Department of Management and Production Engineering

Master's Degree in

Engineering and Management

Master's Degree thesis

Improvement of the welding process of refrigeration circuit for domestic appliances: Haier Europe's case study

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List of acronyms and abbreviations

AI: Artificial Intelligence

AIOT: Artificial Intelligence of Things

ANOVA: Analysis of Variance

CAT: Centro Assistenza Tecnica

CHG: Candy Hoover Group

DMAIC: Defina Measure Analyse Improve Control

EPQ: Expected Production Quality

HQ: Head Quarter

IOT: Intelligence of Things

KPI: Key Performance Indicator

LPG: Liquid Propane Gas

OEM: Original Equipment Manufacturer

PESTLE: Political Economic Sociological Technological Legal Environmental

PEX: Product Exchanged

R&D: Research and Development

ROE: Return on Equity

SCR: Service Call Rate

SOP: Start of Production

WP: Welding Point

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1. Introduction and scope of the thesis

The thesis “Improvement of the welding process of refrigeration circuit for domestic appliances: Haier Europe’s case study” has been developed during my entire internship period in the headquarter of Haier Europe, based in Brugherio (Milan).
The activities developed during the internship period as a quality data analyst in the Cooling business sector, can be summarized according to these activities: the acquisition of raw data and the subsequent cleaning of them for the realization of a reliable analysis of the quality trend for all refrigeration products.
The headquarter environment is very dynamic, where the business of all the market are managed and monitored, particularly in the Haier Europe organization, where all the activities carried out by all the business sectors are driven by an unique focus: the customer satisfaction. The data analyst is the first gate that is able to get the first feedback from the market. After the cleaning of the raw data, it’s clearer what are the most defective structures and especially what kind of problem presents after being sold to the final consumers.
Hereafter once is discovered an intrusive defects or problem, or maybe an unexpected quality trend for a new structure, it will be presented to the other team member of the quality team, the NPI cooling quality specialist, who will start an action plan to recover the bad quality of the product and find out how to resolve it, joining effort with the R&D department if the problem is a design matter.
This type of operation is very important, especially for monitoring the performances of the new plant, Haier Tech s.r.l. just built in Romania, with the SOP (Start of Production) in summer 2021.
Furthermore, I had the opportunity to better understand the role of a quality team member joining the task force, which I developed the thesis, which goal is to improve the Welding Process of a specific supplier of OEM refrigerator (Original Equipment Manufacturer).
The objective of the thesis is to analyze the welding procedure of a refrigeration circuit and to understand which action plan initiate to improve the welding process of a specific supplier which has a failure rate of 73% higher with respect to the benchmark (obviously concerning leakages of the refrigeration circuit).

Following this introduction (Chapter 1), the thesis is organized and deployed in four further chapters:

- Chapter 2 provides an overview of Haier company and the presentation of the specific work environment in the Europe HQ.

- Chapter 3 is dedicated to present in details all the welding procedure of a refrigeration circuit, following all the steps that an operator should follow.

- Chapter 4 deals with deployment of the case study, starting from the initial phase of definition of the task force and data collection, ending with the action plan initiated.

- Chapter 5 is the conclusive chapter in which the final consideration are presented.

2. Haier Smart Home

Intelligent products have begun to enter society and the family as a result of the advancement of modern science and technology, as well as the popularity of the Internet. Intelligent homes are realized through intelligent networks combined with a series of sensors and linkage devices, resulting in the intelligent family, which has brought great convenience to people's lives. With the advancement of The Times and intelligent technology, intelligence is becoming an unavoidable trend in the home appliance business, and this trend has begun to appear.

As customer interest in intelligent home appliances grows, more intelligent home appliances will be introduced to the market. People can use integrated devices to operate all of their home appliances, regardless of their location or time. At the same time, it sets higher standards for household appliance manufacturers. The market requires more consistent performance and lower prices, as well as collaboration with other groups to launch items that are appropriate for their consumption. Household appliance companies can only continue to develop if they follow The Times' pattern. Otherwise, only the deluge of history may annihilate them.

The development of the smart home sector has advanced greatly in the current period, owing to the broad market space, 5G, LOT, AI, and other rapid iterations of technology, the policy dividend of new infrastructure, and the demand of new consumption situations. This racetrack attracts domestic giants. In Beijing, Qingdao, and other cities, Haier Smart Home has opened Three-winged bird experience boutiques. Specifically, give balconies, kitchens, bathrooms, whole-house air, whole-house water, audio-visual, and other ecological situations. Furthermore, Haier Smart Home has developed the industry's first and only Home OS 3.0 operating system for Smart Home scene ecology, demonstrating Haier Smart Home's unrivalled expertise in Smart Home AIOT technology.

In recent years, the smart home sector has become more competitive than ever. In today's business world, financial analysis is becoming increasingly vital. Financial data can be better understood and analysed, allowing businesses to make more accurate decisions and give ideas for improvement.

With the introduction of COVID-19, demand for home appliances is dwindling, people' purchasing power is dwindling, and market competition in the home appliance business is intensifying. In the face of the epidemic, Haier Smart Home has excelled in three areas: enterprise innovation, channel transformation, and cross-platform interconnection. Haier Smart Home is always up to date with the latest news and operates through several channels. While doing well offline, Haier Smart Home competes with and collaborates with other household appliance brands to grow the online domain and ensure the brand's depth and breadth. As a result, this chapter focus on Haier Smart Home's transformation and upgrade, as well as providing some guidance for the growth and operation of other Smart Home appliance makers.
The purpose of this Chapter is to provide an overview of Haier Smart Home's development history as well as an analysis of the company's core businesses, products, and brand strategy. The enterprise's basic competitiveness state and total external competitive environment are then analysed using PESTLE and Porter's Five Forces Model. The enterprise's financial indicators are examined later on, and research conclusions and recommendations for the Haier Smart Home appliance industry's future development are presented at the end of the chapter.

2.1 History and business sector

2.1.1 Company history

Qingdao Haier, which was founded in 1984 and went public in 1993, has renamed itself Haier Smart Home. Its primary business is the manufacture, research, development, and sale of white appliances, and Haier Group is the company's controlling shareholder. In 27 years, Haier Smart Home has evolved into a leading white home appliance company. Haier Smart Home in China and the overseas market built a complete production and sales network through the combination of domestic growth and foreign mergers and acquisitions, resulting in the globalization of successful product expansion. According to Euro monitor, Haier Smart Home has ranked first in the world market share of electrical appliances for 11 years in a row. In 2020, Haier Smart Home will have a global market share of 16.5 percent.

Haier Smart Home built a strong refrigerator and washing machine business from the start of the brand, integrated the white goods industry, and rapidly extended its market share. Following that, Haier Smart Home picked the development path of abroad and high-end brand creation, innovated to construct a worldwide brand strategy, completed large-scale acquisitions, and dedicated to realizing the brand's long-term layout. In the midst of the current global COVID-19 outbreak, this also allows Haier Smart Home to continue a consistent increase in revenue. (Sun Y. , 2021) (Haier, 2020)

2.1.2 Products

Haier Smart Home now has seven worldwide brands: Haier, Casarte, and Leader, which serve the Chinese market, and GEA, Fisher Paykel, Aqua, and Candy Hoover Group, which serve the international market. The global operation support system of Haier Smart Home boosts the company's global market share and profit rate. It has a leading brand position in international marketplaces and high-end sectors as a result of this, and it has been named to the Fortune Global 500 multiple times.
Haier's brand strategy not only strives to broaden the company's global reach, but also to enrich product categories and brand positioning. Haier's sub-brands feature distinct positioning, comprehensive category coverage, and a high degree of integration.

Audiences	Young audience	Fashionable white-collar	Urban elite		Luxury groups		The nobility
	leader	Haier	Candy	Aqua	GEA	Casarte	FPA
Air conditioning	✓	✓	/	/	/	✓	For overseas
Refrigerator	✓	✓	For overseas	For overseas	✓	✓	For overseas
Washing Machine	✓	✓	For overseas	/	/	✓	For overseas
Water heater	✓	✓	/	/	/	✓	/
Television	✓	✓	/	/	/	✓	/
kitchen appliances	✓	✓	For overseas	/	✓	✓	For overseas
Freezer / Wine cabinet	✓	✓	For overseas	For overseas	✓	✓	For overseas
Coffe maker/Dish washer	/	✓	For overseas	For overseas	✓	/	For overseas
Vacum cleaner	/	✓	For overseas	For overseas	/	✓	/
Brand positiong	Sub-brands	Mass-market brand			high-end brand		Super high-end brand

Tab. 1. Haier series of products and brand layout

In terms of product positioning, the figure above shows that Leader caters to the youthful masses, Haier caters to the young fashionable white-collar employees, Candy and Aqua cater to the urban elites, and are only available in the overseas, Hong Kong, and Taiwan regions. GEA is at the top of the urban stratum, whereas FPA is built on the star aristocrat, and Casarte is progressively progressing towards noble luxury. The seven brands cater to a wide range of consumer groups, with careful positioning and "each playing its part."

Haier Smart Home, which relies on research and development, manufacturing, and marketing localization of layout, has established itself as one of the market's leading brands, with the goal of serving the world's 1 billion households. The benefits of forming a high-end brand also give basic benefits for Haier Smart Home in transforming its track-to-scene and ecological brands. In recent years, the corporation has been committed to digital transformation, advocating a cost-cutting and efficiency-improving development plan. Haier Smart Home will focus on reforming product innovation and scene reconstruction, as well as boosting digital reconstruction, to realize the value-added of the entire process, in order to achieve high-quality market share growth. (Haier, 2021)

2.1.3 Business sector

Chinese smart home business, international smart home business and accessories, small household appliances, channel distribution, and so on are among Haier Smart Home's primary businesses.

One of the most revolutionary clothes networks, air networks, and water networks for the full house solutions has been offered.

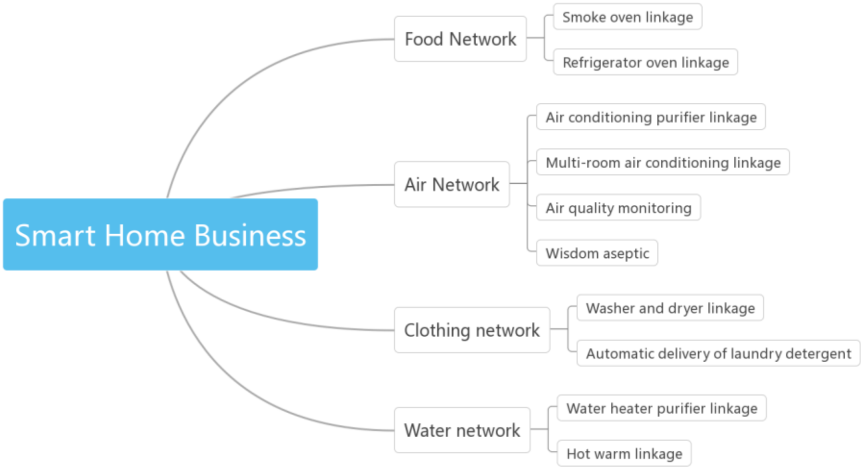

Fig. 1. Haier Smart Home smart home business

In each network, a variety of products are displayed in the image. Smart solutions for smoke oven and refrigerator oven linking are available through the food network. Air Network primarily addresses smart business issues such as family ventilation and air purification. The clothing network is in charge of smart laundry, such as washer and dryer connections. Laundry detergent is delivered automatically; Water heater purifier linkage and hot warm linkage are part of the water network.

2.2 An examination of the smart home sector in China

By regulating single or multiple household equipment, the smart home sector aspires to provide resolutions to suit the needs of varied human living scenarios. (Sun Q. , 2021)

2.2.1 Policy support

From "made in China" to "produced in China," China's manufacturing industry is undergoing a transformation. The government encourages the development of high-profit, high-tech products. The smart home sector is a high-tech industry that utilizes 5G communication technologies, the Internet of Things, and artificial intelligence algorithms to attract government attention. In 2016, the government's work report included the term "smart house," and in 2017, it was raised to one of the six main areas of demonstration projects. Governments in various provinces have established various supporting policies for smart home firms, including favourable loan interest rates and tax reductions, under the direction of the central government.

2.2.2 Technology innovation

Perception, judgment, and response are the three main intelligence modules of smart home technology. Smart home patent innovations have exploded in popularity as a result of policy backing, with at least 3,000 patents filed for smart home technologies every year in 2015.

A few well-established home appliance businesses, such as Xiaomi and Gree, are at the forefront of innovation. Such businesses have a lot of money, so they can hire a lot of people and pay for a lot of research and development.

2.2.3 Social demand is increasing

People in China have raised their expectations for home comfort, convenience, and safety as the economy has grown. Smart home technology can help people achieve a variety of goals, such as enhancing their quality of life and resolving social inequalities. (Zhang, 2021)

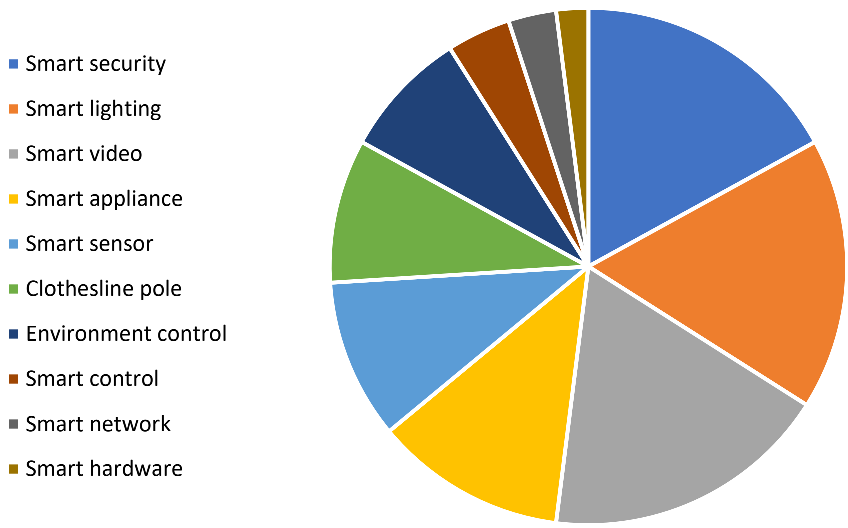

Fig. 2. Number of new patent applications of Smart home appliances

Some strict needs can be met by smart home gadgets. The major problem of China's aging population, along with the introduction of the three-child policy, has increased the need for elder and childcare. Smart monitors, for example, allow individuals to keep an eye on what's going on at home while they're away.

In addition, the smart home appliance can help with some home improvements. Many young people are paying more and more attention to a healthy lifestyle as a result of the heavy pressures of work. Smart kitchens, for example, can offer food inventory management, cooking time and seasoning control, and other technologies to aid in the development of healthy eating habits, while smart bedrooms can offer sleep time management techniques to aid in the development of excellent sleeping habits.

2.2.4 No industry standards in place

Various firms are averse to share connection platforms and frequently utilize different product connection ports to safeguard their technical patents. As a result, a vast number of smart home solutions on the market today are incompatible with one another. When consumers buy products from several manufacturers, they must download multiple APPs for separate administration, which not only prevents multiple brands of electrical appliances from working together, but also forces different manufacturers to design operation platforms twice, wasting money.

2.2.5 Environmental technology upgrade

On the one hand, advancements in environmental protection technology have reduced pollution caused by household appliances. Home appliances, as we all know, pollute the environment in various ways during the production, usage, and disposal processes. However, the development of a number of environmental protection technologies, such as degradable plastic production technology and waste household appliance recycling technology, has gradually reduced the pollution that electrical appliances may create.

The smart home industry, on the other hand, can help to conserve the environment. Smart circulation systems can monitor and reduce indoor PM2.5 and formaldehyde levels, while smart stoves can limit the amount of smoke created when cooking. (Sun Q. , 2021)

2.2.6 The progress of the economy

The impact of the COVID-19 on the Chinese home appliance sector caused retail sales to drop 2,73% in the first half of 2020. The traditional home appliance business has come close to saturation in recent years due to the influence of the rural home appliance policy. Furthermore, the recession in the real estate sector has a negative impact on the home appliance market.

70% of smart home items were sold through e-commerce platforms in the first half of 2020. Smart lighting, home security, smart home appliances, smart audio, and video all have a bigger market share in the smart home category.

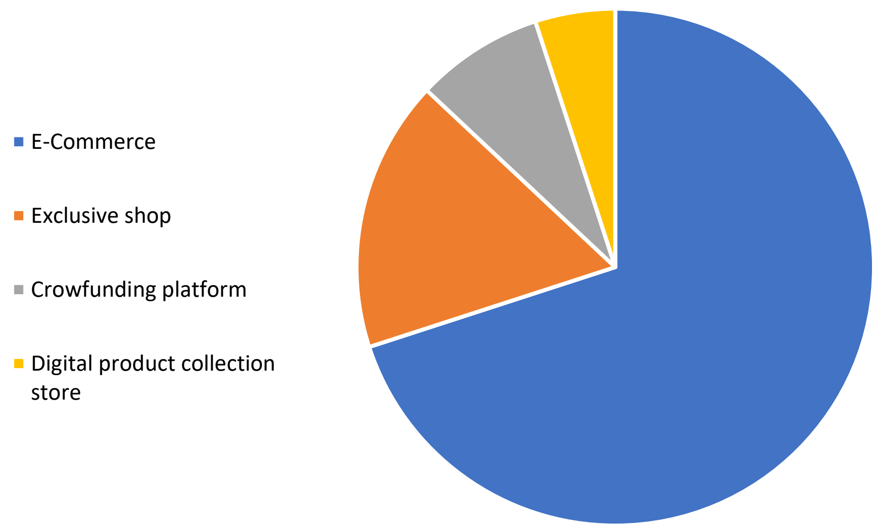

Fig. 3. Percentage of sales channels

However, at the moment, the majority of new goods introduced by various companies are little intelligent furniture, and communication between different items is not possible. As a result of the epidemic, the smart home market has remained stagnant. To put it another way, the future smart home market has a lot of promise.

