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DIPARTIMENTO DI TECNICA E GESTIONE DEI SISTEMI INDUSTRIALI

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"Serial effect on small numbers in special purpose machinery manufacturing"

Relatore:

CHIAR.MO PROF. Roberto Panizzolo

Laureando:

Michele Di Pieri

Correlatori:

ING. Andrea Gatto

DOTT. PROF. Hans Gut

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A Giorgio e Rosanna

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Summary

This thesis, developed in De Pretto Industrie in Schio, is a study over the impact of costs on a production change of the RIKT compressor, from a single production to a small series production. Through a detailed analysis of the departments involved in this compressor's fabrication, the saving that can be obtained with such a kind of change has been defined.

Introduction

This thesis is a study about the production of a RIKT (radial isothermal compressor) in the companies De Pretto Industrie srl and MAN Diesel & Turbo.
De Pretto Industrie (DPI) is a company that produces components for turbomachinery (like compressors and turbines), or the complete machine, too. The most important client for De Pretto is MAN Diesel & Turbo, the division of MAN group related with turbomachinery. For the RIKT compressor, from DPI point of view MAN is supplier for some parts (the rotor for example), and also final client. Moreover, MAN takes the orders from other clients, to which the compressor will be sold, and these ones are the final clients of the product.

This small introduction about the companies is required to understand the relations between them, and above all, the reason why this work has been done. In fact, the focus of the thesis will be the possibility to change the way of production of the RIKT, from the actual "in order" production to a new, small series production, not only in DPI, but also in MAN, as producer of some parts needed for the compressor. As the location of MAN Diesel & Turbo is in Zürich, the thesis is made in cooperation with Kathrin Binder, student at the HTWG – Hochschule Konstanz Technik, Wirtshaft und Gestaltung (Konstanz University of Applied Science), that will follow the part related to MAN. This thesis, instead, is mostly focused on De Pretto.

The change in production is required from the market: although the RIKT is a standard product, and is produced since early 2000s, its demand is still high; but, at the moment, the orders received by De Pretto are not so much. The orders of DPI depend mostly from the orders taken by MAN (as it is the Swiss company that follows the contacts with the clients); and they have problems in taking orders of batches of compressors, above all for higher costs than the competitors. So, to understand how much the final cost could be reduced with a small series production instead of the "in order" production, the two companies decided this work to be developed by students in a master thesis.

The objective is to find the possible discount applicable to clients to be more competitive in the market, for various sizes of batch. In particular, the work will study what happens with batches going from 2 to 10 compressors, and which will be the differences between the actual single production and the series production. The analysis will involve all the departments where any saving can be possible: engineering, project management, purchasing, production, quality. Then, the influence of the warehouse will be calculated and the presence of some constraints in the companies will be checked.

The thesis will start with an historical background of De Pretto Industrie, from its foundation to the present. Then, there will be an overview about the actual situation of the company: what it is doing, which are its objectives, how its actual layout is.
After this introductive part, there will be an analysis over the state of the art of production by now, with the differences between in order production and series production. During this work, it has been discovered that no literature is present treating the passage from in order production to small series production: normally the batches are of hundreds or thousands of parts, not of 5 or 10. Moreover, this study deals with very big parts, which require a lot of hours to be produced, involve a lot of money to be invested in, and a lot of space where to store parts. So, it seemed that this work could be something completely new.
Going back to the thesis, afterwards there will be the presentation of the RIKT compressor: its components, an example of a bill of materials, the work cycles required for the production.
Then, there will be the central part of the work, that is the study of the costs and possible savings in the two companies, divided into two parts: a first one, where the actual state of the RIKT production is illustrated, presenting every department involved in the production with its costs; and a second one, in which every saving is explained in detail. The final chapter analyzes the constraints present in the companies, including warehouse; at the end, the final result (i.e. the discount applicable to clients) can be found.

CHAPTER 1

Historical background of De Pretto Industrie

1.1 From “Fonderia De Pretto” to “MAN Turbomacchine Italia”

The company “De Pretto” was born in Schio in 1885, from initiative of the engineer Silvio De Pretto, who, encouraged by the textile industrial Alessandro Rossi, started a mechanical foundry in an old mill outside the city, with 8 employees.

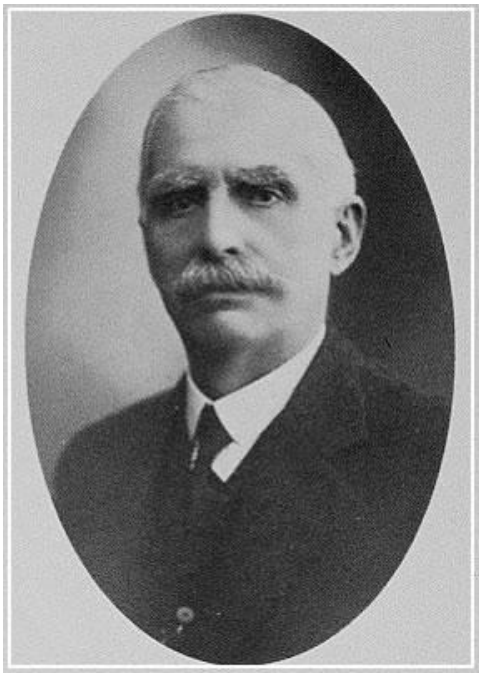


Fig. 1.1: eng. Silvio De Pretto

At the beginning, the “Fonderia stabilimento meccanico Ing. Silvio De Pretto & C.” repaired looms, but soon it started producing hydraulic turbines and machines for paper mills. During First World War, the city of Schio was too close to the frontier lines, so the inhabitants of the valley were forced to move to other zones of Italy. Eng. De Pretto had to move his firm in the zone of Brescia, from where he could come back only after 1920, when happened the first joint venture with a Suisse company, the “Escher Wyss”; this permitted to the Zürich company to enter the Italian market and to the newborn “De Pretto – Escher Wyss” to access to new technologies and to start the production of the first steam turbines.

Next decades were characterized by the definitive confirmation of the company in the hydraulic sector, while new interesting perspectives were opened also in the production of machines and components for paper industry.

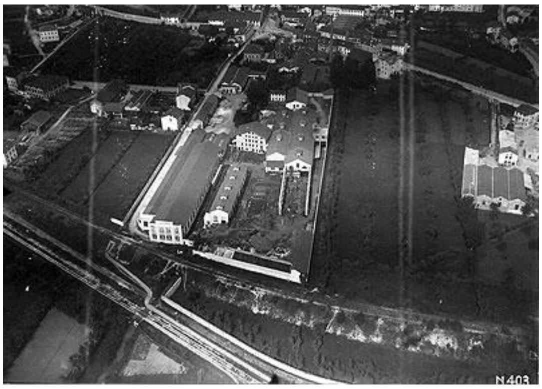


Fig. 1.2: aerial view of the company in the 30s

In 1969, the Escher Wyss Group, which “De Pretto – Escher Wyss” was part of, was bought by the Suisse company Sulzer, from Winterthur, whit whom from the very beginning the company worked in very close synergy, especially regarding technological research and professional and managerial formation at every level. During the 80s, the company obtained a certain acknowledgment for its activity in the research field; in fact, took part in various projects related to the research about nuclear fusion. Apart from various vacuum chambers (University of Padua RFX, Max Plank Institute in Germany, Wisconsin University vacuum chamber), the most important results were the ones related to the participation to JET project, giving a contribution for the whole mechanical part (JET, Joint European Torus, is still now the only nuclear reactor which can generate energy for some minutes), and to the ESA Observatory in Chile, whose mechanical components were all produced in Schio. At the end of the 80s, “De Pretto – Escher Wyss” had more than 1000 employees.

The 90s opened for “De Pretto – Escher Wyss” with many news. In 1993 participated, joint with another metal mechanical company, the “F.lli Vicentini” from Cavazzale (Vicenza), to the creation of a new society, the VDP (“Vicentini De Pretto”), which reunited the activity of foundry of both.
In 1994 was found a new society, the “Voith Sulzer Paper Technology Italia”, intended to manage independently the activity of the paper sector which before were headed by “De Pretto – Escher Wyss”.
The transformations happened at the beginning of the 90s and the strategic decision to concentrate only to the high added value components, with the subsequent strong productive decentralization and personnel reduction, permitted the company to maintain its competitiveness in the market. Between the 1990 and the 1995, the personnel were reduced from 620 to 430 employees.

Until 1999, “De Pretto – Escher Wyss” concentrated on the hydraulic sector, directly managing design, production, assembly, testing, and after sales service of hydraulic turbines (Pelton, Francis and axial ones like the Kaplan), pump turbines, steam turbines for thermoelectric power plants, axial and radials turbo compressors.
In 1997 was sold the NIPCO technology related to machines for paper mills.
In 1999, after the sale of “Sulzer Hydro” to the Austrian multinational company VA Tech Escher Wyss, the hydraulic sector was separated from De Pretto. In the same year, “De Pretto – Escher Wyss” became part of the “Sulzer Turbo” group, and his focus became the production of axial and radial turbo compressors and of steam turbines under ABB patent.

In 2000, the multinational company “MAN Turbomaschinen Ag Ghh BORSIG” bought from Sulzer its turbomachine division (Sulzer Turbo), creating the new group “MAN Turbo” in 2001. “De Pretto – Escher Wyss” entered this group under the name of “MAN Turbomacchine Srl De Pretto”, soon changed in “MAN Turbo De Pretto” (MTM-I), continuing operating on the same machine’s typology.

Fig 1.3: aerial view of the company today

“MAN Turbo” was just one of the operational branches of the multinational company MAN, active in many markets. The following figures show with data updated to 2012 that the core business of MAN is essentially the industrial transport vehicles sector (meanwhile, the MAN Turbo division has been united with the MAN Diesel division, forming the MAN Diesel & Turbo division).

Revenue by business area

€ million	2012	%
Commercial Vehicles	11,692	74
Power Engineering	4,256	27
Others/Consolidation	– 176	– 1
MAN Group	**15,772**	**100**

Revenue by region

€ million	2012	%
Federal Republic of Germany	3,170	20
Other EU countries	4,153	27
Other European countries	1,744	11
Asia	2,335	15
Americas	3,510	22
Africa	696	4
Australia and Oceania	164	1
MAN Group	**15,772**	**100**

Figures 1.4 and 1.5: revenue of MAN group in 2012, divided by business area and by region

Actually, MAN group is European leader in design and production of systems and machinery for industry and commercial vehicles, with a yearly revenue of more than 15 billion Euros (the 80% of which coming from foreign markets), and an operating profit of more than 900 million Euros.

Income statement

€ million	2012	%
Revenue	15,772	100.0
Cost of goods sold and services rendered	−12,499	−79.2
Gross margin	3,273	20.8
Other operating income[3]	540	3.4
Selling expenses[1]	−1,091	−6.9
General and administrative expenses[1]	−949	−6.0
Other operating expenses[3]	−877	−5.6
Income from investments[1,2]	68	0.4
Operating profit	964	6.1

Operating profit by business area

€ million	2012
Commercial Vehicles	454
Power Engineering	503
Others/Consolidation	7
MAN Group	**964**

Figures 1.6 and 1.7: operating profit of MAN group, and its division by business area

With almost 55.000 employees all over the world, MAN group operates through two strategic Business Unit, one related to Commercial Vehicles (divided into MAN Truck & Bus and MAN Latin America, which deal respectively with Europe and South America/Africa market), specialized in the production of industrial vehicles, buses, and Diesel or natural gas motors, and the other related to Power Engineering (which comprehends the MAN Diesel & Turbo division), specialized in the production of gensets, two-stroke engines for giant container ships, power units, turnkey diesel power plants, single compressors and turbines, complete machine trains for various industrial applications.

MAN Diesel & Turbo division offers the most complete product portfolio available in the international compressors' (axial, centrifugal, integrally gear-type, hermetically sealed, isothermal, pipeline, process-gas screw, vacuum blower compressors) and turbines' (industrial gas and industrial steam turbines) market. It is currently divided into 4 divisions: Engines & Marine Systems, Power Plants, Turbomachinery and After Sales. The main reason that led to this split was the will to focus at the best on customer's necessities: in fact, Man Diesel & Turbo offers a large variety of products that can be sold in different markets.

However, in the years in which De Pretto was property of MAN, the Diesel and Turbo divisions were separated; so, we will proceed considering only the part related to the MAN Turbo division, which "MAN Turbo De Pretto" was part of.

1.2 Production sites

To fully understand the position that “MAN Turbo De Pretto” had inside MAN group, is necessary to make an overview over those which were the main production sites until 2008, and then concentrate over the one of Schio.

Oberhausen

In Oberhausen factory, axial, centrifugal, screw and pipeline compressors, industrial gas (THM and FT8) and steam (condensing, back-pressure) turbines, and expanders were produced. The production supplied various markets:

- basic chemical industry;
- intermediate petrochemical sector;
- gas generation;
- steam generation.

1.2.1 Berlin

In Berlin factory, axial, centrifugal and screw compressors were produced, and they were destined exclusively to primary refinery market.

1.2.2 Zürich

In Zürich factory, axial, centrifugal, isothermal, screw and Tubair vacuum blower compressors were produced. The production supplied various markets:

- tertiary oil and gas industry;
- Vacuum gas industry.

1.2.3 Schio

In Schio factory, the typology of axial and radial compressors was the same of the factories of Oberhausen and Zürich: in these, especially in the second one, contact with the final client was managed, main deadlines were defined, basic engineering, control and impellers’ production, final assembly and tests were realized; MTM-I dealt with the detail engineering, the production of internal and external casings, the discharge spirals and with every stator part and the realization of robotic welding over which was extremely specialized.

Fig 1.8: work on a Francis impeller

For what is concerning steam turbines, the typology of the orders was attributable to three types:

I. orders for third parties: Schio received the complete basic project of the machine from an external company. It must deal with the detail engineering, the purchasing of various external components and the production;
II. orders: basic engineering was made inside Schio's plant, too; then activities linked to detail engineering, production, and management of the contacts with the client will follow;
III. orders given directly by MAN (Oberhausen or Zürich factory), which will manage directly the contacts with the client, the basic engineering, and gives to Schio's plant only the scope of supply (which components realize and with which deadline).

"MAN Turbomacchine Italia" offered also its experience and its resources to carry out works based on client's drawings (Jobbing). The range of offered products went from welded tested constructions of big size, to the most various mechanical workings, to the assembly of machines or sub-assemblies. Most of the work done was however inside the power components area (parts for gas turbines, parts or sub-assemblies for steam turbines, complete impellers or revamping of hydraulic systems).

1.3 Applications of the products offered by MAN Turbo De Pretto

The industrial applications for turbo compressors are uncountable: from the simple compression and the liquefaction of gases for chemical industry, to the hydrocarbons compression for the petroleum and petrochemical industry, from the "driving force" in the pipelines, to the ventilation in big industrial plants like foundries, rolling mills and mining complexes. A niche application is its use in wind tunnels.

Steam and gas industrial size turbines are part, instead, of the power generation market, which has a very long tradition in the company. Often they're also used as "motor" in turbo compressors in complex industrial plants, with an efficiency improvement and a simplification of the plant.

In the following tables a general overview of the turbomachinery's typologies that were realized by MAN Turbo division is presented, with the specification of their related areas of application.

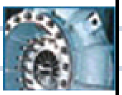
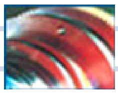
	COMPRESSORS					
						
	Axial	Centrifugal	Pipeline	Isotherm	Gear-Type	Process-Gas Screw
Oil & Gas	■	■	■	■	■	■
Refinery	■	■			■	■
Chemical & Petrochemical		■			■	■
Fertilizer	■	■		■	■	
Industrial Gases	■	■		■	■	■
Iron & Steel, Mining	■	■		■	■	■
Power Generation	■	■			■	■

Table 1.1: applications for turbomachinery for compression

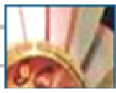
	EXPANDER	TURBINES		
				
	Expander	THM Gas Turbine	FT8 Gas Turbine	Steam Turbine
Oil & Gas	■	■	■	■
Refinery	■			■
Chemical & Petrochemical	■			■
Fertilizer	■			■
Industrial Gases				■
Iron & Steel, Mining	■			■
Power Generation	■	■	■	■

Table 1.2: applications for turbomachinery for expansion

One important thing to emphasize is that, after the spin-off of the Hydro business, products whose know-how was entirely owned by De Pretto weren't present anymore in Schio. Officially entering in the Sulzer Turbo Group, De Pretto became a company specialized in the production of stator parts for turbo compressors, whose research and development activities were made in Zürich or in other sites of the company. Engineering activities performed in Schio, the ones called "detail engineering", were mostly focused on production support.

Machines' rotors, which are the central part of turbomachinery, were (and still are) normally built in other plants and then provided to MAN Turbo to be assembled in the machine before shipping.

1.4 The sale of Schio’s production site: the new De Pretto Industrie

Starting from 2006, MAN Turbo, analyzing the world market trend (pushed from the price of the petroleum barrel always greater), believed that had to increase its productive capacity.

The choose was to invest first in a new plant in China, an important market from a strategic point of view, as it absorbed more than the 50% of the machines sold by the group. The presence in China wasn’t, in Man Turbo idea, aimed at cost reduction, but rather at the aggression of an internal market dominated by Chinese constructors, where the companies with foreign production couldn’t enter. Basically, the idea was to build in China about the 30% of the compressors requested by the market.

An internal study of 2008 showed that the continuously growing trend of the market could probably request the creation of another productive site.
But this result was presented in the moment when the financial crisis had already started to erode markets, situation that became always clearer at the beginning of 2009.

In the meanwhile, internal Supply Chain studies of the Oil & Gas division of MAN Turbo had already defined the stator components of compressors as components to be submitted to a make or buy strategy, so not strategic and eventually buyable from third-party suppliers.

On this considerations’ basis, in 2009 MAN Turbo decided to sell Schio’s plant, searching an industrial partner that could ensure its survival, both as key supplier of MAN Turbo itself, and as independent entity in other markets.

The long selling process ended the 29th of July 2010, when MAN concluded an agreement with the holding Selink, owned by Ciscato family, giving the control of the 49% of the company. In the following years, that share rose up till the 100%.

Selink is now controlling a group formed basically by two historical companies of Vicenza’s zone:

- FOC Ciscato, a forging company placed in Seghe di Velo (Vicenza), founded in 1879;
- the newborn De Pretto Industrie (DPI), new name of the old MAN Turbo De Pretto, direct heir of the company founded 125 years before by Silvio De Pretto.

The new group (with almost 450 employees) placed immediately clear objectives, which can be resumed in a few basic concepts:

- joint work to raise the value for the client;
- sale of the service, in addition with the product itself;
- expansion in international markets;
- creation of a new product under its own brand;
- continuous growth in the respect of tradition.

CHAPTER 2

De Pretto Industrie: the company today

The information present in this chapter about De Pretto Industrie is mostly taken from DPI's official website.

2.1 Actual situation

De Pretto Industrie s.r.l. takes full advantage of the experience and the competences it has gained over its 125 years of history and continues to produce turbomachinery and their related parts (steam and gas turbines, industrial, chemical and hydrocarbons gas compressors) in collaboration with the associated companies and other leaders operating in this field.

These skills span the whole process that goes from the purchasing of raw materials to the production, mechanical working, assembly and packaging; in particular, they lie in the manufacturing and mechanical working of welded casings for large turbomachinery, and in the assembly of the entire product. Furthermore, the company provides a point of reference for other manufacturers that entrust it some delicate phases of their main production processes such as, for example, the working of hydraulic shovels and Francis wheels, lathing operations, and blading of rotors.

The specialized technicians drive the various phases of the production, starting from working drawings to later focus on the purchasing of raw materials and components. The coworkers are dedicated to the commissioning and the regular care of the after-sales service, even with reference to the plant-engineering sector. The Service department works side by side with customers to maximize the performance and the life of systems and plants present in Italy. As of today, this list includes about 200 machines provided by historically recognized brands, like GHH, Borsig, Sulzer, and Escher Wyss.
The company has now about 250 employees and his productive capacity is about 150.000 hours/year.

In particular, De Pretto Industrie is now concentrated mostly on the sale of new installations, on works for third parties, and on service.

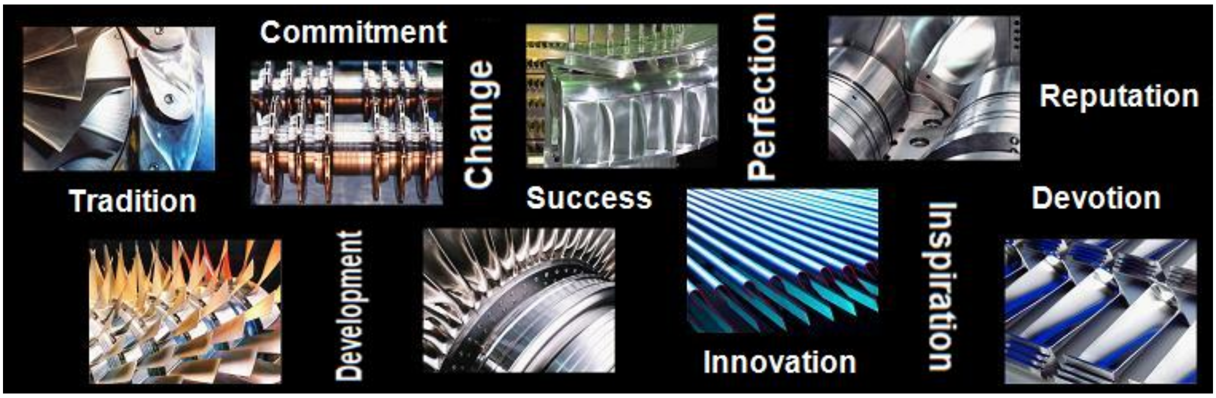


Figure 2.1: the values of De Pretto Industrie

2.1.1 New plants

The long experience gained in the construction of steam turbines over almost 70 years of activity entitles De Pretto Industrie to offer a wide range of steam turbines of either impulse (action) or reaction type up to 40 MW power output.

The high thermodynamic efficiency and the flexibility of the modem modular construction system make this machine range the most suitable for:

- industrial thermal power stations;
- combined cycles power plants;
- biomass and waste incineration plants;
- solar power plants;
- heat recovery plants from industrial processes;
- combined heat and power generation;
- chemical and paper mill plants;
- mechanical drive for compressors, pumps, blowers, fans.

2.1.2 Third-parties jobs

Key elements for the continuous development of the company are the delivery speed, the operational flexibility, the quality and the reliability of the work carried out, the organization and optimization of production, the constant pursuit of new production technologies to guarantee a high-quality product and service for the customer.

Furthermore, the quality of the product is guaranteed by the use of high-technology CNC machines, the continuous technological updating of the staff, the strict quality control of the production, and the use of computer technology to determine customer’s requirements.

To customers are offered:

- a constantly high quality level;
- efficient logistic;
- internationally competitive prices;
- the drive and capacity for innovation and technical creativity;
- entrepreneurial flexibility.

The customer benefit from:

- competitive advantages resulting from technical collaboration;
- partnership works with mutual advantages;
- a growing volume of orders within the context of a reliable and long-lasting business relationship;
- references for their sphere of influence in international marketing.

2.1.3 Service

De Pretto Industrie offers technical support to customers on a wide range of products and application, thanks to its extensive and consolidated experience in designing, building and installing turbomachinery and related systems. Moreover, synergies with other associated companies of MAN Turbo Group allow DPI to intervene promptly and offer the most innovative and effective solutions to meet the customer's needs while respecting the environment.

Its support service accompanies turbomachineries through their entire life cycle: after the first installation phase, routine and special maintenance are performed on site as well as periodic monitoring. The company can also provide predictive consultancy on machine operation. For all Service's activities, original components are used for the entire range of De Pretto Industrie and MAN Diesel & Turbo products. Remarkable quick on-site servicing can be guaranteed in Italy and even abroad, a factor that marks DPI in the market.

2.2 Present and future objectives

To better emphasize the actual situation of De Pretto Industrie, the company's Mission and Vision will be now illustrated, showing where the company is now and what it wants to reach, so which are its scopes and objectives for medium and long term.

2.2.1 Mission

The Mission represents the company's current driving force, and describes its medium-term strategic course of action.

According to De Pretto Industrie's official website, "our goal is to achieve and consolidate constant growth by expanding our global network, developing new market segments and launching new top-selling products. Through an intense exchange of expertise within the Group, we have created an environment which allows innovation and proper management of continual changes, and where individuals and teams work together in a motivated atmosphere. All this gives us the opportunity to find the perfect common ground between the expectations of our customers and those of our collaborators".

2.2.2 Vision

The Vision expresses the desired state of the company for its future.

Still according to DPI's website, the vision of the company is to make its name "synonymous with innovation in the turbomachinery market while respecting the environment and guaranteeing the highest quality. We strive to be a reliable partner for our customer, supporting him through the entire life cycle of our product. And in order to successfully meet the new market challenges in today's economy, we pay the utmost attention to expanding our presence in the global market and remaining up-to-date with the latest technological progress".

It is clear (and in part direct consequence of what just said) that the future strategy of De Pretto Industrie will focus on two main guidelines:

- continue to follow with quality and care the client MAN, which for the company still remains the main client and, likely, it will continue to be it also in the future;
- prepare to enter in new markets both proposing itself as strategic partner for companies with complex products, both developing an own product.

2.3 Layout of the plant

The plant is basically divided into 4 departments:

- welded constructions department;
- machining department;
- assembly department;
- painting and sandblasting department.

Now for every department its machinery, its equipment and the operations carried out in it will be described in synthesis.

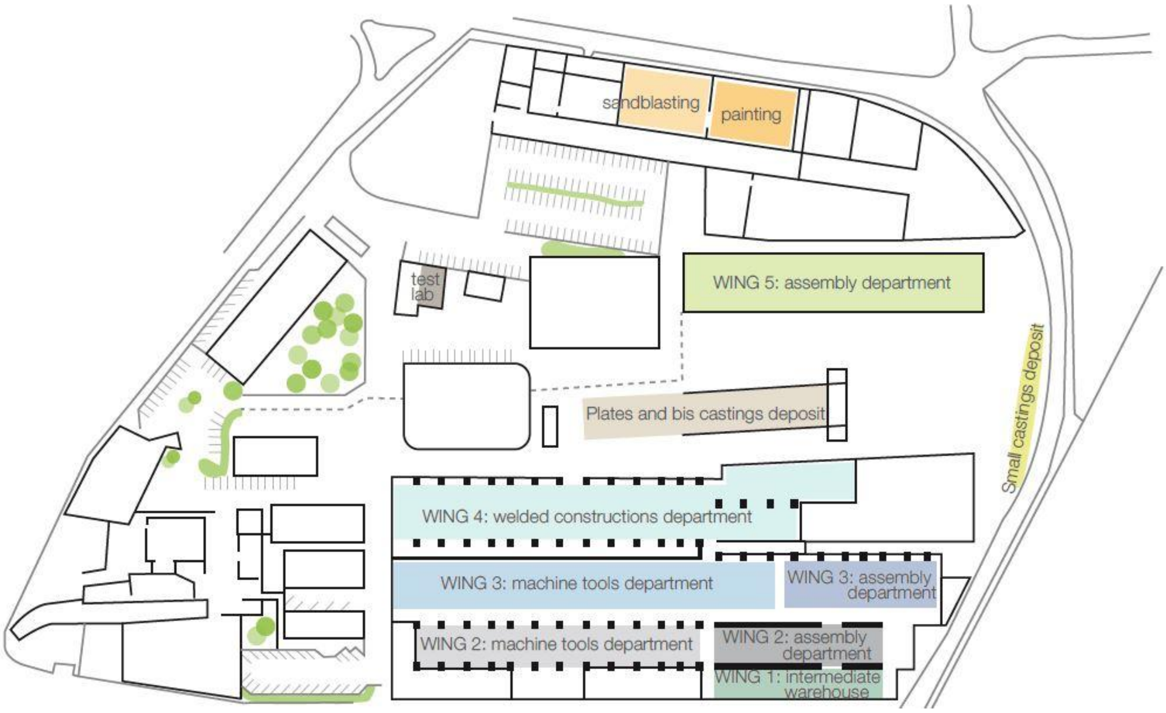


Figure 2.2: general layout

2.3.1 <u>Welded constructions department</u>

The welded constructions department covers an area of about 3000 m^2. The layout of the department has been designed to guarantee an optimal flow of the materials so as to minimize the crossing and handling times, from the cutting of the plate metal up to its welding.

Generally here the first operations of the cycle of the internal produced materials are performed. In this department there are: a pantograph for nesting and numerically-controlled oxygen and plasma cutting, a couple of furnaces for heat treatment, a bending machine, a couple of presses (used for particulars that depend from plate cutting and welding constructions in general), a furnace and a press for press-forging, a small welding robot, a big portal welding robot for casing welding, a robot for submerged arc welding, some positioners, a laser welding system. The remaining internal space of the department is divided into free spaces used to spot-weld or to weld the bigger components like the casings (which born as welding constructions), benches where is realized the construction of small components, department's warehouse where the semifinished products are stored on shelving.

Outside there is a deposit, served by a bridge crane (capacity of 20 tons), where the basic plates, the fusion roughs, the forgings and the semifinished products from the plate cutting are stored. This department provides, besides the external deposit, also the painting and sandblasting department.

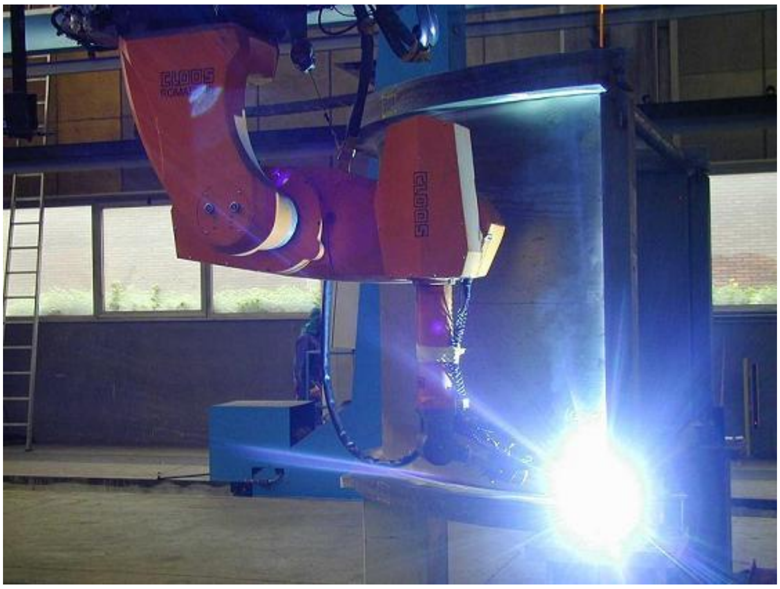


Figure 2.3: welding robot

2.3.2 Machining department

The area dedicated to machining extends over a surface area of about 4385 m^2 and is equipped with lifting systems that allow the handling of components weighing up to 140.000 kg. Here are normally performed the intermediate operations of the productive process, typically of: marking off, milling, boring, turning, dimensional control. The department's organization is the one typical of a job shop, and so the layout is of the functional type.

In this department there are: benches for the marking off, big boring machines (Pama 200, Pama ACC 180/420, Pama 140 and the Colgar Fral 70 C16), one medium boring machine (Pama AP 130), two medium milling centers (Pamacenter and Mandelli), a big work center (Pama Speedmat), a drill (Sass 3500), two big vertical lathes (Ceruti TVB 50 and Phoenix 36/43 H), a medium vertical lathe (Morando VH 20), an horizontal lathe (Froriep D 1250), the area for the dimensional control (test benches and CMM machine), the tools warehouse. The department is adjacent to the assembly department and connected to the welded constructions one.

Machining department is also efficiently supported by a dedicated department for setting the tools and equipment, which studies and prepares everything necessary for the machining processes. It is also supported by an office for the numerically controlled programming which, relying on a high-quality software system, provides effective programs.

Figure 2.4: boring machine PAMA 200 working in the bearing zone of a RIKT

2.3.3 Assembly department

Assembly department can rely on its ideal layout within the company: it extends throughout the 3 main wings of the plant, next to the machining department and in direct contact with the main warehouse, and with its 4160 m^2 of useful surface area and a maximum lifting capacity of 150 tons, it is perfect for any type of assembly work. In here, the final assembly of the machines and the components that require it (pre-assemblies of the stator parts, of the supports, etc…), the casings' pressure tests, the fettling - after the mechanical workings and before the sandblasting and final painting - and the preparation for the shipment are performed.

The department also has two assembly pits which enable complete assembly of the turbomachinery (especially RIKT compressors), even with heights greater than 11 m.

Figure 2.5: preparation for the hydraulic pressure test

2.3.4 Painting and sandblasting department

Placed in a working area of 800 m^2, it includes a paint drying oven, a sandblasting machine, 2 painting booths, a washing area with wastewater collection tank, and two floor filtration areas for painting. In this department the washing of the casings and the operations from which it takes name (sandblasting and painting) are performed; these operations are generally planned before the machining, to protect the surfaces from corrosion, and before the final assembly for the materials with a work cycle; for some purchased materials, a preventive painting is planned before assembly.

CHAPTER 3

State of the art: in order vs. series production

In this chapter the differences between in order and series production will be presented, as can be found in literature (the text of reference will be *Produktionsplanung und –steuerung. Grundlagen, Gestaltung und Konzepte*, by Günther Schuh and Carsten Schmidt). Then, it will be analyzed where De Pretto Industrie is located now and to where it will go changing its way of production.

3.1 Different types of production

We can say that, mostly, there are 4 possible types of production:

- one-of-a-kind production (also called "in order production");
- single and small series production;
- series production;
- mass production.

As we can see in the following table, the main difference between them lies in two criteria: average edition size of products, and average repeatability per year. The first one indicates how many products are made in one batch, while the second one how many times the production of the batch is repeated during the year.

One-of-a-kind production	Single and small series production	Series production	Mass production
Criteria:	**- average edition size of products** **- average repeatability per year**		
Low edition size; no repeats	Edition size < 50; number of repeats < 12	Edition size > 50; number of repeats < 24	Very large edition size; Continuous production

Table 3.1: criteria to define production types

As clear from its name, the one-of-a-kind production is a single production, the product made is unique (or is produced in a very little batch), and there are no repeats of the product during the year. Going towards series production, the size of the batches grows, and also the number of repeats, until arriving to the mass production with a continuous production flow and very large batches.

Besides these two criteria, there are some characteristics which mark the different production types, giving to each of them its own feature. These characteristics are:

- type of order triggering;
- product range;
- product structure;
- determination of products/components need;
- triggering of dependent requirements;
- procurement type;
- storage;
- processing type in production;
- processing type in assembly;
- production structure;
- customer’s influence on changes during production.

Type of order triggering: it is the relation between the orders and the production, i.e. when the production starts; could be after a customer’s order or forecasting it.
Product range: the product range is the level of customization of the product.
Product structure: it is the level of complexity of the product, which depends from the number and the size of its parts and components.
Determination of product/components need: it is how the company determines when to purchase the components required for the product.
Triggering of dependent requirements: it shows when some requirements, depending from others, are activated.
Procurement type: it is the level of external/internal procurement in the company.
Storage: it is the influence of production in warehouse level, i.e. how many components/products need to be stored.
Processing type in production: it shows which the layout of the workshop is, for the production part.
Processing type in assembly: it shows which the layout of the workshop is, for the assembly part.
Production structure: it is the level of structuring in production.

Customer’s influence on changes during production: it is the possibility for the customer to ask for changes during production.

Combining different values of these attributes, we can obtain the four production types. Moreover, it is possible to define which attributes are proper for different oriented manufacturing companies, which can be related to one or two production types.

In the following tables, examples of a make-to-order and a make-to-stock manufacturing companies (which are the opposite ends of production) are presented, to better explain this concept. The columns distinguish the production types; with blue background the proper features of the company’s type are indicated.

It is clear that a make-to-order company will produce following a one-of-a-kind or a small series production, while a make-to-stock company a series or mass one. As this work concerns the passage from the “in order” production to the small series one, we will focus on the first table, the make-to-order company.

The most important features of such a company are:

- production to order with individual orders;
- products realized according to customer’s specifications;
- multi-part products with complex structures;
- processing type: shop fabrication / manufacturing islands.

Each of these characteristics is detectable in De Pretto Industrie.

	Characteristics	Make-to-order oriented manufacturing company				
1	Production type	One-of-a-kind production	Single and small serial production	Series production	Mass production	
2	Type of order triggering	Production to order with individual orders	Production to order with frame contracts	Pre-production without customer relation / final-production customer order-related	Make-to-stock production	
3	Product range	Products acc. customer's specifications	Typecasted products with customer specific variants	Standardized products with variants	Standardized products without variants	
4	Product structure	Multi-part products with complex structures	Multi-part products with simple structure	Poor-part products		
5	Determination of products / components need	Demand-oriented on product level	Expectation- and demand-oriented on component level	Expectation-oriented on component level	Expectation-oriented on product level	Consumption - oriented on product level
6	Triggering of dependent requirements	Order-oriented	Partly order-oriented / partly period-oriented	Period-oriented		
7	Procurement type	Extensive external procurement	External procurement to a greater extent	External procurement negligible		
8	Storage	No storage of need positions	Storage of need positions of subordinate structure level	Storage of need positions of higher structure level	Storage of products	
9	Processing type in production	Shop fabrication	Manufacturing islands	Serial production	Flow production	
10	Processing type in assembly	Fixed station assembly	Fitting teams assembly	Continuous row assembly	Progressive (flow) assembly	
11	Production structure	Production with great degree of structuring	Production with medium degree of structuring	Production with little degree of structuring		
12	Customer's influence on changes during production	Influences on changes in larger extent	Occasional influences on changes	Negligible influences on changes		

Table 3.2: ideal characterization of a make-to-order manufacturing company

No.	Characteristics	Make-to-stock oriented manufacturing company				
1	Production type	One-of-a-kind production	Single and small serial production	Series production	Mass production	
2	Type of order triggering	Production to order with individual orders	Production to order with frame contracts	Pre-production without customer relation / final-production customer order-related	Make-to-stock production	
3	Product range	Products acc. customer's specifications	Typecasted products with customer specific variants	Standardized products with variants	Standardized products without variants	
4	Product structure	Multi-part products with complex structures	Multi-part products with simple structure	Poor-part products		
5	Determination of products / components need	Demand-oriented on product level	Expectation- and demand-oriented on component level	Expectation-oriented on component level	Expectation-oriented on product level	Consumption - oriented on product level
6	Triggering of dependent requirements	Order-oriented	Partly order-oriented / partly period-oriented	Period-oriented		
7	Procurement type	Extensive external procurement	External procurement to a greater extent	External procurement negligible		
8	Storage	No storage of need positions	Storage of need positions of subordinate structure level	Storage of need positions of higher structure level	Storage of products	
9	Processing type in production	Shop fabrication	Manufacturing islands	Serial production	Flow production	
10	Processing type in assembly	Fixed station assembly	Fitting teams assembly	Continuous row assembly	Progressive (flow) assembly	
11	Production structure	Production with great degree of structuring	Production with medium degree of structuring	Production with little degree of structuring		
12	Customer's influence on changes during production	Influences on changes in larger extent	Occasional influences on changes	Negligible influences on changes		

Table 3.3: ideal characterization of a make-to-stock manufacturing company

3.2 Situation of De Pretto Industrie

As slightly mentioned before, De Pretto Industrie is operating with very low volumes and a very high customization level; so high, that we can say every product delivered to a client is different from another one, precisely because it is defined directly by the client himself. The designing follows the demand, and very often the company consults data and projects in archive to find solutions adopted in the past and which can be still used as a starting point for the new requested products. So there is a certain production discontinuity and a concentration on the productive cycle effectiveness, due to the creation of much defined projects. Another important point is the presence of service, which isn't simply an after-sales relationship, but it is more complete and concerns activities before the order, during production, and also after the purchasing; this is a big difference compared to series production companies, as it is shown in the figures below.

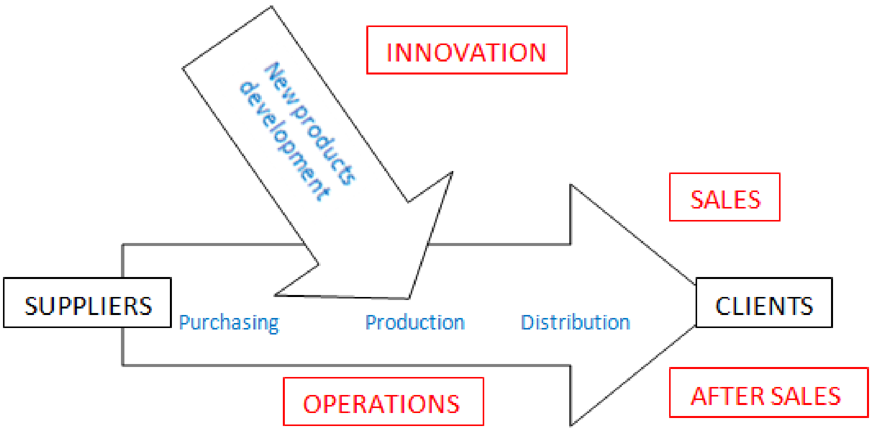


Figure 3.1: schematic representation of a company operating by series production.

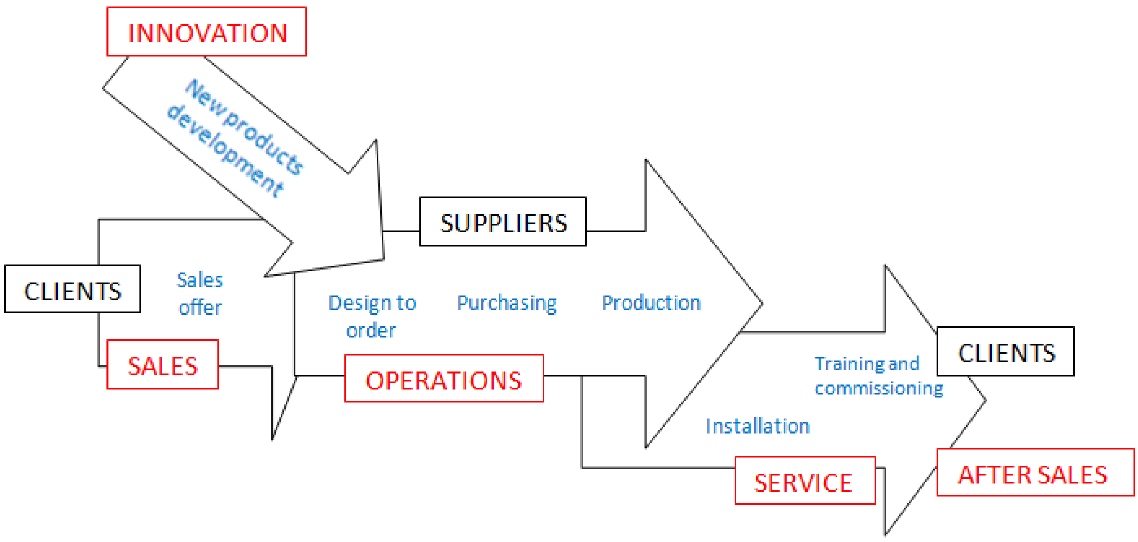


Figure 3.2: schematic representation of a company operating by in order production.

From the comparison of the figures, other aspects about companies operating by in order production emerge:

- the sale phase isn't divided from operations activities, but it activates them. The client plays an important role in the sale phase as he gives his specifications;
- product development does not end before sale, but there's a strong part of designing based on client's wishes;
- besides after-sales (warranty and post-warranty service) there are Service's activities, which are activated before the end of production;
- the industrialization is often omitted because there's no assurance over product's repeatability.

So, basically, the work in DPI is now characterized by the following features:

- a complex, custom final product;
- very high variety, theoretically infinite;
- very low unit volumes;
- high specialization for workers;
- a reliable supplier network built during the years;
- need of great operational flexibility.

Starting from this situation, the objective of this work is to pass to a small series production for the compressor RIKT. As showed before in table 3.2, for a make-to-order company there aren't such big differences between the two production types (for example, the unit volumes will stay at a low level, the customer's specifications will remain important, etc); however, there are some changes to make to pass to this kind of production.

The work will analyze these changes in engineering, project management, purchasing, production and quality.

CHAPTER 4

RIKT compressor

In this chapter, after an overview over compressors, the RIKT compressor is presented specifically, starting from a general point a view and reaching the particulars, with the assemblies and the work cycles used to produce them.

4.1 Turbo compressors

Turbo compressors are used in industry, wherever large gas volume flows should be compressed, which means a volume reduction at constant mass flow. Like turbines, turbo compressors belong to the field of turbomachinery, i.e. machines with a rotating shaft inside and a fixed outer casing. However, unlike turbines, which extract energy from a medium such as gas in order to drive other devices, turbo compressors operate in the reverse of this principle as a work machine. Therefore, power has to be supplied to the system by an external drive (fig. 4.1). At the compressor shaft, this operating power is in turn converted into rotational energy via gearbox and couplings.

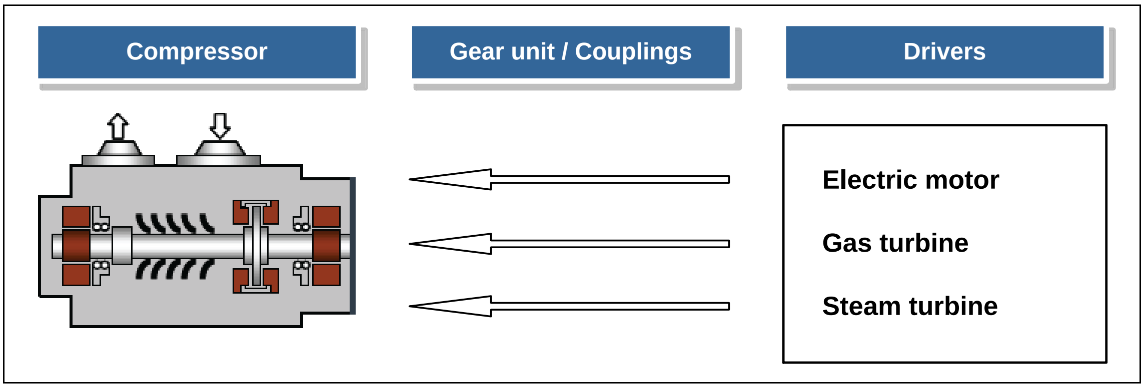


Figure 4.1: Drivetrain options for compressors

Towards the compressor outlet, the energy is transferred from the rotor to the compressible medium, typically air from the atmosphere or other gases, by impellers, which are fixed on the shaft and fitted with blades (fig. 4.2). This leads to higher pressure or rather higher temperatures of the medium. The diffuser, which is located directly downstream of the impeller, provides further pressure and temperature increase by a deceleration of speed.

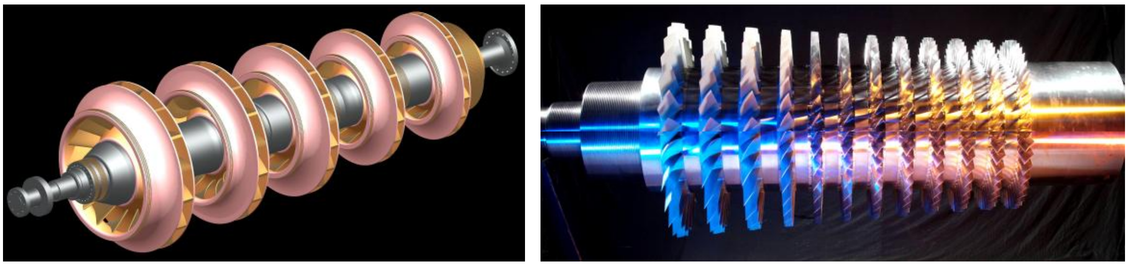


Figure 4.2: Rotors of a centrifugal (left) or axial (right) compressor

Turbo compressors can be distinguished between axial and radial or centrifugal compressors according to the main flow direction of the medium. In axial compressors, the working fluid principally flows parallel to the shaft axis, whereas it is deflected perpendicularly to the shaft axis in centrifugal compressors. In radial - centrifugal compressors both principles are combined in order to benefit from their main advantages: first, a group of axial stages sucks high flow rates, which are subsequently compressed to high pressure in the radial stage. The third and more seldom category is the so-called diagonal machine, a mixture of both types wherein the fluid flows at an angle to the rotor axis. Figure 4.3 shows the three different directions of through flow.

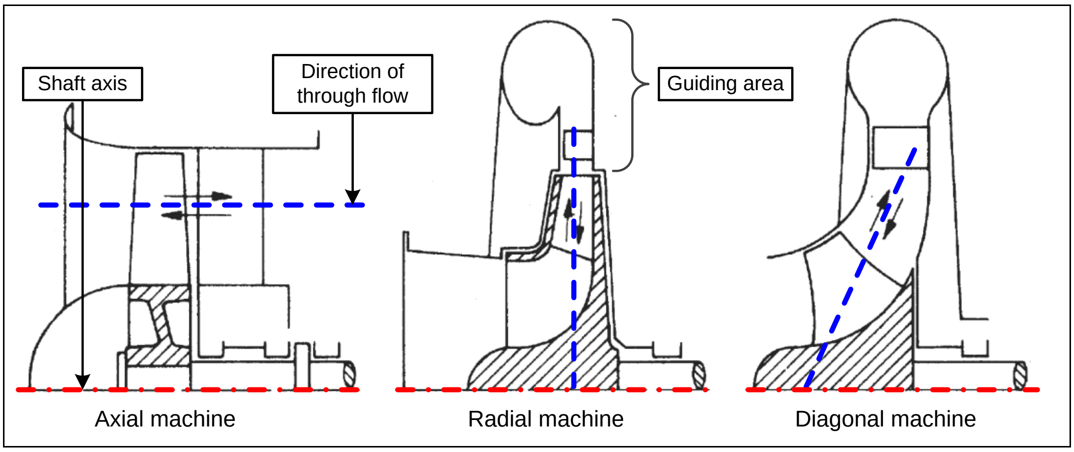


Figure 4.3: Direction of through flow for axial, radial and diagonal machines

4.1.1 Axial compressors

Inside the axial compressor, a shaft with many bent propeller-like blades rotates around the shaft axis (fig. 4.4). Between each row of rotating blades (rotor blades) a row of fixed blades (stator blades) is mounted. Each row of rotor and stator blades forms a compressor stage. The largest axial compressors have 20 of these stages.

Characteristic for axial compressors are large volume flows of up to 1.5 million m^3/h and relatively low pressure differences from the inlet to the outlet. The maximum discharge pressure does not exceed 20 bar. The flow in shaft direction is hardly deflected and as a result subjected with relatively low losses. On the other hand, the static pressure increase takes place in absence of a radial flow component only by the deflection of the fluid at the impeller blades. Hence, in comparison with centrifugal compressors, more stages have to be connected in series to obtain an equal pressure increase.

Due to the small size of the impeller blades, parts of the compressible medium flow unused through the gap between blade tip and channel wall. So, axial compressors are used for volume flows above a minimum of 70.000 m^3/h and consequently for larger dimensions.

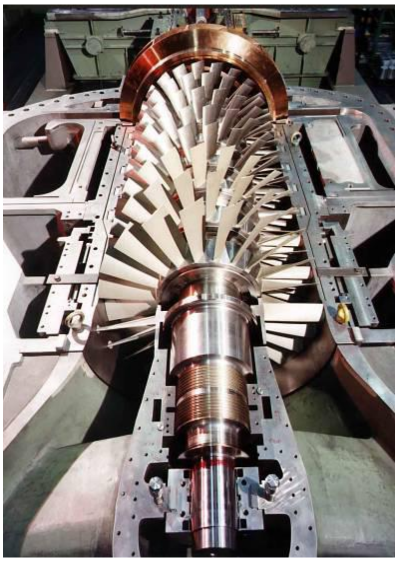


Figure 1.4: Axial compressor

4.1.2 Centrifugal compressors

Centrifugal or radial compressors draw the compressible medium in the direction of the impeller axis and deflect it subsequently perpendicular thereto in radial direction. Compared to axial compressors, the increase in pressure is higher through the use of the centrifugal force field and the redirection and deceleration at the impeller blades and downstream radial diffusers. Thus, large deflection and guiding areas are required, which influences in turn the casing dimensions. In addition, the long flow paths mean losses, and therefore, the efficiency of centrifugal compressors is lower than that of the axial design. Since the external dimensions and the mass of the compressor are limited, paths behind the impeller cannot be extended indefinitely. This leads to a limitation of the recoverable volume flow.

However, centrifugal compressors can be equipped with an intermediate cooling between the single stages (fig. 4.5). These so-called isotherm compressors lower the outlet temperature of the medium by heat dissipation and for that reason allow higher pressures. Furthermore, the required drive power is reduced.

