entry, which in this case is Individual result of the inspection characteristic.

8. Parameter 8: Corresponds to the results of the notification, this means that results can be entered.

9. Parameter 9: corresponds to the fixed size, determines the number of inspected units.

10. Parameter 10: corresponds to the documentation which in this case is not required, it should not record any additional text as documentation for this inspection characteristic during the result entry.

11. Parameter 11: corresponds to the measured values, if this option is selected, measured values for this quantitative characteristic must be checked and reported.

12. Parameter 12: Corresponds to the printout of the inspection characteristic.

13. Parameter 13: Corresponds to inspection characteristics that do not contain formulas.

14. Number of Decimals: Corresponds to the number of decimals that are considered in a value.

15. Unit: Corresponds to the unit of measure of the standard values (target value and tolerance limits) of a quantitative inspection characteristic.

16. Target value: Corresponds to the target value of a quantitative characteristic which must be within the tolerance limits.

17. Lower limit: corresponds to the lower limit, which is the lowest value that an inspection characteristic can take in order not to exceed the working limits (Rejected).

18. Upper limit: corresponds to the upper limit, which is the highest value that an inspection characteristic can take in order not to exceed the work limits (Rejected).

| WERKS | MKMNR | GUELTI | JANNIE | LOEK | KURZTEXT | SORTFEL | TOLERU | TOLERO |
|---|---|---|---|---|---|---|---|---|
| Plant | **ID Characteristic** | **Valid from** | **Quantitative characteristic** | **Status** | **description** | **Search field** | **Param 1** | **Param 2** |
| 1000 | C_006 | 30.11.19 | X | 2 | Hardness | Hardness | X | X |
| 1000 | C_007 | 30.11.19 | X | 2 | Spessor | Spessor | X | X |

| STICHPR | ADDPRO | ASPCMK | ESTUKZ3 | RZWANG1 | DOKUKZ1 | PUMFKZ4 | MESSWERTE |
|---|---|---|---|---|---|---|---|
| **Parameter 4** | **Param 5** | **Param 6** | **Param 7** | **Param 8** | **Param 9** | **Param 10** | **Param 11** |
| X | X | X | X | X | X | X | X |
| X | X | X | X | X | X | X | X |

| DRUCK1 | KEINEFORMEL | STELLEN | MEINZ | SOLLWERT | TOLERANZUN | TOLERANZOB |
|---|---|---|---|---|---|---|
| **Parameter 12** | **Parameter 13** | **Decimal places** | **Unit of measure** | **Target value** | **Lower limit** | **Upper limit** |
| X | X | 2 | % | 70 | 58 | 70 |
| X | X | 2 | mm | 53,65 | 53,14 | 54,16 |

*Table 6 Quantitative Characteristics Load Sheet (own elaboration).*

#### 5.3.2.3. Work Center

The loading program enters the transaction CR01 and completes the field shown in Table 7, the first line corresponds to the fields of the database table that must be filled.

1. plant: corresponds to the plant where the data are loaded, it is a form of unique identification.

2. Work center: a key that identifies a work center which is an organizational unit, this key defines where and by whom an operation is performed.

3. Class (0007): corresponds to a production line. Key differentiating the work centers with regard to their use or class (e.g. production work center, maintenance work center).

4. Description: Refers to the work center description.

5. Responsible: corresponds to the person responsible for the job.

6. Usage: corresponds to the use of task lists.

7. Standard value key: The standard value key corresponds to the assignment of which will be the standard values in the operation, which could range from 1 to 6. The system uses standard values as parameters to calculate operation time, capacity requirements and costs. Standard value key is used to assign a parameter ID to those standard values.

| **WERKS** | **ARBPL** | **VERWE** | **STEXT** | **VERAN** | **PLANV** | **VGWTS** |
|---|---|---|---|---|---|---|
| Plant | **Work centre** | **Category** | **Description** | **Responsible** | **Usage** | **Standard key** |
| 1000 | 10 | 7 | Lav 07 | JTE | 4 | Z001 |
| 1000 | 20 | 7 | Pre 04 | JTE | 4 | Z001 |

*Table 7. Work center Load Sheet (own elaboration).*

#### 5.3.2.4. PRT (Production resource/tool)

They are a set of measuring instruments to be created in the system, most of them are physically located in both the production area and the quality management laboratory. The loading program enters the transaction CF01 and completes the following fields, also shown in Table 8:

1. PRT: Key which clearly identifies production resources/tools.

2. Plant: Corresponds to the plant where the data are loaded, it is a form of unique identification.

3. Location: This parameter, along with the plant, identifies the location where the production resource/tool is maintained, stored or used.

4.Description of the PRT: Text with which production resources/ tools are described in more detail.

5. Grouping key for PRT: An open key, with which production resources/tools can be group together (for example, measurement instruments or test equipment).

6. PRT master Status: Gives information about the processing status of the PRT master. For example, it is possible to use the status to control whether the PRT has already been released for use in the task list.

In the system there are 4 status that are already being used:

I. On creation: When the PRT is being created, the system proposes the status of "being created". However, there is the option of changing the status proposed by the system.

II. Release for usage in the warehouse: when the PRT is being used in the different material warehouses.

III. Release for usage in production: when the PRT is being used in the productive area of the company or throughout the production processes.

IV. Deletion flag: To delete a master record the next time a file is executed, the status "deletion flag" must be set. A background processing program then checks whether the master record is referenced. However, if there is a reference to this master record, it can only be deleted if the usages have already been deleted.

7. PRT usage: With this key, it is controlled in which task lists the production resources/tools may be used. The following options are available:

I. Only routings
II. Only maintenance task lists
III. Master recipe + process order
IV. All task list types

8. Unit of measures for PRT: Unit of measure in which the production resources/tools are managed.

| SFHNR | WERKS | STAND | FHKTX | FGRU1 | STATUS | PLANV | BASEH |
|---|---|---|---|---|---|---|---|
| **PRT** | **Plant** | **Location** | **Description of the PRT** | **Grouping key PRT** | **PRT Status** | **PRT usage** | **Unit of meas. for PRT** |
| Calibro | 1000 | Laboratory | Calibro mm Borletti CD | 3000 | 3 | 4 | mm |

*Table 8. PRT load sheet (Own elaboration).*

#### 5.3.2.5. Assignment of Inspection Characteristics to Material

The loading program enters transaction MM02 and fills the following fields (see Table 9), the first line corresponds to the database table fields that must be filled.

1. Plant: corresponds to the plant where the data are loaded is a form of unique identification.

2. Inspection characteristic 1: corresponds to the previously created inspection characteristic. It is possible to add as many as wanted.