2.3 Porter’s 5 forces

Porter's Five Forces is a framework for determining an industry's vulnerabilities and strengths by identifying and analysing five competitive forces that define every business. A five-forces analysis is widely used to define corporate strategy by identifying an industry's structure. Porter's model can be used to understand the amount of competition within an industry and improve a company's long-term profitability in any sector of the economy. Michael E. Porter, a Harvard Business School professor, is the creator of the Five Forces paradigm.

2.3.1 Threat of new entrants

The premier intelligent home appliance company has broken the pricing and technological barriers. In emerging businesses, there is a cost and technological mismatch. It is difficult to become the head enterprise, even if it leads under intelligent respect. Some businesses choose to operate in the OEM mode, but the majority are second-tier businesses with a significant gap between their products and those of the leading companies. Traditional companies like Haier, Midea, and Gree currently dominate the market.

2.3.2 Threat of Substitutes

Intelligent home appliances, from the standpoint of the intelligent home appliances industry, may primarily replace aging home appliances and traditional manual labor, resulting in a competitive advantage.

In the smart home sector, there is a lot of product homogenization among different producers. Gree, Midea, and Haier Smart Home are some of the most well-known companies. Smart refrigerators, smart water heaters, and smart washing machines all create items that are interchangeable. The giants have devised a number of competitive strategies in reaction to the threat of substitutes.

Home appliance that is intelligent Leading companies place a high value on strengthening their R&D technology advantages, implementing a global strategy, progressively establishing a global R&D center, and absorbing and integrating the technical advantages of international brands. Washing machines, for example, are developed by Haier in Japan, whereas cookware and dishwashers are developed by

FPA, and refrigerators are developed by GEA in the United States. Global resources are integrated on a single platform to address the demands of various locations in this way.

Create their scene brand and operating system with the aid of blockchain, the Internet of Things, and other resources.

Continue to grow the high-end home appliance sector and introduce new premium sub-brands. Previously, Siemens, Whirlpool, Philips, and other foreign brands dominated the local high-end home appliance market, but the strategy of increasing high-end market share aided China's high-end home appliance market development.

2.3.3 Bargaining Power of Suppliers

The transmission layer, perception layer, and processing layer make up the smart home's upstream link.

The transmission layer's fundamental component is the wireless communication chip. The most extensively utilized wireless communication in the smart home is Zigbee, Wi-Fi, and Bluetooth. By 2020, foreign manufacturers will hold an 80 percent, 90 percent, and 60 percent market share in the Wi-Fi, Zigbee, and Bluetooth chip sectors, respectively. Smart home chip suppliers in China have more development space.

In comparison to upstream smart home wireless communication chips, the wireless communication module sector has a lower total production threshold, a bigger number of producers, a more dispersed market concentration, and more fierce rivalry. As a result, suppliers' bargaining strength has been weakened. In comparison to upstream smart home wireless communication chips, the wireless communication module sector has a lower total production threshold, a bigger number of producers, a more dispersed market concentration, and more fierce rivalry. As a result, suppliers' bargaining strength has been weakened.

The sensor supplier is the perception layer of a smart home's upstream link. Sensors are a technologically complex sector that requires a significant amount of scientific research resources and cutting-edge skills. Foreign sensor providers hold more than 70% of the market share in China's sensor market, and the supply price of sensors is regulated by the overseas market. Sensor makers have more negotiating leverage in this regard.

AI technology suppliers are primarily responsible for delivering software and hardware goods and solutions for smart home firms in the processing layer of the upstream link of the smart home sector. China's AI business continues to grow thanks to constant improvements in data collecting, technology, and underlying processing capacity. In terms of AI technology and algorithm suppliers, the whole AI technology and algorithm supply tends to become platform, which minimizes the accounting cost and development cycle for enterprises to hire AI development teams independently and increases research and development efficiency. As a result, suppliers in the processing layer have a lot of negotiating power.

2.3.4 Bargaining Power of buyers

Globalization of production leads to globalization of sales, and most of the top smart home appliance brands sell in both domestic and international markets. Customers of Haier Smart Home, for example, can be found in China, the United States, Europe, and Australia. Amazon, Gome, Suning, and other huge retailers are the main sales channels. Enterprises sell directly to end consumers — primarily young and middle-aged populations in first- and second-tier cities — thanks to the emergence of e-commerce platforms and live delivery, so their bargaining power is strong.

2.3.5 Industry rivalry

In recent years, the smart home market has attracted a diverse range of businesses, including Internet technology firms, traditional home appliance firms, and even real estate firms. The intelligent module is added to the excellent and mature product system by the traditional home appliance head company. For example, Haier, Gree, and Xiaomi have all created smart home production lines; other Internet and technology businesses, such as Huawei, Apple, and Amazon, have expanded markets using advanced intelligent technologies. Several real estate corporations pioneered the concept of exquisite decoration (decorating after delivery) by leveraging their channel advantages to form partnerships with home appliance companies.

The rivalry in the home appliance sector is getting increasingly tough, and the profit margin is shrinking, due to technological advancements, a shortage of industry talent, a shortened product life cycle, and the simplicity with which it may be imitated. (Yiru Pan, 2021)

2.4 Financial ratio analysis

The major research object in this part is Haier Smart Home's important financial indicators from 2016 to 2020. It can be assessed Haier Smart Home's total business status and future development trend by examining the company's profitability, efficiency, solvency, and development capability, as well as comparing it to Midea and Gree in the same industry.

2.4.1 Profitability

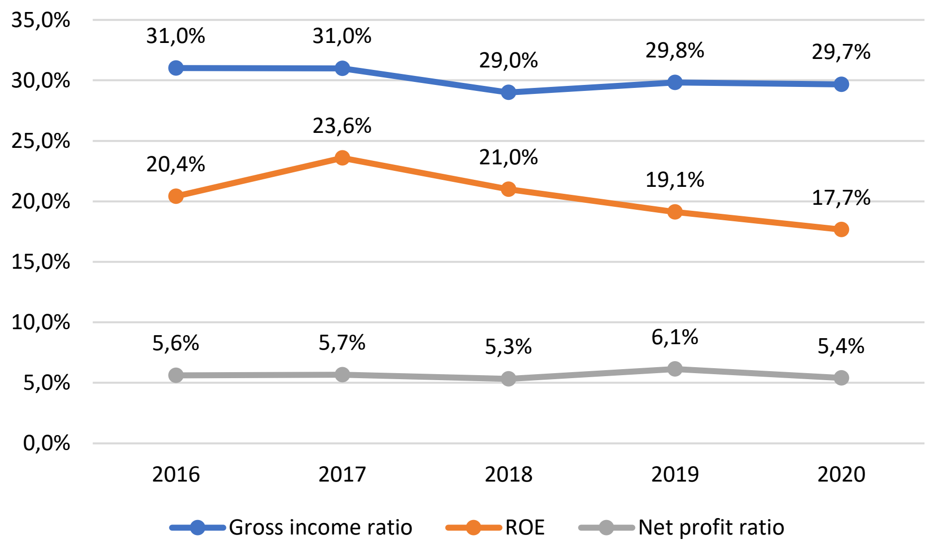

Fig. 4. Profitability ratio of Haier Smart Home *from 2016 to 2020*

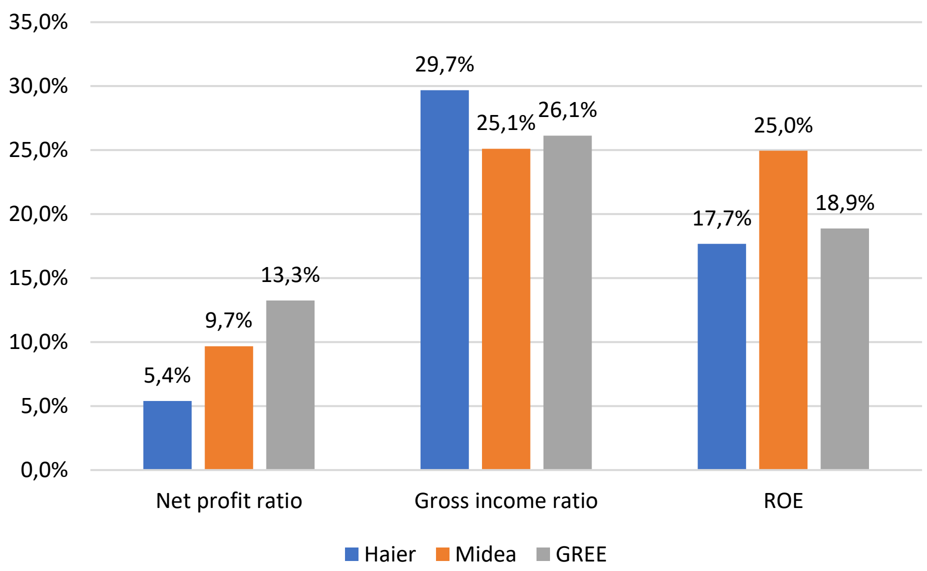

Fig .5. Comparative analysis of the profitability of Haier Smart Home, Midea *and* Gree *in 2020*

According to the financial report for the years 2016 to 2020, Haier Smart Home's net profit ratio is much lower than the average range of 20% to 30%, showing that Haier Smart Home has a weak ability to generate sales revenue. Meanwhile, Haier Smart Home's ROE and gross revenue ratio have both decreased over the last five years. The reason for this is due to increased rivalry in the smart home industry, which has caused most businesses to lower their pricing in order to grow their market share. The fall in sales gross margin is also linked to raw material prices.

The gross income ratio of Haier Smart Home is similar to the other two, but the net profit ratio of Haier Smart Home is much lower than the other two, according to an examination of the profitability of Haier Smart Home, Midea, and Gree in 2020. The key causes include the additional management costs incurred as a result of Haier Group's intricate equity system, as well as internal competition for sales performance.

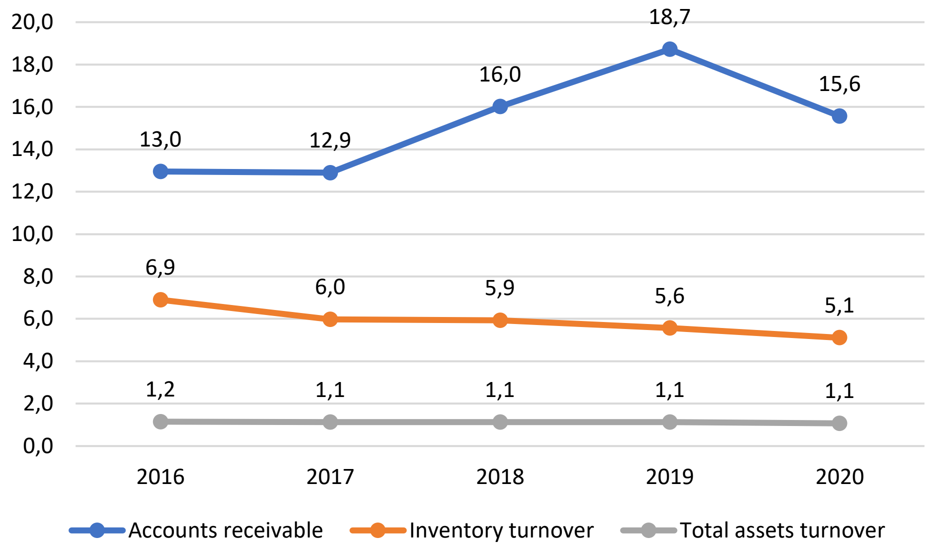

Fig. 6. Efficiency ratio of Haier Smart Home *from 2016 to 2020*

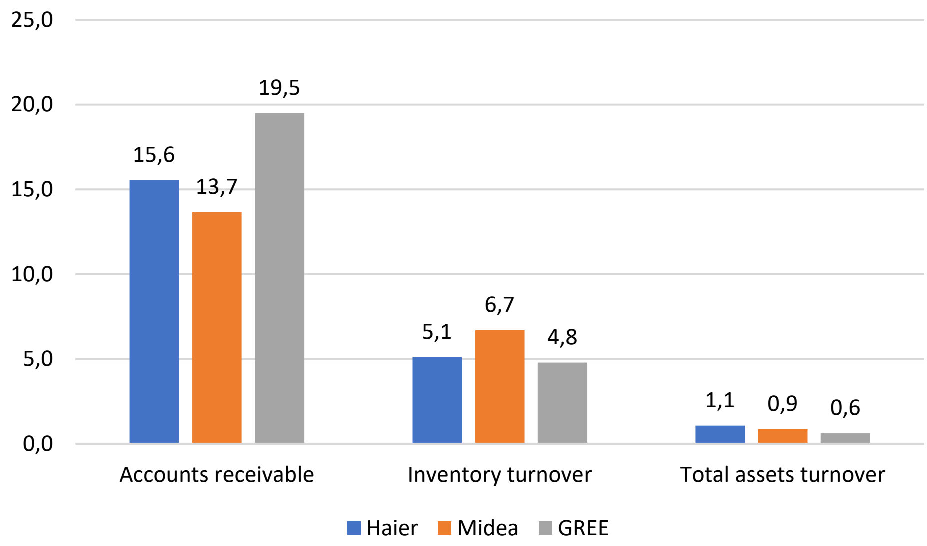

Fig. 7. Comparative analysis of efficiency of Haier Smart Home, Midea, *and* Gree *in 2020*

In the last five years, inventory turnover and total asset turnover at Haier Smart Home have been reasonably consistent. Because of the severe market rivalry, Haier smart home had to extend the credit period, resulting in money being held up for a long time, accounts receivable turnover is expected to decline in 2020.

When comparing the efficiency of Haier Smart Home, Midea, and Gree in 2020, it can be seen that Haier Smart Home's accounts receivable and inventory turnover are in the middle, while its total asset turnover is larger than 1 and higher than the other two businesses. This demonstrates Haier Group's strong sales capability as well as favourable asset investment returns.

2.4.2 Growth capacity

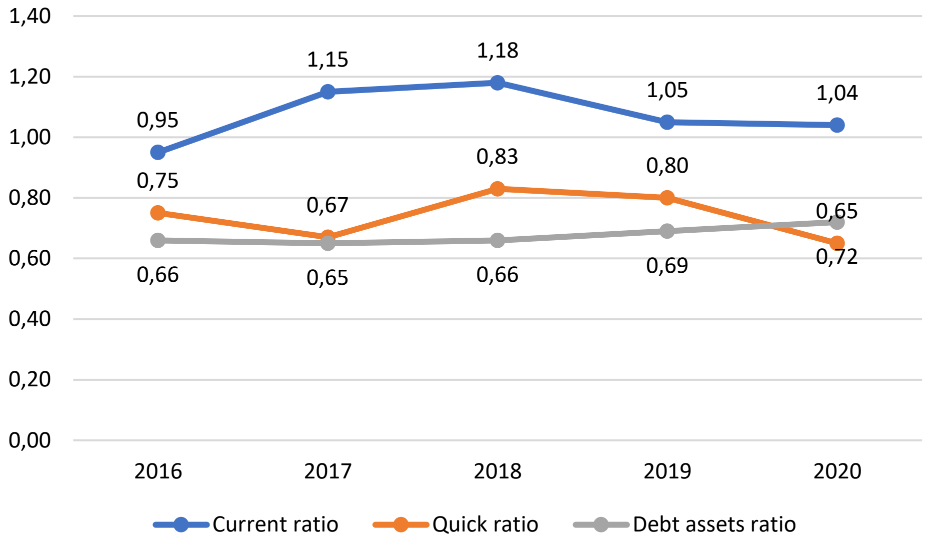

Fig. 8. Solvency ratio of Haier Smart Home *from 2016 to 2020*

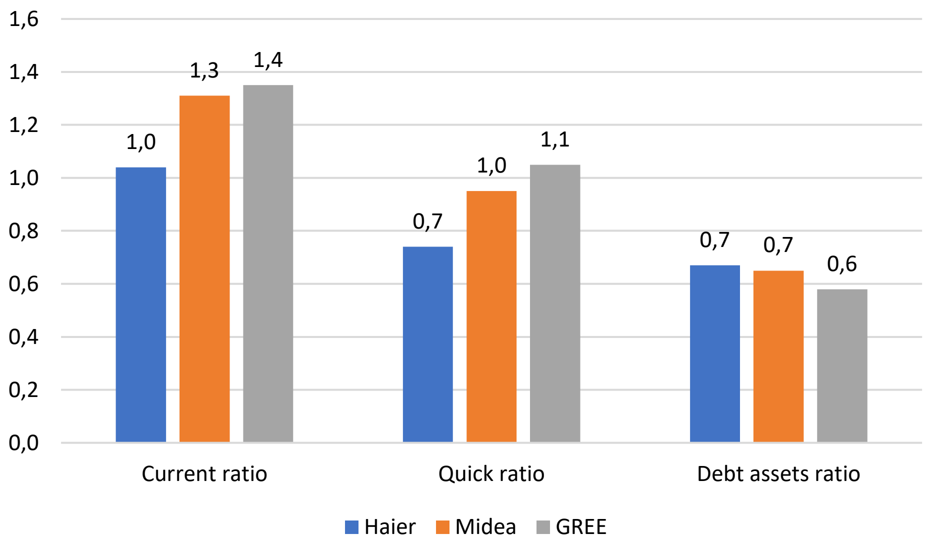

Fig. 9. Comparative analysis of solvency of Haier Smart Home, Midea *and* Gree *in 2020*

Revenue, net profit, and total assets all surged dramatically as a result of the acquisition of General Electric in 2016, although the metrics gradually recovered to normal levels after 2018. The general development speed of the smart home market has slowed as macroeconomic growth has slowed. The fact that three growth rates have been relatively modest in the last three years is due to this pattern.

When compared to other companies in the industry, Haier Smart Home's net profit and sales growth rates are among the highest. Though Haier Smart Home's total asset growth rate is lower than Midea's, it is still positive, demonstrating that Haier is growing at a steady pace. (Yu Ming, 2021)

2.5 Possible future

2.5.1 Suggestion for development

It was proposed some proposals for Haier Smart Home's future development direction based on the foregoing study of financial indicators and the future development trend of the smart home appliance sector.

