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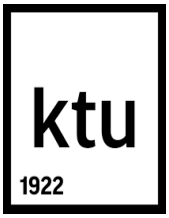

VALDEMARAS JAGMINAS

MODERNIZATION OF SHOT-BLASTING AND SPRAYING PROCESSES FOR INDUSTRIAL PRODUCTS

Final Project for Master's degree

Supervisor

Assoc. prof. dr. Saulius Baskutis

KAUNAS, 2017

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FACULTY OF MECHANICAL ENGINEERING AND DESIGN
DEPARTMENT OF PRODUCTION ENGINEERING

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Final Project for Master's degree

Industrial engineering and management (code 621H77003)

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Industrial engineering and management 621H77003
(Title and code of study programme)

MODERNIZATION OF SHOT-BLASTING AND SPRAYING PROCESSES FOR INDUSTRIAL PRODUCTS

DECLARATION OF ACADEMIC INTEGRITY

___ _____ ____
Kaunas

I confirm that the final project of mine, **Valdemaras Jagminas** on the subject "Modernization of shot-blasting and spraying processes for industrial products", is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

I fully and completely understand that any discovery of any manifestations/case/facts of dishonesty inevitably results in me incurring a penalty according to the procedure(s) effective at Kaunas University of Technology.

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Approved:
Head of Production engineering Department

(Signature, date)

Kazimieras Juzėnas
(Name, Surname)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree, is a research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

MODERNIZATION OF SHOT-BLASTING AND SPRAYING PROCESSES FOR INDUSTRIAL PRODUCTS

Approved by the Dean Order No.V25-11-8, 21 April 2017

2. Aim of the project

Ensure surface quality using shot-blasting and painting technologies.

3. Structure of the project

INTRODUCTION, INDUSTRIAL PRODUCTION FOR SHOT BLASTING AND PAINTING, SHOT BLASTING CHAMBER, ELECTROPLANTING AND SHEET METAL PAINTING, INDUSTRIAL SPRAY BOOTH, PROJECT CALCULATION, EXPERMENTAL PART, CONCLUSIONS, REFERENCES.

4. Requirements and conditions

1. Make a shot-blasting project calculations in customer needs; 2. Make a spraying project calculation in customer needs; 3. Analyze painting materials; 4. Analyze recuperator buy off period; 5. Analyze frequency drive buy off period.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2017 _____ __st.

Student _____ _____
(*Name, Surname of the Student*) (*Signature, date*)

Supervisor _____ _____
(*Position, Name, Surname)* (*Signature, date*)

Jagminas, Valdemaras. *MODERNIZATION OF SHOT-BLASTING AND SPRAYING PROCESSES FOR INDUSTRIAL PRODUCTS* Master's Final Project / supervisor assoc. prof. dr. Saulius Baskutis; Faculty of Mechanical engineering and Design, Kaunas University of Technology.

Research field and area: Technological Sciences, Production Engineering

Keywords: Shot-blasting, surface, coating, drying

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SUMMARY

Shot-blasting is a means of the surface finishing technique which has great influence on the surface of an object using a controlled stream of abrasive shot material. It is faster and more effective than filing, during which filing material might remain on the part after the casting or stamping process. Shot-blasting is also used for removal of burrs, roughness and rust that may affect the surface of the part. Shot blasting can also prepare the surface by removing old existing coating from the surface and it will help prepare the surface for a new finishing process which will help to have greater adhesion with the surface.

Sheet metal painting is essentially similar to the processes of painting any other surfaces. Primer can be applied after lightly sanding the surface and then paint of a variety of colors can be used for surface protection and desired look. However, while the processes are relatively similar and depending on one another, black metal painting products are offered in different combinations. One of them is covering the surface with paint directly on the blasted surface.

Characteristics of surface coating materials have been tested with the help of the equipment in company “Svydis”. Carrying out the study the consumption of different materials was calculated in order to know the output of material needed to cover the surface with 300 μm layer, as well as to find out the surface drying time. The testing results were graphically compared among themselves. Company “Svydis” helped with the tests of surface coating and drying when parts were pained and dried in a special drying chamber adapted for coating and being able to maintain stable temperature inside.

All the study results are presented and analyzed in this project.

Jagminas, Valdemaras. *PRAMONINIŲ GAMINIŲ ŠRATAVIMO IR DAŽYMO PROCESŲ MODERNIZAVIMAS* Magistro baigiamasis projektas/vadovas doc. dr. Saulius Baskutis; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

Mokslo kryptis ir sritis: Gamybos inžinerija, Technologijos mokslai.

Reikšminiai žodžiai: Šratavimas, paviršius, padengimas, džiovinimas

Kaunas, 2017. 52 p.

SANTRAUKA

Šratavimo procesas tai paviršiaus paruošimo apdailai būdas, kuris sparčiai įtakoja gaminio paviršių su tolygiu šratavimo abrazyvo srautu. Tai greitesnis ir efektyvesnis procesas nei paprastasis šlifavimas, kurio metu nuo šlifavimo medžiagų gali atsirasti atsikartojimo žymės. Šratavimas taip pat naudojamas atplaišų, nelygumų ar rudžių pašalinimui, kurie gali įtakoti galutinę paviršiaus išvaizdą. Šratavimo pagalba taip pat galima paruošti gaminio paviršių pašalinant pasenusią apdailos dangą ir paruošti naujam apdailos procesui, kuris turės didesnį sukibimą su paviršiumi.

Juodojo metalo dažymo procesas yra panašus į kitų paviršių dažymą. Gruntas gali būti užpurškiamas po glotniojo paviršiaus šlifavimo. Sekančiu etapu padengiami norimos spalvos dažai paviršiaus apsaugai ir norimai išvaizdai. Anaiptol, kai procesai yra panašūs ir priklausomi vienas nuo kito, juodojo metalo dažymui yra siūlomos įvairios produktų kombinacijos. Viena iš jų, tiesioginis dažų padengimas ant šratuoto paviršiaus.

Medžiagų charakteristikų tyrimas atliktas pasinaudojant įmonės UAB „Svydis" turima įranga. Tyrimo metu buvo atlikti skirtingų medžiagų sunaudojimo skaičiavimai tam, kad padengti 300 µm storio sluoksniu paviršių ir ištirti dangos džiūvimo laiką. Gauti rezultatai grafiškai buvo lyginami tarpusavyje. UAB „Svydis" padėjo atliekant paviršinio padengiamumo ir dangų džiūvimo tyrimus, kurių metu gaminiai buvo dažomi ir džiovinami specialioje kameroje, pritaikytoje dažymui ir galinčioje palaikyti stabilią temperatūrą jos viduje.

Visi tyrimo metu gauti rezultatai yra pateikiami ir analizuojami šiame projekte.

Gratitude

I would like to express my gratitude to the supervisor S. Baskutis, for help in my master's project investigation.

CONTENTS

1. INTRODUCTION

The main goal of industrial products is to create individual parts, or large-scale structures. The term covers a wide range of work from large ships and bridges to precise engine parts and delicate jewellery. It, therefore, requires a correspondingly wide range of skills, processes, and tools.

The aim of shot-blasting is to prepare the surface of the materials for further operations, such as painting, galvanising, paint reconditioning, etc. The structures to be cleaned can be loaded on trolleys and carried into the shot blasting chamber. This proposal includes the supply of a complete abrasive recovery system which consists of a scraper device installed under the grating that collects the abrasive and transfers it to the transversal Archimedean screw conveyor. The abrasive recovered by the screw conveyors is transferred to media separator by a bucket elevator. Inside the separator flashes and slag are automatically removed by a vibrating selection screen, and the shot is cleaned and selected by an air flow to separate dust and exhausted abrasive. The complete elimination of dust from the chamber and from the shot, which guarantees the continuous effectiveness of the plant, is obtained through an automatic high-efficiency self-cleaning filter: furthermore, the dust collector has the aim to guarantee the emission in the atmosphere of air containing dust quantity within 3 mg/m^3.

The painting/drying booth is a work room used for preparing and painting industry parts to be repaired, as well as drying the sprayed paint. It must be illuminated, ventilated, with a glass main door with 4 wings (a wing is the personnel door) and, possibly an access door with a side/back glass wing that is opened by pushing from the inside towards the outside and self-closing. All of the mechanical structures and insulations are realized with non-combustible materials.

2. INDUSTRIAL PRODUCTION FOR SHOT BLASTING AND PAINTING

Industrial metal forming is used in almost every sector of industrial production (examples are shown in fig. 2.1):

- Automotive industry (e.g. doors, hoods, fenders)
- Aircraft industry (e.g. wings, fuselage)
- Home appliance industry (e.g. sinks, cooker hoods, freezers)
- Food industry (e.g. cooking pots, canned goods)

a) b) c) d)

Fig. 2.1 Industrial production examples. [1]
a) automotive industry; b) aircraft industry; c) home appliance industry; d) food industry;

Sheet metal forming is used for industrial manufacturing in many sectors – from a car door to a tin can. In sheet metal forming, the final shape of a part is made from a flat metal sheet. The desired shape is achieved through plastic deformation, without undergoing any machining like milling. In most cases, a certain amount of elastic deformation leads to spring back which occurs after forming is complete.

According to DIN 8582 [2], the process is divided corresponding to the stresses which typically appear in the sheet:

- Forming under compressive conditions
- Forming under combination of tensile and compressive conditions
- Forming under tensile conditions
- Forming under bending conditions
- Forming under shearing conditions

The forming of the sheet can be carried out using mechanical tools with air or with liquids, magnetically or with explosives. Special sheet metal processes include super plastic forming and press hardening, as well as the hot forming of aluminum and magnesium.

3. SHOT-BLASTING CHAMBER

In the manual shot-blasting chamber one operator carries out the blasting operation by ejecting abrasive media through a special nozzle. The plant components are manufactured according to the rules and standards in force in the European Community, in terms of design, safety, and environmental pollution.

3.1. OPERATING PRINCIPLE

The jet of shot-blasting agent is directed by the person working with the object in the chamber, by moving hand-held pistol. The chamber is rubber-protected. High work efficiency is reached by the continuous shot-blasting agent returning and cleaning system. It depends on the customer's needs and demands what size of the shot-blasting chamber, the number of shot-blasting pots and the bearing strength of the chamber floor must be customized. The continuous shot-blasting agent returning and cleaning system can have screw conveyors or scraping conveyors applied either to the whole shot-blasting chamber surface or only part of it. High work efficiency can be achieved by different platforms for working on heights, devices for spinning rotated treated object around longitudinal axis and shot-blasting agent sucking devices.

3.2. BEFORE AND AFTER SHOT BLASTING

3.2.1. Checking conditions before blasting

Most coatings are not well adhesive to surfaces if they are polluted with oil and grease. Blasting actually drives them further into the steel instead of removing these contaminants and thus contributes to coating failure. Therefore, it is necessary to check if there are any visual surface contaminants before starting blasting. If there is oil and grease on the surface of the object, they should be removed with solvent cleaning.

It is also important to measure ambient conditions before blasting. If blasting is not done immediately by coating application, then first steps are to remove the existing coating, rust, and mill scale, and to check ambient conditions before the final blast. But if blasting is to be followed immediately by coating, then, before blasting begins, ambient conditions should be checked.

It is important to check if the dew point, air temperature, relative humidity, and surface temperature are suitable for blasting. These measures insure that condensation will not be forming on the metal surface during or after blasting and cause flash oxidation, which can be harmful to the quality and the coating process. Dew point is the temperature at which moisture condenses on the

surface. When the dew point is 10° C, condensation will be formed if the metal's temperature is 10 degrees or below this temperature. Generally it is considered that, final blast cleaning should be done only when the surface is a least 3° C above the dew point. For instance, if the dew point is 10° C, the steel temperature should be at least 13° C. A margin of error can occur in case of instrument inaccuracies, quickly changing weather conditions, or human error. Dew point is calculated according to the relevant psychometric tables. The psychometer is a hand-operated instrument that has 2 glass thermometers.

In order to measure ambient conditions, the following equipment is needed:

- a surface temperature gauge or surface thermometer.
- a psycho meter for measuring dry bulb and wet bulb temperature, and psychometric tables for calculating dew point and relative humidity.

3.2.2. Checking blasting abrasives and equipment

The equipment should be checked for efficiency and abrasives and equipment should also be checked for cleanliness before blasting. There parts of the blasting equipment must be checked for contaminants:

- the compressor;
- the moisture separator;
- the air that comes through the hoses

3.2.3. Checking the surface after blasting

All dust from the blast-cleaned surface should be removed after blasting, either by blowing down the surface with compressed air or by vacuuming, because dust on the surface can interfere with the coating's ability to adhere to the surface. In order to be sure that the surface is clean, brush a clean white cloth across the surface (without touching the substrate with the hands as body oils or salts can easily contaminate it) after blowing or vacuuming the surface,. If dust appears on the cloth, do the blowing down or vacuuming the surface again. Check if there are any non-visible contaminants, especially soluble salts, which are not good to coating performance. If it is clear that the blasted surface is free of dust and other contaminants, it is necessary to check the surface profile and degree of cleanliness as to see that the specifications have been met. Dusty and rusty surface is shown in fig.3.1. Surface after the blasting is shown in fig.3.2.

Fig. 3.1 Surface before blasting

Fig.3.2 Surface after blasting

3.3. RECORD KEEPING

Record keeping is essential for quality control checks and they should be documented and kept as part of the quality control records for the job. This way, historical information is available for verifying in compliance with specifications.

THE SHOT BLASTING CHAMBER EQUIPMENT

Fig 3.3 Shot blasting chamber. [3]
1-Chamber; 2-Scraper system; 3-Transversal scraper system; 4-Buckets elevator;
5-Vibrating selection screen; 6- Shot separator and classifier; 7-Abrasive silo

1. **Chamber** – A place where shot blasting process is going. The inside walls, doors included, are completely protected by wear proof rubber sheets. The rubber is fixed on the installed panels. The whole floor is made of grating with a maximum load capacity of 620 Kg/m^2. Two rails are provided all along the cabin, to allow the movement of the railway carriage.

