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ENGINE AUXILIARY MODULE CABLING OPTIMIZATION

Technology

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FOREWORD

I spent summer 2013 in Jordan, IPP3 power plant as an electrical trainee. The assignment lasted 6 months. During that time I got acquainted with many people who were complete professionals in their own field. I learned a lot from them. This thesis is supporting that trainee period very well and the other way around. I had not seen a Wärtsilä engine live before that site assignment, either. This helped me a lot to perceive matters.

I was very excited about this thesis because the subject interested me a lot and I knew all the time what and why I was doing something and why things has to be done in certain way. I had a clear vision about the matters at the beginning because I worked a lot with problems which are solved or taken into better direction in this thesis.

The starting point of the thesis was good because it had straight connection to site work and I knew lot of people who are working with this subject in field and office. They were good contacts to me because their points of views were important to develop solutions to right direction. I consulted Wärtsilä's project team many times about the matters and what they think about our solutions and developing direction.

I would like to thank Mr. Rami Berg from the Technology department who operated as my primary supervisor. He helped me to perceive different kind of issues and content of this thesis.

I would like to thank also Mr. Mikael Malm from the Power plant project department who generated the original idea of this thesis. These two persons and their colleagues helped me a lot along with my work

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Sähkötekniikan koulutusohjelma

TIIVISTELMÄ

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Opinnäytetyön tarkoituksena oli etsiä uusia ratkaisuja moottorin apukoneikko kaapin (BJA) kaapeloinnille, jolla pystyttäisiin minimoimaan kaikki työmaalla tapahtuvat reklamaatiot sekä tuottamaan mahdollisimman laadukkaita tuotteita. Vanha kaapelointitapa altisti BJA-kaapin monelle ongelmalle, joita on myös vaikea korjata jälkeenpäin. Tarkoituksena oli löytää ratkaisu, joka tuottaisi merkittävää helpotusta BJA-kaapin kaapeloinnille ja joka myös vaikuttaisi positiivisesti moduulien toimitusaikoihin.

Wärtsilä on yksi maailman johtavista voimalaitoksien toimittajista, mikä luo suuret odotukset myös asiakkaan puolelta. Voimalaitoksen pitää olla laadultaan huippuluokkaa, jonka takia laitoksien täytyy olla jokaista yksityiskohtaa myöten hyvin suunniteltu ja toteutettu. Kun uusia ratkaisuja etsittiin, oli tärkeää huomioida standardit ja määräykset. Tämä pystyttiin varmistamaan sillä, että komponenteiksi valittiin vain ensiluokkaisia tuotteita ja joiden määräyksien täyttyminen pystyttiin varmistamaan. Suurin osa lähdeaineistosta saatiin internetistä, tuoteluetteloista sekä suunnittelu- ja projekti-insinöörien aiemmista kokemuksista ja näkemyksistä. Myös omat käytännössä koetut asiat vaikuttivat työn etenemiseen.

Työ eteni hyvin kronologisesti asia kerrallaan, joten työ oli hyvin johdonmukainen. Oli mielenkiintoista huomata, miten hyvin ennalta tiedettyihin ongelmiin oli jo ratkaisut olemassa. Tämä selvisi usein kun myyntiedustajalle esitettiin ongelma ja siihen toivottavan tyyppinen sovellus. Kaiken kaikkiaan ongelmiin löytyi sopiva ratkaisu. Työn tulokset on tarkoitus ottaa käytäntöön lähiaikoina ja ne tulevat helpottamaan kaikkien osapuolien töitä aina kokoonpanosta asennusvaiheeseen asti.

Avainsanat	laatu, BJA-kaapelointi, voimalaitos

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ABSTRACT

Author	Pekka Hautio
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The purpose of this thesis was to find a solution regarding to the common issues of the Engine auxiliary module panel (BJA) cabling. The old cabling method exposed the BJA panel to several quality issues which are not tolerated. The issues can be very difficult to solve after installation. The issues have also a strong influence on quality which generates a lot of problems. The aim was to find solutions which outstandingly improve The BJA panel cabling. This affects strongly the time of delivery also.

When new solutions were searched for, it was important to take into consideration the requirements and standards. The thesis proceeded chronologically from the issue recognizing stage to solving stage. Each chapter handles different kind of solution regarding to the BJA panel. The main sources were found on the internet, product catalogues and by interviewing design and project engineers who have worked on with the BJA panel issues.

The results of this thesis were good. It was interesting to notice that there are solutions when the matter was introduced to the right person. Often the product representative had a solution when he was informed about the issues by us. The economical inspect was held also in mind during the research. The purpose is that the solutions suggested in this thesis are taken into use in the near future and when that happens, it will help everyone from the assembly line to the site installation personnel.

Keywords Quality, BJA panel cabling, power plant, new solutions

CONTENTS

LIST OF FIGURES AND TABLES

LIST OF USED ABBREVIATIONS

AI	Analog input
AO	Analog output
Base load	Generating power for continuous use
BJA Panel	Engine auxiliary module control panel
CCR	Central Control Room
DF	Duel Fuel (diesel and natural gas)
DI	Digital input
DIN rail	used for mounting equipment inside electrical cabin
DIN	Deutsches Institut für Normung. (German standardisation institution)
EAM	Engine Auxiliary module
EFB	Engine Fuel Booster
EMC	Electro Magnetic Compatibility
EN	European Standard
FAT	Factory Test
HFO	Heavy Fuel Oil
IDM	Wärtsilä Integrated Document Management
IEC	International Electrotechnical Commission (Electrical standards)
IP	Enclosure classification

LFO	Light Fuel Oil
PA6	Polyamide
Peak load	Generating power for peak use
PT100	heat adjustable resistor
UL-94	flame-retardant classification standard
U_N	Rated nominal voltage level

LIST OF APPENDICES

1 INTRODUCTION

The purpose of this thesis was to improve the weaknesses of the Wärtsilä BJA panel. This topic is very important for Wärtsilä because Wärtsilä is delivering different kind of power plants all over the world and has a huge amount of BJA panels in the field. There are lots of teething problems in the panel installation and planning which must be solved. The customer and stringent standards demand quality for the results and that is why products must be developed all the time. Hot weather, moisture, regulations, heat resistance, vibration and dust are the major factors which must be taken into account when planning new solutions. The background for this thesis was Wärtsilä's power plant projects.

The BJA panel has fallen behind from the other developed products. That is why it is important to update the BJA panel to meet requirements of these days. This thesis deals with how to improve the BJA cabling to produce user friendly cabinets. The simpler installation method means often better results and this leads to a situation where the amount of mistakes can be minimized. There have been a lot of problems with time of delivery. This is important section which must be paid attention to keep a good market position. The solutions of this thesis have straight influence on the time of delivery because the object is to develop faster and more reliable BJA cabling.

The aim of this thesis was to find out better solutions for cabling the BJA panel in a new way. The old way was performed with fixedly installed cables and this needed to change. The target was to get completely rid of pre-installed cables which demand cabin manufacturers to deliver the BJA panel in advance to the module factory. To make this solution possible it was mandatory to develop a way which eliminates this bottle neck.

2 RESEARCH METHODS

At the beginning of this work I discussed with my supervisor from school and Wärtsilä to get the overview what to do. I understood very quickly what to do because all of the problems that I have dealt with in this thesis were familiar before. The IDM were very useful and familiar from my earlier experience in Wärtsilä. From IDM I was able to check a lot of things regarding this thesis.

Because of site work which I completed in summer 2013 I knew very well what a power plant includes. Also the components of electrical cabinets were familiar from my earlier working experience. The starting point to the cable optimization was good. I got a lot of support and advance information from the Wärtsilä site team. They also told me which the weak spots to be solved were.

I worked in cooperation with my supervisor from Wärtsilä. His professional point of view helped me a lot along this thesis.

The most important tool was the manufacturers' catalogues both in printed and in electronic form. The catalogues were utilized when find the required component for the solution.

3 GENERAL INFORMATION OF WÄRTSILÄ

Wärtsilä is leading global leader at delivering different kind of energy solutions for different purposes. Wärtsilä has focused on engine technology which produces power solutions of energy market and offers lifetime maintenance service for customers. Very important section for Wärtsilä is politic of green values. All of its solutions are based on this. Wärtsilä will maximize the environment effectiveness and economical views of ships and power plants. This is possible when paying attention to innovations of technology and total efficiency. /27/

In 2013 the turnover of Wärtsilä was 4,7 billion euros and number of staff was approximately 18 700. Wärtsilä has over 200 offices in nearly 70 countries around the world. The stock of Wärtsilä has been listed in NASDAQ OMX Helsinki. Wärtsilä has three main sections. /27/

3.1 Wärtsilä Power Plants

Wärtsilä is remarkable power plant supplier on the power plant market of decentralized energy production. Wärtsilä is supplying power plants for basic load, peak load and to own production of the energy of the industry around the world irrespective of place. The benefits of power plants of Wärtsilä are flexible solutions, high efficiency rate and low emissions. Wärtsilä has strong market position on all of its main segments. This Thesis is connected to this item that is why it needs more detailed information. /27/

3.1.1 Flexibility of Engines of Wärtsilä

Power plants of Wärtsilä covers range from 1 to over 500 MW. According to rising demands of emissions and required power, Wärtsilä is supplying flexible solutions to all purposes. The engines can be used such as processing facilities, pump stations, marine terminals etc. Engines can be run on natural gas, HFO or LFO or the combination of the previous which is called Dual-Fuel (DF) engine. This opportunity makes possible to run power plant with fuel which has lowest price or best availability at the moment and the fuel can be changed when is needed. This is called fuel-sharing. The engines have also very good tolerance against quality variances which makes it even more practical because the qualities of fuels can different depending of the location. /28/

3.1.2 Modular Construction

Wärtsilä has modular construction in whole power plant. The main principle is to create modules to make site installation easier, faster and more reliable. The power plant is based in the pieces in a way. Thanks to the FAT test, the modules are always working when they arrives to their destination. In general the functions and components are prefabricated, only hauling to its position and connection to system with site cabling and piping is needed. All of the internal piping and wiring are prefabricated. This reduces the installation time and amount of mistakes dramatically which is good matter from everybody point of view.

Very considerable matter is also easy way to extend the power plant if the output power became too small. Modular construction will help in this case. It is relatively easy and pretty fast as well to add more engines and generators to the system and to get more power this way. This is very common for old power plants when the consumption of the electricity increases and more power will be needed. This is valuable argument. Customer can start with smaller initial investment and upgrade its power plant later if needed. All of the power plants are unique and they are tailored to meet the purposes of the customer. /28/

3.2 Wärtsilä Ship Power

Wärtsilä is leading supplying of engines of marine use, propulsion and steering systems. Wärtsilä is supplying motors and aggregators, gear reducer, propulsion equipments, monitoring systems and sealing solutions for all type of ships and offshore applications. Wärtsilä has strong market position on all of the segments of marine as supplier of engines and systems./27/

3.3 Wärtsilä Service

Wärtsilä is will support customer for the whole life circle of the delivered system. Wärtsilä will survive and repair engines of ships and power plants. Next to the traditional service work Wärtsilä has extended its services to the innovative services which support the business of customer. These are for example sign independent maintenance at main harbors all over the world and anticipatory maintenance and training of conditions of engines. /27/

4 PURPOSE OF BJA PANEL

The BJA panel has a very important role in using the engine. It is used to control the auxiliary apparatuses of the diesel or gas engine. In principle it can be said that it controls and monitors everything regarding to the auxiliary components of engine. BJA has a remote I/O rack inside with analog and digital cards which are controlled, and monitored from the central control room (CCR). Inside of the cabinet there are a lot of terminals where incoming and outgoing cables and signals are connected. The overview of BJA panel can be seen in figure 1.

