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RE-ROUTING OF COOLING WATER PI- PELINE

Tekniikka ja liikenne

2011

OPENING WORDS

This thesis has been done in co-operation with Wärtsilä Finland Oy, Power Plant engineering management office. I have been working for Wärtsilä as a summer trainee for 2 summers now. In the summer of 2009 I worked as a machinist and got familiar with production. I machined cylinder heads for Wärtsilä 32 engines. In the following summer in 2010 I was a mechanical supervisor trainee in power plants. I was working in a project in Maracanaú, Brazil. There we were building a power plant with eight Wärtsilä W20V46F engines and it was producing electricity for power-distribution network. With this experience I had quite a good basis for doing my thesis on power plants.

I want to thank my teachers and different employees in Wärtsilä who have helped me with my thesis.

Vaasa 15.3.2011

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Kone- ja tuotantotekniikka

ABSTRACT

| | |
|--------------------|--------------------------------------|
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| Name of Supervisor | Lotta Saarikoski |

This thesis was made for Wärtsilä Finland Oy department of Power Plants. The purpose of this thesis was to compare different solutions and to find the best and cost-efficient solution for cooling water pipelines when radiators were located on the roof of the power plant.

Making this thesis began by gathering all the possible solutions together and divides into different groups depending on the solution. There were five different groups and five different solutions were selected for a closer inspection. While searching the best route for cooling water pipelines I gathered information by interviewing designers, pipe-experts and engineers.

The result is a well-defined matrix table where the comparison and all the different pipeline solutions were gathered. Prices for pipelines (€/m and €/kg), entry to Power House, entry from top or under the hall and directness were taken into account in the comparison. The result of this thesis is good basis to start standardizing the certain solution. The matrix is not included in this thesis because the information is classified.

Keywords: Wärtsilä, cooling system, power plants, research

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Kone- ja tuotantotekniikka

TIIVISTELMÄ

| | |
|--------------------|---|
| Tekijä | Tuomas Kuusisto |
| Opinnäytetyön nimi | Jäähdytysvesiputkiratkaisujen vertailu ja suunnittelu |
| Vuosi | 2011 |
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| Ohjaaja | Lotta Saarikoski |

Tämä päättötyö tehtiin Wärtsilä Finland Oyj Power Plants yksikölle. Tavoitteena oli vertailla eri ratkaisutapoja ja löytää paras ja edullisin ratkaisu jäähdytysvesiputkistolle, kun jäähdyttimet sijaitsivat voimalaitoksen katolla.

Päättötyön tekeminen alkoi keräämällä kaikki tämän hetkiset ratkaisumahdollisuudet yhteen ja jakamalla ne ryhmiin käytetyn ratkaisumallin mukaan. Ryhmiä tuli 5 ja sieltä valittiin 5 erilaista ratkaisua lähempään tarkasteluun. Parasta putkitusreittiä suunniteltaessa tietoa haettiin haastattelemalla suunnittelijoita, putkiasiantuntijoita ja insinöörejä.

Lopputuloksena saatiin selkeä matriisitaulukko, johon on koottu kaikki erilaiset putkitusmahdollisuudet ja niistä tehty vertailu. Vertailussa on otettu huomioon putkitushinnat (€/m ja €/kg), putkituksen sisääntuloreitti, sisääntulo halliin ylä- tai alaosasta sekä reitin suoruus. Tämän tutkimustyön tuloksia on helppo käyttää jatkossa, kun tiettyä putkitusratkaisua aletaan standardoida. Taulukkoa ei ole liitetty tähän työhön, koska tiedot ovat luottamuksellisia.

Asiasanat: Wärtsilä, suunnittelu, jäähdytys

USED TERMS AND ABBREVIATIONS

CW Cooling water

PH Power House

HT High Temperature

LT Low Temperature

EMO Engineer Management Office

EPC Engineer, Procure and Construct

EEQ Engineered Equipment Delivery

IDM Integrated Document Management

FTH Fuel Treatment House

EAM Engine Auxiliary Modules

W32 Wärtsilä 32 Engine

SG Gas engine

CONTENT

OPENING WORDS

ABSTRACT

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1 INTRODUCTION

1.1 The objective

This thesis was made for Wärtsiä Finland Oy, unit of Power Plants. The objective of this thesis was to find out the easiest and cost efficient route for Cooling Water (CW) pipes from engine to radiator when the radiators are located on the roof of the power plant. The engines are in the Power House and their main purpose is to produce electricity for power-distribution network. There are many different installation ways for CW pipes when the radiators have been installed on the roof and this has been a problem. Now we are trying to find the best solution for CW pipes.

This subject was given by EMO group. Engineering Management Office (EMO) is established as a result of the Cost down Project. EMO incorporates the previous Documentation Organization. The objective is to manage the customer solution engineering process including partnerships with engineering companies, such as Citec Oy.

1.2 Research Plan

The Research starts by collecting all the different solutions of CW routes from engine to radiators in the power plants delivered by Wärtsilä and dividing these into different groups depending on the installation ways. For this thesis information were collected by interviewing designers, engineers and pipe experts who have experience in this type of installation. Costs for different solutions were obtained from Citec Oy which has all information of pipelines.

1.3 Thesis structure

Thesis has been divided into eight different chapters. The chapters one, two and three deals the company and theory of this subject. In the chapter four we can see the principles of cooling system. The chapter five deals cooling water re-routing and researching methods. In the chapter six we can see the comparison of different solutions and in the chapter seven results and conclusions.

2 INTRODUCTION OF THE COMPANY

2.1 Wärtsilä Corporation

Wärtsilä was founded in 1834 in city of Tohmajärvi, East Finland. Today, Wärtsilä has over 170 years of experience in different power solutions for marine and energy markets. In 2010, Wärtsilä's net sales were EUR 4,553 million and employed 17,528 employees in 160 locations in 70 countries around the world. Net sales consist of Ship Power with share of 26%, Services with share of 40% and Power Plants with share of 34%. Wärtsilä is listed on the NASDAQ OMX Helsinki, Finland. A figure of Wärtsilä's and its areas of business is given below.

/01/, /02/

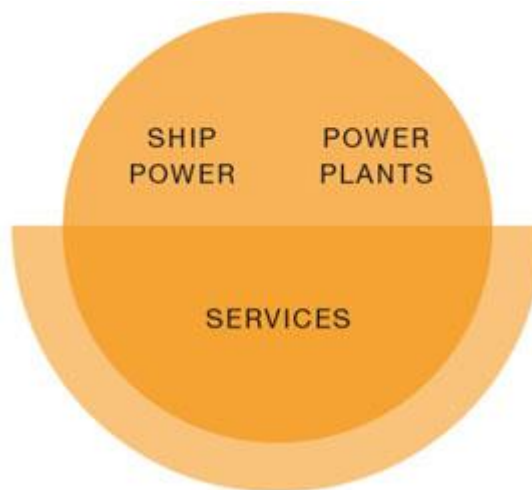


Figure 1. Wärtsilä's areas of business /10/

Wärtsilä has operations in three different areas of business – Ship Power, Services and Power Plants. Ship Power provides different solution for marine markets, such as engines, generating sets, reduction gears, propulsion equipment, automation and power distribution systems. Wärtsilä Power Plants offers flexible power plants for the decentralized power generation market. Wärtsilä Services supports its customers throughout the lifecycle of their installations.