2. **Scraper system** – The abrasive recovery system is installed under the grating. It consists of scrapers conveyors having the aim to recover the abrasive coming from shot blasting operations. Each conveyor is made of flexible wear proof rubber scrapers installed at prefixed

pitch on a special oscillating frame, provided of reciprocating movement. The installation requires a minimum depth of 160 mm. This system, considering the working conditions, is reliable because the wear of rubber blades is negligible and can be adjusted by any unskilled operator.

3. **Transversal scraper system** – The abrasive recovering system is located at the middle length of the cabin, and it receives the shots from the scraping units. It consists of a transversal hopper covered by grating. Inside the hopper there is a scraper system which transfers the abrasive to the base of buckets elevator.

4. **Buckets elevator** – The buckets elevator lifts and conveys the abrasive to the media separator. The body consists of a bent-sheet pipe with inspection doors. Internally there is a pulley which rotates on outlining dustproof supports. The position of the supports can be adjusted to give the possibility to set the belt tensioning. The elevator belt is made of textile reinforced rubber with bolted buckets. The belt is driven by the top worm screw gear motor.

5. **Vibrating selection screen** – It is located inside the shot separator, and its scope is to separate from the shots the bigger residuals coming from the blasted pieces. It is made by a punched steel channel fitted with a motor-vibrator.

6. **Shot separator and classifier –** This device allows the elimination of the exhausted abrasive by means of air counter flow. It is made of steel sheets with suitable chutes and includes the followings:

- draw able type static screen to allow periodical cleaning;
- bathing device with counterweighted swinging gate;
- suction pipes for air counter washing;
- built-in grit collecting hopper and dust decanter;
- manganese steel sheet protection for the area's most subject to wear;
- flexible duct equipped with non-return valve for the elimination of polluted materials.

7. **Abrasive silo** – One abrasive silo having a capacity of 3000 Kg is foreseen to feed the pressure blasting unit. The container is made by welded steel plates reinforced with profiles and columns supporting the structure from the ground level.

3.4. THE SHOT-BLASTING SAFETY DEVICES

The shot blasting chamber installation is designed according to CE rules: consequently, it identified the possible hazards and the correspondent risk reduction procedure with the following safety applications [4]:

1. All the main doors and the safety doors are provided with automatic interlocking system suitable to stop the shot blasting process.
2. If during the shot blasting phase, the operator leaves the gun, which falls on the grating, automatically the abrasive ejection is stopping.
3. The operator is provided with safety helmet and mask fed by separate air pump and including special proper filter (see fig. 3.4).
4. One operator safety equipment is foreseen in the centre of the chamber at floor level.
5. One emergency light is foreseen above the safety door.
6. During the shot blasting process two red lights installed outside of the chamber beside the main doors, are switched on.

Fig. 3.4 Operators safety wear

4. ELECTROPAINTING AND SHEET METAL PAINTING

To protect prototypes and production pieces a number of different methods are known. Electro painting and painting occupy the opposite ends of each spectrum. Electropainting (fig.4.1) can create a very thin layer of metal such as iridize joined to the component over the aluminum base.

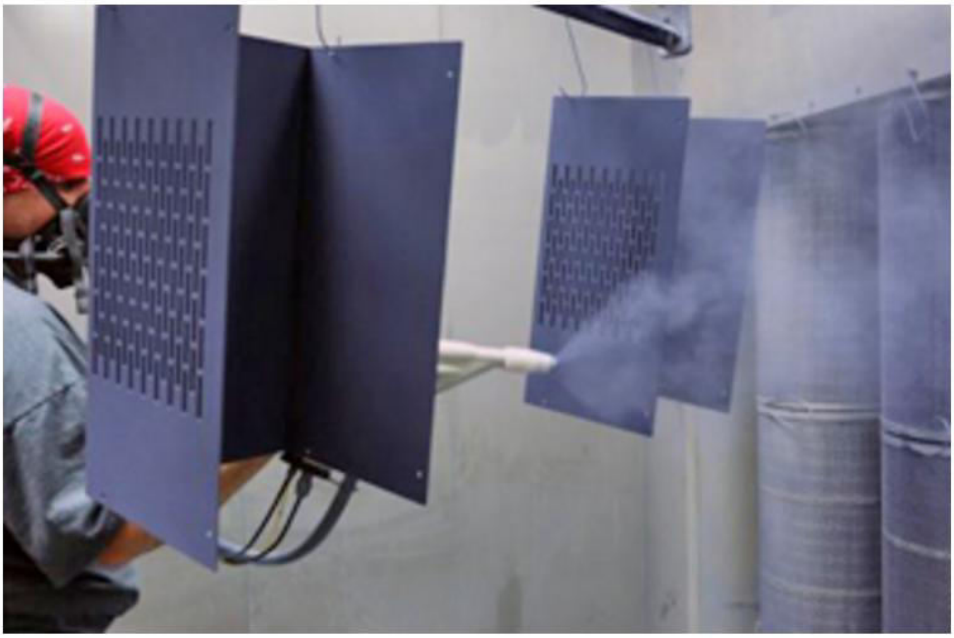


Fig. 4.1 Electropainting example [5]

Sheet metal painting is essentially similar to the process for painting any other surface. A primer can be applied after lightly sanding the surface and then paint of a variety of colors can be used as a protective coating. However, as the processes are relatively similar and straightforward, they offer very different advantages to the finished product following sheet metal fabrication.

4.1. BENEFITS OF ELECTROPAINTING

To apply electropainting in coating is much better than painting, in terms of corrosion resistance and limited degradation due to strikes. Moreover, because the metal expands and contracts at the same rate as the coating, it can be used in environments where temperatures can change drastically over time. It is also easier to make a relatively even layer of a secondary metal, which is critical when the component has to fit into a system with tight tolerances. Several different metal options that can be used in electropainting, as well. In parts that must be used together with others: chrome works as a lining that minimizes friction and wear and at the same time adds an attractive look. Zinc helps to protect against water damage and tin painting helps when joining materials that are different to sheet metal aluminum components.

4.2. SHEET METAL PAINTING

Electropaiting offers significant resistance to a variety of environmental problems, but sometimes it may have disastrous outcomes. Painting can cost less in certain cases, when the entire part does not need to be sprayed. If the full surface area does not need to be protected, paint can offer more flexibility than other options. In addition, there are more varieties of colors that can be used and project engineers can also take advantage of A&E Manufacturing's silk screen capabilities to add logos and other designs.

4.3. OTHER SHEET METAL FINISHING OPTIONS

Powder coating is one of the choices for finishing the product. This coating offers a variety of finishes, including matte and glossy, which does not make the cost of components very high. There are many different schools of thought as to which is better painting or powder coating, and the answer is probably dependent upon the individual need requirements of the part being made. The general assumption is that powder coating is more durable than paint, but in manufacturing experience in many cases paint is a better alternative to powder coat because it is possible rework in case of scratches or revision changes. It was also discovered that consistency in color and texture is better when painting because craftsmen and ISO Quality System say that these factors stay consistent batch to batch. Powder coating has relied on the powder manufacturer to produce consistent batches every time, which has not always been easy for them to achieve. The final choice is anodizing or sealing. In these cases a chemical reaction is induced in the outside layer of the aluminum and makes it stiffer, but also more brittle. Being cheaper than electropainting, it improves protection against solvents and other corrosives.

5. INDUSTRIAL SPRAY BOOTH

Industrial spray booth consists of the following components: the basement with filters through which the air is exhausted; the parametric panels which define the working area; the plenum for the distribution of the hot air coming from the thermoventilation unit through the intake ducts; the power and control panel. The thermoventilation unit heats the air of the atmosphere. The filtered air (heated or not heated, according to the requirements) enters into the booth box through the plenum. Thanks to an exhaust fan, the air is filtered and exhausted to the outside. Construction of industrial spray booth cabin is shown in fig.5.1.

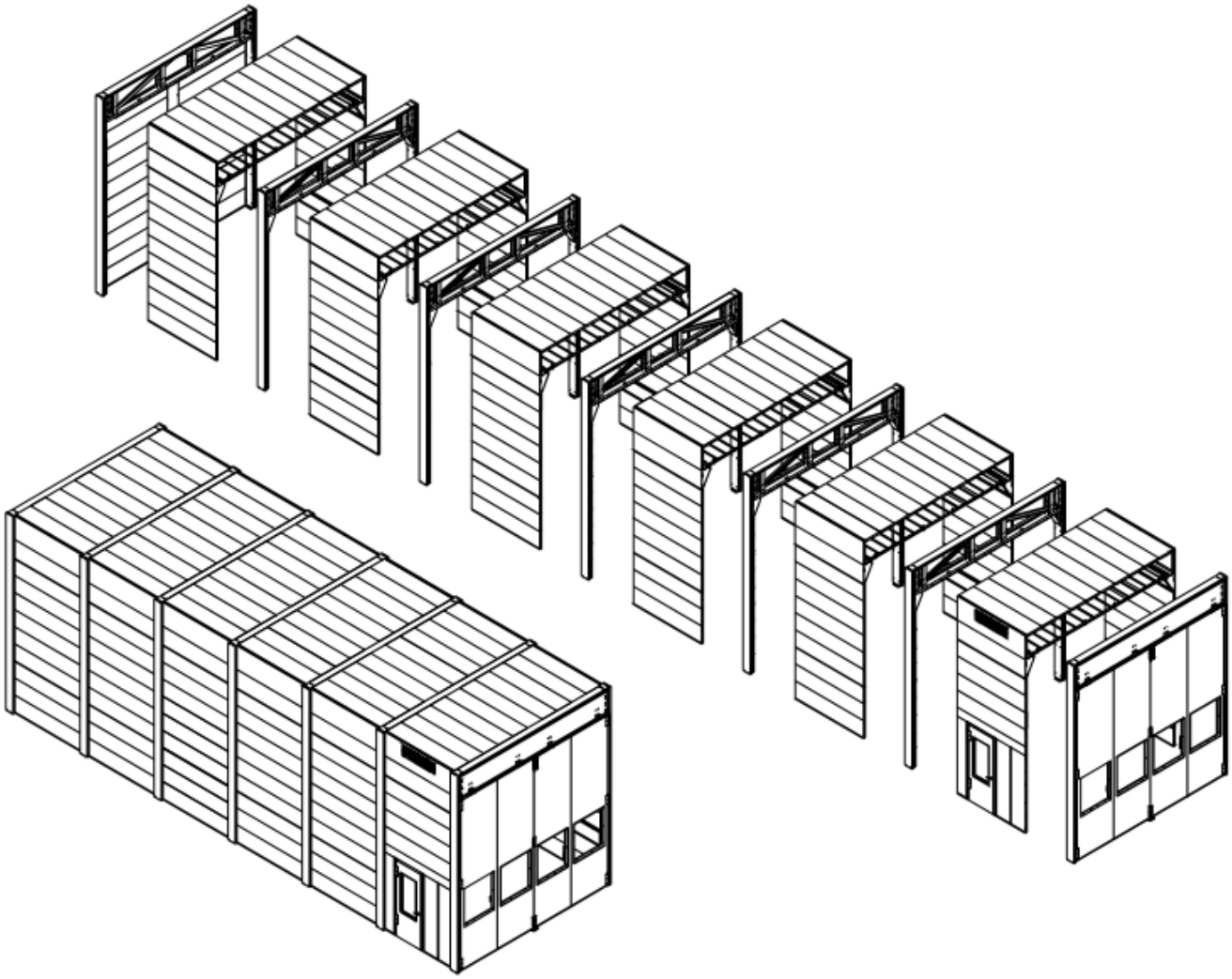


Fig. 5.1 Construction of industrial spray booth [6]

5.1. TERMS AND DEFINITIONS

This chapter contains the information to understand the installation, use and care of the "industrial spray booth".

- **Booth box:** closed area where the object is sprayed with paint and where the paint is dried.
- **Thermoventilation unit**: set of ventilation unit/s, cycle locks, and heating system.
- **Heating system:**
  - Heat exchanger with gas/LPG/diesel burner
  - Direct gas system with make-up burner
- **Flue:** a pipe that releases products combusted by the burner (where required).
- **Cycle lock:** a lock and servomotor driven unit that intercepts and diverts the air, enabling the booth to run in the painting, flash off, drying and cooling phases.
- **Pre-filtering unit:** a set of dry filters fitted in the extraction unit that removes large dust particles at the initial filtering phase.
- **Ceiling filter unit:** a set of dry filters placed in the booth ceiling that totally removes the dust still in the air.
- **Paint-stop unit:** a set of dry filters fitted in the booth basement that removes a high percentage of the dry paint residue conveyed in the exhaust air.
- **Delivery plenum:** a chamber in the top part of the painting-drying booth, between the roof and the ceiling, that collects and calms the air before it is released into the booth.
- **Exhaust plenum:** the bottom part under the booth grating that collects and calms the air before it is exhausted or recycled.
- **Electrical panel:** electromechanical or electronic equipment that powers and/or commands, manoeuvres, protects, controls and grants the component safety, housed in one or more containers.
- **Ducts:** ducts that collect transport and distribute the air.
- **Fire cut off damper:** it is installed between the thermoventilation unit and the booth box. It blocks the passage of the air coming from the thermoventilation unit whenever there is an anomalous increasing of the air temperature (which might be produced by a fire). It intervenes automatically. The fire cut off damper is delivered upon request, when required by the regulations of the country. When the temperature goes beyond the fuse calibration (180°C), the REI120 fire cut off damper blocks the air flow to the plenum and at the same time it stops the ventilation and the burner.
- **Regulating locks:** set of dampers that open and close manually, or by means of the servo motor. These dampers are fitted in the air circuit in order to control the rate and the

pressure. Normally the locks are fitted at the inlet of the ventilation units.