Figure 1. The energized BJA panel, located on top of the pipe module. /21/

Even though the cabin looks very simple outside but in reality it has very a lot of functionalities inside. In total, the cabin keeps inside approximately 80 cables. There are lots of cables which are already installed at the module factory. However, there are still plenty of cables which must be installed at the site. All the cables are hidden beneath a pipe module on the cable trays. The engine auxiliary module (EAM) and the Engine Fuel Booster (EFB) contain a lot of valves, motors, probes and sensors which are controlled and monitored by BJA.

4.1 The Control Environment of BJA Panel

- Engine Auxiliary module consist of
  - Cooling water control
  - Pre-lubrication control
  - Pre-heating control
  - Lube oil cooling control
- Engine Fuel Booster consist of (diesel and dual fuel engines)
  - Fuel temperature control (HFO Engines)
  - Fuel selection control LFO/HFO
  - Leak tanks control (diesel and dual fuel engines
- Compact gas ramp (gas and dual fuel engines)
- Lube oil separator unit
- Oil mist separator unit
- Exhaust gas ventilation unit (gas and DF engines)
- Engine booster unit (diesel and dual fuel engines)
- Charge air inlet unit
- Engine turning gear device
- Generator anti condensation heater /26/

5 THE STARTING POINT FOR A STUDY

The starting point for this study is good in that sense that it is known what needs to be improved. The information about all the issues has been gathered from my supervisor, site personnel and project engineers. Many of issues have been recognized a long time ago, but not until now there is an attempt to solve the problems. The BJA panel has been a target of problems for a long time. It has many design issues. In the future it will be much easier to install and cable.

The problems concentrate on the bottom of the cabin, which is always too full of cables. This has caused quality claims and other debates. When smarter cabling suffer, it causes many other things, such as improper cable clamps, enclosure class etc. Even if proper armatures are used in wrong places or in a wrong way, they can cause problems. For example, if cable gland flanges (multi flanges) are used and the membranes are pierced in a wrong way or too many, the enclosure class can change dramatically and does not meet the regulations anymore, despite the fact that the manufacturer has stamped their products to meet certain standards. BJA is located in the engine hall where there is dust, vibration and other disturbances which must be eliminated so they do not cause any harm for the sensitive components. The cables will conduct vibrations from the construction to another and leaking cable glands can cause a fire risk or let dust inside the cabinet and cause serious malfunctions for electronic devices and connectors. This is why new better solutions are needed to achieve high quality results in all conditions.

It is necessary to know which standards Wärtsilä complies with while developing new solutions. Sometimes the client can ask “is this the right way to do something”, and if we know the standard is complied with exactly at this stage there is not going to be a debate regarding some suspicious matters. The following chapters deal with common issues with the BJA panel. It is also good to know that in the gas power plants has only EAM. Diesel and dual-fuel power plants have both EAM and EFB.

6 REQUIREMENTS OF CABLE PLUG

The objective of using a plug was to find a suitable solution for easier, faster and more reliable BJA cabling. The site conditions also have to be taken into consideration, there is often very limited tools which mean that the termination technology must be as simple as possible. Also the enclosure class must be at least IP54. Spring loaded connections are the best ones for this purpose. There are also lots of other connections types, such as crimp terminal connections. It is sure that they can produce very reliable connection but special tools are often needed, that is why they not suitable for the use looked for. In the market there are many manufacturers who all have the same principles in their products. The spring-load connection type was decided to be preliminary the best solution. The solutions were quite similar among the manufactures. It was important to do research about available alternatives regarding connecting solutions. This made it possible to compare the features and prices of connectors with each other. The comparison was moderately easy. The BJA panel needed at least 25 pins and 46 connection surfaces for all the different signals. Nevertheless, all the possible additions must be taken in to consideration when calculating the suitable pin amount. That was the first requirement. The second one was doing the connection without any special tools which eliminate the most of the options. Information about various suppliers was compared and it was noticed that their solutions were basically very similar.

The BJA panel is made by two manufacturers depending on their production price. After the BJA panel is ready, it will be delivered to the module manufacturer where its each cable is connected fixedly between the module and the BJA panel. Because of the fixed installation the cables must be long enough to reach the delivering position of the panel properly. The delivery position of the panel is located on the top of the module, in the opposite corner where the cables are. Also the height limit of the container which is used to transport the modules defines that the cabin must be delivered on the exact position. Otherwise the height will rise too much. There is only one allowed position for that. That is why cables are so long. The length of cables can be seen in figure 2.

When Wärtsilä starts using the plug at the end of the BJA cables there is no need any more to send the BJA cabin to the module factory but the cabinet can be sent straight to its final destination. In there it is hauled on the right position and the plug cables are connected to the sockets. Using this method the slack of cables is no longer a problem because the length can be optimized. In the future the cables are still connected fixedly to the module but not to the BJA cabinet. The objective of this solution is to make the cabling of the BJA factory cables as simple as possible.

Figure 2. Slack of cables between Engine Auxiliary Module and BJA panel. /21/

When the module and BJA panel have been hauled on its final position inside the engine hall there is no more than a few meters distance between the module and BJA panel. The rest of the cable must be hidden under the pipe module out of sight, somewhere on the cable tray.

6.1 Defining the Type of the Cable Plug

After deciding which the requirements of the cable plug are, it was possible to begin the more exact examination. After researching a few manufacturers we ended up to Phoenix Contact because of earlier and present purchasing, which means better discounts for products. Two possible products were found with advantages and disadvantages. That is why a comparison between the two options was necessary. Costs, contacting technology and reliability were the main objectives which were taken into account. There are two alternative pin surface materials available, silver and gold. Silver plate contacts are suitable because the signals are sufficiently strong. It is recommended to use gold plate contacts if the voltage is under 5 V and the current under 5 mA. When the comparison was finished, the list was sent to the Phoenix representative for the request for quotation and samples of products for the developing team at Wärtsilä.

6.1.1 Crimp Connection

The amount of needed connection pins was 25 in the EFB (Engine Fuel Booster) and 46 in the EAM (Engine Auxiliary Module). Using a crimp connection pins makes it possible to connect even 32 or 48 wires which is more than enough. Nevertheless, the possibility of changes must be remembered, it is very probable that there will be additions and modifications. That is why there must be several extra pins available.

The crimp connection makes it possible to create a very simple and low wall-mount installation. The assembly principle of the crimp connection can be seen in figure 3 below. There is only a mounting flange where the contact plate is attached. Mounting flanges are attached on the side of the BJA panel with four screws. This combination is called a socket.

The counterpart is called a plug. It consists of three parts, contact plate, entry lateral housing and in this case metal cable gland. Cable glands are available also in plastic and EMC type if necessary. When the plug is attached properly it fills IP65 class which is accepted. Depending on which components are used, the IP classification can reach even IP68 (0.2bar/24h) or IP69. This method of installation is called “Advance housing”.

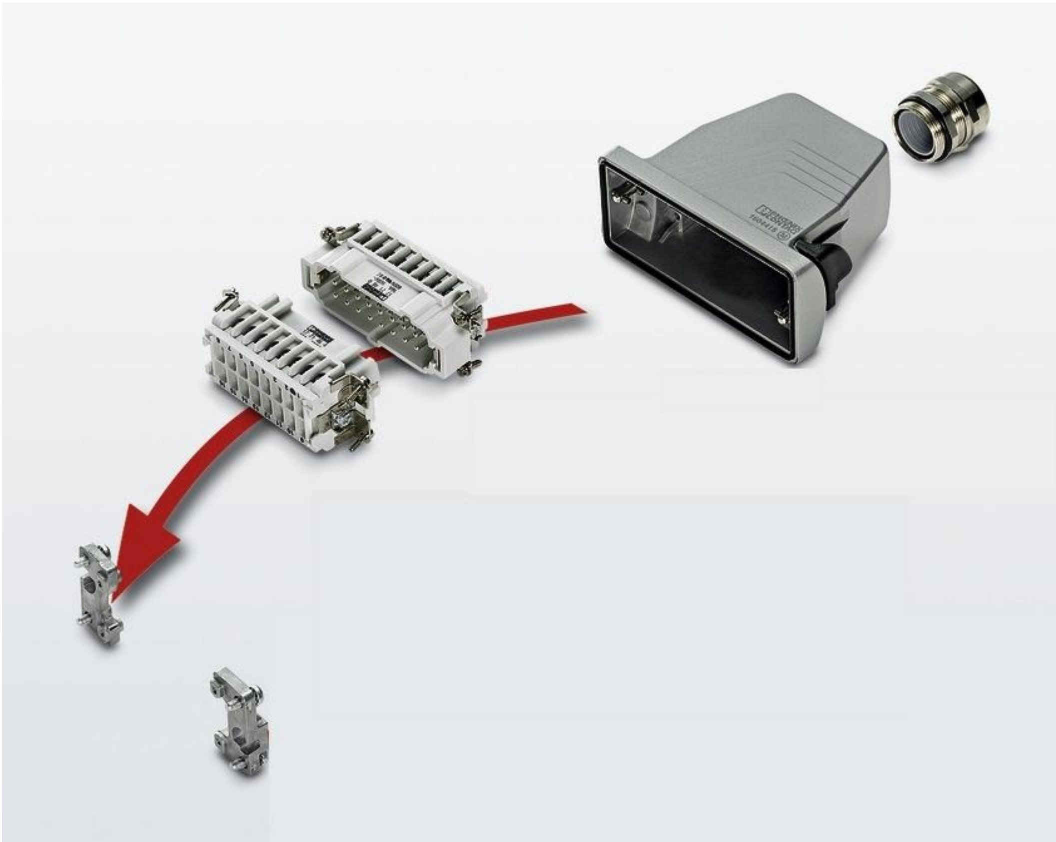

Figure 3. Advance housing. Crimp connection type. /18/

If this solution is used, tools must be used in the installation. The tools required are the crimping pliers (which are used to make connection at the end of the wires. See figure 4), assembly tool (for attaching the connection to the socket or plug) and removal tool (for removing assembled connection). All of the previous tools are mandatory. Otherwise there is no guarantee that the connection is proper. It is important to use the assembly and removal tool to protect the material. Their durability can suffer if wrong tools are used.

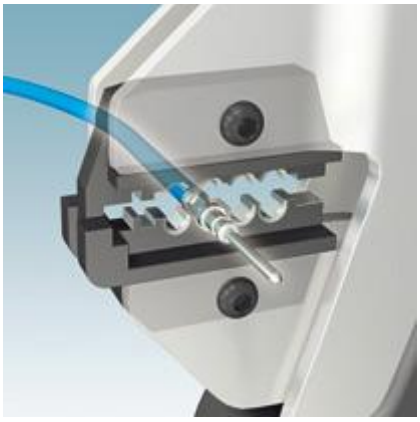

Figure 4. Crimping pliers for making crimp connection. /6/

The result of the connections can be seen in figure 5. The gasket is surrounding the plugs inside surface. This creates a very tight connection. The plug is attached with two screws on the socket. This is to avoid loosening if the connection is exposed to vibration or mechanical forces.

Figure 5. Cabin side mounted socket (Advance housing) and plug with metal cable gland. This socket has only 10 pins available. /16/

The plug and socket can be equipped with small plastic plates (coding plates) for avoiding cross connections if the same cabin has more than one similar plugs and sockets. By using them it is made sure the cables are always plugged into the right sockets when the cabin is arrives at its destination.