Haier Smart Home should connect retail and online sales channels, with an emphasis on the latter. Consumers are gradually changing their consumption attention to online as a result of the COVID-19. Haier Smart Home will continue to promote the diversity of offline sales channels while accelerating the development of an online sales platform. Live broadcasts can be used to demonstrate product features, increase user engagement, and increase customer purchasing power.

The proportion of customized items in Haier Smart Home can be increased. After production, customized products can be sent straight to the user's home, saving money on storage and avoiding inventory. As a result, customized products might help to increase inventory turnover.

The Haier Smart Home should help to stabilize the domestic market while also extending into other territories. In different places of the world, different strategies should be adopted. More focus should be placed on the concept of energy conservation and environmental preservation in Europe and the United States, and on durable and cost-effective performance in Asia and Africa. At the same time, the company should pay attention to China's rural market's prospective development.

Haier Electric Appliances has been privatized on July 31, 2020, according to the firm. Haier Smart Home will have new prospects after the privatization process is completed. Internal management efficiency is predicted to be improved. Internal consumption due to redundant employees and complex processes will be drastically reduced, resulting in faster turnover, a lower financial expense ratio, and a more appropriate capital structure.

In the long run, privatization is projected to be a turning point in the company's profit performance and assist it in becoming a leader in the next stage of the smart home industry's development. (Zhang, 2021)

2.5.2 Smart home development trend

Smart home systems are proactive in that they can automatically monitor the family's status, foresee any risk, and take appropriate action. It can also acquire data on consumers' living patterns, do data mining and analysis, and connect the analysis results with third-party service providers to give consumers with customised services.

Scenarioization: A unified industry-standard access port and operation platform will be required in the future. Customers' wants in different situations in the same place can be met by combining distinct product states. As a result, producers can concentrate on tiny segmentation research.

Standardization: Because intelligent products are expensive and difficult to install, standardized intelligent design blueprints will be available in the future for a variety of housing types. Customers will save a significant amount of money on purchasing and decorating as a result of this.

Finally, the smart home system will be gradually unified from the bottom up in order to achieve multi-device collaboration. Consumers can easily switch between multiple-use scenarios to meet a variety of needs, allowing whole-house intelligence to be fully realized. (Yiru Pan, 2021)

2.6 Conclusion

This chapter uses Haier Smart Home as an example to examine the smart home industry's potential development trends. It was examined the macro environment of Haier Smart Home using the PESTLE model, which considers policy, economics, society, environment, and regulations.

The upstream and downstream of the smart home industrial chain, as well as the degree of rivalry, are studied using Porter's Five Forces model. This study examines Haier Smart Home's financial status from the perspectives of profitability, efficiency, solvency, and growth capability, using the financial analysis approach. This study also makes recommendations for Haier Smart Home's future development plan and forecasts the smart home industry's future development trend.

The macro environment of smart homes has been supported in policy, economy, society, and environment, but there is a shortage of regulation, according to the report. Although new rivals find it difficult to enter the smart home sector, and the industry has strong bargaining power both upstream and downstream, product substitutability is high, and competition in the smart home appliance industry is fierce. In terms of financial indicators, Haier Smart Home's profitability and growth potential are average, and it has efficiency benefits, but it should be wary of the possibility of going bankrupt. In this regard, it is possible to anticipate that Haier Smart Home's business situation will improve following the conclusion of privatization, and that the smart home sector will evolve in the future toward a proactive and standardizing trend.

Although this chapter analyses the smart home industry's future development trend to some extent, there is a lag in interpreting the trend due to the difficulties in getting internal data and the most recent data. Nonetheless, this chapter focuses primarily on the Chinese industry (where paradoxically you can find more information than the Haier Europe brand) and does not address the current state of the other markets. It is necessary to establish the universality of its conclusion in the international market.

2.7 The internship

The opportunity internship consists of a working position in the Headquarter of Haier-Europe, located in Brugherio in the Quality team. From the first day, the importance of working in an international company characterized by a very challenging and exciting environment can be felt. The tutor and my department colleagues were friendly and, above all, extremely available to help each other in diving into the basics of work making the learning curve steep.

Starting from the first day of the internship, due to the importance of knowing the entire context of Quality department in Milan Headquarter, following the organizational chart scheme, took place different inductions in order to be able to know who are the owner of different responsibilities and their activities.

The activities developed during the 6 months (and counting, after the positive feedback from the team) of the internship period as a quality data analyst, can be divided according to these activities:

- Acquisition and collection of data from different data sources;
- Filter and "clean" the data for a reliable analysis of the quality trend;
- Interpretation, analysis and reporting of data with the right allocation of resources according the company target;
- Collaborate with management to prioritize business and information needs;
- Identify and define new processes and opportunities for product improvement.

One of the most exciting aspect of this experience was having the opportunity to work with other colleagues with different roles in order to see and learn at 360 degrees how to work in a team and how to manage important projects, like the start of production in the new plant just built in Romania.

2.7.1 Quality data analysis

All the Service Centres (C.A.T.) are equipped with the program W.M.A., that allows then to enter for each repair work all the essential information necessary for the Quality Department, to analyse in-depth problems during product life cycle.

By the middle of each month, all the repairs carried out during the previous month, on Haier products under warranty and on products life cycle, are available in the central Data System; where they are alter used and processed for the estimation of the S.C.R. (Service Call Rate) and the EPQ (Expected Product Quality).
The Service Call Rate is a consumptive KPI. It is a final figure obtained dividing the number of repairs carried out in observation period, by the number of sold machines, under warranty, that potentially could suffer a breakdown (from now on, this figure, the denominator, will be called Park at Risk).
To calculate the 1st year SCR the number of repairs carried out are referred only to the first year of warranty (12 months).
On the central Data System are available also the data referred to repairs carried out during second year of warranty.
Significant fluctuations in the park at risk assessment can lead to a SCR's variability that cannot be attributed to product real performances.
Park at risk is calculated using the following formula:
Park at risk = 20% of machines sold in the current Semester + 50% of machines sold in the Semester -1 + 80% of machines sold in the Semester -2 + 50% of machines sold in the Semester -3.
SCR is released every month and can be segmented by:

- Product Line;
- Plant;
- Country;
- Defect Code;
- Model.

SCR is used especially for the calculations of cabinet fee for Service Budget and, first of all, monthly calculations processed by defect code.

EPQ is a forecast KPI. This figure is obtained dividing the total number of the expected repairs by the monthly production. In formulas:

$$EPQ = \frac{Total\ Expected\ Repairs}{Monthly\ Production\ q.ty}$$

The calculation of the *Total Expected Repairs* is done by using the following formula:

$$Total\ Expected\ Repairs = \frac{Repairs\ done\ at\ month\ n.}{Percentage\ of\ the\ month\ n. (FACTOR)}$$

Where:

- Month n.: means n months of product life from production.
- Repairs at month n.: number of interventions made during the "n" months of life of the product.
- FACTOR: it is the ratio, calculated month by month, of the % the real interventions made over the total interventions over 24 months life. It is based on historical curves as explained here after.

Using historical data, it's possible to build a curve that allows to foresee how many defects have been already arisen from production data with respect to the totality of defects.

The example below shows the case in which, after 9 months from production, the 50% of faults occurred. This means that from that moment on, the appraisal of EPQ return reliable result.

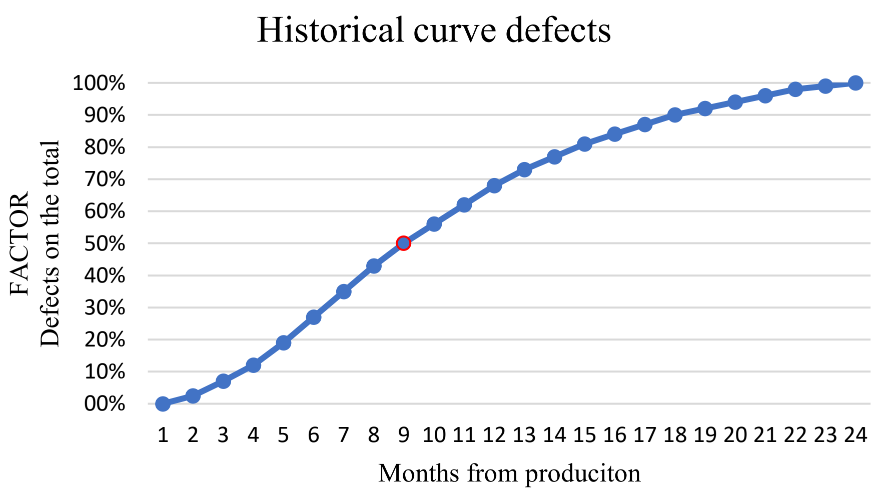

Fig. 10. Historical curve defects

The updated EPQ released each month is the aggregated EPQ value calculated on annual or semesterly basis (in order to have a higher degree of reliability).
As the months go by, EPQ is based more and more on real input data and less on forecasts; from month to month, therefore, EPQ gets closer to a real value and progressively moves away from predictions.
The Con's of using this KPI are the following:

- Changes such as production mix, speed of distribution and trade, structural changes can cause significant fluctuations in the appraisal of expected repairs;
- The more the base is split and worked on a little quantity, the more "nervous" will be the indicator.

EPQ can be segmented by product line or plant, and it has to be used also as early warning.
Summing up, the analysis of these cited above indicators, let to see a clear situation of all the major defects and problem regarding all type of products, in order to start, if needed, corrective or pre-emptive actions. (Candy Hoover Group S.R.L., 2018)

2.7.2 Final consideration

Being a member of the quality systems team at the corporate level allowed me to consolidate my technical expertise in the field of quality while also allowing me to take a broad and transversal view of the entire organization and the various processes that define it. The opportunity to follow the evolution and the start-up of the factory allowed to get to know salient aspects on site and also the tasks given, not only data analysis, allowed to better understand the production reality.

3. Analysis of the welding process

Before discussing about the case study, it’s important to take in exam the basis of how a refrigerator/freezer works and why a welding process is needed.

3.1 How a refrigerator system works

Refrigerators work by evaporating and condensing a refrigerant gas as it passes through the pipes inside. As the gas evaporates, it absorbs heat from the refrigerator's compartments, creating a cold atmosphere.
All foods include a large number of beneficial "gut bacteria" that are largely safe. Some foods, such as yogurt and bread, are manufactured entirely of bacteria (lactobacillus and yeast). Food deterioration occurs when these bacteria multiply too quickly.
Refrigeration's main concept is to slow down the decomposition process by inhibiting the growth of microorganisms in our food. The refrigerator accomplishes this by maintaining a constant low-temperature environment through the use of evaporation.
A widespread myth regarding refrigerators is that they use cold air to lower the temperature in their sections. They really extract heat from the air within and transfer it to the outside.
A liquid absorbs heat when it evaporates into the air. A refrigerator cools its interior by using the power of evaporation, but it ensures that the generated vapor does not escape. Instead, it is restored to its liquid state, where the cycle begins all over again.

3.1.1 The refrigeration cycle

The cycle goes like this: The compressor is where it all begins. The heart of the refrigerator is this section. The compressor raises the refrigerant gas's pressure and temperature before pumping it into the condenser. The condenser is the coils in the back of the refrigerator. Its job is to turn the hot high-pressure refrigerant gas from the compressor into liquid. After that, the liquid is pushed into the expansion valve. Then take the action the expansion valve, also known as the capillary tube, lowers the pressure of the liquid refrigerant, lowering its boiling point. The low-pressure

liquid is circulated through the evaporator coils, where it slowly evaporates. The low-pressure liquid is then cycled back to the compressor, where the process begins all over again.
Some refrigerators start and stop throughout the day. The refrigeration cycle is controlled by an internal thermostat. When the fridge becomes too cold, the compressor is turned off, and when it becomes too warm, it is turned back on.
This is the case with non-inverter refrigerators, as their compressors are unable to work at varied speeds. Because the compressor generates the greatest noise and consumes the most energy when it first starts up, they are both noisy and inefficient. Inverter refrigerators, on the other hand, do not turn off the compressor when the temperature is reached. Instead, it maintains the temperature by running the compressor at a slower speed. They become quieter and more efficient as a result of this.

3.1.2 Type of refrigerant gases

The refrigerant gas is the fridge's blood, if the compressor is its heart. This is the gas that evaporates and condenses to keep our refrigerators cool.
Refrigerators, air conditioners, and other commercial uses use a variety of refrigerant gases today. Each one has its own set of characteristics. Freon was the most used refrigerant gas back in the day (R-12). Freon, on the other hand, is a CFC (chlorofluorocarbon) that depletes the ozone layer. Because of this, Freon has been phased out in favour of more environmentally friendly refrigerants. R-134a and R-600a are the most commonly used refrigerant gases in refrigerators nowadays. To summarize, R-600a has a lower environmental impact and is generally more efficient than R-134a. One disadvantage of R-600a gas is that it is combustible and might cause minor health problems if it escapes from the refrigerator.

3.1.3 Types of cooling systems

While all refrigerators produce cold air in the same way, how this cold air is distributed across the compartments varies. This is why refrigerators are classified according to the cooling system they use, such as direct cool (also known as manual defrost) and no frost (otherwise known as fan cooling).

Simply said, a direct cool refrigerator uses its evaporator coil to chill the air directly, as the name implies. A no-freeze refrigerator, on the other hand, employs the evaporator to cool the air, but it also incorporates fans to help spread the cold air uniformly throughout the compartments. But the story does not end there. These differences in methodology have many ramifications.

The typical cooling system is direct cooling. It relies solely on the evaporator to chill the air, with no circulation assistance. A no frost refrigerator, on the other hand, contains a fan to assist the evaporator in uniformly dispersing the chilly air throughout the refrigerator. The following are the ramifications of this design difference:

- Energy consumption

When compared to direct cool refrigerators, no frost refrigerators use more energy. The wattage figures of direct cooling vs. no frost refrigerators are shown below.

Capacity	Direct Cool	No Frost	Difference
5,0 cu.ft. - 5,9 cu.ft.	0,78kWh/24h	1,49kWh/24h	91%
6,0 cu.ft. - 6,9 cu.ft.	0,95kWh/24h	1,32kWh/24h	39%
7,0 cu.ft. - 7,9 cu.ft.	1,04kWh/24h	1,23kWh/24h	18%
8,0 cu.ft. - 8,9 cu.ft.	1,17kWh/24h	1,06kWh/24h	-9%
9,0 cu.ft. - 9,9 cu.ft.	1,26kWh/24h	1,15kWh/24h	-9%

Tab. 2. Energy consumption

Note: Because there are more inverter models in this category, the average energy consumption of the no frost models tends to decrease in this table.

Direct cool refrigerators are the less complicated of the two cooling methods since they do not use fans or heating components to melt frost from the freezer.

A no-frost refrigerator, on the other hand, includes many fans to equally disperse cold air throughout its compartments, as well as a heating element buried inside the freezer to melt the frost. This increases the cost of operation at the expense of convenience.

- Capacity

Because it is inefficient to chill an area that large using only the evaporator coils, direct cool refrigerators rarely reach beyond the 12.0 cu.ft. range.
Meanwhile, no frost variants (usually french door or side-by-side models) can go up to 30.0 cu.ft. and can cool their vast compartments with ease thanks to their multiple evaporator fans.

- Convenience

No frost freezers are more handy than direct cool models since they do not require constant defrosting. This is accomplished by turning on and off a heating element in the freezer, which prevents frost from accumulating.
Granted, most direct cool versions now offer a semi-automatic defrost system that only requires the press of a button. However, there are still certain drawbacks to that.
To begin with, if the ice has been building up for a long period, the melting ice may be too much for the drain pan to handle, resulting in a leak. A no-frost refrigerator avoids this by removing frost on a regular basis, therefore the risk of a drain pan overflow is low.
A semi-automatic defrost system, on the other hand, turns off the compressor for the duration of the defrost cycle. During such period, the cooling performance suffers, which may cause issues for things that are sensitive to temperature changes.

- Maintenance

A direct cool refrigerator is easier to maintain and less expensive due to its simplified technology.
Meanwhile, a no frost refrigerator is more difficult to maintain than a direct cool type because it has more moving parts.
Broken evaporator and condenser fans (which can create cooling and noise concerns) and a defective heating element are common problems with no frost refrigerators (which can cause your freezer to ice up).
Summing up, while they have similar qualities, the price difference between them can be substantial. Always consider the advantages and disadvantages of a direct-cool vs. a no-frost refrigerator from a final consumer prospective. Calculate how much the consumer is willing to pay for the extra features of a no-frost model. (Appliance, 2021)

3.2 Alloy selection criteria

Closed the topic about the principal mechanics of how a refrigeration system works, it's possible to enter in to the specific of the welding process. In simple terms, the process that let the union/assembly/link of all the main component of the refrigeration system, with the goal of no internal or external refrigerant gas leaks.

Different joints to make:

1- Discharge connection on the compressor
2- Suction connection on the compressor
3- Charge connection on the compressor
4- Filter – condenser connection
5- Filter – capillary connection
6- Condenser connection with anticondensation

The realization of the joints described above involves the brazing of: iron – iron; iron – copper; copper – copper. Below the alloy selection criteria.

The alloys of Ag-Cu-Zn-Cd; Ag-Cu-Zn-Sn; Ag-Cu-Zn have been widely used in past years because they are useful for brazing the three different types of joints, they are progressively replaced both for the very high cost and for the need to eliminate residues of flux they need. They can be used for small series, or particularly difficult joints, or for repair or maintenance.

The alloys of Ag-Cu-P; And Cu-P; combine the advantage of a significantly lower price than alloys of Ag-Cu-P; and Cu-P; combine the advantage of a significantly lower price than alloys of Ag-Cu-Zn-Cd; the possibility of being used without flux on Cu-Cu joints; they cannot be used of Fe-Fe and Fe-Cu joints as they form brittle intermetallic compounds. They can be used in the brazing of the refrigerant circuit if a second alloy is suitable for Fe-Fe and Fe-Cu joints. (Enea, 2021)

Brass, excluding the use of powder flux or paste difficult to remove after welding, but in combination with vaporized deoxidizer and MR brasses in combination with vaporized deoxidizer, they are progressively replacing Ag-Cu-Zn-Cd alloys for the joints in question; o Ag-Cu-Zn Sn o Ag-Cu- Zn; and the Ag-Cu-P alloys; or Cu-P; for their peculiar characteristics: low cost, possibility of using a only type of alloy for the complete circuit, negligible deoxidizer residues on the joint.