2.2 Power Plants

Wärtsilä is a leading supplier of power plants for the decentralized power generation market and for the oil & gas industry. Its product portfolio consists of power plants, solutions for oil & gas industry and related support services with an output range of 1 to 300 MW. Wärtsilä deliver more than 2000 MW of power plants every year. There are four different kinds of power plant solutions.

- Gas power plants
- Oil power plants
- Combined heat & power plants
- Biopower /06/

Wärtsilä's values are presented in the figure 2.



Figure 2. Wärtsilä's values /8/

These days Wärtsilä has outsourced everyday designing and diagram drawing to Citec Oy. There are a lot of matters which should be taken into consideration when designing a power plant. The power output, fuel used and location of the radiators are a few examples that cause differences in the design.

3 COSTS IN THE EARLY STAGE OF THE PROJECT

The control of the costs is especially important when the project is in definition and planning phase. It is very important that the wideness, the resources, the time scale and many other things are decided before the project starts. These decisions define the whole structure of the costs and the budget of the project. /11/

In figure 3 it can be seen how important it is to define the costs in the beginning of the project. Most of the projects costs will be determined by the solutions which have been made in the early planning stage of the project. A possibility to influence the costs of the project will become weaker after the project is started. As the starting point is defined in the beginning, the solutions which have already been made become harder to change and more expensive. /11/

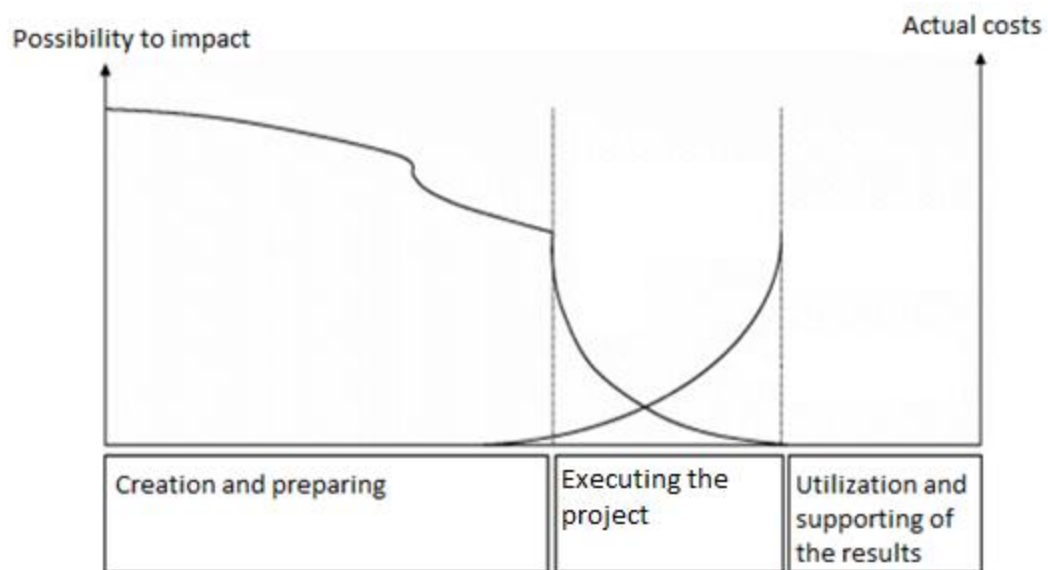


Figure 3. Actual costs and influence possibilities on the costs. /9/

Figure 4 below shows the importance and number of the decisions during the project. The number of the decisions in the beginning is small but the importance of these is great.

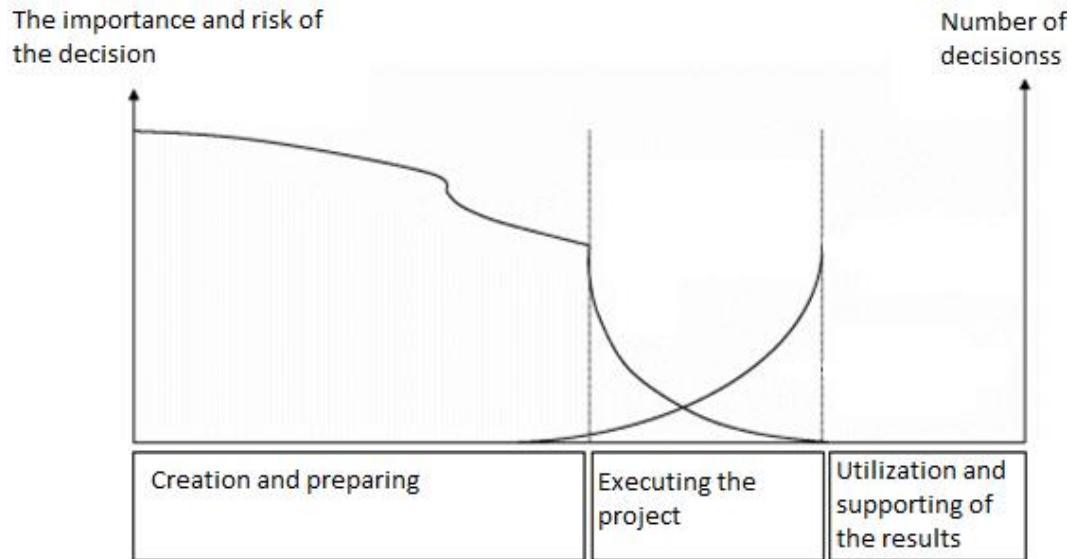


Figure 4. The importance and number of decisions in the life span of the project.
/11/

For example, the approval of the projects scale and investment decisions in the beginning creates limits for upcoming costs. The projects sale price may become too low if the delivery company underestimates the costs while making the offer, therefore it can be an unprofitable project. When the project moves on the number of decisions increases but the significance of a single decision is much smaller.

/11/

It is very important that the costs are defined in the beginning of the project. The good planning in the beginning can save a lot of money and time in the project. Changing the decisions is a lot harder after the project has been started.

4 COOLING SYSTEM

4.1 Basics

A cooling system of a power plant consists of five different parts: air & dirt separators, cooling temperature control, cooling towers, heat exchangers, and radiators.

The main purpose of the engine cooling system is to remove the generated heat made by the engine and keep the lubricating oil at a normal temperature. A secondary function is preheating the engine block before starting. The cooling water system removes heat from four main sources of heat in a diesel/gas engine:

- Cylinder jacket and cylinder head cooling
- High Temperature charge air cooler (HT CAC)
- Low Temperature charge air cooler (LT CAC)
- Lube oil cooler (LOC)

The circuit of cooling system can be seen in figure 5.