Advantages of crimp connection

- Simpler installation (no base needed)
- Reliable connection
- Spare pins
- Sufficient IP class (IP65)
- proper plug attachment

Disadvantages of crimp connection

- Tools are needed
- Field working is more difficult

6.1.2 PUSH-IN Connection

The push-in connection type makes it Possible to connect the maximum of 24 wires. This causes a problem because the needed amount is 25 (in the EFB) and 46 (In the EAM). The solution to the problem is to install 2x16 or 2x24 push-in connection sockets and plugs in a row. After that it is possible to get up to 32 or 48 wires connected. There is some room for extra additions and modifications. In this solution special tools are not needed. Regular tools for mounting are a screw driver for removing the wire and normal pliers for preparing the wire for the connector and attaching a ferrule at the end of the wire. The principle of the push-in solution can be seen in figure 6, where it can be seen that no tools are needed for the wire termination. Only a ferrule is needed at the end of the wire. Finally, the wire is just pushed into the connector and it locks the wire itself inside the connector. If the wire needs to be removed, the yellow button is pushed with a thin screw driver which releases the mechanism of the connector.

Figure 6. principle of the Push-in connector. /19/

With this method it is very easy in field conditions to do modifications and attach a loosened wire because of the push-in technology. This is a huge benefit in field conditions.

The installation components are shown in figure 7. There are no mounting flanges but a mounting base which takes a lot more space than flanges only. In figure 7 there are only 16 pin connectors which are not suitable for the purpose but the principle is the same.

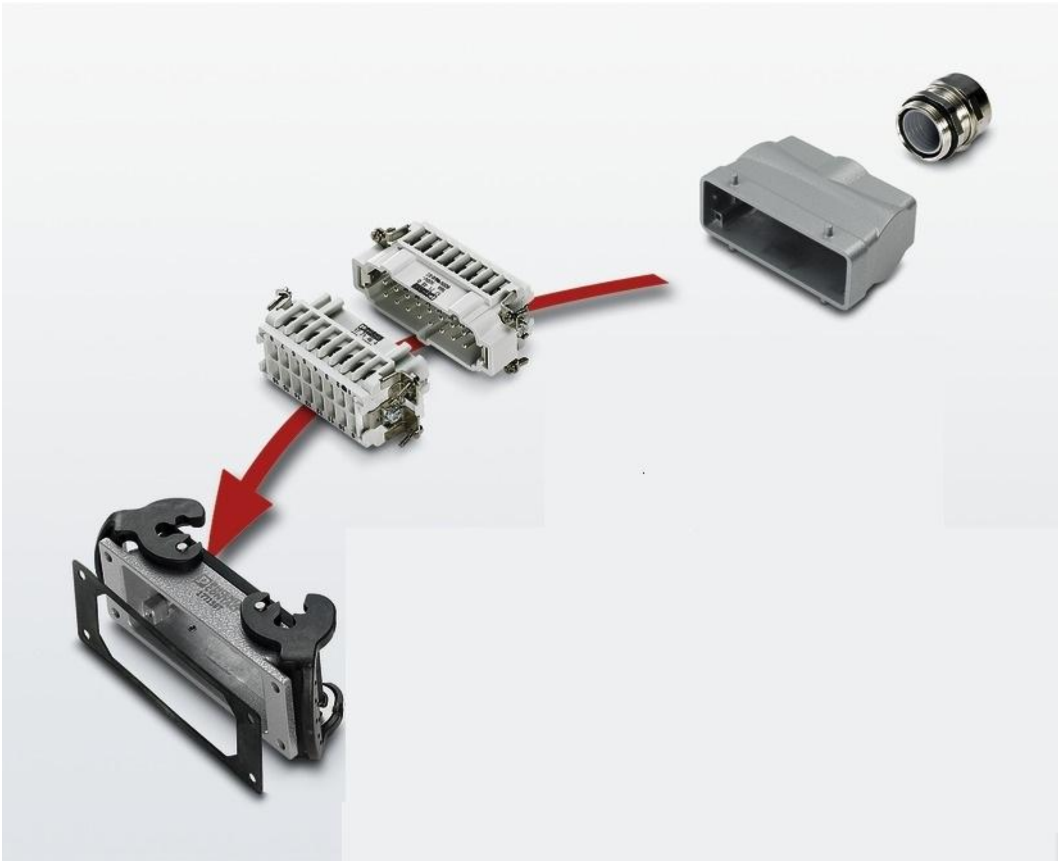

Figure 7. Single socket and plug B-Housing installation type. A bigger mounting base is needed. /18/

If double sockets and plugs are used, a wider mounting base is mandatory. This means a two times wider mounting base and plug compared to the single base. This installation type without flanges is called B-Housing.

Advantages of push-in connection

- Easy wire connecting
- Sufficient IP class
- Spare pins
- Quick lock plug attachment
- Quick wire connecting
- Modification in the field is very easy
- No special tools needed
- Whole plug or socket can be changed easily in the field if damage occurs

Disadvantages of push-in connection

- High mounting base (compared to advance housing installation solution)
- Wide socket and plug
- Connector can be damaged easily during the termination because of excessive force

6.1.3 Conclusions of the Phoenix Contact Plugs

When the needs were surveyed, the list of needed components were made and sent to local representative of the component supplier asking for prices and availability. The prices of components arrived fairly soon.

After calculations were made, the results showed that crimp connectors were a little bit cheaper than push-in connectors. This was expected. Taking the cost of crimping tools into account (hundreds of euros), the gap between the crimp and push-in connectors narrowed. Also it is very obvious that in the field it is much more difficult for the repairmen to do modifications for crimp connectors than push-in connectors. Often there are no required special tools available. When it was also considered that someone needs to produce wires with crimp connectors, crimp connectors were a more expensive alternative in the final analysis.

The push-in solution is definitely the best and easiest solution when thinking of all points of view. It became not so expensive when variable elements are taken into consideration and it could be even cheaper. But the most important thing is that the connector type is easy to do and it can be done locally without any special connecting tools. The biggest reason why push-in connectors were more expensive solution than crimping connectors, were the mounting base. The mounting base was approximately even 20 times more expensive than the mounting flanges, which were relatively cheap. However, according to the comparison of these two types of connectors, the best solution is the connector with push-in technology.

To illustrate to ourselves and to our partner what does the solution looks like, the samples were decided to order. After a few weeks the samples arrived. The manufacturer of the plugs was Phoenix Contact and their solution can be seen in Figure 8.

Figure 8. Phoenix Contact cable plugs. Left side is produced with push-in connectors and right side is for crimping connectors.

As mentioned in the previous chapters where comparison between these two solutions were made that if push-in connectors are used, two connection plates are required and if crimping connections is used required plates is only one. Figure 8 shows the huge size difference between these two solutions. Even though we decided earlier that the push-in connectors are best alternative, the crimping connectors were decided to pronounce as a better solution. Crimping connector plug and socket is much smaller than in push-in. Crimping connector is smaller because of the one connection plate and attaching flange which means that the base is not needed. The bigger enclosure weights also too much. It would be very clumsy on the side panel of the BJA panel. Push-in connector enclosure is approximately 15 cm high and crimp connector enclosure is approximately 10, 5 cm high.

6.2 Quick Lock Connection

Later, one very interesting manufacturer contacted us and offered their products. The name of the manufacturer was Harting. The starting point of the meeting was very good because the requirements were known based on the products the manufacturer had supplied previously. Thus, there was no need to even ask them about crimping connectors because they were already chosen for one option, as mentioned in previous chapter. The interesting focus was only on solutions which were not crimping solution. Therefore, they presented us a product which carried the name, quick lock. The supplier convinced us that they have a perfect solution for us.

The product of the Phoenix contact was a compromise in several matters. The height, width, number of pins, mounting base and expansion possibilities were the main sacrifices which were made. Harting industrial connectors were promised to fix all of these issues.

The solution was very flexible. The main principle was that the solution was made of modules, so it can be tailored for each use. It is possible to pass through the plug, for example optical fiber, bus, Ethernet, compressed air and other protocols. That is why it is a very good solution when thinking about the future and product developing. The modular construction can be seen in Figure 9 which shows how the connector can be tailored to meet the requirements. Hard wire connectors are available even up to 1000 V / 200 A. The solution which was chosen had no screw locking but a quick locking latch. Screw locking plugs were not available for some reason.

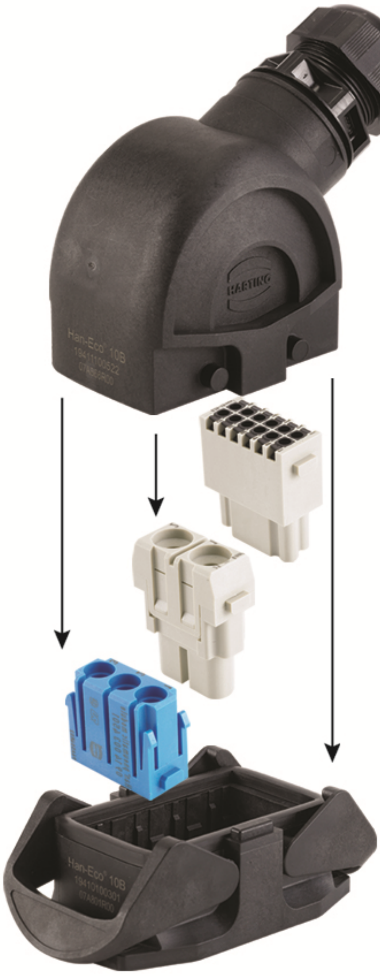

Figure 9. Modular construction of Harting connectors

First, the suitable base was chosen and after that it is possible to assemble the plug using needed modules. In this case all of the special protocols were not needed. The basic current and voltage is the only thing which is carried through the plug. The solution chosen was according to Figure 10. In Figure 10 it can be seen that there are 12 connector pins. This means that the needed amount of EAM was 46 so the needed number of these modules was 4. This makes it possible to connect 12 + 12 + 12 + 12 = 48 wires. The EFB module required 25 wires. This means that the needed number of modules was 3. This makes is possible to connect 12 + 12+ 12 =36 wires. So there will be some spare connect pins.

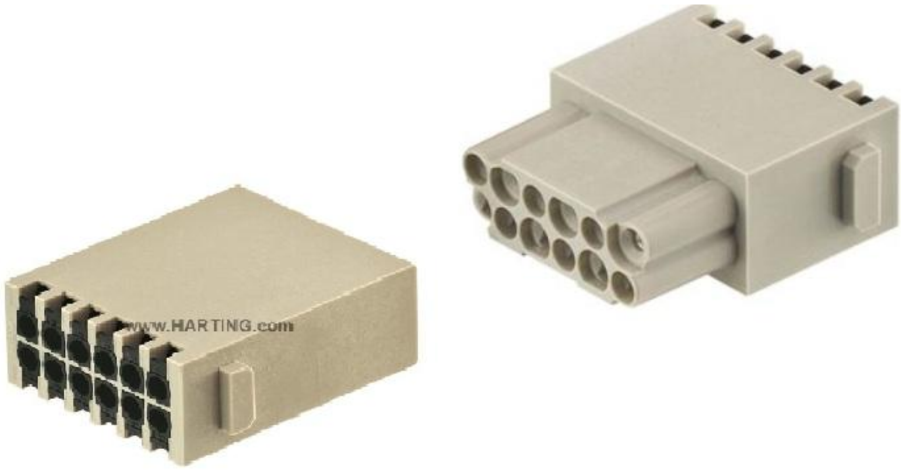

Figure 10. Harting Han Female and male plug connectors /10/

When this kind of modular construction is possible to use, there is possible to find well-fitting solution without compromises. This solution solves the size problem. The aim was also that the cross connecting is avoided. This was decided to solve by choosing two different sizes of bases. That is why the plug is possible to connect only to the right socket. It would have been possible to use one base for each EFB and EAM but this would cause the need of blind socket which is used to block the extra holes of the plug. When using two different sizes of bases, it is possible to solve two matters at the same time. The solution gets easier and simpler.

6.2.1 Operational Principle of Quick Lock Termination

The basic idea when looking for a suitable solution was that it must be easy to do modifications and even repair in the field conditions. It is possible that for some reason the wire becomes loose and even pops out from the terminal. This is very important to take into consideration when it comes to connecting technology. The connectors must also be very durable during the operation and withstand different kind of environment conditions. Assembly and disassembly principles can be seen in Figure 11 and Figure 12.

