FRAMEWASH PROJECT
VOLVO CAB PLANT UMEÅ

EUROPEISKA UNIONEN
Europeiska regionala utvecklingsfonden

Viable
BUSINESS HUB

region västerbotten

Steve Lindeberg

Senior Equipment leader

Department: Engineering support

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Summary

This project is part of the Viable Business Hub, a regional cooperation platform for sustainability in the industry. This report serves as project documentation and knowledge sharing within the hub. The directive for this project is to insource the cleaning process of fixtures, skids and frames for painting plastic parts at the Volvo Cab plant in Umeå, both to secure business continuity and to develop a more environmentally sustainable process. The project is currently in the concept study phase but put on hiatus due to technical challenges and budget constraints. No concept fully met our requirements and was within the budget frame. No single process has been found that can strip off the paint within a reasonable cycle time. There needs to be a combination of processes and logistic solutions. The main track worked on is a pyrolysis process (oven) in combination with a flywheel blasting machine. The blasting machine must be able to completely clean off the ash of our mix of objects. A tough technical challenge to solve. Specially designed machines are needed which require a high investment. There is no verified technical solution so far. Some suppliers have informed that they have stopped making customer specific machines because of the high investment level. To move the current process and the civil works to prepare the inhouse production area for this process also went way over the estimated budget. The project work will give a good start when it starts up next time with a higher budget and, or more mature technologies on the market.

1. Background

Volvo Lastvagnar AB in Umeå Sweden request proposal for a new cleaning process in the plant for stripping off paint from paint fixtures, rack, and frames.

Currently these equipment's are cleaned at a small local company. A pyrolysis process is used to burn off the paint from the steel structures, followed by a cleaning step to remove the paint ashes with high pressure water.

Overall, the process delivers a good and sufficient cleaning result but there are several drivers for change

- Ovens reaching end of life and must be replaced or refurbished
- Environmental impact
- use of propane gas
- logistic flow transporting the equipment's back and forth
- Business critical to only relay on one small external company
- New projects are introducing longer and taller fixtures that don’t fit in current process

Moving the cleaning process into the plant will give possibilities to savings in environment, running cost and secures business continuity.

2. Directive

Project directive and demands.

- Expected date when the solution is running in full operational mode: w09 2023
- Manning demand: Max 2 man / shift for max volume. Capacity to run in the same pace as the paint shop, shift by shift. Follow the paint shop production times
- OEE demand: Furnace 98%, process 98%
- Cycle time demand: 120s
- Budget: 10 Msek
- FTT demand: 100% no reruns in furnace
- Other demands: Full meet all Volvo environmental, ergonomically and work environment requirements
- Proposed process area: Complete cleaning process to be fitted and placed in in the paint shop in an area of Width: 21m, Length: 38m, Height: 8,2m to roofbeams
- Environment friendly
- Flexible regarding volumes and new objects to clean
- Redundancy in the process setup
- No manual handling. Handling only by forklift

3. Scope

The scope includes a wide variety of fixtures, skids and racks to be cleaned. The objects vary much in size and weight.

Examples in table below WxLxH [m]

Small fixture	0,8 x 1,2 x 05
Fixture	1,3 x 2,4 x 2,6
Frame	1,2 x 1,85 x 2,7
Skid	1,6 x 4,1 x 0,48
Rack	2,4 x 2,4 x 2,4