- **Activated charcoal air purifier:** this equipment removes solid and gaseous pollutants from the air exhausted from the booth by forcing it through dry and activated charcoal filters. The purifier has its own ventilation unit that takes the air from the exhaust plenum, filtrates it through the dry and activated charcoal filters, and then releases it outside through the exhaust duct.
- **Activated charcoal filters:** cylinder-shaped elements, made of perforated galvanized sheet that contain activated charcoal. The air passes through them and is cleaned from solvents.
- **Unpainted pieces:** vehicles, machines or other components that have undergone all the necessary operations: preparation, making, etc., so that they can be painted.
- **Servo motors:** electric or pneumatic motors which open or close the regulating locks (or other installation components). The servo commands can be driven automatically or manually.

5.2. TECHNICAL DATA AND OPERATIONS OF THE THERMOVENTILATION UNIT

There are two different heating systems:

1. Heating system with a shell and tube heat exchanger with combustion chamber entirely made of aluminum steel sheet (highly recommended for this purpose because of its excellent thermal and anticorrosion properties). It is with burner-connection plate, anti-explosion device, combustion-inspection glass, inspection hatch for maintenance and flue coupling; it can be combined with a blown-air burner running with methane gas, LPG or Diesel. (see fig. 5.2)

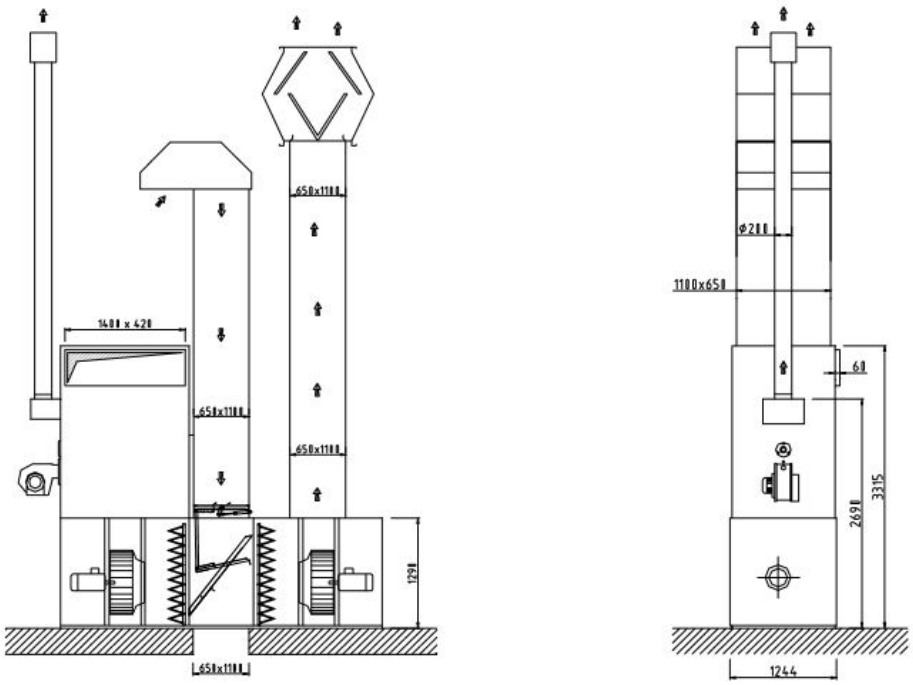


Fig.5.2 Heat exchanger system [7]

2. Heating system with make-up burner (direct exchange) see fig. 5.3

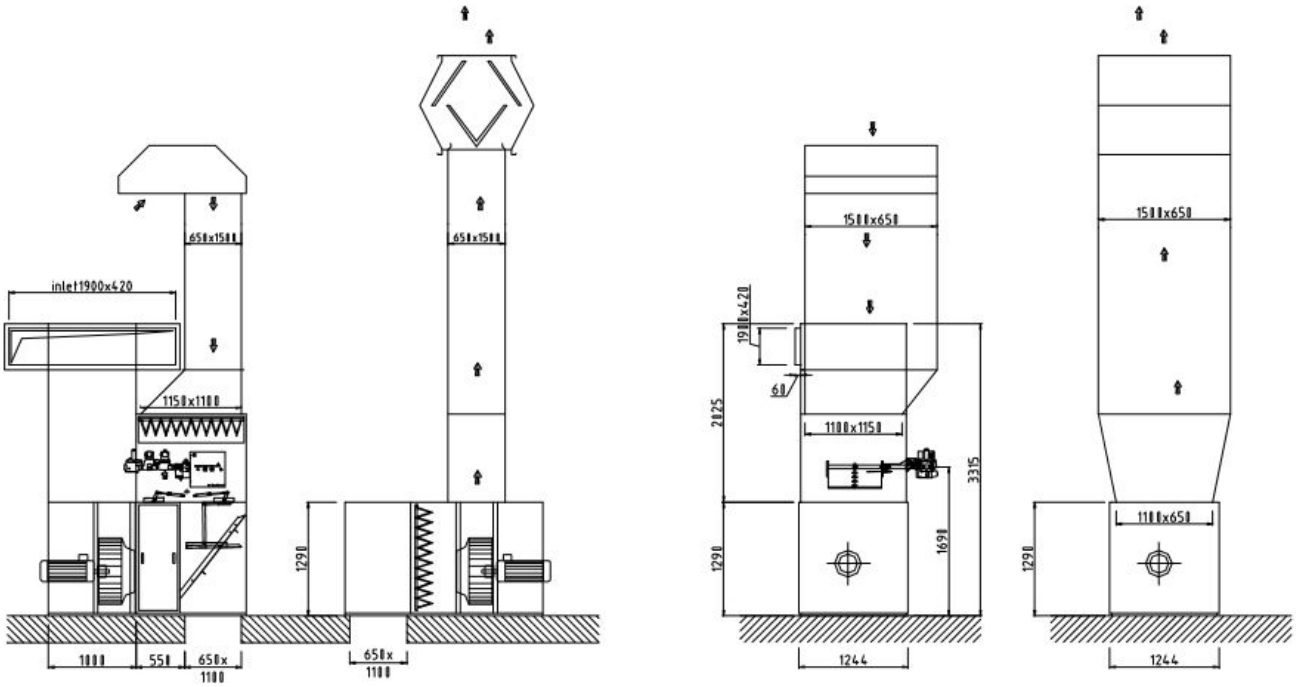


Fig.5.3 Direct fire system [8]

The thermoventilation units with heat exchanger or air make-up technology are high performance industrial type generators, created to satisfy the requirements of systems for high flow rates and pressures. They are constructed essentially of self-supporting sandwich panels with a pre-

coated white external sheet, an internal special galvanized sheet metal and an anti-deterioration thermal acoustic coating with following characteristics:

- material: glass wool insulation
- binder: thermosetting resin
- classification: non-flammable
- maximum operating temperature: 90°C
- thickness: 60 mm - density: 15 kg/m³ (discharge section)
- thickness: 6 -10 mm - density: 55 - 80 kg/m³ (ventilating section)
- heat conductivity: 0.036 kcal/m²
- class 0 (zero) fire-reactive material

Spray booth section view is shown in fig.5.4.

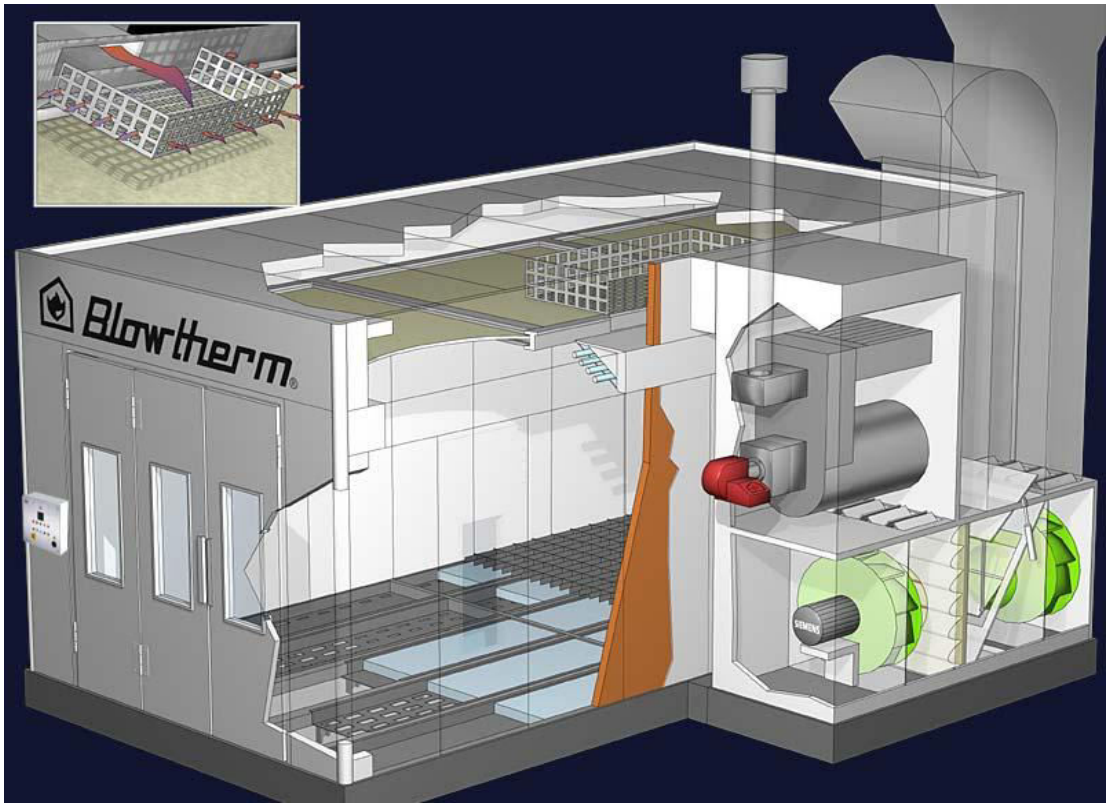


Fig. 5.4 Spray booth section view [9]

The filtering section is composed of several pocket filter units with the following characteristics:

- material: acrylic fiber
- binder: acrylic
- classification: self-extinguishing
- maximum operating temperature: 90°C
- average filtering efficiency (gravimetric method): 80%

The ventilating section is composed of several single action centrifugal fans featuring impellers of coated steel with inverted blades with high fluid dynamic performance (around 75%) and a spiral casing in a special galvanized sheet metal. The asynchronous electric motors used feature high efficiency cage rotors with 4 poles, with or without inverter. They have class F insulating properties and IP 55 protection. The coupling with the electric motor is direct, by means of a flange.

5.3. SPRAY BOOTH SAFETY DEVICES

Limit and safety thermostat (only in presence of burner)

This is installed in the air supply paneling of the thermoventilation unit; whenever there is heating with an exchanger or an air make-up burner. It has two functions: Limit thermostat: this intervenes when the air temperature exceeds 110°C by switching off the burner. Resetting is automatic. Safety thermostat: this intervenes when the air temperature exceeds 125°C by switching off the burner. Resetting is manual. The two functions of limit and safety are carried out by a single Double Thermostat.

Fire Damper (only in presence of burner)

This is installed between the unit and the plenum only when there is heating with an air make-up burner or exchanger. The damper is characterized by a particularly rigid structure. It guarantees an automatic, rapid interruption in the flow of air in the event of a fire, preventing the flames and smoke from spreading towards the preparation station. It is equipped with an evacuation section to connect to externally using a duct with suitable technical features. If the temperature of the air flow exceeds 180°C, the blowing of the fuse allows the release device to activate the control lever. With the activation of the torsion spring, the blade moves to the closed position

Antidepression beam

One of the plenum lateral beams has a hole and a silicon damper. In the event that there is depression in the booth box, the damper opens allowing the external air to enter in the booth box and avoids the risk of implosion of the spray booth.

CO detector (only with air make up burner)

A probe is installed near the supply fan which detects the percentage of CO in the air flow. The Label Sicurtronic alarm control unit (see fig 5.5 a), on the other hand, is positioned inside the electrical panel of the burner. If the percentage detected exceeds 50 ppm, the control unit switches off the burner and emits an acoustic signal (ventilation continues). To halt the alarm and switch the burner back on, after having identified and eliminated the cause of the anomaly, press button R on the control unit.

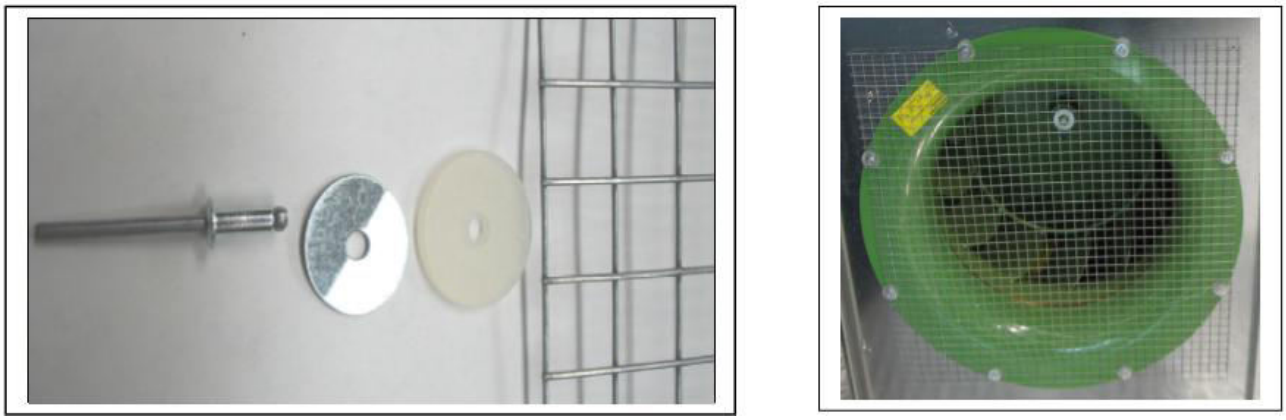
a) b)

Fig.5.5 CO detector. [10]
a) CO control unit; b) CO probe

The CO probe (see fig.5.5 b) must be replaced after 3 years from the date of installation, indicated on the label attached to the box on the outside of the Archimedean screw which contains the probe itself. Attention: check that the copper pipe is always tilted downwards, in order to allow any condensation present inside the pipe to drain away. When the appliance is powered, the green LED starts to flash for 40 seconds. Check that the yellow LEDs in the anomaly section are not on. Carry out the test for correct operation, holding down the T key. In this way, the red LEDs in the alarm section start to flash. After 20 seconds the appliance goes into alarm mode: the red LEDs are on permanently and the buzzer starts to emit an intermittent sound. Release the button and the sound stops; the red LEDs stay on and show that an alarm has occurred. At this point, check that the solenoid valve has interrupted the flow of gas.