In particular, the brass MR series in bars superficially impregnated with a quantity of deoxidizer extremely low, ≈0.5% by weight, used in combination with flux supplied by the appliance vaporizer by means of the flame, acquire greater smoothness and penetration into the joint leaving irrelevant flux residues after brazing. Below table 3 describing all the Pros and Cons of the different alloys.

Alloy	Ag-Cu-Zn-Sn Ag-Cu-Zn-Cd Ag-Cu-Zn	Ag-Cu-P	Cu-P	Brass used in pairing with deoxidizer vaporized	Brass MR used in pairing with deoxidizer vaporized
Cost alloy for single joint	Very high	High	Low	Low	Low
Circuit brazing complete with an only type of alloy	Yes	No	No	Yes	Yes
Speed of execution of the joint	Very high	Very high	High	High	High
Ease of execution of the joint	Very high	Very high	High	High	High
Appearance of the brazed joint	Great	Great	Great	Great	Great
Residues of deoxidizer on joint	Considerable	Void	Void	Irrelevant	Irrelevant
Percentage of valid joins	Very high	High	High	High	Very high

Tab. 3. Alloy selection criteria.

3.3 Fuel gas selection criteria

The choice of the fuel gas and the relative comburent, oxygen or air, depends on the type of flame the same produce, of the application or process, of safety, ecology, productivity, economy, possibility of on-site production, etc ... The two tables below, 4 and 5, highlighting the peculiar characteristics of the various gases available, can be of help in the choice.

Combustible gases	Oxygen or air needed for burn 1m_ of gas in m_		Temperature maximum obtainable °C	Calorific value INF K Cal		Specific power Kw/cm_ of surface	Density referred in the air=1
	O min	AIR min		Per 1kg	At 0°C at 1atm per 1m_		
Hydrogen H_2	0,5	2,39	2830	28700	2570	8,5	0,07
Acetylene C_2H_2	2,5	11,95	3170	11600	13600	18	0,899
LPG	5,5	26	2940	11000	21700	5,5	1,56
Methane CH_4	2	9,56	2790	11900	8550	5,5	0,554
Propane C_3H_8	5	23,9	2850	11050	23350	4,5	1,52

Tab. 4. gas-oxygen and gas-air blend.

Combustible gases	Hydrogen H_2	Acetylene C_2H_2	LPG	Methane CH_4	Propane C_3H_8
Maximum obtainable temperature	Medium	Very high	High	Low	Medium
Quantity of heat developed by 1m_ of gas with oxygen	Low	Medium	High	Low	Very high
Quantity of heat developed by 1kg of gas with oxygen	Very high	High	Medium	High	Medium
Concentration capacity of the flame and rapid rise of temperature	High	Very high	Medium	Medium	Medium
Necessary oxygen consumption to burn 1m_ of gas	Low	Medium	High	Medium	High
Necessary air consumption to burn 1m_ of gas	Low	High	Very high	Medium	Very high
Cheapness	Very high	Low	Medium	High	Medium
Future development forecast	Very high	Medium	Medium	Medium	Medium
Safety self-production	Yes	No	No	No	No
Ecological characteristics of the residues of combustion	Very high	Medium	Medium	High	Low

Tab. 5. Fuel gas selection criteria.

3.4 Heating systems

For the joints in question, the commonly used heating system is the manual torch consisting of a handle, usually in aluminium, incorporating the gas control taps in the front part so that they can be maneuvered with the thumb and forefinger of the same hand, by spears and various points dimensions and shapes, according to the gas flow rate.

The most used lances are the forked type, which allow fast and uniform heating. The torch allows to obtain the flame and to direct the heat to the welding point through the tip of ignition, point where the stable, adjustable and soft flame is formed.

The power of the torch expressed in l/h is the quantity of combustible gas, for example acetylene, that it an burn in an hour, is indicated on the tips and is chosen according to the amount of heat needed to bring in temperature in the required modalities the joints to be brazed.

Example of a forked torch:

Fig. 11. Forked Torch

3.4.1 Torch ignition procedure:

- open the valves of the acetylene and oxygen cylinders or the relative valves on the line, adjust the pressure reducers, acetylene 0.5 ÷ 1 bar and oxygen 1 ÷ 2 bar according to the type of joint;
- open the oxygen supply a little, bring the tip of the torch close to the economizer flame, open the acetylene supply, then adjust both gases so that the flame does not go out and does not detach from the lance as table N ° 12.

By increasing the oxygen, the dart in the centre of the flame is reduced in proportion, thus increasing the acetylene you will get the elongation of the flame and the dart, the length of the flame will reach the limit imposed by the power of the torch, 15 ÷ 30 mm.

3.4.2 Backfire:

Overheating or obstruction of the tip hole due to metal sprays move the combustion area from the outside to the inside of the torch which can go out after a few detonations.

Action is taken, firstly by intercepting the acetylene then the oxygen, secondly if the phenomenon is attributable to the excessively hot or obstructed tip, let it cool and clean it with brass wire.

Provide appropriate safety non-return valves on both the gas and oxygen supply pipes upstream of the torch so that any backfire does not spread upstream of the system.

3.4.3 Stopping the brazing station:

When the shutdown is final, firstly the acetylene valve is closed and then the oxygen valve placed on the line. If you are using acetylene and oxygen in cylinders, first close the valve of the acetylene cylinder, then that of the oxygen cylinder. In both cases, let the gases escape from the downstream pipes, then close the acetylene and oxygen taps directly on the torch.

When the stop is momentary, the acetylene and oxygen taps are closed directly on the torch or the torch is hung on the hook of the economizer device, if present in the system, thus intercepting the gas outlet from the torch.

3.4.4 Flame:

The flame is produced by the combustion of combustible gases: acetylene, methane, hydrogen, propane, LPG, etc., and oxidizing gases: oxygen, air; the acetylene-oxygen mixture is characterized by the highest combustion temperature ≈ 3170 ° as per the previous table.

The figure 12 and 13 below highlights the different areas of the flame:

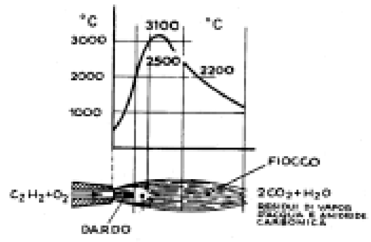

Fig. 12. Areas of flame

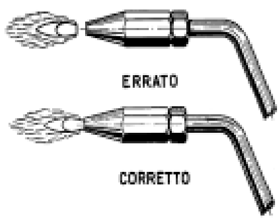

Fig. 13. Areas of flame

dazzling white dart and bow; normally a neutral flame is used characterized by a white conical dart with clear contours at the tip of the torch. An excess of oxygen, an oxidizing flame, reduces the brightness and length of the dart and tends to burn the joint; an excess of acetylene, fuel flame, determines the elongation of the dart with smoke emission.

3.5 Deoxidant supply systems

For the joints in question, the traditional system is to immerse the tip of the alloy rod suitably heated by the torch in the flux powder, the heated part is coated with the flux necessary for brazing.

The deoxidizer applied to the joint by means of the bar reacts when hot with the surface oxides of the joint metals, dissolving them and bringing them to the surface of the molten alloy bath, favouring the penetration of the alloy itself by capillarity, and also protects the metals of the joint from volatilization.

The metals of the joint must be cleaned before brazing, as the deoxidizers do not remove grease, oil or various contaminants.
The residual flux on the joint after brazing must be eliminated to avoid the possible corrosive action over time.

3.6 New deoxidant supply system

Referring to what is anticipated in the chapter "Alloy selection criteria", which highlights the advantages of using only one type of special brass alloy for all the joints of the complete circuit in combination with deoxidizer dispensed by a vaporizing device by means of the flame, below it is described this new type of plant.

3.6.1 Steamer appliance:

The combustible gas: acetylene, methane, hydrogen, propane, LPG, etc., bubbling through the volatile deoxidizing liquid contained in the vaporizing device, becomes saturated with a relatively limited quantity of deoxidizer, reaching the torch it carries out its deoxidizing action through the flame.

3.6.2 Adjustment:

The maximum deoxidant delivery is obtained with valves 2 and 3 completely open, vertical, and valve 1 completely closed.
By gradually opening valve 1, the concentration of deoxidizer in the outgoing gas decreases until the required regulation is obtained.
With valve 1 open and valves 2 and 3 closed, horizontal, the direct passage of the deoxidant-free gas is obtained.

3.6.3 Loading:

Close the gas supply valve 7 on the control panel, open the valve 1, close the valve 2, keep the valve 3 of the vaporizing device open, discharge the pressure of the gas contained in the vaporizing device by keeping the torch open, possibly on , close the torch and the valve 3.

Disconnect the gas inlet and outlet pipes using the quick safety couplings 5 and 6, bring the vaporizer to the area equipped for handling flammable liquids or outdoors, unscrew the cap 4 afterwards making sure to have released the pressure, pour the quantity of liquid suggested by the manufacturer into the vaporizer, close the cap and check that the seal is intact.

3.6.4 Shutdown:

At the end of the work, close the gas supply valve 7, close the oxygen supply valve 8, open the valve 1, close the valve 2, keep the valve 3 of the vaporizer open, release the gas pressure contained in the vaporizer, keeping the torch open, possibly on, close the torch and valve 3.

3.6.5 Maintenance, repairs:

before carrying out these operations, discharge the pressure of the gas contained in the vaporizer and disconnect the gas supply pipe following the procedures described above.

Open all valves every month and clean with compressed air. Every six months or when the liquid becomes opaque and not very active due to gas humidity or air infiltrations, remove the top cover, clean the inside of the vaporizer by eliminating the remaining liquid, make sure that the inside is well dry and that the seals are intact.

Scheme of the entire system, figure 14:

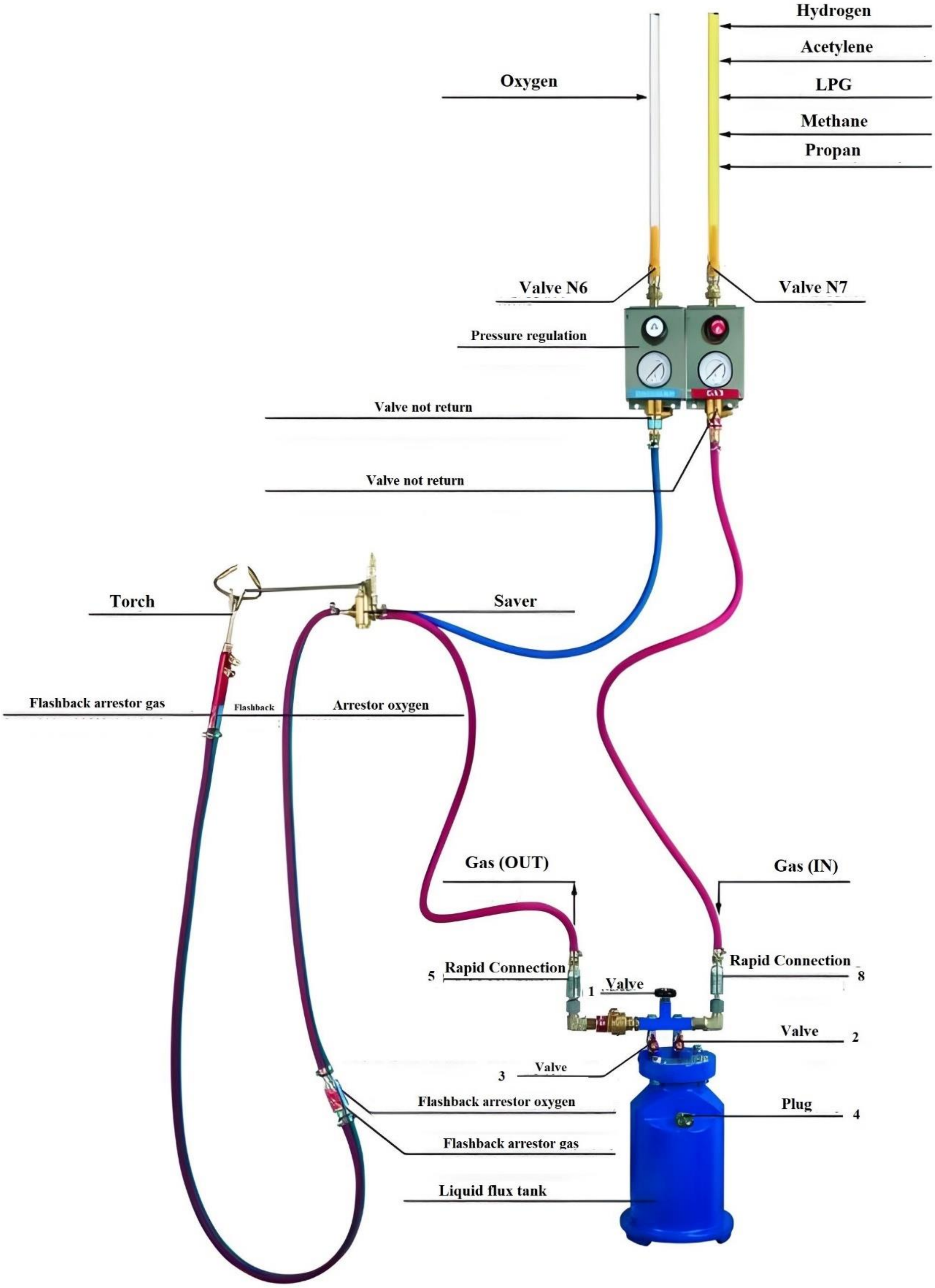

Fig. 14, Complete scheme

3.7 Welding without heating: Lokring

There is another type of connection system between pipes: Lokring. The lokring method for connecting pipes is proposed as an innovative system of connections without the heat welding. Lokring connections can be made with simple hand tools and without much effort. Lokring guarantees an absolutely long-lastting and clean mechanical connection between pipes, with a long-lasting hermetic seal. Another point in favour of this type of connection system relies on its cheapness.

To make a lokring connection are needed: two or more ring called lokring precisely, a joint, an assembly tool and some lokprep, a special fluid that it can be analysed afterwards. Moreover, there a few steps to connects two or more pipes using lokring technology. First, the cleaning of the tubes ends is required and insert and slide the lokring over the tube. Once the ends are free of dirt and production grooves, it’s possible to apply the lokprep on the external surface of the ends of the pipes. After that, insert the pipes inside the joint, making sure that the ends of the pipes are inserted until they reach the internal stop and that they remain locked in this position during the assembly. Finally, press the lokring axially on the joint, until it slides against the stop of the joint. (Lokring, Applicazione, OEM-Produzione, 2021)

In other words, the lokring connection consists of a tubular joint into which two pipes, or more, are inserted. During the assembly, the ends of the tubes are pushed to the inner end of the joint. A tool is then used to axially push the lokrings onto the joint. Due to the internal taper of the lokring and the particular profile of the joint, the connection diameter is reduced during assembly, so as to obtain a hermetic connection on the metal thanks to the pressure on the surfaces. The duration of the hermetic seal of the connection is guaranteed by a constant elastic pre-tensioning, produced by the balancing of the radial forces exerted by the lokring, which act on the pipe in the opposite directions.

The hermetic characteristic given by this technology is also given using the lokprep. Metal pipes may have longitudinal scratches on the surface right from the start; These manufacturing defects can be easily compensated by applying lokprep to the ends of the pipes. Thanks to its capillarity characteristic, it has the ability to pour even into the microscopic cavities and fill them completely. (Lokring, 2021)

Fig. 15. Lokring double ring

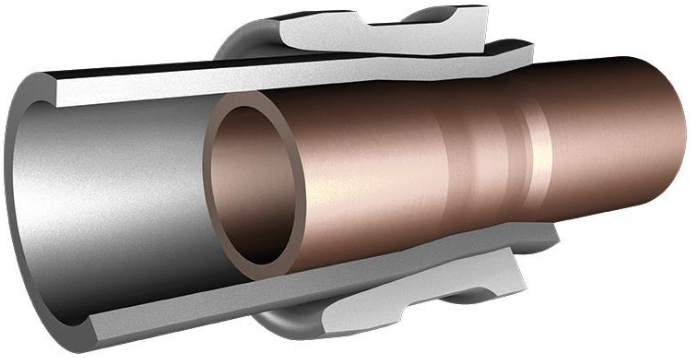

Fig.16 Lokring single ring

3.8 Hygiene and safety

The main source of danger in the brazing operation consists in exposure to toxic fumes and gases. The various international codes that regulate the subject, set threshold limit values for exposure to specific substances.

The most dangerous substances for the human body are zinc smoke, CO monoxide and CO2 carbon dioxide, and if silver alloys containing cadmium are used, cadmium oxide smoke.

Especially during manual brazing, the operator tends to assume a bent position on the pieces, with his face within the smoke emission area, a position to be avoided. If the contamination of the breathed atmosphere exceeds acceptable limits, ventilation or suction systems must be installed.

Torch brazing determines the emission of radiations that are dangerous for the eyes which must be protected with goggles, filtration degree 3 ÷ 4; in the case of using flame-vaporized flux, green flame, glasses with green lenses, filtration degree 5.

For the protection of limbs and hands, the operator must wear suitable clothing: heat-resistant overalls, aprons, gloves. (A. V. Saldature S.R.L., 2020)

4. Case study

Analysing the feedback data market, numerous claims regarding bad functioning product of a specific supplier were recorded, all of these were attributed as internal leakage of the refrigeration circuit. This phenomenon was attributed to a specific supplier, so internally it was taken the decision to start an action plan and to imitate a task force to resolve the problem following the Lean Six Sigma theory.