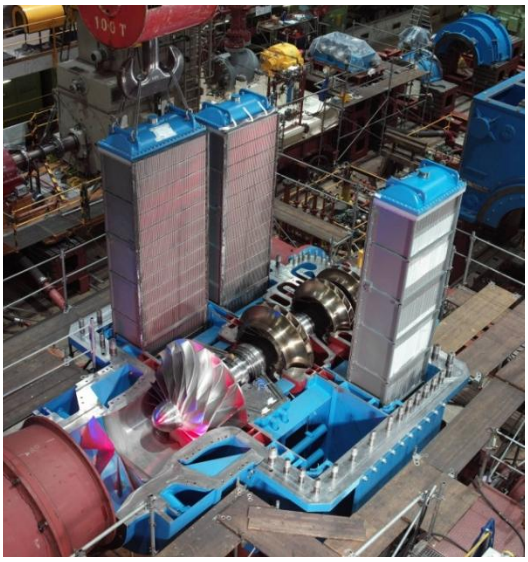


Figure 4.5: Radial isothermal compressor RIKT

Moreover, centrifugal compressors can be distinguished according to the cutting plane through the casings, which can be horizontal or vertical. The horizontal split design is used for relatively low operating pressures (max. 80 bar) but higher volume flows (2.000 to 660.000 m^3/h) (fig. 4.5 and 4.6), whereas the vertically parted type design, due to its shape also named barrel compressor, allows operating pressures of 1.000 bar with therefore lower volume flows (2.000 to 230.000 m^3/h). For the assembly of the barrel type, the compressor unit (cartridge) is placed inside the casing via a rail device. Cartridge and casing are vertically screwed together with pins (fig. 4.7).

Figure 4.6: Centrifugal compressor with horizontal split design

Figure 4.7: Centrifugal compressor with barrel design

4.2 General introduction of RIKT

The acronym “RIKT” stands for “Radial Isotherm Kompakt Turbo”, whereby the “T” is stemming from the old designation of a gear type compressor, which shows an identical shape of the impeller of the first stage. This overhanging, open impeller without shroud is characteristic for the RIKT and allows sucking in large volumes of air or gas. RIKT compressors are available as standard in seven sizes. Regarding their product name, e.g. “RIKT 140”, the number specifies the nominal diameter of the impeller of the second stage in centimeters. Main areas of application of RIKT compressors are air separation (air / N_2), steel industry (blast furnace), chemical industry (nitric acid), process air, air storage and jet engine test cells.

Key technical data:	▪	Suction pressure:	atmospheric
	▪	Pressure heads:	6 – 13.6 barg[1] (standard RIKT) 6 – 22 barg (high pressure RIKT)
	▪	Volume flows:	80.000 – 660.000 m^3/h

4.2.1 Design of RIKT

The RIKT core machine consists essentially of three modules, which are again divided into individual assemblies. The first module is the rotor, which is the centerpiece of the compressor. In the drawing of figure 4.8, the rotor parts are highlighted in red. The rotor is comprised of a shaft, a particular number of impellers, bearings, a balance piston and labyrinth strips. It is set into rotation by an external drive. The second module is the welded casing (green colored) with an axial inlet and a radial outlet. It consists of the inlet casing, the prerotation, the inlet piece, the outer casing, the cooler covers, the man hole cover, the bearing housing, the mounting parts (channel and intermediate wall, diffusers) and the outlet spiral. Finally, the third module is the cooling system (blue colored). The coolers are mounted inside the casing on both sides of the rotor. The main components of a cooler are the cooler bundle, the water chambers and the water separator.

[1] The unit barg, spoken as "bar gauge", is zero-referenced to atmospheric pressure (~1.01325 bar), e.g. a gauge pressure of 10 barg means an absolute pressure of ~11 bar.

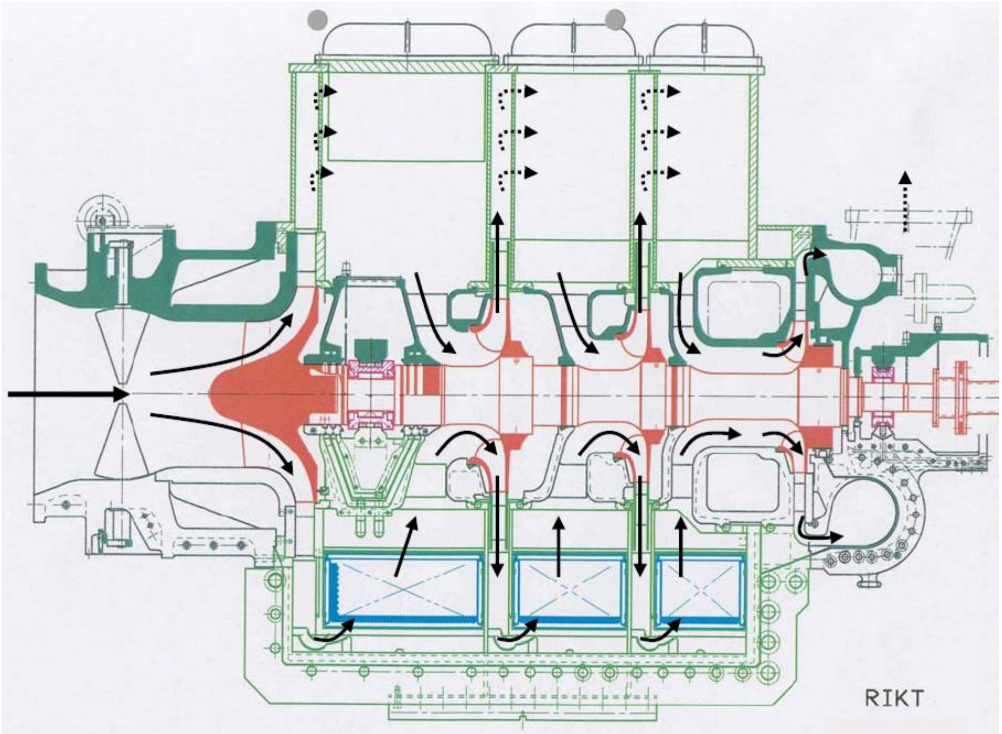


Figure 4.8: Schematic structure and flow profile of RIKT

4.2.2 Functioning of RIKT

A RIKT is intended basically to compress air in large quantities. The general process flow is presented in the following; the flow profile is illustrated by the black arrows in figure 4.8.

Firstly, the air is sucked from the environment by the suction of the first impeller and flows through the inlet casing (axial air intake) into the compressor. The first stage impeller draws in the air and forces it through the entire circumference outward in the inside of the compressor. On its way, the air is compressed by the declining cross-section of the impeller and gains in flow energy. In the downstream diffuser, which is located directly behind the impeller outlet, the flow energy is converted into pressure.

Since the air is heated up during the compression, it is directed through a cooler by special baffles before it reaches the second stage impeller. The baffles ensure a turbulence-free medium flow, and hence, low flow losses. Then, the cooled air runs through the channel and intermediate wall into the inlet of the second impeller and the process starts again.

However, it is possible to do two sequenced stages without cooling in between. Using this principle, higher pressures can be reached, since flow losses are less due to the more direct and shorter path. At the end of the process, the compressed medium enters the outlet spiral, wherefrom it is fed into the subsequent process.

4.2.3 Modularization / Standardization of RIKT

RIKT compressors are one of the most standardized and modularized compressor types of the MAN product range. The aim of this standardization is to reduce costs and delivery time. This is achieved by, firstly, a reduction of engineering hours due to the use of a modular system, secondly, the conclusion of frame agreements with key suppliers and finally, the increase in experience. In consequence, for instance, most customers forgo mechanical shop testing of standard compressors.

According to a geometrical design rule, the frame sizes of the different series and the components within these frame sizes are strictly standardized (fig. 4.9, left). Thus, for example, there are for each of the seven standard sizes (RIKT 80, 90, 100,112, 125, 140, 160) three to four different rotors available (standard rotor S, M, L, XL). Figure 4.9 (right) shows the different options how, depending on the customer order, specific suction flows and discharge pressures can be achieved with optimal power consumption.

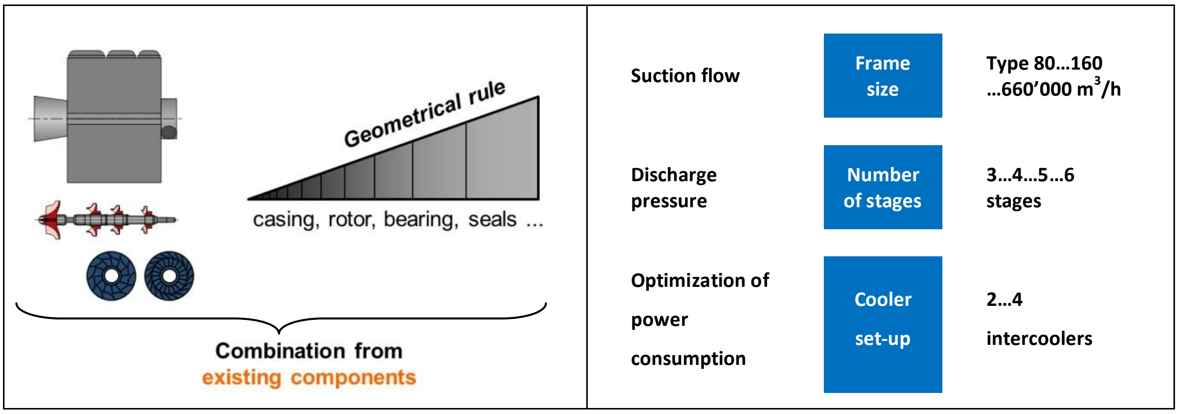
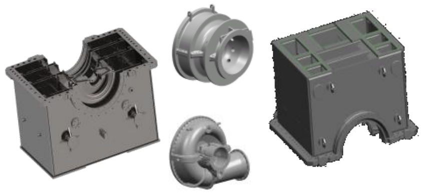


Figure 4.9: Idea of standardization of RIKT

Thereby, the standardization applies not only to the core machine, but also to the auxiliaries, such as the gearbox or the oil system. The full plant is composed modularly. The different modules and their sourcing are shown in figure 4.10.

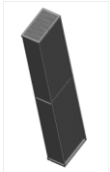
ROTOR
4 standard rotors S,M, L, XL

- MAN Diesel & Turbo Zurich (Switzerland)



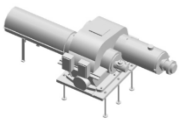
CASING (UPPER / LOWER / INLET CASING, OUTLET SPIRAL)
7 standard sizes 80, 90, 100 ,112, 125, 140, 160

- De Pretto Industries (Italy)
- MAN Diesel & Turbo Changhou (China)



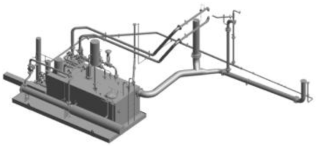
COOLERS
7 standard sizes

- Astra (Italy), GEA (Germany)
- Shuagliang (China)



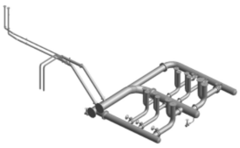
GEARBOX
3 standard sizes 63, 71, 80

- BHS (Germany)



OIL SYSTEM
3 standard sizes SV9

- COES (Italy)
- Huali (China)



PIPING (E.G. FOR COOLING, CONDENSATE) / AUXILIARIES
Standard

- Europe
- China
- India

Figure 4.10: Modular design of RIKT

The standard RIKT provides the customer a ‘functional unit’. In addition, it is possible to choose between "Pre Engineered Options" (parts or components, which have been already designed → low effort) and "Engineering Options" (not yet designed, drawings are not available → greater effort). Both options have an impact on delivery time and cost.

4.2.4 Production situation

The modularization and standardization also simplify a production at several locations. In view of that, the production of the core machine is organized as follows:

- The rotor is fully manufactured at MAN Diesel & Turbo in Zurich (Switzerland).
- The welded casing is produced at two different sites: on the one hand at De Pretto Industrie, whose core competence is the welding of large casings, and on the other hand at MAN Diesel & Turbo's production site in Changzhou (China), which was opened in the end of 2008.
- The coolers are purchased either in Germany, Italy or China and shipped directly to the assembling factories.
- The assembly of the RIKT compressors also takes place either at DPI or at the production site in Changzhou. Here are also carried out final inspections like the pressure test.

4.3 Individual assemblies

This subchapter explains the individual components of a RIKT core machine in more detail. It should give a deeper understanding of the individual assemblies, which are relevant for the later analysis of the serial effect.

4.3.1 Rotor

RIKT compressors are designed with up to six impellers. In order to achieve higher efficiency, the outer diameter of the impellers becomes smaller towards the outlet.

Key data of a RIKT rotor:

- Maximum achievable pressure 22 barg
- Maximum temperature allowed 150 °C
- Distance between bearings 2499 – 3976 mm
- Speed range 3880 – 7200 rpm
- Power range 8.5 – 65 MW

4.3.1.1 Shaft

The shaft is prefabricated from forged bars and delivered by suppliers. The final processing takes place at MAN Diesel & Turbo Zurich. As shaft material, commercially available quenched and tempered steel is used (27NiCrMoV11-6).

4.3.1.2 Impellers

The overhanging impeller of the first stage is milled from solid (figure 4.11).

Figure 4.11: Milling impeller 1st stage

It is vertically centered on the suction side end of the shaft by means of axial pins and is tightened and fastened on the shaft with a tie rod. For aerodynamic reasons, a rounded cover is bolted to the front of the impeller (picture 4.12). Moreover, to avoid too high entry speeds, the surface of the impeller is enlarged by installing recessed intermediate blades.

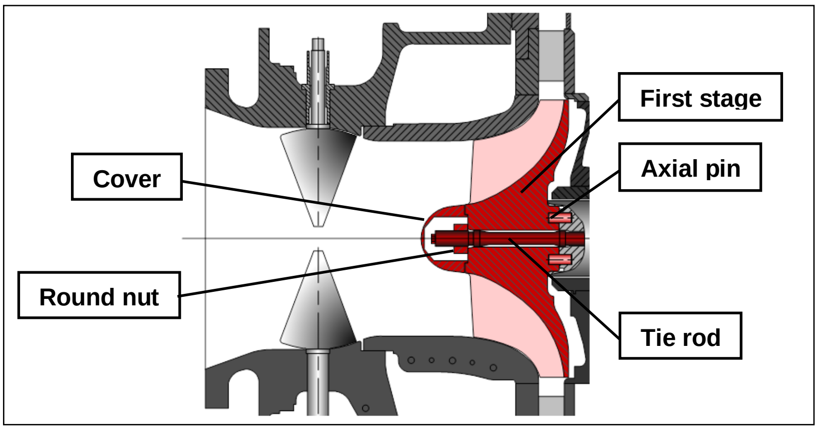


Figure 4.12: Sectional view 1st stage

For the impellers of the following stages, the blades are machined from either the hub or the shroud depending on size and requirements. Afterwards, the blades are welded to the counterpart (hub / shroud). Up to an outside diameter of 475 mm, the impellers are made of tubes. For larger diameters, forged blanks are purchased from suppliers. Then, hubs and shrouds receive their final shape / geometry in machining centers of MAN Diesel & Turbo in Zurich (figure 4.13).

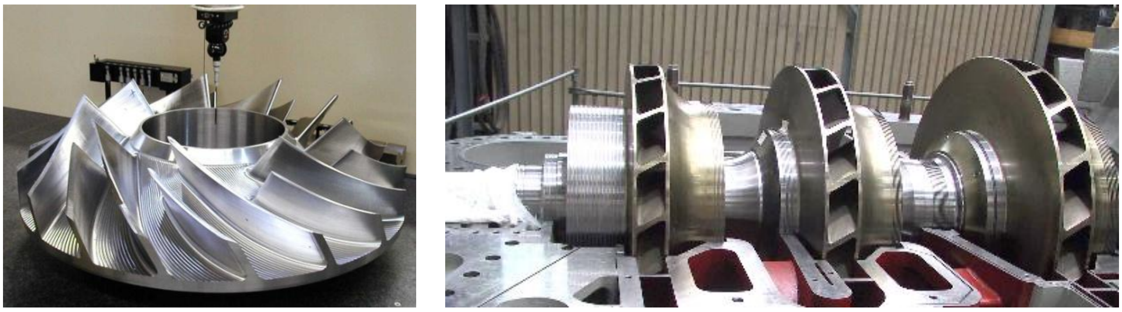


Figure 4.13: Impellers stages 2nd to 4th

4.3.1.3 Labyrinth strips

The labyrinth strips are made of stainless steel (X6CrMo17-1) with a thickness of about 0.3 mm. The J-shaped labyrinth strips are attached with the help of caulking wires in the grooves of the shaft, the balancing piston or the impellers like it is shown in figure 4.14.

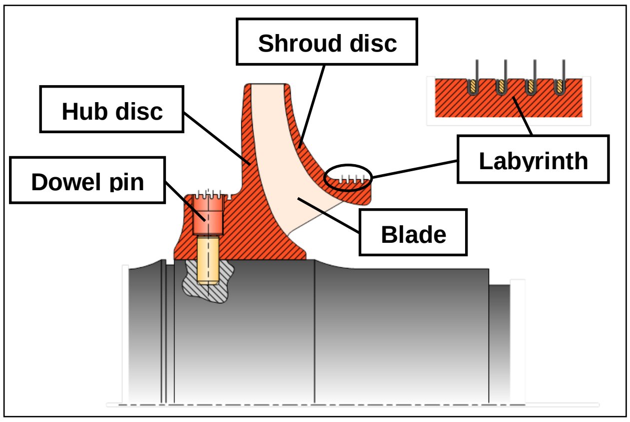


Figure 4.14: Sectional view labyrinth strips

This type of labyrinths have the decisive advantage that on the one hand a deformation of the shaft caused by heat is impossible and on the other hand the heat flux to the rotor is minimal due to the very small surface of the strips. So, only smooth and not stepped labyrinths are used for all RIKT models, because of lower costs and high reliability even for large heat differences between shaft and stator.

4.3.1.4 Bearings

There are two types of bearings used in a RIKT compressor: on the pressure side, the rotor is supported by a journal bearing, whereas it is supported on the suction side by a combined journal-thrust bearing.

The journal bearing is divided horizontally. The two halves are screwed together in the joint face by two bolts on both sides of the shims. Four identical tilting pads are mounted in the bearing housing and are connected with the housing by bolts. The bearing center is adjustable (figure 4.15).

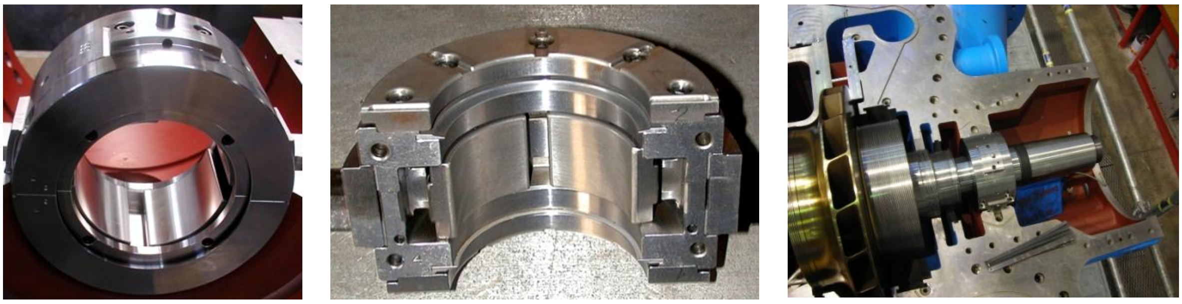


Figure 4.15: Journal bearing

The combined journal-thrust bearing is positioned behind the first impeller to minimize the gap and therefore, losses between the impeller and the channel wall. It is similar to the journal bearing but shows segments for the axial support of the rotor on both end faces (figure 4.16). For each frame size, the dimensions of the combined bearings are specified. But since the required amount of lubricant is dependent on the rotational speed and the axial and radial loads, the nozzle diameters of the oil injections differs.

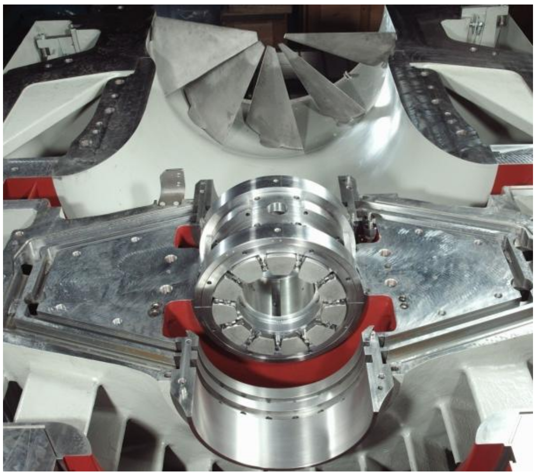


Figure 4.16: Combined journal-thrust bearing and bearing housing

In each RIKT, thermocouples are integrated into the two lower segments of the bearings to monitor the bearing temperature. In the combined journal-thrust bearing, the temperature is also observed in the axial part of the bearing.

4.3.1.5 Balance piston

The balance piston, which is part of the last impeller stage, counteracts the net thrust in the direction of the compressor inlet resulting due to the pressure rise developed through the impeller. The balance piston is made of a forged steel segment ring (piston bushing) with white metal coating and shows a minimum clearance (figure 4.17).

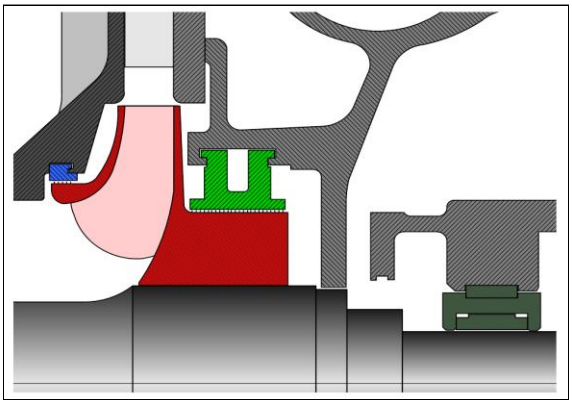


Figure 4.17: Balance piston (green)

4.3.2 <u>Casing</u>

The welded casing of a standard RIKT consists of an upper and a lower part (figure 4.18) and allows a maximum pressure head of 13.6 barg, while one of a high pressure RIKT tolerates up to 22 barg. The casing is designed for temperatures of up to 220 °C.

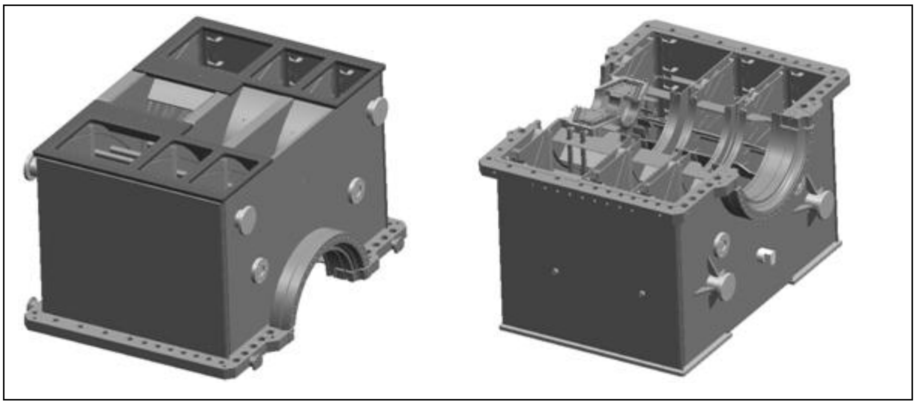


Figure 4.18: Upper (left) and lower (right) casing

4.3.2.1 Inlet casing, prerotation and inlet piece

The inlet casing of the RIKT is composed of a horizontally divided cast construction made of spheroidal graphite iron (EN-JS 1062) (figure 4.19). Through the inlet casing, the medium to be compressed flows into the compressor. Using an annular flange, the inlet casing is releasable fastened to the outer casing.

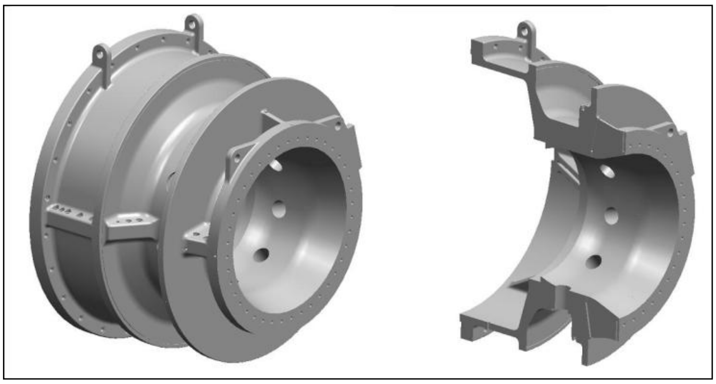


Figure 4.19: Inlet casing without prerotation

The nine to ten blades of the prerotation are integrated into the inlet casing and are symmetrically placed to its circumference (figure 4.20). The opening angles between the individual blades of the prerotation are mechanically adjustable by a servo motor.

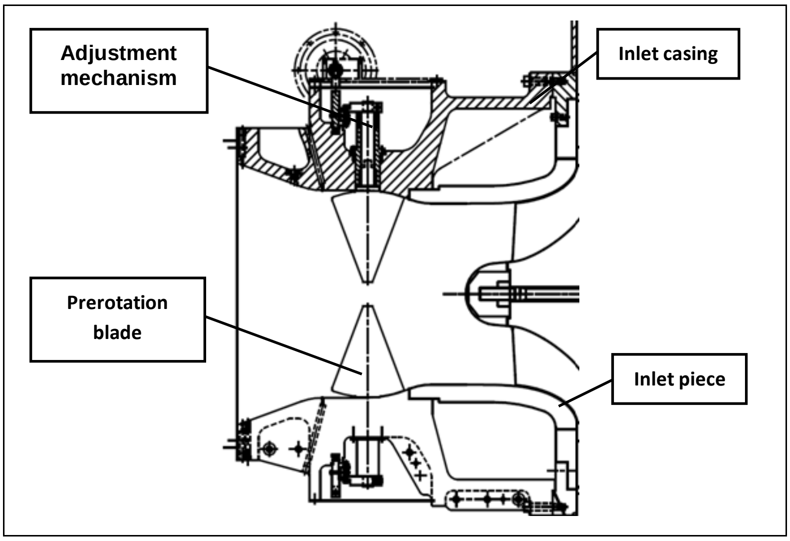


Figure 4.20: Inlet casing and inlet piece

On the one hand, the prerotation should minimize the start torque and thus, the loads on the shaft, couplings, etc. during the start-up of the compressor. On the other hand, during operation, it is used for the process regulation at constant speed.
The blades of the prerotation are molded. For the RIKT 90, the blades are molded in one piece, whereas for all other frame sizes, the blades are molded in two pieces: blades and shafts are produced separately and are welded together afterwards.
Like the inlet casing, the inlet piece is a horizontal divided ring, which is located at the transition from the inlet casing to the first stage (figure 4.21). The inlet piece has to be newly adjusted for each compressor since the impeller of the first stage is deformed during operation depending on factors like peripheral speed, outlet width, and flow volume. To

increase the efficiency of the compressor, the inlet piece has to fit as accurately as possible with the outer contour of the first impeller and the gap between impeller and inlet piece should be minimized.

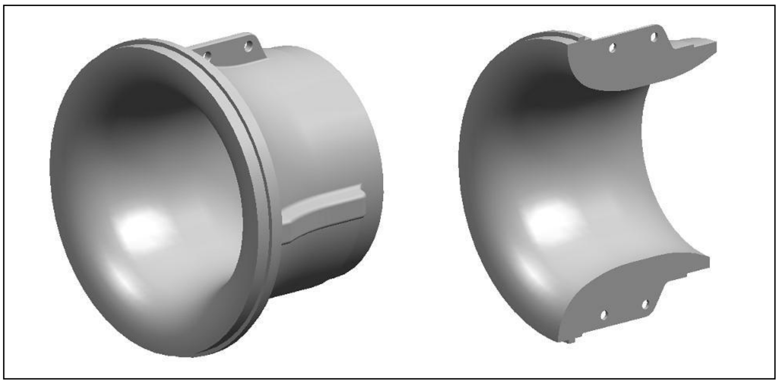


Figure 4.21: Inlet piece

4.3.2.2 Outer casing

The outer casing of the RIKT consists of a horizontally divided weldment made of one of the structural steels S235 JR G2 or S275 JR. Which of both materials is used in each individual case depends on the current market situation and has no technological backgrounds. The main parts of the outer casing are shown in figure 4.22.

Two plates (compressor feet) are bolted laterally at the parting flange of the lower casing. Together with the flange, they are supported and screwed on the foundation. In that way, the compressor feet is able to transmit the forces from the casing to the foundation.

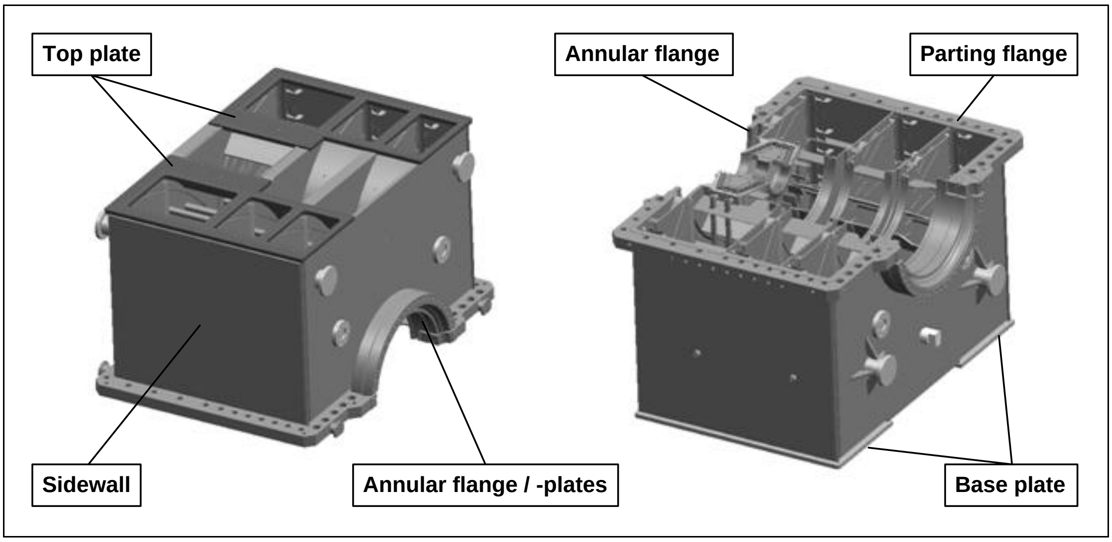


Figure 4.22: Main parts of the outer casing

4.3.2.3 *Inner casing, mounting parts*

The inner casing consists of the following four components, which are closely connected:

- Diffusers are mounted directly behind the impellers and form a fluid dynamic unit with them. Width, diameter and angel of the diffuser blades are designed according to the respective upstream impeller. Diffusers are either milled directly from a steel ring or their blades are manufactured separately and welded between two steel rings.

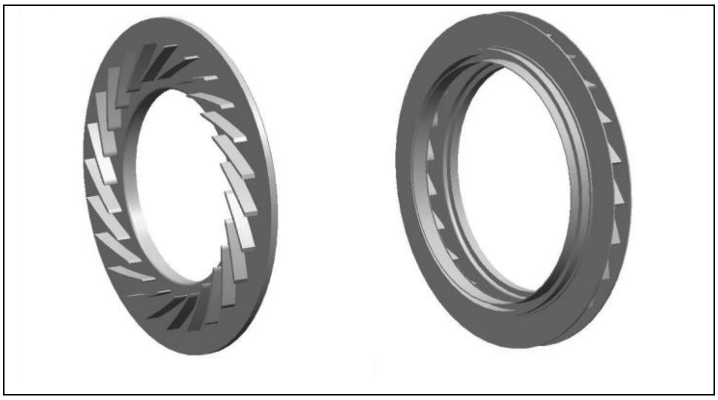


Figure 4.23: Diffuser milled (left) and welded (right)

- Channel walls are made from grey cast iron and are used to pass the medium through the stages. If it exists only one stage behind the last cooler, the channel wall has to be wider and hence, in this case, spheroidal graphite iron is used instead of grey cast iron.

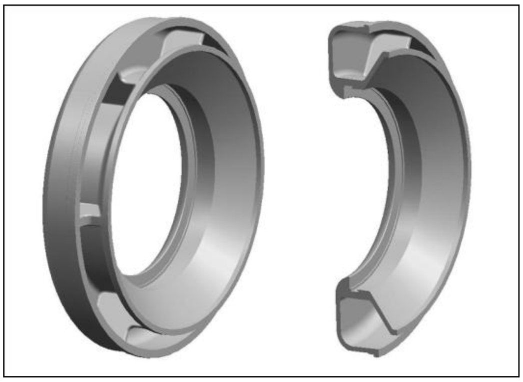


Figure 4.24: Channel wall

- Intermediate walls, which are also made of grey cast iron (EN-JL 1040), are located in front of the impellers and can be equipped with stationary or adjustable prerotation blades. Figure 4.25 shows an intermediate wall with stationary blades.

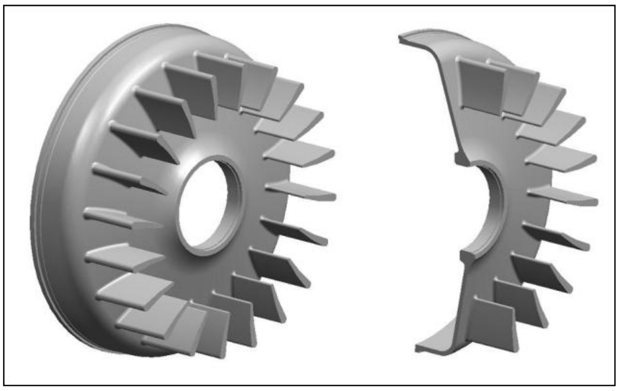


Figure 4.25: Intermediate wall

- The deflecting wall is located behind the second last stage (figure 4.26) and is required in order to achieve higher pressures. Its horizontally parted cast design is made from spheroidal graphite iron (EN-JL 1030) and has fixed prerotation blades. The deflecting wall is screwed or pinned to the channel wall of the last stage.

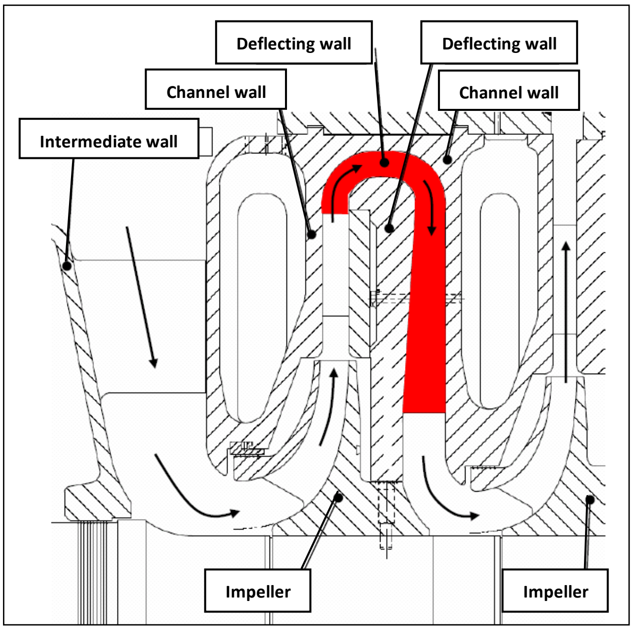


Figure 4.26: Channel, intermediate and deflecting wall

4.3.2.4 Outlet spiral

The outlet spiral is also a two-part construction of spheroidal graphite iron (EN-JS 1062), which is attached on the outer casing by screw connections. Again, the construction has to be parted due to assemblablity of the mounting parts, such like piston bushing or journal bearing.

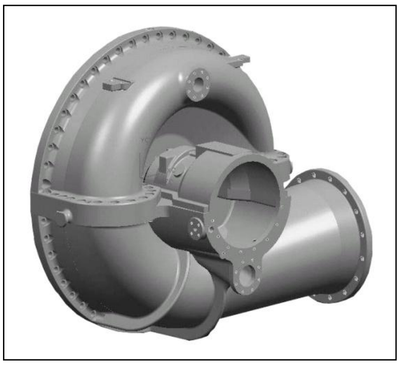


Figure 4.27: Outlet spiral

A welded outlet spiral would also be technically feasible. However, the decisive disadvantage of a weldment would be a softer bearing block and thus would influence the rotor dynamics.

4.3.2.5 Man hole and cooler covers

The man hole cover is located above the combined journal-thrust bearing. It ensures the accessibility of the combined bearing for maintenance at any time. The man hole cover is welded of one of the structural steels S235 JR G2 or S275 JR like the casing itself.

The cooler covers are positioned on the upper casing above every cooler bundle. They are made of spheroidal graphite iron (EN-JS1020) and are screwed on the top and base plate of the outer casing. By disassembling the cooler covers, each cooler bundle can be removed for maintenance even if the compressor casing is closed. Furthermore, the fitting bores inside the cooler covers ensure an accurate placement of the cooler bundles.

4.3.2.6 Bearing housing

The bearing housing of the combined journal-thrust bearing is situated inside the casing on the bearing bracket. It is separately produced, usually made of cast steel (EN 10213-2) and subsequently welded on the casing. The bearing housing containment gives access to the temperature measurements and the jacking oil system. The bearing housing of the journal bearing is integrated in the outlet spiral. Both bearing housings are horizontally divided, the two halves are interconnected by means of a flange.

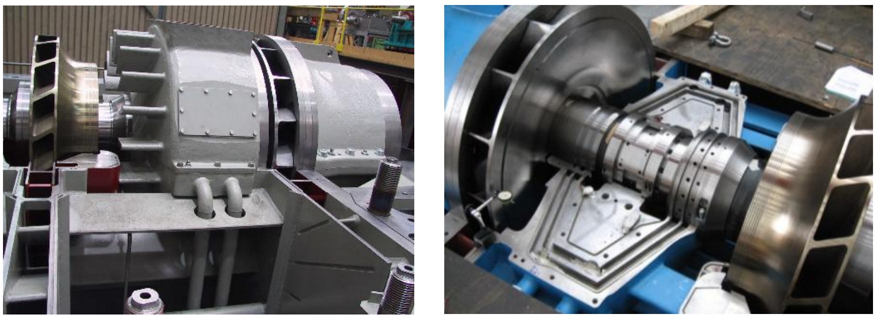


Figure 4.28: Bearing housing

4.3.3 Cooler

RIKT compressors have an internal process air cooling. Normally, one pair of cooler bundles is located between two stages. This is termed as type 1+1+1+1 and means four stages and three pairs of cooler bundles. As mentioned above, other cooling designs are possible. For example, a compressor can be constructed as type 1+1+2. That would mean a four stage compressor with only two coolers. In this case, the last two stages would not be cooled.

The intercoolers of the RIKT are standardized within each frame size. Thereby, they refer wholly to purchased parts, frame agreements are concluded.

4.3.3.1 Cooler bundle

The cooler bundles are screwed with the lower and the upper water chambers. Before the installation, water separators are attached to the cooler bundles. A wire-cloth layer of stainless steel wool is placed between bundle and water separator (figure 4.29). The wire-cloth / mesh reduces the flow velocity of the process air and, furthermore, filters out parts of the condensate before reaching the water separator. The cooler bundles are available with finned tubes or plate fins. They are free for thermal expansion and are easy removable for maintenance.

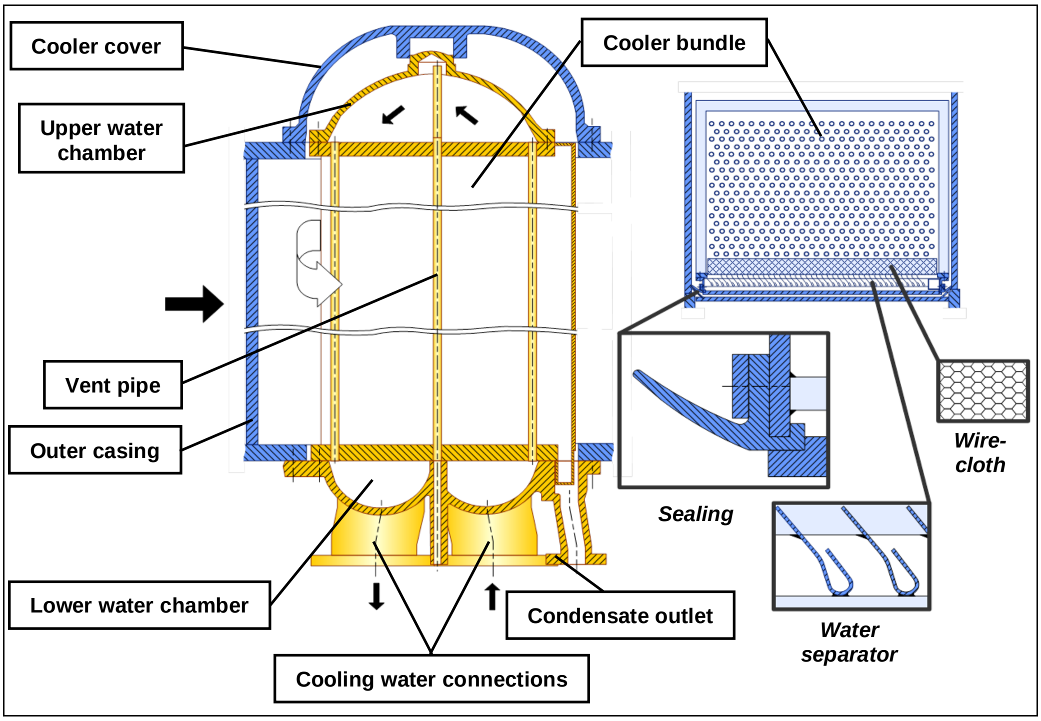


Figure 4.29: Intercooler - 2 water path

With the suppliers of the RIKT cooler bundles, materials have been defined in a design standard:

- Cooling tube material: CuNi10Fe1Mn
- Fins: Al
- Tube bottom / side panels: Carbon Steel
- Corrosion protection: Vendor specific

4.3.3.2 Water chambers

The water chambers are cast constructions made of spheroidal graphite iron (EN-JS1020). There is one lower and one upper water chamber for every cooler bundle. Basically, there are two different types of lower water chambers. The standard model for a two water path cooling or optional one for a four water path cooling, which is needed at lower amounts of cooling water.

For the assembly, the lower water chamber is screwed and pinned directly to the casing. During assembly, the cooler bundle is lifted into the casing, put on the lower water chamber and bolted with them. The upper water chamber is screwed directly with the cooler bundle.

4.3.3.3 Water separators

Due to the increasing compression of the process air and the simultaneously cooling, the saturation limit of air is reached and condensate is formed. The water separators are used to remove this condensate from the process air.

A water separator consists essentially of J-shaped sheets made of stainless steel, which are angular positioned to the flow direction, and a dripping edge. These are screwed directly at the outlet of the cooler bundle. The condensate passes from the lower water chamber through a collector pipe into the condensate outlet

4.4 Bill of materials

The RIKT compressor's bill of materials is a 6-levels bill, with a number of components that is over one thousand. Most of them are purchased, or produced externally in outsourcing; the biggest and most important ones are produced in De Pretto or in MAN.

Here a simplified vision of a bill of materials will be presented, based on the compressor Yutianair 140 produced in 2008-2009 (a 140 size, 4 stages compressor). This compressor will be the base over which all the work has been made.

It is not pointed out the biggest part of the raw materials, such as plates or bolts and nuts, but only the main components. The ones that will be analyzed in the work, as produced by the two companies, are:

- compressor RIKT 140 Yutianair 2008 (DPI);
- rotor, complete RIKT 140 Yutianair 2008 (MAN);
- impeller D 1700-AGD11-165,8 machined/M (MAN);
- impeller D 1500-APD9-120,0 machined/welded/MW (MAN);
- hub D 1500-APD9-120,0 machined/MW (MAN);
- shroud D 1500-APD9-120,0 machined/MW (MAN);
- impeller D 1250-AID8-106,3 machined/welded/MW (MAN);
- hub D 1250-AID8-106,3 machined/MW (MAN);
- shroud D 1250-AID8-106,3 machined/MW (MAN);
- impeller D 1120-ZD10-95,2 machined/welded/MW (MAN);
- hub D 1120-ZD10-95,2 machined/MW (MAN);
- shroud D 1120-ZD10-95,2 machined/MW (MAN);
- machined rotor D 475 X 4993 RIKT 140-4 (MAN);
- round nut m72 x 4 / D144 x 72 (MAN);
- cover RIKT 140 zu D 1700-AGD11 (MAN);
- tie rod M72 x 4 x 908 (MAN);
- transport cap D 440 x 265 for D 1700 (MAN);
- casing, complete RIKT 140 Yutianair 2008 (DPI);
- casing, complete machined RIKT 140 (DPI);
- casing lower part welded RIKT 140 (DPI);
- bearing casing UT RIKT 140 premachined (DPI);
- casing upper part welded RIKT 140 (DPI);
- bearing casing OT RIKT 140 premachined (DPI);
- bracket for bearing housing RIKT 140 premachined (DPI);
- discharge spiral complete machined RIKT 140 (DPI);

- bearing cover machined RIKT 140 (DPI);
- man hole cover RIKT 140 (DPI);
- cooler cover RIKT 140 1st stage machined (DPI);
- cooler cover RIKT 140 2nd stage machined (DPI);
- cooler cover RIKT 140 3rd stage machined (DPI);
- prerotation complete stage 1 RIKT 140 (DPI);
- adjusting ring (prerotation) RIKT 140 (DPI);
- inlet casing RIKT 140 machined (DPI);
- inlet piece RIKT 140 (DPI);
- channel wall complete machined 1050 kg RIKT 140 (DPI);
- intermediate wall complete machined 1031 kg RIKT 140 (DPI);
- channel wall complete machined 1145 kg RIKT 140 (DPI);
- intermediate wall complete machined 836 kg RIKT 140 (DPI);
- channel wall complete machined 2196 kg RIKT 140 (DPI);
- milled diffusor GD11 D1700 (DPI);
- welded diffusor 2nd stage D1500 (DPI);
- welded diffusor 3rd stage D1250 (DPI);
- milled diffusor 4th stage D1120 (DPI);
- intermediate cooler complete 1st stage RIKT 140 (DPI);
- lower water chamber RIKT 140 machined 1st stage (DPI);
- upper water chamber RIKT 140 machined 1st stage (DPI);
- intermediate cooler complete 2nd stage RIKT 140 (DPI);
- lower water chamber RIKT 140 machined 2nd stage (DPI);
- upper water chamber RIKT 140 machined 2nd stage (DPI);
- intermediate cooler complete 3rd stage RIKT 140 (DPI);
- lower water chamber RIKT 140 machined 3rd stage (DPI);
- upper water chamber RIKT 140 machined 3rd stage (DPI);
- casing foot machined RIKT 140 (DPI).

These components are pointed out, in blue the ones of DPI, in red the ones of MAN.

Code	Level	Component	Quantity
10513836	1	Compressor RIKT 140 Yutianair 2008	1
10468918	2.1	Rotor, complete RIKT140 Yutianair 2008	1
10468917	2.1.1	Impeller D 1700-AGD11-165,8 machined/M	1
10468915	2.1.1.1	Hub D 1700-AGD11-165,8 machined/M	1
10457430	2.1.1.1.1	Hub D 1700-GD-11 forged	1
10078090	2.1.1.2	Helicoil thread insert Screw-Lock M16x2	4
10468914	2.1.2	Impeller D 1500-APD9-120,0 machined/welded/MW	1
10468913	2.1.2.1	Hub D 1500-APD9-120,0 machined/MW	1
10468912	2.1.2.1.1	Hub D 1500-APD9 forged	1
10468911	2.1.2.2	Shroud D 1500-APD9-120,0 machined/MW	1
10468910	2.1.2.2.1	Shroud D 1500-APD9 forged	1
10468909	2.1.3	Impeller D 1250-AID8-106,3 machined/welded/MW	1
10468908	2.1.3.1	Hub D 1250-AID8-106,3 machined/MW	1
10457420	2.1.3.1.1	Hub D 1250-AID8 forged	1
10468907	2.1.3.2	Shroud D 1250-AID8-106,3 machined/MW	1
10457418	2.1.3.2.1	Shroud D 1250-AID8 forged	1
10468906	2.1.4	Impeller D 1120-ZD10-95,2 machined/welded/MW	1
10468905	2.1.4.1	Hub D 1120-ZD10-95,2 machined/MW	1
10468904	2.1.4.1.1	Hub D 1120-ZD10 forged	1
10468903	2.1.4.2	Shroud D 1120-ZD10-95,2 machined/MW	1
10468902	2.1.4.2.1	Shroud D 1120-ZD10 forged	1
10468901	2.1.5	Machined rotor D 475 X 4993 RIKT 140-4	1
10468900	2.1.5.1	Shaft forged RIKT 140 rotor XLA	1
832674020631	2.1.5.2	Steel centre RIKT 140 rotor XLA	1
10100094	2.1.6	Dowel pin D 25 x 54	4
10100093	2.1.7	Dowel pin D 22 x 48	8
50031331	2.1.8	Balancing ring Typ 12 DN=605,6	0,4
10066230	2.1.9	Round nut M72 x 4 / D144 x 72	1
10100757	2.1.10	Cover RIKT 140 zu D 1700-AGD11	1
10374695	2.1.11	Tie rod M72 x 4 x 908	1
10468899	2.1.12	Labyrinth strip set rotot RIKT 140-4	1
10100774	2.1.13	Transport cap D 440 x 265 for D 1700	1
10015418	2.1.14	Eye bolt special M48x60	1
10519860	2.2	Casing, complete RIKT140 Yutianair 2008	1
10519804	2.2.1	Casing, complete machined RIKT140	1
10519793	2.2.1.1	Casing lower part welded RIKT 140	1
10519792	2.2.1.1.1	Bearing casing UT RIKT 140 premachined	1
10103606	2.2.1.1.1.1	Bearing casing UT RIKT 140 premachined casted	1
10519771	2.2.1.2	Casing upper part welded RIKT 140	1
10519834	2.2.1.3	Bearing casing OT RIKT 140 premachined	1
10103604	2.2.1.3.1	Bearing casing OT RIKT 140 premachined casted	1
10328631	2.2.1.4	Bracket for bearing housing RIKT 140 premachined	1
10519859	2.2.2	Discharge spiral complete machined RIKT 140	1
50026278	2.2.2.1	Outlet spiral lower RIKT 140 casted	1
50026279	2.2.2.2	Outlet spiral upper RIKT 140 casted	1
10503093	2.2.2.3	Bearing cover machined RIKT 140	1
50026280	2.2.2.3.1	Bearing cover RIKT 140 casted	1
10104579	2.2.3	Man hole cover RIKT 140	1
10104580	2.2.4	Cooler cover RIKT 140 1st stage machined	2
10100134	2.2.4.1	Cooler cover RIKT 140 1st stage casted	1
10090138	2.2.5	Cooler cover RIKT 140 2nd stage machined	2
50026793	2.2.5.1	Cooler cover RIKT 140 2nd stage casted	1
10090140	2.2.6	Cooler cover RIKT 140 3rd stage machined	2
50026794	2.2.6.1	Cooler cover RIKT 140 3rd stage casted	1
10093982	2.2.7	Hub (to be welded) for temperature-detec	2
10108821	2.2.8	Cover for bearing pedestal RIKT 140	1
10108833	2.2.9	Cover lateral for housing pedestal RIKT140	2
10539382	2.3	Prerotation complete stage 1 RIKT 140	1
10300199	2.3.1	Adjusting ring (prerotation) RIKT 140	1
10103979	2.3.2	Prerotation blade RIKT 140 Stage 1	9
10109182	2.3.4	Guide vane bearing D 230/95 X 501	9
10109186	2.3.5	Lever for prerotation 1. Stage	9
10109442	2.3.6	Toggle joint lever complete M14 X 1.5	9
10109567	2.3.7	Prerotation casing (control) RIKT 140	1
10380853	2.3.8	Inlet casing RIKT 140 machined	1
10103972	2.3.8.1	Intlet casing lower RIKT 140 casted	1
10103973	2.3.8.2	Intlet casing upper RIKT 140 casted	1

10325694	2.4		Inlet piece RIKT 140			1
10103974	2.4.1			Half inlet ring RIKT 140 casted		2
10520227	2.5		Channel wall complete machined 1050 kg RIKT 140			1
10471579	2.5.1			Channel half-wall RIKT 140 casted		2
10539066	2.6		Intermediate wall complete machined 1031 kgRIKT 140			1
50026854	2.6.1			Intermediate half-wall RIKT 140 casted		2
10516689	2.7		Channel wall complete machined 1145 kg RIKT 140			1
10516686	2.7.1			Channel half-wall RIKT 140 casted		2
10539549	2.8		Intermediate wall complete machined 836 kg RIKT 140			1
50046216	2.8.1			Intermediate half-wall RIKT 140 casted		2
10381879	2.9		Channel wall complete machined 2196 kg RIKT 140			1
10364199	2.9.1			Channel half-wall RIKT 140 casted		2
10531969	2.10		Milled diffusor GD11 D1700			1
10498530	2.10.1			Half rings forged		2
10519899	2.11		Welded diffusor 2nd stage D1500			1
10532030	2.11.1			Diffusor blade D 1500-26° A=120		26
10519895	2.12		Welded diffusor 3rd stage D1250			1
10532031	2.12.1			Diffusor blade D 1250-25° A=106.3		26
10519891	2.13		Milled diffusor 4th stage D1120			1
10104651	2.14		Shaft seal sleeve SS 2/2 RIKT 140			1
10302736	2.14.1			Shaft seal sleeve SS 480/376x254 115kg		1
10104662	2.15		Shaft seal sleeve DS 2/2 RIKT 140			1
10302737	2.15.1			Shaft seal sleeve DS 480/376x254 85kg		1
10519889	2.16		Intermediate cooler complete 1st stage RIKT 140			2
10101147	2.16.1			Water separator 1st stage RIKT 140 <200°		1
10489271	2.16.2			Wire-cloth separator 2913x1310x64		1
10489273	2.16.3			Wire-cloth separator 2913x1310x64		1
10514477	2.16.4			Coolerbundle 1. Stage RIKT 140		1
10302125	2.16.5			Lower water chamber RIKT 140 machined 1st stage		1
10101377	2.16.5.1				Lower water chamber RIKT 140 casted	1
10302126	2.16.6			Upper water chamber RIKT 140 machined 1st stage		1
10100154	2.16.6.1				Upper water chamber casted RIKT140 1.St.	1
10519888	2.17		Intermediate cooler complete 2nd stage RIKT 140			2
50027247	2.17.1			Water separator 2nd stage RIKT 140 <200°		1
10344708	2.17.2			Knitmesh Demister Type 9001		1
10344709	2.17.3			Knitmesh Demister Type 9001		1
10514485	2.17.4			Coolerbundle 2. Stage RIKT 140		1
10090295	2.17.5			Lower water chamber RIKT 140 machined 2nd stage		1
50027181	2.17.5.1				Lower water chamber RIK 140 casted	1
50026305	2.17.6			Upper water chamber RIKT 140 machined 2nd stage		1
50027251	2.17.6.1				Upper water chamber casted RIKT140 2.St.	1
10519887	2.18		Intermediate cooler complete 3rd stage RIKT 140			2
50027248	2.18.1			Water separator 3rd stage RIKT 140 <200°		1
10344710	2.18.2			Knitmesh Demister Type 9001		1
10344711	2.18.3			Knitmesh Demister Type 9001		1
10514493	2.18.4			Coolerbundle 3. Stage RIKT 140		1
10090296	2.18.5			Lower water chamber RIKT 140 machined 3rd stage		1
50027182	2.18.5.1				Lower water chamber RIK 140 casted	1
50026306	2.18.6			Upper water chamber RIKT 140 machined 3rd stage		1
50027252	2.18.6.1				Upper water chamber casted RIKT140 3.St.	1
10301057	2.19		Sealing air ring D 550/406 X 38 2/2			1
10427431	2.19.1			Half ring air sealing ARI 63 casted		2
10375611	2.20		Casing foot machined RIKT 140			2
10300756	2.21		Scale deal complete			1
50039884	2.21.1			Scale deal		1
50039885	2.21.2			Index for scale deal		1
10303049	2.22		Adapter and probe housing SS-RIKT 140			1
10303050	2.22.1			Support for radial vibration sensors		2
10303051	2.22.2			Support axial probe		2

Table 4.1: simplified bill of materials of a RIKT compressor

4.5 Work cycle analysis

A work cycle is a succession of operations; each of them is made in a specific work center, and requires a certain amount of time to be completed. The work cycles are made by manufacturing technicians in the production office.