Wirenet of protection

A metallic net of protection of the fan is installed (fig. 5.6).



a) b)

Fig.5.6 Wirenet protection [11]
a) Mounting elements; b) installed wirenet protection

Before removing the net for any operation of maintenance verify that the general interrupter of power supply is disarmed.

Grounding

All electrical circuits should be connected to ground (see fig.. 5.7) for the below mentioned reasons. If the man works with the equipment, exposed metal parts must be connected to ground in order to prevent the user's contact with dangerous voltage when electrical insulation fails. In electrical power distribution systems, a protective ground conductor is a very important and an essential part of the safety grounding system. Connection to ground also limits the build-up of static electricity when working with products which can inflame or with electrostatic-sensitive devices. In some telegraph and power transmission circuits, the ground itself can be used as one conductor of the circuit, and it saves the cost of installing a separate return conductor.

fig.. 5.7 circuit connected to ground

6. PROJECT CALCULATION

Various metal manufacturing companies decided to purchase an equipment for shot-blasting and painting.

For the calculation, it is needed to know:

1. Maximum dimension of part which will be blasted and painted; (length, width, height)
2. Maximum mass of the part;
3. Part transporting to the working area;
4. Foundation possibility;
5. Dimensions of an accommodation where all processes will be done;
6. Part material (steel, aluminum, plastic or other);
7. Parts quantity during one process;
8. Parts per shift/day;
9. Type of paints (diluent/aqueous);
10. Type of the process in painting (painting/drying/painting and drying);
11. Fuel type for heating (diesel/gas/hot water).

Customer answers to the questions:

1. Length – 10 m;
   Width – 1 m;
   Height – 1 m;
2. Mass – 5 t;
3. Crane and carriage;
4. No possibility to do a pit;
5. Length – 35,5 m;
   Width – 11 m;
   Height – 3,5 m;
6. Steel
7. Two parts;
8. Four parts per day;
9. Diluents;
10. Painting and drying;
11. Diesel.

Having customer answers we can make a primary plan, how all equipment will be set up and calculate the cost of the project. Primary equipment scheme is shown in figure 6.1.

The primary plan is made according to customer answers. Because it is not possible to do a pit, paint dust extraction will be made from the outside. The client will process only four parts per day, so, logically thinking, he will not want to bring down the back wall. In fig. 6.1 the top view of the equipment is seen. The ,,DUCT" will be on top of the building near the ceiling. It will not prevent part movement from one hangar corner to another. The part coming from acceptance, will be taken by the crane, and brought to the shot-blasting chamber. When the blasting is done, the part goes to the painting zone where the part is painted and dried. After drying, the part goes to a storage zone.

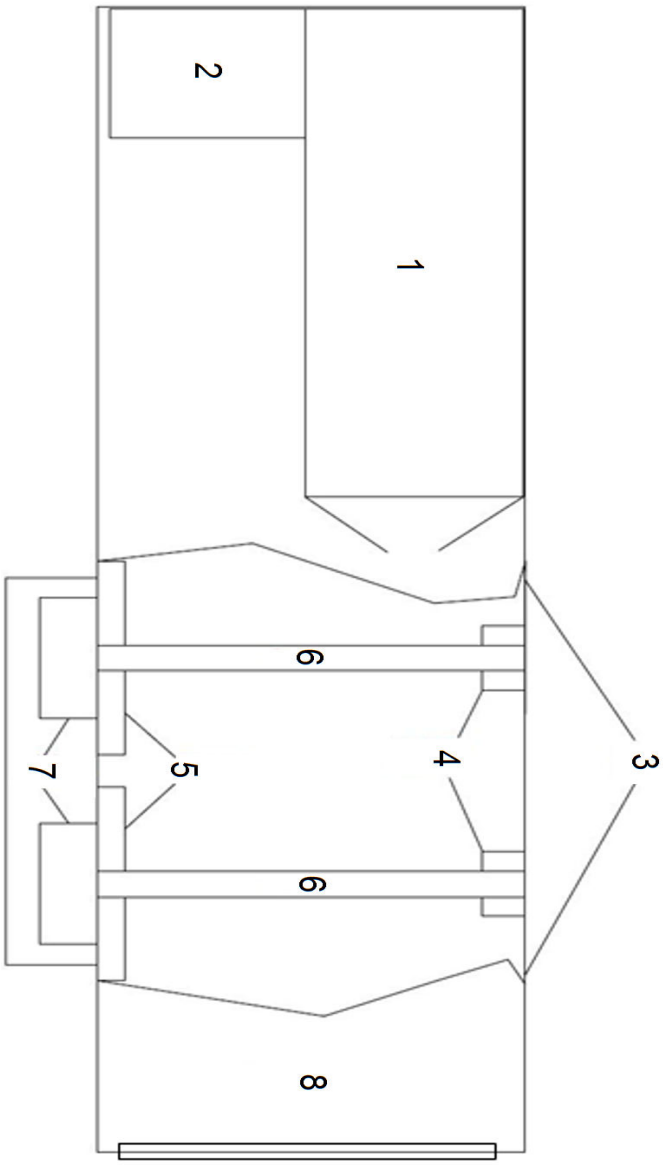


Fig.6.1 Primary equipment scheme. 1-shot-blasting chamber; 2-chamber equipment; 3-painting zone; 4-air intake diffusors; 5-extraction wall; 6-duct; 7-painting equipment; 8-acceptenance/storage zone.

6.1. SHOT-BLASTING CALCULATION

In case the blasting part maximum dimensions are 1x10x1 m (h) and two parts will be blasted during one process, the blasting chamber dimensions must be: length – 13 m, width – 6,5 m, height – 3,2 m. It is necessary to have 13 m length because 1,5 m distance must be left to the front and the back walls, and to have free aisle for the operator and comfortable space for his work. The same situation must be with the width. Because there will be two parts in the chamber, the width of one part is 1m, and 1,5 m is needed for the operator, so the width

of the chamber has to be 6,5 m. The height is 3,2 m because the blasting equipment is of this height and it has to be connected with the chamber. The principal scheme of the parts in the chamber is shown in fig. 6.2.

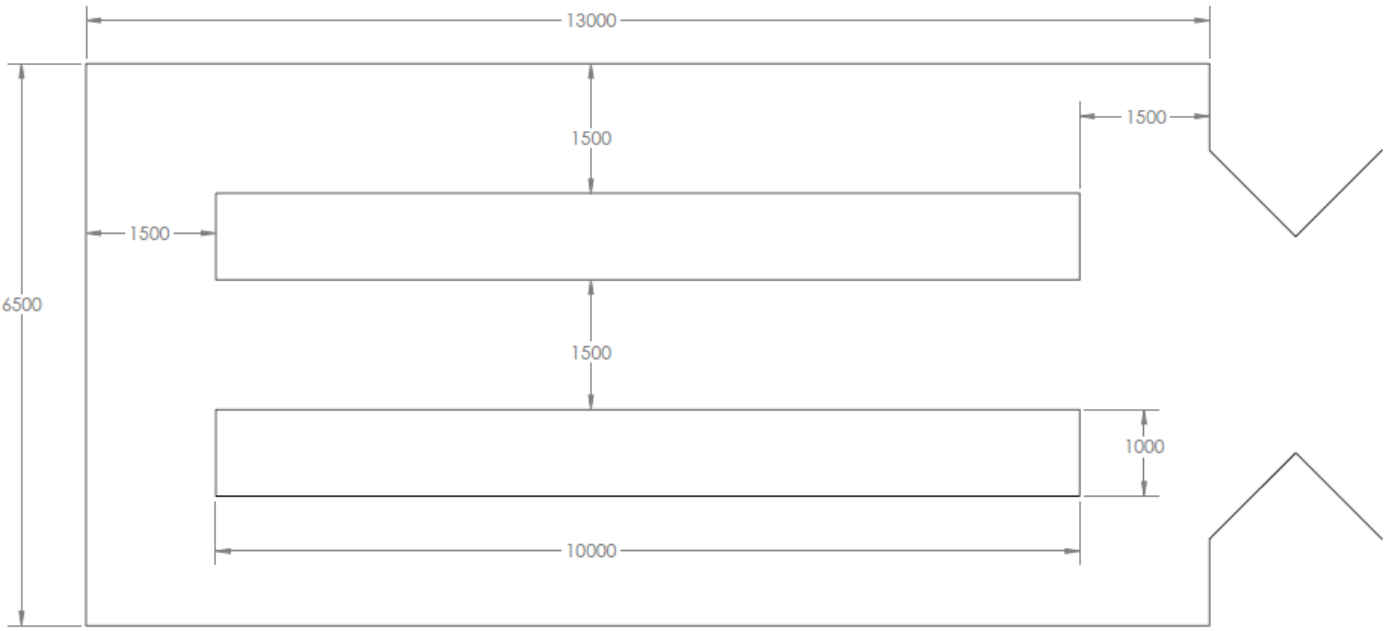


Fig.6.2 Principal scheme of parts in the chamber

6.1.1 Shot-blasting working principle

During the cleaning abrasive falls down to the floor and it is manually scraped to the area of the rear wall of the chamber where abrasive is extracted and transported to a hose separator. In the separator the abrasive, suitable for further use, is separated from dust and coarse impurities. Cleaned abrasive falls onto the magnetic separator, which removes metallic impurities. Clean abrasive falls into a storage vessel which is located under a magnetic separator. The separated abrasive in the dust separator hits the cyclone. Dispenser abrasive will be installed in the storage. Vessel. Bridging the dispenser balls will be done by hand during work breaks. Ventilation of the chamber consists of pulling out the polluted air from the chamber on dry dedusting filters and recycling the filtered air into the chamber.

6.1.2 Construction of the chamber

Chamber design having a steel skeleton containment plate layer 60 mm thick will be constructed. The chamber will have front wing doors to have the access to parts inside and outside, and side service door for the operator's entrance or emergency exit. For protection from the

abrasive, which goes out from the gauge, bounces from to the walls and in order not to hit the operator, the walls, ceiling, wing door and service door will be protected from the inside with 3 mm thick rubber cover.

6.1.3 Lightening in the chamber

The chamber is illuminated by a series of lamps positioned on the ceiling of the chamber, where they will be installed in special glass boxes, which are mounted over the lamp. The access to them will be possible from above without the removal the panels. Lightining in the chamber is shown in fig.6.3.

Figure 6.3 Lightning in chamber

6.1.4 Ventilation and dedusting

The chamber is equipped with a ventilation system comprising a fan, and dust collector channels (see fig. 6.4). It features a ventilation system with air recirculation after filtering. Polluted air will be delayed, purified in a two-stage dust collector through the filter and returned to the chamber. First it will be treated initially in the filter chamber and then in special filter cartridges. In contrast to the filter paper, which most vendor sell, they will be resistant to water and oil, and adhesion of solid particles, whereby the filtration area will not be significantly reduced during the operation. Dirty cartridges made of polyester can be washed, dried and further exploited.

Low dust purified air obtained on polyester filters allow circulation back into the chamber. Only the excess air is discharged outside. Recirculation of the air in the chamber allows to maintain favorable climatic conditions inside (temperature and humidity). Two vertical exhaust diffusers, where dusty air taken in from the blasting will be transported to the filter module, will be constructed on both sides.

In order to withdraw the air from the chamber two-stage dust collectors allowing recirculation of the air will be installed according to the following parameters:

- The type of filter media: dry, polyester,
- Durability of filter cartridges approx. 5 years
- Treatment of: reversibly, compressed air
- A way of regeneration of filter cartridges: washing with water under pressure,
- The content of dust in the exhaust air: below 4 mg/m^3
- Surface filters: 360 m^2
- Fan capacity: 20.000 m^3/h
- Engine power: 22 kW

Fig. 6.4 Ventilation and dedusting equipment

6.1.5 Equipment for transport, purification and dispense of abrasive

Equipment for transportation, cleaning and abrasive metering will consist of a set of extraction and purification of abrasive and pressurized dispensers. Abrasive scraping from the floor will be manual. The floor over the entire surface will be covered by steel sheet. Extraction and recovery of abrasive propose a pneumatic system for the extraction and separation of abrasive which consists of a vacuum unit of the side channel, blower module and separators (cyclone and magnetic).

Abrasive scraped from the floor, the rear wall of the chamber will be collected by the suction nozzle and transported pneumatically to a cyclone separator where it will be cleaned out of dust. Abrasive nominal will be decreased to a magnetic separator, where metal contaminants will be captured. Cleaned abrasive will fall into the abrasive storage vessel and dust and dirt together with

the carrier air get to the cyclone vacuum module. Clean air will be sucked off by the vacuum module.