4.1 Lean Six Sigma

The lean six sigma technique combines six sigma and lean production ideas and tools to minimize waste, optimize resource utilization, work areas, and production cycles, and ensure high quality in production and management operations.

The organization can profit from the application of principles from two schools of thought thanks to the lean six sigma methodology.

Six Sigma is a process improvement methodology that focuses on reducing variability and eliminating process flaws. Six Sigma is a quality control program developed by Motorola in 1986 that emphasizes a reduction in production time and a reduction in process defects (both physical and informational) to a level of less than 3,4 per million. Since 2016, Six Sigma has evolved into a broader business management philosophy focused on meeting customer needs and improving customer loyalty.

Focus on eliminating waste and optimizing resources in production processes through lean manufacturing. The term "lean production" was coined by Womack and Jones in 1991 in their book "the machine that changed the world" after studying and theorizing the Toyota production methodology.

The correct application of the lean six sigma methodology can thus ensure, on the one hand, the improvement of product or service quality, the elimination of production defects, and the control of problems related to process standard deviation (six sigma), and, on the other hand, the reduction of waste, resource optimization, and customer value creation, in addition to maintaining the level of quality achieved, thanks to the concept of contingency (lean production).

The five DMAIC phases of the Lean Six Sigma approach are defined as follows: Definition (Define the opportunity from both the company's and the customer's perspectives), Measurement (Measure the product's manufacturing and performance), Analysis (Examine the most important aspects that affect performance), Improve (solutions to be implemented), and Control (Plan for process and product control). Lean Six Sigma is a very successful approach that enables businesses to compete with their products in today's changing market.

The organization gains various benefits from the combined use of ideas and tools from the two techniques, Lean and Six Sigma, resulting in an improvement in production and profitability. Statistically, the economic gains for organizations that successfully use the Lean Six Sigma approach can range from 2% to 5% of turnover, with peaks of above 10%.

The following are some of the most important benefits of correctly applying the lean six sigma methodology:

Product quality improvement: adding value to the consumer and concentrating on market demands.

Improving customer service through providing better (value) and faster responses to customers (supply and delivery).

Product cost reduction: waste removal, resource management and utilization, work areas, and manufacturing processes optimization.

More process efficiency: the creation and implementation of operational standards that enable you to optimize workflows, maintain effective control, and enhance business processes over time.

Staff motivation improves as a result of improved working circumstances, which leads to increased operator satisfaction and productivity.

Competitive repositioning entails gaining an edge over firm competitors in order to lower the cost per product.

Ability to generate new ideas: increased stimulation for the identification and implementation of solutions for continuous process improvement.

4.2 Definition

Thanks to sudden quality analysis made by quality team, it was easy to find out that the leakage problem increased quite rapidly the PeX (Product exchanged), due to the impossibility of re-working the leakage points. Moreover, this particular increase in defects was attributed to the products of a specific supplier of OEM refrigerator (Original Equipment Manufacturer).

As a consequence, the supplier and the quality together decided to start the project to take in place a quality improvement regarding the leakage failure rate for this specific supplier's Combined Static Refrigerator (the first one in terms of quantity and complaints for the circuit leakage fault) productive line.

Around a virtual "table", it was defined a project charter and all the main figures that took part of the project: firstly, was assigned the sponsor, the supplier director; then was assigned the owner of the project, the quality leader; two green belt figures as operative figures of the project.

Considering the failure rate calculated as the number of calls received for the units produced in the last 6 months of 2020 (from July 2020 to December 2020) with a time to failure of 1, 2, 3; this is 73% higher with respect to the benchmark.

The goal of the project is to reduce the failure rate of the 50% in nine months, from 0,055% to 0,027%. Definition of the boundaries also, the project is going to consider just the specific supplier production process, not the one outside the factory (service, transportation, …).

Then, the welding points to be scanned were selected, from 1 to 19 welding point, due to the boundaries defined above, the team selected the 100% screening of welding point 5 to welding point 12. This choice was almost obligatory because the other welds are performed by the evaporator supplier.

Fig 17. Welding points BI Combi Static I

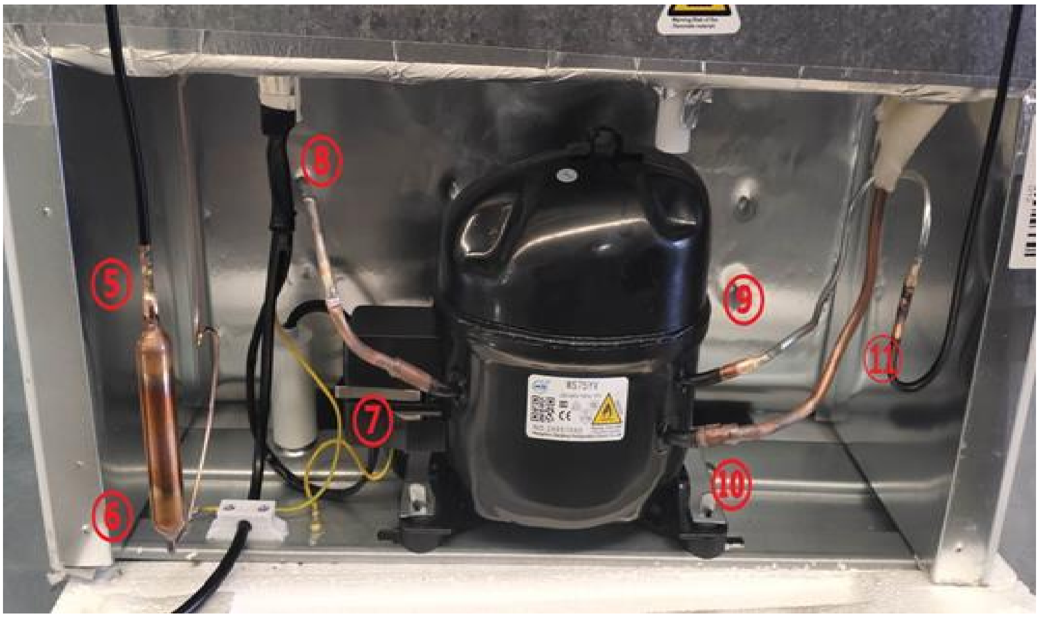

Fig 18. Welding points BI Combi Static II

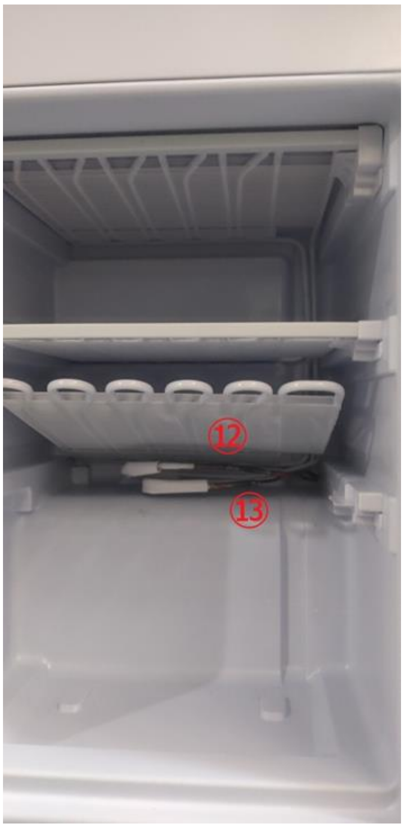

Fig. 19 Welding points BI Combi Static III

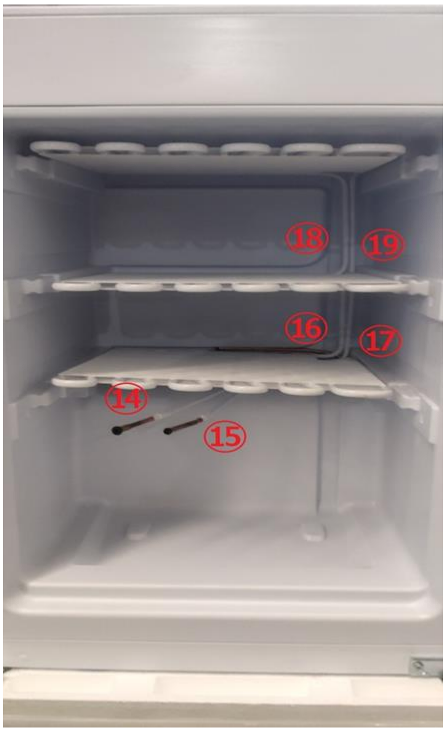

Fig 20. Welding points BI Combi Static IV

The importance of this project is relevant to the impact of an intern/external leakage of a refrigeration circuit. The performance of a sealed system (systems with hermetic compressors) is severely affected by refrigerant leakage from a refrigeration system. The system's running time continues to increase as a result of refrigerant leakage. Due to the loss of refrigerant, both suction and discharge pressures decrease. There will be less liquid and more flash gas, which will have a negative impact on various system components. For instance, instead of liquid, a mixture of liquid and vapour could enter the expansion valve, causing it to malfunction, valve chattering, and erosion owing to greater velocities, among other things.
The lubricating oil return becomes problematic due to decreasing suction pressures. Furthermore, the risk of oil leaking with refrigerant deprives the compressor of lubricating oil, potentially resulting in compressor damage. There is a risk of air seeping into the system if the suction pressure drops below atmospheric pressure owing to refrigerant leakage. This will introduce moisture into the system, and moisture has a negative impact on the system.

4.3 Measurement

Once it has been decided which welding point to analyse (WP from 5 to 13), it’s time to define the horizontal gap in which all the detection must to be recognized: from January to November 2021 have been collected all the circuit leakage in the supplier production line, divided by welding point. Below an extract of the month of January as an example of which type of raw data the project team worked on.

	Welding 5	Welding 6	Welding 7	Welding 8	Welding 9	Welding 10	Welding 11	Welding 12	Welding 13
01/01/2021									
02/01/2021	0	1	1	0	0	1	0	2	1
03/01/2021	0	0	0	1	0	0	1	1	1
04/01/2021	0	0	0	0	1	2	0	1	0
05/01/2021	0	1	0	2	0	1	0	1	2
06/01/2021	0	0	0	1	0	0	1	2	0
07/01/2021	1	0	2	0	0	0	0	0	0
08/01/2021	0	0	0	2	0	0	1	0	0
09/01/2021	1	1	1	0	1	0	1	0	1
10/01/2021	1	0	0	1	1	0	0	0	0
11/01/2021	1	0	2	1	0	0	1	0	0
12/01/2021	0	1	0	0	0	2	3	1	0
13/01/2021	0	2	1	0	1	0	0	0	2
14/01/2021	0	0	0	1	0	2	3	0	0
15/01/2021	1	0	0	0	1	0	0	1	0
16/01/2021	0	1	0	0	2	1	1	0	0
17/01/2021	0	3	0	0	0	0	2	1	0
18/01/2021	0	1	3	0	0	1	1	0	0
19/01/2021	1	0	0	1	2	0	0	0	2
20/01/2021	1	0	0	0	0	0	0	0	0
21/01/2021	1	0	0	2	1	2	0	0	0
22/01/2021	0	0	1	0	3	0	1	1	1
23/01/2021	2	0	0	2	0	0	0	0	0
24/01/2021	0	1	0	0	1	2	0	1	0
25/01/2021	0	0	1	1	0	0	2	1	1
26/01/2021	2	0	0	0	1	1	0	0	0
27/01/2021	0	2	0	0	0	0	0	2	1
28/01/2021	0	0	0	1	1	2	0	0	0
29/01/2021	1	0	0	0	2	0	0	0	0
30/01/2021	0	0	0	1	0	0	3	1	0
31/01/2021	0	1	0	0	1	0	0	2	0

Fig 21. Raw data Leakages by Welding point

The crucial point in this section is: how to detect the leakages?

The team conduct a study to select the proper equipment to use, in such a way that it’s not hard to use and time consumer.

The following are three commonly used leak detection methods:

- Soap Bubble method;
- Halide leak detector
- Electronic leak detector

For decades, technicians have depended on the soap bubble method. It should be self-explanatory. In essence, the technicians use soapy water or a leak detecting spray to check for leaks at specific locations. At the leaking points, bubbles should appear.

While popular and reliable, the soap bubbles approach is hampered by the fact that pinpointing leaks can be difficult in certain circumstances, such as when the leak is small or when it is windy outside. As a result, using the soap bubble approach in conjunction with another method, notably one of the electrical leak detection methods, may be most advantageous.

The halide leak detector operates on the idea of a flame changing colour when refrigerants are present. When a fluorocarbon-based refrigerant like R12 or R22 is sucked through a sample tube and passed over a surface with a high surface temperature (about 500oC), the refrigerant vapour degrades and creates phosgene, a foul-smelling gas (COCl2). When this gas is carried over a flaming copper (heated by the torch's flame), copper chloride is formed, changing the flame's color from pale blue to vivid green. The halide torch, which often burns methyl alcohol, butane gas, or acetylene, is built similarly to a blow lamp but with the ability to pull air for combustion through a sample tube. The presence of refrigerant in the air (due to leakage) is detected by a change in the colour of the flame. Leaks as tiny as 1.5 to 2 oz. per year could be detected with halide leak detectors. However, when employing halide leak detectors, some care must be observed. Hydrocarbon refrigerants are not compatible with it.

The premise behind an electronic leak detector is that as halogen vapour is heated, positive ion concentration rises, which is amplified to produce an auditory or visual signal. As a result, the leak detector is made out of a sampling tube through which air from the refrigeration system is sucked by a small fan. The air sample is passed over a platinum element that has been heated. Positive ion current flows between the ion emitter and collector (anode and cathode) under a voltage of 240 V in normal (clean air) conditions. However, when a sample containing halogens is drawn into the probe, an immediate increase in positive ions occurs, which is amplified by the electrical circuit, resulting in an audible or visual signal.

The strength of the signal increases as the probe moves closer to the leak and diminishes as it moves away from the leak, allowing the precise location of the leak to be established. A reference leak is integrated into some leak detectors for comparison and adjustment of the detector's sensitivity. It's also feasible to compensate for contamination from the environment. The electronic leak detector is extremely sensitive, detecting leakage as little as 0.25 to 0.50 ounces per year. The procedure is safe, quick, and does not pose a fire concern. However, maintaining the input voltage is critical for the detector's sensitivity. They're made to detect refrigerant leaks, however they shouldn't be submerged in or retained in refrigerant streams, for example from the refrigerant cylinder.

Method	Effectiveness
Soap Bubbles	Good for pinpointing leaks but can be undermined if the leak is very small or if it is windy outdoors
Halide leak detector	Can be messy and adversely effect system performance and longevity
Electronic leak sniffer	Best and most efficient and effective. Very sensitive and good for finding most leaks if properly used and maintained

Fig 22. Type leakage detection comparison

Looking at the table above, it's clear that the electronic sniffer is the best choice for this task. (Bacharach, 2021)

4.4 Analysis

The goal of the Analyse phase is to identify and test the root causes of problems so that improvement can be targeted there.

To find out the critical factors with major impact on performance, the project team applied the Ishikawa model firstly, followed by a root cause analysis, and at last a sequence of statistic test.

Ishikawa diagrams (also known as fishbone diagrams, herringbone diagrams, cause and effect diagrams) are causal diagrams designed by Kaoru Ishikawa that depict the possible causes of a certain event (Kaoru Ishikawa, 1943).

To identify probable components creating an overall effect, the Ishikawa diagram is commonly used in product design and quality defect prevention. Each source of variation is cause or reason for imperfection. To detect and characterize various sources of variation, causes are frequently classified into primary categories. Regarding the macro-categories, it's commonly used the 5M model when a manufacturing process need to be analysed, the 5 "Ms" stand for: Materials, Method/Process, Manpower, Machine/Equipment and Measurements. Each of them will be

more analysed below. Increasing the area of research, it's feasible to add a 6th macro-category: the environment.
After analysed the welding process, brainstorming session with the quality team in plant and with the line operators also, it was possible to apply the Ishikawa method, exploding the macro-categories one by one.

4.4.1 Manpower

Concerning the operators that execute the welding process, are one of the variables that affect the variance of the entire process. The greatest sources of variance are very different to each other in this field. The most relevant is the fact that the operator does not have enough time to perform the welding properly, it's one of the biggest challenges referring to production line. Another type of problem could be the absence of a proper work shift, could happen when an operator is on vacation and there is no substitute. Thinking more simpler, could happen that the circuit leakage is caused by a no skill operator, due to an absence of a practice program or training session.

4.4.2 Measurements

With this macro-category, the variance that cause the internal leakage is explained by all the scenarios related to the detecting of the leakage. In other words, could happen that the operator does not use the proper instrument for detecting the defect, or the instrument is out of tolerance. Taking up the same topic about the time disposal, could happen that the line operator has short time detection of the defects and due to time shortage doesn't check the blind spots, activity more time consuming than the others one. All these factors can take to a not detection of the leakage, but could happen another event: leakage detected, but not reworked. This scenario can take place when the process is not standardized or not well defined, so could happen that there is a missing data sheet where register the defects or there are communication problems between processes.

4.4.3 Environment

Before it was talked about the manpower, but another source of variance is the environment that surrounds the operator. It's very important maintain a desk spot well organized, all the tools and stuff well-ordered and ready to use. Another key factor is the comfortability of the working station: it's very helpful for the operator have a well-lighted space to see better where and how he/she is working the welding spot, moreover applying a brief survey to the operator on the production line, it's was found that lots of operator have found very helpful a little support with a mirror build on, in this way they could the see better the blind spots and finish a welding point properly. On the same survey was found that some operators needed a chair or a support where they can seat in order to work the welding point comfortably.

4.4.4 Method/Process

One of the key factors is the process and method with all the work is done. It's very important standardize all of the welding process, in such a way that the risk of a future leakage of the refrigeration circuit is minimum as possible. Regarding the process, could happen various scenario that brings in place the main event: the operators don't check the blind spots (scenario that could be linked to manpower macro-categories) or the firm doesn't have set a proper training program for the operators, doesn't check his skill and talent, or doesn't provide the right equipment. Could happen that the production line doesn't have much time buffer between two operators, in this case the second operator for example could not pay so much attention due to shortage of time; so could take place to the welding materials that does not melt properly, due to an incorrect timing of solder addition or to a failure of the circuit to preheat.