Each of the components has, of course, its particular work cycle. Before entering the detailed production analysis, it is necessary a first view of them.

As shown in figure 4.30, are indicated in the work cycle of a piece:

- in the heading: the code, the name and the code of the component, the main product for which it's produced, the name of the technician that wrote it;
- in the text body: the sequence of the operations, and for each of these, its progressive number, the work center identification number, a description of the workings to be done in the work center and the required time.

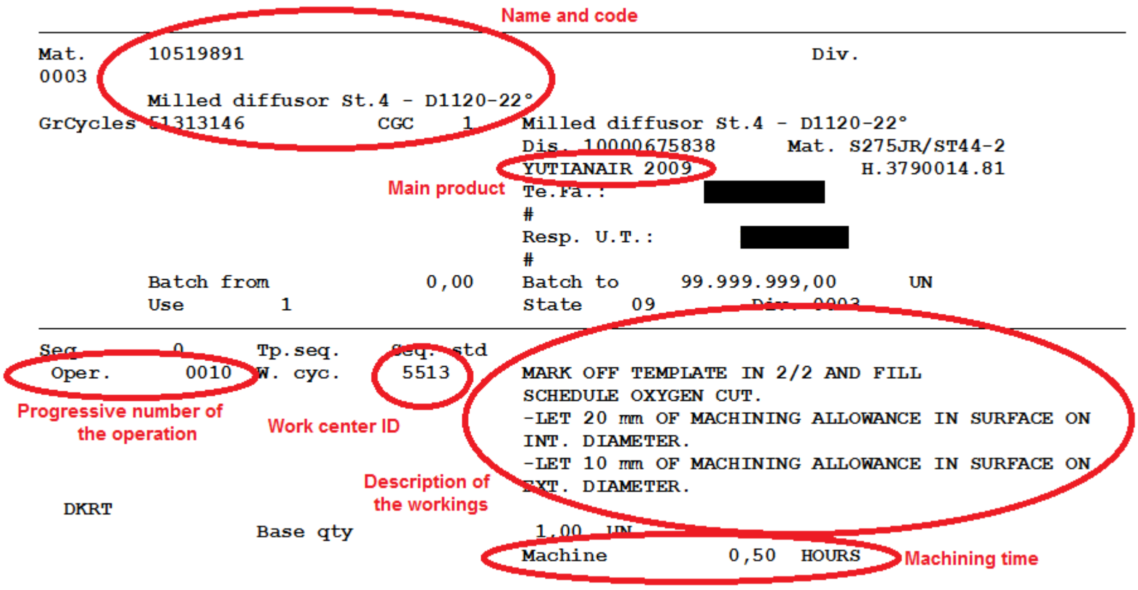


Figure 4.30: example of a work cycle

Now, before the presentation of the work cycles of the analyzed components, it is necessary to introduce the work centers.

4.5.1 <u>Work centers</u>

As work center is intended a big machine, or a part of a department where the same operations are carried out. So, for example, painting and sandblasting are divided into two different work centers, while being part of the same department.

In DPI and in MAN, to every work center is associated a unique identification number. The numerical identification will be adopted, for quickness and convenience, in all the analysis, above all for what concern the machining department.

Here the list of the work centers which will be involved in the study and their ID number is presented.

In De Pretto Industrie:

1501	Non destructive tests
1601	Quality control
2601	Painting
3051	Intermediate assembly
3101	Marking
41012	Medium vertical lathe TV Morando VH20
43012	Medium boring machine AMF Pama 130
44011	Flexible machine Pama Speedmat
46012	Big vertical lathe TV Ceruti
46013	Big vertical lathe TV Morando Phoneix
51012	Big boring machine AMM Pama 140
53011	Big boring machine AMM Pama 180
53012	Big boring machine AMM Colgar Fral 70
53013	Big boring machine AMM Pama 200
5511	Fabrication for welded construction
5513	Fabrication for welded construction
5531	Sandblasting
5601	Forming machines
5602	Forming machines
5701	Manual welding
57511	Robot welding
5901	Heat treatments
6401	Assembly

In MAN:

1501	Testing MT, PT, UT
24003	Allocation cost center external production of small parts PMZET
32402	CNC vertical lathe Comau
32702	CNC machining center DMG
33103	Boring machine Pama Speedmat
33202	Boring machine Pama
33312	Boring machine Schiess
33504	CNC vertical lathe Carnaghi
33603	Lathe Gigant
33604	Stator manufacturing
35301	Rotor manufacturing
35401	Low speed balancing
35901	Dimensional control / measurement
35902	Dimensional control / measurement
36301	Impeller metalwork
36402	CNC lathe Wohlenberg
36605	Shaft turning between centers
36801	Big spin system
43321	Painting
44102	Assembly core machine
66109	Shaft manufacturing turning / grinding

4.5.2 Work cycles

The sequence of the work centers, associated with the hours needed for the operations in them to be completed, gives a fast vision of the work cycle of a component.
As production in general is the main company department involved in RIKT's fabrication, as the one with the biggest hour need, it is important to point out the work cycle of every component; moreover, this is fundamental in further analysis, such as in the production's one.

The cycles have been simplified in a table, where are shown the needed work centers, the hours requested in each of them and if there is some machining requirement.
The detailed view of machining requirements in the cycle, with the indication of the set-up time, the machining time, and the number of positionings, is important for the future set-up reduction analysis. In fact, while there is no possible improve in machining time (except with improvements of the machine itself, and this falls outside the context of this thesis), there can be some in set-up time in series production. There is a set-up time for every positioning; but, for simplicity and immediacy in the vision of data, it has been decided to merge the set-up times, and not keep them divided for every positioning. It has been verified that this does not have an influence; this however will be remind furthermore in the work.

Here the tables of the work cycles of the components of interest produced in DPI are presented, while the ones produced in MAN will be in Annex 1.

Compressor RIKT 140

Work centers	Hours
6401	420
6401	2
1601	0
Needs of machining:	NO

Casing complete

Work centers	Hours
6401	160
5531	21
2601	86
5531	1
2601	1
1601	0
Needs of machining:	NO

Tables 4.2 – 4.3: compressor RIKT 140 and casing complete work cycle

Casing complete machined

Work centers	Hours
3101	14,5
53013	367,7
1601	0
3051	0
6401	25
53013	94
1601	0
6401	12
3051	0
2601	17
5511	65
5701	80
6401	70,25

Needs of machining:	YES
Work center	53013
Set-up time	24
Machining time	343,7
Number of positionings	4
Work center	53013
Set-up time	4
Machining time	90
Number of positionings	1

Tables 4.4 - 4.5: casing complete machined work cycle

Bearing house OT premachined

Work centers	Hours
3101	5
44011	9
5701	16
5531	0,6
2601	1,5
44011	29,5
1601	0
3051	5,5

Needs of machining:	YES
Work center	44011
Set-up time	1,25
Machining time	7,75
Number of positionings	2
Work center	44011
Set-up time	1,25
Machining time	28,25
Number of positionings	2

Tables 4.6 - 4.7: bearing house OT premachined work cycle

Bearing house UT premachined

Work centers	Hours
3101	4,5
44011	16
1601	0

Needs of machining:	YES
Work center	44011
Set-up time	1,25
Machining time	14,75
Number of positionings	2

Tables 4.8 - 4.9: bearing house OT premachined work cycle

Casing lower part welded

Work centers	Hours
Internal parts working	613,25
External production	-
5513	20,25
5601	30
5511	6,5
5602	10
5531	26
5511	217
5701	329
57511	75
5701	79
5511	48,5
5701	79
1501	50
External heat treatment	20 working days
5701	36,5
5531	22
1501	0
5531	43
2601	95
1601	0
Needs of machining:	YES
Work center No series effect	57511

Casing upper part welded

Work centers	Hours
Internal parts working	613,25
External production	-
5513	20,25
5601	30
5511	6,5
5602	5
5531	26
5511	172
5701	286
57511	75
5701	79
5511	48,5
5701	79
1501	50
External heat treatment	20 working days
5701	20,25
5531	22
1501	0
5531	43
2601	95
1601	0
Needs of machining:	YES
Work center No series effect	57511

Tables 4.10 - 4.11: casing lower and upper part welded work cycle

Bracket for bearing house premachined

Work centers	Hours
5511	0,6
5601	1,5
5901	1,5
5531	0,5
2601	1,5
44011	15
1601	0
3051	4
Needs of machining:	YES
Work center	44011
Set-up time	0,5
Machining time	14,5
Number of positionings	1

Cover for bearing house

Work centers	Hours
5531	1
2601	1,5
3101	2
43012	14
1601	0
3051	0
6401	4,5
5531	1
2601	3
Needs of machining:	YES
Work center	43012
Set-up time	1,5
Machining time	12,5
Number of positionings	2

Tables 4.12 – 4.13: bracket and cover for bearing house work cycle

Discharge spiral

Work centers	Hours
1601	0
5531	3
2601	4
3101	9
53012	96
1601	0
3051	7
51012	8
46012	38,4
1601	0
6401	23
5531	6
2601	12
6401	14

Needs of machining:	YES
Work center	53012
Set-up time	5
Machining time	91
Number of positionings	3
Work center	51012
Set-up time	1,5
Machining time	6,5
Number of positionings	1
Work center	46012
Set-up time	10
Machining time	28,4
Number of positionings	2

Tables 4.14 – 4.15: discharge spiral work cycle

Man hole cover

Work centers	Hours
5513	1
5601	2
5602	5
5511	6
5701	10
5511	2
1501	0
5531	1,5
2601	2
43012	11
6401	2
2601	4
Needs of machining:	YES
Work center	43012
Set-up time	1,5
Machining time	9,5
Number of positionings	1

Cooler cover 1st stage machined

Work centers	Hours
5531	0,5
2601	0,6
44011	8,5
1601	0
6401	2
5531	0,5
2601	1,8
6401	0,5
Needs of machining:	YES
Work center	44011
Set-up time	1
Machining time	7,5
Number of positionings	2
Total quantity of pieces	2

Tables 4.16 – 4.17: man hole cover and cooler cover 1st stage work cycle

Cooler cover 2nd and 3rd stage machined (same work cycle)

Work centers	Hours
5531	0,5
2601	0,6
44011	7,5
1601	0
6401	2
5531	0,5
2601	1,8
6401	0,5

Needs of machining:	YES
Work center	44011
Set-up time	1
Machining time	6,5
Number of positionings	2
Total quantity of pieces	2 each

Tables 4.18 – 4.19: cooler cover 2nd and 3rd stage work cycle

Intermediate cooler 1st, 2nd and 3rd stage (same w. c.)

Work centers	Hours
6401	27,6
1601	0
6401	0
3151	3,5
6401	2,5
Needs of machining:	NO
Total quantity of pieces	2 each

Prerotation complete

Work centers	Hours
6401	57,5
2601	8
Needs of machining:	NO

Tables 4.20 – 4.21: intermediate cooler 1st, 2nd and 3rd stage and prerotation complete work cycle

Adjusting ring

Work centers	Hours
5513	1
5601	1,5
5901	2
5602	1,5
53012	29
3051	2,5
46013	9
1601	0
6401	1,5
5531	1,5
2601	4
6401	8

Needs of machining:	YES
Work center	53012
Set-up time	2,5
Machining time	26,5
Number of positionings	4
Work center	46013
Set-up time	1
Machining time	8
Number of positionings	1

Tables 4.22 – 4.23: adjusting ring work cycle

Inlet casing machined

Work centers	Hours
1601	0
5531	5
2601	8
3010	9
53011	31,7
3051	6
46013	12
53012	7,7
3051	1,75
53012	12
3051	5
53012	5,7
46013	25,9
53012	57,6
3051	3
1601	0
3101	1
6401	30
5531	5
2601	15

Needs of machining:	YES
Work center	53011
Set-up time	2,5
Machining time	29,2
Number of positionings	4
Work center	46013
Set-up time	1,5
Machining time	10,5
Number of positionings	1
Work center	53012
Set-up time	1,5
Machining time	6,2
Number of positionings	1
Work center	53012
	,
Set-up time	1,5
Machining time	10,5
Number of positionings	2
Work center	53012
Set-up time	1
Machining time	4,7
Number of positionings	1
Work center	46013
Set-up time	2
Machining time	23,9
Number of positionings	2
Work center	53012
Set-up time	2,5
Machining time	55,1
Number of positionings	3

Tables 4.24 – 4.25: inlet casing work cycle

Inlet piece

Work centers	Hours
5531	0,8
2601	2
3101	4,5
44011	17
3051	3
41012	21,5
3051	1,7
43012	4
3051	2
43012	2
41012	21,5
1601	0
3051	1,7
44011	4,5
6401	2,75
5531	1,6
2601	8
6401	0
41012 (eventual)	1
2601	1

Needs of machining:	YES
Work center	44011
Set-up time	2,5
Machining time	14,5
Number of positionings	4
Work center	41012
Set-up time	1
Machining time	20,5
Number of positionings	1
Work center	43012
Set-up time	1
Machining time	3
Number of positionings	2
Work center	43012
Set-up time	1
Machining time	1
Number of positionings	1
Work center	41012
Set-up time	1,5
Machining time	20
Number of positionings	2
Work center	44011
Set-up time	0,5
Machining time	4
Number of positionings	1
Work center (eventuale)	41012
Set-up time	1
Machining time	1
Number of positionings	1

Tables 4.26 – 4.27: inlet piece work cycle

Channel walls 1050 and 1145 kg machined (same work cycle)

Work centers	Hours
5531	1,25
2601	1,5
3101	3,5
43012	12,5
46013	23,5
1601	0
6401	2,5
5531	2,25
2601	4,5
Needs of machining:	YES
Work center	43012
Set-up time	1,5
Machining time	11
Number of positionings	2
Work center	46013
Set-up time	1,5
Machining time	22
Number of positionings	2

Channel wall 2196 kg machined

Work centers	Hours
5531	1,25
2601	1,5
3101	3,5
51012	17
46013	23,5
1601	0
6401	2,5
5531	2,25
2601	4,5
Needs of machining:	YES
Work center	51012
Set-up time	1,5
Machining time	15,5
Number of positionings	2
Work center	46013
Set-up time	1,5
Machining time	22
Number of positionings	2

Tables 4.28 – 4.29: channel walls machined work cycle

Intermediate walls 1031 and 836 kg machined (same work cycle)

Work centers	Hours
5531	1
2601	1,5
3101	3,5
43012	18
46013	19
1601	0
6401	3,5
5531	2
2601	4,5

Needs of machining:	YES
Work center	43012
Set-up time	3,5
Machining time	14,5
Number of positionings	6
Work center	46013
Set-up time	1,5
Machining time	17,5
Number of positionings	2

Tables 4.30 – 4.31: intermediate walls machined work cycle

Milled diffusor GD 11

Work centers	Hours
1601	0
51012	4
46013	23
51012	60
46013	18
1601	0
6401	4
5531	3
2601	5,5
Needs of machining:	YES
Work center	51012
Set-up time	0,75
Machining time	3,25
Number of positionings	2
Work center	46013
Set-up time	1,5
Machining time	21,5
Number of positionings	2
Work center	51012
Set-up time	2,75
Machining time	57,25
Number of positionings	4
Work center	46013
Set-up time	1
Machining time	17
Number of positionings	1

Milled diffusor 4^{th} stage

Work centers	Hours
5513	0,5
5601	1,4
5901	3
5602	0,6
43012	3
46013	16
44011	35,75
1601	0
6401	2,5
5531	3
2601	5
6401	0
46013	6
1601	0
Needs of machining:	YES
Work center	43012
Set-up time	0,75
Machining time	2,25
Number of positionings	2
Work center	46013
Set-up time	1,5
Machining time	14,5
Number of positionings	2
Work center	44011
Set-up time	2,75
Machining time	33
Number of positionings	4
Work center	46013
Set-up time	1
Machining time	5
Number of positionings	1

Tables 4.32 – 4.33: milled diffusors work cycle

Welded diffusors 2nd and 3rd stage

Work centers	Hours
5513	3,5
5601	3
5602	6
5531	2
5511	53
5701	25,4
5901	3
5511	10
5701	4
5531	3
2601	2
3101	4
53012	24
46013	14
1601	0
6401	7
2601	5

Needs of machining:	YES
Work center	53012
Set-up time	1
Machining time	23
Number of positionings	4
Work center	46013
Set-up time	1
Machining time	13
Number of positionings	2

Tables 4.34 – 4.35: welded diffusors work cycle

Lower water chambers 1st, 2nd and 3rd stage (same work cycle)

Work centers	Hours
5531	0,75
2601	1,5
3101	2,5
44011	14,2
1601	0
6401	5,5
5531	1,5
2601	3
Needs of machining:	YES
Work center	44011
Set-up time	1
Machining time	13,2
Number of positionings	2
Total quantity of pieces	2 each

Upper water chambers 1st, 2nd and 3rd stage (same work cycle)

Work centers	Hours
5531	0,75
2601	1,25
44011	9
1601	0
6401	2
5531	1,5
2601	2,75
Needs of machining:	YES
Work center	44011
Set-up time	1
Machining time	8
Number of positionings	2
Total quantity of pieces	2

Tables 4.36 – 4.37: lower and upper water chambers work cycle

Casing foot machined

Work centers	Hours
5513	0,25
5601	1,5
5511	4
5701	3,5
1501	0
5901	3
5511	1
5531	1
2601	1,25
53012	17
1601	0
6401	2,5
5531	0,5
2601	3

Needs of machining:	YES
Work center	53012
Set-up time	1
Machining time	16
Number of positionings	1
Total quantity of pieces	2

Tables 4.38 – 4.39: casing foot work cycle

CHAPTER 5

Actual state in RIKT production

Here the main part of the work will begin. In this chapter, the RIKT production as it is now in the two companies is analyzed in every part, from its start to the end. There will be an explanation of how the 5 mentioned before departments (engineering, project management, purchasing, production, quality) work; then, there will be the presentation of how they are involved in RIKT production, with an analysis of the costs related to them.

As "actual state", the production of one RIKT compressor at a time is intended; in this sense, even when two or more compressors are wanted, they are always produced one after the other. This has the same meaning also for the other departments beside production: engineering, project management and purchasing are intended to work on the first compressor, than on the second one, and so on.

A very important thing to be pointed out is that everything in this work is calculated under the hypothesis of an empty workshop and an ideal situation. This means, that there is no excess warehouse at the beginning, there aren't problems in the best possible use of machines (no other products to be realized), no delays.

5.1 Engineering

Purpose and site of operation determine the design of the final RIKT. Design engineers calculate the compressor based on these requirements in close cooperation with the departments of aero-, rotor-, and thermodynamics. Even though RIKT compressors are highly standardized products, costumer specific modifications are necessary. For example casing assemblies, such as the inlet piece and the diffusors, have to be redesigned for each RIKT.

Engineering can be distinguished in basic, detail and rotor engineering. Basic and rotor engineering always take place at MAN in Zurich. The detail engineering, i.e. the creation of drawings or the bill of materials, can be done either at MAN or at De Pretto Industrie.

The extent of hours for engineering is limited for RIKT compressors. This number includes the implementation of all necessary design calculations, drawings and specifications, the preparation of the bill of materials and material selection. The hours, which are needed for the design of a RIKT core machine, are listed below. They are not related to the frame size of the RIKT, but vary with the type of order.

- Single RIKT, with standard rotor: 260 h
  - Basic engineering 100 h
  - Detail engineering 100 h
  - Rotor 60 h

- Single RIKT, completely new designed: 580 h
  - Basic engineering 200 h
  - Detail engineering 260 h
  - Rotor 120 h

In this work, only standard RIKTs are examined in terms of serial effects, which it means 260 hours for the engineering of a RIKT in single production.

5.2 Project management

Generally speaking, the task of project management is to bring in line the provided service with the related costs and deadlines. Special attention must be paid to ensuring that the performance (quality and quantity) is maximized and, in addition, the consumption of resources (time, personnel capacities and money) is minimized (figure 5.1)

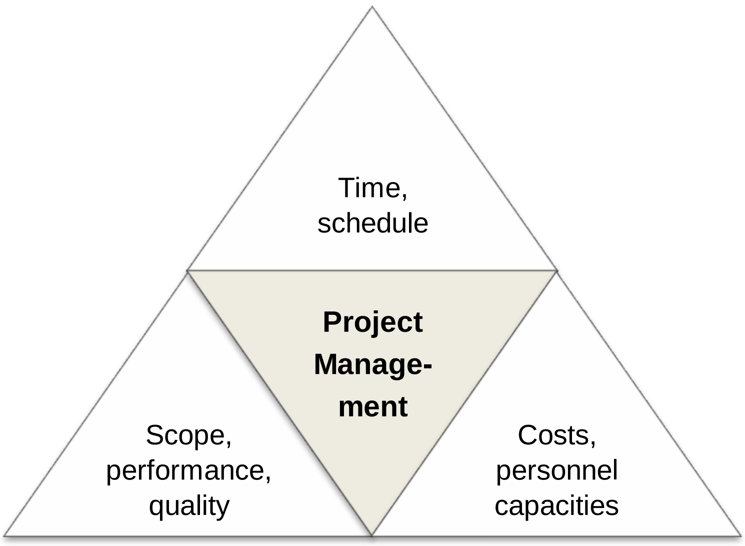


Figure 5.1: Triple constraint

For all RIKTs, the project management is situated exclusively within MAN Diesel & Turbo and includes the complete order processing, starting from the beginning of the project. It is based on the results of the bid management, i.e. technical and commercial details have already been defined in contract negotiations. The responsibility ends with the handover of the project to PrimServ, MAN's technical field service.

Thus, the project management includes the supervision of engineering, production and works assembly, purchasing, shipping, site assembly and the final acceptance from the customer. Figure 5.2 shows the classification of the project management in accordance with OPUS 2.0 (Optimierte Prozesse und Systeme, in engl. Optimised Processes and Systems), the process management system of the SBU Turbomachinery and the BU PrimeServ Turbo.

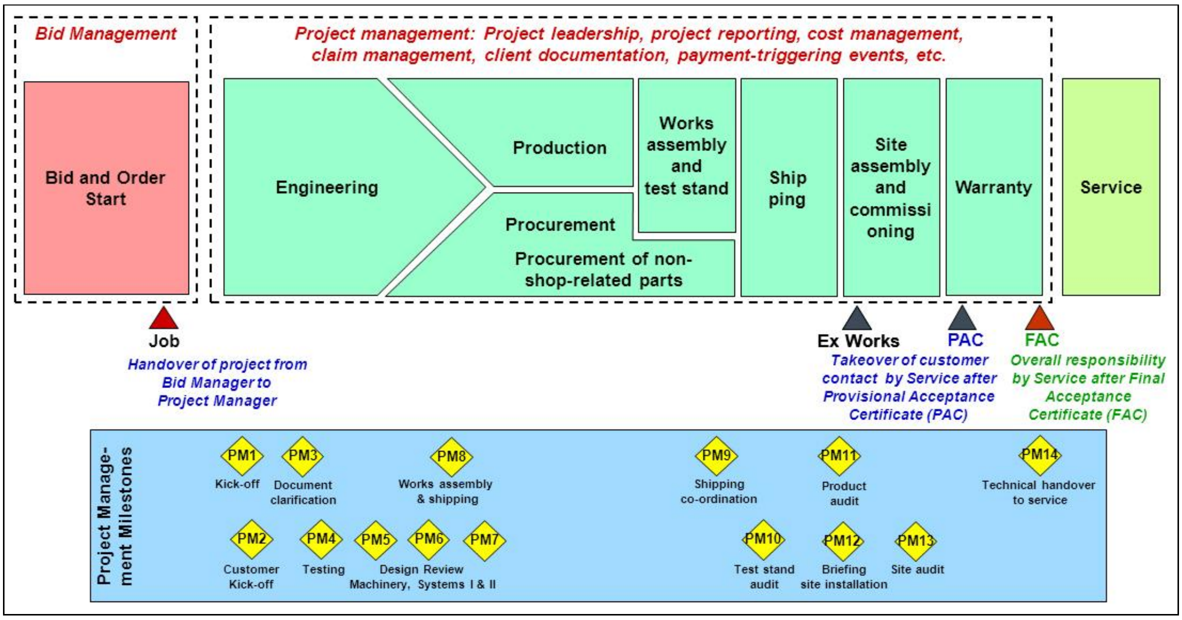


Figure 5.2: Overview of project management milestones

The responsibility of the project management is further illustrated in table 5.1 by means of short descriptions of the individual milestones.

Designation		Content of the task
PM1	Project kick-off	Information to all involved in the project regarding the project, based on a reliable, secure basis on start of order
PM2	Customer kick-off meeting	Project start meeting with customer

PM3	Document clarification	Detailed clarification regarding the area of documentation: Scope, scheduling, creation
PM4	Testing	Clarification of details for preparations for testing of machine / system
PM5	Design review machine	Design review with focus on the machine after completion of basic machine design
PM6	Design review systems 1	Design review with focus on systems engineering and integration of the overall system after completion of the basic system design
PM7	Design review systems 2	Design review with focus on Instrumentation & Controls after completion of basic design I&C Organizational clarification of the construction site.
PM8	Assembly and dispatch coordination	Detailed clarification of aspects affecting assembly (and disassembly) and shipping
PM9	Shipment coordination	Detailed clarification of shipping issues for shipping preparation
PM10	Test center audit	Gathering and feedback of unusual features during test runs to design
PM11	Product audit	Elimination of last errors immediately before shipping and feedback of errors into the Q control loop
PM12	Briefing – Field Service personnel	Briefing of personnel involved in Technical Field Service regarding the project
PM13	Site audit	Elimination of last errors immediately before commissioning of system and feedback of errors into the Q control loop and ISD
PM14	Remaining work and archiving	Handover of machine data, purchasing documents, calculations, design and technical documentation.

Table 5.1: Description of project management milestones

Stated below are the amounts of hours, which can be used as a basis for the project management of a single RIKT. Again, the amounts vary with the type of order, but are independent on the frame size of the RIKT.

- Single RIKT Standard 350 h
- Single RIKT 500 h
- RIKT Airtrain 1.300 h
  (with steam turbine and booster)

As already specified, only the standard type is investigated in the analysis of serial effects, which means 350 hours for the project management of a RIKT in single production.

5.3 Purchasing

In this case, there is a division between the purchasing departments in MAN and DPI. In fact, each of the companies has to manage the purchasing of its own components. Nevertheless, there is also a relation between them: some components (in particular the castings) are bought by MAN and provided to DPI as free supply.
However, the behavior of the two departments is almost the same; it will be analyzed specifically the case of DPI, while data related to MAN will be explained in annex 3.

5.3.1 Purchasing in DPI

The purchasing department deals with raw materials supplying. It must find suppliers and manage contacts with them, generating purchasing orders in such a way that allows having at disposal the materials in the moment they are required.

From its suppliers, DPI requires:

- a constantly high level of quality;
- efficient logistics;
- internationally competitive prices
- the drive and capacity for innovation and technical creativity;
- entrepreneurial flexibility.

The suppliers benefit from:

- competitive advantages resulting from technical collaboration;
- partnerships with mutual advantages;
- a growing volume of orders within the context of a reliable and long-lasting business relationship;
- references for their sphere of influence in international marketing.

Entering more in details in internal management, De Pretto Industrie manages the materials by dividing them in 3 typologies: ROH, HAWA and HALB. The first two refer to standard materials, which can be found in the suppliers' catalogue. The third one instead marks components which are realized externally (so, purchased), but which are based on internally realized drawings. This difference will be important later in the work, speaking about discounts.

Another distinction occurs in the pieces purchasing management: in fact, while some are managed by the warehouse (and so don't depend directly from the project – above all they are ROH pieces), and they are purchased in high quantities, others are required exclusively for the ongoing project, and they are purchased exactly in the quantity required by the project itself (above all, but not only, HALB parts).

Speaking about costs, there can be identified two typologies of them: order cost and material's cost. The first one comprehends all the administrative expenses of the order's ejection, while the second one concerns the effective cost of the purchased material. It has been calculated that, on average, the order cost in DPI is 100 €; while, obviously, the material's cost vary from order to order.

Reminding the hypothesis of empty workshop, and so the necessity of purchasing every single component, the analysis showed that at least 48 orders are required to buy every part needed for the production of one RIKT. Some of these orders will be shown in details here below; for the others, there will be the reference in annex 2. In this same annex, the list of all the components will be found, with their code (always referring to Yutianair compressor), quantity, internal type of component, the total cost for one compressor and the order number.

The analysis is structured in two tables for each order; in the first one there are the data of the pieces (keep in mind that the cost is for one RIKT, so for the quantity indicated in the third column); in the second one, the costs. Every order has a different structure of costs; there will be presented some of them, the most characteristic ones. N indicates the number of compressors.
It is shown the "actual state", as stated at the beginning of the chapter.

<u>Order 1</u>

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Threaded rod DIN 975 M10 x 70	10066057	2	UN	ROH	2,4	2
Hub (to be welded) 1/2"G	10075918	5	UN	ROH	41	50
Washer special for M20	10303019	6	UN	HALB	54	6
Jacking screw M36 x 120	10072369	2	UN	HALB	90	2
Jacking screw M56x4 x L=200 DIN561 FormB	10462075	4	UN	HALB	240	4
Cheese-head bolt M 20x80 w. locking	50050890	4	UN	HALB	14,72	4

Order 1			
	Single production		
N	Order cost	Total material cost	Total cost
1	100	811,12	911,12
2	200	1212,24	1412,24
3	300	1613,36	1913,36
4	400	2014,48	2414,48
5	500	2415,6	2915,6
6	600	2816,72	3416,72
7	700	3217,84	3917,84
8	800	3618,96	4418,96
9	900	4020,08	4920,08
10	1000	4421,2	5421,2

Tables 5.2 – 5.3: order number 1

The cost of this order grows up proportionally with the number of compressors for every part except for the hub: in fact, it is purchased in 50 pieces at a time. So, its total cost will directly impact on the 1st compressor for all the 50 pieces; then, it will be split between 2, 3, 4 compressors, and so on.

The formula used in the material cost of this order is the following:

$$N*(2,4+54+90+240+14,72)+(41/5)*50$$

as the 50 hubs cover the requirements for 10 RIKTs (so there is not the needing of more hubs), while the other costs, as just said, grow in direct proportion with N.

<u>Order 2</u>

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Hexagon nut DIN 934 M 36	10011359	4	UN	ROH	10,48	100
Stop plate DIN 432 for M 8 galvanized	10011829	1	UN	ROH	2	1
Stop plate for M10 UNI 6601	10303056	4	UN	HALB	8	4
Stop plate for M8 (DIN 93 invalid)	10011998	28	UN	ROH	5,88	100
Stop plate for M16 (DIN 93 invalid)	10013545	2	UN	ROH	3,2	50
Stop plate UNI 6601for M16	10302922	2	UN	ROH	3,36	2
Tab washer D 10,5-A4 (DIN 93 invalid)	10010068	28	UN	ROH	6,86	100
Spring pin ISO 8752 D 3 x 12	10015620	1	UN	ROH	0,02	19

Order 2			
	Single production		
N	Order cost	Total material cost	Total cost
1	100	401,35	501,35
2	200	414,71	614,71
3	300	428,07	728,07
4	400	487,03	887,03
5	500	500,39	1000,39
6	600	513,75	1113,75
7	700	527,11	1227,11
8	800	586,08	1386,08
9	900	599,44	1499,44
10	1000	612,80	1612,80

Tables 5.4 – 5.5: order number 2

This order is a little bit more complicated: in fact many components are not proportional with the number of compressors. Moreover, some parts are bought in number greater than what it is needed, and some others, although purchased in big batches, need a second batch to be bought to complete the 10 compressors.

So, the formula for the material cost is:

if N =<3, (2+8+3,36)*N+(5,88+6,86)/28*100+0,02*19+10,48/4*100+3,2/2*50
if 4=<N=<7, (2+8+3,36)*N+(5,88+6,86)/28*100*2+0,02*19+10,48/4*100+3,2/2*50
if 8=<N=<10, (2+8+3,36)*N+(5,88+6,86)/28*100*3+0,02*19+10,48/4*100+3,2/2*50

as the costs of the stop plates DIN 432, for M10 and for M16 UNI 6601 are proportional with N, the stop plate for M8 and the tab washer are bought in batches of 100 (while needing 28, and so, there is the necessity of purchasing another batch after the 3^{rd} compressor and another one after the 7^{th}), the spring pin in batch of 19, the hexagon nut and the stop plate for M16 in batches of 100 and 50 while needing 4 and 2.

<u>Order 7</u>

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Hexagon nut DIN 439 B M20 x 1,5 LEFT	10013523	1	UN	ROH	0,73	1
Hexagon nut DIN 439 B M24 x 1,5	10089701	1	UN	HALB	0,78	1
Cyl. head screw ISO4762 M12x35	10012403	6	UN	ROH	0,53	100
Socket head screw ISO 4762 M16 x 80/44	10014349	288	UN	ROH	106,56	1000
Cheese-head bolt ISO 4762 M16 x 180/44	10014351	90	UN	ROH	81	90
Socket head screw ISO 4762 M20 x 35	10014670	16	UN	ROH	6,24	16
Socket head screw ISO 4762 M24 x 40	10014669	8	UN	ROH	6,4	8
Socket head screw ISO 4762 M24 x 80	10012522	18	UN	ROH	23,76	200
Cylinder head screw M42 x 120 ISO 4762	10306065	20	UN	ROH	180	20
Hexagonal head screw DIN 931 M10 x 50/26	10009403	24	UN	ROH	6,96	250
Hexagonal screw DIN933 M12x35	10004163	20	UN	ROH	1,8	100

Order 7			
	Single production		
N	Order cost	Total material cost	Total cost
1	100	999,48	1099,48
2	200	1274,63	1474,63
3	300	1549,78	1849,78
4	400	2194,93	2594,93
5	500	2470,08	2970,08
6	600	2745,23	3345,23
7	700	3390,38	4090,38
8	800	3665,53	4465,53
9	900	3940,68	4840,68
10	1000	4215,83	5215,83

Tables 5.6 – 5.7: order number 7

This order is very similar to the previous one, with some parts bought in big batches, and some other bought just for the RIKT.

The formula to calculate the material cost is:

if N =< 3,

(0,73+0,78+81+6,24+6,4+180)*N+1,8*5+6,96/24*250+106,56/288*1000+0,53/6*100+23,76/18*200

if 4=<N=<6,

(0,73+0,78+81+6,24+6,4+180)*N+1,8*5+6,96/24*250+106,56/288*1000*2+0,53/6*100+23,76/18*200

if 7=<N=<10,

(0,73+0,78+81+6,24+6,4+180)*N+1,8*5+6,96/24*250+106,56/288*1000*3+0,53/6*100+23,76/18*200

<u>Order 42</u>

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Seeger circlip Ring DIN 471 D 20 x 1,2	265320	2	UN	ROH	0,06	50
Hexagon nut DIN 439 B M20 x 1,5	10011608	1	UN	ROH	0,28	100
Hexagon nut DIN934 M10	232261	6	UN	ROH	0,1	100
Hub (to be welded) 1/2"G	10315114	1	UN	HALB	15	50
Washer DIN 7989 A for M27	10702633	4	UN	ROH	1,16	100
Safety washer DIN 6798 A per M10	10037573	8	UN	ROH	0,08	100
SPRING WASHER DIN 127B per M30	10037853	64	UN	ROH	20,88	1000
Spring washer DIN 128A D 18,1/10,2 x 1,8	10014387	2	UN	ROH	0,04	100
Parallel pin ISO 2338-8 D8 h8 x 30	10013398	4	UN	ROH	1	50
Hexagonal head screw DIN 561B M16 x 80	211584	12	UN	ROH	14,4	150
Hexagon screw DIN 561B M20 x 100	10012378	4	UN	ROH	16	50
Screw hex. head DIN 561B M20 x 80	10076892	2	UN	HAWA	47	20
Cheese-head bolt ISO 4762 M16 x 90/44	10014350	198	UN	ROH	83,16	3000
Hexagon head screw DIN 931 M16 x 60/38	10002367	36	UN	ROH	10,08	400
Hexagon screw DIN 931 M30 x 120/66	10012375	9	UN	ROH	22,5	100
hexagonal head screw DIN 933 M16 x 40	10005020	32	UN	ROH	6,63	500
Hexagon head bolt DIN 933 M20 x 50	10012468	14	UN	ROH	5,18	300
VITI T.E. M 30*90	10076709	64	UN	HAWA	128	650

Order 42			
	Single production		
N	Order cost	Total material cost	Total cost
1	100	5138,51	5238,51
2	100	5138,51	5238,51
3	100	5138,51	5238,51
4	100	5138,51	5238,51
5	100	5138,51	5238,51
6	100	5138,51	5238,51
7	100	5138,51	5238,51
8	100	5138,51	5238,51
9	100	5138,51	5238,51
10	100	5138,51	5238,51

Tables 5.8 – 5.9: order number 42

This is a "special" order, and it is the only one with this structure. In it, every piece is purchased in big batches, so that there is no need to make more than one order also for 10 compressors. So, this order has a great influence over the production of one compressor, while a lower one over the production of ten compressors.

<u>Orders 47 – 48: plates</u>

The last two orders regard the purchasing of plates.

First, it is calculated by the nesting operator (later the meaning of nesting will be explained) the thickness of the requiring plates, and their number. Then, the purchasing offer is sent. Normally plates are purchased by two different suppliers (the two with lower prices, but always respecting high quality), also if one has lower prices for every kind of plate. This is done to maintain contacts with more than one supplier, to avoid possible difficulties in case of problems with the main one.

However, as in the bill of materials is indicated the quantity in kilograms, and not the number of plates, the calculations are based on the kilos. It is a simplified manner to view the problem, but the result is the same.

Order 47

Piece	Code	Total quantity	U.M.	Typology	Cost
Plate EN 10029 th.=10	10066367	20,496	KG	ROH	10,86
Plate EN 10029 th.=120	10066641	830,844	KG	ROH	556,67
Plate EN 10029 th.=12	10066368	1766,502	KG	ROH	971,58
Plate EN 10029 th.=15	10066369	130,078	KG	ROH	70,24
Plate EN 10029 th.=15	10300381	173,108	KG	ROH	93,48
Plate EN 10029 th.=180	10096858	17286,97	KG	ROH	11236,53
Plate EN 10029 th.=190	10104317	6,986	KG	ROH	5,07
Plate EN 10029 th.=25	10066372	6767,075	KG	ROH	3654,22
Plate EN 10029 th.=35	10066374	13231,158	KG	ROH	7012,51
Plate EN 10029 th.=45	10066376	15651,22	KG	ROH	8451,66
Plate EN 10029 th.=55	10066378	1.139,11	KG	ROH	683,47
Plate EN 10029 th.=60	10066379	15168,145	KG	ROH	8570,01

Order 47			
	Single production		
N	Order cost	Total material cost	Total cost
1	100	41316,30	41416,30
2	200	82632,60	82832,60
3	300	123948,90	124248,90
4	400	165265,20	165665,20
5	500	206581,50	207081,50
6	600	247897,80	248497,80
7	700	289214,10	289914,10
8	800	330530,40	331330,40
9	900	371846,70	372746,70
10	1000	413163,00	414163,00

Tables 5.10 – 5.11: order number 47

Order 48

Piece	Code	Total quantity	U.M.	Typology	Cost
Plate EN 10029 th.=70	10066392	11669,72	KG	ROH	5951,56
Plate EN 10029 th.=80	10066394	14336,64	KG	ROH	7455,05
Plate EN 10025 th.=150	10066643	37477,47	KG	ROH	23236,03
Plate EN 10025 th.=30	10066373	410,624	KG	ROH	207,34
Plate EN 10025 th.=50	10066377	2543,968	KG	ROH	1424,62
Plate EN 10029 th.=20	10066371	910,6	KG	ROH	482,618
Plate EN 10029 th.=300	10335017	1.103,54	KG	ROH	993,19

Order 48			
	Single production		
N	Order cost	Total material cost	Total cost
1	100	39750,408	39850,408
2	200	79500,816	79700,816
3	300	119251,224	119551,224
4	400	159001,632	159401,632
5	500	198752,04	199252,04
6	600	238502,448	239102,448
7	700	278252,856	278952,856
8	800	318003,264	318803,264
9	900	357753,672	358653,672
10	1000	397504,08	398504,08

Tables 5.12 – 5.13: order number 48

Total cost

At the end, it is calculated the total cost for purchasing, summing up every cost of the 48 orders.

This total is presented in the following table.

	Single production		
N	Order cost	Total material cost	Total cost
1	4.800	174.095,70	178.895,70
2	9.500	336.557,24	346.057,24
3	14.200	499.018,79	513.218,79
4	18.900	662.774,55	681.674,55
5	23.600	825.762,09	849.362,09
6	28.300	988.396,14	1.016.696,14
7	33.000	1.151.586,29	1.184.586,29
8	37.700	1.314.368,45	1.352.068,45
9	42.400	1.477.577,74	1.519.977,74
10	47.100	1.640.342,09	1.687.442,09

Table 5.14: total purchasing cost in DPI

5.4 Production

With production is intended the transformation process which goes from raw materials to the final product. Part of this is made in DPI, part in MAN.

This process can be divided into 4 parts: nesting, work preparation, machining, and total workings. Nesting is the only one made exclusively in DPI, while the others are common for both the companies.

Another time, this work is focused on De Pretto Industrie; the part related with MAN can be found in Annex 4.

5.4.1 Nesting

After receiving an order for a RIKT, nesting is the first step made in DPI. With the word "nesting" is intended a sequence of operations made by a skilled worker. This sequence includes:

- the study of the drawings to understand which plates are required;
- a search (with software tools) in the warehouse to see if some plates are already available;
- the definition of which components are obtained from each plate (that is the real nesting process), in order to define the quantity and thickness of these plates;
- the forwarding of the previously defined plates list to the purchasing office.

In DPI only a single operator makes the nesting. His experience is very important for this job, because it permits to go faster through it: he already knows which components must be obtained from plates, and so, just watching the drawings, he can understand which typologies of plates are required for each of them.

To define plates for a single RIKT, 140 hours are required: 100 for the study of the engineering drawings and to draw in a software program the components that are necessary; and 40 to define the position of these parts into the proper plate (depending on thickness and kind of plate) in an optimum way (which means, trying to fill the plate as much as possible, reducing the wasted space).
If a big part of the plate is not used, it can be stored in the warehouse, waiting for another compressor requiring the same kind of plate.

The hourly cost of the cost center which the nesting operator is assigned to is 55 €/h.

Table 5.15 shows the cost required for the nesting, in the single production, to make from 1 to 10 compressors.

N	h_{single}	$€_{single}$
1	140	7.700,00
2	280	15.400,00
3	420	23.100,00
4	560	30.800,00
5	700	38.500,00
6	840	46.200,00
7	980	53.900,00
8	1120	61.600,00
9	1260	69.300,00
10	1400	77.000,00

Table 5.15: nesting cost

5.4.2 Work preparation

Work preparation is the process of writing work cycles and numerical control programs. These are requested by the big machines, which are numerical control machines. Every passage in a machine has its own n.c. program. For example, the inlet casing requires one time the boring machine PAMA 180, two times the vertical lathe Morando Phoneix and 4 times the boring machine Colgar Fral 70. So, in its work cycles, there are 7 different numerical control programs.

Work cycles and numerical control programs are defined and written in the production office.
To complete this work, 160 hours are required for a single RIKT.
The cost of the office is 48 €/h.
In the following table the cost of these operations is presented.

N	h_{single}	$€_{single}$
1	160,00	7.680,00
2	320,00	15.360,00
3	480,00	23.040,00
4	640,00	30.720,00
5	800,00	38.400,00
6	960,00	46.080,00
7	1.120,00	53.760,00
8	1.280,00	61.440,00
9	1.440,00	69.120,00
10	1.600,00	76.800,00

Table 5.16: work preparation cost

5.4.3 Machining

In this paragraph, the impact of set-up in machining is going to be analyzed. It has been defined that the only possible saving in set-up with a series production are in machining department, and not in the other ones. So, the focus is on the big machines.

This section will be divided into work centers, and for each of them, there will be the definition of which parts are worked in it, the time required for the set-up and the workings, and the number of positioning. Then, it will be defined a formula to calculate the total time for the machining of N compressors.
The savings obtained with the series effect will be calculated in next chapter.

5.4.3.1 41012 - Vertical lathe Morando VH20

Parts worked:

- Inlet piece (3 passages)

1st passage	
Set-up time	1
Machining time	20,5
Number of positionings	1
2nd passage	
Set-up time	1,5
Machining time	20
Number of positionings	2
3rd passage (eventual)	
Set-up time	1
Machining time	1
Number of positionings	1

Table 5.17: inlet piece, center 41012

For the 1st and the 3rd passage, there is this situation: set-up → machining.
For the 2nd, it is: set-up → 1st positioning, machining → set-up → 2nd positioning, machining.

Reminding that the set-up time is the sum of the intermediate set-up times (that is, the 1,5 hours of the set-up time of the 2nd passage is the sum of the set-up required for the 1st and 2nd positioning), the formulas to calculate the time required for N compressors are:

- 1st passage, (1+20,5) * N hours;
- 2nd passage, (1,5+20) * N hours;
- 3rd passage, (1+1) * N hours.

The total in the work center is 45 * N hours.

As the hourly cost of the machine is 75,4 €/h, the total cost to produce up to 10 compressors is presented in the following table.

N	$\mathbf{h_{single}}$	$\mathbf{€_{single}}$
1	45	3.393,00
2	90	6.786,00
3	135	10.179,00
4	180	13.572,00
5	225	16.965,00
6	270	20.358,00
7	315	23.751,00
8	360	27.144,00
9	405	30.537,00
10	450	33.930,00

Table 5.18: 41012, total cost

5.4.3.2 43012 – Boring machine AMF PAMA 130

Parts worked:

- Milled diffusor 4th stage

Set-up time	0,75
Machining time	2,25
Number of positionings	2

- Inlet piece (2 passages)

1st passage	
Set-up time	1
Machining time	3
Number of positionings	2

2nd passage	
Set-up time	1
Machining time	1
Number of positionings	1

- Channel wall complete machined 1050 kg

Set-up time	3,5
Machining time	14,5
Number of positionings	6

- Channel wall complete machined 1145 kg

Set-up time	3,5
Machining time	14,5
Number of positionings	6

- Intermediate wall complete machined 1031 kg

Set-up time	1,5
Machining time	11
Number of positionings	2

- Intermediate wall complete machined 836 kg

Set-up time	1,5
Machining time	11
Number of positionings	2

- Man hole cover

Set-up time	1,5
Machining time	9,5
Number of positionings	1

- Cover for bearing house

Set-up time	1,5
Machining time	12,5
Number of positionings	2

Tables 5.19 – 5.26: parts worked by w.c. 43012

For the parts with 1 or 2 positionings, the situation is the same of the previous work center. For the channel walls, which require 6 positionings, it is: set-up → 1st positioning, machining → set-up → 2nd positioning, machining, → set-up → 3rd positioning, machining → set-up → 4th positioning, machining → set-up → 5th positioning, machining → set-up → 6th positioning, machining.

Reminding for the last time that the set-up time is the sum of the intermediate set-up times, the formulas to calculate the time required for N compressors are:

- Milled diffusor 4th stage, (0,75+2,25) * N hours;
- Inlet piece, 1st passage, (1+3) * N hours;
- Inlet piece, 2nd passage, (1+1) * N hours;
- Channel wall complete machined 1050 kg, (1,5+11) * N hours;
- Channel wall complete machined 1145 kg, (1,5+11) * N hours;
- Intermediate wall complete machined 1031 kg, (3,5+14,5) * N hours;
- Intermediate wall complete machined 836 kg, (3,5+14,5) * N hours;
- Man hole cover, (1,5+9,5) * N hours;
- Cover for bearing house (1,5+12,5) * N hours.

As the hourly cost of the machine is 85,2 €/h, the total cost to produce up to 10 compressors is presented in the following table.

N	h_{single}	$€_{single}$
1	95	8.094,00
2	190	16.188,00
3	285	24.282,00
4	380	32.376,00
5	475	40.470,00
6	570	48.564,00
7	665	56.658,00
8	760	64.752,00
9	855	72.846,00
10	950	80.940,00

Table 5.28: 43012, total cost

5.4.3.3 44011 - Flexible machine PAMA Speedmat

Parts worked:

- Cooler cover 1st stage (2 pieces)

Set-up time	1
Machining time	7,5
Number of positionings	2

- Cooler cover 2nd stage and 3rd stage (2 pieces each)

Set-up time	1
Machining time	6,5
Number of positionings	2

- Bracket for bearing housing

Set-up time	0,5
Machining time	14,5
Number of positionings	1

- Lower water chamber 1st, 2nd and 3rd stage (2 pieces each)

Set-up time	1
Machining time	13,2
Number of positionings	2

- Upper water chamber 1st, 2nd and 3rd stage (2 pieces each)

Set-up time	1
Machining time	8
Number of positionings	2

- Milled diffusor 4th stage

Set-up time	2,75
Machining time	33
Number of positionings	4

- Inlet piece (2 passages)

1st passage	
Set-up time	2,5
Machining time	14,5
Number of positionings	4
2nd passage	
Set-up time	0,5
Machining time	4
Number of positionings	1

- Bearing house OT (2 passages)

1st passage	
Set-up time	1,25
Machining time	7,75
Number of positionings	2
2nd passage	
Set-up time	1,25
Machining time	28,25
Number of positionings	2

- Bearing house UT

Set-up time	1,25
Machining time	14,75
Number of positionings	2

Tables 5.29 – 5.37: parts worked by w.c. 44011

For the components produced only in one piece, the situation is the same already analyzed. For the ones (cooler covers, water chambers) which require 2 positioning and 2 pieces, it is: set-up → 1st positioning 1st piece, machining → 1st positioning 2nd piece, machining → set-up → 2nd positioning 1st piece, machining → 2nd positioning 2nd piece, machining.