3. Date: corresponds to the date from when the inspection plans are active.

4. Counter: corresponds to a key that uniquely identifies the task list group.

5. Material: corresponds to an alphanumeric key that uniquely identifies the material, which is given to a certain product by means of the material master.

| **WERKS** | **MKMNR** | **STTAG** | **PLNAL** | **MATNR** |
|---|---|---|---|---|
| PLANT | **INSPECTION CHARACTERISTIC** | **DATE** | **COUNTER** | **MATERIAL** |
| 1000 | C_001 | 01.01.2019 | 3 | 113 |
| 1000 | C_002 | 01.01.2019 | 3 | 121 |

*Table 9. Inspection Characteristics to Material assignment Load Sheet (Own elaboration).*

#### 5.3.2.6 Parametrization of QM material master view.

The data required to manage quality inspections along the logistics chain must be entered in the quality management view of the material master. Therefore, the loading program enters the transaction MM02 and filled the following fields, also shown in Table 10:

1. Material: corresponds to an alphanumeric key that uniquely identifies the material, which is given to a certain product by means of the material master.
2. Plant: corresponds to the plant where the data are loaded is a form of unique identification.
3. Base Unit of Measure: is the unit of measure in which stocks of the material are managed. The system converts all the quantities entered to the base unit of measure.
4. Inspection Setup: It exists for Material/Plant, If this indicator is set, a (quality management) inspection setup exists for the material and plant.
5. Inspection with Task List: If this indicator is set, the inspection is performed based on the task list (routing).
6. Inspect by Characteristics: Characteristic-based results recording is a prerequisite for characteristic-based inspection using task list or material specification.
7. Preferred Inspection Type: If this indicator is set, the system creates preferred inspection lots with this inspection type for the corresponding inspection lot origins.
8. Inspection Type: The inspection type defines how an inspection is performed. Several inspection types can be assigned to an inspection lot origin.

| MATRN | WERKS | MEINS | QMATV | PPL | MER | APA_01 | AKTIV_01 |
|---|---|---|---|---|---|---|---|
| Material code | Plant | Base Unit of Meas. | Inspection Setup | Task List Inspection | Inspect by Characteristics | Preferred Insp. Type | Inspection Type |
| 35862 | 1000 | PC | x | x | x | x | 03 |

*Table 10. QM material master view parametrization load sheet.*

**Assign Inspection characteristics to Routing.**

When quality control must be done during the manufacturing process, Quality Inspection characteristics are assigned to the different routing operations. To do so, the loading program enters transaction CA02 and fill the following parameters by means of the load sheet shown in Table 11:

1. Material Number Alphanumeric key uniquely identifying the material.
2. Plant: Key uniquely identifying a plant.
3. Operation/Activity Number: Determines in which order the operations of a sequence are carried out.
4. Inspection Characteristic Number: The number that explicitly identifies an inspection characteristic within an operation in quality control point.
5. Master Inspection Characteristic: Name that uniquely identifies a master inspection characteristic within a plant. An inspection characteristic describes what is to be inspected, that is, the inspection requirements for materials, parts, and products.
6. Inspection Characteristic description: Text of up to 40 characters that describes the inspection characteristic in a more detailed way.
7. Quantitative Characteristic: If this indicator is set, it causes the characteristic to be treated as a quantitative characteristic. the control indicators that are relevant for the inspection characteristic must be defined. A quantitative characteristic is subject to measurement inspections, both tolerance limits and target value are required.
8. Qualitative Characteristic: If this indicator is set, it causes the characteristic to be treated as a qualitative characteristic. The control indicators that are relevant for the inspection characteristic must be defined. Inspection results are recorded with the valuation OK or not OK.
9. Target Value for a Quantitative Characteristic: Value of a quantitative characteristic, from which the actual value of the inspection characteristic should deviate as little as possible.

10. Lower Specification Limit: Lower limiting value for the actual value of an inspection characteristic.
11. Upper Specification Limit: Upper limit value for the actual value of an inspection characteristic.
12. Sampling Procedure in Inspection Characteristic: Code that defines the procedure by which the sample size for an inspection is determined. In the sampling procedure, the valuation mode is also defined for the inspection result.
13. Test equipment: Number that specifies the resource/tool to be used for measuring the inspection characteristics.
14. Description of the test equipment: production resource/tool description.

| MATNR | WERKS | VORNR | MERKNR | MKMNR | MKMNRTEXT | QUANTITAET |
|---|---|---|---|---|---|---|
| **Material Number** | **Plant** | **Operation Number** | **number of Ins. Characteristic** | **Insp. Characteristic** | **Insp. Characteristic description** | **Quantitative Insp. Characteristic** |
| SANC01 | 2310 | 01 | 01 | C_001 | Diametro Interno | x |

| QUALITAET | SOLLWERT | TOLERANZUN | TOLERANZOB | STICHPRVER | PSNFH | TXTZ1 |
|---|---|---|---|---|---|---|
| **Qualitative Insp. Characteristic** | Target Value | Lower Speci. Limit | Upper Speci. Limit | Sampling procedure | Test equipment | Equipment description |
| | 2,2 | 1,9 | 2,2 | c2 | 40 | Calibro |

*Table 11. Inspection Characteristics to routing assignment load sheet (Own elaboration).*

# 6. Conclusion

One of the main objectives set in the company at the time of implementing the SAP QM module was to be aligned to the requirements of today's companies, which must have access to reliable, accurate, organized and real-time information of events which take place in relation to quality control in all areas of the company. Currently, with the solution presented in this thesis the company is able to monitor both the entire performance of the manufacturing process and the quality of its outcome in each of the stages. However, the real benefits of the system will be perceived in the medium and long term, since there is an evident correlation between the time an ERP system is used and the experience acquired by the organizations. This is because the company must adapt to the good practices imposed by SAP as Software certified worldwide.

This project has permitted to obtain a notable improvement in the processes of the Quality management in both the Laboratory and the area of production, allowing the company to entry data to the system in an effective and simple way, thus, taking the standardization and the performance to a higher level. The planning and realization of the project were done in a simplified manner thanks to the ASAP methodology, which indicates the path to follow for a good implementation of any SAP module. Taking into account all the previously mentioned aspects, the SAP QM/PP modules were parameterized according to the specific processes of the company, complying with all the technical, functional and operational requirements that it demands. For this, the Master Data, manufacturing standards and variables to be sampled have been defined in a consistent way.

After the realization stage (chapter 5), it can be stated that the improvements obtained with the implementation of SAP QM are mainly reflected in the following aspects:

1. Quality control management during the production process: When a production order is generated, it will automatically activate the specific inspection lot corresponding to the product to be produced. In the system, there are predefined quality controls for more than eighteen thousand materials, with their respective characteristics to inspect in the different stages of the productive process. In this way, both the probability of human errors and the set-up times in the quality control stages are considerably reduced, since all the steps and procedures to follow are present in the system.

2. Production control: At the time of performing the inspections and only if the product meets the requirements at a specific point of the manufacturing process, the quality personnel will release this material to be used in the subsequent process or to finally be sent to the finished product warehouse. This means that the production is stopped if there are anomalies in the production process or in the product in process, and it is only possible to continue with the authorization of the supervisor or shift leader, who would leave a record of the inconvenience presented, ensuring strict control in this way and interdependence between the departments of the company (PP, QM and WM).

3. Entry of Nonconformities: Recording of Defects found in inspections and generations of Quality reports (nonconformities) related to any anomaly presented. These can be recorded with the help of the system making use of the predefined codes within the catalogs. In this way the entry of nonconformities must always have a cause assigned, a type of defect and a corrective action, thus leaving a complete report of what happened in the

process, and this data could be used for further analysis seeking to improve the production processes. In addition, there is the option of generating a printed document or sending it via e-mail to the Quality Supervisor or Shift Manager.

4. Graphics and Statistics. For the decision making and the continuous improvement in the company it will be possible to use historical data of the inspected characteristics, whose results, among other things, could be visualized later in the form of statistics and graphs; according to a time span and products selected, all of this can be done in an easy, intuitive and fast way.