Abrasive extraction vacuum module parameters (see fig. 6.5):

• rated power -7,5kW;
• max vacuum -30 % / 3000 mm;
• air volume – 500 m^3/h;
• maximum suction performance -4 t/h;

Fig.6.5 Abrasive extraction vacuum module[12]

The chamber is equipped with a single station dispenser pressure cap. 200dm^3 with automatic pneumatic holding:

- Valve glass beads;
- Pneumatic control module;
- Lever RLX-III;
- Allowable working pressure - 1 MPa.

6.1.6 Control device

The chamber is equipped with a control module, wiring and signaling equipment. Control module will be based on a system microprocessor, controls the operation of devices in the chamber. It will include control systems of turn on and off individual devices, locks, security system and signaling faults.

The following power will be installed in the blasting machine:

- lighting approx. 2 kW;
- filter 20,000Pa 22 kW;
- vacuum module 7.5 kW;

The device will be powered by:

- supply voltage 3 x 400/230 (TN-C-S)
- control voltage 220 V, 50 Hz, 12 and 24V DC
- voltage indicator lights 24V DC,

The electrical equipment will consist of:

- electrical installation;
- signaling and alarm;
- control cabinet.

The chamber will have a mutual interlocking systems and signaling system to ensure safe operations:

- indicator light in work chamber;
- automatic shutdown mode when you open the gate or door;
- lock operation at the open gate or door;
- automatic cleaner off by dropping the hose by the operator;
- switching on and off the cleaner by the operator.

Sequential and distribution of individual receivers will be as follows:

- supply and exhaust ventilation;
- lighting;
- recirculation system abrasive.

The chamber will require the following power connections:

- electricity – 32 kW- brought to the rail cabinet;
- needed air -15 m^3/min, brought to the area cleaner (dry and oil-free).

6.1.7 Health and Safety Issues

The chamber meets the regulation, safety regulations and standards in force in the EU. European in the Regulation of the Minister of Economy, Labour and Social Policy: In case of health and safety when cleaning the surface, paint and metal spraying. OJ No. 16 p.156 of 2004. [13]

6.1.8 Cost of shot-blasting equipment

The total cost of the project is 64.545,00 EUR net, which consists of:

- Chamber design with rubber gate and door service - 14.772,00 EUR;
- (Chamber construction with rubber covers, wings gates and maintenance door)
- Lighting - 2.727,00 EUR;
- Two-stage dust collector - 14.545,00 EUR;
- Ducts - 4.090,00 EUR;
- Vacuum module SUSPS250P - 6.363,00 EUR;

- Abrasive separator and a storage tank - net 6.136,00 EUR;
- Dispenser pressure type AN1 / 200 SP - 1.477,00 EUR;
- Control module - 3.181,00 EUR;
- Electrical installation - 3.636,00 EUR;
- Supply and installation of the equipment - 7.727,00 EUR;

The above prices are also included:

- Guidelines for the design of foundations and connections;
- Delivery of equipment to the premises;
- Installation and commissioning of equipment without the participation of the employees of the Investor;
- Training of the employees.

This price does not include:

- Project construction executive;
- Foundations and railways;
- Unloading supplied items on the premises;
- Supply of electricity and compressed air;
- Others not included in the offer of supplies and services.

Final prices are subject to change after determining the technical details, terms of delivery and installation of the granted discount.

6.2 SPRAYING PROCESS CALCULATION

In case there is no possibility to do a pit and build a spraying chamber, it can be decided to build spraying suction walls with air recirculation. It is necessary to build two smaller and separate suction walls, to have the possibility to work with smaller parts and save energy. In order to save some place in the hangar, all needed equipment for spraying process is placed in the separate building, which is connected with the hangar. To have a better air flow, keep heat in the spraying area and avoid dust, it is decided to install movable PVC curtains. Spraying zone is shown in figure 17.

Number meanings in fig.6.6:

2) Thermoventilation unit for spraying;
3) Air suction wall;
4) Duct;
5) Incoming air collector;
6) Movable PVC curtain;
7) Building for equipment;

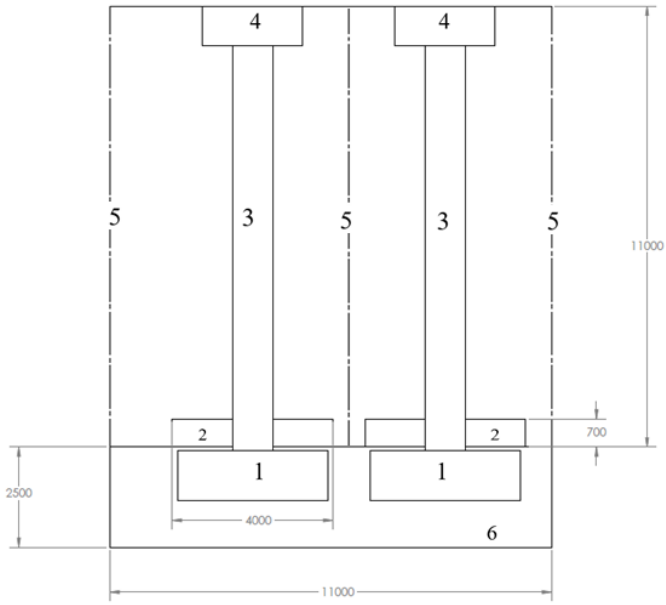


Fig. 6.6 Spraying zone scheme

Working principles:

Painting cycle:

Fresh air is taken from outside, goes to thermoventilation unit (1), where the air is heated and filtrated. After the hot air is filtrated, with the help of the duct (3), it goes to the incoming air collector (4) where the air is filtrated again and diverted to the air suction wall (2). The incoming air collector is needed to have better air flow and stable temperature in the spraying zone. In order to keep the air, PVC curtains are necessary (5), for the air not to escape from the zone, where the process is going on. The air with paint dust is extracted from the suction wall (2). The suction wall has triple filtration to collect all paint dust from the air. Filtrated air goes outside with the help of thermoventilation unit.

Drying cycle:

When the painting process is done, there is less painting dust in the hangar. Therefore, to keep higher temperature and use less energy only 20% of fresh air is taken from outside and 80% of the air circulates in the hangar. The air goes to thermoventilation unit (1) where the air is heated and filtrated. After the hot air is filtrated, with the help of the duct (3), it goes to incoming air collector (4) where the air is filtrated again and it is diverted to the air suction wall (2). The incoming air collector is necessary to have better air flow and steady temperature in the spraying zone. The air

with paint dust is extracted from the suction wall (2). The suction wall has triple filtration, to catch all paint dust from the air. Filtrated air goes outside with help of thermoventilation unit.

6.2.1 Air extraction

In case the pit is not allowed, it is decided to build air suction wall (fig.6.7). To use all possible space and to have possibility to work with small parts in separate zones two suction walls are selected. Suction walls are placed near the left wall of the hangar and connected with the thermoventilation units which are placed in the building connected with the hangar. Since we have eleven meters in the spraying zone, it is decided to build two suction walls having four meters each. Both constructions will have guides on their sides. The height of suction walls depends on maximum height of the part being prepared, which is one meter.

Extraction walls calculation:

Space for spraying zone – 11 m;
Suction wall length – 4 m;
Suction height – 1 m;
Air flow for 1m^2 – 3000 m^3/h;

Fig. 6.7 air suction wall [14]

Usable one suction wall area:
length x height = 4 x 1 = 4 m^2
Air flow for 4m^2:
suction wall area x air flow for 1m^2 = 4 x 3000 = 12000 m^3/h;

6.2.2 Thermoventilation unit calculation

Since the airflow to one suction wall is 12000 m^3/h, it is decided to use diesel fuel for air heating and to install 2x5,5 kW thermoventilation units. (figure 6.8).

Thermoventilation unit parameters:

Heater power (diesel) – 208 kW;
Intake engine power – 5,5 kW;
Extraction engine power – 5,5 kW;
Theoretical air capacity – 18.000 (400 Pa) m^3/h;
Real air capacity – 13.000 (700 Pa) m^3/h;

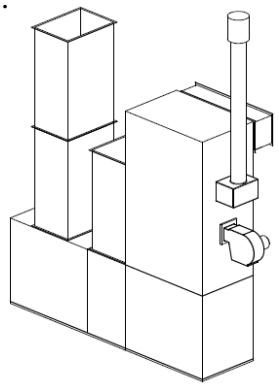


Fig.6.8 Thermoventilation unit [15]

Control box (fig. 6.9):

1) Automatic pressure regulation;
2) Spraying/drying mode;
3) Filter monitoring;
4) start/delta engine starting.

Fig. 6.9 Control box [16]

There are two types of air flow (theoretical and real) as it can be seen in the parameters. For selecting the thermoventilation unit, it is necessary to use real air capacity, which means that filtration resistance in the air flow is calculated. This type of the control box is selected, because it has four functions for longer lifetime of the engines. With the regulation of automatic pressure it is possible to regulate unit dampers to maintain the same air flow when the filters are getting dirty and start blocking the incoming air. Having spraying/drying mode, we save fuel and energy costs. When we use drying mode, thermoventilation unit dampers change their position and recirculate the air which has already been heated. Filter monitoring is a good addition to this control box in order to know when it is time to change filters. When automatic pressure regulation reaches its maximum position and we have great resistance from filters, they sends a signal to the control box that it is time to change air intake or extraction filters. Start/delta engine is used to start engines not immediately, but equivalently. This type of function helps control the air flow, when the engines are started and makes engine lifetime longer.

6.2.3 Air intake construction

The air intake construction (fig. 6.10) is designed to divert air flow to the air suction wall. It must have air filtration, that there were no dust going to the painted area. The calculations of the air intake construction are the same as the ones of the air suction wall. If we have 12000 m^3/h air flow, then income air area must be 4 m^2.

Fig. 6.10 Air intake construction [17]

6.2.4 Cost of the shot-blasting project

The total cost of the project is 37.840,00 EUR net, which consists of:

- Thermoventilation units for spraying – 12.920,00 EUR;
- Air suction walls – 7.350,00 EUR;
- Incoming air collectors 8.960,00 EUR;
- Ducts – 5.480,00 EUR;
- Movable PVC curtain 3.130 EUR.

The above prices also include:

- Guidelines for the design of foundations and connections;
- Delivery of equipment to the premises;
- Installation and commissioning of equipment without the participation of employees of the Investor;
- Training of the employees.

This price does not include:

- Project construction executive;
- Unloading supplied items on the premises;
- Supply of electricity and compressed air;
- Others not included in the offer of supplies and services.

7. EXPERMENTAL PART

7.1 PAINTS FOR SURFACE COATING

There are a lot of different types of paint for metal coating. Choosing the best type of the product, depends on the hangar temperature (20°C) and material output on 10 m^2. Costs were calculated. In table no. 1 material and the price per litre are shown.

Testing material:

Table no.1 Material and prices

Material	Price eur/l
Hempadur 15500	21.42
Hempadur 17630	10.52
HEMPADUR 35760	8.80
HEMPADUR 35900	6.87
Hempadur EM 35740	9.14
HEMPADUR FAST DRY 17410	27.84
Hempadur Quattro 17634	15.02

One of the testing purposes was to check how many litres are needed to cover the surface with 300µm material thickness. Results are shown in fig.7.1.

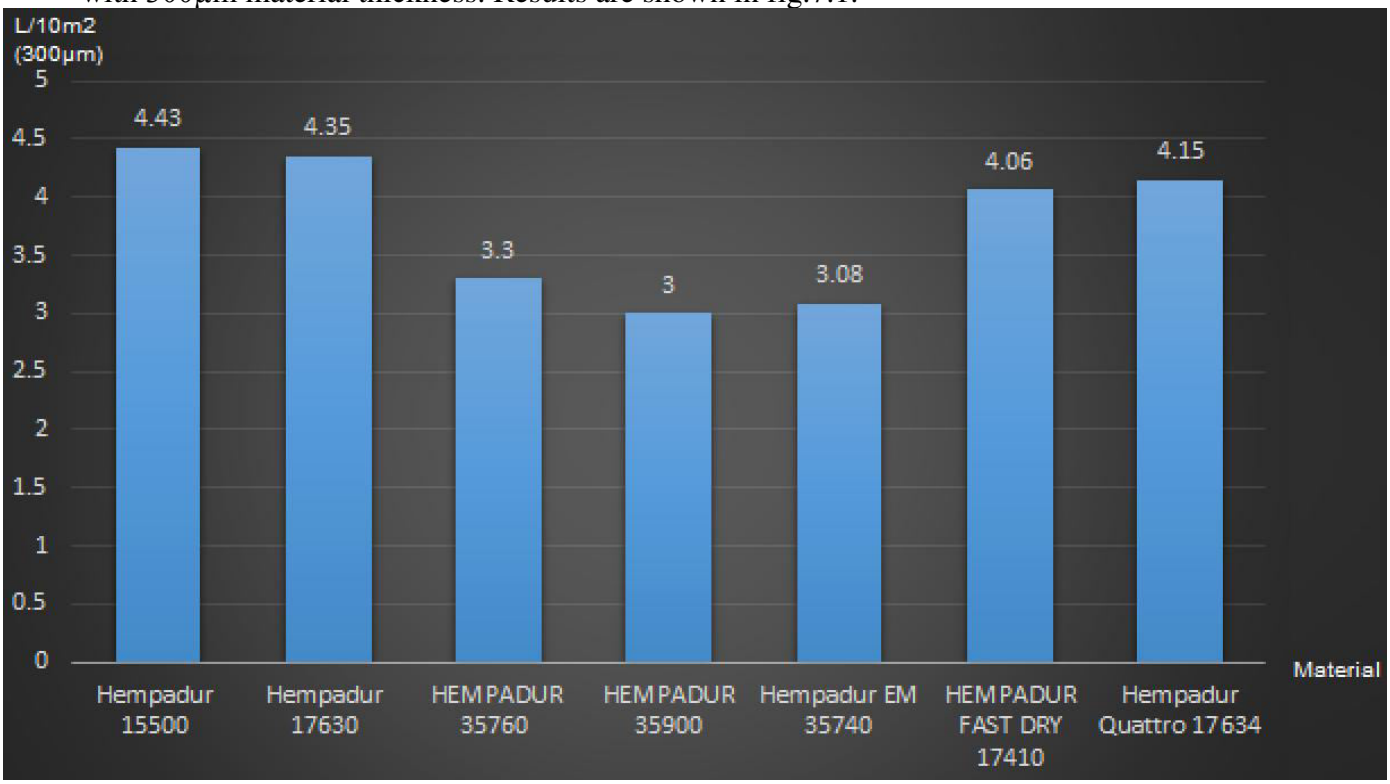


Fig.7.1 surface covering with 300 µm thickness of material

Kremlin Airmix 20.50 Pump (fig. 7.2) was used to put material on the surface,. Airmix 20.50 Pump is of stainless Steel: The 20.50 pump is ideal for industrial production where multiple guns will be fed by medium to heavy bodied materials from one fluid supply.