4.4.5 Materials

The next macro-category is "material", specifically it will be analysed the materials used, the materials and specification of the parts of the fridge in general involved in the welding process. For example, the main event, the leakage, could take place because the pipes of the refrigeration circuit have the diameter or the thickness that don't meet the standard, in this way the welding material does not weld properly.

Could happen also that the welding rod does not contain enough silver, therefore there is a problem of the chemical formula for the compounds used.

4.4.6 Machine/Equipment

In this macro-category, are analysed all the scenarios linked to Equipment and tools used in the line process, so that cases the bring place to the welding material does not melt properly. They could be some problem linked to the gas, the operator could not check the pressure of the refrigeration gas, or maybe he/she could use a defective pressure gauge and as a result, the pressure could be not the correct one, due to some inner dirt in the circuit and the gas does not flow properly or more serious, the gas could be not the correct one. In addition to the problems related to the gas, the operator could use some defective equipment: could happen that the diameter of the welding nozzle is too small or the nozzle could be blocked by some residue; these variables could lead to a not correct welding procedure because the flame is not hot enough, and adding all variables related to the gas , could happen that the final result is that the welding material does not melt properly, consequently a probable inner leakage.

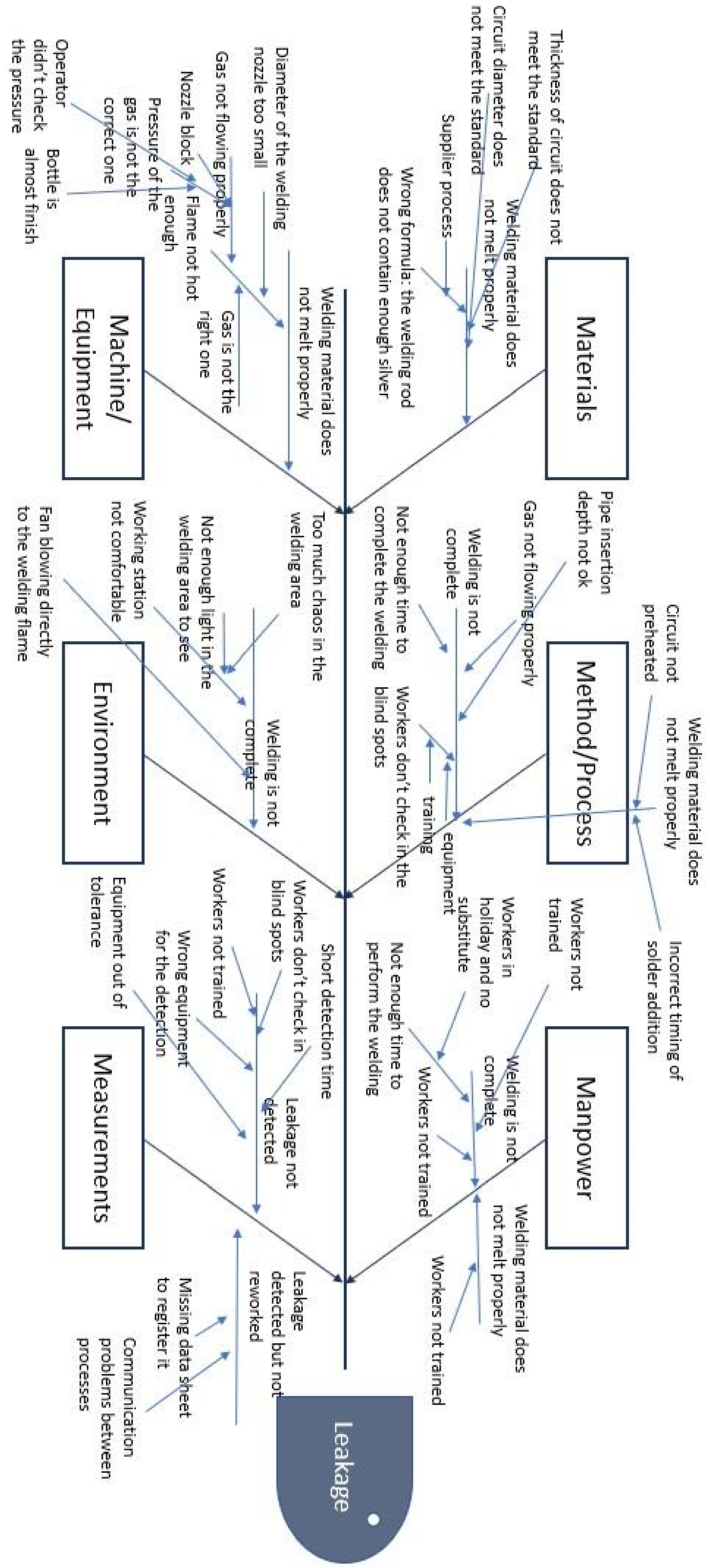

Fig 23. Ishikawa Diagram

4.4.7 Root Cause Analysis

To increase the level of inspection, the Ishikawa method is followed by a root cause analysis. The goal of root-cause analysis is to uncover crucial correlations between diverse variables, and the potential causes offer additional insight into process behaviour. The causes arise from analysis, frequently during brainstorming sessions, and are organized on the fishbone's main branches.

The principal critical factors that cause the main event are two: the welding material does not melt properly; welding is not complete during the process line.

Starting from the first one, it could be correlated to various scenarios. When circuit specification does not meet the standard, concerning the diameter or the thickness, otherwise even if the circuit follow the specifications, the not preheating of the refrigerator circuit could happen that a small crack near the welding appears.

Could happen also that the bad working of the product depends on the lack of skill of the operator due to a missing training schedule, going into details, the operator misses the right timing and/or the right quantity concerning solder addition.

The principal scenario instead is that the welding point does not melt properly because of the flame is not heat enough. the lack of temperature can depend on various factors: one of the most important decisions to control this step is the choice of the gas, as it's explained in the previous factor, the choice of the gas could alter all the process. The problem of the flame not enough heat could be related probably to an equipment with some defect or it's not the proper one, for example the diameter of the welding nozzle is too small, or maybe the nozzle is blocked. All this will result that the gas will not flow properly, but another reason to a not flowing gas could be the incorrect pressure of the gas. This last reason could be generated or by lack of gas in the cylinder, or maybe the operator could not check the pressure of the gas.

The other principal reason for which a leakage could present is when the welding during the process in line is not complete. This event could be related to various scenarios: one of them is when the working station is not comfortable, this brings the operator to not work properly, like there is not enough light in the welding area to see properly, or the entire working station has not been cleaned, and tools and stuff are badly organized. Taking as an example when technician manager found out that an operator had his fan pointed blowing directly to the welding flame, which fan purpose was only to "refresh" the operator during the hot months. Occasionally could happen that welding point is not in a comfortable position; in this way the operator has greater difficulties and is not able to finish the welding. Another serious problem is when there is no enough time to complete the welding; maybe there is no time buffer between one work and another one or the operator is so skilled to do the job in the time requested, or when the operator is supposed to do a difficult welding, maybe in a blind spot, that requires him more time. However, talking about blind spot, the operator could not have the right equipment and tools to work properly.

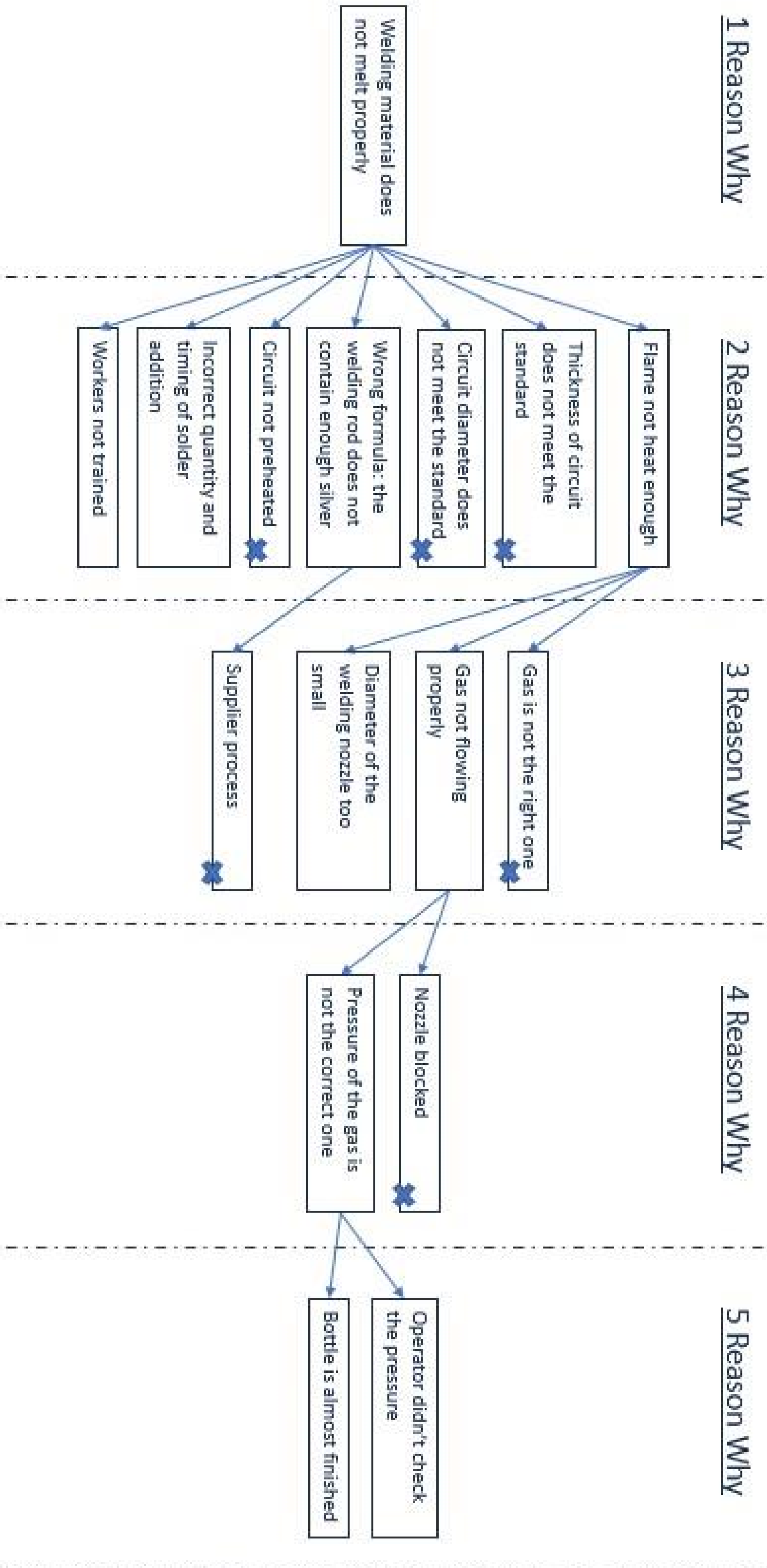

Fig 24. Root Cause Analysis I

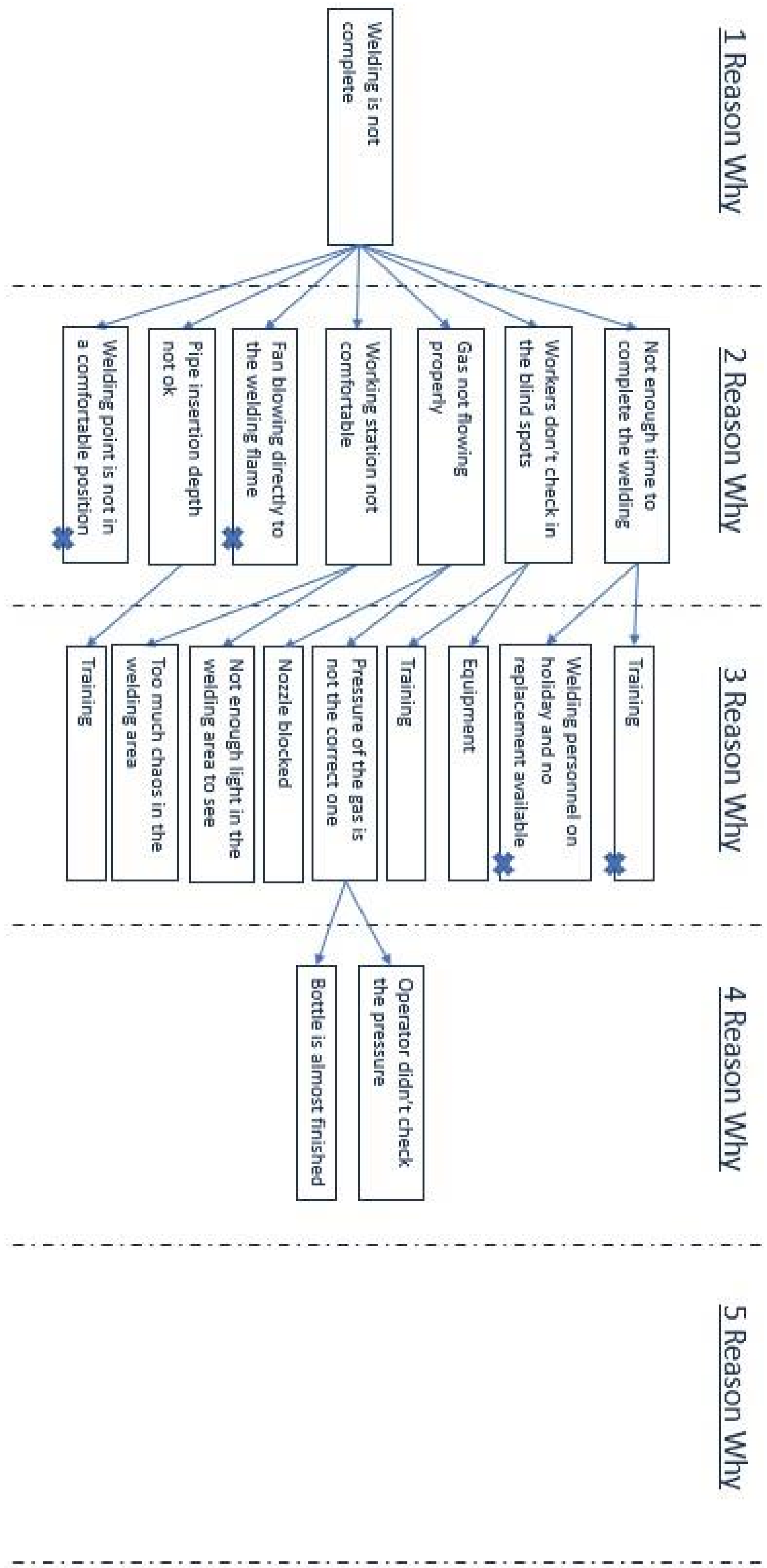

Fig 25. Root Cause Analysis II

4.4.8 Statistical test

After all the study regarding the different scenarios and variables that trigger the main event, the leakage, the next step is a deep analysis on the data, the different trend of %defects over time, in a way to find where the most of the variance is hidden.

Starting from the overall picture of the all leakages detected during the 11 months of inspection, the team started to study the trend of the average per month of leakages by welding point in order to understand if there is a specific welding point which that cause more general defectiveness than the others one.

Instead of analysing the losses directly, the team decided to study the trend of the fraction of losses on the daily production, in this way the quantity produced is also taken into consideration.

Speaking in formula:

$$Rating\ WP_{it} = \frac{Number\ of\ Leakages_{it}}{Daily\ Production_{t}}$$

The result is the weight of the leakages for the i-th welding point over the daily production, at the same time t.

Due to the great horizontal gap (11 months), instead of the daily rating of the WP, it was taken in consideration the average of the rating by WP of the entire month.

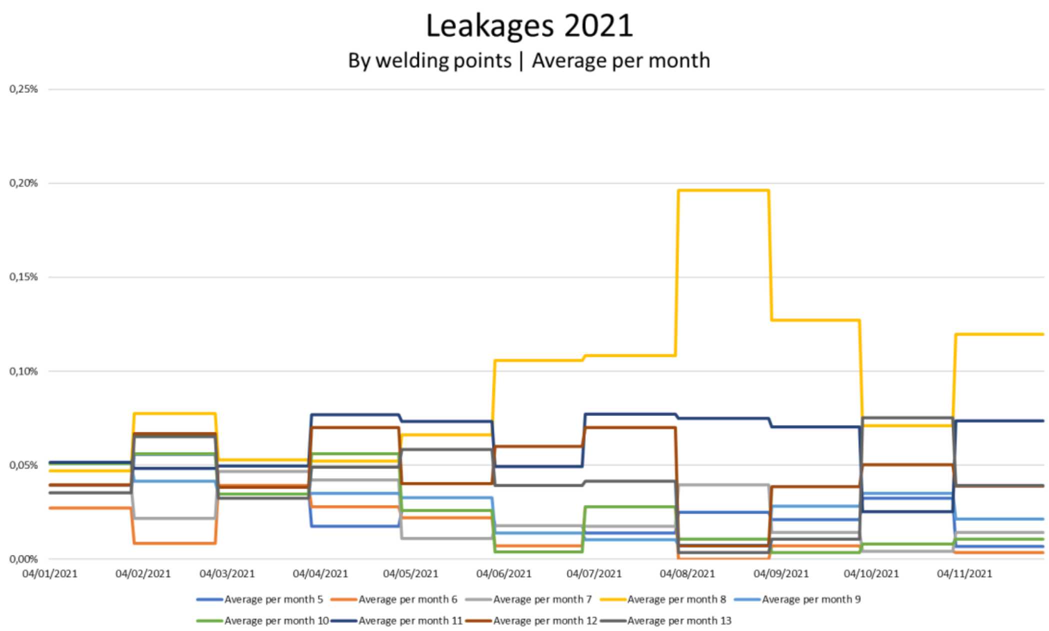

Fig 26. Average per month of leakages by welding point

From this picture it can be seen a high variability of defectiveness between all the welding points, especially for the welding point number 8. To have a better visualization of the situation, a useful tool was used, the Box and Whisker plot.