5. Traceability: It has been considerably improved, since with the current system it is possible to access all the information stored during the stages of production and quality control, this in order to support all the processes of the company, have a control of the practices that are carried out at each point of the value chain, and to rapidly identify and solve any problem that may arise.

Additionally, a future job is the extension of Quality Management to equipment calibration in order to monitor the accuracy of the calibration devices, in this case the QM module will be integrated with the PM (plant maintenance) module. Also, it is convenient the constant training to the employees as new updates of the system are available and new functionalities are added to the system.

Finally, I value this first work experience in a very positive way, which allowed me to know several aspects of the business world and put into practice concepts of production and quality learned in my academic career. Thanks to this project I was able to deepen the functioning and importance of Quality Management and ERP systems in the companies.

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# Appendix 1

This part deals with the O-rings definition and information about the properties of the raw materials, generally, rubber elastomer compounds are used. Additionally, it illustrates typical O-ring applications, fundamentals of static and dynamic seal design and an FMECA analysis of O-rings.

## O-Rings

An O-ring is a torus, or doughnut-shaped ring, see Figure 36, generally molded from an elastomer. O-rings are also made from other thermoplastic materials and in some cases metals are employed as well. Those O-rings are used primarily for sealing, but can be also used as light-duty, mechanical drive belts, among others. This project, however, deals entirely with elastomeric O-rings.

An O-ring seal is used to prevent the loss of a fluid or gas. The seal assembly consists of an elastomer O-ring and a gland. The gland usually cut into metal or another rigid material contains and supports the O-ring (see Figure 38). The combination of these two elements; O-ring and gland constitute the classic O-ring seal assembly shown in Figure 38. (Parker Hannifin Corporation, 2018)

*Figure 36. Basic O-Ring (Parker Hannifin Corporation, 2018)*

**Advantages of O-Rings**

• They seal over a wide range of pressure, temperature and tolerance.

• Ease of service, no smearing or retightening.

• No critical torque on tightening, therefore unlikely to cause structural damage.

• O-rings normally require very little room and are light in weight.

• In many cases an O-ring can be reused, an advantage over non-elastic flat seals and crush-type gaskets.

• The duration of life in the correct application corresponds to the normal aging period of the O-ring material.

• O-ring failure is normally gradual and easily identified.

• Where differing amounts of compression effect the seal function (as with flat gaskets), an O-ring is not affected because metal to metal contact is generally allowed for.

• They are cost-effective (Parker Hannifin Corporation, 2018).

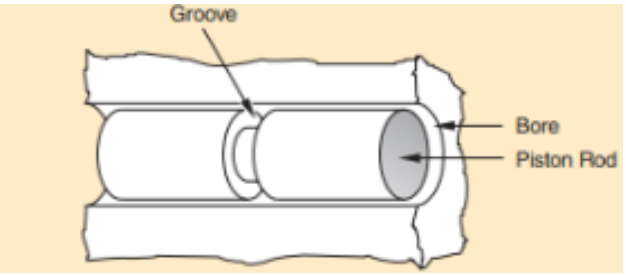


*Figure 38. Basic gland (Parker Hannifin Corporation, 2018).*

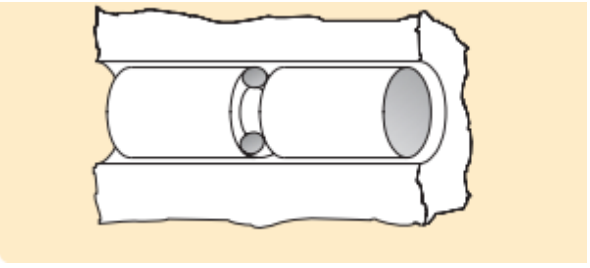

*Figure 38. Gland and O-Ring seal (Parker Hannifin Corporation, 2018).*

**How O-Rings work**

All robust seals are characterized by the absence of any pathway by which fluid or gas might escape. Detail differences exist in how zero clearance is obtained welding, brazing, soldering, ground fits or lapped finishes or the yielding of a softer material wholly or partially confined between two harder and stiffer members of the assembly. The O-ring seal falls in the latter class.

The rubber seal should be considered as essentially an incompressible, viscous fluid having a very high surface tension. Whether by mechanical pressure from the surrounding structure or by pressure transmitted through hydraulic fluid, this extremely viscous fluid is forced to flow within the gland to produce “zero clearance” or block to the flow of the less viscous fluid being sealed. The rubber absorbs the stack-up of tolerances of the unit and its internal memory maintains the sealed condition. Left part of the (Parker Hannifin Corporation, 2018) illustrates the O-ring as installed, before the application of pressure. Note that the O-ring is mechanically squeezed out of round between the outer and inner members to close the fluid passage. The seal material under mechanical pressure extrudes into the microfine grooves of the gland. The right side of Figure 40 illustrates the application of fluid pressure on the O-ring. Note that the O-ring has been forced to flow up to, but not into, the narrow gap between the mating surfaces and in so doing, has gained greater area and force of sealing contact. Left side of Figure 40 shows the O-ring at its pressure limit with a small portion of the seal material entering the narrow gap between inner and outer members of the gland. Finally, the right side of Figure 40 illustrates the result of further increasing pressure and the resulting extrusion failure. The surface tension of the elastomer is no longer enough to resist flow and the material extrudes (flows) into the open passage or clearance gap (Parker Hannifin Corporation, 2018).

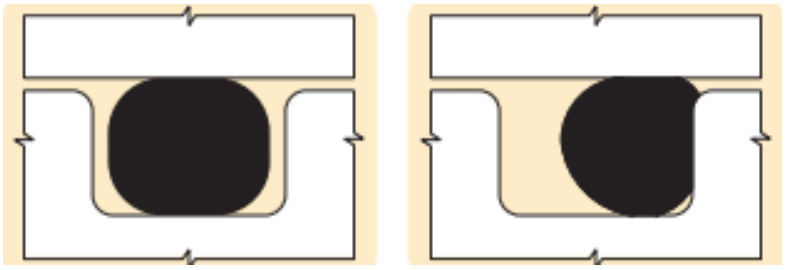

*Figure 40. O-Ring installed and O-ring under pressure (Parker Hannifin Corporation, 2018)*

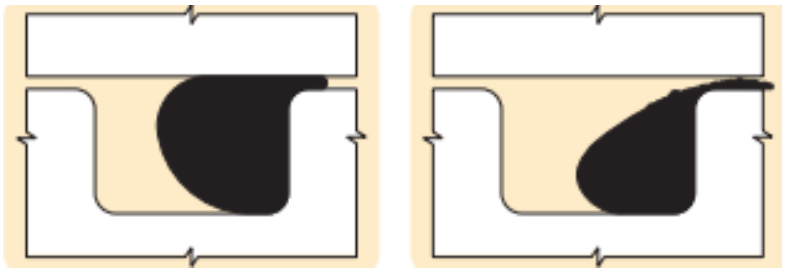

*Figure 40. O-Ring extruded and O-ring failure (Parker Hannifin Corporation, 2018).*

**Scope of O-Ring Use**

**Static Seals**: In a truly static seal, the mating gland parts are not subject to relative movement (except for small thermal expansion or separation by fluid pressure), as contrasted from seals in which one of the gland parts has movement relative to the other. Examples of static seals are: a seal under a bolt head or rivet, a seal at a pipe or tubing connection, a seal under a cover plate, plug or similar arrangement or, in general, the equivalent of a flat gasket. Figure 6 illustrates a typical static seal (Parker Hannifin Corporation, 2018).