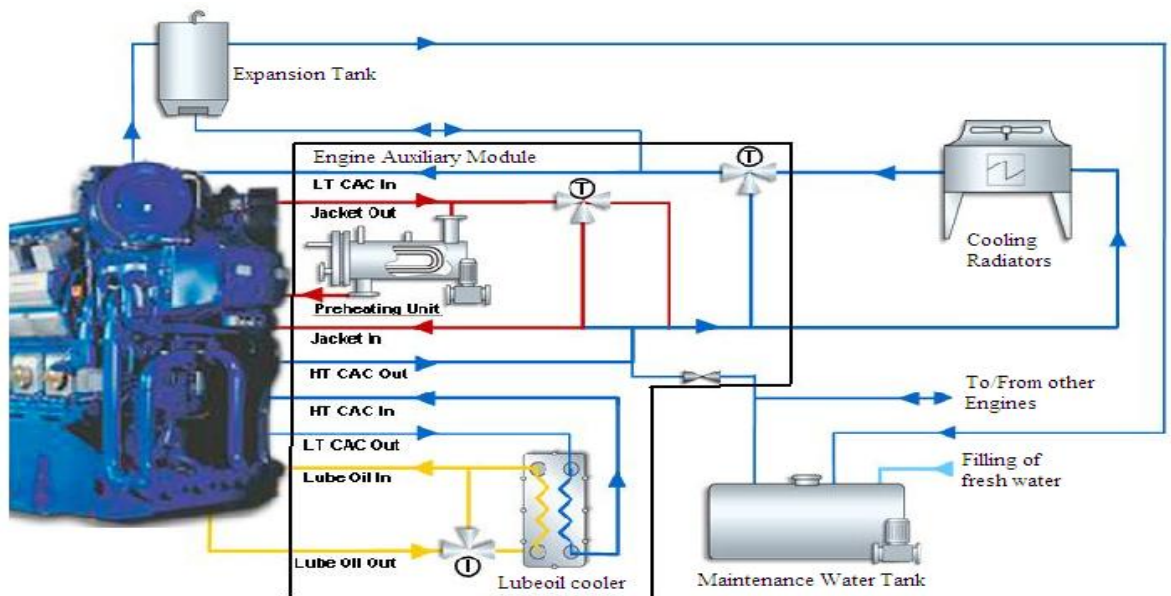


Figure 5. Cooling water system with radiator cooling. /3/

4.2 Cooling Water System Components

4.2.1 Air & Dirt Separators

The spirovent air & dirt separator is a standard component in the EAM. The design makes it possible for the separator to remove air bubbles that rise up and collect into the air chamber and the dirt particles that sink onto the bottom of the dirt chamber. See the operational principle in the figure 7 and location in the figure 6.

/3/

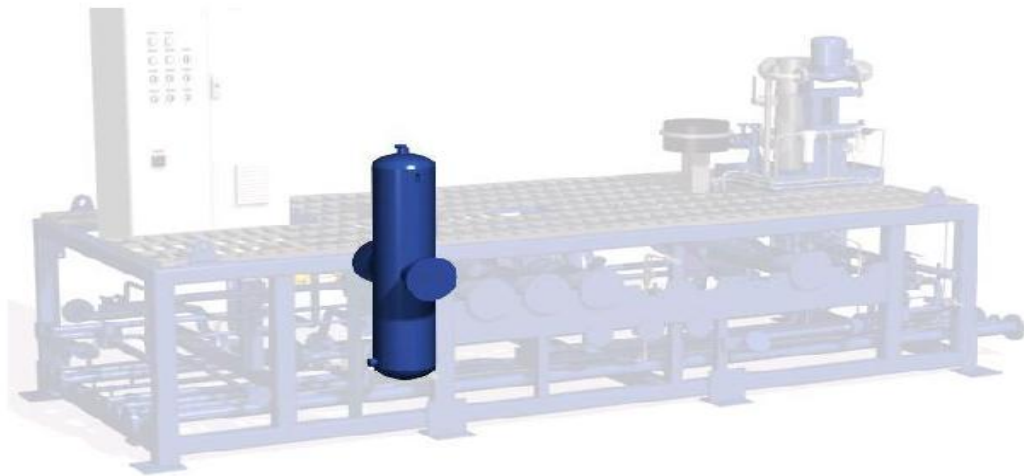


Figure 6. Spirovent air & dirt separator installed in EAM. /3/



Figure 7. Spirovent air & dirt separator. /3/

4.2.2 Cooling water temperature control

The cooling water temperature control in the engine is done by controlling the positions of HT and LT 3-way valves (TCVs) to get water of the optimal temperature into the engine. The primary cooling system which can be commonly used by radiators, the cooling tower or some special cooling arrangement is advised to be controlled with the help of variable frequency drives in order to match it with the 3-way valve control enabling optimized cooling control. See the typical remote-controlled 3-way valve in figure 8. /3/



Figure 8. Remote-controlled 3-way valve. /3/

4.2.3 Heat Exchanger

When we want to recover as much energy produced by the engine as possible, a heat exchanger should be installed in the condensate line before the condensate returns to the feed water tank. In this exchanger the heat will pass from the HT water engine system to the condensate water of the waste heat recovery system. See picture of heat exchanger in the figure 9. /3/



Figure 9. Lube oil cooler as a heat exchanger. /3/

4.3 Radiators

There are two mainly used places for radiators. The radiators can be mounted on the roof of the power house or on a separate radiator field next to the power house. The radiator cooling system is a closed circuit system where the coolant liquid flows through a cell which is full of small tubes and that is cooled by a forced air flow. Radiator cooling has the following advantages:

- Closed system so there is no water consumption
- Power plant can be located anywhere regardless of water availability
- Easy system to use, easy to maintain and does not require a lot of service
- Simple and easy to keep clean /5/

4.4 Radiator Locations

4.4.1 Radiator Field

The radiator field is the commonly used solution. Its advantages are:

- Easy to build and work with
- Easy to maintain

The disadvantages of the radiator fields are:

- Pipe costs are high
- Takes a lot of space in the area
- Cooling is not so efficient as in the solution with radiators on roof

In the figure 10 we can see a radiator field solution.



Figure 10. Radiator field in a power plant, Brazil.

4.4.2 Radiators on the Roof

When the space is limited, the radiators are usually mounted on the roof of the power house. A closer inspection for this solution is in chapter 5. In the figure 11 we can see radiators on the roof solution.



Figure 11. Radiators on the roof in a power plant, Brazil.

5 RE-ROUTING OF COOLING WATER

5.1 The Starting Point for the Re-Routing

The objective of this thesis was to find out the easiest and most cost efficient route for CW pipes from the engine to the radiator when the radiators are located on the roof of the power plant. There are many different installation ways for CW pipes when the radiators have been installed on the roof. It was agreed that a matrix should be produced as a result where we can see all the different installation ways and all the necessary specifications, such as entry to PH, entry from top or under the hall, directness, and price for €/m and €/kg. The matrix is not included to this thesis because the information is classified.