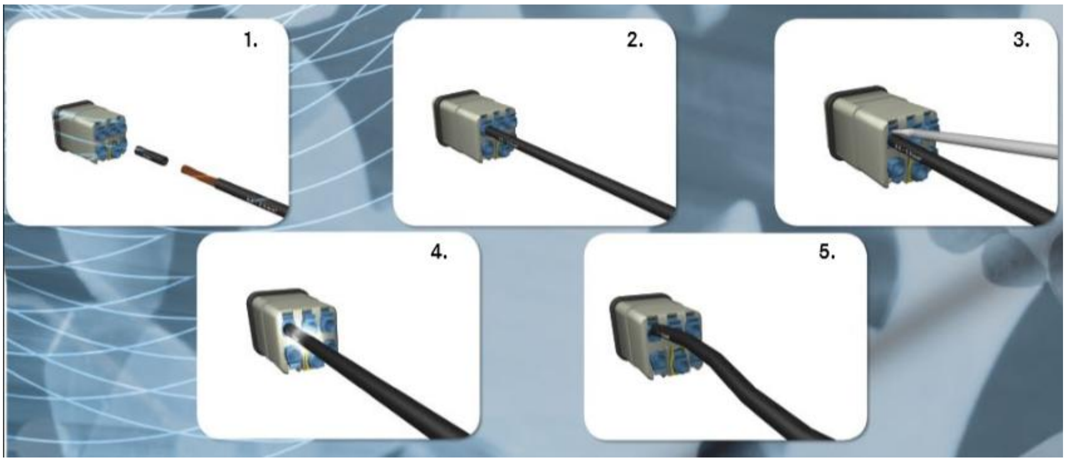

Figure 11. Assembly instructions of the Quick lock termination /10/

Assembly instruction

1. *Step: Remove the cable sheath and wire stripping (10 mm). Do not twist conductors.*
2. *Step: Insert wire into the* ***Han-Quick Lock®*** *contact chamber*
3. *Step: Push in the active termination element with a screwdriver until it comes to a stop*
4. *Step: Visual inspection – Check if the wire is long enough for the contact chamber.*
5. *Tensile test – Check, whether the wire is in the contact camber firmly enough./10/*

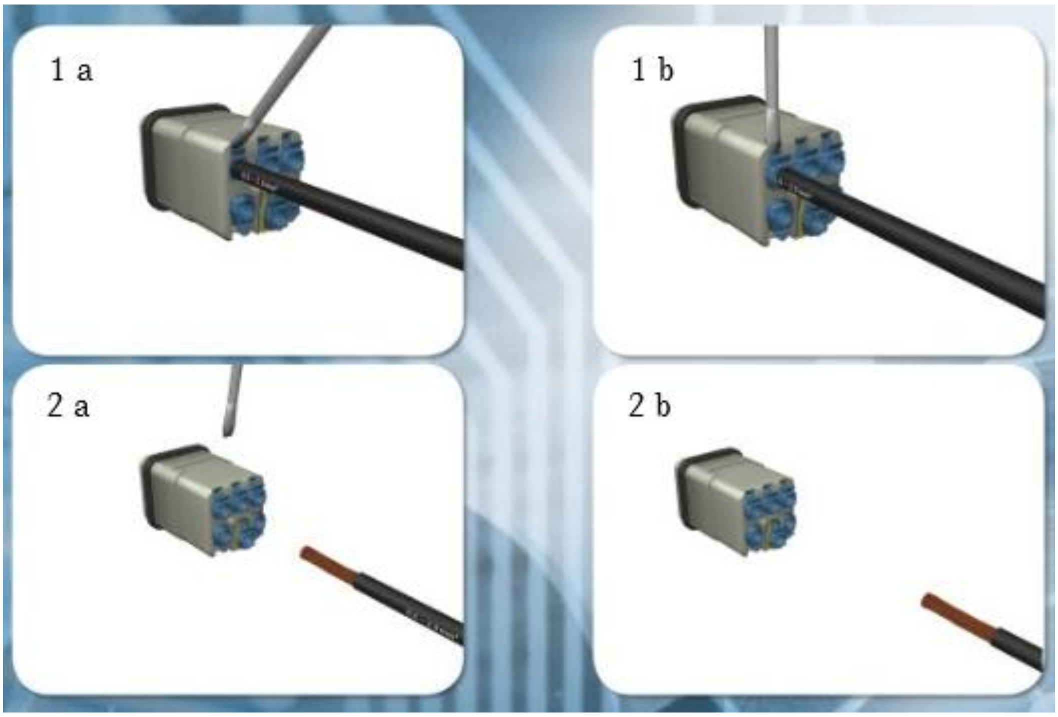

Figure 12. Disassembly instructions of the Quick lock termination /10/

Disassembly instruction

1. *a/b Step: Insert a screwdriver into the side slot of the active termination element at an angle and slide this out*
2. *a/b Step: Pull the wire out /10/*

These installation instructions have been taken from the Harting catalogue.

Harting promises reliability to its products and to prove its claims, Harting has put its product through the standardized measurements. These measurements have been passed clearly.

The special features of this connection technology are:

1. *Time Saving*. This is important when thinking of an efficient installation. According to Harting's measurement, it saves more than 20 % of time compared to the traditional technique
2. *High vibration safety*. The quick lock solution meets the requirements of vibration and shock tests. The tests have been performed in accordance with the DIN EN 61373 standard
3. *High wire pull out forces*. It is important that all of the wires are properly attached in its positions and will not come loose when the wire is exposed to a pulling. The minimum requirements are greatly met, in accordance with the DIN EN 60352-7
4. *Low contact resistance*. Low contact resistance is important when sensitive signals are handled and transferred. The connector has passed test clearly, in accordance with the DIN EN 60352-7 /10/

6.2.2 Conclusion of the Harting Plugs

Harting was a very interesting choice because it does not have most of the disadvantages of Phoenix Contact connectors. The connector is small, reliable and easy to use. We were shown in the product presentation how the connector works. The modular construction makes it possible to extend the connector on demand. If this solution is compared to Phoenix Contact push-in connectors, this has a much smaller plug size. The modular construction makes this possible. This solution has also a mounting base which is as big as push-in solution but the plug is significantly smaller. This is due to that there is no need to put two connector plates side by side, only one is needed. The smaller plug size is also better protected against accidental damages.

It is good to have an economical point of view also. The Harting quick lock termination solution was approximately 30 % more expensive than the corresponding Phoenix Contact contactor. However, Harting provides a solution which is not a compromise in any circumstances. The advantages of this product are size, connection speed and possibility to make changes in the future.

Due to these features, the Harting Quick lock connection solution was chosen as the best possible solution for requirements.

7 RE-CABLING OF BJA PANEL

In this chapter the objective was to define the required components to do the module cabling of BJA panel in a smarter way. The main principle was that the side of the EAM and EFB modules is equipped with the junction boxes where all of the instrument cables are collected. From there the signals are conducted to the main cables (one main cable for each, EAM and EFB) which end at the side of the BJA panel using industrial plugs. The plugs were chosen in the chapter 6. The new solution was based in the following sections.

7.1 Choosing of the Proper Terminals

First of all the type of terminations had to be decided. There were many alternatives available regarding the wire connecting solutions. Because of this, the obvious choice was spring-loaded terminals because of the lack of cost differences between other solutions. Also there is no need for special tools for installation. Nevertheless, at the factory it is highly recommended to use plastic installation tool which resembles a shape of a flat head screwdriver. It is softer than a metallic one, so it is gentler for the connectors and will not cause any harm if it slips. However, the metallic flat head screwdriver can be used.

There are two kinds of terminals needed because the EAM and EFB signals need two or three –wired probes, sensors and controls. That is why two and three layer terminals are used. The terminals can be seen in figures 13-14. This makes it possible to create a very smart installation because the wires of the same apparatus are located one on top of one another. First, the number of needed terminal types had to be analyzed from the drawings. There are also side covers to cover bare metal rails inside the terminal. Only the last terminal has to be covered.

The size of terminals was decided to adapt the 2,5 mm^2 wire with ferrule and at least 16 A of current, otherwise the durability of terminals would not withstand hits and damages enough. The small terminals are not long lasting. That is why we decided to use spring-loaded connectors, to eliminate the possibility of connectors breakage because of too tight screws used for attaching wires.

Figure 13. 3-layer spring-cage terminal attached on the DIN rail /24/

Figure 14. 2-layer spring-cage terminal attached on the DIN rail /23/

Needed terminals of the modules

Engine Auxiliary Module:

- 3-layer spring-cage terminal 8 pcs
- 3-layer spring-cage terminal side cover 2 pcs

- 2-layer spring-cage terminal 12 pcs
- 2-layer spring-cage terminal side cover 2 pcs
- lock terminal for each side 2 pcs

Engine Fuel Booster

- 3-layer spring-cage terminal 8 pcs
- 3-layer spring-cage terminal side cover 2 pcs
- 2-layer spring-cage terminal 5 pcs
- 2-layer spring-cage terminal side cover 2 pcs

The subcontractor is able to decide the manufacturer of terminals freely. The bottom line is that the terminals will meet the above mentioned requirements. When calculating the number of the terminals, attention is paid to extra wires of the main cable. It is a good way to end the unused wires to the empty terminals. In such a way it can be made sure that the unused wires will not cause any issues by going to a wrong place. For example, it is possible that the extra wire goes by accident in the connector of the terminal and starts to conduct electricity somewhere where it does not belong. This could cause a shortcut or immediate danger for human beings or material.

7.1.1 Terminal Changes

Unlike the earlier plan, a few modifications were decided to make regarding the terminals. Based on the comparison of prices it was decided to make the solution cheaper and maybe a bit clearer to terminate wires. After the price enquiry the 3-layer terminal seemed to be many times more expensive than the 1-layer terminals. Therefore it was decided to replace all 3-layer terminals except PT100 3-layer terminals with 1-layer terminals. All of the demands of the 1-layer terminal were the same as the other terminals. The chosen 1-layer terminal is the according to Figure 15.

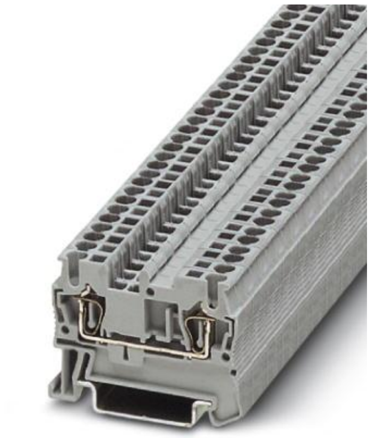

Figure 15. 1-layer spring-cage terminal attached on the DIN rail /22/

This has a direct influence on the width of the terminal row which has to be taken into consideration when choosing the junction box. 1-layer terminals are 19 mm shorter than 2-layer terminals, which is an insignificant difference. Also 11mm difference in height is irrelevant.

The 1-layer terminals were also decided to divide into parties because of different kind of signals. The new layouts can be seen in Figure 17. This helps to keep wire termination and layout clear because PT100, DI, AO, AI signals were separated from each other.

The new amount of terminals for EAM and EFB junction boxes were:

Engine Auxiliary Module:

- 3-layer spring-cage terminal 5 pcs
- 3-layer spring-cage terminal side cover 2 pcs
- 1-layer spring-cage terminal 33 pcs
- 1-layer spring-cage terminal side cover 4 pcs
- lock terminal for each side 2 pcs

With this combination the space required in the horizontal direction is 92 mm more than before.

Engine Fuel Booster

- 3-layer spring-cage terminal 3 pcs
- 3-layer spring-cage terminal side cover 2 pcs
- 1-layer spring-cage terminal 23 pcs
- 1-layer spring-cage terminal side cover 4 pcs

With this combination the space required in the horizontal direction is 66 mm more than before.