The formulas to calculate the time required for N compressors are:

- Cooler cover 1st stage (2 pieces), (1+7,5+7,5) * N hours;
- Cooler cover 2nd stage and 3rd stage (2 pieces each), (1+6,5+6,5) * N hours each;
- Bracket for bearing housing, (0,5+14,5) * N hours;
- Lower water chamber 1st, 2nd and 3rd stage (2 pieces each), (1+13,2+13,2) * N hours each;
- Upper water chamber 1st, 2nd and 3rd stage (2 pieces each), (1+8+8) * N hours each;
- Milled diffusor 4th stage, (2,75+33) * N hours;
- Inlet piece, 1st passage, (2,5+14,5) * N hours;
- Inlet piece, 2nd passage, (0,5+4) * N hours;
- Bearing house OT, 1st passage, (1,25+7,75) * N hours;
- Bearing house OT, 2nd passage, (1,25+28,25) * N hours;
- Bearing house UT, (1,25+14,75) * N hours.

As the hourly cost of the machine is 106,7 €/h, the total cost to produce up to 10 compressors is presented in the following table.

N	**h_{single}**	**$€_{single}$**
1	303,95	32.431,47
2	607,9	64.862,93
3	911,85	97.294,40
4	1215,8	129.725,86
5	1519,75	162.157,33
6	1823,7	194.588,79
7	2127,65	227.020,26
8	2431,6	259.451,72
9	2735,55	291.883,19
10	3039,5	324.314,65

Table 5.38: 44011, total cost

5.4.3.4 46012 - Vertical lathe TV Ceruti

Parts worked:

- Discharge spiral

Set-up time	10
Machining time	28,4
Number of positionings	2

Table 5.39, discharge spiral, center 46012

As the situation is always the same, is presented only the formula:

- Spiral, (10+28,4) * N

The hourly cost of the machine is 95,5 €/h. So the costs of the center to produce up to 10 compressors are:

N	h_{single}	$€_{single}$
1	38,4	3.667,20
2	76,8	7.334,40
3	115,2	11.001,60
4	153,6	14.668,80
5	192	18.336,00
6	230,4	22.003,20
7	268,8	25.670,40
8	307,2	29.337,60
9	345,6	33.004,80
10	384	36.672,00

Table 5.40: 46012, total cost

5.4.3.5 46013 - Vertical lathe TV Morando Phoneix

Parts worked:

- Welded diffusor 2nd stage

Set-up time	1
Machining time	13
Number of positionings	2

- Welded diffusor 3rd stage

Set-up time	1
Machining time	13
Number of positionings	2

- Milled diffusor GD 11 (2 passages)

1st passage	
Set-up time	1,5
Machining time	21,5
Number of positionings	2

2nd passage	
Set-up time	1
Machining time	17
Number of positionings	1

- Milled diffusor 4th stage (2 passages)

1st passage	
Set-up time	1,5
Machining time	14,5
Number of positionings	2
2nd passage	
Set-up time	1
Machining time	5
Number of positionings	1

- Adjusting ring

Set-up time	1
Machining time	8
Number of positionings	1

- Inlet casing (2 passages)

1st passage	
Set-up time	1,5
Machining time	10,5
Number of positionings	1
2nd passage	
Set-up time	2
Machining time	23,9
Number of positionings	2

- Channel wall complete machined 1050 kg

Set-up time	1,5
Machining time	22
Number of positionings	2

- Channel wall complete machined 1145 kg

Set-up time	1,5
Machining time	22
Number of positionings	2

- Channel wall complete machined 2196 kg

Set-up time	1,5
Machining time	22
Number of positionings	2

- Intermediate wall complete machined 1031 kg

Set-up time	1,5
Machining time	17,5
Number of positionings	2

- Intermediate wall complete machined 836 kg

Set-up time	1,5
Machining time	17,5
Number of positionings	2

Tables 5.41 – 5.51: parts worked by w.c. 46013

The formulas to calculate the time required for N compressors are:

- Welded diffusor 2nd stage, (1+13) * N hours;
- Welded diffusor 3rd stage (1+13) * N hours;
- Milled diffusor GD 11, 1st passage, (1,5+21,5) * N hours;
- Milled diffusor GD 11, 2nd passage, (1+17) * N hours;
- Milled diffusor 4th stage, 1st passage, (1,5+14,5) * N hours;
- Milled diffusor 4th stage, 2nd passage, (1+5) * N hours;
- Adjusting ring, (1+8) * N hours;
- Inlet casing, 1st passage, (1,5+10,5) * N hours;
- Inlet casing, 2nd passage, (2+23,9) * N hours;
- Channel wall complete machined 1050 kg, (1,5+22) * N hours;
- Channel wall complete machined 1145 kg, (1,5+22) * N hours;
- Channel wall complete machined 2196 kg, (1,5+22) * N hours;
- Intermediate wall complete machined 1031 kg, (1,5+17,5) * N hours;
- Intermediate wall complete machined 836 kg, (1,5+17,5) * N hours.

The hourly cost of the machine is 95,5 €/h; the total cost to produce up to 10 compressors is:

N	**h_{single}**	**$€_{single}$**
1	246,4	23.531,20
2	492,8	47.062,40
3	739,2	70.593,60
4	985,6	94.124,80
5	1232	117.656,00
6	1478,4	141.187,20
7	1724,8	164.718,40
8	1971,2	188.249,60
9	2217,6	211.780,80
10	2464	235.312,00

Table 5.52: 46013, total cost

5.4.3.6 51012 - Boring machine PAMA 140

Parts worked:

- Milled diffusor GD11 (2 passages)

1st passage	
Set-up time	0,75
Machining time	3,25
Number of positionings	2
2nd passage	
Set-up time	2,75
Machining time	57,25
Number of positionings	4

- Discharge spiral

Set-up time	1,5
Machining time	6,5
Number of positionings	1

- Channel wall complete machined 2196 kg

Set-up time	1,5
Machining time	15,5
Number of positionings	2

Tables 5.53 – 5.55: parts worked by w.c. 51012

The formulas to calculate the time required for N compressors are:

- Milled diffusor GD11, 1st passage, (0,75+3,25) * N hours;
- Milled diffusor GD 11, 2nd passage, (2,75+57,25) * N hours;
- Discharge spiral, (1,5+6,5) * N hours;
- Channel wall complete machined 2196 kg, (1,5+15,5) * N hours.

As the hourly cost of the machine is 106,7 €/h, the total cost to produce up to 10 compressors is presented in the following table.

N	h_{single}	$€_{single}$
1	89	9.496,30
2	178	18.992,60
3	267	28.488,90
4	356	37.985,20
5	445	47.481,50
6	534	56.977,80
7	623	66.474,10
8	712	75.970,40
9	801	85.466,70
10	890	94.963,00

Table 5.56: 51012, total cost

5.4.3.7 53011 - Boring machine PAMA 180

Parts worked:

- Inlet casing

Set-up time	2,5
Machining time	29,2
Number of positionings	4

Table 5.57, inlet casing, center 53011

The formula to calculate the time required for N compressors is:

- Inlet casing, (2,5+29,2) * N hours.

As the hourly cost of the machine is 106,7 €/h, the total cost to produce up to 10 compressors is presented in the following table.

N	h_{single}	$€_{single}$
1	31,7	3.382,39
2	63,4	6.764,78
3	95,1	10.147,17
4	126,8	13.529,56
5	158,5	16.911,95
6	190,2	20.294,34
7	221,9	23.676,73
8	253,6	27.059,12
9	285,3	30.441,51
10	317	33.823,90

Table 5.58: 53011, total cost

5.4.3.8 53012 - Boring machine Colgar Fral 70

Parts worked:

- Welded diffusor 2nd stage

Set-up time	1
Machining time	23
Number of positionings	4

- Welded diffusor 3rd stage

Set-up time	1
Machining time	23
Number of positionings	4

- Adjusting ring

Set-up time	2,5
Machining time	26,5
Number of positionings	4

- Inlet casing (4 passages)

1st passage	
Set-up time	1,5
Machining time	6,2
Number of positionings	1
2nd passage	
Set-up time	1,5
Machining time	10,5
Number of positionings	2
3rd passage	
Set-up time	1
Machining time	4,7
Number of positionings	1
4th passage	
Set-up time	2,5
Machining time	55,1
Number of positionings	3

- Casing foot (2 pieces)

Set-up time	1
Machining time	16
Number of positionings	1

- Discharge spiral

Set-up time	5
Machining time	91
Number of positionings	3

Tables 5.59 – 5.64: parts worked by w.c. 53012

The formulas to calculate the time required for N compressors are:

- Welded diffusor 2nd stage, (1+23) * N hours;
- Welded diffusor 3rd stage, (1+23) * N hours;
- Adjusting ring, (2,5+26,5) * N hours;
- Inlet casing, 1st passage, (1,5+6,2) * N hours;
- Inlet casing, 2nd passage, (1,5+10,5) * N hours;
- Inlet casing, 3rd passage, (1+4,7) * N hours;
- Inlet casing, 4th passage, (2,5+55,1) * N hours;

- Casing foot (2 pieces), (1+16+16) * N hours;
- Discharge spiral, (5+91) * N hours.

As the hourly cost of the machine is 106,7 €/h, the total cost to produce up to 10 compressors is presented in the following table.

N	**h_{single}**	**€$_{single}$**
1	289	30.836,30
2	578	61.672,60
3	867	92.508,90
4	1156	123.345,20
5	1445	154.181,50
6	1734	185.017,80
7	2023	215.854,10
8	2312	246.690,40
9	2601	277.526,70
10	2890	308.363,00

Table 5.65: 53012, total cost

5.4.3.9 53013 - Boring machine PAMA 200

In this work center is worked only the casing complete machined. But, as it is: impossible to have a series effect at the time of casing machining, the set-up influence is of 28 hours over 433,7 hours of production, and in every case a possible set-up reduction is only of 2 hours, this center will not be analyzed in this section. Its costs will be considered just in the total production costs.

5.4.3.10 Total machining cost

Finally, it is possible to sum every single work center costs, to have the total hours and costs of machining (excluding the PAMA 200 machine). This total is presented in table 5.66.

N	**h_{single}**	**€$_{single}$**
1	1138,45	114.831,86
2	2276,9	229.663,71
3	3415,35	344.495,57
4	4553,8	459.327,42
5	5692,25	574.159,28
6	6830,7	688.991,13
7	7969,15	803.822,99
8	9107,6	918.654,84
9	10246,05	1.033.486,70
10	11384,5	1.148.318,55

Table 5.66: total machining cost

5.4.4 Total workings

Now it will be considered not only machining, but the whole working process: welding, assembly, machining, painting, sandblasting, oxygen cutting…

Starting from the work cycles and knowing the cost of every work center, it has been calculated the total production cost of every component of the RIKT. The work cycles have already been presented; in table 5.67 the hourly cost of the work centers is shown.

Work center	**Hourly cost (€/h)**
1501	41,6
1601	49
2601	50,7
3051	54,4
3101	53,4
41012	75,4
43012	85,2
44011	106,7
46012	95,5
46013	95,5
51012	106,7
53011	106,7
53012	106,7
53013	106,7
5511	46,3
5513	46,3
5531	77,2
5601	77,9
5602	77,9
5701	50,6
57511	60,2
5901	69,3
6401	58

Table 5.67: work centers cost

To avoid a too long dissertation, only the final total cost, not divided between the components, will be reported here. Machining contributes in RIKT costs is almost the 16%, but of course the set-up time contribution, which is the only one that can be reduced, is also lower.

N	Total time	Cost [€]
1	7.188,45	499.515,30
2	14.376,90	999.030,59
3	21.565,35	1.498.545,89
4	28.753,80	1.998.061,18
5	35.942,25	2.497.576,48
6	43.130,70	2.997.091,77
7	50.319,15	3.496.607,07
8	57.507,60	3.996.122,36
9	64.696,05	4.495.637,66
10	71.884,50	4.995.152,95

Table 5.68: total workings cost

5.4.5 Total cost in production

Finally, the total time required for a RIKT in production department is the sum of nesting, work preparation and total workings. This total is presented in the following table.

N	h_{single}	$€_{single}$
1	7.488,45	514.895,30
2	14.976,90	1.029.790,59
3	22.465,35	1.544.685,89
4	29.953,80	2.059.581,18
5	37.442,25	2.574.476,48
6	44.930,70	3.089.371,77
7	52.419,15	3.604.267,07
8	59.907,60	4.119.162,36
9	67.396,05	4.634.057,66
10	74.884,50	5.148.952,95

Table 5.69: total production cost

As it is easy to imagine, workings costs contribute for the biggest part in production costs, with a 96%. As they are already optimized, and set-up contribution is very low, it can be started to see that it will be difficult to have a big reduction in production with the series effect.

5.5 Quality

Quality plays a very important role for DPI, as can guarantee fidelity of the client, a lower number of scrap and complains, and so, more earnings for the company.

According to De Pretto's official website, quality "is not associated only with the product. In addition to the design and construction, we also carefully oversee the start-up phase and provide extensive after-sales service. This requires a philosophy that instils quality as a company culture, which is achieved by the continuous planning, control and improvement in the decisional, operational and production processes".

During RIKT production, there are 5 different moments where there is quality control:

- identification;
- intermediate control;
- final control;
- during pressing operations;
- during painting operations.

The control depends from the component: in fact, each part requires different controls. Table 5.70 presents the relation between quality control type and components, with the indication of the number of hours needed for each control.

	Type of control				
Component	Identification	Intermediate	Final	Pressing	Painting
Compressor complete	0	0	0	0	5
Casing	5	7	5	3	0
Inlet casing	1	2	3	0	0
Discharge spiral	1	2	3	0	0
Inlet piece	0	0	2	0	0
Diffusor stage 1	1	0	2	0	0
Internal parts	0	0	1,5	0	0
Shaft seal sleeves	0	0	1	0	0
Water chambers	0	0	1	0	0
Covers	0	0	1	0	0
Coolers (series)	0	0	0	2	0
Foot	0	0	1	0	0
Adjusting ring	0	0	1	0	0
Rotor without wheels	1	4	6	0	0
Total	9	15	27,5	5	5

Table 5.70: matrix components/type of control

The total number of hours required for one RIKT is 61,5.

As the hourly cost of quality department is 49 €/h, it is possible to define the cost for quality control from 1 up to 10 compressors.

N	h_{single}	$€_{single}$
1	61,50	3.013,50
2	123,00	6.027,00
3	184,50	9.040,50
4	246,00	12.054,00
5	307,50	15.067,50
6	369,00	18.081,00
7	430,50	21.094,50
8	492,00	24.108,00
9	553,50	27.121,50
10	615,00	30.135,00

Table 5.71: quality control cost

5.6 Total cost

The total cost of a RIKT, in a single production way as it is in the actual state, is the sum of the single costs of the five departments analyzed.

It is important for MAN and De Pretto Industrie to define their contribution to costs both separately and united: in fact, at the end, there will be two types of discounts. One is the total discount, made by the sum of MAN's and DPI's contributions, which can be applied to the final client. The other one is based only on DPI's data, and it will be the discount applicable by De Pretto to MAN in the stator parts sell.

The total contribution of DPI does not include Engineering and Project Management, as they are made by MAN only. This contribution is presented in table 5.72. In table 5.73 the single department contribution to the total is presented.

On the contrary, MAN's contribution does not include nesting. Its contribution is shown in table 5.74. In table 5.75 there is the single department contribution.

Then, in table 5.76, is presented the total cost of the RIKT, always from 1 to 10 compressors. Another time, in table 5.77 the different departments contribution is given; finally, in table 5.78, the contribution of the two companies to the total cost is presented.

N	Quality	Purchasing	Production	Total
1	3.013,50	178.895,70	514.895,30	696.804,49
2	6.027,00	346.057,24	1.029.790,59	1.381.874,83
3	9.040,50	513.218,79	1.544.685,89	2.066.945,18
4	12.054,00	681.674,55	2.059.581,18	2.753.309,73
5	15.067,50	849.362,09	2.574.476,48	3.438.906,07
6	18.081,00	1.016.696,14	3.089.371,77	4.124.148,91
7	21.094,50	1.184.586,29	3.604.267,07	4.809.947,86
8	24.108,00	1.352.068,45	4.119.162,36	5.495.338,81
9	27.121,50	1.519.977,74	4.634.057,66	6.181.156,90
10	30.135,00	1.687.442,09	5.148.952,95	6.866.530,04

Table 5.72: total cost in DPI

N	Quality	Purchasing	Production	Total
1	0,43%	25,67%	73,89%	696.804,49
2	0,44%	25,04%	74,52%	1.381.874,83
3	0,44%	24,83%	74,73%	2.066.945,18
4	0,44%	24,76%	74,80%	2.753.309,73
5	0,44%	24,70%	74,86%	3.438.906,07
6	0,44%	24,65%	74,91%	4.124.148,91
7	0,44%	24,63%	74,93%	4.809.947,86
8	0,44%	24,60%	74,96%	5.495.338,81
9	0,44%	24,59%	74,97%	6.181.156,90
10	0,44%	24,57%	74,99%	6.866.530,04

Table 5.73: single department contribution in DPI

As it is possible to see from this table, the most important department in RIKTs fabrication in De Pretto is production, with a contribution of nearly 75%. Purchasing contributes for almost all the rest of the costs, while quality has a very little role. Moreover, it can be seen that the proportion with a growing number of RIKT stands more or less equal; the little changes are given by the decided hypothesis on purchasing orders (empty workshop => big batches of components bought for the first RIKT), as already stated in purchasing paragraph.

N	Engineering	Project mgmt	Purchasing	Production	Total
1	21.079,66	28.376,46	603.588,59	212.066,35	865.111,06
2	42.159,31	56.752,92	1.207.177,18	424.132,69	1.730.222,11
3	63.238,97	85.129,38	1.810.765,78	636.199,04	2.595.333,17
4	84.318,63	113.505,84	2.414.354,37	848.265,39	3.460.444,23
5	105.398,28	141.882,31	3.017.942,96	1.060.331,73	4.325.555,28
6	126.477,94	170.258,77	3.621.531,55	1.272.398,08	5.190.666,34
7	147.557,60	198.635,23	4.225.120,14	1.484.464,43	6.055.777,40
8	168.637,25	227.011,69	4.828.708,73	1.696.530,77	6.920.888,45
9	189.716,91	255.388,15	5.432.297,33	1.908.597,12	7.785.999,51
10	210.796,57	283.764,61	6.035.885,92	2.120.663,47	8.651.110,57

Table 5.74: total cost in MAN

N	Engineering	Project mgmt	Purchasing	Production	Total
1	2,44%	3,28%	69,77%	24,51%	865.111,06
2	2,44%	3,28%	69,77%	24,51%	1.730.222,11
3	2,44%	3,28%	69,77%	24,51%	2.595.333,17
4	2,44%	3,28%	69,77%	24,51%	3.460.444,23
5	2,44%	3,28%	69,77%	24,51%	4.325.555,28
6	2,44%	3,28%	69,77%	24,51%	5.190.666,34
7	2,44%	3,28%	69,77%	24,51%	6.055.777,40
8	2,44%	3,28%	69,77%	24,51%	6.920.888,45
9	2,44%	3,28%	69,77%	24,51%	7.785.999,51
10	2,44%	3,28%	69,77%	24,51%	8.651.110,57

Table 5.75: single department contribution in MAN

In MAN, instead, the biggest contribution is given by purchasing department, with nearly the 70% of the total cost. Production follows, with nearly the 25%. Project management and engineering contribute at a lower level. In MAN, despite the hypothesis of empty workshop, the influence of big batches is lower, so that the contribution percentage does not change with a growing RIKT number.

N	Quality	Purchasing DPI	Production DPI	Engineering	Project mgmt	Purchasing MAN	Production MAN	Total
1	3.013,50	178.895,70	514.895,30	21.079,66	28.376,46	603.588,59	212.066,35	1.561.915,55
2	6.027,00	346.057,24	1.029.790,59	42.159,31	56.752,92	1.207.177,18	424.132,69	3.112.096,95
3	9.040,50	513.218,79	1.544.685,89	63.238,97	85.129,38	1.810.765,78	636.199,04	4.662.278,35
4	12.054,00	681.674,55	2.059.581,18	84.318,63	113.505,84	2.414.354,37	848.265,39	6.213.753,95
5	15.067,50	849.362,09	2.574.476,48	105.398,28	141.882,31	3.017.942,96	1.060.331,73	7.764.461,35
6	18.081,00	1.016.696,14	3.089.371,77	126.477,94	170.258,77	3.621.531,55	1.272.398,08	9.314.815,25
7	21.094,50	1.184.586,29	3.604.267,07	147.557,60	198.635,23	4.225.120,14	1.484.464,43	10.865.725,25
8	24.108,00	1.352.068,45	4.119.162,36	168.637,25	227.011,69	4.828.708,73	1.696.530,77	12.416.227,26
9	27.121,50	1.519.977,74	4.634.057,66	189.716,91	255.388,15	5.432.297,33	1.908.597,12	13.967.156,41
10	30.135,00	1.687.442,09	5.148.952,95	210.796,57	283.764,61	6.035.885,92	2.120.663,47	15.517.640,61

Table 5.76: total cost combined

N	Quality	Purchasing DPI	Production DPI	Engineering	Project mgmt	Purchasing MAN	Production MAN	Total
1	0,19%	11,45%	32,97%	1,35%	1,82%	38,64%	13,58%	1.561.915,55
2	0,19%	11,12%	33,09%	1,35%	1,82%	38,79%	13,63%	3.112.096,95
3	0,19%	11,01%	33,13%	1,36%	1,83%	38,84%	13,65%	4.662.278,35
4	0,19%	10,97%	33,15%	1,36%	1,83%	38,86%	13,65%	6.213.753,95
5	0,19%	10,94%	33,16%	1,36%	1,83%	38,87%	13,66%	7.764.461,35
6	0,19%	10,91%	33,17%	1,36%	1,83%	38,88%	13,66%	9.314.815,25
7	0,19%	10,90%	33,17%	1,36%	1,83%	38,88%	13,66%	10.865.725,25
8	0,19%	10,89%	33,18%	1,36%	1,83%	38,89%	13,66%	12.416.227,26
9	0,19%	10,88%	33,18%	1,36%	1,83%	38,89%	13,66%	13.967.156,41
10	0,19%	10,87%	33,18%	1,36%	1,83%	38,90%	13,67%	15.517.640,61

Table 5.77: single department contribution in total cost

N	Total DPI	Total MAN	Total	% DPI	% MAN
1	696.804,49	865.111,06	1.561.915,55	44,61%	55,39%
2	1.381.874,83	1.730.222,11	3.112.096,95	44,40%	55,60%
3	2.066.945,18	2.595.333,17	4.662.278,35	44,33%	55,67%
4	2.753.309,73	3.460.444,23	6.213.753,95	44,31%	55,69%
5	3.438.906,07	4.325.555,28	7.764.461,35	44,29%	55,71%
6	4.124.148,91	5.190.666,34	9.314.815,25	44,28%	55,72%
7	4.809.947,86	6.055.777,40	10.865.725,25	44,27%	55,73%
8	5.495.338,81	6.920.888,45	12.416.227,26	44,26%	55,74%
9	6.181.156,90	7.785.999,51	13.967.156,41	44,25%	55,75%
10	6.866.530,04	8.651.110,57	15.517.640,61	44,25%	55,75%

Table 5.78: contribution of the different companies

As it can be easily expected, the two departments which more contribute to the total cost of a RIKT are purchasing in MAN (~38%) and production in DPI (~33%). In general, purchasing contributes with a 48-49% and production with a 46%. Finally, it is possible to notice that costs are well balanced between the two companies: in fact, DPI contributes with the 44%, and MAN with nearly the 56%.

CHAPTER 6

Serial effect in RIKT production

In this chapter the effects of series production will be discussed. The chapter resumes the previous chapter, with the same features; so, the parts related with purchasing and production in MAN will be found in the same annexes of before, with the serial effect included; and so will be made for the other parts of the work which already are in annexes. It will not be pointed out anymore.

With serial effect is intended the realization of some RIKTs, completely equals among them, after a client’s order. This means that every department has to work for this number of RIKT: for example, setting this number on 4, project management will define deadlines for all the 4 RIKTs once, purchasing must issue orders for all the 4 compressors, production must realize the parts in series, and so on. However, every department has its own features and its behavior is different from the other ones.

Still the hypothesis of empty workshop and ideal situation are valid.

6.1 Engineering

In accordance with Marco Ritz, head of design compressors (MAN Diesel & Turbo Zurich), significant savings in engineering hours or rather engineering costs are possible through series production. If a RIKT is produced in series, the amount of engineering hours is fully needed only for the first compressor. For all subsequent RIKT standard compressors, only ten percent of the original amount is required for generating relevant documents, like drawings, bills of material, specifications (figure 6.1). This rate cannot be completely reduced to zero, since the total engineering hours are relatively tightly calculated for standard RIKTs.

100%	10%	10%	10%	10%	10%	10%	10%	10%	10%
1st standard RIKT	2nd	3rd	4th	5th	6th	7th	8th	9th	10th

Figure 6.1: staggering of required engineering and project management hours

Table 6.1 shows the possible savings for the engineering of a standard RIKT core machine, which are based essentially on savings in working hours.
Column 2 contains the working time required for the single production of each quantity (N compressors), which equals the product of N and the scheduled working time for one RIKT. Column 3 shows the working hours needed for the different quantities in series production including the reduced time requirements of ten percent of the initial value from quantities of two. The costs for engineering are listed in column 5 and 6. They result by multiplication of the hours for single or rather series production with an hourly rate of 120 CHF at an exchange rate of 1.4801 CHF/ EUR. This exchange rate is the one used in the work. From now on, the costs in MAN will directly be expressed in euro.
The savings are calculated in absolute data for working hours (col. 4) and costs (col. 7) as difference between the hours / costs of single and series production for the respective number of compressors. Finally, the percentage of the saved hours/costs with reference to the total engineering hours/costs of single production is mentioned in the last column.
This structure of the table will be used also for the other departments.

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	260,00	260,00	0,00	21.079,66	21.079,66	0,00	0,00%
2	520,00	286,00	234,00	42.159,31	23.187,62	18.971,69	45,00%
3	780,00	312,00	468,00	63.238,97	25.295,59	37.943,38	60,00%
4	1.040,00	338,00	702,00	84.318,63	27.403,55	56.915,07	67,50%
5	1.300,00	364,00	936,00	105.398,28	29.511,52	75.886,76	72,00%
6	1.560,00	390,00	1.170,00	126.477,94	31.619,49	94.858,46	75,00%
7	1.820,00	416,00	1.404,00	147.557,60	33.727,45	113.830,15	77,14%
8	2.080,00	442,00	1.638,00	168.637,25	35.835,42	132.801,84	78,75%
9	2.340,00	468,00	1.872,00	189.716,91	37.943,38	151.773,53	80,00%
10	2.600,00	494,00	2.106,00	210.796,57	40.051,35	170.745,22	81,00%

Table 6.1: serial effect on engineering costs / hours

Figure 6.2 shows the savings in percentages in relation to the number of items. The curve rises steeply for a quantity up to four. For larger quantities, the curve flattens.

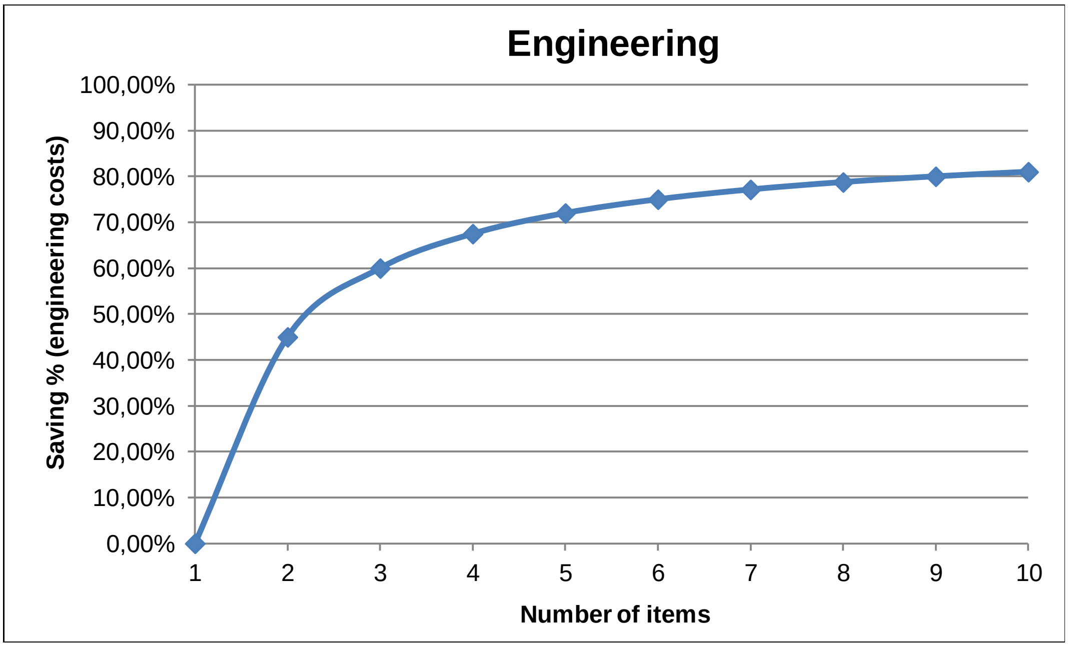


Figure 6.2: engineering, serial effect

6.2 Project management

In discussions with Urs Fischer, project manager, and Zoran Paunovic, product manager (both MAN Diesel & Turbo Zurich), it becomes apparent that savings within the project management due to serial production are corresponding by percentage to the savings of the engineering. Thus, the full extent of working hours is only required for the first standard RIKT. Again, only ten percent of the original set is needed for subsequent compressors. These savings result primarily from internal processes. Hence, for example kick-off meetings, document clarification, design reviews, etc. can be combined for several identical compressors of one series. In the working time that is provided directly to customer, e.g. the acceptance, any savings are expected (figure 6.3).

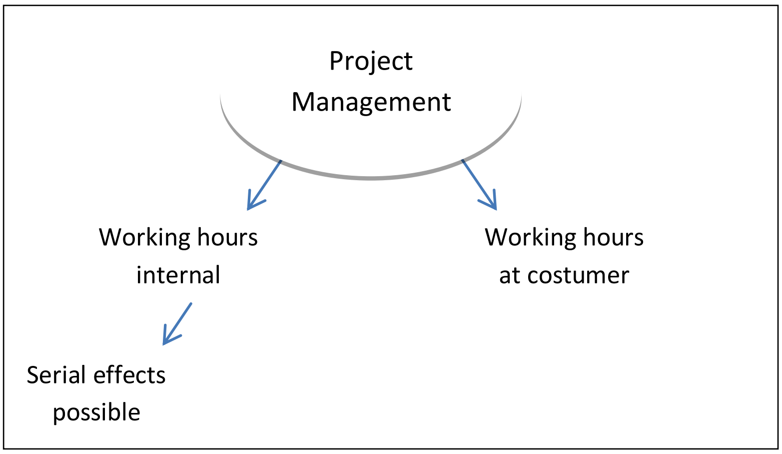


Figure 6.3: potential savings within project management

The results of the analysis of the project management are summarized in table 6.2 and figure 6.4 in the same way as already seen for the engineering.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	350,00	350,00	0,00	28.376,46	28.376,46	0,00	0,00%
2	700,00	385,00	315,00	56.752,92	31.214,11	25.538,81	45,00%
3	1.050,00	420,00	630,00	85.129,38	34.051,75	51.077,63	60,00%
4	1.400,00	455,00	945,00	113.505,84	36.889,40	76.616,44	67,50%
5	1.750,00	490,00	1.260,00	141.882,31	39.727,05	102.155,26	72,00%
6	2.100,00	525,00	1.575,00	170.258,77	42.564,69	127.694,07	75,00%
7	2.450,00	560,00	1.890,00	198.635,23	45.402,34	153.232,89	77,14%
8	2.800,00	595,00	2.205,00	227.011,69	48.239,98	178.771,70	78,75%
9	3.150,00	630,00	2.520,00	255.388,15	51.077,63	204.310,52	80,00%
10	3.500,00	665,00	2.835,00	283.764,61	53.915,28	229.849,33	81,00%

Table 6.2: serial effect on project management costs / hours

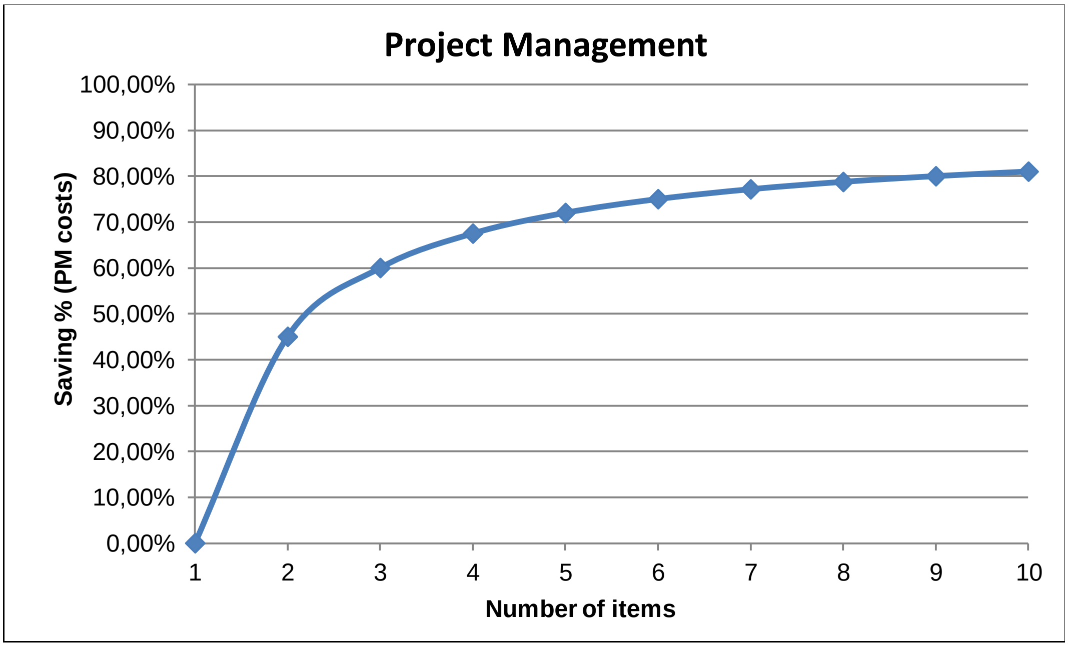


Figure 6.4: project management, serial effect

6.3 Purchasing

As already stated, in DPI there are 3 different typologies of purchased components: ROH, HAWA and HALB. Since ROH and HAWA components are catalogue's parts, there is no quantity discount for them: the price is already the lowest, and the supplier however produces these parts as they are standard. The only possible discount is in HALB components: in fact, as they are based on De Pretto's drawings, it is different for the supplier to produce one or more than one of them. In particular, from the interview of Francesco Franco, purchasing manager in DPI, it has been defined that a possible discount is possible starting from the components needed for the 5th compressor. This discount may vary from 10 to 15%; for simplicity, it has been calculated as a medium value of 12,5%.

Another possibility of discount is in the order cost: in fact, as the client's order arrives already with a defined quantity of compressors, the purchasing office can issue just one order with the quantity needed by all the RIKTs. This permits to save the cost of all the orders after the first.

For the orders here presented, the structure is similar to the one presented in the previous chapter: after the list of the components, a table will show the difference between the single production and the series production. For each of them, order cost, material cost and total cost are shown; then, it is pointed out the saving expressed in euro and in percentage over the total.

<u>Order 1</u>

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Threaded rod DIN 975 M10 x 70	10066057	2	UN	ROH	2,4	2
Hub (to be welded) 1/2"G	10075918	5	UN	ROH	41	50
Washer special for M20	10303019	6	UN	HALB	54	6
Jacking screw M36 x 120	10072369	2	UN	HALB	90	2
Jacking screw M56x4 x L=200 DIN561 FormB	10462075	4	UN	HALB	240	4
Cheese-head bolt M 20x80 w. locking	50050890	4	UN	HALB	14,72	4

Order 1								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	811,12	911,12	100	811,12	911,12	0	0,00%
2	200	1212,24	1412,24	100	1212,24	1312,24	100	7,08%
3	300	1613,36	1913,36	100	1613,36	1713,36	200	10,45%
4	400	2014,48	2414,48	100	2014,48	2114,48	300	12,43%
5	500	2415,6	2915,6	100	2166,4	2266,4	649,2	22,27%
6	600	2816,72	3416,72	100	2517,68	2617,68	799,04	23,39%
7	700	3217,84	3917,84	100	2868,96	2968,96	948,88	24,22%
8	800	3618,96	4418,96	100	3220,24	3320,24	1098,72	24,86%
9	900	4020,08	4920,08	100	3571,52	3671,52	1248,56	25,38%
10	1000	4421,2	5421,2	100	3922,8	4022,8	1398,4	25,80%

Tables 6.3 – 6.4: order 1, serial effect

In this order, the rod and the hub are ROH pieces, so there is no discount for them; instead, the others are HALB components, so the discount is applicable.
Furthermore, notice that the order cost stays at 100 €, as it will be just one order issued for all the components.

The formula used to calculate the material cost of the series production for this order is:

$$\text{if } N =< 4, \qquad N*(2,4+54+90+240+14,72)+(41/5)*50$$

$$\text{if } 5 =< N =< 10, \qquad N*(2,4)+N*(54+90+240+14,72)*0.875+(41/5)*50$$

<u>Order 2</u>

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Hexagon nut DIN 934 M 36	10011359	4	UN	ROH	10,48	100
Stop plate DIN 432 for M 8 galvanized	10011829	1	UN	ROH	2	1
Stop plate for M10 UNI 6601	10303056	4	UN	HALB	8	4
Stop plate for M8 (DIN 93 invalid)	10011998	28	UN	ROH	5,88	100
Stop plate for M16 (DIN 93 invalid)	10013545	2	UN	ROH	3,2	50
Stop plate UNI 6601for M16	10302922	2	UN	ROH	3,36	2
Tab washer D 10,5-A4 (DIN 93 invalid)	10010068	28	UN	ROH	6,86	100
Spring pin ISO 8752 D 3 x 12	10015620	1	UN	ROH	0,02	19

Order 2								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	401,35	501,35	100	401,35	501,35	0	0,00%
2	200	414,71	614,71	100	414,71	514,71	100	16,27%
3	300	428,07	728,07	100	428,07	528,07	200	27,47%
4	400	487,03	887,03	100	487,03	587,03	300	33,82%
5	500	500,39	1000,39	100	495,39	595,39	405	40,48%
6	600	513,75	1113,75	100	507,75	607,75	506	45,43%
7	700	527,11	1227,11	100	520,11	620,11	607	49,47%
8	800	586,08	1386,08	100	578,08	678,08	708	51,08%
9	900	599,44	1499,44	100	590,44	690,44	809	53,95%
10	1000	612,80	1612,80	100	602,80	702,80	910	56,42%

Tables 6.5 – 6.6: order 2, serial effect

In this order, the only component where the discount is applicable is the stop plate for M10. The formula is very close to the one of the single production, and the results depends almost exclusively to order cost reduction, as series effect on material cost has a very low impact on this order.

if N =<3, (2+8+3,36)*N+(5,88+6,86)/28*100+0,02*19+10,48/4*100+3,2/2*50

if N=4, (2+8+3,36)*N+(5,88+6,86)/28*100*2+0,02*19+10,48/4*100+3,2/2*50

if 5=<N=<7, (2+8*0.875+3,36)*N+(5,88+6,86)/28*100*2+0,02*19+10,48/4*100+3,2/2*50

if 8=<N=<10, (2+8*0.875+3,36)*N+(5,88+6,86)/28*100*3+0,02*19+10,48/4*100+3,2/2*50

<u>Order</u> 7

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Hexagon nut DIN 439 B M20 x 1,5 LEFT	10013523	1	UN	ROH	0,73	1
Hexagon nut DIN 439 B M24 x 1,5	10089701	1	UN	HALB	0,78	1
Cyl. head screw ISO4762 M12x35	10012403	6	UN	ROH	0,53	100
Socket head screw ISO 4762 M16 x 80/44	10014349	288	UN	ROH	106,56	1000
Cheese-head bolt ISO 4762 M16 x 180/44	10014351	90	UN	ROH	81	90
Socket head screw ISO 4762 M20 x 35	10014670	16	UN	ROH	6,24	16
Socket head screw ISO 4762 M24 x 40	10014669	8	UN	ROH	6,4	8
Socket head screw ISO 4762 M24 x 80	10012522	18	UN	ROH	23,76	200
Cylinder head screw M42 x 120 ISO 4762	10306065	20	UN	ROH	180	20
Hexagonal head screw DIN 931 M10 x 50/26	10009403	24	UN	ROH	6,96	250
Hexagonal screw DIN933 M12x35	10004163	20	UN	ROH	1,8	100

Order 7								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	999,48	1099,48	100	999,48	1099,48	0	0,00%
2	200	1274,63	1474,63	100	1274,63	1374,63	100	6,78%
3	300	1549,78	1849,78	100	1549,78	1649,78	200	10,81%
4	400	2194,93	2594,93	100	2194,93	2294,93	300	11,56%
5	500	2470,08	2970,08	100	2469,60	2569,60	400,49	13,48%
6	600	2745,23	3345,23	100	2744,65	2844,65	500,59	14,96%
7	700	3390,38	4090,38	100	3389,70	3489,70	600,68	14,69%
8	800	3665,53	4465,53	100	3664,75	3764,75	700,78	15,69%
9	900	3940,68	4840,68	100	3939,81	4039,81	800,88	16,54%
10	1000	4215,83	5215,83	100	4214,86	4314,86	900,98	17,27%

Tables 6.7 – 6.8: order 7, serial effect

In this order, too, the series effect due to materials is very low, as it depends just from the hexagon nut 439 B M 24 x 1,5. And another time, the formulas are very similar to the single production, as only one component is HALB.

if N =< 3,

(0,73+0,78+81+6,24+6,4+180)*N+1,8*5+6,96/24*250+106,56/288*1000+0,53/6*100+23,76/18*200

if N=4,

(0,73+0,78+81+6,24+6,4+180)*N+1,8*5+6,96/24*250+106,56/288*1000*2+0,53/6*100+23,76/18*200

If 5=<N=<6,

(0,73+0,78*0,875+81+6,24+6,4+180)*N+1,8*5+6,96/24*250+106,56/288*1000*2+0,53/6*100+
+23,76/18*200

if 7=<N=<10,

(0,73+0,78+81+6,24+6,4+180)*N+1,8*5+6,96/24*250+106,56/288*1000*3+0,53/6*100+23,76/18*200

Order 42

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Seeger circlip Ring DIN 471 D 20 x 1,2	265320	2	UN	ROH	0,06	50
Hexagon nut DIN 439 B M20 x 1,5	10011608	1	UN	ROH	0,28	100
Hexagon nut DIN934 M10	232261	6	UN	ROH	0,1	100
Hub (to be welded) 1/2"G	10315114	1	UN	HALB	15	50
Washer DIN 7989 A for M27	10702633	4	UN	ROH	1,16	100
Safety washer DIN 6798 A per M10	10037573	8	UN	ROH	0,08	100
SPRING WASHER DIN 127B per M30	10037853	64	UN	ROH	20,88	1000
Spring washer DIN 128A D 18,1/10,2 x 1,8	10014387	2	UN	ROH	0,04	100
Parallel pin ISO 2338-8 D8 h8 x 30	10013398	4	UN	ROH	1	50
Hexagonal head screw DIN 561B M16 x 80	211584	12	UN	ROH	14,4	150
Hexagon screw DIN 561B M20 x 100	10012378	4	UN	ROH	16	50
Screw hex. head DIN 561B M20 x 80	10076892	2	UN	HAWA	47	20
Cheese-head bolt ISO 4762 M16 x 90/44	10014350	198	UN	ROH	83,16	3000
Hexagon head screw DIN 931 M16 x 60/38	10002367	36	UN	ROH	10,08	400
Hexagon screw DIN 931 M30 x 120/66	10012375	9	UN	ROH	22,5	100
hexagonal head screw DIN 933 M16 x 40	10005020	32	UN	ROH	6,63	500
Hexagon head bolt DIN 933 M20 x 50	10012468	14	UN	ROH	5,18	300
VITI T.E. M 30*90	10076709	64	UN	HAWA	128	650

Order 42								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	5138,51	5238,51	100	5138,51	5238,51	0	0,00%
2	100	5138,51	5238,51	100	5138,51	5238,51	0	0,00%
3	100	5138,51	5238,51	100	5138,51	5238,51	0	0,00%
4	100	5138,51	5238,51	100	5138,51	5238,51	0	0,00%
5	100	5138,51	5238,51	100	5138,51	5238,51	0	0,00%
6	100	5138,51	5238,51	100	5138,51	5238,51	0	0,00%
7	100	5138,51	5238,51	100	5138,51	5238,51	0	0,00%
8	100	5138,51	5238,51	100	5138,51	5238,51	0	0,00%
9	100	5138,51	5238,51	100	5138,51	5238,51	0	0,00%
10	100	5138,51	5238,51	100	5138,51	5238,51	0	0,00%

Tables 6.9 – 6.10: order 42, serial effect

As already said in single production paragraph, this order is “special” in the sense that every component is purchased in a quantity which can support the production of 10 RIKT. So, as the order was already single, and the components are ROH or HAWA, there is no discount. The only HALB component, the hub (to be welded), does not have any discount effect (it was proved looking in past orders).

Orders 47 – 48: plates

Plates have a different kind of discount than the other components. For them, it should be possible to obtain a discount from 5% to 10%, so expressed here by the medium value 7,5%, starting from the purchase of the plates for the 5^{th} compressor. This discount is applicable on every plate.

Order 47

Piece	Code	Total quantity	U.M.	Typology	Cost
Plate EN 10029 th.=10	10066367	20,496	KG	ROH	10,86
Plate EN 10029 th.=120	10066641	830,844	KG	ROH	556,67
Plate EN 10029 th.=12	10066368	1766,502	KG	ROH	971,58
Plate EN 10029 th.=15	10066369	130,078	KG	ROH	70,24
Plate EN 10029 th.=15	10300381	173,108	KG	ROH	93,48
Plate EN 10029 th.=180	10096858	17286,97	KG	ROH	11236,53
Plate EN 10029 th.=190	10104317	6,986	KG	ROH	5,07
Plate EN 10029 th.=25	10066372	6767,075	KG	ROH	3654,22
Plate EN 10029 th.=35	10066374	13231,158	KG	ROH	7012,51
Plate EN 10029 th.=45	10066376	15651,22	KG	ROH	8451,66
Plate EN 10029 th.=55	10066378	1.139,11	KG	ROH	683,47
Plate EN 10029 th.=60	10066379	15168,145	KG	ROH	8570,01

Order 47								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	41316,30	41416,30	100	41316,30	41416,30	0	0,00%
2	200	82632,60	82832,60	100	82632,60	82732,60	100	0,12%
3	300	123948,90	124248,90	100	123948,90	124048,90	200	0,16%
4	400	165265,20	165665,20	100	165265,20	165365,20	300	0,18%
5	500	206581,50	207081,50	100	191087,89	191187,89	15893,61	7,68%
6	600	247897,80	248497,80	100	229305,47	229405,47	19092,34	7,68%
7	700	289214,10	289914,10	100	267523,04	267623,04	22291,06	7,69%
8	800	330530,40	331330,40	100	305740,62	305840,62	25489,78	7,69%
9	900	371846,70	372746,70	100	343958,20	344058,20	28688,50	7,70%
10	1000	413163,00	414163,00	100	382175,78	382275,78	31887,23	7,70%

Tables 6.11 – 6.12: order 47, serial effect

Order 48

Piece	Code	Total quantity	U.M.	Typology	Cost
Plate EN 10029 th.=70	10066392	11669,72	KG	ROH	5951,56
Plate EN 10029 th.=80	10066394	14336,64	KG	ROH	7455,05
Plate EN 10025 th.=150	10066643	37477,47	KG	ROH	23236,03
Plate EN 10025 th.=30	10066373	410,624	KG	ROH	207,34
Plate EN 10025 th.=50	10066377	2543,968	KG	ROH	1424,62
Plate EN 10029 th.=20	10066371	910,6	KG	ROH	482,618
Plate EN 10029 th.=300	10335017	1.103,54	KG	ROH	993,19

Order 48								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	39750,408	39850,408	100	39750,408	39850,408	0	0,00%
2	200	79500,816	79700,816	100	79500,816	79600,816	100	0,13%
3	300	119251,224	119551,224	100	119251,224	119351,224	200	0,17%
4	400	159001,632	159401,632	100	159001,632	159101,632	300	0,19%
5	500	198752,04	199252,04	100	183845,637	183945,64	15306,40	7,68%
6	600	238502,448	239102,448	100	220614,7644	220714,7644	18387,6836	7,69%
7	700	278252,856	278952,856	100	257383,8918	257483,89	21468,96	7,70%
8	800	318003,264	318803,264	100	294153,0192	294253,0192	24550,2448	7,70%
9	900	357753,672	358653,672	100	330922,1466	331022,15	27631,53	7,70%
10	1000	397504,08	398504,08	100	367691,274	367791,274	30712,806	7,71%

Tables 6.13 – 6.14: order 48, serial effect

Total cost

Here it is finally presented the total cost for purchasing, both in single and series production, with the saving. It is evident that, due to the discount of the HALB parts and plates, there is a big step between the 4th and the 5th compressor, from 2% to 11%. Then the value is stable around 11,5%.

	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	4.800	174.095,70	178.895,70	4.800	174.095,70	178.895,70	0	0,00%
2	9.500	336.557,24	346.057,24	4.800	336.557,24	341.357,24	4.700,00	1,36%
3	14.200	499.018,79	513.218,79	4.800	499.018,79	503.818,79	9.400,00	1,83%
4	18.900	662.774,55	681.674,55	4.800	662.774,55	667.574,55	14.100,00	2,07%
5	23.600	825.762,09	849.362,09	4.800	749.544,48	754.344,48	95.017,62	11,19%
6	28.300	988.396,14	1.016.696,14	4.800	896.935,00	901.735,00	114.961,14	11,31%
7	33.000	1.151.586,29	1.184.586,29	4.800	1.044.881,63	1.049.681,63	134.904,66	11,39%
8	37.700	1.314.368,45	1.352.068,45	4.800	1.192.420,26	1.197.220,26	154.848,18	11,45%
9	42.400	1.477.577,74	1.519.977,74	4.800	1.340.386,04	1.345.186,04	174.791,71	11,50%
10	47.100	1.640.342,09	1.687.442,09	4.800	1.487.812,86	1.492.612,86	194.829,23	11,55%

Table 6.15: total purchasing, serial effect

Figure 6.5: purchasing, serial effect

6.4 Production

Regarding production, there are possible savings in nesting, work preparation, and machining, while in other workings, like for example welding, this possibility is excluded, as the expected time for the workings is already optimized and there is no way to reduce set-up times.

Like in previous chapter, the parts that are part of production are analyzed separately, and then there will be a total for the whole production process.

6.4.1 Nesting

As already said in chapter 5.4.1, the nesting for 1 RIKT requires 140 hours, that can be divided into 100 + 40. In series production, the RIKTs must be equals; so, the engineering drawings and the components are also equals among them. After an interview with Luciano Danzo, nesting operator in DPI, it was clear that the 100 hours would remain the same also for more compressors for this reason: in fact, if the RIKTs are equals, there is the need of drawing only one time the components in the software, and then they can be copied as many times as the number of RIKTs. Also, the study of the drawings has to be made just once.

On the contrary, there is an increase in the 40 hours, because the number of components is bigger and so more time is needed to place the software drawn parts into the plates. Hence, the time increase for 2 RIKTs is the 25%, reaching 50 hours, and for 3 RIKTs it is the 50%, reaching 60 hours.