Information and documents were collected of power plant projects that had radiators on the roof. The Excel file of 36 projects and there was a section where the projects could be divided into two parts, radiators on the roof or not. With a help of a web-based IDM system, we could find 36 projects and we started to collect layout drawings from the cooling systems. Some of the projects were not delivered as EPC (Engineer, Procure and Construct) type so the project folder was usually empty. That kind of projects is called EEQ (Engineered Equipment Delivery). It means that Wärtsilä only delivers the equipment and the customer builds the engine hall and other buildings by themselves. EEQ projects were excluded from this comparison.

5.2 Installation Groups

We got 13 projects the drawings of which we were able to find. We printed out the layouts and started to divide the different installation ways into different groups. We got the following groups:

1. CW pipes enter the hall from the upper side of the hall and through the wall. A direct line from each radiator group to the engine.
2. CW pipes enter the hall from the lower side of the hall and through the wall. A direct line from each radiator group to the engine.
3. CW pipes enter the hall from the lower side of the hall, but first the CW pipes are collected into a group on the roof and on the ground and divided for each engine.
4. CW pipes enter the hall from the upper side of the hall and through the wall, but first the CW pipes are collected into a group on the roof and inside the hall divided for each engine.
5. CW pipes enter the hall through the roof. A direct line from each radiator group to the engine.

We took 13 different projects for a closer inspection. We excluded three projects right away because the design was so unique that it was not good for this comparison and ten projects were taken for the comparison. We started to edit the matrix and arranged the projects by their delivery year. We printed out the matrix and used it for the interviews.

5.3 Collecting Information for the Comparison

We had a look at different installation ways and made a small grading for each of them. Interviews were started by collecting the names and locations of designers, supervisors and project engineers. A questionnaire was drawn up with a few simple questions regarding installation ways and their advantages and the disadvantages and an opportunity to give a proposal for any improvements. Six different designers and engineers were interviewed. Eight good answers were received from around the world, which was a good basis for the comparison.

In the comparison the interviewees were comparing two different solutions: radiators on the roof and the radiator field solution. While interviewing, notes were taken and all the advantages and the disadvantages were gathered together. The designers pointed out the critical spots from the layouts. There were a lot of different kinds of opinions. Especially the route from the engine to the radiator and the pre-fabricating provoked a lot of discussion.

Advantages when the radiators are on the roof:

- Air venting piping easy to make from the radiators to the expansion vessel
- Higher efficiency
- CW pressures are better, less CW air problems
- Tank yard, FTH, the unloading station and the other buildings can be built closer to the Power House. Therefore less space needed for the plant, less piping, fewer cables and less pipe supports

Disadvantages when the radiators are on the roof:

- More complicated construction work, such as the roof, the steel structures, the roof ventilation units and the platforms
- CW piping inside the power house requires a lot of working hours
- Working on the roof. You have to cover the roof from welding splashes and sparks
- More leaking possibilities due to the lead-ins
- Possible extra insulation for the HT water pipelines

5.4 Route from the Engine to the Radiator

The location of the radiators in the old design is very wide. There have not been any standardized designs for CW pipe routes. Designers have taken old models and edited them for their own projects. In this way, all possible faults will also follow to the other projects, which is not good. Now we are researching the best route for CW pipes. The different solutions were divided into different groups and most of the solutions belonged to group number one. That is very commonly used

and most of the new projects are using this solution. Its advantages are short route from the radiator to the engine and it does not need any lead-ins because the entry is next to the engine hall through the wall. Its disadvantages are that when the CW pipes go inside the PH, working with the pipes is very difficult and it takes a lot of man hours. Also logistics can cause some problems for the installation. If the engines come onto the site early and the building of power houses starts when the engines are already inside, the installation work for CW pipes will be very difficult. There are, for example, exhaust gas pipes, EAM modules and charge air inlet tubes in the way when you are mounting the CW pipes. If we are using SG (Gas Engine) engines it is even more difficult. SG engines use gas as their fuel so they do not need any separator for the fuel. The lack of separator means, that there is no second crane like in a HFO engine. A crane helps when mounting the pipes inside the PH.

5.5 Pre-fabricating

5.5.1 Basics

One other thing that was researched by interviewing was the pre-fabricating of the CW pipes. It is not the first time when Wärtsilä is using pre-fabricated pipes. They have used in projects with a short delivery time or when fabricating at the site has been very expensive.

Advantages of pre-fabricating:

- Fast to mount
- Pipes are cleaner because of less welding seams
- Less possible leaking points
- Easier to clean (flushing and pickling)
- Installation is cheaper

Disadvantages of pre-fabricating:

- Logistics gets more complicated
- Installation requires more accuracy

- Possibly more Change Order work
- Expensive

As we can see from above, there are some advantages and disadvantages. Logistics will become more complicated because all the pre-fabricated pipes have to be numbered very well. Also organizing the pipes into a container is more complicated due to the pre-fabricated angles, etc. Installation work will also be more difficult. Pictures and layouts have to be followed and ensured that the right pipe is in the right place. If the supervisors and the subcontractor do not pay enough attention to the installation work, there is a possibility that the heads of the pipes do not match and the subcontractor tries to do a change order. Change order work pays extra for the company.

The pre-fabricated pipes are good for a project with a short delivery time. It saves time because there is not so much welding work. Generally pipes are cleaner because the angles are made by bending. This helps when cleaning, flushing and pickling the pipes. Welding seam is a very critical spot when pickling. Usually the hardest place to clean is the welding seam. By reducing welds the cleaning procedure is faster and easier.

It depends on the country as well, if there are any reasons to use pre-fabricated pipes or not. Wärtsilä sells power plants all over the world. The price level varies widely between different countries. For example, work in Canada is much more expensive than in Brazil or in Pakistan. If Wärtsilä sells a power plant to Canada, it is not self-evident that it saves money if some of the products are pre-fabricated. There are also different Labor Productivity indices between countries. See list of Labor Productivity indices in table 1.

Table 1. World Labor Productivity. /7/

| TABLE 3 | |
|---------------------------------|---------------------|
| World Labor Productivity | |
| Location | Productivity |
| Austria | 1.60 (1.57 - 2.10) |
| Australia | 1.20 (0.96 - 1.45) |
| Argentina | 2.30 (1.30 - 2.60) |
| Brazil | 2.80 (1.23 - 3.10) |
| Belgium | 1.45 (1.30 - 1.50) |
| Canada, East | 1.14 (1.08 - 1.17) |
| Canada, West | 1.07 (1.02 - 1.11) |
| Ceylon | 3.50 |
| Chile | 2.70 (2.00 - 2.09) |
| Denmark | 1.28 (1.25 - 1.30) |
| Dominican Republic | 2.77 |
| Finland | 1.28 (1.24 - 1.28) |
| France | 1.33 (0.80 - 1.54) |
| Germany | 1.28 (1.00 - 1.33) |
| Ghana | 3.50 |
| India | 4.50 (2.50 - 10.0) |
| Iran | 4.00 |
| Iraq | 3.50 |
| Italy | 1.45 (1.10 - 1.48) |
| Japan | 1.90 (1.00 - 2.00) |
| Mexico | 2.00 (1.54 - 3.15) |
| Netherlands | 1.80 (1.60 - 3.30) |
| Nicaragua | 2.67 |
| Norway | 1.23 |
| Philippines | 1.80 |
| Portugal | 3.00 |
| Puerto Rico | 1.80 |
| Singapore | 4.00 |
| South Africa | 1.58 |
| Spain | 2.95 |
| Sweden | 1.13 (1.10 - 1.20) |
| Taiwan | 6.80 (2.00 - 7.20) |
| Turkey | 2.32 |
| United Kingdom | 1.53 (0.70 - 2.46) |
| Venezuela | 1.22 |
| Yugoslavia | 1.40 (1.25 - 2.03) |

For example, if you manufacture one part in Finland and it takes an hour, but if you manufacture that same part in Ghana it takes about three times longer. This is why you have to calculate the prices very well.