7.2 Choosing the Suitable Cables and Cable Glands

The principle is that from the EAM and EFB unction boxes the signals are conducted through the one multi core cable which is proper for the use. RFE-HF manufactured by Helkama was chosen as a cable type. According to standards it is suitable even for marine use which has higher regulations than normally. It is very important to use heavy duty and industrial purpose components and equipment to reach high quality results. Thus, the lifetime and reliability of the products also will rise. Wärtsilä has used Helkama cables before which means that there was no reason to change the cable brand.

Details of the RFE-HF cable:

- Armored instrumentation and communication cable
- It is recommended to avoid direct sunlight. Can be used in sunlight if a black color cable sheath is used
- U_n 150 V / 250 V
- Flame-retardant
    - IEC 60332-1-2 test for single insulated wire and cable
    - IEC 60332-3-22 test for bunched wires and cables, category A

- Halogen free IEC 60754 series
- Smoke emission IEC 61034 series
- Lowest operation temperature -40 °C
- Minimum recommended installation temperature -15 °C /11/.

To implement the idea of BJA cabling like this requires two kinds of cables. The cable needed for EAM junction box was 24x2x0, 75. Which means that the cable consists of 24 pairs of wires which makes 48 wires and their cross sectional area is 0, 75 mm^2. The wires have consecutive numbering to make connection possible.

The structure of the cable can be seen in Figure 16 where all different layers are clearly visible. The way which is used to prevent disturbances between wires can also be seen in Figure 16. All wires have been twisted around each other to prevent crosstalk and inductive disturbances.

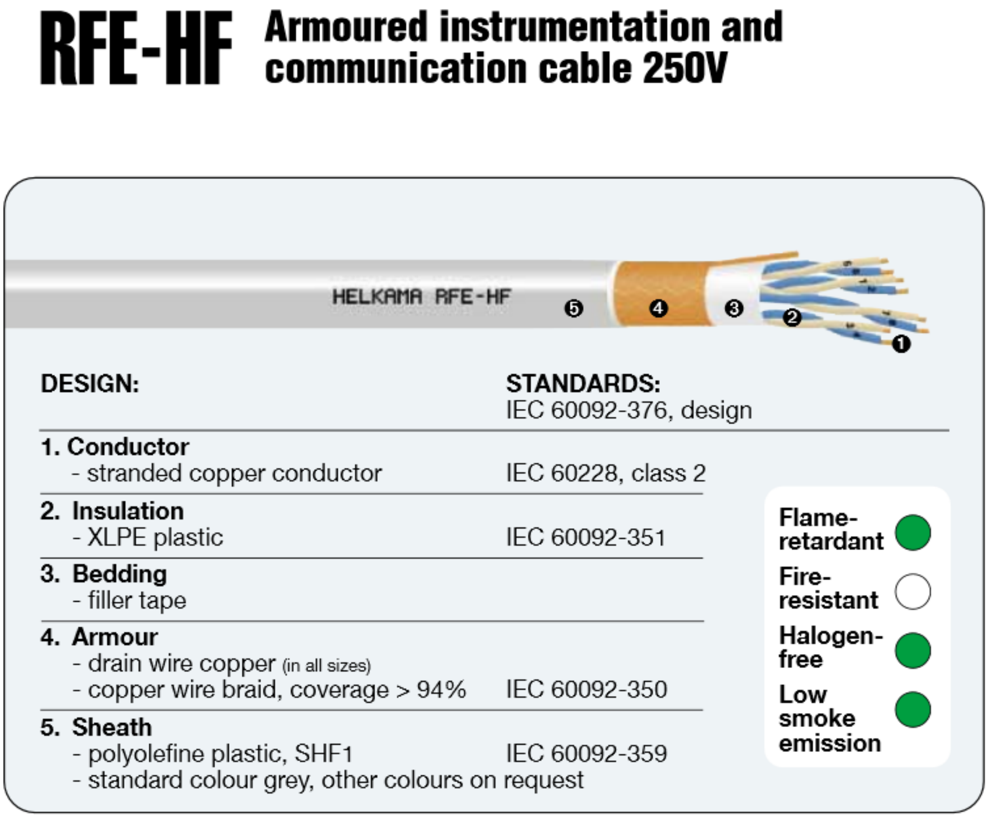

Figure 16. The Structure of RFE-HF cable which is used as the main cable of EAM and EFB. /11/

The dimensions of the needed cables can be seen in Table 1.

Table 1. Physical size of the Helkama RFE-HF cables. /12/

RFE-HF 250V Part number	Number of conductors & cross-section n x mm²	Nominal outer diameter mm	Approximate weight kg/km	Min. bending radius fixed installation mm
20362	1x2x0,5	7,0	85	45
20364	2x2x0,5 Quad	8,0	105	50
20363	2x2x0,5	10,5	130	60
20366	4x2x0,5	11,5	175	70
20368	7x2x0,5	14,0	245	85
20369	8x2x0,5	14,5	270	85
20370	10x2x0,5	17,0	355	100
20371	12x2x0,5	17,5	390	105
20372	14x2x0,5	18,5	440	110
20373	16x2x0,5	19,5	485	120
20374	19x2x0,5	21,0	545	125
20376	24x2x0,5	23,5	670	140
20378	37x2x0,5	28,0	930	170
20382	1x2x0,75	7,5	95	45
20384	2x2x0,75 Quad	9,0	125	55
20383	2x2x0,75	11,0	155	65
20386	4x2x0,75	12,5	215	75
20388	7x2x0,75	15,5	330	90
20389	8x2x0,75	16,0	375	95
20390	10x2x0,75	18,5	440	110
20391	12x2x0,75	19,0	490	115
20392	14x2x0,75	20,5	565	125
20393	16x2x0,75	21,5	620	130
20394	19x2x0,75	23,5	715	140
20396	24x2x0,75	26,0	860	155
20398	32x2x0,75	29,5	1100	175

- Nominal outer diameter of RFE-HF is 16x2x0,75 is 21,5 mm
- Nominal outer diameter of RFE-HF is 24x2x0,75 is 26,0 mm

When the dimensions of needed cables were determined, the proper size of cable glands was possible to choose. It does not matter which manufacturer's table is used because the sizes are standard. In this case the Schneider Electric catalogue was used. The table which was used was in accordance with Table 2. There can be minimal differences in suitable cable sizes between different manufacturers but this difference is around +/- 1 mm.

When the sizes of the cables were known, it was easy to choose a proper cable gland sizes. The chosen cable gland sizes for two main cables were M40.

Table 2. Choosing table of the cable glands. /20/

Ø	1-cable cable gland		
	Ref.	Ø min / max (mm)	drill \ (2)
M12	ISM71501	3 / 6.5	12.2 (0 + 0.2)
M16	ISM71502	4 / 8	16.2 (0 + 0.2)
M20	ISM71503	6 / 12	20.2 (0 + 0.2)
M20 (1)	IMT36150	6 / 12	20.2 (0 + 0.2)
M25	ISM71504	11 / 17	25.2 (0 + 0.2)
M32	ISM71505	15 / 21	32.2 (0 + 0.3)
M40	ISM71506	19 / 28	40.5 (0 + 0.3)

(1) Cable-gland with high resistance to fire.
(2) In brackets: tolerance.

Table 2 shows also very clearly which size of the drill must be used for doing a proper hole for the gland. Too big a mounting hole will not be tolerated. Only a right sized hole and cable makes it possible to achieve IP68 classification and 5 bar pressure resistance. It shows also the maximum and minimum diameters of the cable for each size of the cable gland. The drilled hole can be 0, 2 mm-0, 3 mm too big but not too small. /20/

In this section it was wise to define also the cable gland size for the thinner instrument cables. I was informed by Wärtsilä team that the cable which is used to instrumentation cabling is 2x2x0, 5. The dimension of the instrument cable can be seen in Table 1 and after the physical dimension of the cable was determined, the proper cable gland size could be selected from Table 2. The diameter of the instrument cable is 10,5 mm, therefore the size of the cable gland was chosen M20 which can handle 6-12 mm cable.

7.3 Choosing of the Proper Junction Box

The entire cabling is packed into well-fitting junction box. It is very important to pay attention to the required dimensions of the terminals. Many cables are connected to the box which means that room must be reserved for the wires and cables. It is planned that the bottom of the box is for the main cable which goes to the BJA panel and also for all of the instrument cables.

The number of the instrument cables is 17 in the EAM and 10 in the EFB. All of them are installed fixedly to the module, straight to the apparatuses. This is only in theory because practice will show if there are better ways to organize cables. It is possible to penetrate the box through the side panels if the bottom is too cramped but this is not recommended because it is possible that a leak may appear sooner or later. If the glands are put on the top or the side of the box, the liquid flows along the cable to the gland and if the gland is not completely shielded, the leak can cause damage inside the box.

To make smart installation possible it is mandatory to reserve some space for organizing peeled wires inside the box. The wires must have room to be bent gently to the terminals. It this case spring type terminals are used. This means that the wires need more space when leaving from the terminals because they are attached to the top of the terminal (figures 13, 14 and 15). After all, this causes no trouble because the cable used has only 0, 75 mm^2 wires and they will bend very smoothly and will not need so much bending space than thicker wires.

It is also important to pay attention to that the box is equipped with a lid, because of height of the terminals in the box, the box must be sufficient. The location of the junction box will be very dirty and dusty in course of time. That is why it must be dustproof. For this reason the glands used were according to section 7.2. The size of the box must not be too big because there is limited space in the module frame. The final location of the junction box was not known. Because of this the optimal size of the box was very important. The box had to have enough room for components and wires but at the same time attention had to be paid the lack of space.

The starting point was that the box must be very durable. The whole module has been made from thick steel beams, which means that the junction box cannot break if it is damaged for some reason. Polycarbonate will not tolerate any hard impacts. That is why a steel junction box was chosen. When using a case that is made from the metal instead of plastic/polycarbonate case, there is no need to worry about flame-retardants. . The proper software for the drawing was not available so the accurate layout drawing was made in another way. The drawing illustrates how much space there will be on the sides and above of the terminals. The dimensions on DIN rail were also taken into account during this modeling. A few of layout sketches were made to illustrate how much space the row of terminals will need in vertical and horizontal direction and also how much room the cable glands will need when installed. The sketches were made in accordance with the EAM junction box because it contains more terminals than the EFB junction box. Thus, when the suitable size of the junction box was found, it fitted automatically to EFB also because of smaller space requirement. The same kind of junction box was decided to use for both EAM and EFB.. At this stage the accurate model or manufacturer of the junction boxes was not chosen. The bottom line was to define well fitting size of the junction box.

7.3.1 Layout of the EAM Junction Box

The chosen size of the proper junction box for the EAM and EFB was the 300 mm x 200 mm x120 mm. The layout of the EAM junction box can be seen in Figure 17. From there it can be seen the location and space requirements of terminals. In Figure 17 also the location and fixing points of the cable glands and their number can be seen . 17xM20 and 1xM40 cable gland fits perfectly on the bottom of the box. There is also free space on the DIN rail for additions or other modifications. The separated sections of the terminals are visible.