**Dynamic seals**

**Reciprocating Seals:** In a reciprocating seal, there is relative reciprocating motion (along the shaft axis) between the inner and outer elements. This motion tends to slide or roll the O-ring, or sealing surface at the O-ring, back and forth with the reciprocal motion. Examples of a reciprocating seal would be a piston in a cylinder, a plunger entering a chamber, and a hydraulic actuator with the piston rod anchored. Figure 7 illustrates a typical reciprocating seal.

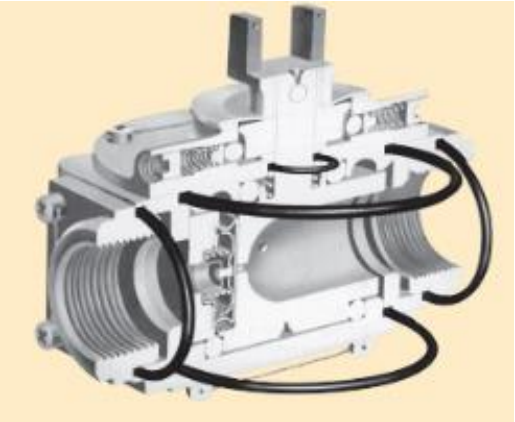

*Figure 42. Static seal application (Parker Hannifin Corporation, 2018).*

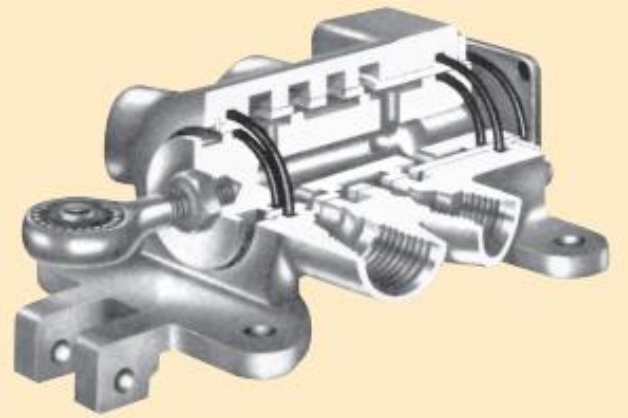

*Figure 42.Reciprocating seal application (Parker Hannifin Corporation, 2018).*

**Oscillating Seals**: In an oscillating seal, the inner or outer member of the seal assembly moves in an arc (around the shaft axis) relative to the other member. This motion tends to rotate one or the other member in relation to the O-ring. Where the arc of motion exceeds 360°, as in multiple turns to operate a valve handle, the return arc in the opposite direction distinguishes the oscillating seal from a rotary seal. Except for very special cases, any longitudinal motion (as caused by a spiral thread) involved in what is classed as an oscillating seal is not important. An example of an oscillating seal is an O-ring seal for a faucet valve stem. See Figure 8.

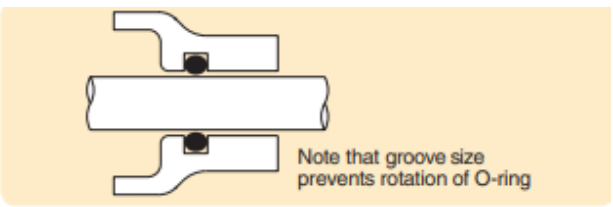


*Figure 44. Rotary seal (Parker Hannifin Corporation, 2018).*

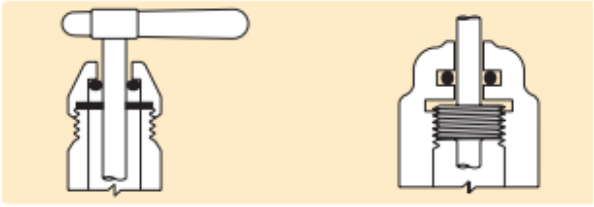

*Figure 8. Oscillating seal (Parker Hannifin Corporation, 2018).*

**Rotary Seals:** In a rotary seal, either the inner or outer member of the sealing elements turn (around the shaft axis) in one direction only. This applies when rotation is reversible but does not allow for starting and stopping after brief arcs of motion, which is classed as an oscillating seal. Examples of a rotary seal include sealing a motor or engine shaft, or a wheel on a fixed axle. See Figure 9.

## FMECA

In the company of study it is very important that the O-rings which are produced fulfil their main function of sealing so the severity corresponding to the effects of failure is always the maximum, however, each of the causes related to the failures differs in their occurrence. The detection of these should be ensured in all cases to meet the objectives of the company, for this purpose, the company has a space for advanced tests with different methodologies which may vary depending on the O-ring or material being tested.

As far as the causes related to the highest RPN, the most frequent failure is spiral damage, since any variation in friction can cause the surface of the O-ring to slide while other parts roll, on the other hand this is easily identifiable since variations in shape and size are visible. On its turn, abrasion is the cause of the effect of failure with the highest RPN, although it has an occurrence of 3 which could be considered medium-low, when it is combined with a low detection, it increases the RPN requiring a special attention. In general, the majority of causes are related to variations in the environment and variables directly related to the mixture of the material used in the production, see Figure 45.

| Description of failure | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Function | Failure Mode | Effect of failure | Severity | Failure Cause or Mecanism | Ocurrency | Detection of failure | Detection | RPN | Risk reducing measures |
| seal | Leakage | 1.Flat surfaces on the O-ring sides compressed | 10 | COMPRESSION SET<br>•The material used has poor compression set resistance or limited resistance to heat.<br>•The O-Ring is swelling in the groove due to fluid incompatibility or it has too much squeeze in the groove | 1 | Manufacture prototypes and test them before defining the final product. | 2 | 20 | •Use: higher quality or lower compression material.<br>•Double check the groove dimensions for proper squeeze and the compatibility of the O-Ring material to the fluid |
| | | 2.O- ring flattened surface on the side subjected to the movement. | 10 | ABRASION<br>•The metal surfaces are either too rough and abrasive to the O-Ring or too smooth, not allowing proper lubrication.<br>•the fluid system is contaminated with abrasive particles<br>•Operating temperatures are too high for the material. | 3 | | 4 | 120 | •Arrange for better lubrication<br>•Use a material suitable for higher temperatures or a more abrasion resistant.<br>•Eliminate any source of contamination |
| | | 3.Short nicks, scratches or peeling on the O-ring surface | 10 | INSTALLATION<br>•The use of sharp edged tools or existence of sharp corners on the O-Ring groove.<br>•O-Ring was not lubricated<br>•O-Ring was twisted or trapped between metal surfaces | 1 | | 3 | 30 | •Cover all threads with masking tape<br>•Break all sharp edges<br>•Lubricate O-Ring during installation<br>•Check correct sized O-Ring |
| | | 4.Ruptures, crater-like pores and small slits within the body of the O-Ring. | 10 | EXPLOSIVE DECOMPRESSION<br>•Gases permeating the O-Ring material and rapid decompression of those gases.<br>•Micro-explosions occuring as decompression takes place. | 1 | | 1 | 10 | •Slow system cycles down<br>•Increase time for decompression<br>•Replace with a harder material<br>•Select a smaller O-Ring cross section |
| | | 5.The O-Ring appears have been twisted or to have rolled in its groove. | 10 | SPIRAL DAMAGE<br>•Side loads causing excessive clearance<br>•Misfit components<br>•Material too soft or no suitable lubrication<br>•Moving speed too slow or surfaces are uneven | 5 | | 1 | 50 | •Decrease the clearances between components<br>•Check for roundness of fitting parts<br>•Provide lubrication or add a back-up ring<br>•Select a harder material |
| | | 6.cracked, hardened and pitted areas can be seen throughout the O-Ring. | 10 | HEAT HARDENING AND OXIDATION<br>•Temperatures higher than recommended for the material<br>•Elastomers becoming dry and the material is evaporating<br>•Oxidation | 2 | | 1 | 20 | •Lower the operating temperatures of the system<br>•Use O-Rings rated for higher temperatures |
| | | 7.Ridges and nibbles along either the inner or outer diameter of the O-Ring. | 10 | EXTRUSION<br>•Excessive system pressures<br>•Too much clearance between mating parts<br>•Material too soft<br>•O-Ring body too large for the groove<br>•Attack by system fluid | 2 | | 1 | 20 | •Decrease or regulate system pressure<br>•Refit mating parts, machining back to proper, concentric fit<br>•Select a harder material<br>•Determine correct O-Ring cross section size<br>•Add back-up rings |
| | | 8.Reduced physical properties | 10 | •The material absorbs system fluids causing swelling<br>•An obvious chemical incompatibility | 1 | | 3 | 30 | •Test fluid compatibility and consult a chemical compatibility chart to determine suitable material. |
| | | 9.Weathering or ozone cracking | 10 | •Attack of the polymer chains, destruction of the material causing cracking | 1 | | 1 | 10 | •Select a material that resists ozone exposure |