5.5.2 Pre-fabrication Cost Estimate for UTE Suape's Solution

We got one cost estimate for cooling water pipes. For the price were included:

- Material
- Work (bending, welding, sawing for certain dimensions and marking of the pipes)
- Painting

Cost estimate does not include:

- Packing/container

The pipes are made so well in Finland that at the site the pipe clips only have to be assembled and the pre-fabricated pipes welded back together regarding the marks.

The total amount of the welds for DN100 and DN 200 pipes were 173 pieces. If we pre-fabricate these pipes we can reduce the amount of welds to 64 pieces. One welding seam takes about two hours to be made. By pre-fabricating we can reduce the production time about 218 hours for one engine. For this calculation the smaller pipes from the expansion vessel is not included. The cost estimate is not included to this thesis because the information is classified.

6 COMPARISON OF DIFFERENT SOLUTIONS

6.1 Basics

We got the information and prices regarding the pipelines from Citec Oy in an Excel file. There were prices for both material and the work. Prices were calculated by using Finland's labor-productivity index. See list of data and picture of example pipeline:

- Sizes
- Pipe length and type (were taken into comparison)
- Reducers
- Bends
- Tees
- Flanges
- Valves
- Supports
- Welds (were taken into comparison)
- Insulated, YES or NO
- Bolts & Gaskets
- Bellows
- Weight (were taken into comparison)
- Subtotal price for material (were taken into comparison)
- Subtotal price for work (were taken into comparison)

Prices were calculated for five different solutions that were selected for this comparison. Key figures were pipe length, weight, and prices for material and work. There were some problems in the comparison because of the number of the radiators. The new design uses six radiator sets instead of four radiator sets in the old one. Prices were calculated for one radiator set so that the prices are comparable. The differences between the different solutions were quite remarkable. The solutions were divided into two different groups depending on the engine type. In the first group, there were Wärtsilä 46 and Wärtsilä 50 engines, mainly using DN200 pipes. In the second group, there were Wärtsilä 32 and Wärtsilä 34SG engines, which mainly use DN150 pipes.

6.2 First group

Three different solutions were in the first group. They were UTE Suape, Attock Gen Limited and Ewekoro projects. Suape and Attock had a direct line from the radiators to the engine, where Ewekoro was collecting the pipes together on the roof and dividing them again on the ground. In the figure 12 it can be seen that Suape's and Attock's solutions are much cheaper than Ewekoro's. The pipe length is much shorter in the two first mentioned projects.

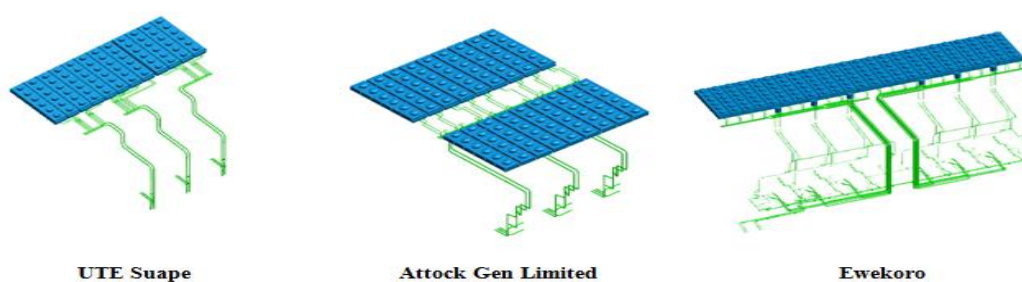


Figure 12. Solutions of the first group.

In the figure 13 it can be seen that UTE Suape is the cheapest solution in this group and Ewekoro the most expensive. The difference between Attock and Suape is not that big.

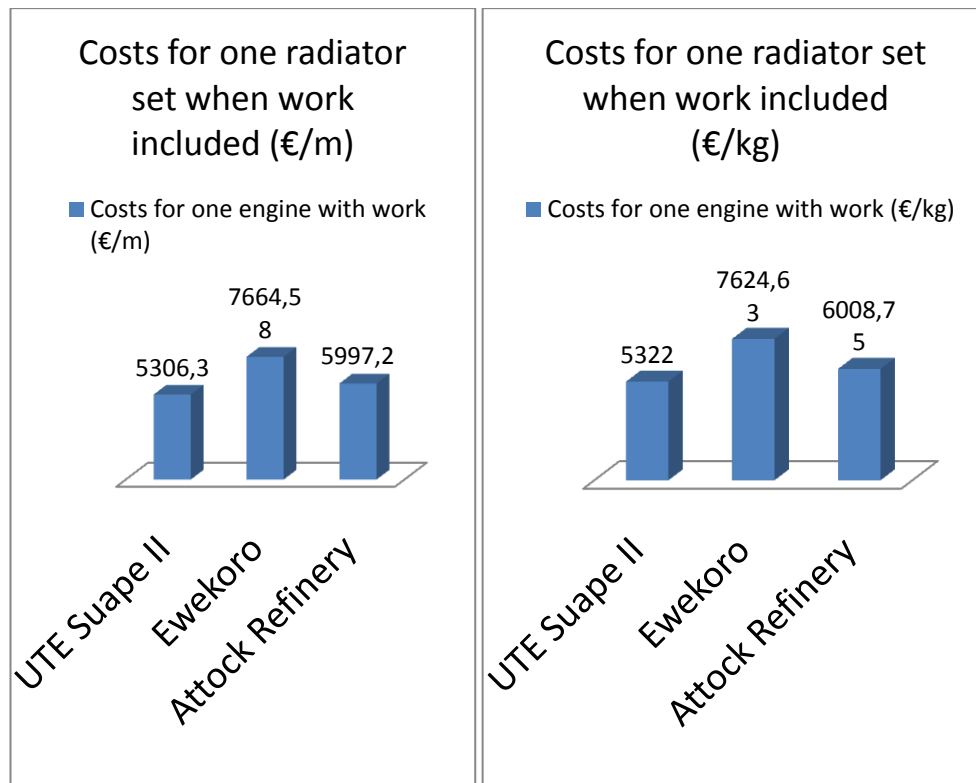


Figure 13. Comparison for one radiator set.