A Box and Whisker Plot (also known as a Box Plot) is a visual representation of data distribution through quartiles.

The "whiskers," which are parallel lines extending from the boxes, are used to illustrate variability outside the top and lower quartiles. Individual dots in line with whiskers are occasionally used to represent outliers. Box plots can be made in both vertical and horizontal directions.

Although Box Plots appear basic when compared to a Histogram or a Density Plot, they have the advantage of taking up less space, which is beneficial for comparing distributions across multiple groups or datasets.

The following are some of the types of observations that can be made while viewing a Box Plot:

- What are the important numbers, such as the average, median, and 25th percentile?
- If any outliers exist, what are their values?

- Is the information symmetrical?
- The degree to which the data is grouped.
- If the data is skewed, in which direction is it skewed?

Variable-width Box Plots and notched Box Plots are two of the most widely used Box Plot variations. (Catalogue, 2021)

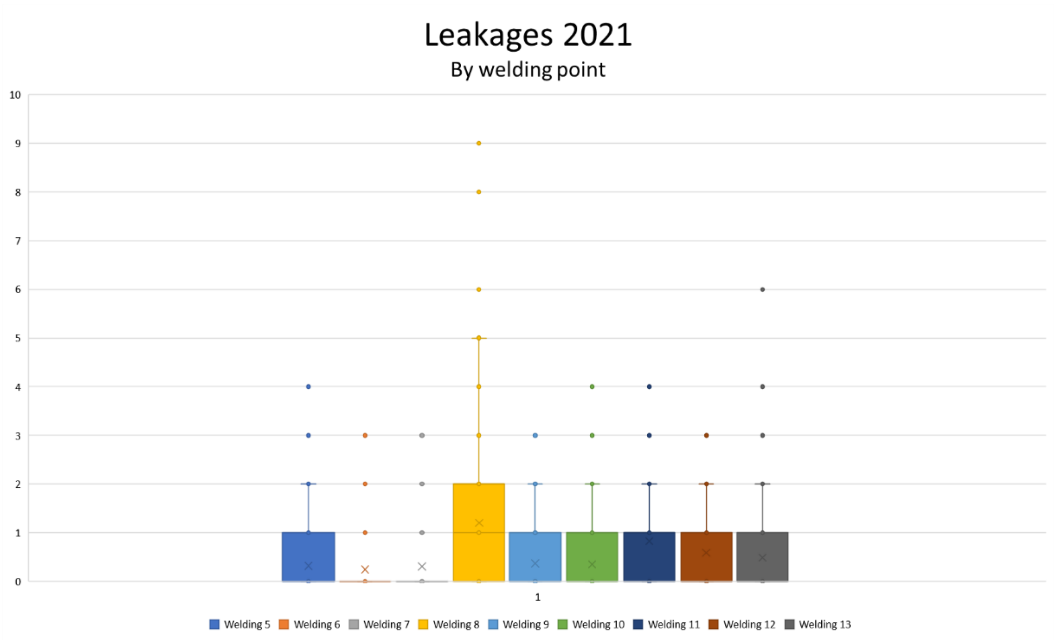

Fig 27. box and whisker plot leakages by welding point

Looking at the picture, the first thing that is highlighted is the high variance of the process concerning the welding point 8, but looking in to the specific, it's notable that the welding point 11-12-13 have a greater average than the others welding point. It's clear that the work on the welding points 6-7 is "in control" instead.

To have a further confirmation of the high variability of the result between the different welding points, it was conducted a "one-way ANOVA" test. Analysis of variance (ANOVA) is a collection of statistical models and associated estimate processes (such as "variation" among and between groups) that are used to examine variations in means. ANOVA is based on the law of total variance, which divides observed variance in a variable into components attributed to various causes of variation. ANOVA, in its most basic form, is a statistical test that determines if two or more population means are equal, and so extends the t-test beyond two means. The F statistic (also known as the F-ratio) is a result of the ANOVA formula that allows for the study of many sets of data to identify the variability between and within samples.

The F-ratio statistic of the ANOVA will be near to 1 if there is no real difference between the tested groups, which is known as the null hypothesis. The F-distribution is the distribution of all potential F statistic values. The numerator degrees of freedom and the denominator degrees of freedom are two characteristic numbers that define this group of distribution functions.

Appling the technique to this case, follow the two hypotheses:

The main hypothesis is H_0: $\mu_5 = \mu_6 = \mu_7 = \mu_8 = \mu_9 = \mu_{10} = \mu_{11} = \mu_{12} = \mu_{13}$;

The counter hypothesis is H_1: At least one mean is different.

Anova: Single factor						
Summary						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Welding 5	274	88	0,321	0,365		
Welding 6	274	67	0,245	0,295		
Welding 7	274	85	0,310	0,376		
Welding 8	274	330	1,204	2,193		
Welding 9	274	102	0,372	0,388		
Welding 10	274	96	0,350	0,434		
Welding 11	274	226	0,825	0,848		
Welding 12	274	161	0,588	0,631		
Welding 13	274	135	0,493	0,654		
ANOVA						
Source of variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	212,774	8	26,597	38,704	0,000	1,942
Within Groups	1688,409	2457	0,687			
Total	1901,182	2465				

Fig 28. Anova test, all welding point leakages

As expecting result, the Hypothesis H_0 is refused, as p-value<0,05.

In inferential statistics, the p-value is the chance of receiving results that are equally or less compatible with those observed during the test, with the aforementioned hypothesis, for a hypothesis that is assumed to be true (null hypothesis). In other words, the p value aids in determining if the discrepancy between the observed and hypothesized results is due to sampling-induced randomness, or if the difference is statistically significant, that is, difficult to explain by sampling-induced randomness. The observed significance level is another name for it.

Continuing in this direction, trying to explain where all the variance is hidden, the project team decided to split the welding point by operators. In this way, it could be clearer if the main event is mora liable on the inherent difficulty in performing a proper joint, or maybe is a lack of skills from the operator (recalling all the speech made before about how an operator can influence the failure of the weld).

Fig 29. Welding points BI Combi Static II

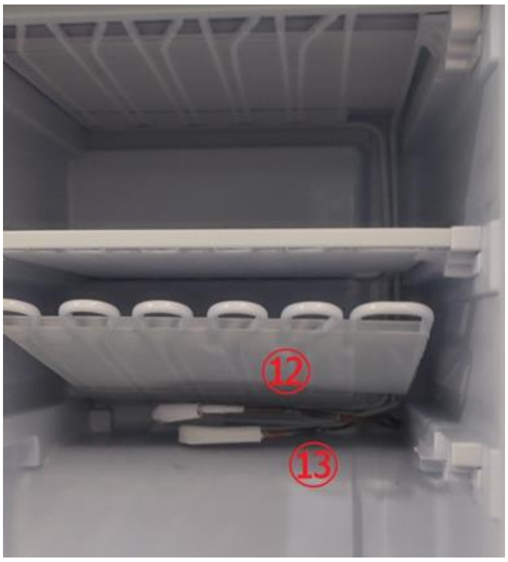

Fig 30. Welding points BI Combi Static III

Welding point	Type of welding	Operator
5	Copper - Iron welding	Operator 1
9	Copper - Iron welding	
11	Iron - Iron welding	
6	Copper - Copper welding	Operator 2
7	Copper - Copper welding	
10	Copper - Copper welding	
8	Copper - Copper welding	Operator 3
12	Copper - Copper welding	Operator 4
13	Copper - Copper welding	

Fig 31. operator's ownership

Like before, the total of leakage by welding point were weighted over the total of product produced, but this time at the numerator, is calculated the number of leakages summed up by operator.

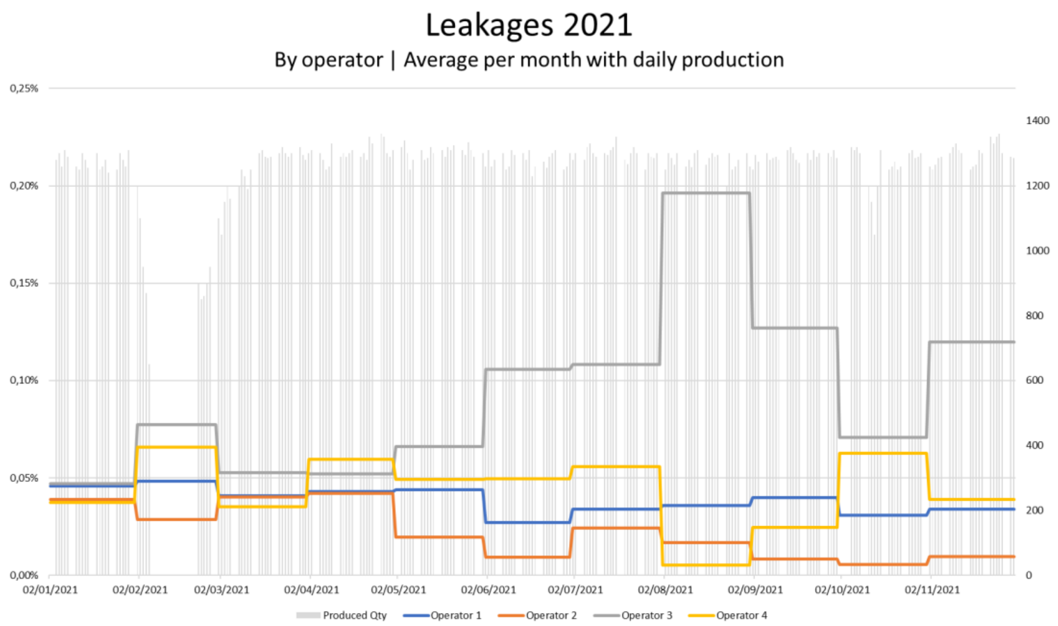

Fig 32. Average per month of leakages by operator

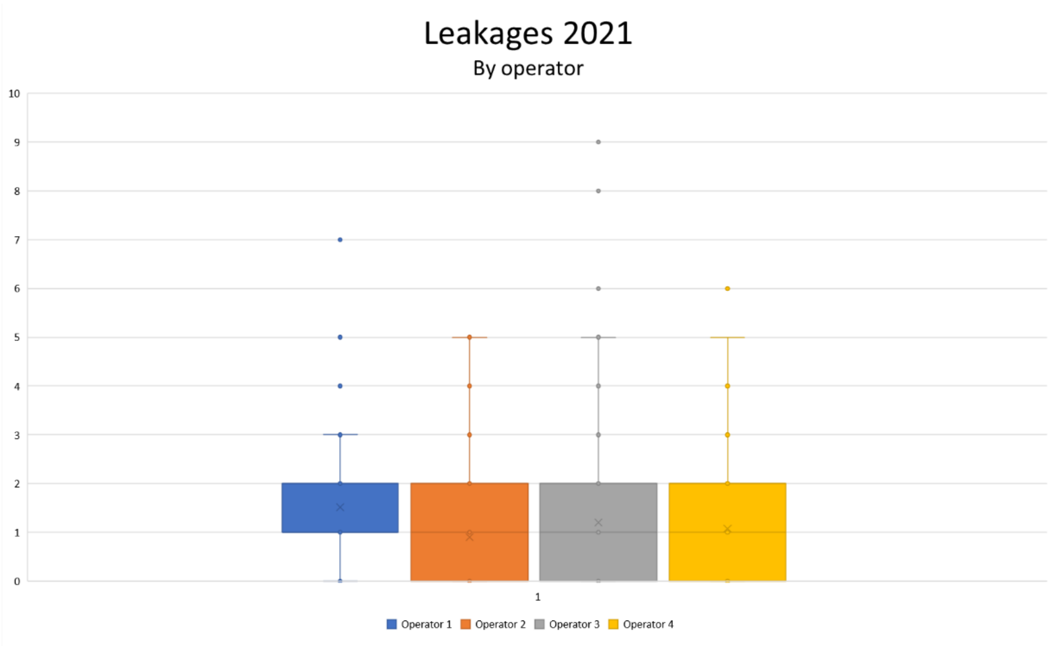

Fig 33. box and whisker plot leakages by welding point

From the graphs above, it can be seen the trend of leakages and how the operators were performing in the production line. Firstly, the Operator 3's curve is identical to the WP8 in the image 32, because clearly he/she is liable only of this joint. Furthermore, it's obvious that the welding point 8 is the most problematic one.

Regarding the other operator's performances, the most efficient one is the operator 2, but concerning the operator 1 and operator 4 the condition is not so clear yet. Another consideration to do is that the operator's performances are not correlated to the volumes to be produced, because the volumes of quantity produced is almost constant over the year, except during February (Chinese New Year).

The graph 33 confirm what's written above, the operator 2 seems that is working properly, it's better to pay more attention to operator 1-4 instead.

Similarly to before, it was applied another ANOVA test, to check if the operator's performances are statistically comparable.

Anova: Single factor						
Summary						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Operator 1	274	139	0,506	0,158		
Operator 2	274	83	0,302	0,132		
Operator 3	274	330	1,204	2,193		
Operator 4	274	148	0,540	0,348		
ANOVA						
Source of variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	126,275	3	42,092	59,484	0,000	2,613
Within Groups	772,718	1092	0,708			
Total	898,993	1095				

Fig 34. Anova test, all welding point leakages divided by operators

As expected, the hypothesis H_0 is refused, the operators have a totally different behaviour regarding their performances.

To have a clearer see over these data, the overall picture was split by operator but not summing the trends of the singular joints. In this way, the first thing that can be noticed is that the defect is more accumulated in the last joint worked in line by the operator. This could be a result of a badly management of time by the operator, or the time disposal to each operator is too short.