*Figure 45. FMECA O-Rings (Own elaboration).*

**Elastomers**

The basic core polymer of an elastomeric compound is called a rubber, it is produced from either natural gum on commercial rubber plantations or manufactured synthetically by the chemical industry.

Modern elastomeric sealing compounds generally contain 50 to 60% base polymer and are often described simply as “rubber.” The balance of an elastomer compound consists of various fillers, vulcanizing agents, accelerators, aging retardants and other chemical additives which modify and improve the basic physical properties of the base polymer to meet the particular requirements of a specific application.

Elastomers used in producing seals, and particularly those used in O-rings, will usually provide reliability, leak free function if fundamental design requirements are observed.

Next, the most used elastomers in the company are presented and a comparison between these is made in Table 12 in terms of temperature resistance.

- **NBR: Nitrile Rubber NBR**

Nitrile rubber (NBR) is the general term for acrylonitrile butadiene copolymer. The acrylonitrile content of nitrile sealing compounds varies considerably (18% to 50%) and influences the physical properties of the finished material. The higher the acrylonitrile content, the better the resistance to oil and fuel. At the same time, elasticity and resistance to compression set is adversely affected. In view of these opposing realities, a compromise is often drawn, and a medium acrylonitrile content selected. NBR has good mechanical properties when compared with other elastomers and high wear resistance. NBR is not resistant to weathering and ozone (Parker Hannifin Corporation, 2018).

Chemical resistance:

•Aliphatic hydrocarbons (propane, butane, petroleum oil, mineral oil and grease, diesel fuel, fuel oils) vegetable and mineral oils and greases.
•HFA, HFB and HFC hydraulic fluids.
•Dilute acids, alkali and salt solutions at low temperatures.

Not compatible with:

•Fuels of high aromatic content or aromatic hydrocarbons (benzene).
•Chlorinated hydrocarbons (trichloroethylene).
•Polar solvents (ketone, acetone, acetic acid, ethylene-ester).
•Strong acids.
•Ozone, weather and atmospheric aging.

- **FKM Fluoroelastomer**

Fluorocarbon (FKM) has extremely good resistance to high temperatures, ozone, oxygen, mineral oil, synthetic hydraulic fluids, fuels, aromatics and many organic solvents and chemicals. Gas permeability is very low and similar to that of butyl rubber. Special FKM compounds exhibit an improved resistance to acids and fuels.

Chemical resistance:

•Mineral oil and grease, ASTM (American Society for Testing and Materials) oil No. 1, and IRM 902 and IRM 903 oils.
•Non-flammable hydraulic fluids (HFD).
•Silicone and Mineral/vegetable oil and grease.
•Aromatic and Aliphatic hydrocarbons (benzene, toluene, butane, propane, natural gas).
•Chlorinated hydrocarbons (trichloroethylene and carbon tetrachloride).
•Gasoline (including high alcohol content).
•High vacuum.
•Very good ozone, weather and aging resistance.

Not compatible with:

•Glycol based brake fluids.
•Ammonia gas, amines, alkalis.
•Superheated steam.
•Low molecular weight organic acids (formic and acetic acids).

- **ETHYLENE-PROPYLENE (EPDM)**

ethylene-propylene-diene rubber (EPDM) terpolymer is a particularly useful when sealing phosphate-ester hydraulic fluids and in brake systems that use fluids having a glycol base.

Chemical resistance

•Hot water and steam up to 149°C (300°F) with special compounds up to 260°C (500°F).
•Glycol based brake fluids (Dot 3 & 4) and silicone-basaed brake fluids (Dot 5) up to 149°C (300°F).
•Many organic and inorganic acids.
•Cleaning agents, sodium and potassium alkalis.
•Phosphate-ester based hydraulic fluids (HFD-R).
•Silicone oil and grease.
•Many polar solvents (alcohols, ketones, esters).
•Ozone, aging and weather resistant.

Not compatible with:

•Mineral oil products (oils, greases and fuels).

- **Silicone Rubber (Q, MQ, VMQ, PVMQ)**

  Silicones have good ozone and weather resistance as well as good insulating and physiologically neutral properties. However, silicone elastomers as a group, have relatively low tensile strength, poor tear strength and little wear resistance.

  Chemical resistance

  •Animal and vegetable oil and grease.
  •High molecular weight chlorinated aromatic hydrocarbons (including flame-resistant insulators, and coolant for transformers).
  •Moderate water resistance.
  •Diluted salt solutions.
  •Ozone, aging and weather.

  Not compatible with:

  •Acids and alkalis.
  •Low molecular weight chlorinated hydrocarbons (trichloroethylene).
  •Hydrocarbon based fuels.
  •Aromatic hydrocarbons (benzene, toluene).
  •Low molecular weight silicone oils.

| *Elastomer material* | **ASTM Designation** | **Working temperature** | |
|---|---|---|---|
| | | Min °C | Max °C |
| *Nitrile Rubber* | NBR | -34 | 100 |
| *Fluorocarbon* | FKM | -26 | 200 |
| *Silicone* | MQ, PMQ, VMQ, PVMQ | -54 | 150 |
| *Ethylene- propylene* | EPDM | -57 | 150 |

*Table 12. Temperature resistance rubber (Own elaboration)*

# Appendix 2

This part deals with aspects of rubber processing, some important manufacturing processes, such as Injection, Compression molding, Cryogenic deflashing, Barrel grinding, Heat-treatment and Vulcanization and illustrated explanations are also given.