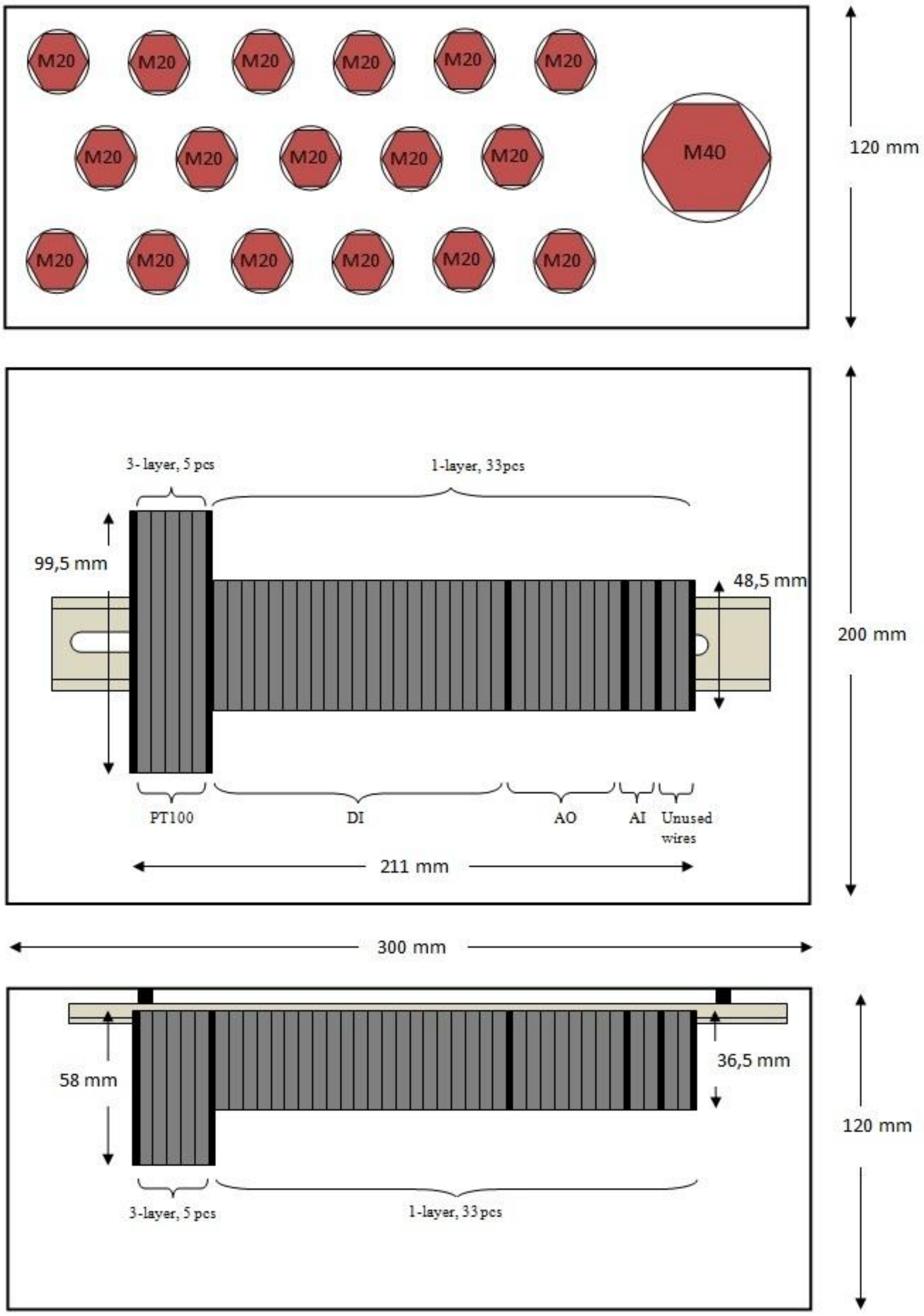

Figure 17. The layout of EAM junction box /3/

7.3.2 Layout of the EFB Junction Box

EFB junction box is of the same size as the EAM junction box. The layout of EFB junction box is in accordance with Figure 18 and the 10xM20 and 1x M40 cable glands of the EFB junction box are visible. The Cable glands have plenty of space because they are fewer in number. As it can be seen from the picture there is no need to locate the glands in similar way as in the EAM junction box. It was possible to put them in straight lines in two rows.

This junction box has much more space inside because of fewer cables. Therefore, the number of the terminals is also smaller. For this use, a smaller junction box would have fitted but we wanted the same panel size in both cases.

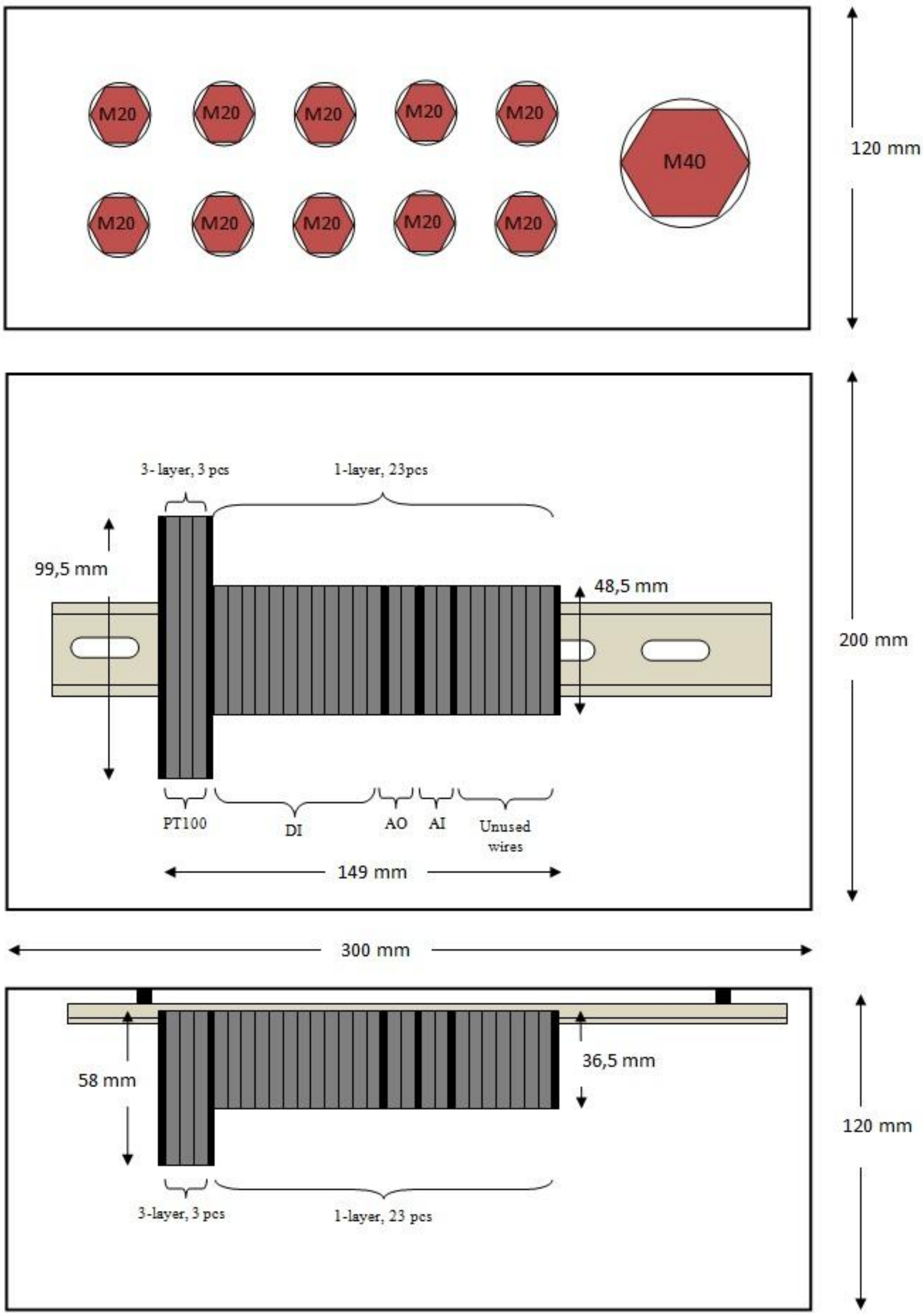

Figure 18. The layout of EFB junction box /3/

7.3.3 Unsuitable Junction Boxes

A few more models were made which were unsuitable for these purposes. The unsuitable boxes can be seen in appendix 1. /3/

The first method of choosing a proper junction box was the area on the bottom. 17xM20 and 1xM40 cable glands should fit there. So first, the cable gland fitting has to be confirmed and after that it was possible to continue. All models shown in appendix 1 were too big. That is why the inside modeling was not necessary. After a few models later a well-fitting junction box was found which corresponded to the requirements and after that it was possible to continue to illustrate the inside components to see how inside components would fit inside. The best match can be seen in Figure 17 and Figure 18.

7.4 Conclusions

This part of the thesis was pretty linear. It had a clear starting point and ending point. There were three main sections in general, choosing terminals, choosing cable and choosing junction box. However, it was mandatory to do background research for reaching a good result. It took some time to browse catalogs through and search for information by emails.

In my opinion the results reached are very good. The components which were chosen could not have been better from the practical and economic point of views. There is no doubt that when this plan is executed it will be a very good and functioning complex which has no serious issues. It is possible that some teething problems can appear but in general it will work. The practical points of view have been taken into consideration as well as possible. The only thing which was not able to be determined at this stage was the final locations of the EAM and EFB junction boxes. That is the reason why the size of the panel was tried to keep as small as possible but still big enough. Optimization was very important thing which should be kept in mind during this section.

8 CABLE INLET ISSUES OF THE BJA PANEL

Cable inlets are located on the bottom of the BJA panel. Through these inlets the cables which are installed at the site are used to access the panel inside. This is only way to perform the site cabling which cannot be done using prefabricated cables. Some customers have not been completely satisfied with solution which is used these days. Also Wärtsilä engineers have noticed that it os good have some alternatives to reach completely satisfaction to all parties.

8.1 Solution in Use Generally Today

Currently the cable inlets are shielded by using multi flanges. The multi flange is made of mixing rubber and non-flammable materials. To be precise, HTC flange is made of TPE-SEBS, .TPE means thermoplastic elastomer and SEBS means styrene block polymer. The material is durable and flexible in the membranes. /1/

The environment of the power house can cause problems for the BJA panel. During the installation there can be lot of dust and impurities in the air which must be keep out of the cabin. Because of these elements the cable inlets must be kept well shielded.

The main problem is the way how the multi flange is used. It has lot of solid rubber membranes which are pierced by a sharp blade. Often a knife is used for this. If this is done following the carefulness, the result can be acceptable. It is very common that during membrane piercing too big a hole is cut and this causes trouble. After this the IP classification is no more acceptable and then there will be lot of problems.

The cable clamp is also a problem in this type of solution. It is impossible to integrate the cable clamp to the multi flange. There is not enough free space under the BJA cabin either where it is possible to mount a steel bar where cables can be tied using cable ties. The only option is to carry out this inside the cabin. The steel bar for fixing point must be attached somewhere near other cable flange where the cables can be tied properly.

The commonly used multi flange is accordance with Figure 19. As it can be seen in Figure 19 in this case the cable flange has the total of 25 penetration membranes. The name of this cable multi flange is HTC-25. The number after letters means how many penetrations there totally are.

Figure 19. HTC-25 multi flange which is used in BJA panel for cable penetration /14/

The fixing points are in accordance with the C opening standard.

Lead-through possibilities of the HTC-25 cable flange are: /14/

- 1 pcs 20 mm–26 mm IP65 or 12 mm–15 mm IP55
- 16 pcs 8 mm-14 mm IP65 or 7 mm-10 mm IP55
- 4 pcs 14 mm-20 mm IP65 or 5 mm-10 mm IP55
- 4 pcs 5 mm-7 mm IP65

It is interesting to notice from the specifications of the flange that if the same membrane is used for thinner option the IP classification is worse than using the thicker option. The thicker cable can be mounted more tightly than the thinner one. The person who is doing the cabling work will decide which membrane is used for each cable. The thinnest membrane is recommended to use to reach the tightest possible penetration.