As in the company a batch of 2 or 3 compressors has already been produced, there is the knowledge that the optimum batch for nesting is 2 RIKTs, but, also with a batch of 3, the disposition in the plates is enough optimized. It has been stated that, when there will be the necessity of producing an even number of RIKTs, the required hours will always be the same number of those needed for 2 RIKTs (100 + 50), because, since the disposition is optimal, it is sufficient to copy this disposition for each other pair of compressors.

Instead, for an odd number of RIKTs, it has been estimated that there would be the necessity to first define the disposition of components required for 3 RIKTs, then the one needed for 2 (that is always optimal), and if the number of compressors is greater than 5, to copy this disposition for 2 as many times as necessary. So, the number of hours required are those needed for 3 compressors plus those for 2.

Putting this explanation into formulas, where "n" is a positive integer number and N the number of compressors, the required hours for nesting are:

if $N = 1$, 140 hours;

if $N = 2$, $100 + 125\%*40$ hours;

if $N = 3$, $100 + 150\%*40$ hours;

if $N = 2*n$, $100 + 125\%*40$ hours;

if $N = 2*n+1$ and $N > 3$, $100 + 150\%*40 + 125\%*40$ hours.

Table 6.16 explains this concept, in the same structure of the other tables already shown in this chapter. It is reminded that the cost of nesting is 55 €/h. A graphical view is given in figure 6.6. It is clear that, as for odd numbers of RIKTs the number of required hours is greater than the one of the following even number, the curve has an up-and-down trend.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	140,00	140,00	0,00	7.700,00	7.700,00	0,00	0,00%
2	280,00	150,00	130,00	15.400,00	8.250,00	7.150,00	46,43%
3	420,00	160,00	260,00	23.100,00	8.800,00	14.300,00	61,90%
4	560,00	150,00	410,00	30.800,00	8.250,00	22.550,00	73,21%
5	700,00	210,00	490,00	38.500,00	11.550,00	26.950,00	70,00%
6	840,00	150,00	690,00	46.200,00	8.250,00	37.950,00	82,14%
7	980,00	210,00	770,00	53.900,00	11.550,00	42.350,00	78,57%
8	1.120,00	150,00	970,00	61.600,00	8.250,00	53.350,00	86,61%
9	1.260,00	210,00	1.050,00	69.300,00	11.550,00	57.750,00	83,33%
10	1.400,00	150,00	1.250,00	77.000,00	8.250,00	68.750,00	89,29%

Table 6.16: nesting, serial effect

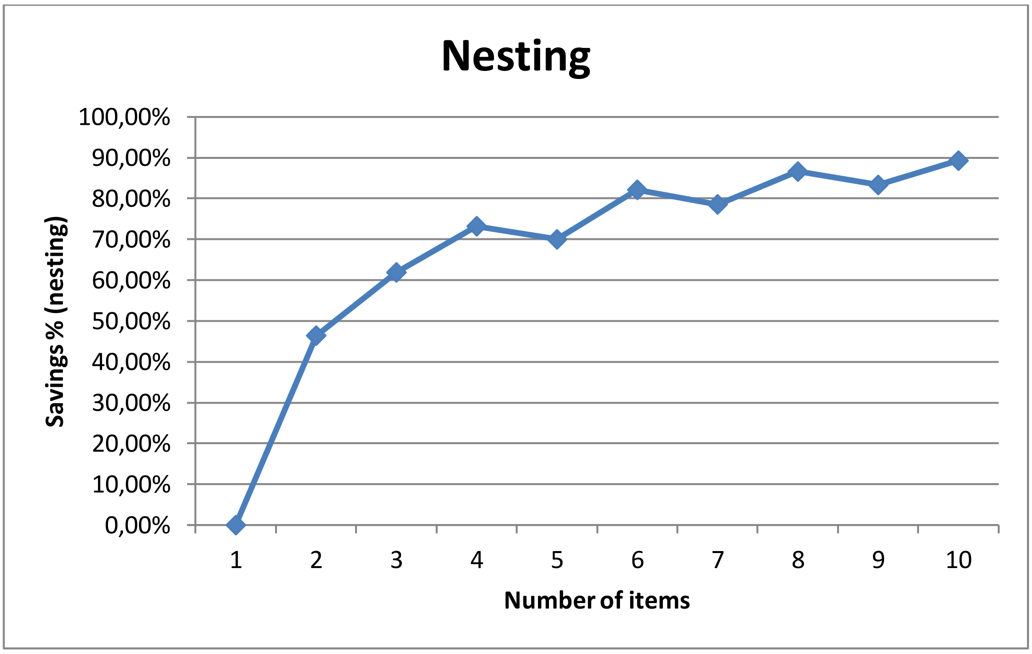


Figure 6.6: nesting, serial effect

6.4.2 Work preparation

Work preparation has big possibilities of savings, too. The situation is very similar to the one already analyzed in Engineering and Project Management in MAN.

Speaking about De Pretto, after the writing of the first work cycles and numerical control programs, the ones for the following compressors are the same. There are only some small changes to do before the components can enter the workshop; and also, there is the possibility that little modifications have to be done after this entrance, because of some differences in materials (for example, more or less allowance in surface, or some workings to do on diffusors to make them fit into the casing, or some problems with the spiral). This can require some lines of numerical control programs, which require a bit of time.

Speaking with Piero Scapin, responsible of production in DPI, it has been defined that this time can be identified with an increase of hours of 10% (of the original amount of time required for one RIKT) for 2nd and 3rd compressors and 5% from the 4th.

With a cost of 48 €/h, table 6.17 and figure 6.7 show the savings in work preparation. It is possible to see a big grow until the 5th compressor, then the grow continues, but in a slower way.

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	160,00	160,00	0,00	7.680,00	7.680,00	0,00	0,00%
2	320,00	176,00	144,00	15.360,00	8.448,00	6.912,00	45,00%
3	480,00	192,00	288,00	23.040,00	9.216,00	13.824,00	60,00%
4	640,00	200,00	440,00	30.720,00	9.600,00	21.120,00	68,75%
5	800,00	208,00	592,00	38.400,00	9.984,00	28.416,00	74,00%
6	960,00	216,00	744,00	46.080,00	10.368,00	35.712,00	77,50%
7	1.120,00	224,00	896,00	53.760,00	10.752,00	43.008,00	80,00%
8	1.280,00	232,00	1.048,00	61.440,00	11.136,00	50.304,00	81,88%
9	1.440,00	240,00	1.200,00	69.120,00	11.520,00	57.600,00	83,33%
10	1.600,00	248,00	1.352,00	76.800,00	11.904,00	64.896,00	84,50%

Table 6.17: work preparation, serial effect

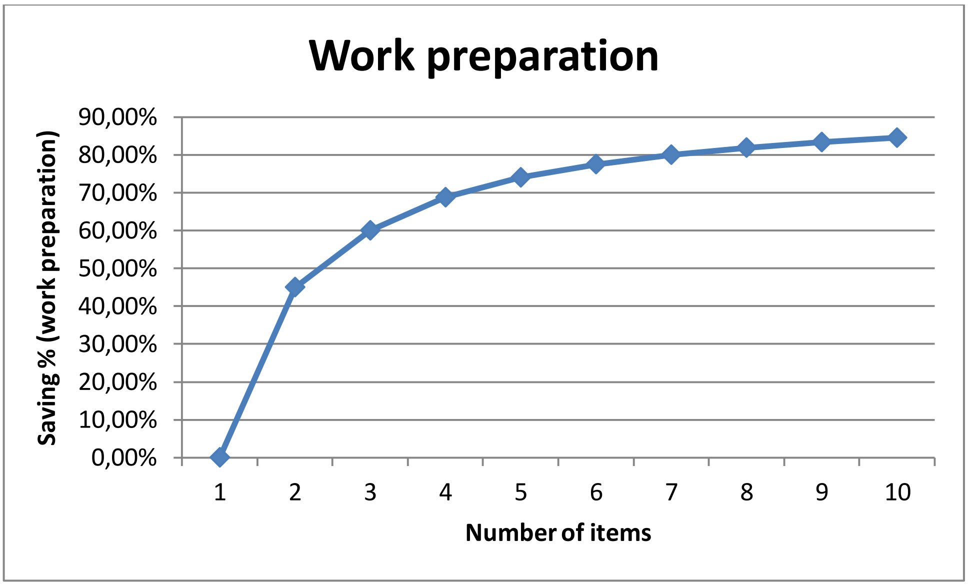


Figure 6.7: work preparation, serial effect

6.4.3 Machining

The division into work centers is repeated like in chapter 5.4.3. But it is repeated only the list of the parts worked, without the details already presented.

Set-up time reduction can be obtained through the upkeep of the tools of the machine, the increase of speed of the operator that already knows exactly what to do after the first piece, the unnecessary repositioning of brackets and stands for the component…

6.4.3.1 41012 - Vertical lathe Morando VH20

Parts worked:

- Inlet piece (3 passages)

To explain how set-up reduction can work, let's use as example a batch of three pieces through the first passage in this machine, so with one positioning.

The situation of single production was: set-up → machining, set-up → machining, set-up → machining. The set-up had to be repeated three times, as the three pieces were not produced one after the other. In series production, this happens; so the situation would be set-up → machining → machining → machining, with just one set-up (the other set-ups can be considered "almost null").

This can be generalized for every number of positioning: for example, with 2 positioning, the single production sequence (that had to be repeated three times under the hypothesis of three pieces) was: set-up → 1st positioning, machining → set-up → 2nd positioning, machining. With series production, this sequence becomes the following: set-up → 1st positioning, machining 1st piece → 1st positioning, machining 2nd piece →1st positioning, machining 3rd piece → set-up → 2nd positioning, machining 1st piece → 2nd positioning, machining 2nd piece → 2nd positioning, machining 3rd piece. Another time, the set-up is only one (divided into two moments).

It should be now possible to understand the following formulas (referred to the 3 passages of the inlet piece in this work center), which are the ones to calculate the time required for N compressors:

- 1st passage, 1+(20,5 * N) hours;
- 2nd passage, 1,5+(20 * N) hours;
- 3rd passage, 1+(1 * N) hours.

The change compared to single production is due to the fact that now not all the time is proportional to the number of compressors, but just the machining one; the set-up time is now independent, its value is constant and does not vary increasing N.

The total savings for the work center are presented in table 6.18, according to the same structure of the previously saving tables.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	45,00	45,00	0,00	3.393,00	3.393,00	0,00	0,00%
2	90,00	86,50	3,50	6.786,00	6.522,10	263,90	3,89%
3	135,00	128,00	7,00	10.179,00	9.651,20	527,80	5,19%
4	180,00	169,50	10,50	13.572,00	12.780,30	791,70	5,83%
5	225,00	211,00	14,00	16.965,00	15.909,40	1.055,60	6,22%
6	270,00	252,50	17,50	20.358,00	19.038,50	1.319,50	6,48%
7	315,00	294,00	21,00	23.751,00	22.167,60	1.583,40	6,67%
8	360,00	335,50	24,50	27.144,00	25.296,70	1.847,30	6,81%
9	405,00	377,00	28,00	30.537,00	28.425,80	2.111,20	6,91%
10	450,00	418,50	31,50	33.930,00	31.554,90	2.375,10	7,00%

Table 6.18: work center 41012, serial effect

6.4.3.2 43012 – Boring machine AMF PAMA 130

Parts worked:

- Milled diffusor 4th stage
- Inlet piece (2 passages)
- Channel wall complete machined 1050 kg
- Channel wall complete machined 1145 kg
- Intermediate wall complete machined 1031 kg
- Intermediate wall complete machined 836 kg
- Man hole cover
- Cover for bearing house

With reference to the diffusor, the inlet piece, the man hole cover and the cover for bearing house, the concept is the same already analyzed in the previous work center: the required set-up for series production becomes one, while the others become “almost null” (for the reasons explained at the beginning of paragraph 6.4.3: upkeep of the tools, quickness of the operator…).

On the contrary, for the channel walls, the situation is a little different. A first reduction is obtainable treating them like the other parts (so, the set-up reduction already explained, which can be defined as “standard”); but then, another reduction is possible. In fact, the two walls, although slightly different in dimensions, need the same workings; so, the changes in set-up between their respective positioning are very minimal and it is possible to realize in series the first positioning of the first kind of wall, then the first of the second kind, and so on.

For these little changes in set-up a certain amount of time, called “security set-up” time, is requested, to verify if there are some variations to do in the disposition of the tools or the brackets; this security set-up time is about the 30% of the original set-up time. In the case of the complete channel walls, will be 0,5 hours.

Schematizing the situation for two compressors:
set-up → 1st positioning wall 1050 kg, machining 1st piece → 1st positioning wall 1050 kg, machining 2nd piece → security set-up → 1st positioning wall 1145 kg, machining 1st piece → 1st positioning wall 1145 kg, 2nd piece → set-up → 2nd positioning wall 1050 kg, machining 1st piece → 2nd positioning wall 1050 kg, machining 2nd piece → security set-up → 2nd positioning wall 1145 kg, machining 1st piece → 2nd positioning wall 1145 kg, 2nd piece.
This can be generalized for the needed number of pieces.

The security set-up is intended with the same hypothesis of the standard set-up, i.e. that the sum of all the security set-ups is the 30% of the total set-up times.

In the case of these channel walls, the set-up time is 1,5 hours, the security set-up time is 0,5 hours, and the machining time is 11 hours for each piece; so, the total time for the production of 2 RIKTs will be 1,5 + 11 + 11 + 0,5 + 11 + 11 = 46 hours, while in the single production it was 50 hours. Producing walls in this way lead to a saving also in the production for one single RIKT.

Same considerations are applicable to the intermediate walls. In this case, the security set-up time is 1 hour, as the total set-up time is 3,5 hours.

The formulas to calculate the time required for N compressors are:

- Milled diffusor 4th stage, 0,75+(2,25 * N) hours;
- Inlet piece 1st passage, 1+(3 * N) hours;
- Inlet piece, 2nd passage, 1+(1 * N) hours;
- Channel wall complete machined 1050 and 1145 kg, 1,5+0,5+(22 * N) hours;
- Intermediate wall complete machined 1031 and 836 kg, 3,5+1+(29 * N) hours;
- Man hole cover, 1,5+(9,5 * N) hours;
- Cover for bearing house, 1,5+(12,5 * N) hours;

The total savings for the work center are presented in table 6.19.

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	95,00	91,50	3,50	8.094,00	7.795,80	298,20	3,68%
2	190,00	170,75	19,25	16.188,00	14.547,90	1.640,10	10,13%
3	285,00	250,00	35,00	24.282,00	21.300,00	2.982,00	12,28%
4	380,00	329,25	50,75	32.376,00	28.052,10	4.323,90	13,36%
5	475,00	408,50	66,50	40.470,00	34.804,20	5.665,80	14,00%
6	570,00	487,75	82,25	48.564,00	41.556,30	7.007,70	14,43%
7	665,00	567,00	98,00	56.658,00	48.308,40	8.349,60	14,74%
8	760,00	646,25	113,75	64.752,00	55.060,50	9.691,50	14,97%
9	855,00	725,50	129,50	72.846,00	61.812,60	11.033,40	15,15%
10	950,00	804,75	145,25	80.940,00	68.564,70	12.375,30	15,29%

Table 6.19: work center 43012, serial effect

6.4.3.3 44011 - Flexible machine PAMA Speedmat

Parts worked:

- Cooler cover 1st stage (2 pieces)
- Cooler cover 2nd stage and 3rd stage (2 pieces each)
- Bracket for bearing housing
- Lower water chamber 1st, 2nd and 3rd stage (2 pieces each)
- Upper water chamber 1st, 2nd and 3rd stage (2 pieces each)
- Milled diffusor 4th stage
- Inlet piece (2 passages)
- Bearing house OT (2 passages)
- Bearing house UT

The two typologies of set-up reduction have already been discussed. From now on, it will be reported which kind of reduction is obtained for the components.

The cooler cover 1st stage, the bracket, the diffusor, the inlet piece and the bearing house UT and OT have the standard reduction. The cooler cover 2nd and 3rd stages and the water chambers have the “security reduction”. In fact, for these components the same hypothesis of the channel walls analyzed in the previous work center are valid: slightly different dimensions, but same workings with same tools. The security set-up is equal to 0,3 hours for all these components (as the set-up time is 1 hour).

Expressing these concepts in formulas to calculate the time required for N compressors:

- Cooler cover 1st stage (2 pieces), 1+[(7,5+7,5) * N] hours;
- Cooler cover 2nd stage and 3rd stage (2 pieces each),
  1+0,3+[(6,5+6,5+6,5+6,5) * N] hours;
- Bracket for bearing housing, 0,5+(14,5 * N) hours;
- Lower water chamber 1st, 2nd and 3rd stage (2 pieces each),
  1+0,3+0,3+[(13,2+13,2+13,2+13,2+13,2+13,2) * N] hours;
- Upper water chamber 1st, 2nd and 3rd stage (2 pieces each)
  1+0,3+0,3+[(8+8+8+8+8+8) * N] hours;
- Milled diffusor 4th stage, 2,75+(33 * N) hours;
- Inlet piece, 1st passage, 2,5+(14,5 * N) hours;
- Inlet piece, 2nd passage, 0,5+(4 * N) hours;
- Bearing house OT, 1st passage, 1,25+(7,75 * N) hours;
- Bearing house OT, 2nd passage, 1,25+(28,25 * N) hours;
- Bearing house UT, 1,25+(14,75 * N) hours.

The total savings for the work center are presented in table 6.20.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	303,95	300,45	3,50	32.431,47	32.058,02	373,45	1,15%
2	607,90	585,40	22,50	64.862,93	62.462,18	2.400,75	3,70%
3	911,85	870,35	41,50	97.294,40	92.866,35	4.428,05	4,55%
4	1.215,80	1.155,30	60,50	129.725,86	123.270,51	6.455,35	4,98%
5	1.519,75	1.440,25	79,50	162.157,33	153.674,68	8.482,65	5,23%
6	1.823,70	1.725,20	98,50	194.588,79	184.078,84	10.509,95	5,40%
7	2.127,65	2.010,15	117,50	227.020,26	214.483,01	12.537,25	5,52%
8	2.431,60	2.295,10	136,50	259.451,72	244.887,17	14.564,55	5,61%
9	2.735,55	2.580,05	155,50	291.883,19	275.291,34	16.591,85	5,68%
10	3.039,50	2.865,00	174,50	324.314,65	305.695,50	18.619,15	5,74%

Table 6.20: work center 44011, serial effect

6.4.3.4 46012 - Vertical lathe TV Ceruti

Parts worked:

- Discharge spiral

In this case, positionings of all the pieces are consecutively performed; but the spiral is a complex component, and in this center it requires a complicated positioning. Series production does not allow here a complete set-up times removal, but as maximum their halving: there is no need to change tools or brackets, but a certain attention and care in positioning is required.

Having a set-up time of 10 hours, this "reduced set-up" time is 5 hours. In an example of 2 compressors, the situation is the following:

set-up → 1st positioning, machining 1st piece → reduced set-up → 1st positioning, machining 2nd piece → set-up → 2nd positioning, machining 1st piece → reduced set-up → 2nd positioning, machining 2nd piece.

The general formula to calculate the time required for N compressors is:

- 10+28,4+(5+28,4) * (N-1) hours.

The total savings for the work center are presented in table 6.21.

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	38,40	38,40	0,00	3.667,20	3.667,20	0,00	0,00%
2	76,80	71,80	5,00	7.334,40	6.856,90	477,50	6,51%
3	115,20	105,20	10,00	11.001,60	10.046,60	955,00	8,68%
4	153,60	138,60	15,00	14.668,80	13.236,30	1.432,50	9,77%
5	192,00	172,00	20,00	18.336,00	16.426,00	1.910,00	10,42%
6	230,40	205,40	25,00	22.003,20	19.615,70	2.387,50	10,85%
7	268,80	238,80	30,00	25.670,40	22.805,40	2.865,00	11,16%
8	307,20	272,20	35,00	29.337,60	25.995,10	3.342,50	11,39%
9	345,60	305,60	40,00	33.004,80	29.184,80	3.820,00	11,57%
10	384,00	339,00	45,00	36.672,00	32.374,50	4.297,50	11,72%

Table 6.21: work center 46012, serial effect

6.4.3.5 46013 - Vertical lathe TV Morando Phoneix

Parts worked:

- Welded diffusor 2nd stage
- Welded diffusor 3rd stage
- Milled diffusor GD 11 (2 passages)
- Milled diffusor 4th stage (2 passages)
- Adjusting ring
- Inlet casing (2 passages)
- Channel wall complete machined 1050 kg
- Channel wall complete machined 1145 kg
- Channel wall complete machined 2196 kg
- Intermediate wall complete machined 1031 kg
- Intermediate wall complete machined 836 kg

The two milled diffusors, the adjusting ring and the inlet casing follow the standard set-up time reduction; the welded diffusors, the channel walls and the intermediate walls follow the security set-up time reduction rule. For them, the security set-up times are respectively 0,3, 0,5 and 0,5 hours.

The formulas to calculate the time required for N compressors are:

- Welded diffusor 2nd and 3rd stages, 1+0,3+(26 * N) hours;
- Milled diffusor GD 11, 1st passage, 1,5+(21,5 * N) hours;
- Milled diffusor GD 11, 2nd passage, 1+(17 * N) hours;
- Milled diffusor 4th stage 1st passage, 1,5+(14,5 * N) hours;
- Milled diffusor 4th stage, 2nd passage, 1+(5 * N) hours;
- Adjusting ring, 1+(8 * N) hours;
- Inlet casing, 1st passage, 1,5+(10,5 * N) hours;
- Inlet casing, 2nd passage, 2+(23,9 * N) hours;
- Channel wall complete machined 1050, 1145 and 2196 kg, 1,5+0,5+0,5+(66 * N) hours;
- Intermediate wall complete machined 1031 and 836 kg, 1,5+0,5+(35 * N) hours.

The total savings for the work center are presented in table 6.22.

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	246,40	242,70	3,70	23.531,20	23.177,85	353,35	1,50%
2	492,80	470,10	22,70	47.062,40	44.894,55	2.167,85	4,61%
3	739,20	697,50	41,70	70.593,60	66.611,25	3.982,35	5,64%
4	985,60	924,90	60,70	94.124,80	88.327,95	5.796,85	6,16%
5	1.232,00	1.152,30	79,70	117.656,00	110.044,65	7.611,35	6,47%
6	1.478,40	1.379,70	98,70	141.187,20	131.761,35	9.425,85	6,68%
7	1.724,80	1.607,10	117,70	164.718,40	153.478,05	11.240,35	6,82%
8	1.971,20	1.834,50	136,70	188.249,60	175.194,75	13.054,85	6,93%
9	2.217,60	2.061,90	155,70	211.780,80	196.911,45	14.869,35	7,02%
10	2.464,00	2.289,30	174,70	235.312,00	218.628,15	16.683,85	7,09%

Table 6.22: work center 46013, serial effect

6.4.3.6 51012 - Boring machine PAMA 140

Parts worked:

- Milled diffusor GD11 (2 passages)
- Discharge spiral
- Channel wall complete machined 2196 kg

Each of the three components has a standard set-up time reduction. So, directly expressing this in formulas to calculate the time required for N compressors, we obtain:

- Milled diffusor GD11, 1st passage, 0,75+(3,25 * N) hours;
- Milled diffusor GD11, 2nd passage, 2,75+(57,25 * N) hours;
- Discharge spiral, 1,5+(6,5* N) hours;
- Channel wall complete machined 2196 kg, 1,5+(15,5 * N) hours.

The total savings for the work center are presented in table 6.23.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	89,00	89,00	0,00	9.496,30	9.496,30	0,00	0,00%
2	178,00	171,50	6,50	18.992,60	18.299,05	693,55	3,65%
3	267,00	254,00	13,00	28.488,90	27.101,80	1.387,10	4,87%
4	356,00	336,50	19,50	37.985,20	35.904,55	2.080,65	5,48%
5	445,00	419,00	26,00	47.481,50	44.707,30	2.774,20	5,84%
6	534,00	501,50	32,50	56.977,80	53.510,05	3.467,75	6,09%
7	623,00	584,00	39,00	66.474,10	62.312,80	4.161,30	6,26%
8	712,00	666,50	45,50	75.970,40	71.115,55	4.854,85	6,39%
9	801,00	749,00	52,00	85.466,70	79.918,30	5.548,40	6,49%
10	890,00	831,50	58,50	94.963,00	88.721,05	6.241,95	6,57%

Table 6.23: work center 51012, serial effect

6.4.3.7 53011 - Boring machine PAMA 180

Parts worked:

- Inlet casing

Another time, we have a piece following the standard set-up time reduction. The formula to calculate the time required for N compressors is:

- Inlet casing, 2,5+(29,2 * N) hours.

The total savings for the work center are presented in table 6.24.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	31,70	31,70	0,00	3.382,39	3.382,39	0,00	0,00%
2	63,40	60,90	2,50	6.764,78	6.498,03	266,75	3,94%
3	95,10	90,10	5,00	10.147,17	9.613,67	533,50	5,26%
4	126,80	119,30	7,50	13.529,56	12.729,31	800,25	5,91%
5	158,50	148,50	10,00	16.911,95	15.844,95	1.067,00	6,31%
6	190,20	177,70	12,50	20.294,34	18.960,59	1.333,75	6,57%
7	221,90	206,90	15,00	23.676,73	22.076,23	1.600,50	6,76%
8	253,60	236,10	17,50	27.059,12	25.191,87	1.867,25	6,90%
9	285,30	265,30	20,00	30.441,51	28.307,51	2.134,00	7,01%
10	317,00	294,50	22,50	33.823,90	31.423,15	2.400,75	7,10%

Table 6.24: work center 53011, serial effect

6.4.3.8 53012 - Boring machine Colgar Fral 70

Parts worked:

- Welded diffusor 2nd stage
- Welded diffusor 3rd stage
- Adjusting ring
- Inlet casing (4 passages)
- Casing foot (2 pieces)
- Discharge spiral

All these pieces follow the standard set-up time reduction, except the welded diffusors, which follow the security set-up time reduction, with a security set-up time of 0,3 hours, as the total of the set-up hours is 1.

The formulas to calculate the time required for N compressors are:

- Welded diffusor 2nd stage and 3rd stage, 1+0,3+(46 * N) hours;
- Adjusting ring, 2,5+(26,5 * N) hours;
- Inlet casing, 1st passage, 1,5+(6,2 * N) hours;
- Inlet casing, 2nd passage, 1,5+(10,5 * N) hours;
- Inlet casing, 3rd passage, 1+(4,7 * N) hours;
- Inlet casing, 4th passage, 2,5+(55,1 * N) hours;
- Casing foot (2 pieces), 1+(32 * N) hours;
- Discharge spiral, 5+(91 * N) hours.

The total savings for the work center are presented in table 6.25.

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	289,00	288,30	0,70	30.836,30	30.761,61	74,69	0,24%
2	578,00	560,30	17,70	61.672,60	59.784,01	1.888,59	3,06%
3	867,00	832,30	34,70	92.508,90	88.806,41	3.702,49	4,00%
4	1.156,00	1.104,30	51,70	123.345,20	117.828,81	5.516,39	4,47%
5	1.445,00	1.376,30	68,70	154.181,50	146.851,21	7.330,29	4,75%
6	1.734,00	1.648,30	85,70	185.017,80	175.873,61	9.144,19	4,94%
7	2.023,00	1.920,30	102,70	215.854,10	204.896,01	10.958,09	5,08%
8	2.312,00	2.192,30	119,70	246.690,40	233.918,41	12.771,99	5,18%
9	2.601,00	2.464,30	136,70	277.526,70	262.940,81	14.585,89	5,26%
10	2.890,00	2.736,30	153,70	308.363,00	291.963,21	16.399,79	5,32%

Table 6.25: work center 53012, serial effect

6.4.3.9 *Total machining cost*

Finally, it is possible to sum every single work center costs and savings, to have the totals of machining (excluding the PAMA 200 machine). This total is presented in table 6.26 and figure 6.8. It can be noticed that, after a big increase in savings in the first 4 compressors, the curve levels off.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	1.138,45	1.127,05	11,40	114.831,86	113.732,17	1.099,69	0,96%
2	2.276,90	2.177,25	99,65	229.663,71	219.864,72	9.798,99	4,27%
3	3.415,35	3.227,45	187,90	344.495,57	325.997,28	18.498,29	5,37%
4	4.553,80	4.277,65	276,15	459.327,42	432.129,83	27.197,59	5,92%
5	5.692,25	5.327,85	364,40	574.159,28	538.262,39	35.896,89	6,25%
6	6.830,70	6.378,05	452,65	688.991,13	644.394,94	44.596,19	6,47%
7	7.969,15	7.428,25	540,90	803.822,99	750.527,50	53.295,49	6,63%
8	9.107,60	8.478,45	629,15	918.654,84	856.660,05	61.994,79	6,75%
9	10.246,05	9.528,65	717,40	1.033.486,70	962.792,61	70.694,09	6,84%
10	11.384,50	10.578,85	805,65	1.148.318,55	1.068.925,16	79.393,39	6,91%

Table 6.26: machining, serial effect

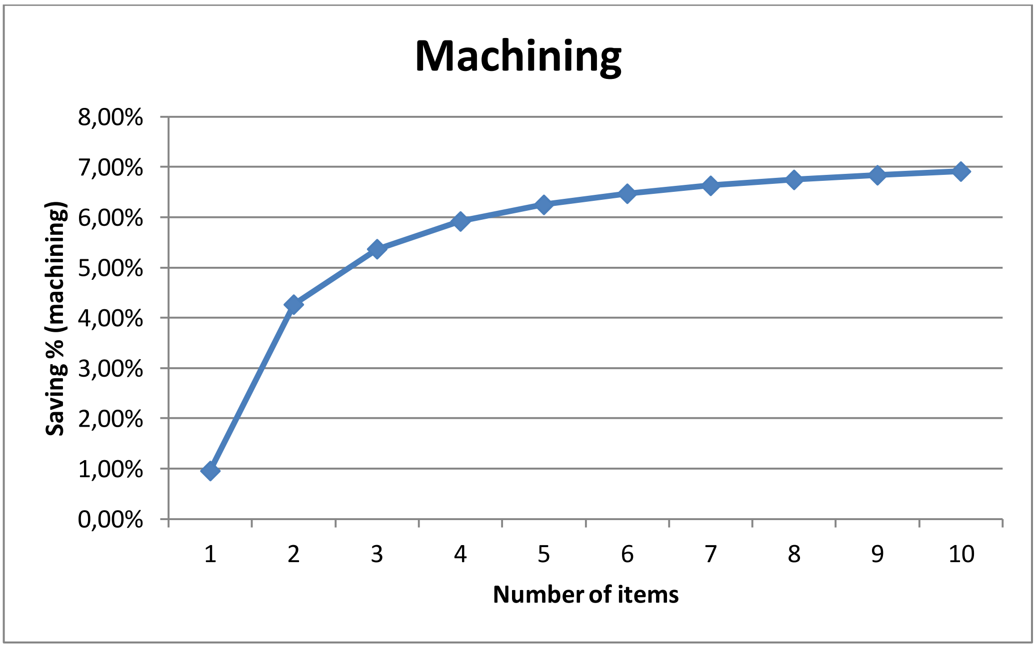


Figure 6.8: machining, serial effect

6.4.4 Total workings

As already mentioned, machining is the only working part which can obtain time reduction, and so savings. Welding, sandblasting, painting, and all the other workings must contribute with their entire value. So, the total workings saving are the same of machining in modulus, but the percentage decreases a lot.

This effect is shown in table 6.27 and figure 6.9. The trend of the curve is totally similar to the machining one.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	7.188,45	7.177,05	11,40	499.515,30	498.415,61	1.099,69	0,22%
2	14.376,90	14.277,25	99,65	998.803,99	989.005,00	9.798,99	0,98%
3	21.565,35	21.377,45	187,90	1.498.205,99	1.479.707,70	18.498,29	1,23%
4	28.753,80	28.477,65	276,15	1.997.607,98	1.970.410,39	27.197,59	1,36%
5	35.942,25	35.577,85	364,40	2.497.009,98	2.461.113,09	35.896,89	1,44%
6	43.130,70	42.678,05	452,65	2.996.411,97	2.951.815,78	44.596,19	1,49%
7	50.319,15	49.778,25	540,90	3.495.813,97	3.442.518,48	53.295,49	1,52%
8	57.507,60	56.878,45	629,15	3.995.215,96	3.933.221,17	61.994,79	1,55%
9	64.696,05	63.978,65	717,40	4.494.617,96	4.423.923,87	70.694,09	1,57%
10	71.884,50	71.078,85	805,65	4.994.019,95	4.914.626,56	79.393,39	1,59%

Table 6.27: total workings, serial effect

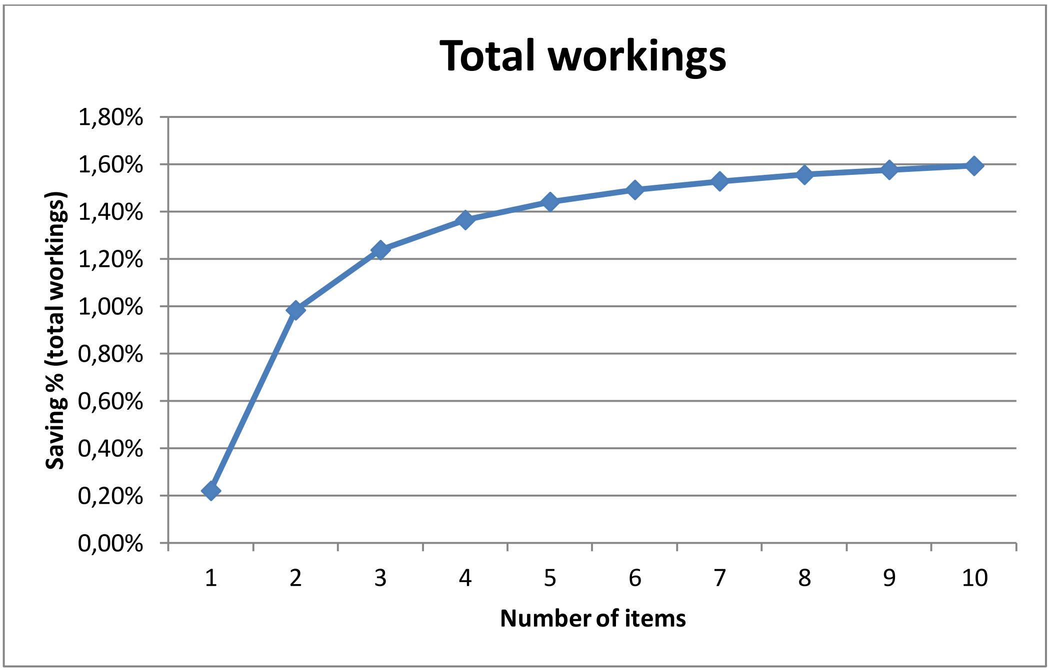


Figure 6.9: total workings, serial effect

6.4.5 Serial effect in production

The total saving possible in production is the sum of the savings of nesting, work preparation and total workings (reminding that machining costs are already included in total workings cost).

This total is presented in table 6.28 and figure 6.10. The strange appearance of the curve is due to nesting. There is a significant increase in savings until the 4th compressor, and then the curve tends to level off.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	7.488,45	7.477,05	11,40	514.895,30	513.795,61	1.099,69	0,21%
2	14.976,90	14.603,25	373,65	1.029.790,59	1.005.703,00	23.860,99	2,32%
3	22.465,35	21.729,45	735,90	1.544.685,89	1.497.723,70	46.622,29	3,02%
4	29.953,80	28.827,65	1.126,15	2.059.581,18	1.988.260,39	70.867,59	3,44%
5	37.442,25	35.995,85	1.446,40	2.574.476,48	2.482.647,09	91.262,89	3,54%
6	44.930,70	43.044,05	1.886,65	3.089.371,77	2.970.433,78	118.258,19	3,83%
7	52.419,15	50.212,25	2.206,90	3.604.267,07	3.464.820,48	138.653,49	3,85%
8	59.907,60	57.260,45	2.647,15	4.119.162,36	3.952.607,17	165.648,79	4,02%
9	67.396,05	64.428,65	2.967,40	4.634.057,66	4.446.993,87	186.044,09	4,01%
10	74.884,50	71.476,85	3.407,65	5.148.952,95	4.934.780,56	213.039,39	4,14%

Table 6.28: production, serial effect

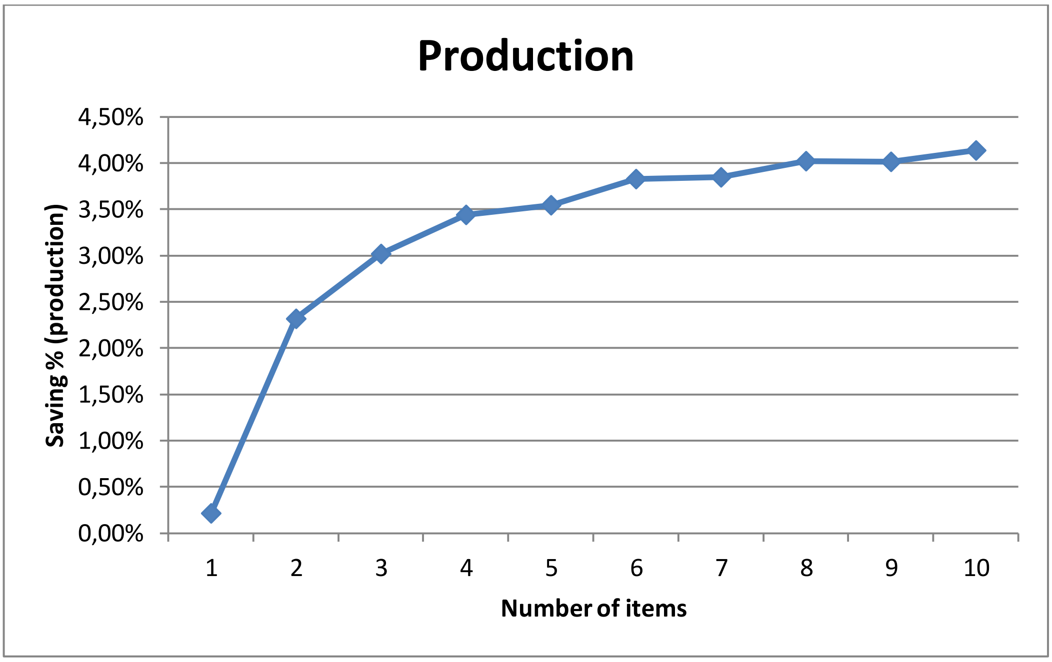


Figure 6.10: production, serial effect

6.5 Quality

For the importance of quality in De Pretto, it is very difficult to reduce the time dedicated to this operation. As already stated in chapter 5.5, there are 5 different moments of quality control: identification, intermediate control, final control, during pressing and during painting. The only time that can be reduced is the one dedicated to final control; however, this reduction does not depend from an increase of speed in performing the control checking, but from the possibility of “set –up time savings” in control tools preparation. In fact, with a series of equal pieces, the control would be done in series, too; the required tools are always the same, and there is no need to go finding them in tool warehouse and make them ready for the control.

This time reduction has been identified by Mirco Casa, responsible of quality control in De Pretto Industrie, with the 15% of the normal time required to perform the operation. So, as the total hours needed for final control are 27,5, this time reduction is of 4 hours for each RIKT after the first one.

In table 6.29 and figure 6.11 the possible savings are presented. There is a big percentage increase until the 4th – 5th compressor, then the curve flattens.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	61,50	61,50	0,00	3.013,50	3.013,50	0	0,00%
2	123,00	119,00	4,00	6.027,00	5.831,00	196,00	3,25%
3	184,50	176,50	8,00	9.040,50	8.648,50	392,00	4,34%
4	246,00	234,00	12,00	12.054,00	11.466,00	588,00	4,88%
5	307,50	291,50	16,00	15.067,50	14.283,50	784,00	5,20%
6	369,00	349,00	20,00	18.081,00	17.101,00	980,00	5,42%
7	430,50	406,50	24,00	21.094,50	19.918,50	1.176,00	5,57%
8	492,00	464,00	28,00	24.108,00	22.736,00	1.372,00	5,69%
9	553,50	521,50	32,00	27.121,50	25.553,50	1.568,00	5,78%
10	615,00	579,00	36,00	30.135,00	28.371,00	1.764,00	5,85%

Table 6.29: quality, serial effect

Figure 6.11: quality, serial effect

6.6 Total saving

After the analysis of all these departments, it is finally possible to define a first total saving, depending from the quantity of compressors. This first result does not include some other costs, which will be analyzed in chapter 7, like warehouse costs, which will decrease the amount of the possible discount. It is important to define that is not the modulus of the discount that is important, but the percentage.

Like in previous chapter, the results are presented first for De Pretto and MAN separately, then together. It has no sense in these results to speak about hours, as the savings in purchasing are not depending from them.

N	$€_{single}$	$€_{series}$	Saving €	Saving %
1	696.804,49	695.704,80	1.099,69	0,16%
2	1.381.874,83	1.352.891,24	28.756,99	2,08%
3	2.066.945,18	2.010.190,99	56.414,29	2,73%
4	2.753.309,73	2.667.300,94	85.555,59	3,11%
5	3.438.906,07	3.251.275,06	187.064,51	5,44%
6	4.124.148,91	3.889.269,78	234.199,33	5,68%
7	4.809.947,86	4.534.420,60	274.734,15	5,71%
8	5.495.338,81	5.172.563,43	321.868,97	5,86%
9	6.181.156,90	5.817.733,40	362.403,80	5,86%
10	6.866.530,04	6.455.764,42	409.632,62	5,97%

Table 6.30: serial effect in DPI

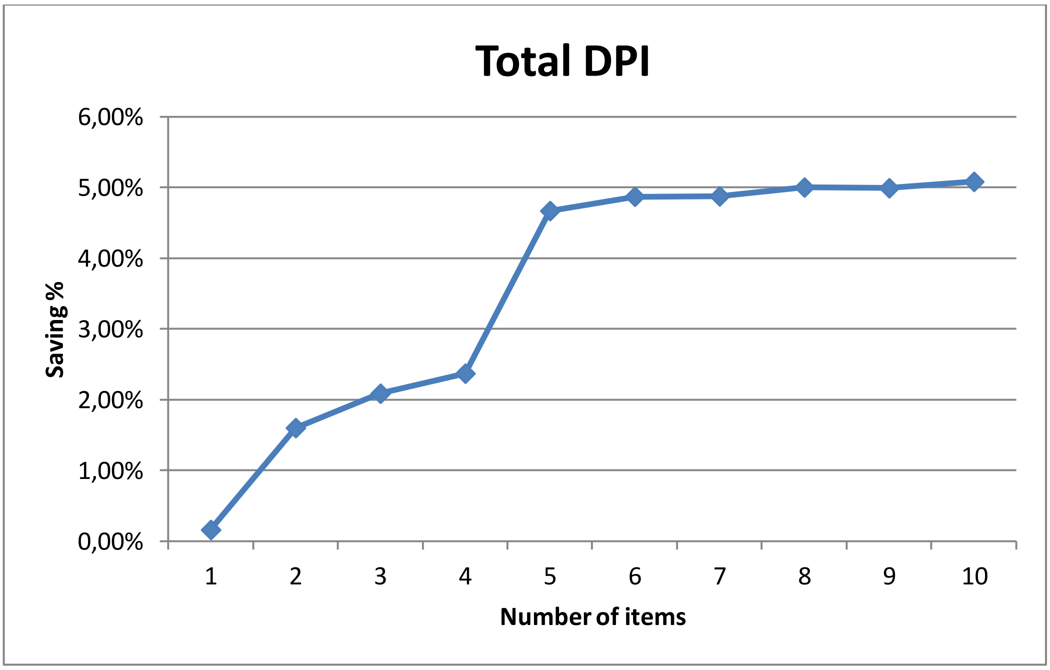


Figure 6.12: serial effect in DPI

In De Pretto Industrie, a first big saving can be obtained with the production of 2 compressors in series, going from 0,16% to a little more of the 2%. Then the increase is minor but significant until the 4th compressor, and then there is an even greater increase than the first one, passing from the 3,11% to the 5,44%. This increase is due, mostly, to purchasing. After this big increase, the curve starts to level off, until a maximum of 5,97% for the series production of 10 RIKTs.

N	$€_{single}$	$€_{series}$	Saving €	Saving %
1	865.111,06	865.111,06	0,00	0,00%
2	1.730.222,11	1.671.320,53	58.901,59	3,40%
3	2.595.333,17	2.477.306,43	118.026,74	4,55%
4	3.460.444,23	3.283.441,38	177.002,85	5,12%
5	4.325.555,28	4.060.352,95	265.202,34	6,13%
6	5.190.666,34	4.860.643,22	330.023,12	6,36%
7	6.055.777,40	5.660.933,49	394.843,90	6,52%
8	6.920.888,45	6.461.223,76	459.664,69	6,64%
9	7.785.999,51	7.261.514,04	524.485,47	6,74%
10	8.651.110,57	8.060.882,92	590.227,65	6,82%

Table 6.31: serial effect in MAN

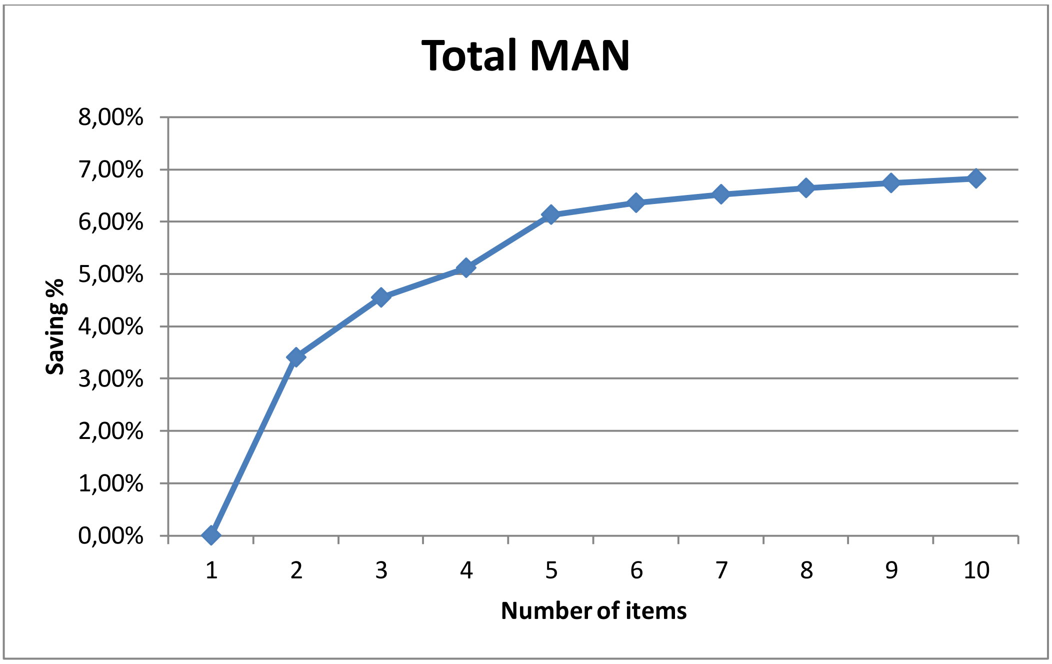


Figure 6.13: serial effect in MAN

In MAN, after a great first saving passing from 1 to 2 compressors (going from 0% to 3,40%), the progressive increase is more linear than the one obtained in De Pretto, without any other big step. At the end, the maximum discount applicable is of 6,82% for 10 compressors.

N	$€_{single}$	$€_{series}$	Saving €	Saving %
1	1.561.915,55	1.560.815,86	1.099,69	0,07%
2	3.112.096,95	3.024.211,77	87.658,58	2,82%
3	4.662.278,35	4.487.497,42	174.441,03	3,74%
4	6.213.753,95	5.950.742,32	262.558,44	4,23%
5	7.764.461,35	7.311.628,01	452.266,84	5,82%
6	9.314.815,25	8.749.913,00	564.222,45	6,06%
7	10.865.725,25	10.195.354,10	669.578,06	6,16%
8	12.416.227,26	11.633.787,19	781.533,66	6,29%
9	13.967.156,41	13.079.247,44	886.889,27	6,35%
10	15.517.640,61	14.516.647,34	999.860,27	6,44%

Table 6.32: total serial effect

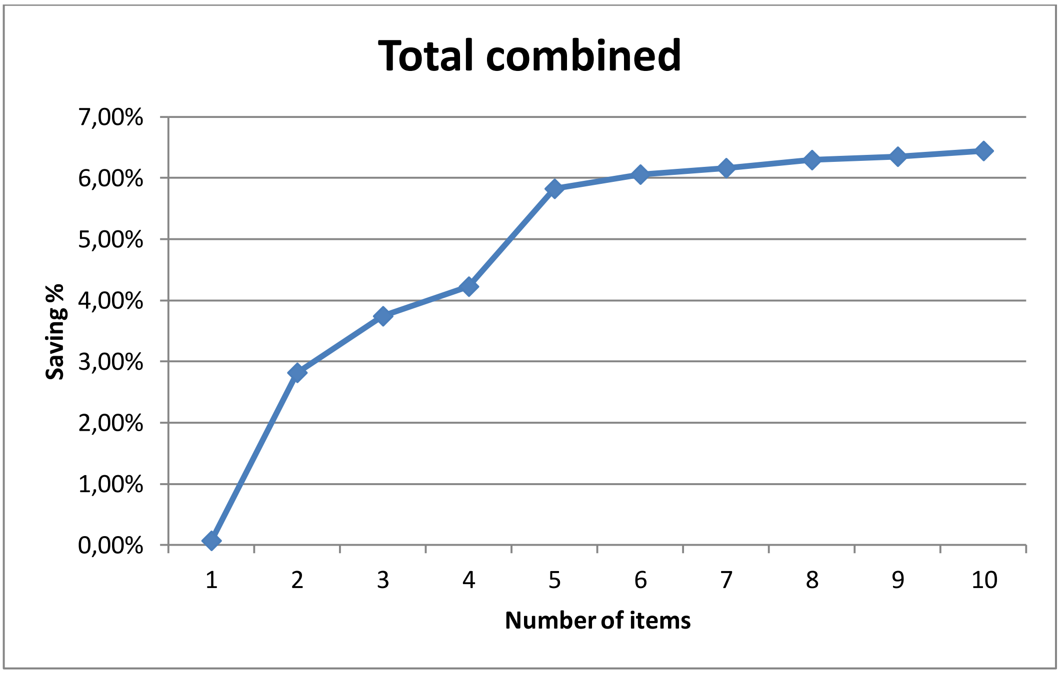


Figure 6.13: total serial effect

The total serial effect is given by the sum of the two previous totals. It is easy to understand that, as DPI contributes with 6,8 millions euro and a saving of 409 thousands euro and MAN with 8,6 millions and a saving of almost 600 thousands euro, the total will follow almost the medium value between them, with a little preponderance of MAN part. So it was expected that, after the first saving increase between one and two compressors, there is the big step, due to DPI, between the 4^{th} and 5^{th} RIKT.

Starting from a discount of 2,82% with the series production of 2 compressors, we arrive to a 6,44% discount for 10 RIKTs. This would be the maximum discount applicable considering only “positive” savings; it is still missing the constraints part, which will be analyzed in next chapter and leads to “negative” savings (i.e. that with a series production there are not savings, but more costs).

CHAPTER 7

Constraints

Production is always subjected to constraints of some type: they could be the time, the number of disposable machines, the number of operators… In the case of De Pretto Industrie, these constraints could be defined with the number of assembly pits and the warehouse. In the case of MAN, with the warehouse. Unfortunately, data of warehouse influence in MAN are not available at the moment. This will give a problem in final results view, as it is not possible to consider warehouse only for a company. So, the only final result presented is the one related with De Pretto Industrie.

7.1 Assembly pits

In De Pretto Industrie there are two assembly pits, one in the assembly department and one in the machining department. Each pit permits the assembly of two RIKTs at a time for sizes until 125, and one RIKT at a time for sizes starting from 140.

So, a first problem was to check if there would have been big queues at the pits with a series production (final assembly is an operation that cannot be outsourced). To make this, it has been used the software Microsoft Project, to understand how the production would have been influenced by series production. As it would have required big difficulties to make a Gantt diagram for a big number of compressors, it has been decided to try with a batch of 4, which is considered representative, and which could have been a good compromise between series production and warehouse problems.

Assembly pits are required in the pressure test (which is made during the "casing complete" phase) and in the final assembly (the "compressor RIKT 140" phase). As could be noticed from the diagram (annex 5), as a maximum two compressors require these operations at the same moment. With this idea, it is clear that assembly pits would not be a constraint, as there should always be at least one pit at disposal for a compressor (under the hypothesis that the 4-RIKTs situation could actually be representative, also for a bigger number of compressors).