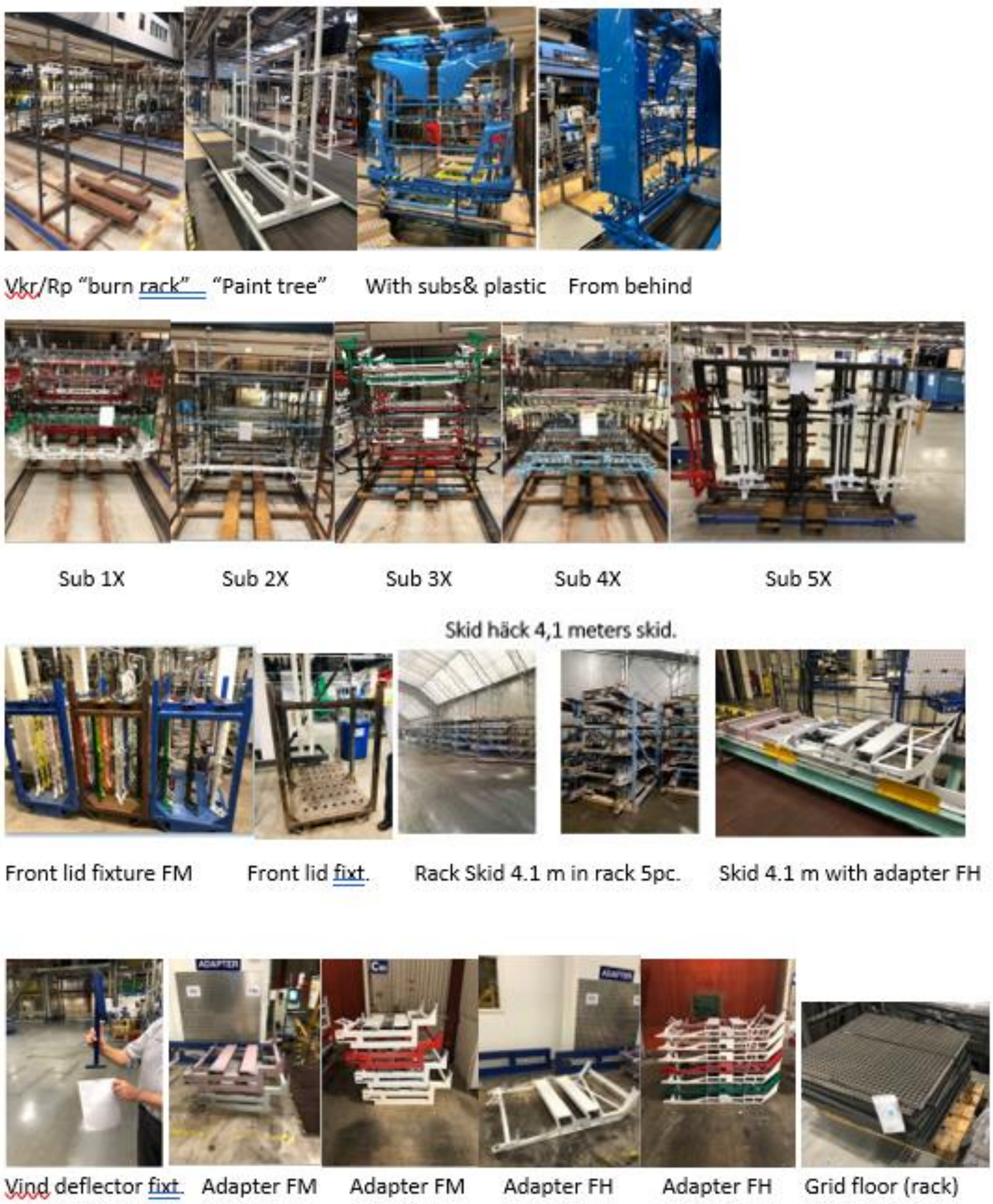


Figure 1. The mix of fixture, racks and skids to be cleaned

4. Current process

4.1. AS/IS cleaning process at the Supplier

In **Appendix 5.3** *AS-IS process area and pictures* there is a drawing of the process area and pictures showing the process equipment. But according to the supplier the area is too small, should probably been double the floor size from start (~400 sqm). There are 2 transports between the supplier and to Volvo plant per day, 3 km single way. The process steps at the supplier are:

- Sorting out goods on the yard for the next run in the oven.
- Forklift truck loading and by hand inside oven.
- Pyrolysis process with propane driven oven
- Ash removal by high pressure water jetting
- Placing the cleaned gods on the yard for return
- Transport back to Volvo plant.

The Supplier want to fill the oven as much as possible because every run cost money. They increase the filling density in the oven by hand. They stack objects on each other and on both sides in the oven. The propane gas they use cost more money than the one Volvo use because they buy it in big bottles instead of filling up a big tank. The price disadvantage due to that is huge. Gas bottles (4 pc.) are stored outside in a cabinet. There is an automated shifting device between bottles when one is empty. A slag machine is used to separate ash from the water before the water is reused. The dried ash is deposited two times per year. The ash is not considered to be harmful to environment. The operators lift and turn weights by hand that is not meeting the ergonomic standard at Volvo. They work in a facility where air climate will not be accepted at the Volvo plant. They open oven doors at a temperature inside the oven of 300°C which will not be allowed to do at the Volvo plant. Because of the too small room area they must place a lot of the fixtures on the yard under roof. That means the port into the room must be open very often even in wintertime. The supplier has not installed any heat recovery because the oven supplier couldn’t offer one at the time it was installed.

4.2. Cleaning frequency of objectes

It’s the paint shop production personal that evaluates and decides if a fixture need to be sent for cleaning or can go for one more lap through the paint process. The criteria they use is how hard the fixture are stuck on the sub fixture after paint process. If it’s stuck heavy it increases the risk for cracks in paint causing reruns. Too much paint can cause dripping in the paint process. That is not ideal and a parameter to be consider in the project. For skids and paint frame there are lap counters to use for automated pick out for cleaning. Some fixtures run only once in the paint shop. All these things also affecting the need cleaning capacity. Paint shop production engineer say it is the variations that occur in the paint process different parameters that makes it hard to set fixed laps before cleaning.