# Definition of the manufacturing processes

## 1. Injection

Injection Rubber Moulding is an ideal process to produce high-volume rubber forming parts (O-rings). This process is suitable for large quantities of small and medium sized parts with complex inserts and closed dimensional tolerances. With injection moulding, the prepared mix of elastomer is poured into the hopper. Then the material goes into the screw which is heated to melt the rubber. Finally, an exact amount of rubber is injected into a closed cavity (the mould) formed by two halves of a steel die which is preheated to rubber curing or vulcanized temperature. Because the injection action is high pressure and fast, the die remains static with high pressure, thus forming the "formed part cavity", and since the die is "at temperature" the curing process is accelerated, see Figure 46.

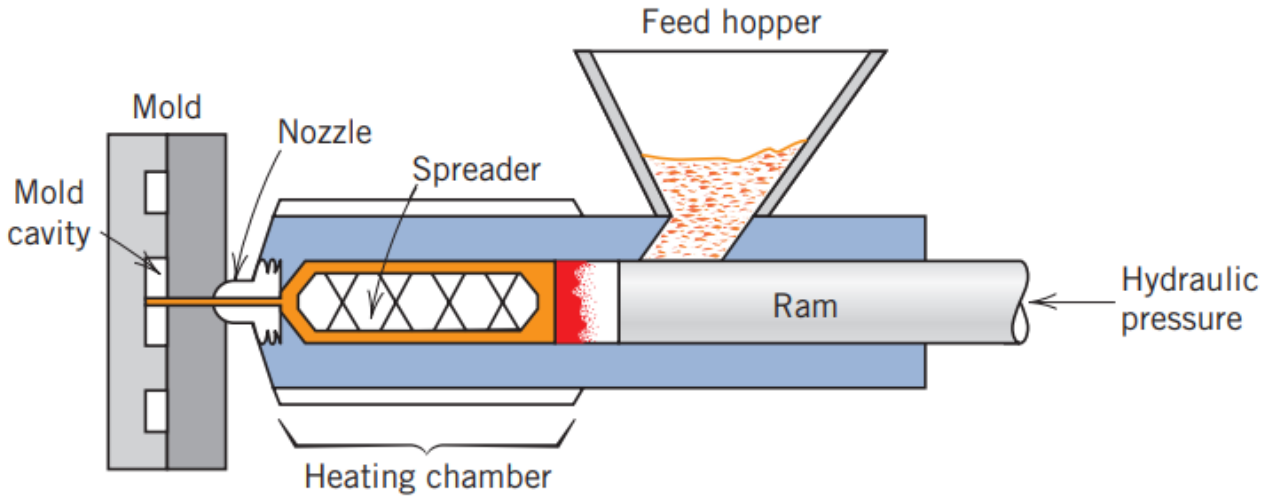


*Figure 46.Schematic diagram of an injection molding process (W. BILLMEYER, 1984).*

## 2. Compression moulding

The Rubber Compression Moulding process begins with a solid rubber part (in this case a sheet of rubber). That is placed in one half of a preheated cavity (the fixed one) of a double cavity mould. Both halves of the mould are joined together; pressure is applied so that the compound in the mould is compressed to fill the mould cavity and form the part (O-ring). Additional heat applied to the mould forces the rubber to soften further and disperse to all parts of the mould cavity and then heats the rubber to its vulcanization temperature see Figure 47. Schematic diagram of a compression molding process.

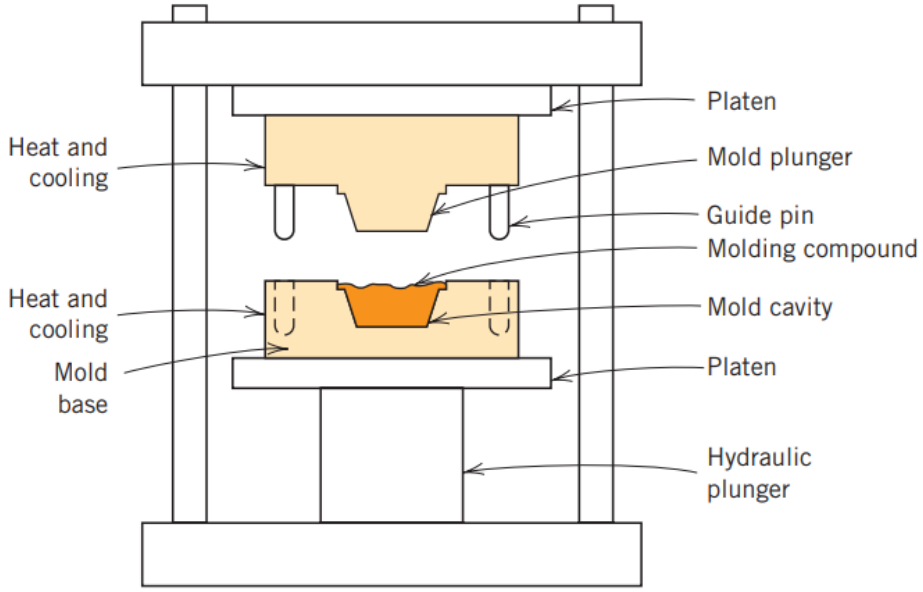


*Figure 47. Schematic diagram of a compression molding process (W. BILLMEYER, 1984).*

### 3. Extrusion process

It begins with a rubber compound being fed into an extruder. The material is fed into a feed hopper, which takes the material and feeds it into a flute in a revolving screw. The screw will begin to carry the rubber forward into the die, with an increase in pressure and temperature occurring as the material gets closer to the die itself see Figure 48.Schematic diagram of an extruder .

Once the material reaches the die, the built-up pressure forces the material through the openings, where it will consequently swell to various degrees based on the material compound and hardness. Because of this tendency toward swelling, many extruded parts require plus or minus tolerances on their cross sections (Timco, 2019).

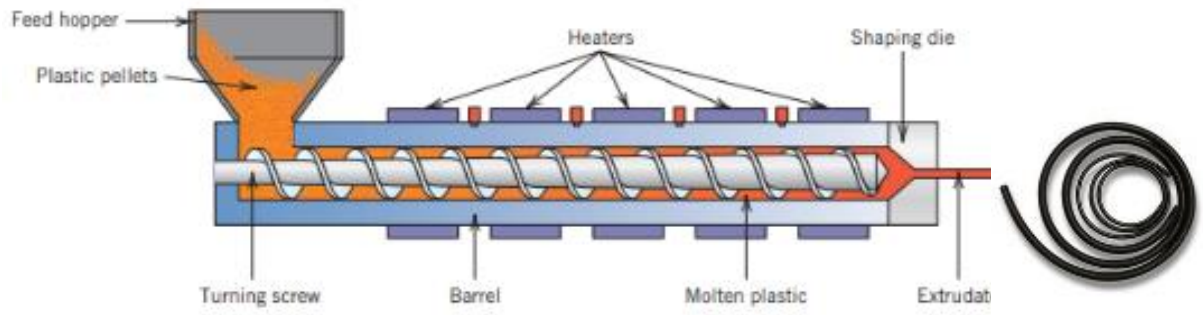


*Figure 48.Schematic diagram of an extruder (W. BILLMEYER, 1984).*

## 4. Finishing processes

- **Cryogenic deflashing.**

  In this process the rubber and plastic parts are placed in a stainless-steel parts basket, which rotates in a blast chamber evenly exposing all parts to the blast media. The chamber is insulated with rigid polyurethane foam to ensure stable temperatures.