If we calculate the prices for one engine, Attock is cheaper because it uses four radiator sets instead of six.

If we calculate the prices for one engine, Attock is cheaper because it uses four radiator sets instead of six. It can be seen in the figure 14.

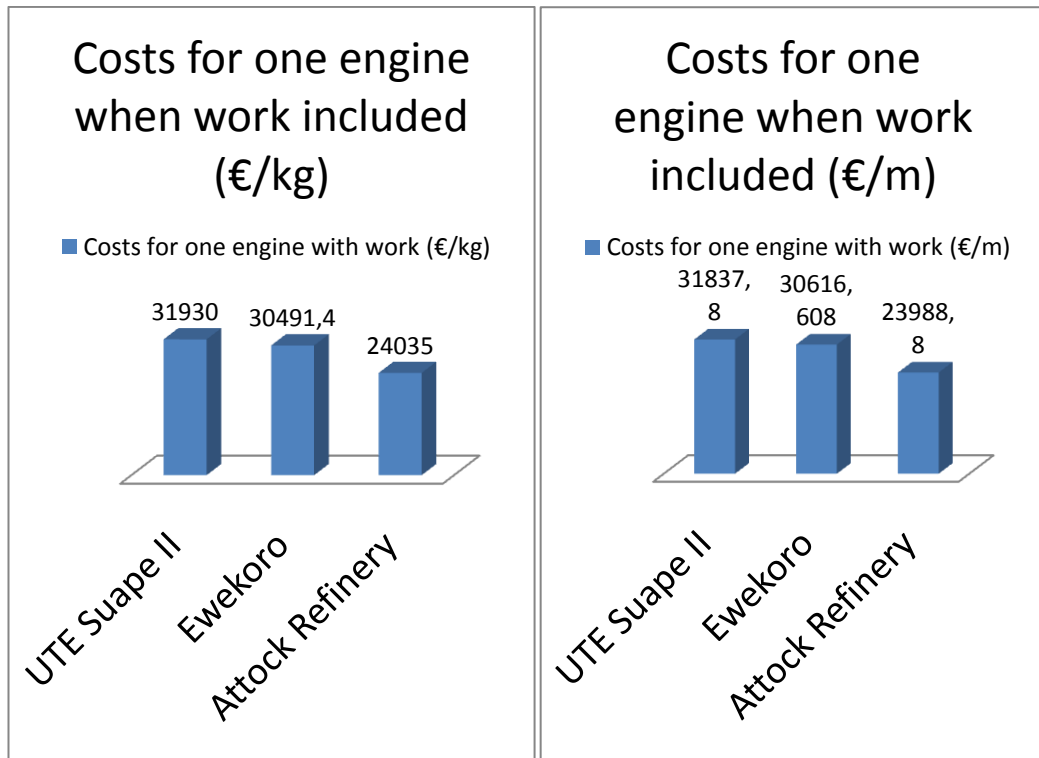


Figure 14. Comparison for one engine. Attock and Ewekoro are using four radiator sets and Suape six.

6.3 Second Group

In the second group there were two different solutions: UTE Linhares and Al-Katrana projects. Both solutions used the same amount of radiator sets so the comparison was easy to do. See the solutions of the second group in figure 15.

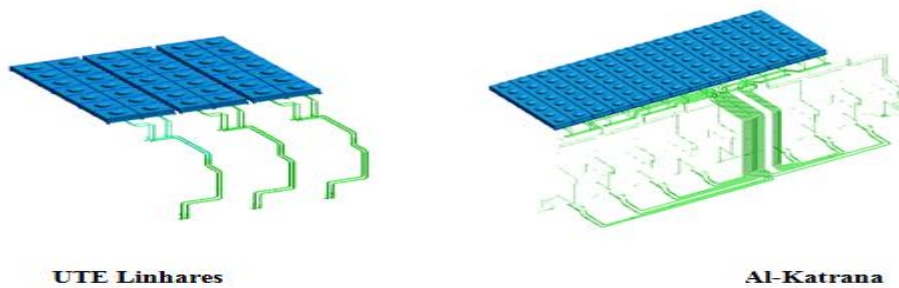


Figure 15. Solutions of the second group.

Al-Katrana has collected pipes together on the roof and divided them again on the ground. It is easy to conclude from the picture that UTE Linhares is cheaper. It is using less pipe meters and it has a direct line from the radiator to the engine.

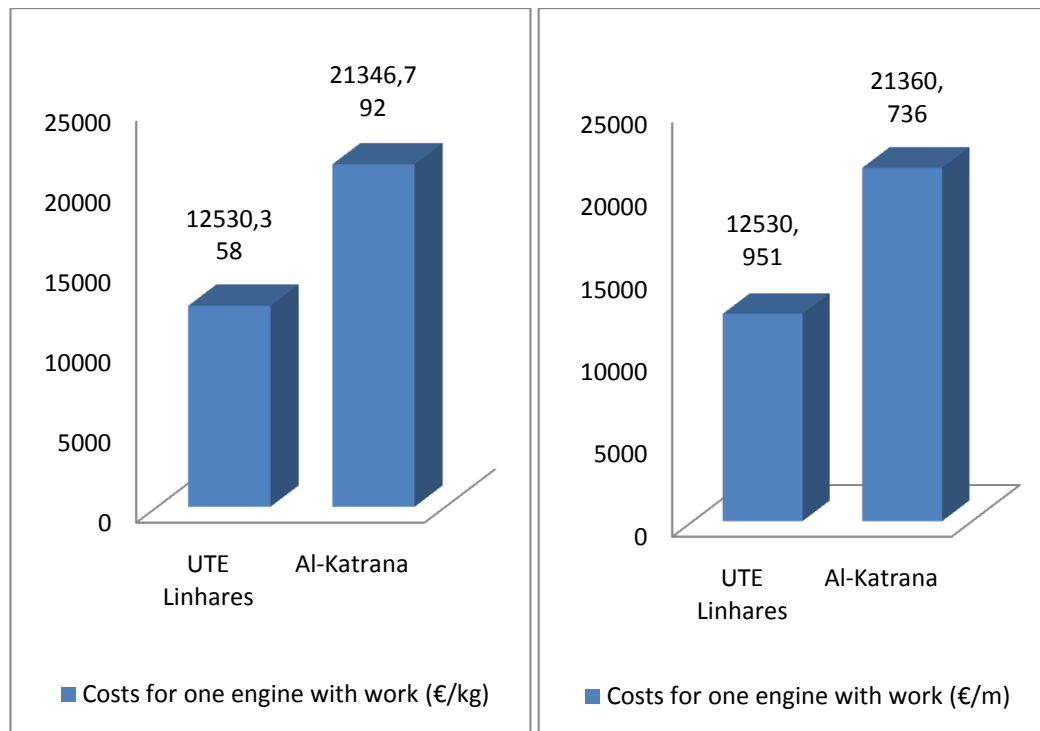


Figure 16. Comparison for one engine

One can see in the figure 16 above that UTE Linhares is a lot cheaper than Al-Katrana. For a power plant with ten engines 88,164€ is saved if Linhares solution is used instead of Al-Katrana's solution.