7.2 Warehouse – DPI

To analyze the impact of warehouse in De Pretto, three different types of cost have been considered: financial cost, logistics cost, and space cost. The sum of these three costs gives the total warehouse cost.

One thing to consider is also that De Pretto's warehouse is not so big. So it is very difficult that components for a big number of RIKT can be stored at the same time. It can be said, that storage capacity can be filled with 5-6 RIKTs; with more, there should be the necessity to put components in an external deposit, with an increase of costs. However, this possibility was not counted in this work, as it is difficult to estimate; but, as it would be seen later, the result avoids this external storage.

7.2.1 Financial cost

As financial cost, the cost of the money is intended, in the sense of how much would cost to the company to take a loan in the bank to cover the expenses to buy materials for all the RIKTs.

The "7th survey on the connection bank – company in the area of Vicenza", by Confindustria Vicenza, shows that this cost is about 3,5%.

So, under the hypothesis that the whole cost has to be financed by the bank, the result is shown in table 7.1. The table has the same structure of the others already seen.

N	€$_{single}$	€$_{series}$	Financial cost$_{single}$	Financial cost$_{series}$	Saving €	Saving %
1	696.804,49	695.704,80	24.388,16	24.349,67	38,49	0,16%
2	1.381.874,83	1.352.885,12	48.365,62	47.350,98	1.014,64	2,10%
3	2.066.945,18	2.010.178,74	72.343,08	70.356,26	1.986,83	2,75%
4	2.753.309,73	2.667.282,56	96.365,84	93.354,89	3.010,95	3,12%
5	3.438.906,07	3.251.250,56	120.361,71	113.793,77	6.567,94	5,46%
6	4.124.148,91	3.889.239,16	144.345,21	136.123,37	8.221,84	5,70%
7	4.809.947,86	4.534.383,85	168.348,17	158.703,43	9.644,74	5,73%
8	5.495.338,81	5.172.520,56	192.336,86	181.038,22	11.298,64	5,87%
9	6.181.156,90	5.817.684,40	216.340,49	203.618,95	12.721,54	5,88%
10	6.866.530,04	6.455.709,30	240.328,55	225.949,83	14.378,73	5,98%

Table 7.1: financial cost

The saving percentage is very similar to the previous obtained total one.

7.2.2 Logistics cost

Logistics cost includes the costs connected with the components movement, such as the use of bridge cranes and forklifts. This cost is given by the operators related with these tools. It is a rough estimation, but it can be considered good in a first analysis.

Workers related with logistics are 10 in De Pretto Industrie. They work 40 hours a week, for 11 months (considering a month of vacations); it can be said that there are 4 weeks in a month, so they work 160 hours a month, and the yearly total is 1760 hours a year for each worker. The total hours worked by logistics operators are 1760 hours * 10 workers, so 17.600 hours.

De Pretto has 150.000 hours a year of workshop; dividing this number for the hours of logistics, we can obtain how many hours of workshop require a logistics hour. This number is 150.000 / 17.600 = 8,52.

On this assumption, it is possible to calculate the number of logistics hours needed for single and series production; and then, as the hourly cost for this kind of workers is 50 €/h, the costs are calculated.

The results are presented in table 7.2

N	h_{single}	h_{series}	Logistics $hours_{single}$	Logistics $hours_{series}$	$Cost_{single}$	$Cost_{series}$	Saving €	Saving %
1	7.549,95	7.538,55	885,86	884,52	44.293,04	44.226,16	66,88	0,15%
2	15.099,90	14.722,13	1.771,72	1.727,40	88.586,08	86.369,80	2.216,28	2,50%
3	22.649,85	21.905,70	2.657,58	2.570,27	132.879,12	128.513,44	4.365,68	3,29%
4	30.199,80	29.061,28	3.543,44	3.409,86	177.172,16	170.492,81	6.679,35	3,77%
5	37.749,75	36.286,85	4.429,30	4.257,66	221.465,20	212.882,85	8.582,35	3,88%
6	45.299,70	43.392,43	5.315,16	5.091,38	265.758,24	254.568,89	11.189,35	4,21%
7	52.849,65	50.618,00	6.201,03	5.939,18	310.051,28	296.958,93	13.092,35	4,22%
8	60.399,60	57.723,58	7.086,89	6.772,90	354.344,32	338.644,97	15.699,35	4,43%
9	67.949,55	64.949,15	7.972,75	7.620,70	398.637,36	381.035,01	17.602,35	4,42%
10	75.499,50	72.054,73	8.858,61	8.454,42	442.930,40	422.721,05	20.209,35	4,56%

Table 7.2: logistics cost

7.2.3 Space cost

Space cost is the cost born by the company to have internal space occupied by parts and components used for the RIKT. This cost is 200 € / m^2 per year; the problem is to understand how much space is occupied every moment by the components.

First of all, it has been calculated the size of the components (in m^2), on the basis of the engineering drawings. This required space is presented in table 7.3.

The 120 square meters of the casing have to be divided 60 for the upper part and 60 for the lower one; and also these 60 must be divided, 20 for the plates in the external deposit and 40 in the welding area. Components which are not specified have negligible sizes.

Component	m^2
Walls	2,27
Bearing house	2,27
Diffusors	2,27
Spiral	2,27
Inlet casing	4,71
Cooler 1 stage	8,6
Cooler 2-3 stage	6,32
Water chamb 1 stage	0,94
Water chamb 2 stage	0,96
Cooler cover 1 stage	0,94
Cooler cover 2-3 stage	0,96
Casing	120*

Table 7.3: space required by components

Then, it has been used another time the Gantt diagram. After the one of 4 compressors, also the diagram for one compressor has been defined. The starting date for the diagrams is the 1st of April 2013; so, time has been divided into quarters, starting with the 1st quarter from this date. Then the moments of production and warehouse for all the components have been defined, basing on the dates indicated by the software; finally, the required space has been substituted to the indication of production / warehouse, obtaining the total space occupied by components in every quarter. As costs are given per year, to obtain the yearly value of medium occupied space is sufficient to make the medium value of the space occupied in the 4 quarters (the production of 1 RIKT lasts one year).

The results are in tables 7.4 and 7.5 for 1-RIKT production, and 7.6 – 7.7 for 4-RIKT production. With the letter P is indicated a component production time, with W a component warehouse time, with X the smaller components not considered; if the letter is P/2, it means that half the production is made in that period, and half in the next one. It has been considered the simplification that every raw material arrives perfectly at the beginning of the production of the component they are needed for (so, no intermediate warehouse for them), except for plates, which arrive at the beginning of the period. With blue background parts which must not be considered (because they are assembled in the same period inside another bigger component; if they would have been considered, their space would have been counted twice) are indicated.

In 4-RIKT tables, where not indicated (with an “x N” symbol), it is intended as the 4 components are produced and stored at one time.

The tables of 4-RIKT production are split in two parts, as they are big.

			1 quarter	2 quarter	3 quarter	4 quarter
Piece	Begin date	End date	01/04-30/06/13	01/07-30/09/13	01/10-31/12/13	01/01-31/03/14
Bearing house UT premachined	01/04/2013	02/04/2013	P			
Casing lower part welded	02/04/2013	13/09/2013	P/2	P/2		
Casing upper part welded	23/04/2013	10/10/2013	P/2	P/2		
Welded diffusor 2. stage D=1500	22/06/2013	12/08/2013		P	W	
Welded diffusor 3. stage D=1250	24/06/2013	14/08/2013		P	W	
Bearing casing OT premachined	23/09/2013	27/09/2013		P		
Inlet casing machined	01/10/2013	23/10/2013			P	
Bracket for Bearing housing premachined	01/10/2013	02/10/2013			P	
Casing complete machined	10/10/2013	20/12/2013			P	
Adjusting ring (prerotation)	23/10/2013	29/10/2013			P	
Lower water chambers 1,2,3. stage machined (x6)	28/10/2013	05/11/2013			P	
Milled diffusor GD11	31/10/2013	11/11/2013			P	
Upper water chamber 1,2,3. stage machined (x6)	04/11/2013	08/11/2013			P	
Cover for bearing house machined	06/11/2013	08/11/2013			P	
Prerotation complete	07/11/2013	13/11/2013			P	
Discharge spiral complete and premachined	11/11/2013	02/12/2013			P	
Milled diffusor 4. stage D=1120	11/11/2013	19/11/2013			P	
Inlet piece	18/11/2013	27/11/2013			P	
Intermediate coolers 1,2,3. stage (x6)	20/11/2013	03/12/2013			P	
Man hole cover	24/11/2013	28/11/2013			P	
Cooler covers 1,2,3. stage machined (x6)	27/11/2013	03/12/2013			P	
Casing foot machined (x2)	02/12/2013	04/12/2013			P	
Channel wall machined 1050 kg	09/12/2013	12/12/2013			P	
Channel wall machined 1145 kg	09/12/2013	13/12/2013			P	
Channel wall machined 2196 kg	09/12/2013	17/12/2013			P	
Intermediate wall machined 1031 kg	10/12/2013	18/12/2013			P	
Intermediate wall machined 836 kg	11/12/2013	20/12/2013			P	
Casing complete	20/12/2013	15/01/2014			P/2	P/2
Compressor RIKT 140	15/01/2014	25/02/2014				P

			1 quarter	2 quarter	3 quarter	4 quarter
Piece	Begin date	End date	01/04-30/06/13	01/07-30/09/13	01/10-31/12/13	01/01-31/03/14
Bearing house UT premachined	01/04/2013	02/04/2013	x			
Casing lower part welded	02/04/2013	13/09/2013	60	60,00		
Casing upper part welded	23/04/2013	10/10/2013	60	60,00		
Welded diffusor 2. stage D=1500	22/06/2013	12/08/2013		2,27	2,27	
Welded diffusor 3. stage D=1250	24/06/2013	14/08/2013		2,27	2,27	
Bearing casing OT premachined	23/09/2013	27/09/2013		2,27		
Inlet casing machined	01/10/2013	23/10/2013			4,71	
Bracket for Bearing housing premachined	01/10/2013	02/10/2013			x	
Casing complete machined	10/10/2013	20/12/2013			40,00	
Adjusting ring (prerotation)	23/10/2013	29/10/2013			x	
Lower water chambers 1,2,3. stage machined (x6)	28/10/2013	05/11/2013			5,72	
Milled diffusor GD11	31/10/2013	11/11/2013			2,27	
Upper water chamber 1,2,3. stage machined (x6)	04/11/2013	08/11/2013			5,72	
Cover for bearing house machined	06/11/2013	08/11/2013			x	
Prerotation complete	07/11/2013	13/11/2013			4,71	
Discharge spiral complete and premachined	11/11/2013	02/12/2013			2,27	
Milled diffusor 4. stage D=1120	11/11/2013	19/11/2013			2,27	
Inlet piece	18/11/2013	27/11/2013			x	
Intermediate coolers 1,2,3. stage (x6)	20/11/2013	03/12/2013			42,48	
Man hole cover	24/11/2013	28/11/2013			x	
Cooler covers 1,2,3. stage machined (x6)	27/11/2013	03/12/2013			5,72	
Casing foot machined (x2)	02/12/2013	04/12/2013			x	
Channel wall machined 1050 kg	09/12/2013	12/12/2013			2,27	
Channel wall machined 1145 kg	09/12/2013	13/12/2013			2,27	
Channel wall machined 2196 kg	09/12/2013	17/12/2013			2,27	
Intermediate wall machined 1031 kg	10/12/2013	18/12/2013			2,27	
Intermediate wall machined 836 kg	11/12/2013	20/12/2013			2,27	
Casing complete	20/12/2013	15/01/2014			40,00	40,00
Compressor RIKT 140	15/01/2014	25/02/2014				40,00
Total m^2			120	126,81	115,61	40

Table 7.4 – 7.5: production / warehouse moments for 1 RIKT production and used space

			1 quarter	2 quarter	3 quarter	4 quarter
Piece	Begin date	End date	01/04-30/06/13	01/07-30/09/13	01/10-31/12/13	01/01-31/03/14
Bearing house UT premachined (x4)	01/04/2013	05/04/2013	P	W (x3)	W (x2)	W(x1)
Casing lower part welded 1	02/04/2013	08/10/2013	P/2	P/2		
Casing upper part welded 1	23/04/2013	17/10/2013	P/2	P/2		
Adjusting ring (prerotation) (x4)	17/06/2013	28/06/2013	P			
Inlet casing machined (x4)	01/07/2013	20/08/2013		P		
Casing lower part welded 2	08/07/2013	07/02/2014		P/2	P/2	
Bearing casing OT premachined (x4)	08/07/2013	22/07/2013		P	W (x3)	W (x2)
Bracket for Bearing housing premachined (x4)	31/07/2013	07/08/2013		P	W (x3)	W (x2)
Lower water chambers 1,2,3. stage machined (x24)	09/08/2013	10/09/2013		P		
Casing upper part welded 2	13/08/2013	21/02/2014		P/2	P/2	
Prerotation complete (x4)	15/08/2013	10/09/2013		P	W (x4)	W (x4)
Cover for bearing house machined (x4)	26/08/2013	30/08/2013		P		
Discharge spiral complete and premachined (x4)	02/09/2013	17/10/2013		P/2	P/2	W (x4)
Upper water chamber 1,2,3. stage machined (x24)	10/09/2013	30/09/2013		P		
Intermediate coolers 1,2,3. stage (x24)	11/09/2013	22/11/2013			P	W (x4)
Man hole cover (x4)	04/10/2013	17/10/2013			P	W (x4)
Casing complete machined 1	17/10/2013	20/03/2014			P/2	P/2
Milled diffusor 4. stage D=1120 (x4)	18/10/2013	04/11/2013			P	W (x4)
Casing lower part welded 3	01/11/2013	20/06/2014			P/3	P/3
Milled diffusor GD11 (x4)	04/11/2013	02/12/2013			P	W (x4)
Inlet piece (x4)	05/11/2013	27/11/2013			P	W (x4)
Casing foot machined (x8)	18/11/2013	02/12/2013			P	W (x4)
Cooler covers 1,2,3. stage machined (x24)	26/11/2013	12/12/2013			P	W (x4)
Welded diffusor 2. stage D=1500 (x4)	04/12/2013	30/01/2014			P/2	P/2 - W/2
Welded diffusor 3. stage D=1250 (x4)	25/12/2013	11/02/2014				P
Casing upper part welded 3	27/12/2013	18/07/2014				P/2
Channel wall machined 1050 kg (x4)	11/02/2014	24/02/2014				P
Casing lower part welded 4	13/02/2014	16/09/2014				P/3
Channel wall machined 1145 kg (x4)	17/02/2014	04/03/2014				P
Channel wall machined 2196 kg (x4)	20/02/2014	12/03/2014				P
Casing complete machined 2	21/02/2014	05/05/2014				P/2
Intermediate wall machined 1031 kg (x4)	22/02/2014	13/03/2014				P
Intermediate wall machined 836 kg (x4)	27/02/2014	26/03/2014				P
Casing complete 1	20/03/2014	15/04/2014				P/2
Compressor RIKT 140 1	15/04/2014	26/05/2014				
Casing upper part welded 4	01/05/2014	13/10/2014				
Casing complete 2	05/05/2014	29/05/2014				
Compressor RIKT 140 2	29/05/2014	09/07/2014				
Casing complete machined 3	18/07/2014	29/09/2014				
Casing complete 3	29/09/2014	24/10/2014				
Casing complete machined 4	13/10/2014	23/12/2014				
Compressor RIKT 140 3	24/10/2014	03/12/2014				
Casing complete 4	23/12/2014	16/01/2015				
Compressor RIKT 140 4	16/01/2015	26/02/2015				

			5 quarter	6 quarter	7 quarter	8 quarter
Piece	Begin date	End date	01/04-30/06/14	01/07-30/09/14	01/10-31/12/14	01/01-31/03/15
Bearing house UT premachined (x4)	01/04/2013	05/04/2013				
Casing lower part welded 1	02/04/2013	08/10/2013				
Casing upper part welded 1	23/04/2013	17/10/2013				
Adjusting ring (prerotation) (x4)	17/06/2013	28/06/2013				
Inlet casing machined (x4)	01/07/2013	20/08/2013				
Casing lower part welded 2	08/07/2013	07/02/2014				
Bearing casing OT premachined (x4)	08/07/2013	22/07/2013	W (x1)	W (x1)		
Bracket for Bearing housing premachined (x4)	31/07/2013	07/08/2013	W (x1)	W (x1)		
Lower water chambers 1,2,3. stage machined (x24)	09/08/2013	10/09/2013				
Casing upper part welded 2	13/08/2013	21/02/2014				
Prerotation complete (x4)	15/08/2013	10/09/2013	W (x2)	W (x2)	W (x1)	
Cover for bearing house machined (x4)	26/08/2013	30/08/2013				
Discharge spiral complete and premachined (x4)	02/09/2013	17/10/2013	W (x2)	W (x2)		
Upper water chamber 1,2,3. stage machined (x24)	10/09/2013	30/09/2013				
Intermediate coolers 1,2,3. stage (x24)	11/09/2013	22/11/2013	W (x2)	W (x2)	W (x1)	
Man hole cover (x4)	04/10/2013	17/10/2013	W (x2)	W (x2)		
Casing complete machined 1	17/10/2013	20/03/2014				
Milled diffusor 4. stage D=1120 (x4)	18/10/2013	04/11/2013	W (x2)	W (x2)	W (x1)	
Casing lower part welded 3	01/11/2013	20/06/2014	P/3			
Milled diffusor GD11 (x4)	04/11/2013	02/12/2013	W (x2)	W (x2)	W (x1)	
Inlet piece (x4)	05/11/2013	27/11/2013	W (x2)	W (x2)	W (x1)	
Casing foot machined (x8)	18/11/2013	02/12/2013	W (x2)	W (x2)	W (x1)	
Cooler covers 1,2,3. stage machined (x24)	26/11/2013	12/12/2013	W (x2)	W (x2)		
Welded diffusor 2. stage D=1500 (x4)	04/12/2013	30/01/2014	W (x2)	W (x2)	W (x1)	
Welded diffusor 3. stage D=1250 (x4)	25/12/2013	11/02/2014	W (x2)	W (x2)	W (x1)	
Casing upper part welded 3	27/12/2013	18/07/2014	P/2			
Channel wall machined 1050 kg (x4)	11/02/2014	24/02/2014	W (x2)	W (x2)	W (x1)	
Casing lower part welded 4	13/02/2014	16/09/2014	P/3	P/3		
Channel wall machined 1145 kg (x4)	17/02/2014	04/03/2014	W (x2)	W (x2)	W (x1)	
Channel wall machined 2196 kg (x4)	20/02/2014	12/03/2014	W (x2)	W (x2)	W (x1)	
Casing complete machined 2	21/02/2014	05/05/2014	P/2			
Intermediate wall machined 1031 kg (x4)	22/02/2014	13/03/2014	W (x2)	W (x2)	W (x1)	
Intermediate wall machined 836 kg (x4)	27/02/2014	26/03/2014	W (x2)	W (x2)	W (x1)	
Casing complete 1	20/03/2014	15/04/2014	P/2			
Compressor RIKT 140 1	15/04/2014	26/05/2014	P			
Casing upper part welded 4	01/05/2014	13/10/2014	P/2	P/2		
Casing complete 2	05/05/2014	29/05/2014	P			
Compressor RIKT 140 2	29/05/2014	09/07/2014	P			
Casing complete machined 3	18/07/2014	29/09/2014		P		
Casing complete 3	29/09/2014	24/10/2014			P	
Casing complete machined 4	13/10/2014	23/12/2014			P	
Compressor RIKT 140 3	24/10/2014	03/12/2014			P	
Casing complete 4	23/12/2014	16/01/2015			1/3 P	2/3 P
Compressor RIKT 140 4	16/01/2015	26/02/2015				P

Table 7.6: production / warehouse in 4-RIKT production

Piece	Begin date	End date	1 quarter 01/04-30/06/13	2 quarter 01/07-30/09/13	3 quarter 01/10-31/12/13	4 quarter 01/01-31/03/14
Bearing house UT premachined (x4)	01/04/2013	05/04/2013	x	x	x	x
Casing lower part welded 1	02/04/2013	08/10/2013	60,00	60,00		
Casing upper part welded 1	23/04/2013	17/10/2013	60,00	60,00		
Adjusting ring (prerotation) (x4)	17/06/2013	28/06/2013	x			
Inlet casing machined (x4)	01/07/2013	20/08/2013		18,84		
Casing lower part welded 2	08/07/2013	07/02/2014	20,00	60,00	60,00	
Bearing casing OT premachined (x4)	08/07/2013	22/07/2013		9,08	6,81	4,54
Bracket for Bearing housing premachined (x4)	31/07/2013	07/08/2013		x	x	x
Lower water chambers 1,2,3. stage machined (x24)	09/08/2013	10/09/2013		22,88		
Casing upper part welded 2	13/08/2013	21/02/2014	20,00	60,00	60,00	
Prerotation complete (x4)	15/08/2013	10/09/2013		18,84	18,84	18,84
Cover for bearing house machined (x4)	26/08/2013	30/08/2013		x		
Discharge spiral complete and premachined (x4)	02/09/2013	17/10/2013		4,54	6,81	6,81
Upper water chamber 1,2,3. stage machined (x24)	10/09/2013	30/09/2013		22,88		
Intermediate coolers 1,2,3. stage (x24)	11/09/2013	22/11/2013			169,92	169,92
Man hole cover (x4)	04/10/2013	17/10/2013			x	x
Casing complete machined 1	17/10/2013	20/03/2014			40,00	40,00
Milled diffusor 4. stage D=1120 (x4)	18/10/2013	04/11/2013			9,08	9,08
Casing lower part welded 3	01/11/2013	20/06/2014	20,00	20,00	60,00	60,00
Milled diffusor GD11 (x4)	04/11/2013	02/12/2013			9,08	9,08
Inlet piece (x4)	05/11/2013	27/11/2013			x	x
Casing foot machined (x8)	18/11/2013	02/12/2013			x	x
Cooler covers 1,2,3. stage machined (x24)	26/11/2013	12/12/2013			22,88	22,88
Welded diffusor 2. stage D=1500 (x4)	04/12/2013	30/01/2014			4,54	9,08
Welded diffusor 3. stage D=1250 (x4)	25/12/2013	11/02/2014				9,08
Casing upper part welded 3	27/12/2013	18/07/2014	20,00	20,00	20,00	60,00
Channel wall machined 1050 kg (x4)	11/02/2014	24/02/2014				9,08
Casing lower part welded 4	13/02/2014	16/09/2014	20,00	20,00	20,00	60,00
Channel wall machined 1145 kg (x4)	17/02/2014	04/03/2014				9,08
Channel wall machined 2196 kg (x4)	20/02/2014	12/03/2014				9,08
Casing complete machined 2	21/02/2014	05/05/2014				40,00
Intermediate wall machined 1031 kg (x4)	22/02/2014	13/03/2014				9,08
Intermediate wall machined 836 kg (x4)	27/02/2014	26/03/2014				9,08
Casing complete 1	20/03/2014	15/04/2014				20,00
Compressor RIKT 140 1	15/04/2014	26/05/2014				
Casing upper part welded 4	01/05/2014	13/10/2014	20,00	20,00	20,00	20,00
Casing complete 2	05/05/2014	29/05/2014				
Compressor RIKT 140 2	29/05/2014	09/07/2014				
Casing complete machined 3	18/07/2014	29/09/2014				
Casing complete 3	29/09/2014	24/10/2014				
Casing complete machined 4	13/10/2014	23/12/2014				
Compressor RIKT 140 3	24/10/2014	03/12/2014				
Casing complete 4	23/12/2014	16/01/2015				
Compressor RIKT 140 4	16/01/2015	26/02/2015				
Total m^2			240	398,22	527,96	604,71

Piece	Begin date	End date	5 quarter 01/04-30/06/14	6 quarter 01/07-30/09/14	7 quarter 01/10-31/12/14	8 quarter 01/01-31/03/15
Bearing house UT premachined (x4)	01/04/2013	05/04/2013				
Casing lower part welded 1	02/04/2013	08/10/2013				
Casing upper part welded 1	23/04/2013	17/10/2013				
Adjusting ring (prerotation) (x4)	17/06/2013	28/06/2013				
Inlet casing machined (x4)	01/07/2013	20/08/2013				
Casing lower part welded 2	08/07/2013	07/02/2014				
Bearing casing OT premachined (x4)	08/07/2013	22/07/2013	2,27	2,27		
Bracket for Bearing housing premachined (x4)	31/07/2013	07/08/2013	x	x		
Lower water chambers 1,2,3. stage machined (x24)	09/08/2013	10/09/2013				
Casing upper part welded 2	13/08/2013	21/02/2014				
Prerotation complete (x4)	15/08/2013	10/09/2013	9,42	9,42	4,71	
Cover for bearing house machined (x4)	26/08/2013	30/08/2013				
Discharge spiral complete and premachined (x4)	02/09/2013	17/10/2013	4,54	4,54		
Upper water chamber 1,2,3. stage machined (x24)	10/09/2013	30/09/2013				
Intermediate coolers 1,2,3. stage (x24)	11/09/2013	22/11/2013	84,96	84,96	42,48	
Man hole cover (x4)	04/10/2013	17/10/2013	x	x		
Casing complete machined 1	17/10/2013	20/03/2014				
Milled diffusor 4. stage D=1120 (x4)	18/10/2013	04/11/2013	4,54	4,54	2,27	
Casing lower part welded 3	01/11/2013	20/06/2014	60,00			
Milled diffusor GD11 (x4)	04/11/2013	02/12/2013	4,54	4,54	2,27	
Inlet piece (x4)	05/11/2013	27/11/2013	x	x	x	
Casing foot machined (x8)	18/11/2013	02/12/2013	x	x	x	
Cooler covers 1,2,3. stage machined (x24)	26/11/2013	12/12/2013	11,44	11,44		
Welded diffusor 2. stage D=1500 (x4)	04/12/2013	30/01/2014	4,54	4,54	2,27	
Welded diffusor 3. stage D=1250 (x4)	25/12/2013	11/02/2014	4,54	4,54	2,27	
Casing upper part welded 3	27/12/2013	18/07/2014	60,00			
Channel wall machined 1050 kg (x4)	11/02/2014	24/02/2014	4,54	4,54	2,27	
Casing lower part welded 4	13/02/2014	16/09/2014	60,00	60,00		
Channel wall machined 1145 kg (x4)	17/02/2014	04/03/2014	4,54	4,54	2,27	
Channel wall machined 2196 kg (x4)	20/02/2014	12/03/2014	4,54	4,54	2,27	
Casing complete machined 2	21/02/2014	05/05/2014	40,00			
Intermediate wall machined 1031 kg (x4)	22/02/2014	13/03/2014	4,54	4,54	2,27	
Intermediate wall machined 836 kg (x4)	27/02/2014	26/03/2014	4,54	4,54	2,27	
Casing complete 1	20/03/2014	15/04/2014	40,00			
Compressor RIKT 140 1	15/04/2014	26/05/2014	40,00			
Casing upper part welded 4	01/05/2014	13/10/2014	60,00	60,00		
Casing complete 2	05/05/2014	29/05/2014	40,00			
Compressor RIKT 140 2	29/05/2014	09/07/2014	40,00			
Casing complete machined 3	18/07/2014	29/09/2014		40,00		
Casing complete 3	29/09/2014	24/10/2014			40,00	
Casing complete machined 4	13/10/2014	23/12/2014			40,00	
Compressor RIKT 140 3	24/10/2014	03/12/2014			40,00	
Casing complete 4	23/12/2014	16/01/2015			40,00	40,00
Compressor RIKT 140 4	16/01/2015	26/02/2015				40,00
Total m^2			473,49	313,49	147,62	40

Table 7.7: space required for 4-RIKT production

The total space request for 1-RIKT production is 402,42 m^2, for 4 quarters; so the medium value is 100,61 m^2. For 4-RIKTs production, these values are 2745,49 and 343,19 m^2 (the first value is divided for 8 quarters).

Now that the yearly required space for 1- and 4-RIKT production is obtained, the required space for the other numbers of compressors can be estimated. As the behavior of a hypothetic curve representing the space cost is unknown, it has been decided to verify two hypotheses: the linear and the exponential. Then, it has been made the medium between them to obtain a value that can be expression of the reality.
The linear curve follows the equation y = 80,86x + 19,75; the exponential y = 66,836 e^(0,409x). Results of the yearly medium space occupied by the components are presented in tables 7.8, 7.9 and figures 7.1 and 7.2.

N	Medium space
1	100,61
2	181,47
3	262,33
4	343,19
5	424,05
6	504,91
7	585,77
8	666,63
9	747,49
10	828,35

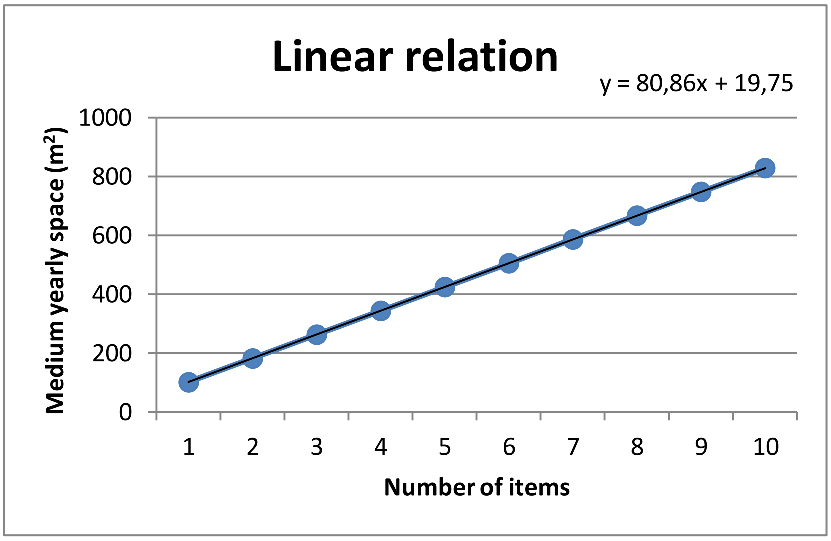


Table 7.8, Figure 7.1: linear relation space/N

N	Medium space
1	100,61
2	151,45
3	227,99
4	343,19
5	516,61
6	777,66
7	1.170,62
8	1.762,14
9	2.652,58
10	3.992,95

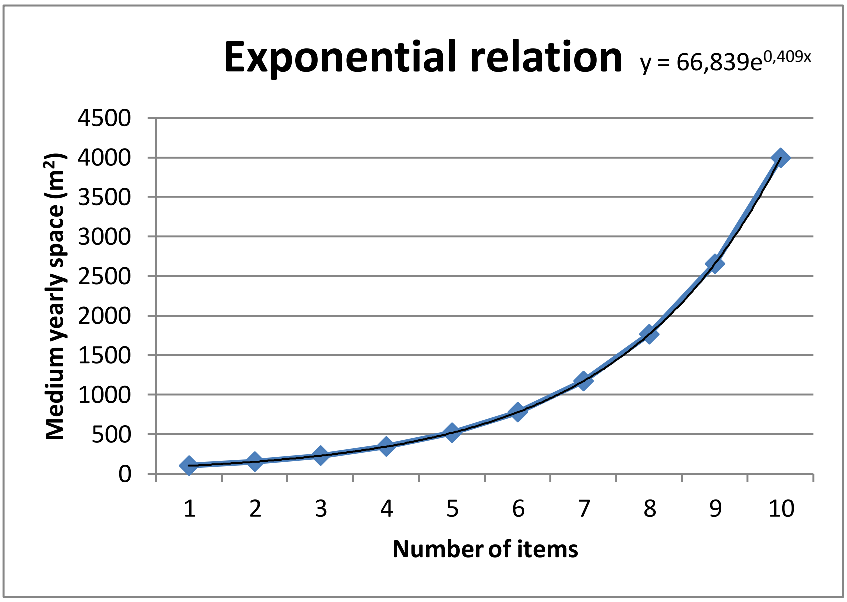


Table 7.9, Figure 7.2: exponential relation space/N

Then, it has been calculated the medium value between them, which is the series production value. Instead the single production value is given by the value for 1 compressor, multiplied for the number of compressors (as it has been usually done in this work). Knowing the cost of 200 €/m^2, it is possible to determinate the saving and the saving %.

N	Medium space$_{single}$	Medium space$_{series}$	Cost$_{single}$	Cost$_{series}$	Saving €	Saving %
1	100,61	100,61	20.122,35	20.122,35	0,00	0,00%
2	201,22	166,46	40.244,71	33.292,47	6.952,23	17,27%
3	301,84	245,16	60.367,06	49.031,66	11.335,40	18,78%
4	402,45	343,19	80.489,41	68.638,09	11.851,33	14,72%
5	503,06	470,33	100.611,77	94.065,92	6.545,84	6,51%
6	603,67	641,28	120.734,12	128.256,79	-7.522,67	-6,23%
7	704,28	878,19	140.856,47	175.638,76	-34.782,29	-24,69%
8	804,89	1.214,39	160.978,82	242.877,44	-81.898,61	-50,88%
9	905,51	1.700,03	181.101,18	340.006,66	-158.905,48	-87,74%
10	1.006,12	2.410,65	201.223,53	482.130,46	-280.906,93	-139,60%

Table 7.10: space cost

As imagined, with series effect costs for warehouse are increasing, and after a certain point (5 compressors), it is more expensive to produce in series than in single production.

7.2.4 Total warehouse cost

Making the sum of these three contributions, it is possible to determine the total warehouse cost. It is presented first the single production total cost, then the series production one, and finally the comparison, with the saving. It can be noticed that, after the 6th compressor, there are no more savings, but more costs.

N	Financial	Logistics	Space	Total
1	24.388,16	44.293,04	20.122,35	88.803,55
2	48.365,62	88.586,08	40.244,71	177.196,41
3	72.343,08	132.879,12	60.367,06	265.589,26
4	96.365,84	177.172,16	80.489,41	354.027,41
5	120.361,71	221.465,20	100.611,77	442.438,68
6	144.345,21	265.758,24	120.734,12	530.837,57
7	168.348,17	310.051,28	140.856,47	619.255,93
8	192.336,86	354.344,32	160.978,82	707.660,00
9	216.340,49	398.637,36	181.101,18	796.079,03
10	240.328,55	442.930,40	201.223,53	884.482,48

Table 7.11: single production, warehouse cost

N	Financial	Logistics	Space	Total
1	24.349,67	44.226,16	20.122,35	88.698,18
2	47.350,98	86.369,80	33.292,47	167.013,25
3	70.356,26	128.513,44	49.031,66	247.901,35
4	93.354,89	170.492,81	68.638,09	332.485,79
5	113.793,77	212.882,85	94.065,92	420.742,55
6	136.123,37	254.568,89	128.256,79	518.949,06
7	158.703,43	296.958,93	175.638,76	631.301,13
8	181.038,22	338.644,97	242.877,44	762.560,63
9	203.618,95	381.035,01	340.006,66	924.660,63
10	225.949,83	422.721,05	482.130,46	1.130.801,34

Table 7.12: series production, warehouse cost

N	€$_{single}$	€$_{series}$	Saving €	Saving %
1	88.803,55	88.698,18	105,37	0,12%
2	177.196,41	167.013,25	10.183,15	5,75%
3	265.589,26	247.901,35	17.687,91	6,66%
4	354.027,41	332.485,79	21.541,62	6,08%
5	442.438,68	420.742,55	21.696,13	4,90%
6	530.837,57	518.949,06	11.888,51	2,24%
7	619.255,93	631.301,13	-12.045,20	-1,95%
8	707.660,00	762.560,63	-54.900,63	-7,76%
9	796.079,03	924.660,63	-128.581,60	-16,15%
10	884.482,48	1.130.801,34	-246.318,86	-27,85%

Table 7.13: warehouse, serial effect

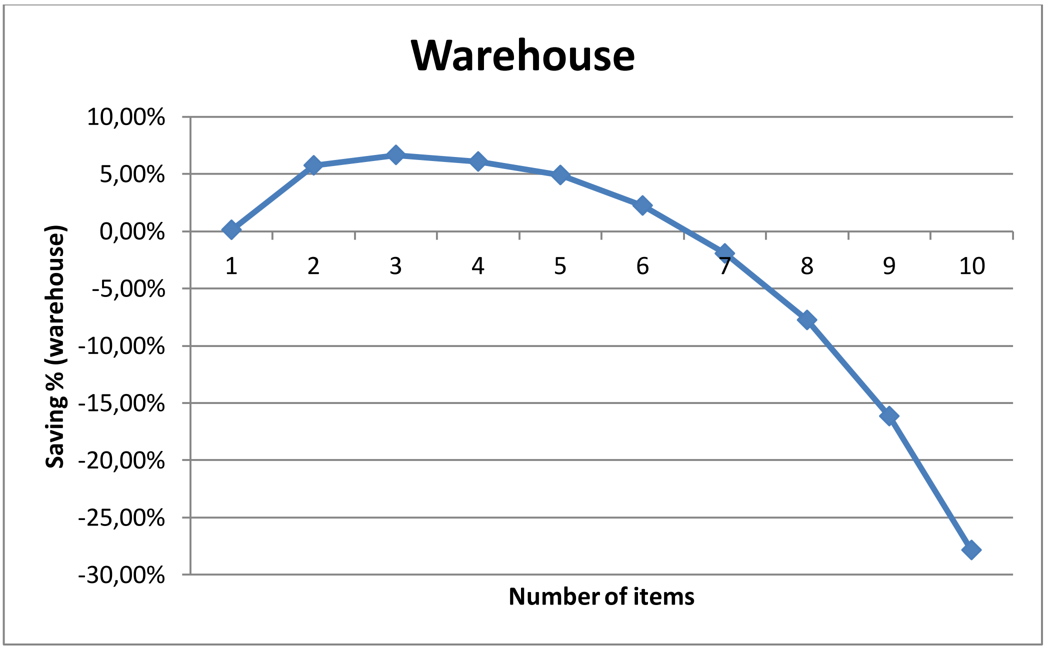


Figure 7.3: warehouse, serial effect

Conclusions

After the analysis of the constraints, it is possible to get the final conclusions of the work. The final result is given by the sum of the total obtained before warehouse ($€_{single}$ and $€_{series}$) and the total warehouse cost. As mentioned in previous chapter, the only final result that can be presented is the one of De Pretto Industrie, as the data of MAN are not available.

This result is presented in the following tables and figures. The final discount applicable to MAN goes from a 2,5% with the production of 2 compressors, to a maximum of almost 5,4% with a batch of 5 RIKTs; then it starts to decrease, until reaching the 2,1% with 10 compressors. It is easily conceivable that this saving will continue decreasing, after reaching a level where series production is not worthwhile anymore.

N	$€_{single}$	$€_{series}$	$€_{single}$WH	$€_{series}$WH	$€_{single}$TOT	$€_{series}$TOT	Saving €	Saving %
1	696.804,49	695.704,80	88.803,55	88.698,18	785.608,04	784.402,98	1.205,06	0,15%
2	1.381.874,83	1.352.885,12	177.196,41	167.013,25	1.559.071,24	1.519.898,37	39.172,87	2,51%
3	2.066.945,18	2.010.178,74	265.589,26	247.901,35	2.332.534,44	2.258.080,09	74.454,35	3,19%
4	2.753.309,73	2.667.282,56	354.027,41	332.485,79	3.107.337,14	2.999.768,35	107.568,79	3,46%
5	3.438.906,07	3.251.250,56	442.438,68	420.742,55	3.881.344,75	3.671.993,11	209.351,64	5,39%
6	4.124.148,91	3.889.239,16	530.837,57	518.949,06	4.654.986,48	4.408.188,22	246.798,27	5,30%
7	4.809.947,86	4.534.383,85	619.255,93	631.301,13	5.429.203,78	5.165.684,98	263.518,80	4,85%
8	5.495.338,81	5.172.520,56	707.660,00	762.560,63	6.202.998,81	5.935.081,19	267.917,62	4,32%
9	6.181.156,90	5.817.684,40	796.079,03	924.660,63	6.977.235,93	6.742.345,03	234.890,90	3,37%
10	6.866.530,04	6.455.709,30	884.482,48	1.130.801,34	7.751.012,52	7.586.510,64	164.501,89	2,12%

Table 7.14: De Pretto, final result

Figure 7.4: De Pretto, final result

As said, there is an optimum production batch which is 5 compressors: it can give the biggest saving to the client (MAN), and so more competitiveness in the market. However, series production until 10 compressors can always give a saving, also for big batches; of course, the influence of space cost is more and more relevant producing in bigger numbers.

To fully understand how much warehouse have an influence in the result, next figure presents the different saving before and after its calculation.

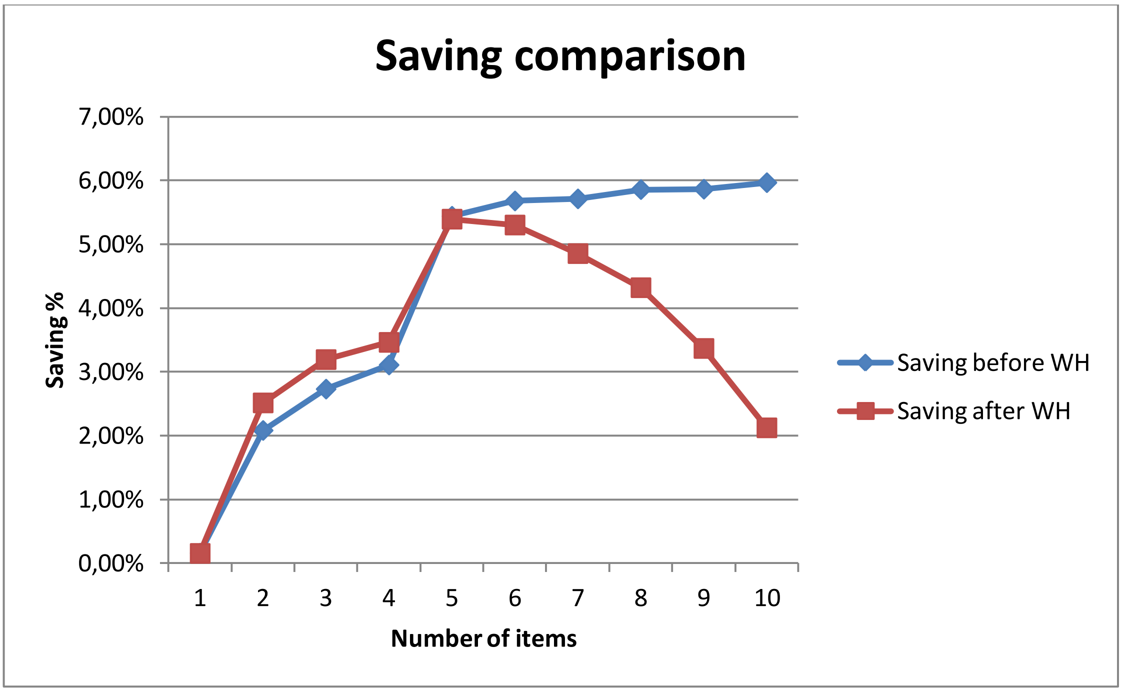


Figure 7.5: before and after warehouse saving

It can be noticed that, while before warehouse's influence there was a situation where the biggest the batch, the biggest the discount, now it is completely changed, giving an optimum batch at 5 compressors and decreasing the discount from there on.

Another interesting thing is to view the single cost compressor trend, obtained dividing the total cost for single and series production for the number of compressors of the batch.

N	€$_{single}$	€$_{series}$	Single prod.	Series prod.
1	785.608,04	784.402,98	785.608,04	784.402,98
2	1.559.071,24	1.519.898,37	779.535,62	759.949,19
3	2.332.534,44	2.258.080,09	777.511,48	752.693,36
4	3.107.337,14	2.999.768,35	776.834,28	749.942,09
5	3.881.344,75	3.671.993,11	776.268,95	734.398,62
6	4.654.986,48	4.408.188,22	775.831,08	734.698,04
7	5.429.203,78	5.165.684,98	775.600,54	737.955,00
8	6.202.998,81	5.935.081,19	775.374,85	741.885,15
9	6.977.235,93	6.742.345,03	775.248,44	749.149,45
10	7.751.012,52	7.586.510,64	775.101,25	758.651,06

Table 7.15: single RIKT cost, DPI

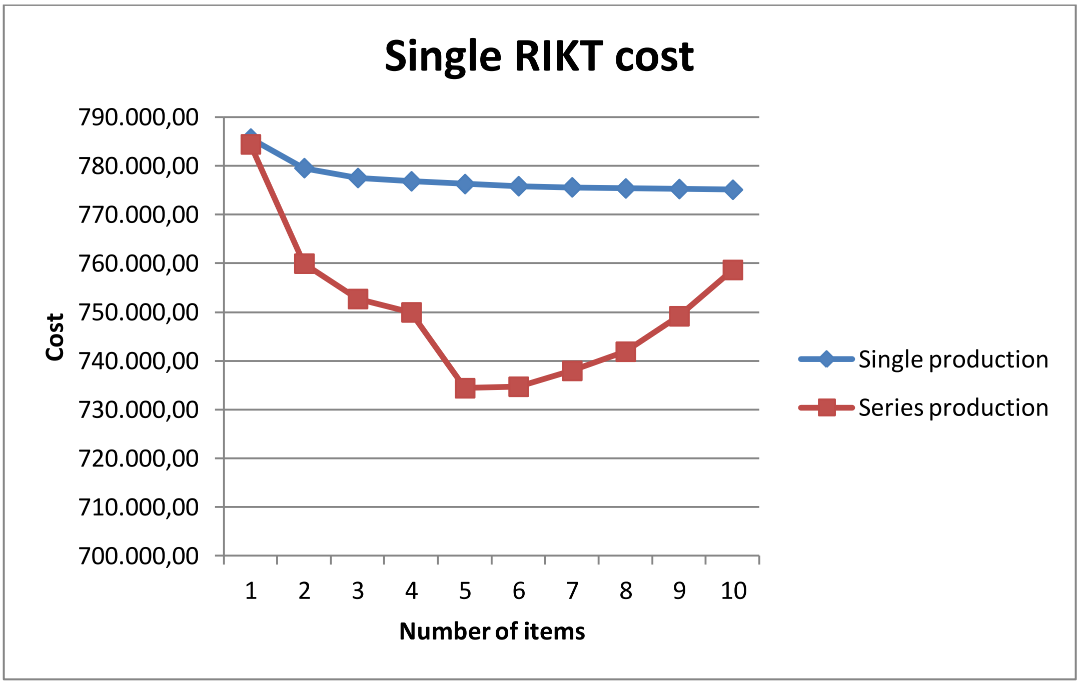


Figure 7.6: single RIKT cost, DPI

While in single production the single RIKT cost is more or less constant (variation given by purchasing hypothesis), in series production it follows the trend of saving, with a minimum at 5 compressors.

This work showed how to calculate the applicable discount to clients for the compressor RIKT 140. However, this is not the only RIKT produced by the companies. Following the model presented in this thesis, there will be the possibility to define the discount also for all the other typologies of RIKT. In fact, quality, nesting, work preparation, engineering and project management require the same amount of time for all the sizes, and so the possible savings are already calculated. Machining and total workings will follow the same structure, only with different working time (the lower the size, the lower the number of hours, and vice versa). Purchasing maintains the same structure, too, but requires a bit more calculations, as some parts may vary depending from the customer's needs.

Moreover, this work can be used to define a sequence of steps to pass from single production to small series production, to give the possibility to the companies to use this also for other products with a behavior similar to RIKT.

This sequence could be:

- study of the product and of its production cycle;
- identification of the departments involved in product realization;
- understanding of how series production can impact on each department's costs;
- calculation of the actual state costs and series production costs;
- identification of the company's constraints;
- evaluation of the impact of these constraints over production;
- definition of the final costs for actual and series production, and calculation of the savings.

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Annex 1

Work Cycles in MAN

Here is the list of the work cycles of the RIKT components produced in MAN.

Rotor complete

Work centers	Hours
1501	0,75
35301	3,2
external heating	
35301	13,7
35301	3,5
35301	7
36605	9,5
35301	19,7
36605	14,2
35301	0,5
35301	17
external balancing	
35301	4,9
1407	2
1501	0,75
43321	3

Needs of machining:	YES
Work center	35301
Set-up time	0,7
Machining time	2,5
Work center	35301
Set-up time	2
Machining time	11,7
Work center	35301
Set-up time	0,7
Machining time	2,8
Work center	35301
Set-up time	1,5
Machining time	5,5
Work center	36605
Set-up time	2
Machining time	7,5
Work center	35301
Set-up time	0,5
Machining time	19,2
Work center	36605
Set-up time	2
Machining time	12,2
Work center	35301
Set-up time	2,2
Machining time	14,8
Work center	35301
Set-up time	0,7
Machining time	4,2

Tables A1.1 – A1.2: rotor complete work cycle

Impeller D 1700-AGD11-165,8 complete machined

Work centers	Hours
33202	16
32402	14
33312	324,6
32402	34,8
42301	11,9
43311	5
35902	2
1505	6,8
external workings	
35901	0,5
35301	5
35401	8,8
35301	5
external centrifugation	
1407	0
35301	4,5
35901	0,5
1505	6,8
1507	0
32402	14,6
33103	7
35902	2
36301	4,5
35301	3
35301	1
35401	7,7
35301	4
1505	0
Needs of machining:	YES
Work center	33202
Set-up time	1
Machining time	15
Work center	32402
Set-up time	1
Machining time	13

Work center	33312
Set-up time	2
Machining time	322,6
Work center	32402
Set-up time	1
Machining time	33,8
Work center	35401
Set-up time	0,5
Machining time	8,3
Work center	32402
Set-up time	1
Machining time	13,6
Work center	33103
Set-up time	1
Machining time	6
Work center	35902
Set-up time	0,5
Machining time	1,5
Work center	36301
Set-up time	0,2
Machining time	4,3
Work center	35301
Set-up time	0,5
Machining time	0,5
Work center	35401
Set-up time	0,3
Machining time	7,4

Tables A1.3 – A1.4: impeller D1700 work cycle

Impeller D 1500-APD9-120,0 machined, welded

Work centers	Hours
42301	7,6
42301	167
42301	141
1505	11
external heat treatment	
41607	0,5
external control	
43111	8,8
32402	11
36301	1,9
1505	5
42301	0
1505	0
33604	3,5
35401	4,3
36801	10,5
1407	0
1505	5
1507	0
32402	7,3
36301	2,4
35401	7,4

Needs of machining:	YES
Work center	32402
Set-up time	1
Machining time	10
Work center	36301
Set-up time	0,2
Machining time	1,7
Work center	33604
Set-up time	0,5
Machining time	3
Work center	35401
Set-up time	0,3
Machining time	4
Work center	36801
Set-up time	0,3
Machining time	10,2
Work center	32402
Set-up time	1
Machining time	6,3
Work center	36301
Set-up time	0,2
Machining time	2,2

Tables A1.5 – A1.6: impeller D1500 work cycle

Impeller D 1250-AID8-106,3 machined, welded

Work centers	Hours
42301	6,3
42301	96
42301	84
1505	7
external heat treatment	
41607	0,5
external control	
43111	7,1
33504	10,3
36301	1,5
1505	3,5
42301	0
1505	0
33604	3,4
35401	4
36801	8,5
1407	0
1505	3,5
1507	0
32402	6,7
36301	2
35401	6

Needs of machining:	YES
Work center	33504
Set-up time	1
Machining time	9,3
Work center	36301
Set-up time	0,2
Machining time	1,3
Work center	33604
Set-up time	0,5
Machining time	2,9
Work center	35401
Set-up time	0,3
Machining time	3,7
Work center	36801
Set-up time	0,3
Machining time	8,2
Work center	32402
Set-up time	1
Machining time	5,7
Work center	36301
Set-up time	0,2
Machining time	1,8

Tables A1.7 – A1.8: impeller D1250 work cycle

Impeller D 1120-ZD10-95,2 machined, welded

Work centers	Hours
42301	5,8
42301	76
42301	67
1505	7
external heat treatment	
41607	0,5
external	
43111	6,3
33504	10
36301	1,4
1505	3,5
42301	0
1505	0
33604	3,5
35401	3,8
36801	8,8
1407	0
1505	3,5
1507	0
32402	6,6
36301	1,9
35401	6,2

Needs of machining:	YES
Work center	33504
Set-up time	1
Machining time	9
Work center	36301
Set-up time	0,2
Machining time	1,2
Work center	33604
Set-up time	0,5
Machining time	3
Work center	35401
Set-up time	0,3
Machining time	3,5
Work center	36801
Set-up time	0,3
Machining time	8,5
Work center	32402
Set-up time	1
Machining time	5,6
Work center	36301
Set-up time	0,2
Machining time	1,7

Tables A1.9 – A1.10: impeller D1120 work cycle

Hub D 1500-APD9-120,0 machined

Work centers	Hours
32402 33202 33312	6,1 1 141,7
Needs of machining:	YES
Work center Set-up time Machining time	32402 0,7 5,4
Work center Set-up time Machining time	33202 0,5 0,5
Work center Set-up time Machining time	33312 2 139,7

Hub D 1250-AID8-106,3 machined

Work centers	Hours
33504 33202 33312	5,4 1 117,2
Needs of machining:	YES
Work center Set-up time Machining time	33504 0,7 4,7
Work center Set-up time Machining time	33202 0,5 0,5
Work center Set-up time Machining time	33312 2 115,2

Hub D 1120-ZD10-95,2 machined

Work centers	Hours
33504 33202 33312	5,4 1 101,3
Needs of machining:	YES
Work center Set-up time Machining time	33504 0,7 4,7
Work center Set-up time Machining time	33202 0,5 0,5
Work center Set-up time Machining time	33312 2 99,3

Tables A1.11 – A1.12 – A1.13: hub D1500, D1250 and D1120 work cycle

Shroud D 1500-APD9-120,0 machined

Work centers	Hours
32402	4,7
Needs of machining:	YES
Work center Set-up time Machining time	32402 0,7 4

Shroud D 1250-AID8-106,3 machined

Work centers	Hours
33504	3,9
Needs of machining:	YES
Work center Set-up time Machining time	33504 0,7 3,2

Shroud D 1120-ZD10-95,2 machined

Work centers	Hours
33504	3,3
Needs of machining:	YES
Work center Set-up time Machining time	33504 0,7 2,6

Tables A1.14 – A1.15 – A1.16: shroud D1500, D1250 and D1120 work cycle

Tie rod M72 x 4 x 908

Work centers	Hours
1506 1506 1511 1501 24003 1501 35901	0 0,5 0,5 0,8 7,5 1,5 0,8
Needs of machining:	YES
Work center Set-up time Machining time	24003 1 6,5
Work center Set-up time Machining time	35901 0,3 0,5

Transport cap D 440 x 265 for D 1700

Work centers	Hours
33603 32702 44102 1501 43311	10,2 3 0,7 1 0,7
Needs of machining:	YES
Work center Set-up time Machining time	33603 1 9,2
Work center Set-up time Machining time	32702 1 2
Work center Set-up time Machining time	44102 0,2 0,5

Tables A1.17 – A1.18: tie rod and transport cap work cycle

Shaft D 475 X 4993 machined

Work centers	Hours
36402	70
33202	14
35901	1,5
66109	16,9
Needs of machining:	YES
Work center	36402
Set-up time	3
Machining time	67
Work center	33202
Set-up time	2
Machining time	12
Work center	35901
Set-up time	0,5
Machining time	1
Work center	66109
Set-up time	1,5
Machining time	15,4

Round nut m72 x 4 / D144 x 72

Work centers	Hours
1501	0,2
24003	2,5
35901	0,4
1501	0,2
Needs of machining:	YES
Work center	1501
Set-up time	0,1
Machining time	0,1
Work center	24003
Set-up time	1
Machining time	1,5
Work center	35901
Set-up time	0,2
Machining time	0,2
Work center	1501
Set-up time	0,1
Machining time	0,1

Tables A1.19 – A1.20: machined rotor and round nut work cycle

Cover RIKT 140 zu D 1700-AGD11

Work centers	Hours
33603	11,6
33603	0
32702	6,2
32702	0
33603	9,9
44102	0,5
1501	1
35901	0,8
Needs of machining:	YES
Work center	33603
Set-up time	1,5
Machining time	10,1

Work center	32702
Set-up time	1
Machining time	5,2
Work center	33603
Set-up time	1,5
Machining time	8,4
Work center	44102
Set-up time	0,2
Machining time	0,3
Work center	35901
Set-up time	0,3
Machining time	0,5

Tables A1.21 – A1.22: cover RIKT work cycle

Annex 2

Purchasing orders in DPI

Here is the list of all the components needed for one RIKT.