  Liquid nitrogen lowers the interior temperature, freezing the flashing to make it brittle. Use of high-purity, moisture-free nitrogen eliminated the need for a dryer and prevents part contamination due to moisture.

  The high-speed impeller shoots polycarbonate plastic pellets into the chamber. Traveling at high speeds, these pellets cleanly trim off the inner and outer diameter flashing of parts in one operation. Blast media and flash can be separated and recovered for reuse (inc, s.f.).

- **Vulcanization (Heat-treatment)**

  It can be defined as a process that increases the retractile force and reduces the amount of permanent deformation remaining after removal of the deforming force. Thus, vulcanization increases elasticity while it decreases plasticity. It is generally accomplished by the formation of a crosslinked molecular network (Mark, Erman , & Roland, 2013).

Vulcanized O-rings are made from extruded cord stock that has been cut and bonded together, as opposed to moulded O-rings; those that have been compression or injection moulded as one piece. Vulcanized O-rings can be made from a range of elastomers and in virtually any size.

O-ring cord is extruded to make a vulcanized O-ring, continuous length cord is cut to length and then joined together. A bonding agent is applied to the ends which are then joined together in a mould at a high temperature for a specified period. This process forms the molecular bond necessary to create a strong joint (DeSpain, 2016).

# Appendix 3

Since the company's critical quality inspection is the one performed during the production process, this section is dedicated to defining the most important objects or master records used in SAP for production planning.

## SAP - Master data objects in production planning

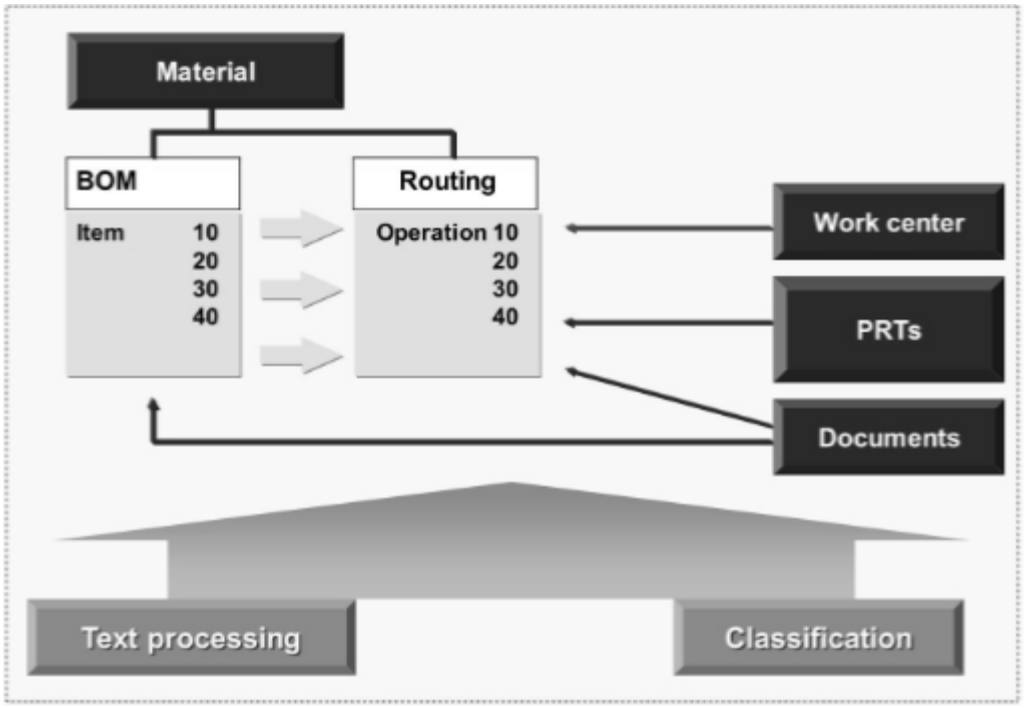


*Figure 49. Master data for production.*

SAP works based on different transactions and through these, the configuration of the data is necessary. The configuration is the foundation on which most of the master data is built. Master data is often referred to as slowly changing data because the data of a particular object does not change all the time. Although, it can change several times a year. Master data maintenance in SAP ERP is a centralized function. The objective is to store data once and avoid replicating it. For production planning, SAP ERP uses the following master data, which is also shown in Figure 49.

- Material masters
- Bills of material (BOM)
- Work centers
- Task lists or routings

Business users are limited to creating, changing, or displaying data based on their role within the organization. During implementation, each company must determine how the Product Lifecycle Management (PLM) process in SAP ERP integrates with the company's specific business processes. As organizations change, the master data must also change to support the business. Companies need to model this properly within the SAP ERP environment.

## 1. Material master

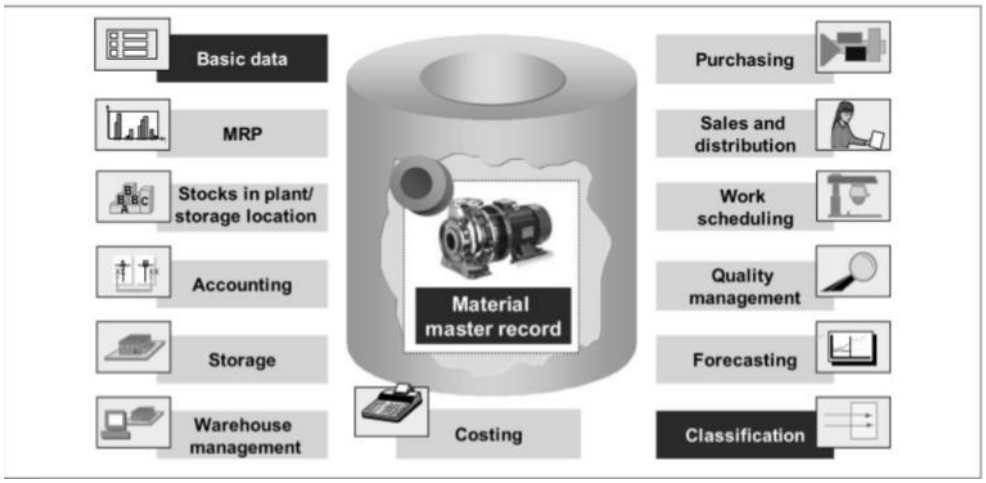


*Figure 50. Material master in SAP.*

The material master contains information about the materials that a company constructs, procures, manufactures, stores, and sells. The information is stored in a database and the material master record integrates data from different areas of a company.

For the company, the material master record is the central source of data on materials. The various SAP applications use the material master. The material can be a finished product, a semi-finished product such as a subassembly, or a raw material. Depending on the industrial sector in which the material is, certain views can be chosen and defined by default.

To create a material master record a unique identification code must be enter. Then the views that will contain all the information about the material are created, these views organize the information and each of them corresponds to the different areas To create a material master record a unique identification code must be enter. Then the views that will contain all the information about the material are created, these views organize the information and each of them corresponds to the different areas Figure 50. Material master in SAP., for instance Accounting, MRP (material resource and planning), Quality Management, Warehouse management, Forecasting, etc.