6.4 Grading for the First Group

6.4.1 UTE Suape

UTE Suape's solution is now the most commonly used solution. When a customer searches for a power plant with the radiators on the roof, Suape's solution is the recommended solution. See the picture of UTE Suape in the figure 17.

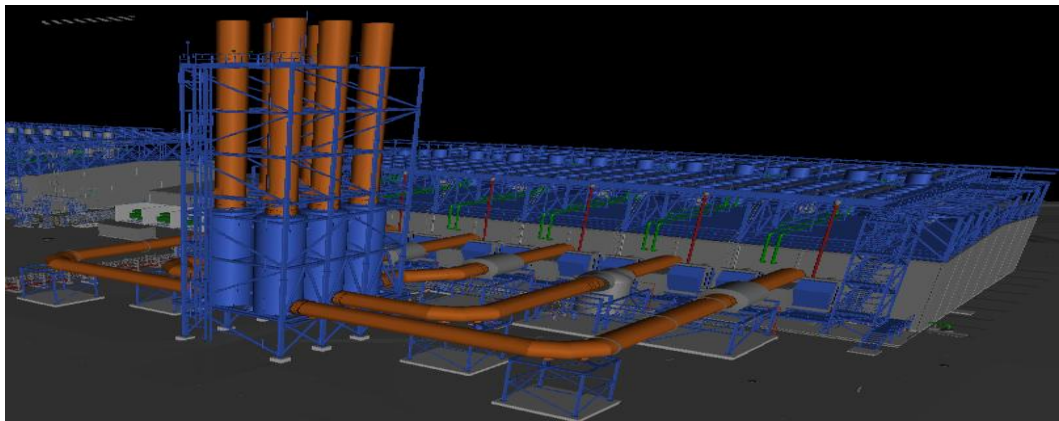


Figure 17. UTE Suape.

| ADVANTAGES | DISADVANTAGES |
|--|--|
| <ul style="list-style-type: none"> • Easy to standardize • Pipings are similar regardless of the number of the engines | <ul style="list-style-type: none"> • A lot of bends and tees • The amount of piping work on the roof and inside the PH |

6.4.2 Attock Gen Limited

Attock Gen Limited was the only solution with a route from the radiators to the engine through the roof. The pipings were quite simple and there were lot of direct lines. See the picture of Attock Gen Limited in the figure 18.

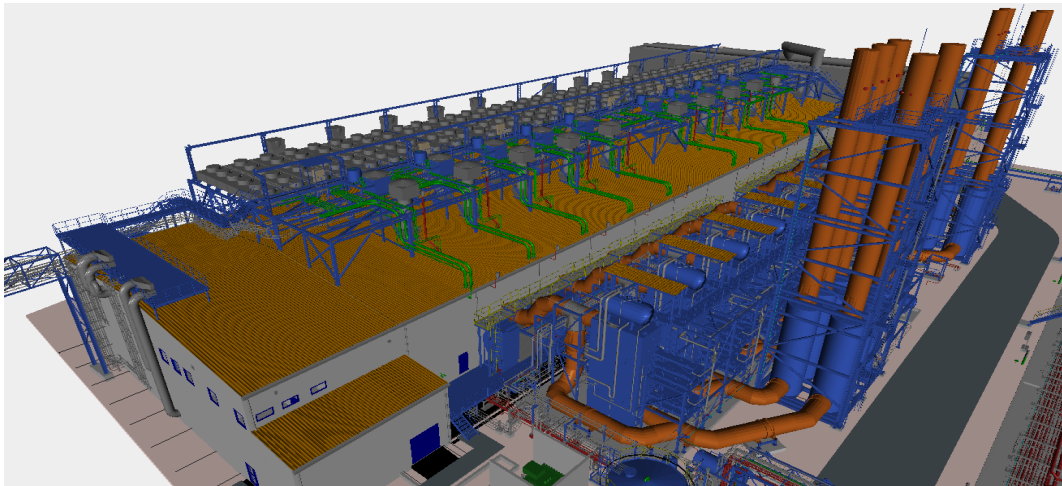


Figure 18. Attock Gen Limited.

| ADVANTAGES | DISADVANTAGES |
|--|--|
| <ul style="list-style-type: none"> • Simple piping route • Small amount of bends, tees and pipes | <ul style="list-style-type: none"> • Possible leakages due to the lead-ins • Hard to standardize • Piping inside the power house requires a lot of man hours. |

6.4.3 Ewekoro

Ewekoro's solution was very expensive. Solution has been used because of the customer's demand. In this solution the pipes are collected together on the roof and divided again on the ground. It is very clear that there are lots of pipe meters, which makes the price higher. See the picture of Ewekoro in the figure 19.

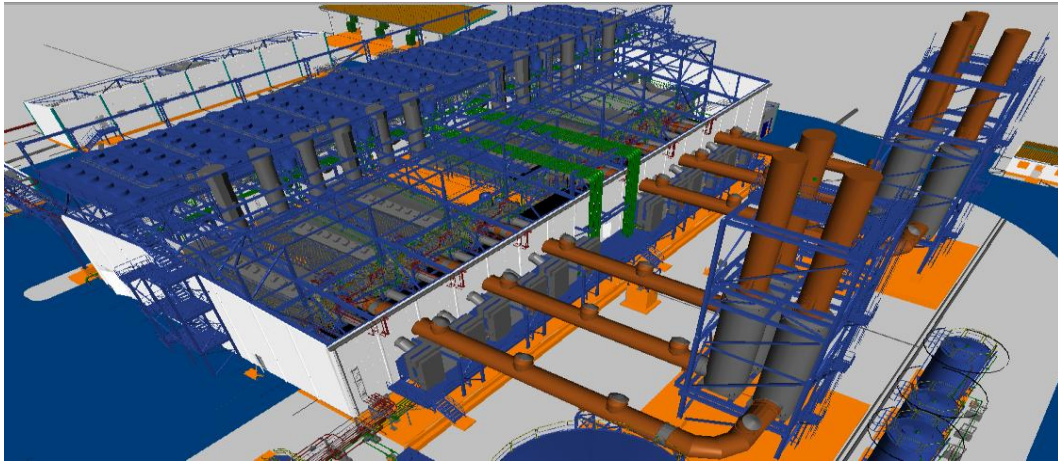


Figure 19. Ewekoro.

| ADVANTAGES | DISADVANTAGES |
|---|--|
| <ul style="list-style-type: none">• Direct lines• Easy to work | <ul style="list-style-type: none">• Expensive• A lot of pipe work |

6.5 Grading for the Second Group

6.5.1 UTE Linhares

UTE Linhares was the same kind of solution as UTE Suape uses. It is quite simple and it would be easy to standardize, like UTE Suape. This solution goes through the roof and has a rather direct line from the radiators to the engine. See the picture of UTE Linhares in the figure 20.