Piece	Code	Total quantity	U.M.	Typology	Cost	Order number
Threaded rod DIN 975 M10 x 70	10066057	2	UN	ROH	2,4	1
Jacking screw M36 x 120	10072369	2	UN	HALB	90	1
Hub (to be welded) 1/2"G	10075918	5	UN	ROH	41	1
Washer special for M20	10303019	6	UN	HALB	54	1
Jacking screw M56x4 x L=200 DIN561 FormB	10462075	4	UN	HALB	240	1
Cheese-head bolt M 20x80 w. locking	50050890	4	UN	HALB	14,72	1
Tab washer D 10,5-A4 (DIN 93 invalid)	10010068	28	UN	ROH	6,86	2
Hexagon nut DIN 934 M 36	10011359	4	UN	ROH	10,48	2
Stop plate DIN 432 for M 8 galvanized	10011829	1	UN	ROH	2	2
Stop plate for M8 (DIN 93 invalid)	10011998	28	UN	ROH	5,88	2
Stop plate for M16 (DIN 93 invalid)	10013545	2	UN	ROH	3,2	2
Spring pin ISO 8752 D 3 x 12	10015620	1	UN	ROH	0,02	2
Stop plate UNI 6601for M16	10302922	2	UN	ROH	3,36	2
Stop plate for M10 UNI 6601	10303056	4	UN	HALB	8	2
Grounding M10	10089789	2	UN	HALB	28	3
Cheese-head bolt M 48x235 w. locking	10105640	4	UN	HALB	300	4
Washer D 149/85 x 45	10319498	36	UN	HALB	1368	4
Washer D 205/115 x 60	10319495	10	UN	HALB	900	5
Round nut M110 x 6	10319504	12	UN	HALB	1224	5
Round nut M80 x 6	10319509	36	UN	HALB	1656	5
Stud bolt M 110 x 6 x 650 ESV	10410779	8	UN	HALB	2160	5
Stud bolt M 80 x 6 x 535 ESV	10410894	36	UN	HALB	4320	5
Stud M 110 x 6 x 762 DSV	10410963	2	UN	HALB	700	5
L - Profile DIN 1028 50 x 5	10016773	1,9	M	ROH	2,67	6
PIPE ANSI 4" Sched. 40	10077303	0,516	KG	ROH	0,89	6
Tube D 250 x 50	10322741	0,8	M	ROH	480,87	6
Hexagonal screw DIN933 M12x35	10004163	20	UN	ROH	1,8	7
Hexagonal head screw DIN 931 M10 x 50/26	10009403	24	UN	ROH	6,96	7
Cyl. head screw ISO4762 M12x35	10012403	6	UN	ROH	0,53	7
Socket head screw ISO 4762 M24 x 80	10012522	18	UN	ROH	23,76	7
Hexagon nut DIN 439 B M20 x 1,5 LEFT	10013523	1	UN	ROH	0,73	7
Socket head screw ISO 4762 M16 x 80/44	10014349	288	UN	ROH	106,56	7
Cheese-head bolt ISO 4762 M16 x 180/44	10014351	90	UN	ROH	81	7
Socket head screw ISO 4762 M24 x 40	10014669	8	UN	ROH	6,4	7
Socket head screw ISO 4762 M20 x 35	10014670	16	UN	ROH	6,24	7
Hexagon nut DIN 439 B M24 x 1,5	10089701	1	UN	HALB	0,78	7
Cylinder head screw M42 x 120 ISO 4762	10306065	20	UN	ROH	180	7
Washing tubes	10092773	3	UN	HALB	180	8
Washing tubes	10092774	3	UN	HALB	180	8
Breather pipe for cooler	10315319	6	UN	HALB	108	8
Socket head screw M 8x40 with holes	50024486	18	UN	HALB	27,36	9
Socket head screw M 12 x 30 with holes	50024491	8	UN	HALB	12	9
Socket head screw M 24x70	50034306	20	UN	HALB	81,8	9
Socket head screw M 30x110 with holes	50047828	24	UN	HALB	340,08	9
Nozzle spraying 60°, R 1/4" (D 5,7)	10014769	12	UN	HAWA	253,8	10
Tube ISO 1127 D = 8 x 2,0	10331833	6	M	ROH	51	11
Taper pin w. threaded stem D 30 X 190	10089542	2	UN	HALB	61,8	12
Plug mit I6kt 1 1/2 " G x 35	10568761	1	UN	HALB	13	12
Safety screw M20 x 40	50026466	8	UN	HALB	200	12
Stop plate 16 x 10 x 22	50026829	2	UN	HALB	22	12
Stud M 42-T x 213	10070055	6	UN	HALB	342	13
Stud bolt M 48-T x L = 270	10089286	24	UN	HALB	528	13
Cap nut M 48	10089541	24	UN	HALB	456	13

Gauged screw DIN 7968 M 20x100	10017045	2	UN	ROH	90	14
Adjusting ring support	50024375	9	UN	HALB	153	14
Plate DU 80x25x3	50024580	16	UN	HALB	211,2	15
Plate DU 50x25x3	50024581	32	UN	HALB	499,2	15
Welding Neck Flange CL150 RF	10515129	4	UN	ROH	192	16
Plug T.E. 1/2" G VSM 12852	212058	15	UN	ROH	11,55	17
Plug T.E. 3/4" G VSM 12852	212062	8	UN	ROH	9,68	17
Plug Hexagonal-Head VSM 12852 G 1"	212066	11	UN	ROH	21,56	17
Plug G 1/4 x 10	212112	4	UN	ROH	17,4	17
Straight male stud fittings ErmetoG1/2"D	10014221	6	UN	ROH	60,96	17
Plug Hexagonal-head NPT 3/4"	10070388	2	UN	HAWA	2,54	17
Curve 90 DIN 2605-2 Type 3 DN 80	10304658	4	UN	ROH	71,6	17
Plug T.E. 3000 lbs 3/4"NPT	8,3726E+11	7	UN	ROH	8,89	17
Tapered pin DIN 258 D 16 x 120/72 x M16	10015274	2	UN	ROH	14	18
Guide hub D 200 x 215 for casing	10072334	2	UN	HALB	140	18
Connection piece for Water chamber	10073274	4	UN	HALB	340	18
Fixing ring D 315 x 50	10085935	16	UN	HALB	1536	18
Hub (to be welded) D 40 x 50 - 1/2"G	10085954	6	UN	HALB	90	18
Bush (to be welded) for oil tube HP	10108957	4	UN	HALB	52	18
Bracket for oil tube HP	10108959	20	UN	HALB	117	18
Hub (to be welded) for bearing housing	10315117	1	UN	HALB	15	18
Locking wire D 1,0 mm	10012753	19	M	ROH	0	19
Threaded rod M30 x 400 w. spot-facing	10089919	4	UN	HALB	104	19
Guide rod M80/6-T/D80 x 2896	10089963	2	UN	HALB	594	19
Guiding pin	10300757	1	UN	HALB	35	19
Radial support for Vibration collector	10303050	2	UN	HALB	76	19
Axial probe support RIKT140	10303051	2	UN	HALB	420	19
Support for Oil baffe ring D440/380 x 45	50026831	1	UN	HALB	520	19
Shaft seal sleeve SS 2/2 RIKT 140	10302736	1	UN	HALB	3200	20
Shaft seal sleeve DS 2/2 RIKT 140	10302737	1	UN	HALB	3200	20
Oil ret.ring in 2-parts D 390/315,2 x 3	50026830	3	UN	HALB	180	20
Taper pin DIN 258 D 20 x200	10308067	2	UN	HALB	52	21
Stop bush D 48 X 25	50026455	16	UN	HALB	128	21
Stop bush D 58 x 30	50026456	8	UN	HALB	112	21
Locking washer for M16	10109184	36	UN	HALB	126	22
Cover of casing (control system) RIKT140	10109568	1	UN	HALB	14,3	22
Cover of casing (control system) RIKT140	10109569	1	UN	HALB	4,9	22
Blind flange UNI 6093-67 DN 100 PN 16	380222	1	UN	ROH	14,5	23
Prerotation casing (control) RIKT 140	10109567	1	UN	HALB	810	23
Vent stack for balance drum RIK125/140	50026828	1	UN	HALB	150	23
Scale deal 240 x 126 x 3	50039884	1	UN	HALB	180	23
Scale deal index 110 x 30 x 3	50039885	1	UN	HALB	100	23
Pipe-support 110 x 60 x65	10092776	12	UN	HALB	456	24
Guide vane bearing D 230/95 X 501	10109182	9	UN	HALB	2367	24
Lever for prerotation 1. Stage	10109186	9	UN	HALB	630	24
Gasket upper/inside St.2	10090300	2	UN	HALB	17,7	25
Gasket upper/outside St.2	10090334	2	UN	HALB	23,8	25
Gasket upper/inside St.3	10090376	2	UN	HALB	15,1	25
Gasket upper/outside St.3	10090377	2	UN	HALB	21,4	25
Gasket upper/inside St.1	10302127	2	UN	HALB	28,3	25
Gasket upper/outside st. 1	10302128	2	UN	HALB	42,7	25
Gasket down/outside st. 3	10349412	2	UN	HALB	20,02	26
Gasket down/outside st. 2	10349449	2	UN	HALB	54,08	26
Gasket down/inside st. 2	10349454	2	UN	HALB	20,02	26
Gasket down/outside st. 1	10349457	2	UN	HALB	70,6	26
Gasket down/inside st. 1	10349460	2	UN	HALB	52,94	26
Gasket down/outside st. 3	10351352	2	UN	HALB	39,7	26
Hub (to be welded) 1"G	10075921	4	UN	ROH	48	27
Cover for bearing pedestal RIKT 140	10108821	1	UN	HALB	280	27
Cover lateral f.housing pedestal RIKT140	10108833	2	UN	HALB	200	27
Pressure spring D 10,6/1,6 X 18	8,3716E+11	68	UN	HALB	74,8	28

Hexagon nut DIN 934 M16	232267	6	UN	ROH	1,2	29
Washer D 12,4/6,4 x 1,6	256106	2	UN	ROH	0,04	29
Washer DIN 125B for M10	256110	6	UN	ROH	0,05	29
Washer DIN 125B M16	256116	2	UN	ROH	0,045	29
Socket head screw ISO 4762 M42 x 140/96	10010492	2	UN	ROH	18,2	29
Hexagonal head screw DIN 933 M 10 x 25	10013142	12	UN	ROH	0,96	29
Hexagon nut DIN 934 M 30	10013550	8	UN	ROH	7,92	29
Socket head screw ISO 4762 M42 x 200/96	10014666	42	UN	ROH	389,5	29
Gasket D 40/27x2	10075814	8	UN	ROH	0,8	29
Hexagonal head screw DIN 933 M8 x 12	10076703	33	UN	HAWA	1,32	29
Socket head screw ISO 4762 M42 x 210/96	10108836	24	UN	ROH	240	29
Union Ermeto PN 315	10013605	6	UN	ROH	95,1	30
Plug TN 192 1/4" NPT	10071100	2	UN	HAWA	1,96	30
Bracket for tube DIN 1596 1 x D = 23	10075903	10	UN	ROH	16	30
Screw Plug VSM 12852 G 1/2"	10090224	6	UN	HALB	21,06	30
Segment ring D 959/913 X 70 4-parts PTFE	10308105	1	UN	HALB	2700	31
Segment ring 4-tlg D 898/852 x 60 PTFE	10435117	1	UN	HALB	2210	31
Labyrinth insert D 1185/1139 x 70 PTFE	10533866	1	UN	HALB	3230	31
Flexible Nipple for conduit	10070457	24	UN	HAWA	36,56	32
Fitting hub CP.75 NPT WP	10070501	16	UN	HAWA	73,12	32
Reducer SST ,75-,5"NPT	10070502	16	UN	HAWA	219,36	32
Flexible sheath ANACONDA	10084292	4	UN	HAWA	304,67	32
Protective connectors set 40180-02	10103578	1	UN	HAWA	95,21	32
Fixing pin D 30/M 27 x 160	10087330	4	UN	HALB	150	33
Taper pin w. thread DIN 258 D25 x 250	10108465	2	UN	HALB	130	33
Threaded bar M14x1,5	10109443	9	UN	HALB	261	33
Nipple for prerotation RIKT 140	10300235	1	UN	HALB	55	33
Coating of prerotation RIKT140	10300444	1	UN	HALB	630	34
Gasket D 45/34x2	10075816	5	UN	ROH	10,65	35
Flat gasket DN 100 162/115X2	10075884	1	UN	ROH	3,5	35
Flat gasket D 27/21 x 1,5	10077035	21	UN	HAWA	19,74	35
Gasket of man hole cover RIKT 140	10108820	1	UN	HALB	39,95	35
Gasket for bearing housing top RIKT 140	10108832	1	UN	HALB	19,95	35
Gasket for bearing housing sw RIKT 140	10108834	2	UN	HALB	11,9	35
Flat gasket DIN 2690 PN 6 DN 200	10303060	1	UN	ROH	5,9	35
Hexagonal head screw DIN 933 M8x16-A4	206530	29	UN	ROH	2,61	36
Washer D 28/50 X 4 DIN 125A	256127	2	UN	ROH	0,2	36
Washer DIN 125A for M36	256136	4	UN	ROH	1,08	36
Flat head screw 90° M 5 x 10	10013389	112	UN	ROH	3,36	36
Spring pin ISO 8752 D 4 x 22	10013397	18	UN	ROH	0,46	36
Stop plate per M 20 (DIN 93 invalid)	10027017	14	UN	ROH	33,6	36
Hexagonal head screw DIN 931 M10x35/26	10076873	4	UN	ROH	0,44	36
Cheese-head bolt ISO 4762 M36 x 125/69	10094967	14	UN	HALB	102,2	36
Locking ring A DIN 471 D 65	10109187	9	UN	ROH	2,79	36
Bearing bush D 120/90 x 105	10109183	18	UN	HALB	4014	37
O-Ring ID 12,37 x 2,62 OR 3050	344816	2	UN	ROH	0,06	38
O-ring ID 26,58 x 3,53 OR 4106	344835	6	UN	ROH	0,69	38
O-Ring ID 32,93 x 3,53 OR 4131	344839	2	UN	ROH	0,25	38
Toggle joint for forked lever M20 x 1,5	10010146	1	UN	ROH	166,88	38
Spherical bearing Type SSA 20.50	10010148	1	UN	ROH	59,4	38
Toggle joint left DIN 71802 AS 19	10010149	9	UN	ROH	36,45	38
Toggle joint DIN 71802 AS 19	10010150	9	UN	ROH	40,5	38
Round cord D 2 mm Industr. seal/O-ring	10015610	12	M	ROH	17,64	38
Cord D 5 mm FPM 75	10080057	42.000	MM	ROH	189	38
O-ring DI 17,00 x 4,00 ORM 0170-40	10093970	4	UN	ROH	5,36	38
Tapered pin DIN 7977 D 25 x 140	10010109	4	UN	ROH	98,4	39
Parallel pin D 16-h8 x L = 40	10088072	8	UN	HALB	53,6	39
Plug mit l6kt G 1" x 25	10568343	1	UN	ROH	8,5	39
Taper pin with thread D 50 X 260	50026452	4	UN	HALB	208	39

Flat head screw DIN 963 M6 x 16	223509	2	UN	ROH	0,03	40
Socket head screw ISO 4762 M8 x 16	226823	4	UN	ROH	0,16	40
Hexagon nut DIN 934 M 20	232271	8	UN	ROH	0,85	40
Safety plate M30 (DIN 93 invalid)	253220	9	UN	ROH	7,2	40
Safety washer per M12 (DIN 93 invalid)	10009996	20	UN	ROH	29,4	40
Cyl. head screw ISO4762 M12x30	10012279	300	UN	ROH	27,3	40
Locking washer DIN 463 zinc coated t.M20	10013387	6	UN	ROH	14,4	40
Hexagon nut DIN 934 M 27	10013393	6	UN	ROH	2,22	40
Cheese-head bolt ISO 4762 M24 x 100/60	10014352	496	UN	ROH	535,68	40
Socket head screw ISO 4762 M36 x 110/84	10015451	8	UN	ROH	39,2	40
Hexagon socket head screw ISO4762 M5x20	10035870	8	UN	ROH	0,48	40
Conical Plug with threaded DIN258D10x65	10067982	2	UN	ROH	3,5	40
Taper pin DIN 258 D16 x100	10067987	2	UN	ROH	10,4	40
Safety washer per M 14	10099290	18	UN	ROH	27,9	40
Safety screw M8 x 21	231483	6	UN	ROH	66	41
Bracket for tube 30/30 x 65	10032807	12	UN	HALB	204	41
Parallel pin D 16 h9 x 36	10073946	6	UN	HALB	30	41
Hub (to be welded) for temperature-detec	10094478	2	UN	HALB	56	41
Guiding dowel for interm.refriger.D20x45	50027271	24	UN	HALB	86,4	41
Hexagonal head screw DIN 561B M16 x 80	211584	12	UN	ROH	14,4	42
Hexagon nut DIN934 M10	232261	6	UN	ROH	0,1	42
Seeger circlip Ring DIN 471 D 20 x 1,2	265320	2	UN	ROH	0,06	42
Hexagon head screw DIN 931 M16 x 60/38	10002367	36	UN	ROH	10,08	42
hexagonal head screw DIN 933 M16 x 40	10005020	32	UN	ROH	6,63	42
Hexagon nut DIN 439 B M20 x 1,5	10011608	1	UN	ROH	0,28	42
Hexagon screw DIN 931 M30 x 120/66	10012375	9	UN	ROH	22,5	42
Hexagon screw DIN 561B M20 x 100	10012378	4	UN	ROH	16	42
Hexagon head bolt DIN 933 M20 x 50	10012468	14	UN	ROH	5,18	42
Parallel pin ISO 2338-8 D8 h8 x 30	10013398	4	UN	ROH	1	42
Cheese-head bolt ISO 4762 M16 x 90/44	10014350	198	UN	ROH	83,16	42
Spring washer DIN 128A D 18,1/10,2 x 1,8	10014387	2	UN	ROH	0,04	42
Safety washer DIN 6798 A per M10	10037573	8	UN	ROH	0,08	42
SPRING WASHER DIN 127B per M30	10037853	64	UN	ROH	20,88	42
VITI T.E. M 30*90	10076709	64	UN	HAWA	128	42
Screw hex. head DIN 561B M20 x 80	10076892	2	UN	HAWA	47	42
Hub (to be welded) 1/2"G	10315114	1	UN	HALB	15	42
Washer DIN 7989 A for M27	10702633	4	UN	ROH	1,16	42
Proximitor 330180 B-N,XL series	10048836	4	UN	HAWA	867,7	43
Extension Cable BENLTY NEVADA	10083661	2	UN	HAWA	243,73	43
Proximitor 330780 B-N 3300 XL 11mm	10083665	2	UN	HAWA	664,2	43
Probe BENLTY NEVADA 330105	10308183	2	UN	HAWA	482,6	43
Probe BENLTY NEVADA 330705	10308184	2	UN	HAWA	604,46	43
Washer Bently nevada	10337528	4	UN	HAWA	24,37	43
Bently nevada gasket	10337530	4	UN	HAWA	3,05	43
Counter nut Bently nevada	10337531	4	UN	HAWA	3,05	43
Probe Sleeve BN 44382-102	10351548	2	UN	HAWA	149,9	43
Probe Housing Bently nevada	10531552	2	UN	HAWA	570,34	43
Probe Sleeve	10546328	2	UN	HAWA	149,9	43
Injection for impeller welded	10534692	2	UN	HALB	200	44
Injection for impeller welded	10534889	2	UN	HALB	210	44
Injection for impeller welded	10534944	2	UN	HALB	210	44
Segment ring in 4-parts RIKT 140	10528812	1	UN	HALB	7660	45
Half-ring forged D2608/1790 x 323	10498530	2	UN	ROH	18000	46

Plate EN 10029 th.=10	10066367	20,496	KG	ROH	10,86	47
Plate EN 10029 th.=12	10066368	1766,502	KG	ROH	971,58	47
Plate EN 10029 th.=15	10066369	130,078	KG	ROH	70,24	47
Plate EN 10029 th.=25	10066372	6767,075	KG	ROH	3654,22	47
Plate EN 10029 th.=35	10066374	13231,158	KG	ROH	7012,51	47
Plate EN 10029 th.=45	10066376	15651,22	KG	ROH	8451,66	47
Plate EN 10029 th.=55	10066378	1.139,11	KG	ROH	683,47	47
Plate EN 10029 th.=60	10066379	15168,145	KG	ROH	8570,01	47
Plate EN 10029 th.=120	10066641	830,844	KG	ROH	556,67	47
Plate EN 10029 th.=180	10096858	17286,97	KG	ROH	11236,53	47
Plate EN 10029 th.=190	10104317	6,986	KG	ROH	5,07	47
Plate EN 10029 th.=15	10300381	173,108	KG	ROH	93,48	47
Plate EN 10029 th.=20	10066371	910,6	KG	ROH	482,618	48
Plate EN 10025 th.=30	10066373	410,624	KG	ROH	207,34	48
Plate EN 10025 th.=50	10066377	2543,968	KG	ROH	1424,62	48
Plate EN 10029 th.=70	10066392	11669,72	KG	ROH	5951,56	48
Plate EN 10029 th.=80	10066394	14336,64	KG	ROH	7455,05	48
Plate EN 10025 th.=150	10066643	37477,47	KG	ROH	23236,03	48
Plate EN 10029 th.=300	10335017	1.103,54	KG	ROH	993,19	48

Table A2.1: list of components

Here is the list of the missing purchasing orders in DPI.

Order 3

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Grounding M10	10089789	2	UN	HALB	28	2

Order 3								
Pieces	Grounding M10							
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	28	128	100	28	128	0	0,00%
2	200	56	256	100	56	156	100	39,06%
3	300	84	384	100	84	184	200	52,08%
4	400	112	512	100	112	212	300	58,59%
5	500	140	640	100	140	240	400	62,50%
6	600	168	768	100	168	268	500	65,10%
7	700	196	896	100	196	296	600	66,96%
8	800	224	1024	100	224	324	700	68,36%
9	900	252	1152	100	252	352	800	69,44%
10	1000	280	1280	100	280	380	900	70,31%

Tables A2.2 – A2.3: order number 3

Order 4

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Washer D 149/85 x 45	10319498	36	UN	HALB	1368	36
Cheese-head bolt M 48x235 w. locking	10105640	4	UN	HALB	300	4

Order 4								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	1668	1768	100	1668	1768	0	0,00%
2	200	3336	3536	100	3336	3436	100	2,83%
3	300	5004	5304	100	5004	5104	200	3,77%
4	400	6672	7072	100	6672	6772	300	4,24%
5	500	8340	8840	100	7297,5	7397,5	1442,5	16,32%
6	600	10008	10608	100	8757	8857	1751	16,51%
7	700	11676	12376	100	10216,5	10316,5	2059,5	16,64%
8	800	13344	14144	100	11676	11776	2368	16,74%
9	900	15012	15912	100	13135,5	13235,5	2676,5	16,82%
10	1000	16680	17680	100	14595	14695	2985	16,88%

Tables A2.4 – A2.5: order number 4

Order 5

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Washer D 205/115 x 60	10319495	10	UN	HALB	900	10
Round nut M80 x 6	10319509	36	UN	HALB	1656	36
Round nut M110 x 6	10319504	12	UN	HALB	1224	12
Stud bolt M 110 x 6 x 650 ESV	10410779	8	UN	HALB	2160	8
Stud M 110 x 6 x 762 DSV	10410963	2	UN	HALB	700	2
Stud bolt M 80 x 6 x 535 ESV	10410894	36	UN	HALB	4320	36

Order 5								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	10960	11060	100	10960	11060	0	0,00%
2	200	21920	22120	100	21920	22020	100	0,45%
3	300	32880	33180	100	32880	32980	200	0,60%
4	400	43840	44240	100	43840	43940	300	0,68%
5	500	54800	55300	100	47950	48050	7250	13,11%
6	600	65760	66360	100	57540	57640	8720	13,14%
7	700	76720	77420	100	67130	67230	10190	13,16%
8	800	87680	88480	100	76720	76820	11660	13,18%
9	900	98640	99540	100	86310	86410	13130	13,19%
10	1000	109600	110600	100	95900	96000	14600	13,20%

Tables A2.6 – A2.7: order number 5

Order 6

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
L - Profile DIN 1028 50 x 5	10016773	1,9 (3,705)	M (KG)	ROH	2,67	40 kg
PIPE ANSI 4" Sched. 40	10077303	0,516	KG	ROH	0,89	90 kg
Tube D 250 x 50	10322741	0,8	M	ROH	480,87	0,8 m

Order 6								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	664,93	764,93	100	664,93	764,93	0	0,00%
2	200	1145,80	1345,80	100	1145,80	1245,80	100	7,43%
3	300	1626,67	1926,67	100	1626,67	1726,67	200	10,38%
4	400	2107,54	2507,54	100	2107,54	2207,54	300	11,96%
5	500	2588,41	3088,41	100	2588,41	2688,41	400	12,95%
6	600	3069,28	3669,28	100	3069,28	3169,28	500	13,63%
7	700	3550,15	4250,15	100	3550,15	3650,15	600	14,12%
8	800	4031,02	4831,02	100	4031,02	4131,02	700	14,49%
9	900	4511,89	5411,89	100	4511,89	4611,89	800	14,78%
10	1000	4992,76	5992,76	100	4992,76	5092,76	900	15,02%

Tables A2.8 – A2.9: order number 6

Order 8

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Washing tubes	10092773	3	UN	HALB	180	3
Washing tubes	10092774	3	UN	HALB	180	3
Breather pipe for cooler	10315319	6	UN	HALB	108	6

Order 8								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	468	568	100	468	568	0	0,00%
2	200	936	1136	100	936	1036	100	8,80%
3	300	1404	1704	100	1404	1504	200	11,74%
4	400	1872	2272	100	1872	1972	300	13,20%
5	500	2340	2840	100	2047,5	2147,5	692,5	24,38%
6	600	2808	3408	100	2457	2557	851	24,97%
7	700	3276	3976	100	2866,5	2966,5	1009,5	25,39%
8	800	3744	4544	100	3276	3376	1168	25,70%
9	900	4212	5112	100	3685,5	3785,5	1326,5	25,95%
10	1000	4680	5680	100	4095	4195	1485	26,14%

Tables A2.10 – A2.11: order number 8

Order 9

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Socket head screw M 8x40 with holes	50024486	18	UN	HALB	27,36	18
Socket head screw M 12 x 30 with holes	50024491	8	UN	HALB	12	8
Socket head screw M 24x70	50034306	20	UN	HALB	81,8	20
Socket head screw M 30x110 with holes	50047828	24	UN	HALB	340,08	24

Order 9								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	461,24	561,24	100	461,24	561,24	0	0,00%
2	200	922,48	1122,48	100	922,48	1022,48	100	8,91%
3	300	1383,72	1683,72	100	1383,72	1483,72	200	11,88%
4	400	1844,96	2244,96	100	1844,96	1944,96	300	13,36%
5	500	2306,2	2806,2	100	2017,93	2117,93	688,28	24,53%
6	600	2767,44	3367,44	100	2421,51	2521,51	845,93	25,12%
7	700	3228,68	3928,68	100	2825,10	2925,10	1003,59	25,55%
8	800	3689,92	4489,92	100	3228,68	3328,68	1161,24	25,86%
9	900	4151,16	5051,16	100	3632,27	3732,27	1318,90	26,11%
10	1000	4612,4	5612,4	100	4035,85	4135,85	1476,55	26,31%

Tables A2.12 – A2.13: order number 9

Order 10

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Nozzle spraying 60°, R 1/4" (D 5,7)	10014769	12	UN	HAWA	253,8	12

Order 10								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	253,8	353,8	100	253,8	353,8	0	0,00%
2	200	507,6	707,6	100	507,6	607,6	100	14,13%
3	300	761,4	1061,4	100	761,4	861,4	200	18,84%
4	400	1015,2	1415,2	100	1015,2	1115,2	300	21,20%
5	500	1269	1769	100	1269	1369	400	22,61%
6	600	1522,8	2122,8	100	1522,8	1622,8	500	23,55%
7	700	1776,6	2476,6	100	1776,6	1876,6	600	24,23%
8	800	2030,4	2830,4	100	2030,4	2130,4	700	24,73%
9	900	2284,2	3184,2	100	2284,2	2384,2	800	25,12%
10	1000	2538	3538	100	2538	2638	900	25,44%

Tables A2.14 – A2.15: order number 10

Order 11

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Tube ISO 1127 D = 8 x 2,0	10331833	6	M	ROH	51	6 m

Order 11								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	51	151	100	51	151	0	0,00%
2	200	102	302	100	102	202	100	33,11%
3	300	153	453	100	153	253	200	44,15%
4	400	204	604	100	204	304	300	49,67%
5	500	255	755	100	255	355	400	52,98%
6	600	306	906	100	306	406	500	55,19%
7	700	357	1057	100	357	457	600	56,76%
8	800	408	1208	100	408	508	700	57,95%
9	900	459	1359	100	459	559	800	58,87%
10	1000	510	1510	100	510	610	900	59,60%

Tables A2.15 – A2.16: order number 11

Order 12

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Stop plate 16 x 10 x 22	50026829	2	UN	HALB	22	2
Taper pin w. threaded stem D 30 X 190	10089542	2	UN	HALB	61,8	2
Plug mit I6kt 1 1/2 " G x 35	10568761	1	UN	HALB	13	1
Safety screw M20 x 40	50026466	8	UN	HALB	200	8

Order 12								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	296,8	396,8	100	296,8	396,8	0	0,00%
2	200	593,6	793,6	100	593,6	693,6	100	12,60%
3	300	890,4	1190,4	100	890,4	990,4	200	16,80%
4	400	1187,2	1587,2	100	1187,2	1287,2	300	18,90%
5	500	1484	1984	100	1298,5	1398,5	585,5	29,51%
6	600	1780,8	2380,8	100	1558,2	1658,2	722,6	30,35%
7	700	2077,6	2777,6	100	1817,9	1917,9	859,7	30,95%
8	800	2374,4	3174,4	100	2077,6	2177,6	996,8	31,40%
9	900	2671,2	3571,2	100	2337,3	2437,3	1133,9	31,75%
10	1000	2968	3968	100	2597	2697	1271	32,03%

Tables A2.16 – A2.17: order number 12

Order 13

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Cap nut M 48	10089541	24	UN	HALB	456	24
Stud M 42-T x 213	10070055	6	UN	HALB	342	24
Stud bolt M 48-T x L = 270	10089286	24	UN	HALB	528	6

Order 13								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	1326	1426	100	1326	1426	0	0,00%
2	200	2652	2852	100	2652	2752	100	3,51%
3	300	3978	4278	100	3978	4078	200	4,68%
4	400	5304	5704	100	5304	5404	300	5,26%
5	500	6630	7130	100	5801,25	5901,25	1228,75	17,23%
6	600	7956	8556	100	6961,5	7061,5	1494,5	17,47%
7	700	9282	9982	100	8121,75	8221,75	1760,25	17,63%
8	800	10608	11408	100	9282	9382	2026	17,76%
9	900	11934	12834	100	10442,25	10542,25	2291,75	17,86%
10	1000	13260	14260	100	11602,5	11702,5	2557,5	17,93%

Tables A2.17 – A2.18: order number 13

Order 14

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Adjusting ring support	50024375	9	UN	HALB	153	9
Gauged screw DIN 7968 M 20x100	10017045	2	UN	ROH	90	2

Order 14								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	243	343	100	243	343	0	0,00%
2	200	486	686	100	486	586	100	14,58%
3	300	729	1029	100	729	829	200	19,44%
4	400	972	1372	100	972	1072	300	21,87%
5	500	1215	1715	100	1119,38	1219,38	495,625	28,90%
6	600	1458	2058	100	1343,25	1443,25	614,75	29,87%
7	700	1701	2401	100	1567,13	1667,13	733,875	30,57%
8	800	1944	2744	100	1791,00	1891,00	853	31,09%
9	900	2187	3087	100	2014,88	2114,88	972,125	31,49%
10	1000	2430	3430	100	2238,75	2338,75	1091,25	31,81%

Tables A2.18 – A2.19: order number 14

Order 15

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Plate DU 50x25x3	50024581	32	UN	HALB	499,2	32
Plate DU 80x25x3	50024580	16	UN	HALB	211,2	16

Order 15								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	710,4	810,4	100	710,4	810,4	0	0,00%
2	200	1420,8	1620,8	100	1420,8	1520,8	100	6,17%
3	300	2131,2	2431,2	100	2131,2	2231,2	200	8,23%
4	400	2841,6	3241,6	100	2841,6	2941,6	300	9,25%
5	500	3552	4052	100	3108,00	3208,00	844	20,83%
6	600	4262,4	4862,4	100	3729,60	3829,60	1032,8	21,24%
7	700	4972,8	5672,8	100	4351,20	4451,20	1221,6	21,53%
8	800	5683,2	6483,2	100	4972,80	5072,80	1410,4	21,75%
9	900	6393,6	7293,6	100	5594,40	5694,40	1599,2	21,93%
10	1000	7104	8104	100	6216,00	6316,00	1788	22,06%

Tables A2.20 – A2.21: order number 15

Order 16

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Welding Neck Flange CL150 RF	10515129	4	UN	ROH	192	4

Order 16								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	192	292	100	192	292	0	0,00%
2	200	384	584	100	384	484	100	17,12%
3	300	576	876	100	576	676	200	22,83%
4	400	768	1168	100	768	868	300	25,68%
5	500	960	1460	100	960	1060	400	27,40%
6	600	1152	1752	100	1152	1252	500	28,54%
7	700	1344	2044	100	1344	1444	600	29,35%
8	800	1536	2336	100	1536	1636	700	29,97%
9	900	1728	2628	100	1728	1828	800	30,44%
10	1000	1920	2920	100	1920	2020	900	30,82%

Tables A2.22 – A2.23: order number 16

Order 17

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Curve 90 DIN 2605-2 Type 3 DN 80	10304658	4	UN	ROH	71,6	4
Straight male stud fittings ErmetoG1/2"D	10014221	6	UN	ROH	60,96	6
Plug Hexagonal-head NPT 3/4"	10070388	2	UN	HAWA	2,54	2
Plug G 1/4 x 10	212112	4	UN	ROH	17,4	4
Plug Hexagonal-Head VSM 12852 G 1"	212066	11	UN	ROH	21,56	11
Plug T.E. 1/2" G VSM 12852	212058	15	UN	ROH	11,55	15
Plug T.E. 3/4" G VSM 12852	212062	8	UN	ROH	9,68	8
Plug T.E. 3000 lbs 3/4"NPT	837258780002	7	UN	ROH	8,89	7

Order 17								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	1028,49	1128,49	100	1028,49	1128,49	0	0,00%
2	200	1172,48	1372,48	100	1172,48	1272,48	100	7,29%
3	300	1316,47	1616,47	100	1316,47	1416,47	200	12,37%
4	400	1460,46	1860,46	100	1460,46	1560,46	300	16,13%
5	500	1604,45	2104,45	100	1604,45	1704,45	400	19,01%
6	600	1748,44	2348,44	100	1748,44	1848,44	500	21,29%
7	700	1892,43	2592,43	100	1892,43	1992,43	600	23,14%
8	800	2036,42	2836,42	100	2036,42	2136,42	700	24,68%
9	900	2180,41	3080,41	100	2180,41	2280,41	800	25,97%
10	1000	2324,4	3324,4	100	2324,4	2424,4	900	27,07%

Tables A2.23 – A2.24: order number 17

Order 18

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Bush (to be welded) for oil tube HP	10108957	4	UN	HALB	52	4
Hub (to be welded) D 40 x 50 - 1/2"G	10085954	6	UN	HALB	90	6
Hub (to be welded) for bearing housing	10315117	1	UN	HALB	15	20
Guide hub D 200 x 215 for casing	10072334	2	UN	HALB	140	2
Fixing ring D 315 x 50	10085935	16	UN	HALB	1536	16
Connection piece for Water chamber	10073274	4	UN	HALB	340	4
Bracket for oil tube HP	10108959	20	UN	HALB	117	20
Tapered pin DIN 258 D 16 x 120/72 x M16	10015274	2	UN	ROH	14	20

Order 18								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	2715	2815	100	2715	2815	0	0,00%
2	200	4990	5190	100	4990	5090	100	1,93%
3	300	7265	7565	100	7265	7365	200	2,64%
4	400	9540	9940	100	9540	9640	300	3,02%
5	500	11815	12315	100	10393,13	10493,13	1821,88	14,79%
6	600	14090	14690	100	12383,75	12483,75	2206,25	15,02%
7	700	16365	17065	100	14374,38	14474,38	2590,63	15,18%
8	800	18640	19440	100	16365,00	16465,00	2975,00	15,30%
9	900	20915	21815	100	18355,63	18455,63	3359,38	15,40%
10	1000	23190	24190	100	20346,25	20446,25	3743,75	15,48%

Tables A2.25 – A2.26: order number 18

Order 19

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Guide rod M80/6-T/D80 x 2896	10089963	2	UN	HALB	594	2
Threaded rod M30 x 400 w. spot-facing	10089919	4	UN	HALB	104	4
Support for Oil baffe ring D440/380 x 45	50026831	1	UN	HALB	520	1
Guiding pin	10300757	1	UN	HALB	35	1
Radial support for Vibration collector	10303050	2	UN	HALB	76	2
Axial probe support RIKT140	10303051	2	UN	HALB	420	2

Order 19								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	1749	1849	100	1749	1849	0	0,00%
2	200	3498	3698	100	3498	3598	100	2,70%
3	300	5247	5547	100	5247	5347	200	3,61%
4	400	6996	7396	100	6996	7096	300	4,06%
5	500	8745	9245	100	7716,88	7816,88	1428,13	15,45%
6	600	10494	11094	100	9260,25	9360,25	1733,75	15,63%
7	700	12243	12943	100	10803,63	10903,63	2039,38	15,76%
8	800	13992	14792	100	12347,00	12447,00	2345,00	15,85%
9	900	15741	16641	100	13890,38	13990,38	2650,63	15,93%
10	1000	17490	18490	100	15433,75	15533,75	2956,25	15,99%

Tables A2.27 – A2.28: order number 19

Order 20

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Shaft seal sleeve DS 2/2 RIKT 140	10302737	1	UN	HALB	3200	1
Shaft seal sleeve SS 2/2 RIKT 140	10302736	1	UN	HALB	3200	1
Oil ret.ring in 2-parts D 390/315,2 x 3	50026830	3	UN	HALB	180	3

Order 20								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	6580	6680	100	6580	6680	0	0,00%
2	200	13160	13360	100	13160	13260	100	0,75%
3	300	19740	20040	100	19740	19840	200	1,00%
4	400	26320	26720	100	26320	26420	300	1,12%
5	500	32900	33400	100	28787,5	28887,5	4512,5	13,51%
6	600	39480	40080	100	34545	34645	5435	13,56%
7	700	46060	46760	100	40302,5	40402,5	6357,5	13,60%
8	800	52640	53440	100	46060	46160	7280	13,62%
9	900	59220	60120	100	51817,5	51917,5	8202,5	13,64%
10	1000	65800	66800	100	57575	57675	9125	13,66%

Tables A2.29 – A2.30: order number 20

Order 21

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Stop bush D 48 X 25	50026455	16	UN	HALB	128	16
Stop bush D 58 x 30	50026456	8	UN	HALB	112	8
Taper pin DIN 258 D 20 x200	10308067	2	UN	HALB	52	2

Order 21								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	292	392	100	292	392	0	0,00%
2	200	584	784	100	584	684	100	12,76%
3	300	876	1176	100	876	976	200	17,01%
4	400	1168	1568	100	1168	1268	300	19,13%
5	500	1460	1960	100	1310	1410	550	28,06%
6	600	1752	2352	100	1572	1672	680	28,91%
7	700	2044	2744	100	1834	1934	810	29,52%
8	800	2336	3136	100	2096	2196	940	29,97%
9	900	2628	3528	100	2358	2458	1070	30,33%
10	1000	2920	3920	100	2620	2720	1200	30,61%

Tables A2.31 – A2.32: order number 21

Order 22

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Cover of casing (control system) RIKT140	10109568	1	UN	HALB	14,3	1
Cover of casing (control system) RIKT140	10109569	1	UN	HALB	4,9	1
Locking washer for M16	10109184	36	UN	HALB	126	36

Order 22								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	145,2	245,2	100	145,2	245,2	0	0,00%
2	200	290,4	490,4	100	290,4	390,4	100	20,39%
3	300	435,6	735,6	100	435,6	535,6	200	27,19%
4	400	580,8	980,8	100	580,8	680,8	300	30,59%
5	500	726	1226	100	726	826	400	32,63%
6	600	871,2	1471,2	100	871,2	971,2	500	33,99%
7	700	1016,4	1716,4	100	1016,4	1116,4	600	34,96%
8	800	1161,6	1961,6	100	1161,6	1261,6	700	35,69%
9	900	1306,8	2206,8	100	1306,8	1406,8	800	36,25%
10	1000	1452	2452	100	1452	1552	900	36,70%

Tables A2.33 – A2.34: order number 22

Order 23

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Vent stack for balance drum RIK125/140	50026828	1	UN	HALB	150	1
Prerotation casing (control) RIKT 140	10109567	1	UN	HALB	810	1
Scale deal index 110 x 30 x 3	50039885	1	UN	HALB	100	1
Scale deal 240 x 126 x 3	50039884	1	UN	HALB	180	1
Blind flange UNI 6093-67 DN 100 PN 16	380222	1	UN	ROH	14,5	1

Order 23								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	1254,5	1354,5	100	1254,5	1354,5	0	0,00%
2	200	2509	2709	100	2509	2609	100	3,69%
3	300	3763,5	4063,5	100	3763,5	3863,5	200	4,92%
4	400	5018	5418	100	5018	5118	300	5,54%
5	500	6272,5	6772,5	100	5497,5	5597,5	1175	17,35%
6	600	7527	8127	100	6597	6697	1430	17,60%
7	700	8781,5	9481,5	100	7696,5	7796,5	1685	17,77%
8	800	10036	10836	100	8796	8896	1940	17,90%
9	900	11290,5	12190,5	100	9895,5	9995,5	2195	18,01%
10	1000	12545	13545	100	10995	11095	2450	18,09%

Tables A2.35 – A2.36: order number 23

Order 24

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Lever for prerotation 1. Stage	10109186	9	UN	HALB	630	9
Pipe-support 110 x 60 x65	10092776	12	UN	HALB	456	12
Guide vane bearing D 230/95 X 501	10109182	9	UN	HALB	2367	9

Order 24								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	3453	3553	100	3453	3553	0	0,00%
2	200	6906	7106	100	6906	7006	100	1,41%
3	300	10359	10659	100	10359	10459	200	1,88%
4	400	13812	14212	100	13812	13912	300	2,11%
5	500	17265	17765	100	15106,88	15206,88	2558,13	14,40%
6	600	20718	21318	100	18128,25	18228,25	3089,75	14,49%
7	700	24171	24871	100	21149,63	21249,63	3621,38	14,56%
8	800	27624	28424	100	24171,00	24271	4153	14,61%
9	900	31077	31977	100	27192,38	27292,38	4684,63	14,65%
10	1000	34530	35530	100	30213,75	30313,75	5216,25	14,68%

Tables A2.37 – A2.38: order number 24

Order 25

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Gasket upper/outside st. 1	10302128	2	UN	HALB	42,7	2
Gasket upper/outside St.2	10090334	2	UN	HALB	23,8	2
Gasket upper/outside St.3	10090377	2	UN	HALB	21,4	2
Gasket upper/inside St.1	10302127	2	UN	HALB	28,3	2
Gasket upper/inside St.2	10090300	2	UN	HALB	17,7	2
Gasket upper/inside St.3	10090376	2	UN	HALB	15,1	2

Order 25								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	149	249	100	149	249	0	0,00%
2	200	298	498	100	298	398	100	20,08%
3	300	447	747	100	447	547	200	26,77%
4	400	596	996	100	596	696	300	30,12%
5	500	745	1245	100	651,88	751,88	493,13	39,61%
6	600	894	1494	100	782,25	882,25	611,75	40,95%
7	700	1043	1743	100	912,63	1012,63	730,38	41,90%
8	800	1192	1992	100	1043,00	1143	849	42,62%
9	900	1341	2241	100	1173,38	1273,38	967,63	43,18%
10	1000	1490	2490	100	1303,75	1403,75	1086,25	43,62%

Tables A2.39 – A2.40: order number 25

Order 26

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Gasket down/outside st. 1	10349457	2	UN	HALB	70,6	2
Gasket down/outside st. 2	10349449	2	UN	HALB	54,08	2
Gasket down/outside st. 3	10351352	2	UN	HALB	39,7	2
Gasket down/inside st. 1	10349460	2	UN	HALB	52,94	2
Gasket down/inside st. 2	10349454	2	UN	HALB	20,02	2
Gasket down/outside st. 3	10349412	2	UN	HALB	20,02	2

Order 26								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	257,36	357,36	100	257,36	357,36	0	0,00%
2	200	514,72	714,72	100	514,72	614,72	100	13,99%
3	300	772,08	1072,08	100	772,08	872,08	200	18,66%
4	400	1029,44	1429,44	100	1029,44	1129,44	300	20,99%
5	500	1286,8	1786,8	100	1125,95	1225,95	560,85	31,39%
6	600	1544,16	2144,16	100	1351,14	1451,14	693,02	32,32%
7	700	1801,52	2501,52	100	1576,33	1676,33	825,19	32,99%
8	800	2058,88	2858,88	100	1801,52	1901,52	957,36	33,49%
9	900	2316,24	3216,24	100	2026,71	2126,71	1089,53	33,88%
10	1000	2573,6	3573,6	100	2251,9	2351,9	1221,7	34,19%

Tables A2.41 – A2.42: order number 26

Order 27

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Cover lateral f.housing pedestal RIKT140	10108833	2	UN	HALB	200	2
Cover for bearing pedestal RIKT 140	10108821	1	UN	HALB	280	1
Hub (to be welded) 1"G	10075921	4	UN	ROH	48	16

Order 27								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	672	772	100	672	772	0	0,00%
2	200	1152	1352	100	1152	1252	100	7,40%
3	300	1632	1932	100	1632	1732	200	10,35%
4	400	2112	2512	100	2112	2212	300	11,94%
5	500	2784	3284	100	2484	2584	700	21,32%
6	600	3264	3864	100	2904	3004	860	22,26%
7	700	3744	4444	100	3324	3424	1020	22,95%
8	800	4224	5024	100	3744	3844	1180	23,49%
9	900	4896	5796	100	4356	4456	1340	23,12%
10	1000	5376	6376	100	4776	4876	1500	23,53%

Tables A2.43 – A2.44: order number 27

Order 28

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Pressure spring D 10,6/1,6 X 18	837162033001	68	UN	HALB	74,8	250

Order 28								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	275	375	100	275	375	0	0,00%
2	200	275	475	100	275	375	100	21,05%
3	300	275	575	100	275	375	200	34,78%
4	400	550	950	100	550	650	300	31,58%
5	500	550	1050	100	550	650	400	38,10%
6	600	550	1150	100	550	650	500	43,48%
7	700	550	1250	100	550	650	600	48,00%
8	800	825	1625	100	825	925	700	43,08%
9	900	825	1725	100	825	925	800	46,38%
10	1000	825	1825	100	825	925	900	49,32%

Tables A2.45 – A2.46: order number 28

Order 29

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Hexagon nut DIN 934 M16	232267	6	UN	ROH	1,2	100
Hexagon nut DIN 934 M 30	10013550	8	UN	ROH	7,92	100
Gasket D 40/27x2	10075814	8	UN	ROH	0,8	100
Washer D 12,4/6,4 x 1,6	256106	2	UN	ROH	0,04	50
Washer DIN 125B for M10	256110	6	UN	ROH	0,05	100
Washer DIN 125B M16	256116	2	UN	ROH	0,045	100
Socket head screw ISO 4762 M42 x 140/96	10010492	2	UN	ROH	18,2	20
Socket head screw ISO 4762 M42 x 200/96	10014666	42	UN	ROH	389,5	42
Socket head screw ISO 4762 M42 x 210/96	10108836	24	UN	ROH	240	24
Hexagonal head screw DIN 933 M8 x 12	10076703	33	UN	HAWA	1,32	500
Hexagonal head screw DIN 933 M 10 x 25	10013142	12	UN	ROH	0,96	200

Order 29								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	980,58	1080,58	100	980,58	1080,58	0	0,00%
2	200	1610,08	1810,08	100	1610,08	1710,08	100	5,52%
3	300	2239,58	2539,58	100	2239,58	2339,58	200	7,88%
4	400	2869,08	3269,08	100	2869,08	2969,08	300	9,18%
5	500	3498,58	3998,58	100	3498,58	3598,58	400,00	10,00%
6	600	4128,08	4728,08	100	4128,08	4228,08	500,00	10,58%
7	700	4757,58	5457,58	100	4757,58	4857,58	600,00	10,99%
8	800	5387,08	6187,08	100	5387,08	5487,08	700,00	11,31%
9	900	6016,58	6916,58	100	6016,58	6116,58	800,00	11,57%
10	1000	6646,08	7646,08	100	6646,08	6746,08	900,00	11,77%