Pump specifications:

Compression ratio	20/1
Fluid volume per cycle (cm3)	10
Number of cycles per litre of products	100
Fluid Output at 30 cycles/min (l/min)	3
Free flow rate (L/min)	6
Air consumption (m3/h) at 30 cycles/min at 4 bar	21.6
Maximum air inlet pressure (bar)	6
Maximum fluid pressure (bar)	120
Maximum Fluid Temperature (°C)	60
Sound level (dBA)	78
Weight (kg)	22
Wet parts	Stainless steel
Height (cm)	86.4
Width (cm)	35.6
Depth (cm)	28

Fig.7.2 Kremlin Airmix 20.50 Pump [18]

Digital paint thickness gauges meter checks how thick the material surface is (fig. 7.3). It can be used to measure paint, chrome on steel and insulating coating, for example, paint and anodizing coatings on non-ferrous metals. The internal probe can work on both principles, magnetic induction and the eddy currents. The probe automatically detects if the substrates are magnetic or not and calculates the thickness of coating and displays it. Five data groups and readings are automatically stored to memory for general groups. Each group has individual statistics, alarm limit settings and calibration.

Fig.7.3 Digital paint thickness gauges meter

Drying time is very important in industry. The less time the surface is drying, the more products can be made at the same time. In fig. 7.4 it is seen how much time is needed to dry the surface at 20°C till it could be loaded to the shipping transport.

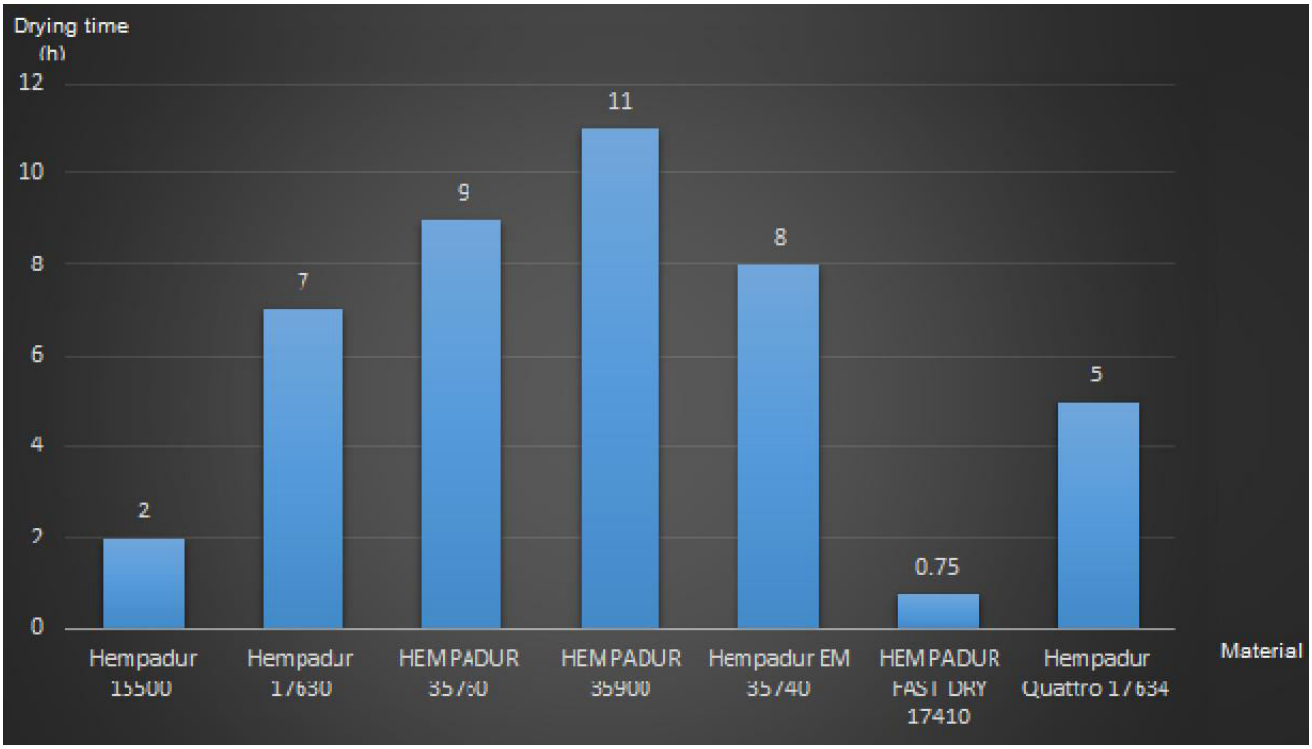


Fig. 7.4 Time needed to dry the surface at 20°C

For this testing, the product was put in the drying chamber (fig. 7.5) were the temperature of 20°C was set and it stayed stable because of the chamber working principle. The air was recirculating all the time and it went through heating battery. When the temperature reached the set value, in this case 20°C, the battery turned off automatically. When the temperature fell more than by 2°C, the battery turned on automatically. To see if the surface was dry, it was checked every 15 min and it was checked if the surface was wet or had already dried. For drying measurement, BOCH PTD1 was used. When the surface reached 10% of humidity it meant that the part was dry.

Fig.7.5 drying chamber

The results show that in order to get the same covering of the surface different quantity of material is needed. In fig. 7.3, it is seen that with HEMPADUR 35900 less time is needed than with other materials. In this graph, the costs to paint the surface with different materials can be seen. Calculation results are shown in fig. 7.6.

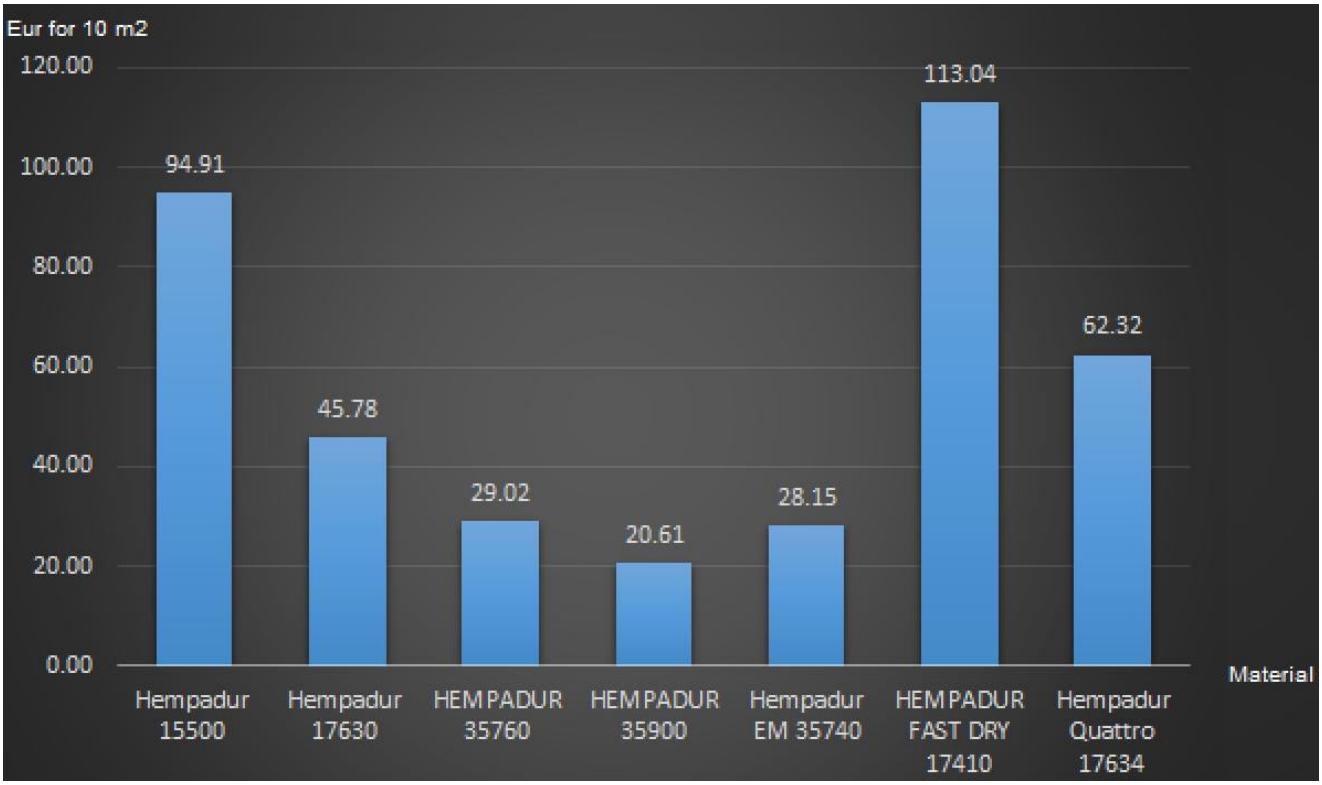


Fig.7.6 Costs of the painted surface

Comparing fig.7.3 and fig.7.4 it is seen that the cost depends on the part drying time. Because four parts per day will be produced and in one painting/drying cycle two parts could be prepared, Hempadur Quattro 17634 was selected. In fig.7.4 and fig.7.6 it seen that the drying time of Hempadur Quattro 17634 is 5 hours. Comparing it with other materials, its cost is in the third place among all tested materials, which is equal to 62,32 Eur.

7.2 RECUPERATOR PAYBACK CALCULATION

Recuperation is one of the elements of the ventilation/air conditioning which includes exchange of stale air in the inner environment to cool the supply from the outside. Recuperation is used to reduce energy consumption and stabilize room temperature by reducing the cost of recovery of energy needed to heat in winter, and provide cooling in summer. Working principles of the recuperator are shown in fig.7.7.

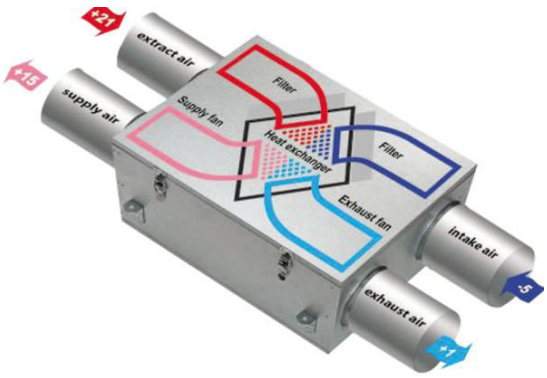


Fig.7.7 Recuperator working principle [19]

Recuperator benefits:

- The rate of energy efficiency
- Saves energy
- Low noise level
- Compact design, easy installation and maintenance

To check differences between working with recuperator and without it, one industrial company's yearly results were taken before (year 2014) installing recuperator and after (year 2015). Company's production in those two years was unchanged. Working temperature was 20°C and it was using one 2x5,5kw thermoventilation unit. Results are shown in table no.2.

Table no. 2 fuel consumption differences between working without recuperator (year 2014) and with it (year 2015)

Year 2014	Fuel consumption (L)	Year 2015	Fuel consumption (L)
January	2762.45	January	2016.59
February	3314.94	February	2320.46
March	1657.47	March	1408.85
April	861.89	April	662.99
May	801.11	May	552.49
June	740.34	June	441.99
July	679.56	July	331.49
August	801.11	August	552.49
September	922.66	September	773.49
November	1229.98	November	1104.98
October	1657.47	October	1408.85
December	2541.46	December	1895.04

It is seen in table no.2 that in 2014 company used 17970.44L of fuel and in 2015, after installing recuperator, the same company used 13469.71L. The yearly difference is 4500.73L. That means that in 2015 company used 25% less fuel than in 2014.

To calculate how much fuel and money could be saved in this project after installing the recuperator, we can use the company's data that were calculated and shown in table no.2. The only difference that in this project two thermoventilation units will be used. In table no.3 we can see how much fuel will be used in a particular month and how much money will be saved at the end of the year. For calculation we take that 1L of fuel costs 0.7 Eur.

Table no.3 Project fuel consumption calculation

Year 2018	**Fuel consumption (L) without recuperator**	**Fuel consumption (L) with recuperator**	**Consumption difference (L)**	**Eur saved**
January	5524.9	4033.18	1491.72	1044.20
February	6629.88	4640.92	1988.96	1392.27
March	3314.94	2817.7	497.24	348.07
April	1723.78	1325.98	397.8	278.46
May	1602.22	1104.98	497.24	348.07
June	1480.68	883.98	596.7	417.69
July	1359.12	662.98	696.14	487.30
August	1602.22	1104.98	497.24	348.07
September	1845.32	1546.98	298.34	208.84
November	2459.96	2209.96	250	175.00
October	3314.94	2817.7	497.24	348.07
December	5082.92	3790.08	1292.84	904.99
TOTAL	**35940.88**	**26939.42**	**9001.46**	**6301.02**

The results show that in one year, after installing the recuperator, company saves 6301.02 Eur. Since two thermoventilation units will be installed and for one unit one recuperator is needed, so in order to calculate when the recuperators buys off, the recuperator price must be divided by total Eur saved, that is shown in table no.3.