## 2. Bill of materials

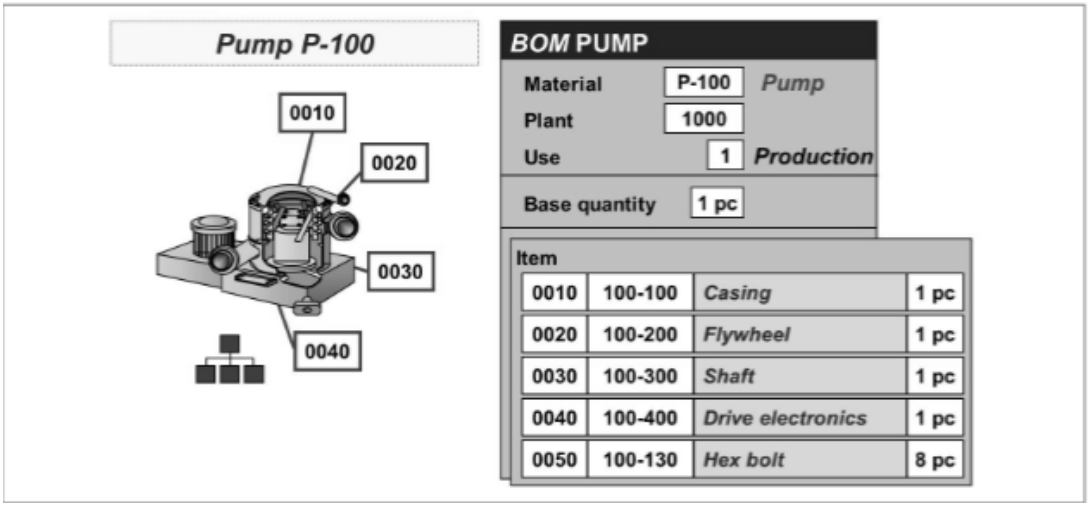


*Figure 17. BOM in SAP*

A bill of material (BOM) is a complete, formally structured list of the components that make up a product or assembly. The list contains a description and object number for each component, together with the quantity and unit of measure. BOMs can exist at plant and/or client level. The header and components contain validity dates that may be affected when engineering change management is used. A BOM is integrated with the material master and can be used along with the routing to schedule a more precise usage point. This integrated BOM is used in material requirements planning, production, procurement, and product costing.

A BOM consists of a header material and BOM items (components). The base quantity in the header material specifies the finished production quantity on which the component quantities are based. BOM items indicate individual parts and assemblies that are identified by their material numbers.

BOMs are single level. A BOM item can also contain components so that multi-level production can be described by a single-level BOM from the finished product, assemblies, or assemblies of the assemblies, and so on. In addition to stock items, which flow into the finished product, a BOM can also contain documents or text items.

### 3. Work center

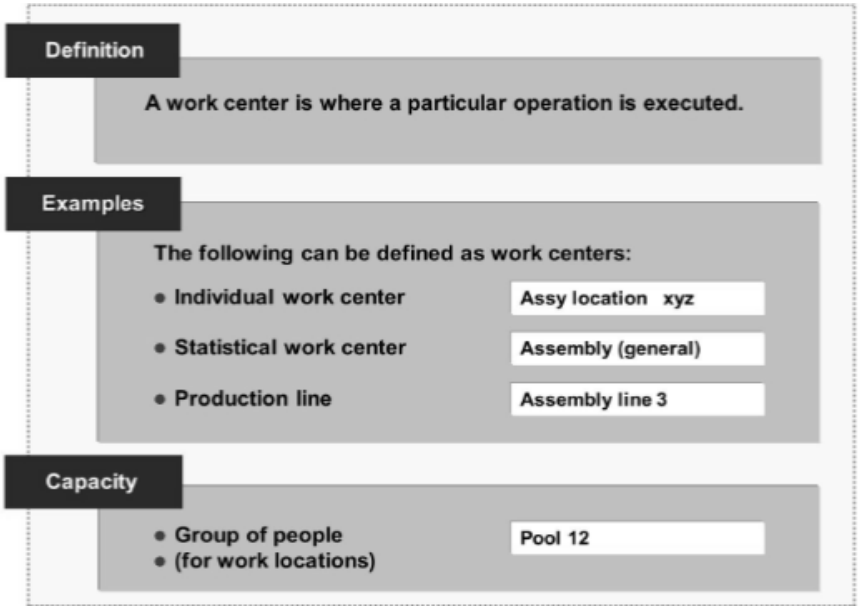


*Figure 18. Workcenters in SAP.*

A work center is a location that defines when and where production resources are required according to order requirements. In different companies, work centers are also called machine, labor, or capacity centers.

Work centers can be defined as individual or multiple machines, people, tools, and so on. Work centers are used in routings (standard networks, inspection plans and maintenance task lists) and in orders. Work centers contain standard values and these represent the times to be measured when the work center is used in a task list, for example, machine time, labor time, and setup time. These times are grouped together using a standard value key. This key also determines which standard values are displayed for the work center.

A major function of work centers is to support capacity planning and scheduling. To plan these functions, the available capacity must be maintained in the work center. Capacity refers to the ability of a work center to perform a specific task. Each work center can have one or more capacity headers to describe any limit to the work it can perform with reference to time.

## 4. Routings

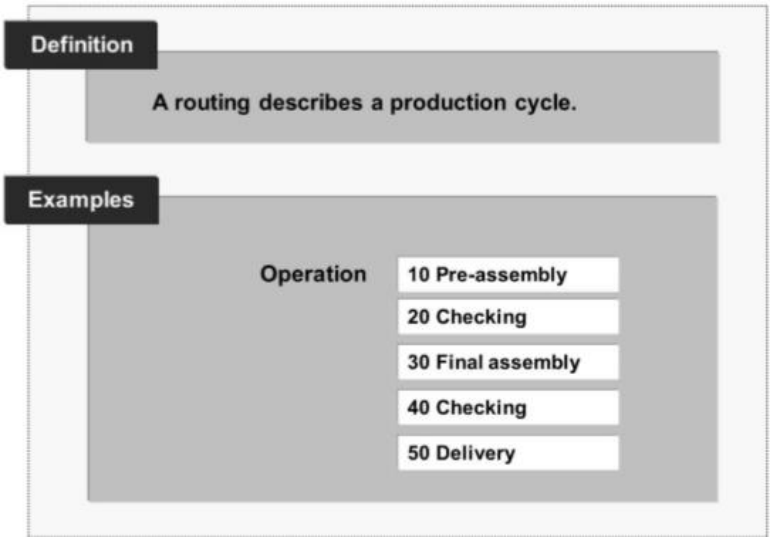


*Figure 19. Routings in SAP.*

A routing is made up of operations to which work centers are assigned. The details of the operations contain the standard values or times of production at a particular work center. They also contain information about each work center where the work is to be performed. The SAP ERP application stores routings in groups that can be assigned internally or externally. A group can contain many routings, each of which is distinguished by a different group counter. Other important assignments in the routing include the material components from the BOM and any production resources/tools (PRTs) that are required for production. PRTs are items (such as tools and fixtures) that are needed for production, but are not consumed. Inspection characteristics can be also assigned to the operations in the routing if a quality inspection is to be performed during an operation

A routing shows operations in a sequence and acts as a template for production orders. Each step defines the work center in which specific work is accomplished.

The planned time for each operation is stored in the routing as a standard value. The standard values are the bases for performing the following tasks:

- Lead-time scheduling
- Product costing
- Capacity planning

A routing is independent of a production order and is used to create an order. When an order for a material is created, the operations and information from the routing assigned to the material are copied to the order (SAP, 2013).