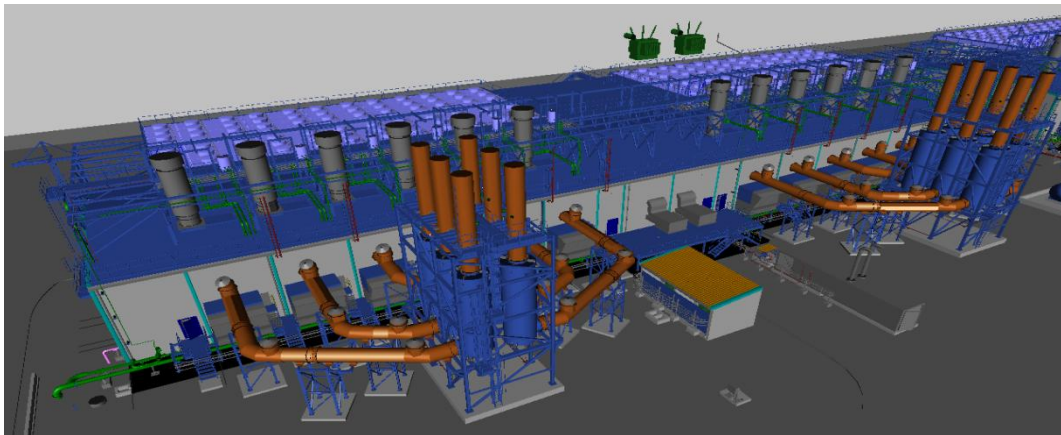


Figure 20. UTE Linhares.

| ADVANTAGES | DISADVANTAGES |
|--|---|
| <ul style="list-style-type: none"> • A direct line • Easy to standardize | <ul style="list-style-type: none"> • Possible leakages due to the lead-ins • Piping inside the power house requires a lot of man hours. |

6.5.2 Al-Katrana

Al-Katrana uses solution similar to Ewekoro's solution. The pipes are collected together on the roof and divided again on the ground. See the picture of Al-Katrana in the figure 21.

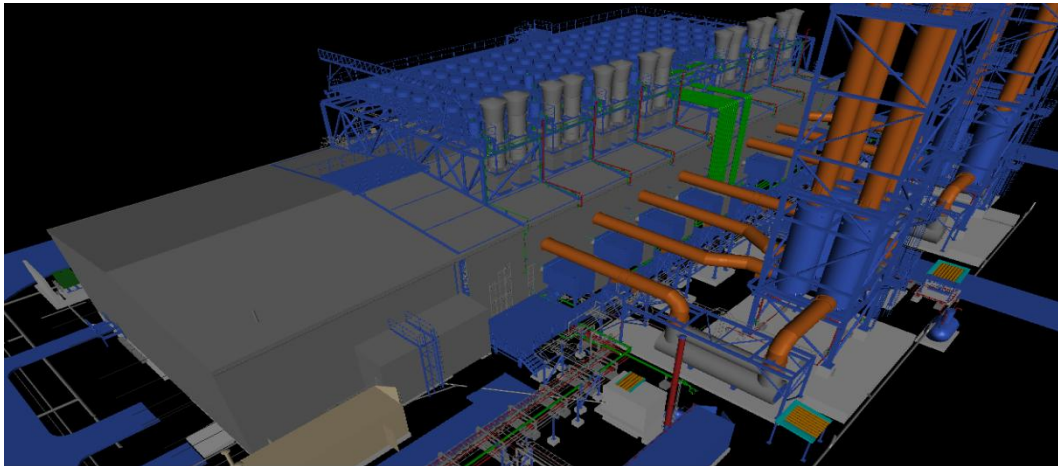


Figure 21. Al-Katrana.

| ADVANTAGES | DISADVANTAGES |
|---|--|
| <ul style="list-style-type: none">• A direct lines• Easy to work | <ul style="list-style-type: none">• Expensive• Lot of pipe work |

7 RESULTS AND CONCLUSION

7.1 Results

As a result we had a well-defined matrix table where all the different pipeline solutions and comparison were compiled. The pipeline layout drawings were linked from IDM into the matrix table and now the comparison, and in the future the standardization, is easy and fast to do.

From the first group UTE Suape's solution was the cheapest if we calculate the pipelines for one radiator set. If we calculate the pipelines for a one engine, Attock Gen Limited's solution is the cheapest. Attock uses the old design whereas Suape uses the newer one, and Attock has two radiator sets less. According to Thomas Staffans, the Development Manager, Wärtsilä does not use the old design anymore, which makes Suape's solution the cheapest. Suape's design is not just the cheapest but it is also the best according to the interviews and the point of view of the standardization. The piping is similar regardless of the number of the engines and this is a great advantage when designing a power plant.

In the second group there were only two different solutions and it was obvious that the solution of UTE Linhares is better and cheaper. Linhares route from the radiator to the engine goes through the roof and has quite a direct line, so it uses a small amount of pipe meters. The matrix and all cost estimates are not included to this thesis because the information is classified.

7.2 Future research

For the future research Suape's solution would be chosen. We came to this decision because this solution is easy to modify for power plants and it does not depend on the number of the engines. There are still some sections that need more research and improvements. Improvements are:

- Piping on the roof more clear and less bends.
- Possible pre-fabrication for smaller pipes on the roof.
- Air ventilation. A straight line from the HT water pipe to the expansion vessel.

7.3 Reliability

Citec Oy gave all the prices regarding the pipelines. The Prices are not the exact prices but very close to it. Each project has its own offers at the time and that depends on the market prices. The table of World Labor Productivity is from year 1983 so it is almost 30 years old. That information will have changed. It still shows how big differences there are between the countries.

7.4 Conclusions

The subject of this thesis was cooling water pipeline re-routing and the comparison of different cooling water pipeline solutions for power plants. I have worked in Wärtsilä's power plant as a mechanical supervisor and my work experience was a great advantage in the study of this thesis.

Thesis went according the time schedule and it was challenging and interesting to do. I had an opportunity to meet new people in Wärtsilä and to get familiar with different areas of business. This is positive in regard to my future plans. Collaboration with colleagues and other people worked very well.

For a result I got well-defined matrix table and it was such as my supervisors wanted. They were satisfied with the result.

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LIST OF APPENDICES

Appendix 1. Questionnaire

Appendix 1



Question form

POWER PLANTS WITH RADIATORS ON ROOF, COOLING WATERPIPES

Please answer for following questions. Questions are related to installations and its phases.

Name of the project:

Year:

Engine type and number of engines:

What was good in this type of installation? (Easy to install, free route to radiators...?)

[You can edit your answer inside this box.]

What was bad in this type of installation? (Hard to install, leakages when it was raining...?)

[You can edit your answer inside this box.]

What would you do on a different way? (Take another route, better waterproofing...?)

[You can edit your answer inside this box.]

Free word

[You can edit your answer inside this box.]

Questionnaire