Recuperators buy off calculation:

Recuperator price – 7800,00 Eur;

Recuperators needed – 2pcs;

Total Eur saved – 6301.02 Eur;

$$\text{Buy off} = \frac{\text{Recuperator price x Recuperators needed}}{\text{Total Eur saved}};$$

$$\text{Buy off} = \frac{7800x2}{6301.02} = 2.5 \text{ years.}$$

It is evident that recuperators will buy off in 2.5 years.

7.3 FREQUENCY DRIVE PAYBACK CALCULATION

Electric power of the thermoventilation unit engines is calculated having an average air flow with dusty filters, when the capacity is low and more power is needed to reach necessary air flow. When the filters are new, their air capacity is high, then it is possible to run engines with lower electric power. To save energy, it is necessary to install frequency drive (see fig.7.8). A Frequency Drive is a motor controller that drives an electric motor by varying the frequency and voltage supplied to the electric motor with air filters capacity. Electricity saving is shown in fig.7.9.

Fig.7.8 Frequency drive

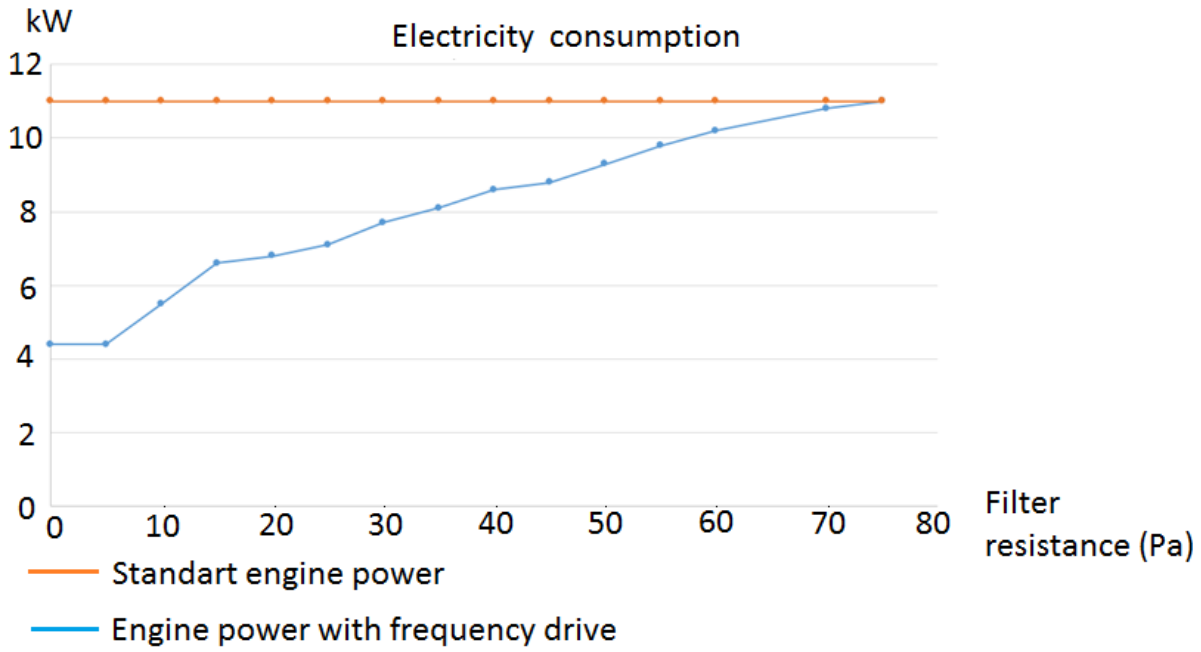


Fig.7.9 Electricity consumption calculation

Fig.7.9 shows that engine power depends on filter resistance. It is seen, that without frequency drive 11kW is used. After installing frequency drive, electricity cost savings are very high. When filters reach more than 77% of air resistance, unit turns off automatically so as not to burn down the engines. Cost saving calculation is shown in table no. 4

Table no.4 Cost saving calculation

Filters air resistance (%)	**Working hours (h)**	**Total power without frequency drive (kW)**	**Total power with frequency drive (kW)**
5	5	55	22
11	16	121	60.5
14	30	154	92.4
31	61	341	238.7
44	105	484	387.2
57	162	627	564.3
75	237	825	825
TOTAL:	**616**	**2607**	**2190**

In table no.4 it is seen that filters reach 75% of resistance in 616 working hours. Because in this case units will work 50 h per week, 616 working hours will be reached in approximately 3 months. Frequency drive costs 425 Eur. Buy off calculation is shown below.

Buy off calculation:

1. 1 working month has 200h (50 h x 4weeks);
2. Filter changing after: 616 h = 3.08 months;
3. Electricity saving = total power without frequency drive – total power with frequency drive = 2607 – 2190 = 417 kW;

   For cost saving electricity price: 1kw/h = 0.127 Eur. With frequency drive we save:

4. Money saving = electricity saving x electricity price = 417x0.127 = 52.96 Eur.

Frequency will buy off after:

5. Buy off$_{cycle}$ = $\frac{\text{Frequency drive price}}{Money\ saving}$ = $\frac{425}{52.96}$ = 8.02 cycle

In 2nd buy off calculation formula it is seen, that one cycle is 3.08 month. One year has approximately 4 cycles. Now we can calculate how long it would take to buy off frequency drive.

6. Buy off$_{time}$ = $\frac{\text{Buy off (cycle)}}{\text{cycles per year}}$ = $\frac{8.02}{4}$ = 2 years.

   In the 6th calculation line of the buy off formula it is seen that frequency drive will buy off in two years.

8. CONCLUSIONS

1) Shot-blasting and spraying equipment were investigated in the project. The equipment positions were projected in the real hangar. To have customer needed shot-blasting and spraying equipment, it would cost 102.385,00 Eur.
2) Seven different surface coating materials were tested to check what type of material is more suitable for the customer.
    a. Firstly, the experiment was done to evaluate how many liters are needed to put 300μm layer of material on the 10 m^2 surface. From the obtained results it is seen that the lowest output of liters was with "Hempadur 35900" (3L) and the biggest output of material was with "Hempadur 15500" (4,43L).
    b. The time needed to dry painted surface at 20ºC temperature was measured. The results showed that "Hempadur fast dry 17410" dries faster than the others. It took 0,75 h to dry the surface. The longest drying time had "Hempadur 35900". It took 11 h to dry the surface
    c. The cost of material needed to put on the surface was analyzed. It was calculated how much litters are needed to put 300 μm thickness layer on the surface. The calculations showed that the price depends on the part's drying time. The most expensive material is "Hempadur fast dry 17410". To put 300 μm layer on the 10 m^2 costs 113,04 Eur. The cheapest material is "Hempadur 35900". To put 300 μm layer on the 10 m^2 costs 20,61 Eur.

    After the analysis of all coating materials, "Hempadur Quattro 17634" was selected. The main criterion for selection was drying time of coating material and price. The calculations showed that the best results were obtained by using coating material "Hempadur Quattro 17634". It was found that its drying time is 5 h and the price is 62,32 Eur.

3) To evaluate cost saving, recuperator benefits were calculated. To check the differences between working with the recuperator and without it, one industrial company's yearly results were taken before (year 2014) installing recuperator and after (year 2015). The results showed that during the 2014 year the company used 17970.44 L, while after installing recuperator, the same company used only 13469.71 L (2015 year). The difference is 4.500,73 L, i.e. in year 2015 company used 25% less fuel than in year 2014. The calculations showed that after recuperator installation the company saves 6.300,00 Eur per year.

4) The price of recuperator is 7.800,00 Eur. Since two thermoventilation units will be installed and for one unit one recuperator is needed, buy off time of recuperators is approximately 2.5 years.
5) For cost saving, frequency drive benefits were also calculated. It is known that engine working time depends on air filter capacity. When filters reach more than 77% of air resistance, the unit turns off automatically. It was obtained that filters reach 75% of resistance after working for 616 hours. Whereas units work 50 h per week, the 616 h limit will be reached in 3 months. As frequency drive costs 425 Eur, buy off calculations showed that time of buy off is approximately two years.

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APPENDICES

Painted surface

Product Data
HEMPADUR 15500

15500: BASE 15509: CURING AGENT 97580

Description:	HEMPADUR 15500 is a two-component, amine adduct cured phenolic epoxy (novolac) paint, which cures to a coating with excellent resistance to a wide range of chemicals as tabulated in separate CARGO PROTECTION GUIDE.
Recommended use:	Internal lining for vessel´s cargo tanks, storage tanks and rail cars.
Service temperature:	Maximum, dry exposure only: 160°C/320°F In seawater (no temperature gradient): 50°C/122°F Wet service temperatures, other liquids: Consult the corresponding CARGO PROTECTION GUIDE.
Certificates/Approvals:	Complies with Section 175.300 of the Code of Federal Regulations Title 21 – Liquid and Dry Foodstuff. Consult Hempel for details.
Availability:	Part of Group Assortment. Local availability subject to confirmation.

PHYSICAL CONSTANTS:

Shade nos/Colours:	11150* / Light grey
Finish:	Flat
Volume solids, %:	68 ± 1
Theoretical spreading rate:	6.8 m^2/l [272.7 sq.ft./US gallon] - 100 micron/4 mils
Flash point:	26 °C [78.8 °F]
Specific gravity:	1.7 kg/litre [13.9 lbs/US gallon]
Surface-dry:	2 hour(s) 20°C/68°F
Through-dry:	6.5 hour(s) 20°C/68°F
Fully cured:	10 day(s) 20°C/68°F (see REMARKS overleaf)
VOC content:	322 g/l [2.7 lbs/US gallon]
Shelf life:	1 year for BASE and 3 years for CURING AGENT (stored in closed container) (25°C/77°F) from time of production. Depending on storage conditions, mechanical stirring may be necessary before usage. **other shades according to assortment list.*

The physical constants stated are nominal data according to the HEMPEL Group's approved formulas.

APPLICATION DETAILS:

Version, mixed product:	**15500**
Mixing ratio:	BASE 15509: CURING AGENT 97580 8.9 : 1.1 by volume. 93.8 : 6.2 by weight
Application method:	Airless spray / Brush
Thinner (max.vol.):	08450 / 08450 According to separate APPLICATION INSTRUCTIONS
Pot life:	3 hour(s) 20°C/68°F
Induction time:	15 minutes 20°C/68°F (see REMARKS overleaf)
Nozzle orifice:	0.018 - 0.021 "
Nozzle pressure:	200 bar [2900 psi] (Airless spray data are indicative and subject to adjustment)
Cleaning of tools:	HEMPEL'S TOOL CLEANER 99610
Indicated film thickness, dry:	100 micron [4 mils] (see REMARKS overleaf)
Indicated film thickness, wet:	150 micron [6 mils]
Overcoat interval, min:	see REMARKS overleaf
Overcoat interval, max:	see REMARKS overleaf

Safety:	Handle with care. Before and during use, observe all safety labels on packaging and paint containers, consult HEMPEL Safety Data Sheets and follow all local or national safety regulations.

Product Data
HEMPADUR 17630

Medium to high temperatures 17630 : BASE 17639 : CURING AGENT 97330

Description:	HEMPADUR 17630 is a two-component, high-build, polyamide adduct-cured epoxy paint which cures to a hard and tough coating with good resistance to abrasion, seawater and various oils.
Recommended use:	As a selfprimed coating for ballast water tanks and similar. As a primer for epoxy systems for atmospheric or in-water service, eg ship hulls. Suitable for application down to 0°C/ 32°F. HEMPADUR 17630 is intended for use in temperate to warm climates. For cold/temperate climates use HEMPADUR 17633.
Service temperature:	Maximum, dry exposure only: 120°C/248°F (see REMARKS overleaf) Ballast water service. Resists normal ambient temperatures at sea (Avoid long-term exposure to negative temperature gradients). In water (no temperature gradient): 40°C/105°F Other liquids. Contact HEMPEL
Certificates/Approvals:	Tested for non-contamination of grain cargo at the Newcastle Occupational Health & Hygiene, Great Britain. Approved as a low flame spread material when used as part of a predefined paint system. Please refer to “Declaration of Conformity” on www.Hempel.com for further details. Complies with EU Directive 2004/42/EC: subcategory j.
Availability:	Part of Group Assortment. Local availability subject to confirmation.

PHYSICAL CONSTANTS:

Shade nos/Colours:	12170 / Grey.
Finish:	Semi-flat
Volume solids, %:	69 ± 1
Theoretical spreading rate:	4.6 m^2/l [184.5 sq.ft./US gallon] - 150 micron/6 mils
Flash point:	32 °C [89.6 °F]
Specific gravity:	1.4 kg/litre [11.4 lbs/US gallon]
Dry to touch:	7 - 8 hour(s) 20°C/68°F
Fully cured:	7 day(s) 20°C/68°F
VOC content:	303 g/l [2.5 lbs/US gallon]
Shelf life:	3 years for BASE and 3 years (25°C/77°F) for CURING AGENT from time of production.

The physical constants stated are nominal data according to the HEMPEL Group's approved formulas.

APPLICATION DETAILS:

Version, mixed product:	**17630**
Mixing ratio:	BASE 17639 : CURING AGENT 97330 4 : 1 by volume
Application method:	Airless spray / Brush
Thinner (max.vol.):	08450 (5%) / 08450 (5%)
Pot life:	2 hour(s) 20°C/68°F
Induction time:	- see REMARKS overleaf
Nozzle orifice:	0.021 - 0.025 "
Nozzle pressure:	250 bar [3625 psi] (Airless spray data are indicative and subject to adjustment)
Cleaning of tools:	HEMPEL'S TOOL CLEANER 99610
Indicated film thickness, dry:	150 micron [6 mils]
Indicated film thickness, wet:	225 micron [9 mils]
Overcoat interval, min:	see REMARKS overleaf
Overcoat interval, max:	see REMARKS overleaf

Safety: Handle with care. Before and during use, observe all safety labels on packaging and paint containers, consult HEMPEL Safety Data Sheets and follow all local or national safety regulations.