8.1.1 Flame-retardant Classification for Multi Flange

This multi flange solution is equipped with UL94-V0 status/14/. This is the classification for flame-retardant properties. It is also available without the UL94 classification but it makes no sense for this purpose. The measuring methods can be seen in appendix 2.. The test was divided to three sections, from best to worse:

- Surface burn
  - Does not ignite under hotter flame
    - UL94 5VA
    - UL94 5VB
- Self extinguishing
  - Tested object will extinguish itself
    - UL94 V0 (best) no drips allowed
    - UL94 V1 (good) no drips allowed
    - UL94 V-2 (drips) drips are allowed
- Slow burn rating
  - Takes more than 3 minutes to burn 4 inches

The cable flange is made of TPE-SEBS material which meets these above-mentioned requirements. Because the solution which is used today is V0 class, it is important to pay attention that the consequent solution will not be worse than this.

It is very important to pay attention to a matter which is connected to IP classification. If the piercing of the multi flange has been improper and membrane has too large an incision, it is not according to the instruction anymore. Therefore, the membrane is not anymore tight and flame-retardant classification is invalid because flames can go through the loosen membrane.

8.1.2 Tightness of the Membrane Gaskets

Even though the manufacturer says that this product will meet the IP65 or IP55 ratings, this is very hard to reach in field conditions. There are no standards which can be used to justify the IP rating for this product. None of the manufacturers knew which standard these IP65 or IP55 ratings were following. Only material standards were available.

With careless actions the IP ratings can be totally different from specifications of the manufacturer. In some projects the client has refused to accept these carelessly cut membranes which does not meet the IP ratings.

In Figure 20 it can be seen that at the bottom of the cables there are incisions which will not be tolerated when inspecting the tightness of the inlets. This cable work has been done at the site.

There is a fan, mounted on the door of the cabin which creates overpressure inside at the same time when it is decreasing the inside temperature. This prevents dust and impurities from getting inside the cabin. But the fan is not spinning all the time. There is a thermostat which keeps the temperature of the cabin even. There is a heater inside the cabin which heats up the cabin temperature if it decreases too low.

Because of location of the BJA panel it is possible that some splashes can appear under the cabin. If this happens, it is possible that some splashes can penetrate through the loose membrane and cause damage inside the cabin.

Figure 20. Membrane gaskets that have been done carelessly /21/

If such conditions are resulted in, actions are needed. Then there are only two alternatives.

All of the cables must be removed, the flange must be changed and replaced with some other solution, such as separate cable glands, and then all of the wires must be connected again. The second alternative is to seal the multi flange somehow. This solution is based on the instructions of the manufacturer. They informed us that there is no official way to fix this issue but silicone based compound or other sealing compound can be used for sealing the pierced membranes again. The sealing compound must withstand fire and it must be well adhesive and it cannot be too thin to avoid dribbling and messing of surroundings. /8/ This is not officially confirmed solution, the final IP classification cannot be confirmed. When this solution is used, it must be approved by the customer.

In a certain project the issue was fixed by using sealing compound. The first step was to create frames around the multi flange, such as in Figure 20. The frames are for the sealing compound to isolate the cast area. It is important to take into consideration that the height of the edges is sufficient to prevent any overflow. In this stage it was wise to move the cable marks slightly upward because when the pond is filled with liquid, the mark cannot be seen. The surface will rise a few centimeters.

The second step was to use sealing compound to prevent the casting flow through the small holes in the membranes. The sealed multi flange was as shown in Figure 21. In this case Hilti FS-ONE was used as a sealing compound. FS-ONE is a fire stop sealant, so it withstands flame and heat. According to Hilti this fire stop sealant can protect the penetration even up to four hours. /13/ In case of the fire this penetration will give out last. It must be taken into consideration that the original flange has 94-V0 fire rating classification. /14/ This is why the sealant compound must meet the requirements or even make it better. The material must not accelerate the burning.

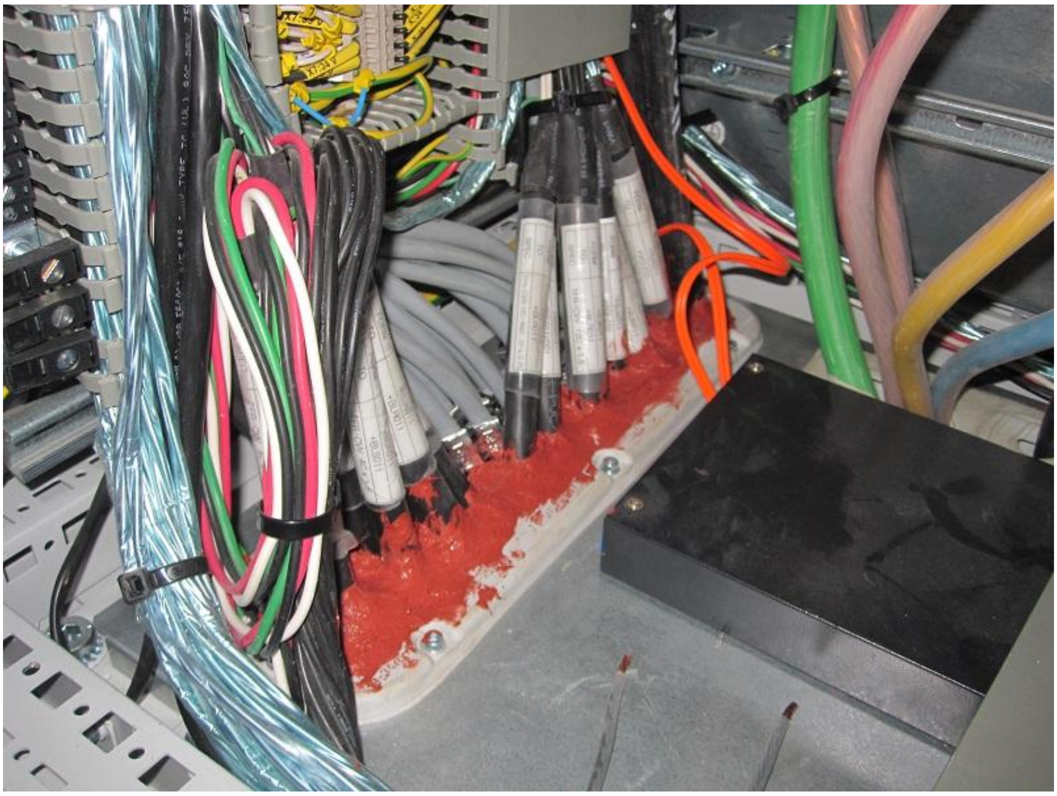

Figure 21. Sealed cable bases inside the BJA cabin. /21/

The final step was to cast the final liquid compound to the pond. In this case the Elastosil silicone compound was used. The type of used compound was Elastosil M 4601 A/B two component silicone rubber that vulcanizes at room temperature. /7/

In Figure 22 it can be seen how thin the Elastosil compound is. It flows very easily through tiny holes and joints. This is why previous steps are important to do properly to achieve a good quality. When the compound dries up, it is flexible and tight. Flexibility is important because the temperature can be different depending on the season. This can cause heat expansion in the steel structures and this is why it is important that the Elastosil can adapt in the conditions and will not crack. It is also good to protect against the vibration with a flexible solution.

Figure 22. The Elastosil compound has been poured into surrounded area /21/

Even though many of the issues appear during the site cable installation, there are the same issues when the cabinet is leaving the factory. The same mistakes are done in the factory and can be seen in Figure 23. Multi flange is not either dust-fire proof when it leaves from the module factory either. This is not a correct way of installation. The membranes have been pierced carelessly using a knife. The membrane is not tight anymore. The membrane must be pierced by a screw driver or another similar tool. The bottom line is that the pierced hole is circle-shaped and not too big and when the cable is pulled through, the membrane will expand automatically to the correct size.

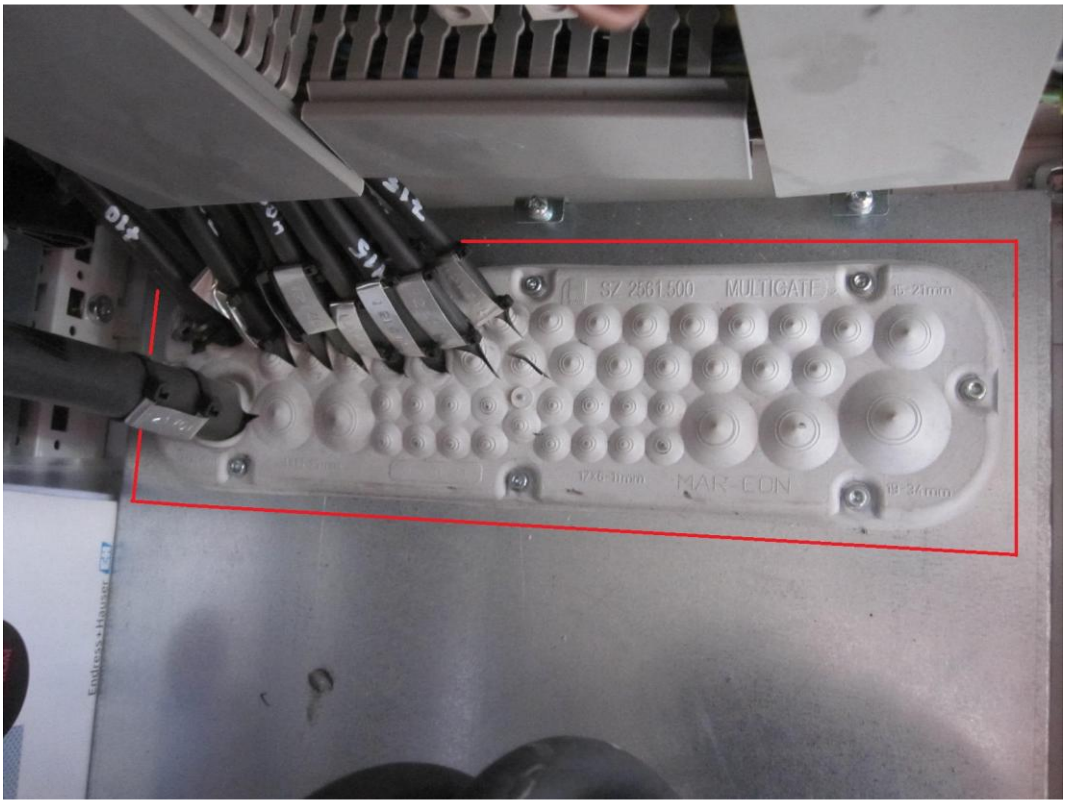

Figure 23. Prefabricated cables have been installed carelessly /21/

8.2 Using the Individual Cable Glands

Using individual cable glands on the bottom of BJA panel is not a common solution. It makes it more complicated because each cable must be put through the gland one by one. Cable glands need also much more space compared to multi flanges because each gland needs a small individual hole. Compared to the multi flange, this solution is not so flexible because each cable gland can seal only a specific size of cable. Thus, too thin a cable slips through the hole and too thick will not fit at all through the hole. However, if the right size of the gland is used for the right size of the cable, the result is high-quality.

Metallic cable glands are available in brass or stainless steel. Stainless steel cable glands are suitable for the EMC use but in this case a basic metal cable gland is sufficient.

The metallic cable gland and functional principle can be seen in Figure 24. This is the type of cable gland which is planned to replace the multi flange solution. The cable gland is planned to install on the plate. There is a thread on the bottom of the gland where the tightening nut is twisted. The plate stays between these two parts. This creates a very reliable and tight cable penetration. Finally, when the cable is pulled through, the cable is attached properly by turning the tightening part. Inside the gland there is a rubber gasket which makes the gland water and dust proof. This cable gland is manufactured according to the specifications which meet the IP 68 classification. The IP68 classification has been proved in accordance with the IEC 60 529 standard. /17/

The cable gland is often delivered with a nut which makes it easier to order and store. There are also some suppliers who deliver cable gland parts separately. This has to be known when doing order or cost comparison.