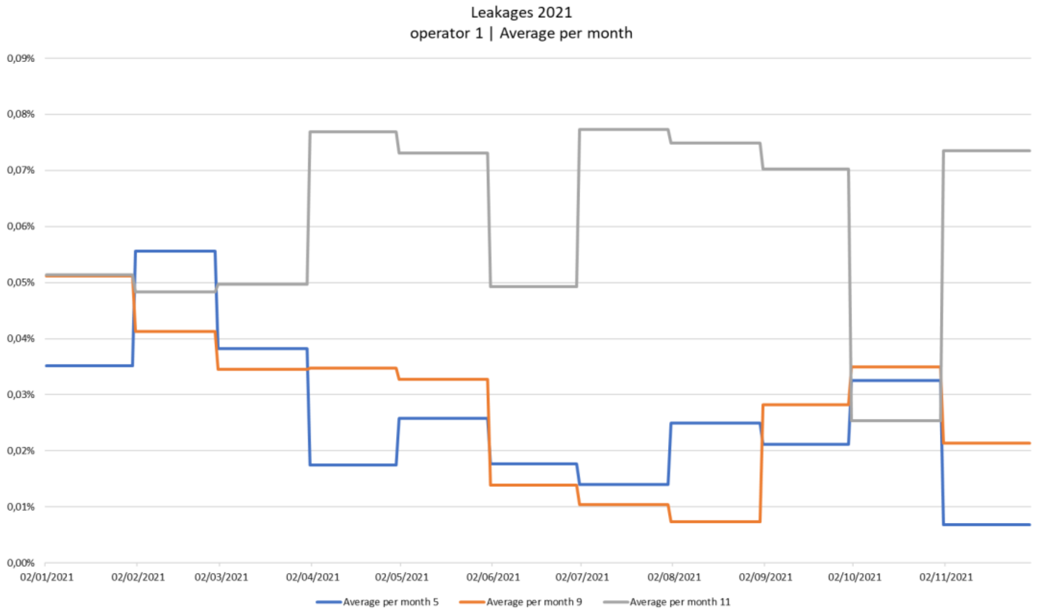

Fig 35. Average per month of leakages by each operator I

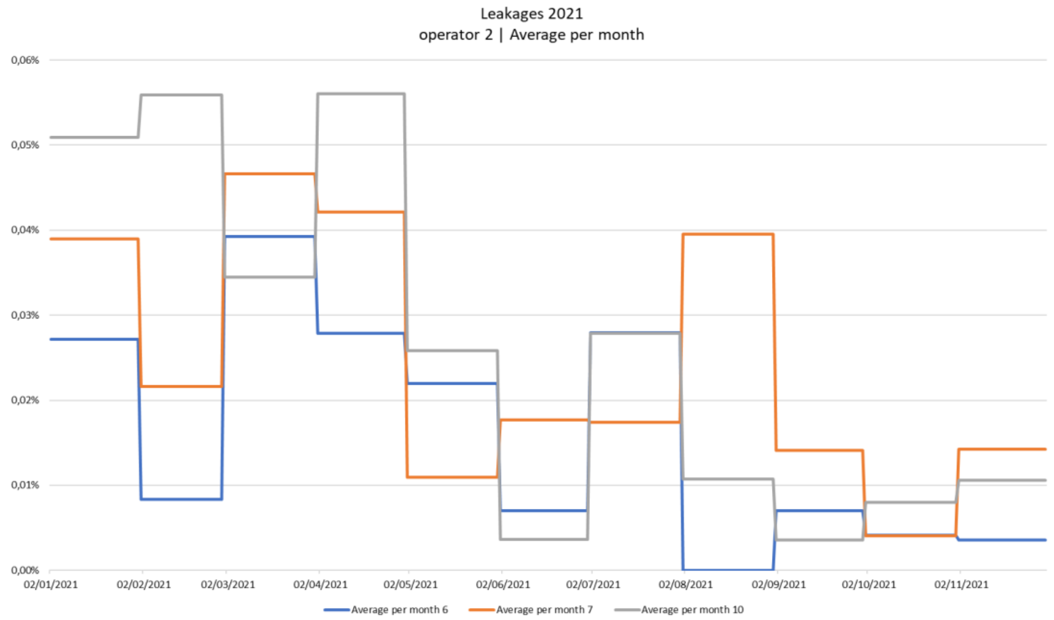

Fig 36. Average per month of leakages by each operator II

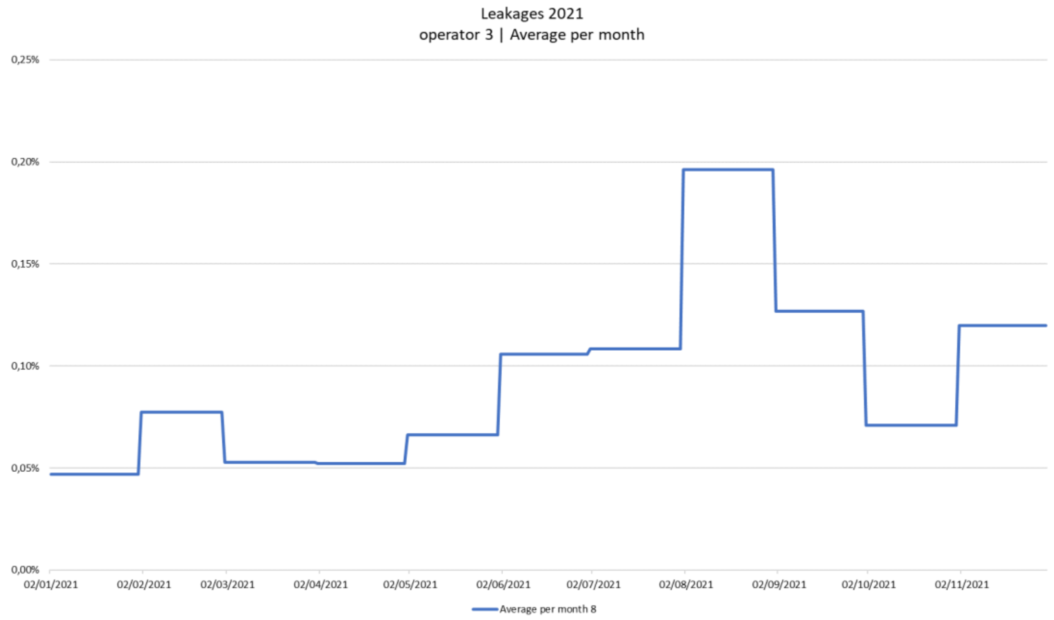

Fig 37. Average per month of leakages by each operator III

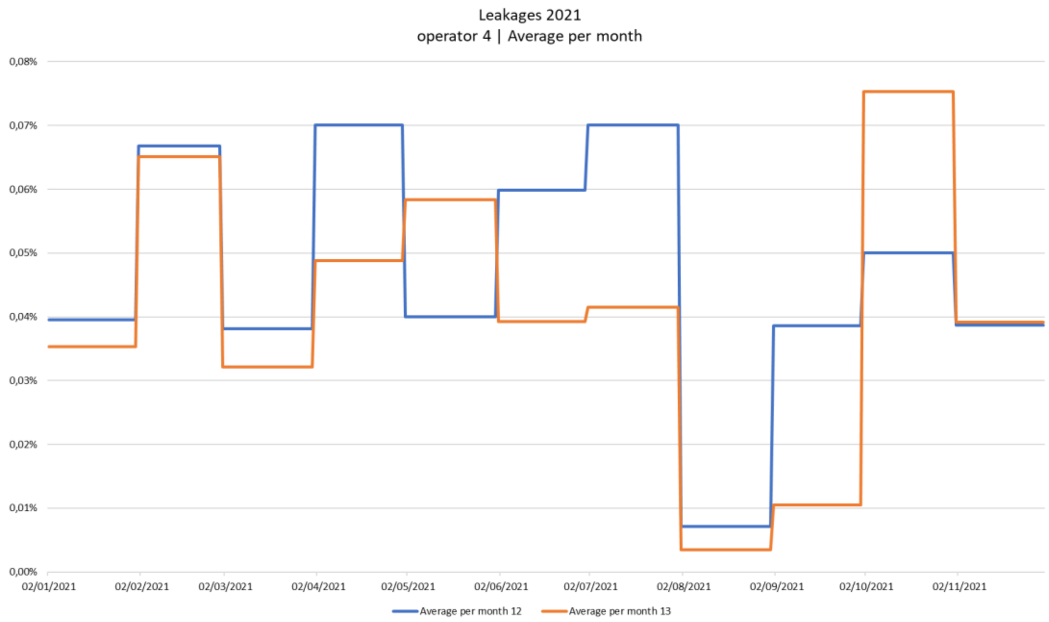

Fig 38. Average per month of leakages by each operator IV

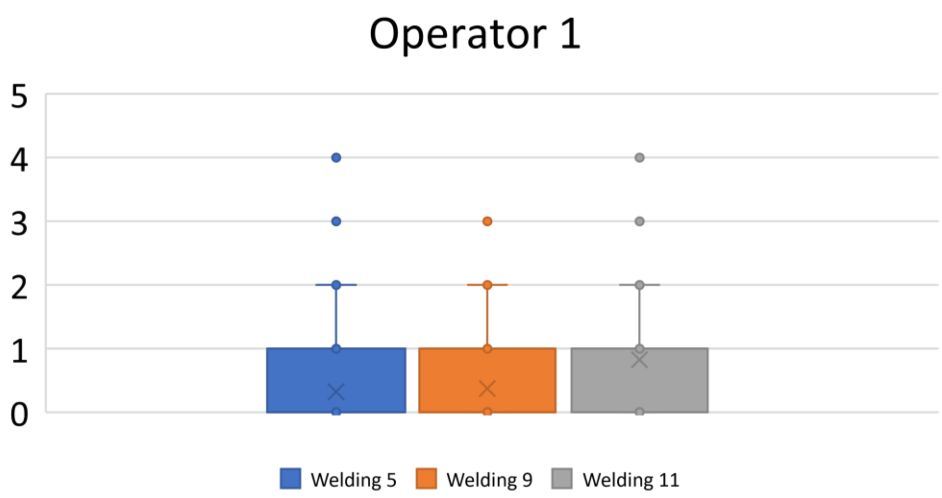

Fig 39. box and whisker plot leakages by each operator I

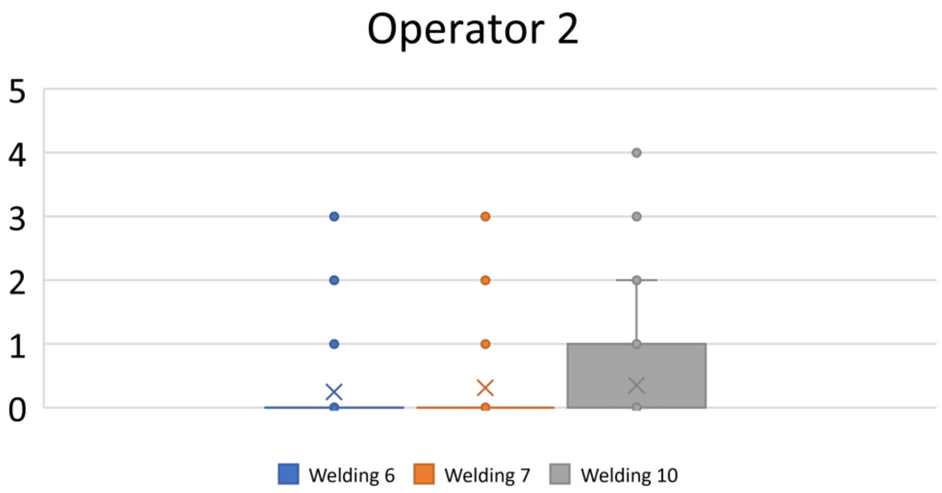

Fig 40. box and whisker plot leakages by each operator II

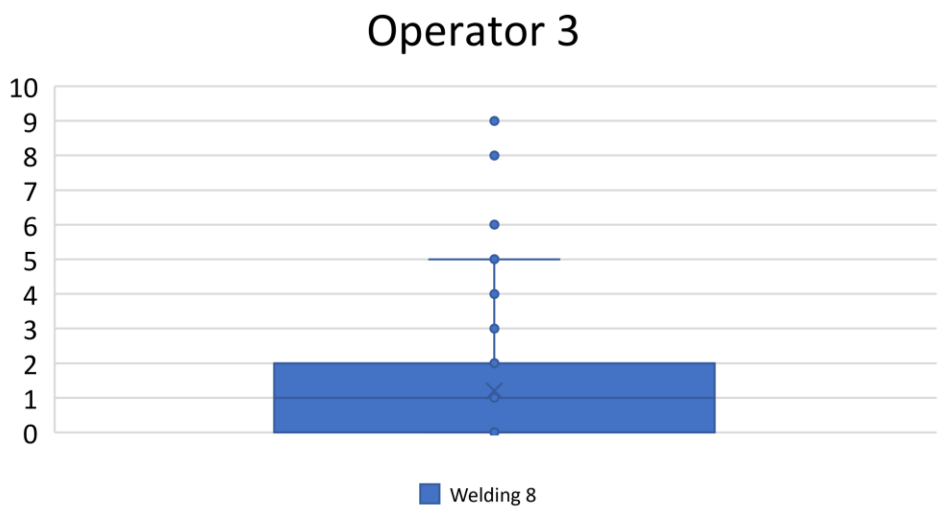

Fig 41. box and whisker plot leakages by each operator III

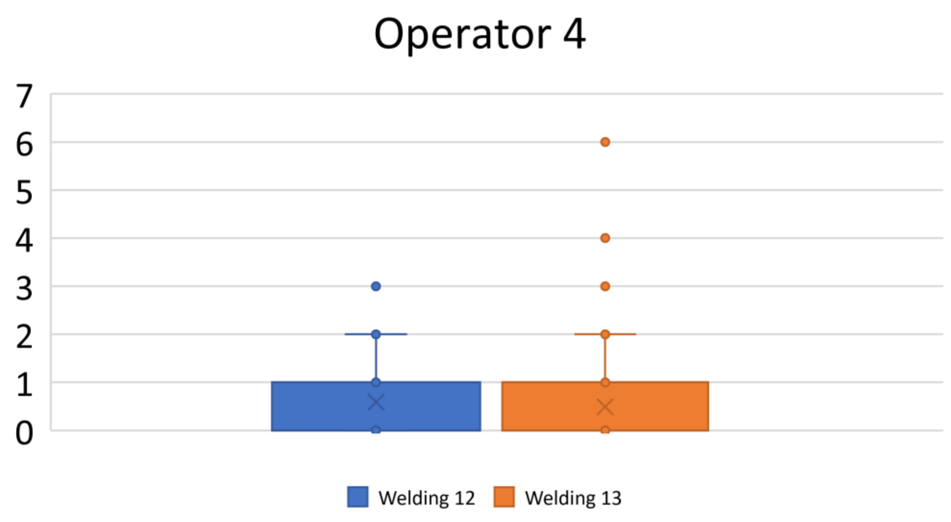

Fig 42. box and whisker plot leakages by each operator IV

After all these considerations, Anova Single Factor analysis has been done on all the welding point leakages grouped by Operator in order to understand if they can be compared from a statistical point of view. For all the test, H_0: All the means are equal; H_1: at least one mean is different

Anova: Single factor						
Summary						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Welding 5	274	88	0,321	0,365		
Welding 9	274	102	0,372	0,388		
Welding 11	274	226	0,825	0,848		
ANOVA						
Source of variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	42,112	2	21,056	39,430	0,000	3,007
Within Groups	437,358	819	0,534			
Total	479,470	821				

Fig 43. Anova test, all welding point leakages by operators 1

H_0 is refused, p-value<0,05

Anova: Single factor						
Summary						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Welding 6	274	67	0,245	0,295		
Welding 7	274	85	0,310	0,376		
Welding 10	274	96	0,350	0,434		
ANOVA						
Source of variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	1,564	2	0,782	2,124	0,120	3,007
Within Groups	301,613	819	0,368			
Total	303,178	821				

Fig 44. Anova test, all welding point leakages by operators 2

H_o not refused, p-value>0,05

t-Test: Two-Sample Assuming Equal Variances		
	Welding 12	***Welding 13***
Mean	0,588	0,493
Variance	0,631	0,654
Observations	274	274
Pooled Variance	0,643	
Hypothesized Mean Difference	0	
df	546	
t Stat	1,385	
P(T<=t) one-tail	0,083	
t Critical one-tail	1,648	
P(T<=t) two-tail	0,166	
t Critical two-tail	1,964	

Fig 45. Anova test, all welding point leakages by operators 4

H_o not refused, p-value>0,05

In conclusion, after all the graphs and tests, the total variance of the inner leakage of the circuit is not hidden equally over all the joints performed by the supplier. Moreover, it’s not only a discussion of which operator is performing the joint, but concern also the inherent difficulty in working that specific weld, or all the aspects that were cited in the first part of this section.

So, targeting the most critic joints are all the welding point performed by the Operator 1 and 3, as a result of the high average of leakage and high variability of performance through time and between the joints themselves.

4.5 Improve

After all the consideration in the chapter Analysis, it's time to decide which action to be implemented in order to improve the overall performances and reach the goal set in the project charter.

Starting from the Root Cause Analysis, here the improvements that were decided to deeply analyse and put in place.

The first action is to resolve the "box" - **Pressure of the gas is not the correct one** – from the Root Cause Analysis. In order to improve the checking of the gas pressure for welding process all the operator will be provided which an automatic manometer which suddenly advises the user if the gas bottle nozzle is below the minimum pressure limit (Oxygen 0,25 MPa; gas 0,001 Mpa).

Another improvement is to **increase the diameter of the welding nozzle**. Increasing the diameter of the welding nozzle will increase the flame temperature, as consequence the operator should be able to perform more properly the joint. The benchmark between the different suppliers showed that all the other suppliers uses a diameter which is 3 times greater than this specific supplier under investigation, so as final decision is set a diameter equal to 15,5-16,0mm.

The next step is to more standardize the actions of the operator, reducing the variability of the process. In doing so, the next improvement is to **standardize the quantity of solder addition**, removing the problem related to "incorrect quantity and timing of solder addition". The solution of this problem is the introduction of a material ring to replace the welding rod and also the introduction of a cap on the welding on the recharging tube.

After these more technical improvements, the next step is to focus on the operator, trying to reduce the variability of the process trying to help the labour force to reach greater skills. The first thing to **start is an active program of training** for the operators who has an inconstant trend of performances, the operator 3 for example, who has the greater dispersion of data in terms of leakage and a trend not stable during the year. The goal of a training program is also to reduce the time in which the operator will work the joint, in this way the result expected it's to delete the difference between the leakage in the first and last joint to work. This is the result of a bad time management by the operator, or as it's said before, the operator is required to work in a short time.

In order to decrease the welding variability and **increase the reliability of the workers**, the working conditions of the welders is under evaluation. The working station must be comfortable in terms of lighting, temperature and at the right height with regard to the process line. In fact, the working station of the operator 1 was not comfortable at all, it was not bright enough and more important than the others, the mirror for checking the blind spots was missing. So not only the working station itself, but there will be a double check of the all equipment provided for each operator that is present in their working area.

4.6 Control

Once all the improvement described in the previous chapter have been applied, the Control phase is the sequent one.

The first idea is to monitor all the quality improvement with the monthly analysis calculating the two major KPI: SCR and EPQ (described and explained in the section 1.7.1 "Quality data analysis"). In this way it's possible to take in consideration the direct market feedback through the customer's claims. As described in the project charter, the goal of the entire project is to reduce the failure rate of the 50%, this improvement can be seen in the long term also. With a proper welding process in the production line, reduce also a possible inner leakage of the circuit month (or even years) after the sales of the product.

Another method to monitor the possible positive or negative trend immediately is to continue to measure one by one, continuing with a screening of the 100% of welding done. As described in the previous chapter, providing all the operators with a proper sniffer, detecting all the possible leakages. To improve the screening and reduce the number of errors, nowadays there are type of sniffers with the possibility of wi-fi connection, in such a way to not loose even one leakage and to ease the collection of raw data to simply all the subsequent analyses.

4.6.1 Next Step

In addition to perform all control actions, the project members decided to continue the work of screening but for different projects.

To improve all the quality performances of the selected supplier, a future action could be to repurpose the project to the sub-supplier for the all evaporator welding. Obviously could be more problematic a 3-members collaboration, but with the right assignments of responsibility, the project will take in place an optimum result in the all process.

Another future action that could be taken in consideration is to repurpose the project for another product family, not only for the BI Total No Frost, in such a way to erase from the beginning possible complications in resolving quality issue regarding all the welding process and paying attention to more problematic or even intrusive topics.

5. Conclusion

As general conclusion, the development of the task force was very useful to better understand where the most of the variance of a possible leakage of the refrigeration circuit was hidden. IT was possible to find out which of the variable is the more impacting and we were able to find out how to resolve and improve the process, starting from the equipment used to the operator's behaviour.

In this way, the focus can be oriented on other issues, especially on the more intrusive one, and starting again with others action plans and focusing more on the just started production in the new Romanian factory, Haier Tech S.R.L.

After that the future feedback of this case study will be analysed, other future action plans will start. Like is shown above, the same project will be applied to the sub-supplier, the evaporator supplier to be specific. Doing so, the entire process of welding tasks is under the direct supervision of the quality team.

Moreover, if the case study will show positive feedback, the project will be applied to other product family, even for the more defective structure, due to their high complexity, like "Side by Side" and "French Door"

The other future next steps are to apply this type of task force in the production line of the new factory, and at the same time start the "every call count" behaviour. This approach consists of to examine in full details every claim from the final customer about the costumer, focusing more on the quality issue claims. Doing so, we are capable to detect as soon as possible all the issue about the product in order to initiate all the improvement as soon as possible, especially when the volumes of product produced is low.

One of the most exciting aspect of this experience was having the opportunity to work with other colleagues with different roles in order to see and learn at 360 degrees how to work in a team and how to manage important projects, like the start of production in the new plant just built in Romania.

Being a member of the quality systems team at the corporate level allowed me to consolidate my technical expertise in the field of quality while also allowing me to take a broad and transversal view of the entire organization and the various processes that define it. The ability to track the factory's development and start-up allowed for a greater understanding of the production reality, as well as the responsibilities assigned, which included more than just data analysis.

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