Tables A2.47 – A2.48: order number 29

Order 30

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Union Ermeto PN 315	10013605	6	UN	ROH	95,1	6
Bracket for tube DIN 1596 1 x D = 23	10075903	10	UN	ROH	16	30
Screw Plug VSM 12852 G 1/2"	10090224	6	UN	HALB	21,06	6
Plug TN 192 1/4" NPT	10071100	2	UN	HAWA	1,96	20

Order 30								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	183,76	283,76	100	183,76	283,76	0	0,00%
2	200	299,92	499,92	100	299,92	399,92	100	20,00%
3	300	416,08	716,08	100	416,08	516,08	200	27,93%
4	400	580,24	980,24	100	580,24	680,24	300	30,60%
5	500	696,4	1196,4	100	683,24	783,24	413,16	34,53%
6	600	812,56	1412,56	100	796,77	896,77	515,80	36,51%
7	700	976,72	1676,72	100	958,29	1058,29	618,43	36,88%
8	800	1092,88	1892,88	100	1071,82	1171,82	721,06	38,09%
9	900	1209,04	2109,04	100	1185,35	1285,35	823,69	39,06%
10	1000	1373,2	2373,2	100	1346,88	1446,88	926,33	39,03%

Tables A2.49 – A2.50: order number 30

Order 31

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Labyrinth insert D 1185/1139 x 70 PTFE	10533866	1	UN	HALB	3230	1
Segment ring 4-tlg D 898/852 x 60 PTFE	10435117	1	UN	HALB	2210	1
Segment ring D 959/913 X 70 4-parts PTFE	10308105	1	UN	HALB	2700	1

Order 31								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	8140	8240	100	8140	8240	0	0,00%
2	200	16280	16480	100	16280	16380	100	0,61%
3	300	24420	24720	100	24420	24520	200	0,81%
4	400	32560	32960	100	32560	32660	300	0,91%
5	500	40700	41200	100	35612,5	35712,5	5487,5	13,32%
6	600	48840	49440	100	42735	42835	6605	13,36%
7	700	56980	57680	100	49857,5	49957,5	7722,5	13,39%
8	800	65120	65920	100	56980	57080	8840	13,41%
9	900	73260	74160	100	64102,5	64202,5	9957,5	13,43%
10	1000	81400	82400	100	71225	71325	11075	13,44%

Tables A2.51 – A2.52: order number 31

Order 32

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Fitting hub CP.75 NPT WP	10070501	16	UN	HAWA	73,12	16
Flexible sheath ANACONDA	10084292	4	UN	HAWA	304,67	4
Flexible Nipple for conduit	10070457	24	UN	HAWA	36,56	24
Reducer SST ,75-,5"NPT	10070502	16	UN	HAWA	219,36	16
Protective connectors set 40180-02	10103578	1	UN	HAWA	95,21	1

Order 32								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	728,92	828,92	100	728,92	828,92	0	0,00%
2	200	1457,84	1657,84	100	1457,84	1557,84	100	6,03%
3	300	2186,76	2486,76	100	2186,76	2286,76	200	8,04%
4	400	2915,68	3315,68	100	2915,68	3015,68	300	9,05%
5	500	3644,6	4144,6	100	3644,6	3744,6	400	9,65%
6	600	4373,52	4973,52	100	4373,52	4473,52	500	10,05%
7	700	5102,44	5802,44	100	5102,44	5202,44	600	10,34%
8	800	5831,36	6631,36	100	5831,36	5931,36	700	10,56%
9	900	6560,28	7460,28	100	6560,28	6660,28	800	10,72%
10	1000	7289,2	8289,2	100	7289,2	7389,2	900	10,86%

Tables A2.53 – A2.54 order number 32

Order 33

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Threaded bar M14x1,5	10109443	9	UN	HALB	261	9
Nipple for prerotation RIKT 140	10300235	1	UN	HALB	55	1
Taper pin w. thread DIN 258 D25 x 250	10108465	2	UN	HALB	130	2
Fixing pin D 30/M 27 x 160	10087330	4	UN	HALB	150	4

Order 33								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	596	696	100	596	696	0	0,00%
2	200	1192	1392	100	1192	1292	100	7,18%
3	300	1788	2088	100	1788	1888	200	9,58%
4	400	2384	2784	100	2384	2484	300	10,78%
5	500	2980	3480	100	2607,5	2707,5	772,5	22,20%
6	600	3576	4176	100	3129	3229	947	22,68%
7	700	4172	4872	100	3650,5	3750,5	1121,5	23,02%
8	800	4768	5568	100	4172	4272	1296	23,28%
9	900	5364	6264	100	4693,5	4793,5	1470,5	23,48%
10	1000	5960	6960	100	5215	5315	1645	23,64%

Tables A2.55 – A2.56 order number 33

Order 34

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Coating of prerotation RIKT140	10300444	1	UN	HALB	630	1

Order 34								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	630	730	100	630	730	0	0,00%
2	200	1260	1460	100	1260	1360	100	6,85%
3	300	1890	2190	100	1890	1990	200	9,13%
4	400	2520	2920	100	2520	2620	300	10,27%
5	500	3150	3650	100	2756,25	2856,25	793,75	21,75%
6	600	3780	4380	100	3307,5	3407,5	972,5	22,20%
7	700	4410	5110	100	3858,75	3958,75	1151,25	22,53%
8	800	5040	5840	100	4410	4510	1330	22,77%
9	900	5670	6570	100	4961,25	5061,25	1508,75	22,96%
10	1000	6300	7300	100	5512,5	5612,5	1687,5	23,12%

Tables A2.57 – A2.58 order number 34

Order 35

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Gasket D 45/34x2	10075816	5	UN	ROH	10,65	50
Gasket of man hole cover RIKT 140	10108820	1	UN	HALB	39,95	1
Gasket for bearing housing top RIKT 140	10108832	1	UN	HALB	19,95	1
Gasket for bearing housing sw RIKT 140	10108834	2	UN	HALB	11,9	2
Flat gasket D 27/21 x 1,5	10077035	21	UN	HAWA	19,74	100
Flat gasket DIN 2690 PN 6 DN 200	10303060	1	UN	ROH	5,9	1
Flat gasket DN 100 162/115X2	10075884	1	UN	ROH	3,5	1

Order 35								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	281,7	381,7	100	281,7	381,7	0	0,00%
2	200	362,9	562,9	100	362,9	462,9	100	17,77%
3	300	444,1	744,1	100	444,1	544,1	200	26,88%
4	400	525,3	925,3	100	525,3	625,3	300	32,42%
5	500	700,5	1200,5	100	655,63	755,63	444,88	37,06%
6	600	781,7	1381,7	100	727,85	827,85	553,85	40,08%
7	700	862,9	1562,9	100	800,08	900,08	662,83	42,41%
8	800	944,1	1744,1	100	872,30	972,3	771,8	44,25%
9	900	1025,3	1925,3	100	944,53	1044,53	880,78	45,75%
10	1000	1200,5	2200,5	100	1016,75	1116,75	1083,75	49,25%

Tables A2.59 – A2.60 order number 35

Order 36

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Locking ring A DIN 471 D 65	10109187	9	UN	ROH	2,79	9
Washer D 28/50 X 4 DIN 125A	256127	2	UN	ROH	0,2	100
Washer DIN 125A for M36	256136	4	UN	ROH	1,08	100
Stop plate per M 20 (DIN 93 invalid)	10027017	14	UN	ROH	33,6	60
Spring pin ISO 8752 D 4 x 22	10013397	18	UN	ROH	0,46	18
Cheese-head bolt ISO 4762 M36 x 125/69	10094967	14	UN	HALB	4389309	14
Hexagonal head screw DIN 931 M10x35/26	10076873	4	UN	ROH	0,44	50
Hexagonal head screw DIN 933 M8x16-A4	206530	29	UN	ROH	2,61	300
Flat head screw 90° M 5 x 10	10013389	112	UN	ROH	3,36	600

Order 36								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	336,95	436,95	100	336,95	436,95	0	0,00%
2	200	442,4	642,4	100	442,4	542,4	100	15,57%
3	300	547,85	847,85	100	547,85	647,85	200	23,59%
4	400	653,3	1053,3	100	653,3	753,3	300	28,48%
5	500	998,75	1498,75	100	934,88	1034,88	463,88	30,95%
6	600	1104,2	1704,2	100	1027,55	1127,55	576,65	33,84%
7	700	1209,65	1909,65	100	1120,23	1220,23	689,43	36,10%
8	800	1315,1	2115,1	100	1212,90	1312,9	802,2	37,93%
9	900	1420,55	2320,55	100	1305,58	1405,58	914,98	39,43%
10	1000	1526	2526	100	1398,25	1498,25	1027,75	40,69%

Tables A2.61 – A2.62 order number 36

Order 37

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Bearing bush D 120/90 x 105	10109183	18	UN	HALB	4014	18

Order 37								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	4014	4114	100	4014	4114	0	0,00%
2	200	8028	8228	100	8028	8128	100	1,22%
3	300	12042	12342	100	12042	12142	200	1,62%
4	400	16056	16456	100	16056	16156	300	1,82%
5	500	20070	20570	100	17561,25	17661,25	2908,75	14,14%
6	600	24084	24684	100	21073,5	21173,5	3510,5	14,22%
7	700	28098	28798	100	24585,75	24685,75	4112,25	14,28%
8	800	32112	32912	100	28098	28198	4714	14,32%
9	900	36126	37026	100	31610,25	31710,25	5315,75	14,36%
10	1000	40140	41140	100	35122,5	35222,5	5917,5	14,38%

Tables A2.63 – A2.64 order number 37

Order 38

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
O-Ring ID 12,37 x 2,62 OR 3050	344816	2	UN	ROH	0,06	20
O-Ring ID 32,93 x 3,53 OR 4131	344839	2	UN	ROH	0,25	20
Cord D 5 mm FPM 75	10080057	42.000	MM	ROH	189	42000 mm
Round cord D 2 mm Industr. seal/O-ring	10015610	12	M	ROH	17,64	40 m
Spherical bearing Type SSA 20.50	10010148	1	UN	ROH	59,4	1
Toggle joint DIN 71802 AS 19	10010150	9	UN	ROH	40,5	9
Toggle joint left DIN 71802 AS 19	10010149	9	UN	ROH	36,45	100
O-ring DI 17,00 x 4,00 ORM 0170-40	10093970	4	UN	ROH	5,36	4
O-ring ID 26,58 x 3,53 OR 4106	344835	6	UN	ROH	0,69	50
Toggle joint for forked lever M20 x 1,5	10010146	1	UN	ROH	166,88	1

Order 38								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	933,79	1033,79	100	933,79	1033,79	0	0,00%
2	200	1394,93	1594,93	100	1394,93	1494,93	100	6,27%
3	300	1856,07	2156,07	100	1856,07	1956,07	200	9,28%
4	400	2376,01	2776,01	100	2376,01	2476,01	300	10,81%
5	500	2837,15	3337,15	100	2837,15	2937,15	400	11,99%
6	600	3298,29	3898,29	100	3298,29	3398,29	500	12,83%
7	700	3818,23	4518,23	100	3818,23	3918,23	600	13,28%
8	800	4279,37	5079,37	100	4279,37	4379,37	700	13,78%
9	900	4746,26	5646,26	100	4746,26	4846,26	800	14,17%
10	1000	5207,4	6207,4	100	5207,4	5307,40	900	14,50%

Tables A2.65 – A2.66 order number 38

Order 39

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Parallel pin D 16-h8 x L = 40	10088072	8	UN	HALB	53,6	24
Taper pin with thread D 50 X 260	50026452	4	UN	HALB	208	4
Tapered pin DIN 7977 D 25 x 140	10010109	4	UN	ROH	98,4	4
Plug mit I6kt G 1" x 25	10568343	1	UN	ROH	8,5	1

Order 39								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	475,7	575,7	100	475,7	575,7	0	0,00%
2	200	790,6	990,6	100	790,6	890,6	100	10,09%
3	300	1105,5	1405,5	100	1105,5	1205,5	200	14,23%
4	400	1581,2	1981,2	100	1581,2	1681,2	300	15,14%
5	500	1896,1	2396,1	100	1704,6	1804,6	591,5	24,69%
6	600	2211	2811	100	1981,2	2081,2	729,8	25,96%
7	700	2686,7	3386,7	100	2418,6	2518,6	868,1	25,63%
8	800	3001,6	3801,6	100	2695,2	2795,2	1006,4	26,47%
9	900	3316,5	4216,5	100	2971,8	3071,8	1144,7	27,15%
10	1000	3792,2	4792,2	100	3409,2	3509,2	1283	26,77%

Tables A2.67 – A2.68 order number 39

Order 40

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Hexagon nut DIN 934 M 20	232271	8	UN	ROH	0,85	100
Hexagon nut DIN 934 M 27	10013393	6	UN	ROH	2,22	100
Locking washer DIN 463 zinc coated t.M20	10013387	6	UN	ROH	14,4	6
Safety washer per M12 (DIN 93 invalid)	10009996	20	UN	ROH	29,4	200
Safety washer per M 14	10099290	18	UN	ROH	27,9	100
Safety plate M30 (DIN 93 invalid)	253220	9	UN	ROH	7,2	100
Taper pin DIN 258 D16 x100	10067987	2	UN	ROH	10,4	20
Conical Plug with threaded DIN258D10x65	10067982	2	UN	ROH	3,5	10
Flat head screw DIN 963 M6 x 16	223509	2	UN	ROH	0,03	100
Hexagon socket head screw ISO4762 M5x20	10035870	8	UN	ROH	0,48	100
Socket head screw ISO 4762 M8 x 16	226823	4	UN	ROH	0,16	500
Cyl. head screw ISO4762 M12x30	10012279	300	UN	ROH	27,3	1000
Cheese-head bolt ISO 4762 M24 x 100/60	10014352	496	UN	ROH	535,68	496
Socket head screw ISO 4762 M36 x 110/84	10015451	8	UN	ROH	39,2	30

Order 40								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	1513,71	1613,71	100	1513,71	1613,71	0	0,00%
2	200	2063,79	2263,79	100	2063,79	2163,79	100	4,42%
3	300	2613,87	2913,87	100	2613,87	2713,87	200	6,86%
4	400	3499,95	3899,95	100	3499,95	3599,95	300	7,69%
5	500	4050,03	4550,03	100	4050,03	4150,03	400	8,79%
6	600	4772,61	5372,61	100	4772,61	4872,61	500	9,31%
7	700	5413,69	6113,69	100	5413,69	5513,69	600	9,81%
8	800	5963,77	6763,77	100	5963,77	6063,77	700	10,35%
9	900	6513,85	7413,85	100	6513,85	6613,85	800	10,79%
10	1000	7063,93	8063,93	100	7063,93	7163,93	900	11,16%

Tables A2.69 – A2.70 order number 40

Order 41

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Hub (to be welded) for temperature-detec	10094478	2	UN	HALB	56	2
Parallel pin D 16 h9 x 36	10073946	6	UN	HALB	30	6
Guiding dowel for interm.refriger.D20x45	50027271	24	UN	HALB	86,4	24
Bracket for tube 30/30 x 65	10032807	12	UN	HALB	204	12
Safety screw M8 x 21	231483	6	UN	ROH	66	50

Order 41								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	926,4	1026,4	100	926,4	1026,4	0	0,00%
2	200	1302,8	1502,8	100	1302,8	1402,8	100	6,65%
3	300	1679,2	1979,2	100	1679,2	1779,2	200	10,11%
4	400	2055,6	2455,6	100	2055,6	2155,6	300	12,22%
5	500	2432	2932	100	2196,75	2296,75	635,25	21,67%
6	600	2808,4	3408,4	100	2526,1	2626,1	782,3	22,95%
7	700	3184,8	3884,8	100	2855,45	2955,45	929,35	23,92%
8	800	3561,2	4361,2	100	3184,8	3284,8	1076,4	24,68%
9	900	4487,6	5387,6	100	4064,15	4164,15	1223,45	22,71%
10	1000	4864	5864	100	4393,5	4493,5	1370,5	23,37%

Tables A2.71 – A2.72 order number 41

Order 43

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Counter nut Bently nevada	10337531	4	UN	HAWA	3,05	4
Extension Cable BENLTY NEVADA	10083661	2	UN	HAWA	243,73	2
Bently nevada gasket	10337530	4	UN	HAWA	3,05	4
Probe BENLTY NEVADA 330105	10308183	2	UN	HAWA	482,6	2
Probe BENLTY NEVADA 330705	10308184	2	UN	HAWA	604,46	2
Probe Housing Bently nevada	10531552	2	UN	HAWA	570,34	2
Probe Sleeve	10546328	2	UN	HAWA	149,9	2
Probe Sleeve BN 44382-102	10351548	2	UN	HAWA	149,9	2
Proximitor 330180 B-N,XL series	10048836	4	UN	HAWA	867,7	4
Proximitor 330780 B-N 3300 XL 11mm	10083665	2	UN	HAWA	664,2	2
Washer Bently nevada	10337528	4	UN	HAWA	24,37	4

Order 43								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	3763,30	3863,30	100	3763,30	3863,30	0	0,00%
2	200	7526,60	7726,60	100	7526,60	7626,60	100	1,29%
3	300	11289,90	11589,90	100	11289,90	11389,90	200	1,73%
4	400	15053,20	15453,20	100	15053,20	15153,20	300	1,94%
5	500	18816,50	19316,50	100	18816,50	18916,50	400	2,07%
6	600	22579,80	23179,80	100	22579,80	22679,80	500	2,16%
7	700	26343,10	27043,10	100	26343,10	26443,10	600	2,22%
8	800	30106,40	30906,40	100	30106,40	30206,40	700	2,26%
9	900	33869,70	34769,70	100	33869,70	33969,70	800	2,30%
10	1000	37633,00	38633,00	100	37633,00	37733,00	900	2,33%

Tables A2.73 – A2.74 order number 43

Order 44

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Injection for impeller welded	10534692	2	UN	HALB	200	2
Injection for impeller welded	10534889	2	UN	HALB	210	2
Injection for impeller welded	10534944	2	UN	HALB	210	2

Order 44								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	620	720	100	620	720	0	0,00%
2	200	1240	1440	100	1240	1340	100	6,94%
3	300	1860	2160	100	1860	1960	200	9,26%
4	400	2480	2880	100	2480	2580	300	10,42%
5	500	3100	3600	100	2712,5	2812,5	787,5	21,88%
6	600	3720	4320	100	3255	3355	965	22,34%
7	700	4340	5040	100	3797,5	3897,5	1142,5	22,67%
8	800	4960	5760	100	4340	4440	1320	22,92%
9	900	5580	6480	100	4882,5	4982,5	1497,5	23,11%
10	1000	6200	7200	100	5425	5525	1675	23,26%

Tables A2.75 – A2.76 order number 44

Order 45

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Segment ring in 4-parts RIKT 140	10528812	1	UN	HALB	7660	1

Order 45								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	7660	7760	100	7660	7760	0	0,00%
2	200	15320	15520	100	15320	15420	100	0,64%
3	300	22980	23280	100	22980	23080	200	0,86%
4	400	30640	31040	100	30640	30740	300	0,97%
5	500	38300	38800	100	33512,5	33612,5	5187,5	13,37%
6	600	45960	46560	100	40215	40315	6245	13,41%
7	700	53620	54320	100	46917,5	47017,5	7302,5	13,44%
8	800	61280	62080	100	53620	53720	8360	13,47%
9	900	68940	69840	100	60322,5	60422,5	9417,5	13,48%
10	1000	76600	77600	100	67025	67125	10475	13,50%

Tables A2.77 – A2.78 order number 45

Order 46

Piece	Code	Total quantity	U.M.	Typology	Cost	Unit in one order
Half-ring forged D2608/1790 x 323	10498530	2	UN	ROH	18000	2

Order 46								
	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	100	18000	18100	100	18000	18100	0	0,00%
2	200	36000	36200	100	36000	36100	100	0,28%
3	300	54000	54300	100	54000	54100	200	0,37%
4	400	72000	72400	100	72000	72100	300	0,41%
5	500	90000	90500	100	78750	78850	11650	12,87%
6	600	108000	108600	100	94500	94600	14000	12,89%
7	700	126000	126700	100	110250	110350	16350	12,90%
8	800	144000	144800	100	126000	126100	18700	12,91%
9	900	162000	162900	100	141750	141850	21050	12,92%
10	1000	180000	181000	100	157500	157600	23400	12,93%

Tables A2.79 – A2.80 order number 46

Annex 3

Purchasing orders in MAN

To avoid a too long list, here only the total cost table is presented.

In MAN, it has been calculated that the minimum number of orders required for the production of RIKT compressor is 17. The order cost is about 200 €.

This is the result.

	Single production		
N	Order cost	Total material cost	Total cost
1	3400	600.188,59	603.588,59
2	6800	1.200.377,18	1.207.177,18
3	10200	1.800.565,78	1.810.765,78
4	13600	2.400.754,37	2.414.354,37
5	17000	3.000.942,96	3.017.942,96
6	20400	3.601.131,55	3.621.531,55
7	23800	4.201.320,14	4.225.120,14
8	27200	4.801.508,73	4.828.708,73
9	30600	5.401.697,33	5.432.297,33
10	34000	6.001.885,92	6.035.885,92

Table A3.1: purchasing in MAN

Speaking about series effect, in Zürich there are different savings from Schio. In fact, following the type of component, there is a discount following table A3.2:

	Numbers of items									
Material Group	1	2	3	4	5	6	7	8	9	10
Gearbox			4%		8%					10%
Armatures / valves			7%		7%					7%
Oil supply system			1%		2%					3%
Coupling			2%		4%					6%
Forgings					3%					
Welded / steel structures			3%		5%					8%
Other drawing parts			4%		7%					12%

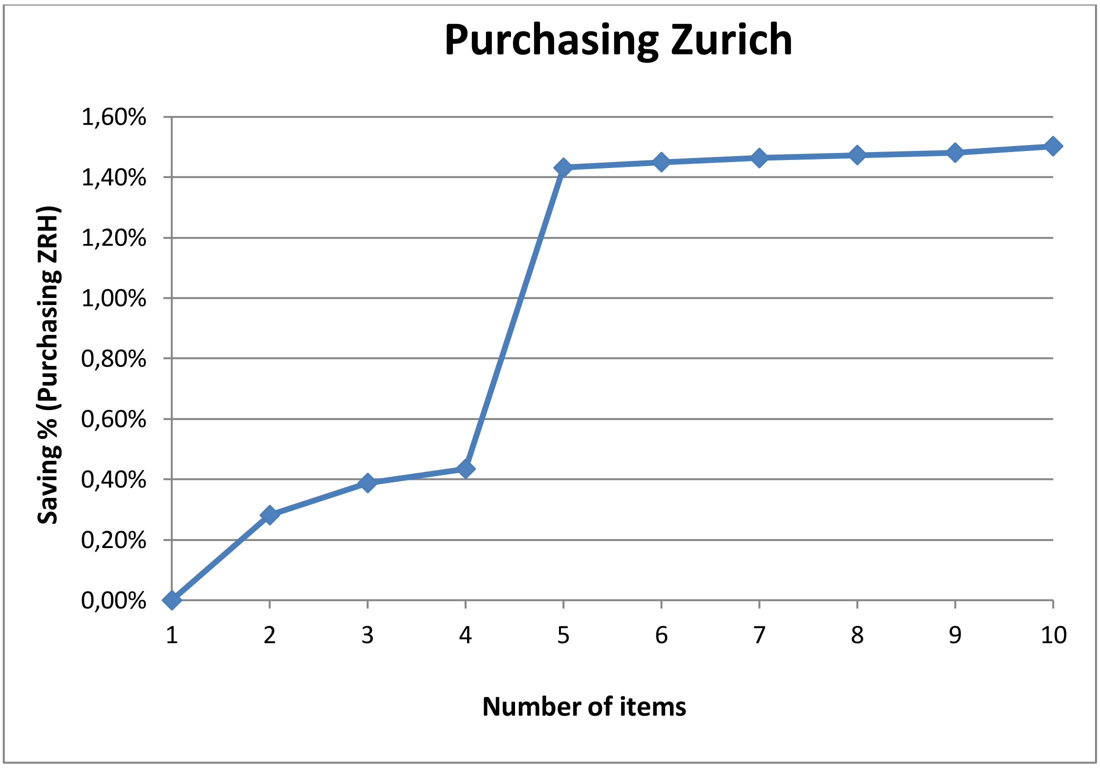
Table A3.2: savings in MAN

Moreover, the order issue follows the same conditions as the one in De Pretto, so there will be one order for all the RIKTs.

The result of savings in purchasing in MAN is presented in table A3.3 and picture A3.1. There is a step between the 4th and the 5th compressor, but not as high as the one in DPI.

	Single production			Series production				
N	Order cost	Total material cost	Total cost	Order cost	Total material cost	Total cost	Saving	Saving %
1	3400	600.188,59	603.588,59	3400	600.188,59	603.588,59	0,00	0,00%
2	6800	1.200.377,18	1.207.177,18	3400	1.200.377,18	1.203.777,18	3.400,00	0,28%
3	10200	1.800.565,78	1.810.765,78	3400	1.800.342,21	1.803.742,21	7.023,56	0,39%
4	13600	2.400.754,37	2.414.354,37	3400	2.400.456,28	2.403.856,28	10.498,08	0,43%
5	17000	3.000.942,96	3.017.942,96	3400	2.971.346,98	2.974.746,98	43.195,98	1,43%
6	20400	3.601.131,55	3.621.531,55	3400	3.565.616,37	3.569.016,37	52.515,18	1,45%
7	23800	4.201.320,14	4.225.120,14	3400	4.159.885,77	4.163.285,77	61.834,38	1,46%
8	27200	4.801.508,73	4.828.708,73	3400	4.754.155,16	4.757.555,16	71.153,57	1,47%
9	30600	5.401.697,33	5.432.297,33	3400	5.348.424,56	5.351.824,56	80.472,77	1,48%
10	34000	6.001.885,92	6.035.885,92	3400	5.941.772,56	5.945.172,56	90.713,36	1,50%

Table A3.3: serial effect on purchasing, MAN



Picture A3.1: serial effect on purchasing, MAN

Annex 4

Production in MAN

Here the information about production in MAN can be found. First, there will be presented the costs due to work preparation (work cycles and numerical control), then the machining (divided by work centers), and at the end the total workings. Savings are already included.

Work preparation

The cost for work preparation is 81,08 €/h. The total hours needed for 1 RIKT are 62, including the writing of work cycles, of numerical control programs and the so-called "initial difficulties", which are losses of time due to problems that can appear when the drawings go to the workshop.

Then, speaking about series production, after the first compressor, there is no need to write again the cycles, and in theory all the difficulties should disappear. So, the hours remain 62 for all the series.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	62,00	62,00	0,00	5.026,69	5.026,69	0,00	0,00%
2	124,00	62,00	62,00	10.053,37	5.026,69	5.026,69	50,00%
3	186,00	62,00	124,00	15.080,06	5.026,69	10.053,37	66,67%
4	248,00	62,00	186,00	20.106,75	5.026,69	15.080,06	75,00%
5	310,00	62,00	248,00	25.133,44	5.026,69	20.106,75	80,00%
6	372,00	62,00	310,00	30.160,12	5.026,69	25.133,44	83,33%
7	434,00	62,00	372,00	35.186,81	5.026,69	30.160,12	85,71%
8	496,00	62,00	434,00	40.213,50	5.026,69	35.186,81	87,50%
9	558,00	62,00	496,00	45.240,19	5.026,69	40.213,50	88,89%
10	620,00	62,00	558,00	50.266,87	5.026,69	45.240,19	90,00%

Table A4.1: savings in work preparation

Machining

The division made here is just between work centers, without entering in details about every component. The savings are due mostly to set-up time reduction, as with a series effect there is the possibility to maintain the same layout of the machine without changing it for every part, with the same tools and numerical control programs; but there are some also due to machining time reduction.

1501 Testing MT, PT, UT

Hourly cost: 81,08 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	1,9	1,9	0	154,04	154,04	0	0,00%
2	3,8	3,1	0,7	308,09	251,33	56,75	18,42%
3	5,7	4,3	1,4	462,13	348,63	113,51	24,56%
4	7,6	5,5	2,1	616,17	445,92	170,26	27,63%
5	9,5	6,7	2,8	770,22	543,21	227,01	29,47%
6	11,4	7,9	3,5	924,26	640,50	283,76	30,70%
7	13,3	9,1	4,2	1.078,31	737,79	340,52	31,58%
8	15,2	10,3	4,9	1.232,35	835,08	397,27	32,24%
9	17,1	11,5	5,6	1.386,39	932,37	454,02	32,75%
10	19	12,7	6,3	1.540,44	1.029,66	510,78	33,16%

Table A4.2: savings in work center 1501

24003 Allocation cost center external production of small parts PMZEET

Hourly cost 67,56 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	10	10	0	675,63	675,63	0	0,00%
2	20	18	2	1.351,26	1.216,13	135,13	10,00%
3	30	26	4	2.026,89	1.756,64	270,25	13,33%
4	40	34	6	2.702,52	2.297,14	405,38	15,00%
5	50	42	8	3.378,15	2.837,65	540,50	16,00%
6	60	50	10	4.053,78	3.378,15	675,63	16,67%
7	70	58	12	4.729,41	3.918,65	810,76	17,14%
8	80	66	14	5.405,04	4.459,16	945,88	17,50%
9	90	74	16	6.080,67	4.999,66	1.081,01	17,78%
10	100	82	18	6.756,30	5.540,17	1.216,13	18,00%

Table A4.3: savings in work center 24003

32402 Vertical lathe Comau

Hourly cost 116,21 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	105,8	105,8	0	12.294,84	12.294,84	0	0,00%
2	211,6	203,2	8,4	24.589,69	23.613,54	976,15	3,97%
3	317,4	300,6	16,8	36.884,53	34.932,23	1.952,30	5,29%
4	423,2	398	25,2	49.179,38	46.250,93	2.928,45	5,95%
5	529	495,4	33,6	61.474,22	57.569,62	3.904,60	6,35%
6	634,8	592,8	42	73.769,07	68.888,32	4.880,75	6,62%
7	740,6	690,2	50,4	86.063,91	80.207,01	5.856,90	6,81%
8	846,4	787,6	58,8	98.358,76	91.525,71	6.833,05	6,95%
9	952,2	885	67,2	110.653,60	102.844,40	7.809,20	7,06%
10	1058	982,4	75,6	122.948,45	114.163,10	8.785,35	7,15%

Table A4.4: savings in work center 32402

32702 Machining center DMG

Hourly cost 116,21 €/h

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	9,2	9,2	0	1.069,12	1.069,12	0	0,00%
2	18,4	16,4	2	2.138,23	1.905,82	232,42	10,87%
3	27,6	23,6	4	3.207,35	2.742,52	464,83	14,49%
4	36,8	30,8	6	4.276,47	3.579,22	697,25	16,30%
5	46	38	8	5.345,58	4.415,92	929,67	17,39%
6	55,2	45,2	10	6.414,70	5.252,62	1.162,08	18,12%
7	64,4	52,4	12	7.483,82	6.089,32	1.394,50	18,63%
8	73,6	59,6	14	8.552,94	6.926,02	1.626,92	19,02%
9	82,8	66,8	16	9.622,05	7.762,72	1.859,33	19,32%
10	92	74	18	10.691,17	8.599,42	2.091,75	19,57%

Table A4.5: savings in work center 32702

33103 Boring machine PAMA Speedmat

Hourly cost 148,64 €/h

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	7	7	0	1.040,47	1.040,47	0	0,00%
2	14	13	1	2.080,94	1.932,30	148,64	7,14%
3	21	19	2	3.121,41	2.824,13	297,28	9,52%
4	28	25	3	4.161,88	3.715,97	445,92	10,71%
5	35	31	4	5.202,35	4.607,80	594,55	11,43%
6	42	37	5	6.242,82	5.499,63	743,19	11,90%
7	49	43	6	7.283,29	6.391,46	891,83	12,24%
8	56	49	7	8.323,76	7.283,29	1.040,47	12,50%
9	63	55	8	9.364,23	8.175,12	1.189,11	12,70%
10	70	61	9	10.404,70	9.066,95	1.337,75	12,86%

Table A4.6: savings in work center 33103

33202 Boring machine PAMA

Hourly cost 141,88 €/h

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	33	33	0	4.682,12	4.682,12	0	0,00%
2	66	61,5	4,5	9.364,23	8.725,76	638,47	6,82%
3	99	90	9	14.046,35	12.769,41	1.276,94	9,09%
4	132	118,5	13,5	18.728,46	16.813,05	1.915,41	10,23%
5	165	147	18	23.410,58	20.856,70	2.553,88	10,91%
6	198	175,5	22,5	28.092,70	24.900,34	3.192,35	11,36%
7	231	204	27	32.774,81	28.943,99	3.830,82	11,69%
8	264	232,5	31,5	37.456,93	32.987,64	4.469,29	11,93%
9	297	261	36	42.139,04	37.031,28	5.107,76	12,12%
10	330	289,5	40,5	46.821,16	41.074,93	5.746,23	12,27%

Table A4.7: savings in work center 33202

33312 Boring machine Schiess

Hourly cost 121,61 €/h

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	684,8	684,8	0	83.280,86	83.280,86	0	0,00%
2	1369,6	1361,6	8	166.561,72	165.588,81	972,91	0,58%
3	2054,4	2038,4	16	249.842,58	247.896,76	1.945,81	0,78%
4	2739,2	2715,2	24	333.123,44	330.204,72	2.918,72	0,88%
5	3424	3392	32	416.404,30	412.512,67	3.891,63	0,93%
6	4108,8	4068,8	40	499.685,16	494.820,62	4.864,54	0,97%
7	4793,6	4745,6	48	582.966,02	577.128,57	5.837,44	1,00%
8	5478,4	5422,4	56	666.246,88	659.436,52	6.810,35	1,02%
9	6163,2	6099,2	64	749.527,73	741.744,48	7.783,26	1,04%
10	6848	6776	72	832.808,59	824.052,43	8.756,17	1,05%

Table A4.8: savings in work center 33312

33504 Vertical lathe Carnaghi

Hourly cost 104,72 €/h

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	38,3	38,3	0	4.010,88	4.010,88	0	0,00%
2	76,6	71,8	4,8	8.021,76	7.519,09	502,67	6,27%
3	114,9	105,3	9,6	12.032,63	11.027,30	1.005,34	8,36%
4	153,2	138,8	14,4	16.043,51	14.535,50	1.508,01	9,40%
5	191,5	172,3	19,2	20.054,39	18.043,71	2.010,67	10,03%
6	229,8	205,8	24	24.065,27	21.551,92	2.513,34	10,44%
7	268,1	239,3	28,8	28.076,14	25.060,13	3.016,01	10,74%
8	306,4	272,8	33,6	32.087,02	28.568,34	3.518,68	10,97%
9	344,7	306,3	38,4	36.097,90	32.076,55	4.021,35	11,14%
10	383	339,8	43,2	40.108,78	35.584,76	4.524,02	11,28%

Table A4.9: savings in work center 33504

33603 Lathe Gigant

Hourly cost 94,59 €/h

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	31,7	31,7	0	2.998,45	2.998,45	0	0,00%
2	63,4	59,4	4	5.996,89	5.618,54	378,35	6,31%
3	95,1	87,1	8	8.995,34	8.238,63	756,71	8,41%
4	126,8	114,8	12	11.993,78	10.858,73	1.135,06	9,46%
5	158,5	142,5	16	14.992,23	13.478,82	1.513,41	10,09%
6	190,2	170,2	20	17.990,68	16.098,91	1.891,76	10,52%
7	221,9	197,9	24	20.989,12	18.719,01	2.270,12	10,82%
8	253,6	225,6	28	23.987,57	21.339,10	2.648,47	11,04%
9	285,3	253,3	32	26.986,01	23.959,19	3.026,82	11,22%
10	317	281	36	29.984,46	26.579,29	3.405,18	11,36%

Table A4.10: savings in work center 33603

33604 Stator manufacturing

Hourly cost 94,59 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	10,4	10,4	0	983,72	983,72	0	0,00%
2	20,8	19,3	1,5	1.967,43	1.825,55	141,88	7,21%
3	31,2	28,2	3	2.951,15	2.667,39	283,76	9,62%
4	41,6	37,1	4,5	3.934,87	3.509,22	425,65	10,82%
5	52	46	6	4.918,59	4.351,06	567,53	11,54%
6	62,4	54,9	7,5	5.902,30	5.192,89	709,41	12,02%
7	72,8	63,8	9	6.886,02	6.034,73	851,29	12,36%
8	83,2	72,7	10,5	7.869,74	6.876,56	993,18	12,62%
9	93,6	81,6	12	8.853,46	7.718,40	1.135,06	12,82%
10	104	90,5	13,5	9.837,17	8.560,23	1.276,94	12,98%

Table A4.11: savings in work center 33604

35301 Rotor manufacturing

Hourly cost 84,45 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	70,5	70,5	0	5.953,99	5.953,99	0	0,00%
2	141	139	2	11.907,98	11.739,07	168,91	1,42%
3	211,5	207,5	4	17.861,97	17.524,15	337,82	1,89%
4	282	276	6	23.815,96	23.309,24	506,72	2,13%
5	352,5	344,5	8	29.769,95	29.094,32	675,63	2,27%
6	423	413	10	35.723,94	34.879,40	844,54	2,36%
7	493,5	481,5	12	41.677,93	40.664,48	1.013,45	2,43%
8	564	550	14	47.631,92	46.449,56	1.182,35	2,48%
9	634,5	618,5	16	53.585,91	52.234,65	1.351,26	2,52%
10	705	687	18	59.539,90	58.019,73	1.520,17	2,55%

Table A4.12: savings in work center 35301

35401 Low speed balancing

Hourly cost 91,21 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	28,6	28,6	0	2.608,61	2.608,61	0	0,00%
2	57,2	55,5	1,7	5.217,22	5.062,16	155,06	2,97%
3	85,8	82,4	3,4	7.825,82	7.515,71	310,11	3,96%
4	114,4	109,3	5,1	10.434,43	9.969,26	465,17	4,46%
5	143	136,2	6,8	13.043,04	12.422,81	620,23	4,76%
6	171,6	163,1	8,5	15.651,65	14.876,36	775,29	4,95%
7	200,2	190	10,2	18.260,25	17.329,91	930,34	5,09%
8	228,8	216,9	11,9	20.868,86	19.783,46	1.085,40	5,20%
9	257,4	243,8	13,6	23.477,47	22.237,01	1.240,46	5,28%
10	286	270,7	15,3	26.086,08	24.690,56	1.395,51	5,35%

Table A4.13: savings in work center 35401

35901 Dimensional control /measurement

Hourly cost 81,08 €/h

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	3,5	3,5	0	283,76	283,76	0	0,00%
2	7	5,7	1,3	567,53	462,13	105,40	18,57%
3	10,5	7,9	2,6	851,29	640,50	210,80	24,76%
4	14	10,1	3,9	1.135,06	818,86	316,19	27,86%
5	17,5	12,3	5,2	1.418,82	997,23	421,59	29,71%
6	21	14,5	6,5	1.702,59	1.175,60	526,99	30,95%
7	24,5	16,7	7,8	1.986,35	1.353,96	632,39	31,84%
8	28	18,9	9,1	2.270,12	1.532,33	737,79	32,50%
9	31,5	21,1	10,4	2.553,88	1.710,70	843,19	33,02%
10	35	23,3	11,7	2.837,65	1.889,06	948,58	33,43%

Table A4.14: savings in work center 35901

35902 Dimensional control /measurement

Hourly cost 94,59 €/h

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	2	2	0	189,18	189,18	0	0,00%
2	4	3,5	0,5	378,35	331,06	47,29	12,50%
3	6	5	1	567,53	472,94	94,59	16,67%
4	8	6,5	1,5	756,71	614,82	141,88	18,75%
5	10	8	2	945,88	756,71	189,18	20,00%
6	12	9,5	2,5	1.135,06	898,59	236,47	20,83%
7	14	11	3	1.324,23	1.040,47	283,76	21,43%
8	16	12,5	3,5	1.513,41	1.182,35	331,06	21,88%
9	18	14	4	1.702,59	1.324,23	378,35	22,22%
10	20	15,5	4,5	1.891,76	1.466,12	425,65	22,50%

Table A4.15: savings in work center 35902

36301 Impeller metalwork

Hourly cost 83,10 €/h

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	15,6	15,6	0	1.296,40	1.296,40	0	0,00%
2	31,2	29,8	1,4	2.592,80	2.476,45	116,34	4,49%
3	46,8	44	2,8	3.889,20	3.656,51	232,69	5,98%
4	62,4	58,2	4,2	5.185,60	4.836,57	349,03	6,73%
5	78	72,4	5,6	6.481,99	6.016,62	465,37	7,18%
6	93,6	86,6	7	7.778,39	7.196,68	581,72	7,48%
7	109,2	100,8	8,4	9.074,79	8.376,73	698,06	7,69%
8	124,8	115	9,8	10.371,19	9.556,79	814,40	7,85%
9	140,4	129,2	11,2	11.667,59	10.736,84	930,75	7,98%
10	156	143,4	12,6	12.963,99	11.916,90	1.047,09	8,08%

Table A4.16: savings in work center 36301

36402 Lathe Wohlenberg

Hourly cost 128,37 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	70	70	0	8.985,88	8.985,88	0	0,00%
2	140	135	5	17.971,76	17.329,91	641,85	3,57%
3	210	200	10	26.957,64	25.673,94	1.283,70	4,76%
4	280	265	15	35.943,52	34.017,97	1.925,55	5,36%
5	350	330	20	44.929,40	42.362,00	2.567,39	5,71%
6	420	395	25	53.915,28	50.706,03	3.209,24	5,95%
7	490	460	30	62.901,16	59.050,06	3.851,09	6,12%
8	560	525	35	71.887,03	67.394,09	4.492,94	6,25%
9	630	590	40	80.872,91	75.738,13	5.134,79	6,35%
10	700	655	45	89.858,79	84.082,16	5.776,64	6,43%

Table A4.17: savings in work center 36402

36605 Shaft turning between centers

Hourly cost 105,40 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	23,7	23,7	0	2.497,94	2.497,94	0	0,00%
2	47,4	46,9	0,5	4.995,88	4.943,18	52,70	1,05%
3	71,1	70,1	1	7.493,82	7.388,42	105,40	1,41%
4	94,8	93,3	1,5	9.991,76	9.833,66	158,10	1,58%
5	118,5	116,5	2	12.489,70	12.278,90	210,80	1,69%
6	142,2	139,7	2,5	14.987,64	14.724,14	263,50	1,76%
7	165,9	162,9	3	17.485,58	17.169,38	316,19	1,81%
8	189,6	186,1	3,5	19.983,51	19.614,62	368,89	1,85%
9	213,3	209,3	4	22.481,45	22.059,86	421,59	1,88%
10	237	232,5	4,5	24.979,39	24.505,10	474,29	1,90%

Table A4.18: savings in work center 32402

36801 Big spin system

Hourly cost 192,55 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	27,8	27,8	0	5.353,02	5.353,02	0	0,00%
2	55,6	54,7	0,9	10.706,03	10.532,73	173,30	1,62%
3	83,4	81,6	1,8	16.059,05	15.712,45	346,60	2,16%
4	111,2	108,5	2,7	21.412,07	20.892,17	519,90	2,43%
5	139	135,4	3,6	26.765,08	26.071,89	693,20	2,59%
6	166,8	162,3	4,5	32.118,10	31.251,60	866,50	2,70%
7	194,6	189,2	5,4	37.471,12	36.431,32	1.039,79	2,77%
8	222,4	216,1	6,3	42.824,13	41.611,04	1.213,09	2,83%
9	250,2	243	7,2	48.177,15	46.790,76	1.386,39	2,88%
10	278	269,9	8,1	53.530,17	51.970,47	1.559,69	2,91%

Table A4.19: savings in work center 36801

43321 Painting

Hourly cost 87,83 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	3	3	0	263,50	263,50	0	0,00%
2	6	5,5	0,5	526,99	483,08	43,92	8,33%
3	9	8	1	790,49	702,66	87,83	11,11%
4	12	10,5	1,5	1.053,98	922,23	131,75	12,50%
5	15	13	2	1.317,48	1.141,81	175,66	13,33%
6	18	15,5	2,5	1.580,97	1.361,39	219,58	13,89%
7	21	18	3	1.844,47	1.580,97	263,50	14,29%
8	24	20,5	3,5	2.107,97	1.800,55	307,41	14,58%
9	27	23	4	2.371,46	2.020,13	351,33	14,81%
10	30	25,5	4,5	2.634,96	2.239,71	395,24	15,00%

Table A4.20: savings in work center 43321

44102 Assembly core machine

Hourly cost 78,37 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	1,2	1,2	0	94,05	94,05	0	0,00%
2	2,4	2	0,4	188,10	156,75	31,35	16,67%
3	3,6	2,8	0,8	282,14	219,44	62,70	22,22%
4	4,8	3,6	1,2	376,19	282,14	94,05	25,00%
5	6	4,4	1,6	470,24	344,84	125,40	26,67%
6	7,2	5,2	2	564,29	407,54	156,75	27,78%
7	8,4	6	2,4	658,33	470,24	188,10	28,57%
8	9,6	6,8	2,8	752,38	532,94	219,44	29,17%
9	10,8	7,6	3,2	846,43	595,64	250,79	29,63%
10	12	8,4	3,6	940,48	658,33	282,14	30,00%

Table A4.21: savings in work center 44102

66109 Shaft manufacturing turning / grinding

Hourly cost 97,97 €/h

N	h_{single}	h_{series}	Saving h	$€_{single}$	$€_{series}$	Saving €	Saving %
1	16,9	16,9	0	1.655,63	1.655,63	0	0,00%
2	33,8	31,3	2,5	3.311,26	3.066,35	244,92	7,40%
3	50,7	45,7	5	4.966,89	4.477,06	489,83	9,86%
4	67,6	60,1	7,5	6.622,53	5.887,78	734,75	11,09%
5	84,5	74,5	10	8.278,16	7.298,49	979,66	11,83%
6	101,4	88,9	12,5	9.933,79	8.709,21	1.224,58	12,33%
7	118,3	103,3	15	11.589,42	10.119,92	1.469,50	12,68%
8	135,2	117,7	17,5	13.245,05	11.530,64	1.714,41	12,94%
9	152,1	132,1	20	14.900,68	12.941,36	1.959,33	13,15%
10	169	146,5	22,5	16.556,31	14.352,07	2.204,24	13,31%

Table A4.22: savings in work center 66109

Total machining

N	h_{single}	h_{series}	Saving h	Saving %	€$_{single}$	€$_{series}$	Saving €	Saving %
1	1.194,90	1.194,90	0,00	0,00%	140.372,07	140.372,07	0,00	0,00%
2	2.389,80	2.336,20	53,60	2,24%	280.744,14	274.779,74	5.964,39	2,12%
3	3.584,70	3.477,50	107,20	2,99%	421.116,21	409.187,42	11.928,79	2,83%
4	4.779,60	4.618,80	160,80	3,36%	561.488,28	543.595,09	17.893,18	3,19%
5	5.974,50	5.760,10	214,40	3,59%	701.860,35	678.002,77	23.857,58	3,40%
6	7.169,40	6.901,40	268,00	3,74%	842.232,42	812.410,45	29.821,97	3,54%
7	8.364,30	8.042,70	321,60	3,84%	982.604,49	946.818,12	35.786,37	3,64%
8	9.559,20	9.184,00	375,20	3,93%	1.122.976,56	1.081.225,80	41.750,76	3,72%
9	10.754,10	10.325,30	428,80	3,99%	1.263.348,63	1.215.633,47	47.715,15	3,78%
10	11.949,00	11.466,60	482,40	4,04%	1.403.720,69	1.350.041,15	53.679,55	3,82%

Table A4.23: savings in machining

Total workings

Finally, here the total of working hours is presented, with everything else besides machining included (welding, assembly…). Savings are possible only in machining, like in DPI.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	2.000,90	2.000,90	0,00	207.039,66	207.039,66	0,00	0,00%
2	4.001,80	3.948,20	53,60	414.079,32	408.114,92	5.964,39	1,44%
3	6.002,70	5.895,50	107,20	621.118,98	609.190,19	11.928,79	1,92%
4	8.003,60	7.842,80	160,80	828.158,64	810.265,46	17.893,18	2,16%
5	10.004,50	9.790,10	214,40	1.035.198,30	1.011.340,72	23.857,58	2,30%
6	12.005,40	11.737,40	268,00	1.242.237,96	1.212.415,99	29.821,97	2,40%
7	14.006,30	13.684,70	321,60	1.449.277,62	1.413.491,25	35.786,37	2,47%
8	16.007,20	15.632,00	375,20	1.656.317,28	1.614.566,52	41.750,76	2,52%
9	18.008,10	17.579,30	428,80	1.863.356,94	1.815.641,78	47.715,15	2,56%
10	20.009,00	19.526,60	482,40	2.070.396,59	2.016.717,05	53.679,55	2,59%

Table A4.24: savings in total workings

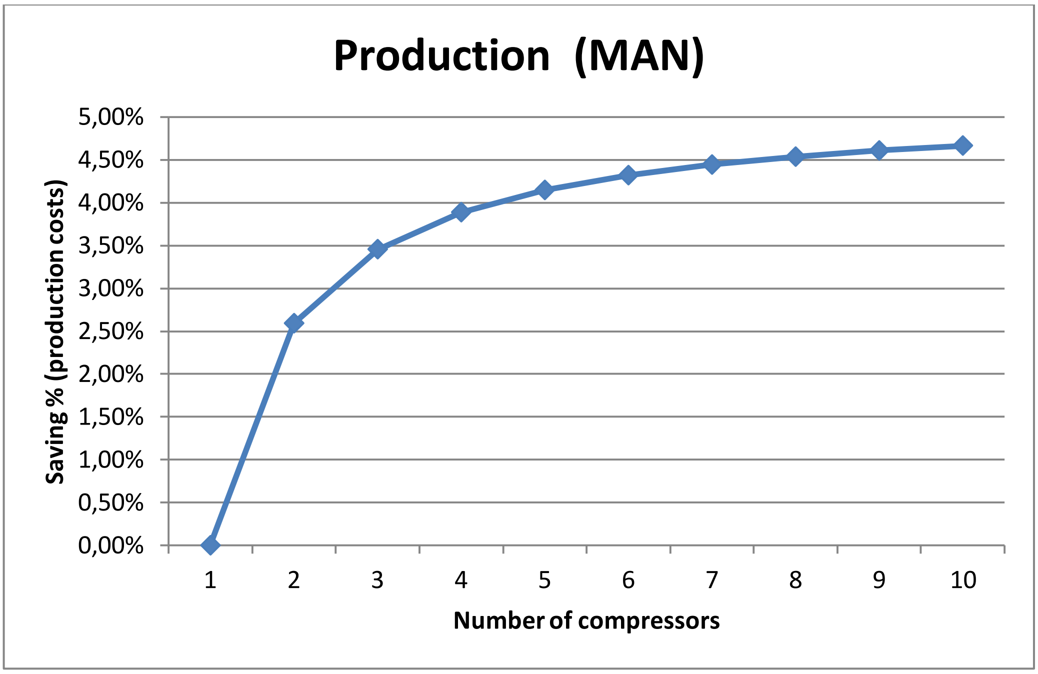
Total of production

The possible saving in production, considering both work preparation and workings, is the following.

N	h_{single}	h_{series}	Saving h	€$_{single}$	€$_{series}$	Saving €	Saving %
1	2.062,90	2.062,90	0,00	212.066,35	212.066,35	0,00	0,00%
2	4.125,80	4.010,20	115,60	424.132,69	413.141,61	10.991,08	2,59%
3	6.188,70	5.957,50	231,20	636.199,04	614.216,88	21.982,16	3,46%
4	8.251,60	7.904,80	346,80	848.265,39	815.292,14	32.973,25	3,89%
5	10.314,50	9.852,10	462,40	1.060.331,73	1.016.367,41	43.964,33	4,15%
6	12.377,40	11.799,40	578,00	1.272.398,08	1.217.442,67	54.955,41	4,32%
7	14.440,30	13.746,70	693,60	1.484.464,43	1.418.517,94	65.946,49	4,44%
8	16.503,20	15.694,00	809,20	1.696.530,77	1.619.593,20	76.937,57	4,53%
9	18.566,10	17.641,30	924,80	1.908.597,12	1.820.668,47	87.928,65	4,61%
10	20.629,00	19.588,60	1.040,40	2.120.663,47	2.021.743,73	98.919,74	4,66%

Table A4.25: savings in production

There is a big step between 1 and 2 compressors, as it could be expected; then a gradual grow until the 5th – 6th compressor, reaching about the 4,50% of saving, where the curve stabilizes on those values.



Picture A4.1: savings in production in MAN

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