Figure 24. IP 68 metal cable gland /15/

8.2.1 Cable Gland Fire-retardant Classification

If the multi flange solution meets the fire-retardant classification, the cable gland solutions have to meet also those requirements or even make it better. In general, there are two possible cable gland types, metallic and plastic. The metallic one has a huge benefit with high resistance against fire and heat. The impact durability is also first class with this material; it will not break easily.

The most generally used cable gland material is plastic, the specific material is polyamide PA6 but it can be called just plastic. It must be taken in consideration when fire-retardant features are changing. The cable gland has no the same kind of features as the multi flange has. This was found out by asking the manufacturers about the more specific details regarding the fire-retardant classification. It turned out that the plastic cable gland has no UL94 classification at all. /9/

Due to this information that a plastic cable gland does not withstand fire, according to the manufacturer's specifications, it cannot be used. The production material also indicates that it will not withstand any hard impacts.

8.2.2 Tightness of the Cable Gland

An individual cable gland solution would be a good alternative when the tightening issues is tried to solve. In the future, there is a lot of space on the bottom of BJA panel for cable glands. A cable plug makes it possible to generate more space. There will be approximately 20 cables less after the plug solution has been adopted. Thus, this work gets easier and makes it possible to create smarter cabling.

Unlike the multi flange, the cable gland has an integrated cable clamp. This is possible because inside the cable gland there is a gasket which tightens around the cable when the hole of the gland gets smaller when the tighten nut is twisted. When the multi flange is used, there must be a bar somewhere near the flange where the cable can be tied using cable ties, otherwise the cables can slip out of the cabinet and cause a lot of damage by ripping device connectors and terminals with it.

To make a tight connection using a cable gland, it is important to pay attention to the physical size of the cable. Each cable gland size has a nominal rated hole size which defines what size of cables can be used. It is very important to follow the manufacturer's instruction about the cable size range, otherwise the gland will not be tight enough and the cable clamp is incomplete.

One concern which must be eliminated at the beginning is that cable sizes must not change. When using a cable gland it has a limited range of cable physical sizes. The range is not very wide. Thus, it is very important to keep the cable sizes the same during the whole project. If some cables are changed to thicker or thinner ones, it is possible that cable glands will not work anymore because the range of the size has been exceeded. For example, aM20 size cable gland can handle 6 mm- 12 mm thick cable. However, if cable sizes are changed for some reason, it is not a big problem. It is easy to drill a new hole for the new bigger or smaller gland on the bottom of the BJA. This is possible if there are only few cables which are changed. If the number of the changed cables will rise too high, then it can cause problems.

From Table 3 it can be seen what kind of diameters the M size metal cable glands can handle to produce proper cable gland. These cable glands are from RITTAL's catalogue. As seen in table 3 the cable glands can handle very wide range of cable sizes. The range shown in table 3 is between 3 mm to 48 mm.

Table 3. Choosing table for the metal cable glands /2/

Size	Cable diameter mm	Packs of	**Model No.**
M12 x 1.5	3 – 7	15 pc(s).	**2411.800**
M16 x 1.5	4.5 – 10	15 pc(s).	**2411.810**
M20 x 1.5	7 – 13	10 pc(s).	**2411.820**
M25 x 1.5	10 – 17	10 pc(s).	**2411.830**
M32 x 1.5	13 – 21	5 pc(s).	**2411.840**
M40 x 1.5	19 – 28	4 pc(s).	**2411.850**
M50 x 1.5	25 – 35	2 pc(s).	**2411.860**
M63 x 1.5	35 – 48	1 pc(s).	**2411.870**

The cable sizes in table 3 are equipped with a strain relief. Sometimes the manufacturer gives two cable sizes for each gland size. This means that the bigger size is the gland only and the smaller size is the gland which has the cable clamp feature. In this case it is mandatory to use the cable glands only with a strain relief feature.

9 CONCLUSIONS

The aim of this thesis was to find out the solutions which can be used to develop the cabling of Wärtsilä's EAM. The purpose of the solutions was to get rid of the quality issues. It was easy to get started because some preliminary researches have been done. Thus, there were several basic ideas which were refined to create even better solutions. My experiences from working had a big effect on the solutions created I believe that all of the improvements which I have made during this thesis are very useful. The chosen solutions were selected to meet the practical work. There will be a lot of modifications in the future because Wärtsilä is developing its products all the time. That is why it is important to include future extension that the solution can be used for a long time and apply to the next generation products.

In my opinion I succeeded very well from the tasks I was given. There were lot of people who were willing to help me to go through the problems. I got a lot of information especially by emailing to the suppliers of the products used to develop the BJA and module cabling. This thesis suited me perfectly because it was so practical. I benefited a lot from my electrician's background. All components were very familiar to me from my earlier experience and I was able to perceive the aim all the time. I was also very interested about this subject because I like the tasks which are close to the real life and which I have worked with.

The solutions which have been presented in this thesis are intended to take into the use in the near future. I am sure that this will help Wärtsilä a lot when they have better solutions in use and clients are even more satisfied with our quality.

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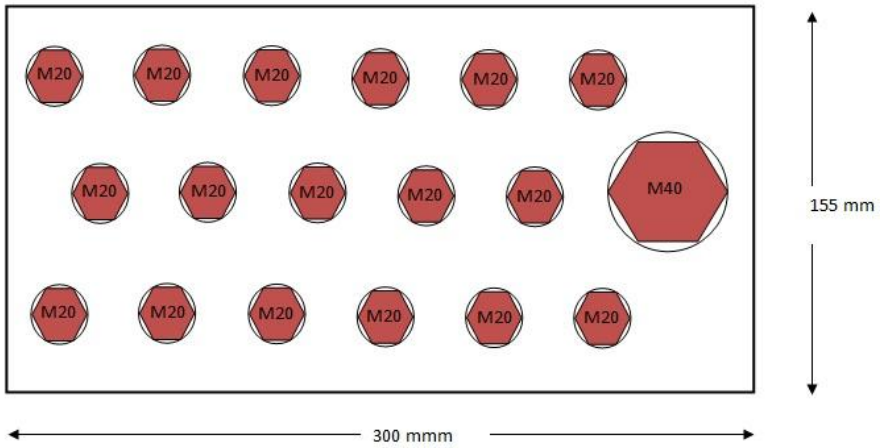
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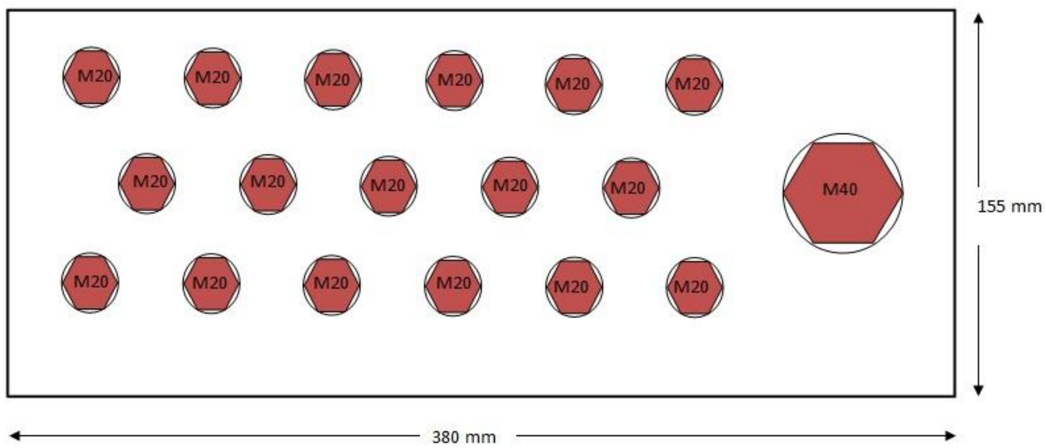
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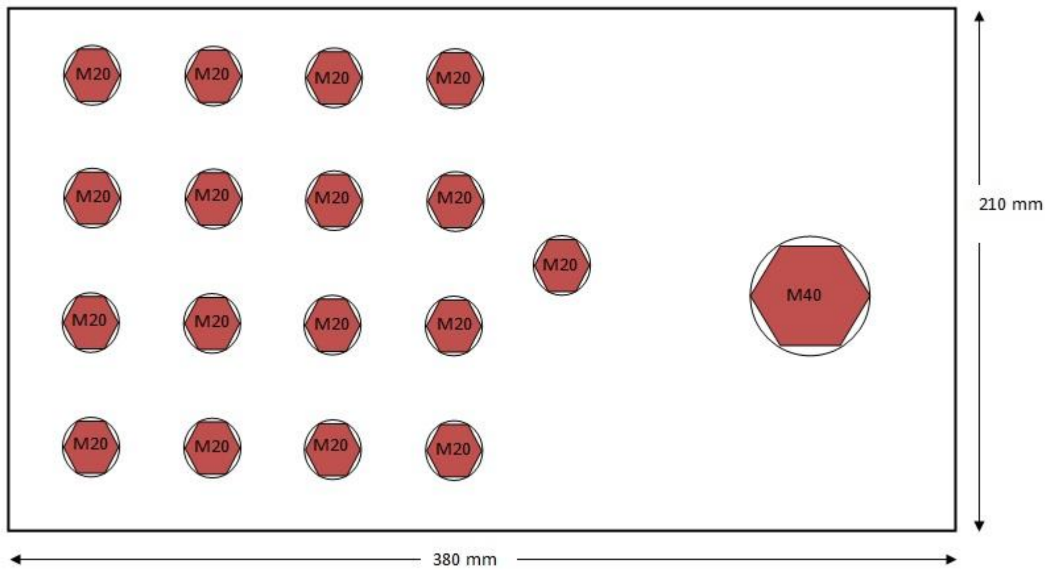
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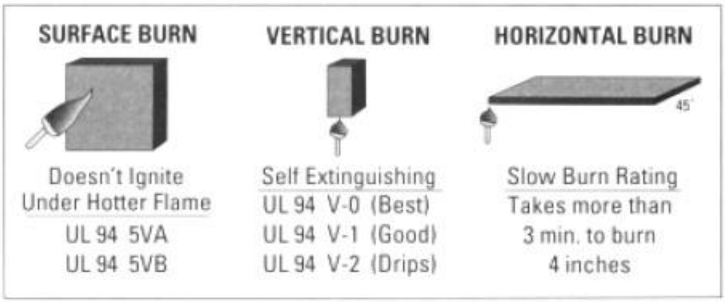
APPENDIX 2. Definition of flame-retardant classifications



UL 94 Flammability Ratings Summary

5VA Surface Burn	Burning stops within 60 seconds after five applications of five seconds each of a flame (larger than that used in Vertical Burn testing) to a test bar. Test specimens MAY NOT have a burn-through (no hole). **This is the highest (most flame retardant) UL94 rating.**
5VB Surface Burn	Burning stops within 60 seconds after five applications of five seconds each of a flame (larger than that used in Vertical Burn testing) to a test bar. Test specimens MAY HAVE a burn-through (a hole).
V-0 Vertical Burn	Burning stops within 10 seconds after two applications of ten seconds each of a flame to a test bar. NO flaming drips are allowed.
V-1 Vertical Burn	Burning stops within 60 seconds after two applications of ten seconds each of a flame to a test bar. NO flaming drips are allowed.
V-2 Vertical Burn	Burning stops within 60 seconds after two applications of ten seconds each of a flame to a test bar. Flaming drips ARE allowed.
H-B Horizontal Burn	Slow horizontal burning on a 3mm thick specimen with a burning rate is less than 3"/min or stops burning before the 5" mark. H-B rated materials are considered "self-extinguishing". **This is the lowest (least flame retardant) UL94 rating.**