Product Data
HEMPADUR 35760

35760: BASE 35769: CURING AGENT 98760

Description: HEMPADUR 35760 is a solvent-free, two-component, high-build phenolic epoxy (novolac) paint, which cures to a durable tank lining with very high corrosion protection properties and excellent chemical resistance.

Recommended use: As a tank lining for new and old storage tanks containing oils, fuels, bio fuels and a wide range of chemicals. It can be used in conjunction with fibre glass to form a resilient reinforced tank lining. Please refer to the separate application instructions.

Service temperature: Maximum, dry exposure only: 140°C/284°F
In various fuels (e.g. diesel, gasoline): 65°C/149°F
Wet service temperatures, other liquids: Consult the corresponding RESISTANCE GUIDE.

Availability: Part of Group Assortment. Local availability subject to confirmation.

PHYSICAL CONSTANTS:

Shade nos/Colours:	20320 Cream
Finish:	Semi-gloss
Volume solids, %:	100
Theoretical spreading rate:	3 m^2/l [120.3 sq.ft./US gallon] - 300 micron/12 mils
Flash point:	65 °C [149 °F]
Specific gravity:	1.4 kg/litre [11.5 lbs/US gallon]
Dry to touch:	9 hour(s) 20°C/68°F
Fully cured:	5 day(s) 20°C/68°F
VOC content:	36 g/l [0.3 lbs/US gallon]

**other shades according to assortment list.*

The physical constants stated are nominal data according to the HEMPEL Group's approved formulas.

APPLICATION DETAILS:

Version, mixed product:	**35760**
Mixing ratio:	BASE 35769: CURING AGENT 98760 6.4:3.6 by volume Stir CURING AGENT before adding it to the BASE.
Application method:	Airless spray / Brush/Roller
Thinner (max.vol.):	Do not dilute.
Pot life:	40 minute(s)
Nozzle orifice:	0.019 - 0.025 " (Consult the separate APPLICATION INSTRUCTIONS)
Nozzle pressure:	250 bar [3625 psi] (Airless spray data are indicative and subject to adjustment)
Cleaning of tools:	HEMPEL'S TOOL CLEANER 99610
Indicated film thickness, dry:	250 - 600 micron [10 - 24 mils]
Indicated film thickness, wet:	250 - 600 micron [10 - 24 mils]
Overcoat interval, min:	see REMARKS overleaf
Overcoat interval, max:	see REMARKS overleaf

Safety: Handle with care. Before and during use, observe all safety labels on packaging and paint containers, consult HEMPEL Safety Data Sheets and follow all local or national safety regulations.

Product Data
HEMPADUR 35900

35900: BASE 35909: CURING AGENT 95900

Description:	HEMPADUR 35900 is a two-component solventfree high build amine cured phenolic epoxy (novolac) coating with excellent adhesion and resistance to crude oil up to 93°C/ 200°F.
Recommended use:	As an interior lining in tanks, pipelines etc. for crude oil, water and produced water. HEMPADUR 35900 may be reinforced with fibre glass mats as a solution for the repair of pitted tank bottoms. For this specific use a clear version of HEMPADUR 35900 is available. (Please refer to the specific Application Instruction 3590000000 Fibre Mats)
Service temperature:	Maximum, dry exposure only: 160°C/320°F In water (no temperature gradient): 93°C/200°F
Availability:	Part of Group Assortment. Local availability subject to confirmation.

PHYSICAL CONSTANTS:

Shade nos/Colours:	20320/ Cream
Finish:	Semi-gloss
Volume solids, %:	100
Theoretical spreading rate:	2.5 m^2/l [100.2 sq.ft./US gallon] - 400 micron/16 mils
Flash point:	82 °C [179.6 °F]
Specific gravity:	1.4 kg/litre [11.3 lbs/US gallon]
Dry to touch:	11 hour(s) , 20°C/68°F
Fully cured:	7 day(s) , 20°C/68°F (See separate APPLICATION INSTRUCTIONS)
VOC content:	24 g/l [0.2 lbs/US gallon]
Shelf life:	1 year for BASE and 3 years (25°C/77°F) for CURING AGENT from time of production.

The physical constants stated are nominal data according to the HEMPEL Group's approved formulas.

APPLICATION DETAILS:

Version, mixed product:	**35900**
Mixing ratio:	BASE 35909: CURING AGENT 95900 3:1 by volume 4.75:1 by weight
Application method:	Airless spray / Brush (touch up)
Thinner (max.vol.):	Do not dilute.
Pot life:	1 hour(s) 20°C/68°F (See separate APPLICATION INSTRUCTIONS)
Nozzle orifice:	0.019 - 0.025 "
Nozzle pressure:	250 bar [3625 psi] (minimum)
	(Airless spray data are indicative and subject to adjustment)
Cleaning of tools:	HEMPEL'S TOOL CLEANER 99610
Indicated film thickness, dry:	500 micron [20 mils]
Indicated film thickness, wet:	500 micron [20 mils]
Overcoat interval, min:	see REMARKS overleaf
Overcoat interval, max:	see REMARKS overleaf

Safety: Handle with care. Before and during use, observe all safety labels on packaging and paint containers, consult HEMPEL Safety Data Sheets and follow all local or national safety regulations.

Product Data
HEMPADUR EM 35740

35740: BASE 35749: CURING AGENT 98040

Description:
HEMPADUR EM 35740 is a two-component, ultra high solids and very low VOC epoxy coating. It has good self priming properties and is suited for application even under humid conditions and on marginally prepared surfaces. Treated areas, e.g. ballast tanks, can quickly be re-immersed and put back in service.
Time to ballast: 8 hours (20°C/68°F).

Recommended use:
For smaller difficult access areas where climate control and surface preparation is difficult. It is especially recommended for spots and small area onboard maintenance and repair in e.g. water ballast tank. HEMPADUR EM 35740 can be used on moist surfaces, under conditions of 100% relative humidity. It is mainly intended for brush application.

Features:
Damp surface tolerance
Fast re-immersion
Ultra high solids
Very low VOC

Service temperature:
Maximum, dry exposure only: 120°C/248°F

Availability:
Subject to confirmation.

PHYSICAL CONSTANTS:

Shade nos/Colours:	47960*/ Green
Finish:	Semi-gloss see REMARKS overleaf
Volume solids, %:	97 ± 1
Theoretical spreading rate:	6.5 m^2/l [260.7 sq.ft./US gallon] - 150 micron/6 mils
Flash point:	33 °C [91.4 °F]
Specific gravity:	1.3 kg/litre [11.1 lbs/US gallon]
Dry to touch:	8 approx. hour(s) 20°C/68°F
Fully cured:	5 day(s) (approx.), 20°C/68°F
VOC content:	37 g/l [0.3 lbs/US gallon]

**other shades according to assortment list.*

The physical constants stated are nominal data according to the HEMPEL Group's approved formulas.

APPLICATION DETAILS:

Version, mixed product:	**35740**
Mixing ratio:	BASE 35749: CURING AGENT 98040 2:1 by volume
Application method:	Brush
Pot life:	1 hour(s) 20°C/68°F see REMARKS overleaf
Cleaning of tools:	HEMPEL'S TOOL CLEANER 99610
Indicated film thickness, dry:	150 micron [6 mils] (See separate APPLICATION INSTRUCTIONS)
Indicated film thickness, wet:	175 micron [7 mils]
Overcoat interval, min:	According to specification.
Overcoat interval, max:	According to specification.

Safety:
Handle with care. Before and during use, observe all safety labels on packaging and paint containers, consult HEMPEL Safety Data Sheets and follow all local or national safety regulations.

Product Data
HEMPADUR FAST DRY 17410

17410: BASE 17419: CURING AGENT 98410

Description: HEMPADUR FAST DRY 17410 is a two-component epoxy paint, which combines high volume solids with a short drying time. Contains zinc phosphate for better corrosion protection.

Recommended use: HEMPADUR FAST DRY 17410 is suitable for onshore corrosion protection of new-build steel constructions where fast to handle and short overcoating times are required, such as steel for factory buildings, stadiums, exhibition halls, airports, power plants, refineries, chemical and petrochemical plants.

Service temperature: Maximum, dry exposure only: 140°C/284°F

Certificates/Approvals:

Availability: Part of Group Assortment. Local availability subject to confirmation.

PHYSICAL CONSTANTS:

Shade nos/Colours:	11320* / Grey. (see REMARKS overleaf)
Finish:	Semi-gloss
Volume solids, %:	74 ± 1
Theoretical spreading rate:	7.4 m^2/l [296.7 sq.ft./US gallon] - 100 micron/4 mils
Flash point:	26 °C [78.8 °F]
Specific gravity:	1.5 kg/litre [12.8 lbs/US gallon]
Surface-dry:	45 minute(s) 20°C/68°F
Through-dry:	2.5 hour(s) 20°C/68°F
Fully cured:	7 day(s) 20°C/68°F
VOC content:	266 g/l [2.2 lbs/US gallon]
Shelf life:	3 years for BASE and 1 year (25°C/77°F) for CURING AGENT from time of production.

**other shades according to assortment list.*

The physical constants stated are nominal data according to the HEMPEL Group's approved formulas.

APPLICATION DETAILS:

Version, mixed product:	**17410**
Mixing ratio:	BASE 17419: CURING AGENT 98410 4 : 1 by volume
Thinner (max.vol.):	HEMPEL'S THINNER 08450 <5% depending on purpose (see REMARKS overleaf)
Pot life:	1.5 hour(s) 20°C/68°F
Nozzle orifice:	0.019 - 0.021 "
Nozzle pressure:	225 bar [3262.5 psi] (Airless spray data are indicative and subject to adjustment)
Cleaning of tools:	HEMPEL'S TOOL CLEANER 99610
Indicated film thickness, dry:	70-125 micron/2.8-5 mils
Indicated film thickness, wet:	100-175 micron/4-7 mils
Overcoat interval, min:	see REMARKS overleaf
Overcoat interval, max:	see REMARKS overleaf

Safety: Handle with care. Before and during use, observe all safety labels on packaging and paint containers, consult HEMPEL Safety Data Sheets and follow all local or national safety regulations.

Product Data
HEMPADUR QUATTRO 17634

17634: BASE 17636: CURING AGENT 97334

Description: HEMPADUR QUATTRO 17634 is a two-component universal epoxy paint, which cures to a hard and tough coating with good resistance to abrasion, seawater and various oils.

Recommended use: As a universal epoxy and self-primed high performance coating system for atmospheric or in-water service, including water ballast tanks and cargo oil tanks to be coated according to IMO-PSPC requirements (Resolutions MSC.215(82) and MSC.288(87)). HEMPADUR QUATTRO 17634 is intended for all year application down to -10°C/15°F and for in-shop applications where fast recoating and handling is required.

Features:
Excellent anticorrosive and very good mechanical properties.
Short drying time.
Curing down to -10°C/14°F.

Service temperature:
Maximum, dry exposure only: 120°C/248°F
Ballast water service. Resists normal ambient temperatures at sea (Avoid long-term exposure to negative temperature gradients).
Other liquids: Contact HEMPEL

Certificates/Approvals:
PSPC type approved. (Consult HEMPEL for specific Type Approval Certificates)
Tested according to section 175.300 of the Code of Federal Regulations Title 21 - Dry Foodstuff. Consult Hempel for details.
Tested for non-contamination of grain cargo at the Newcastle Occupational Health & Hygiene, Great Britain.
Approved as a low flame spread material when used as part of a predefined paint system. Please refer to “Declaration of Conformity” on www.Hempel.com for further details.

Availability: Part of Group Assortment. Local availability subject to confirmation.

PHYSICAL CONSTANTS:

Shade nos/Colours:	50630*/ Red
Finish:	Semi-flat
Volume solids, %:	72 ± 2
Theoretical spreading rate:	5.8 m^2/l [232.6 sq.ft./US gallon] - 125 micron/5 mils
Flash point:	27 °C [80.6 °F]
Specific gravity:	1.4 kg/litre [11.6 lbs/US gallon]
Surface-dry:	2 hour(s) 20°C/68°F
Through-dry:	5 hour(s) 20°C/68°F
Fully cured:	7 day(s) 20°C/68°F 20 day(s) 5°C/41°F
VOC content:	275 g/l [2.3 lbs/US gallon]
Shelf life:	3 years for BASE and 1 year (25°C/77°F) for CURING AGENT from time of production.

**other shades according to assortment list.*

The physical constants stated are nominal data according to the HEMPEL Group's approved formulas.

APPLICATION DETAILS:

Version, mixed product:	**17634**
Mixing ratio:	BASE 17636: CURING AGENT 97334 4:1 by volume
Application method:	Airless spray / Brush / Roller
Thinner (max.vol.):	08450 (5%) / 08450 (5%) / 08450 (5%)
Pot life (Airless spray):	2 hour(s) 20°C/68°F
Pot life (Brush):	2 hour(s) 20°C/68°F
Induction time:	- see REMARKS overleaf
Nozzle orifice:	0.021 - 0.025 "
Nozzle pressure:	250 bar [3625 psi] (Airless spray data are indicative and subject to adjustment)
Cleaning of tools:	HEMPEL'S TOOL CLEANER 99610
Indicated film thickness, dry:	125 micron [5 mils]
Indicated film thickness, wet:	175 micron [7 mils]
Overcoat interval, min:	see REMARKS overleaf
Overcoat interval, max:	see REMARKS overleaf

Safety: Handle with care. Before and during use, observe all safety labels on packaging and paint containers, consult HEMPEL Safety Data Sheets and follow all local or national safety regulations.