5. Concept Study

5.1. The cleaning methods evaluated

Paint stripping:

- CO2 Ice blasting
- Laser blasting
- Sand blasting
- Ultrasonic cleaning
- Fluidizing bed
- Pyrolysis

Ash cleaning after a pyrolysis process:

- Ultrasonic ash cleaning
- Fly wheel blasting machine ash cleaning

5.2. CO2 ice blasting of paint

The first method to be evaluated was CO-2 ice ball blasting. It's a method comparable to normal blasting where different material and sizes are used to grind the surface. In CO-2 ice blasting small ice balls diameter 3-5mm are used. They are made from CO-2 gas. Balls with diameters typically 3-5mm. The blasting effect is regulated with the air pressure true the nozzle. It's the kinetic power in the ice balls the knocks off the paint dirt.

To do CO-2 Iceblasting this will be needed:

I. Compressed air 3-20 bar
II. Needed air volume 0,5-20 cubic meters
III. Oil free and dry air
IV. Ice blasting equipment
V. Readymade ice balls, bought from supplier or own machine. Machine is about the same size as the Ice blasting machine
VI. The person that run the machine need personal protection gear.

Figure 5.2a Nozzle & protection gear**, b.** Machine **c.** Work, being close to object.

It was evaluated to be installed for an in-line cleaning process of plastic paint frames and fixtures. The first quick tests show poor process performance. The first test was done by supplier Cryotech located in Skövde Sweden. Small multilayer painted plates 10x15 cm to simulate the real paint layers on our objects was sent to them. We then decide together with the supplier Cryotech to do a more practical full test at Umeå plant despite the results from first quick test. Cryotech arrived with their equipment and made 3mm ice balls on site. A powerful mobile compressor was hired from a local company in Umeå. From production we picked out frames and skids about to be cleaned. The test done is only valid for the Volvo plant and the conditions that we have. Paint layers, paint type and paint thickness layer for layer and hardening times/days was not measured and documented. The paint layers also vary in thickness depending on where to measure on the fixture. This test was only about to see if the process performance could be useful for us. We also saw during the test that reachability with beam to all surfaces and the right angle was important. No spot on the fixtures can be leaved, every square centimeter must be covered with the beam. The conclusion after testing was that it didn’t fulfill our expectations nor our requirements.

Specific information for using the method:

- Nothing is wet after the cleaning process. The CO2 Ice goes from solid to gas without passing a fluid state. This process is called sublimation.
- It’s not abrasive to a metallic surface
- The hitting angle for the ice balls for an effective performance is important because the cleaning result comes from the impact energy.
- The reachability inside the fixtures and 360° around must be feasible.
- The beam nozzle must be very close to object all time to be effective.
- Every spot on the fixtures and frames must be covered by the beam.
- Insufficient cleaning performance for our needs.
- Machine investment. Price estimation from the supplier is ~500 000 - 1000 000 SEK (with CO2 ICE bullet making for one machine (one nozzle).
- Readymade ice bullets are expensive to buy. For our use it was estimated to be ~1,7-2,5 SEK/cm2 when we did the test.
- Ice bullets price was 5 SEK/liter for 3 mm bullets.
- Logistics for continues deliveries and transport of ice bullets are costly and energy consuming. Suggested where daily deliveries from the supplier in southern Sweden.
- Ice is dry when new but get wet when stored and then gives a poorer result because of weight loss. Ice bullets stored in special boxes lose weight with time, around 2% of weight per day.

- The machine consumes a lot of air, estimated to be 0,12 SEK/cm2 and the compressor must have the right continuous power.
- The machine consumes 4-5 cubic meter air/minute at 6-7 bar pressure.
- The machine produces high levels of noise. And so does the air compressor
- Manually blasting demands facemask and protection clothes.
- CO_2 is a smell free, invisible and a poisonous gas that is heavier than air.

5.3. Laser blasting of paint

Laser blasting is done with a highly concentrated laser beam that generates heat in a small point on the surface that cause the paint dirt to chip off from the surface.

Figure 5.3 Handheld laser blasting machine

Some smaller initial tests were done with this method. Smaller multilayer painted plates 10x15cm was sent for test at suppliers. We asked them to film the cleaning process and send it to us. The result was not acceptable for us because the performance was poor.

Specific information for using the method:

- No or very small laser grinding effect on the metallic substrate.
- Laser light is reflected from white/light colors. About ~60% of the Volvo trucks customer choose variants of white colors.
- Laser light beam must be in focus to be effective. It means that the distance between the nozzle and object must be kept in limits during the hole process to be effective.
- The laser beam must be able reach every spot also at the same time to be in focus.
- The process area must be separated and protected due to the laser light dangerousness.

5.4. Sand blasting of paint

For many years ago the paint shop used sandblasting for some objects. But they discovered that the dust level in the paint shop went up and that it affected the paint quality on our cabs. This method was then stopped to be used. Sandblasting also have a grinding effect on the steel substrate on our frames and fixtures and can't therefore be accepted. This information unfortunately kept us from looking at other blasting methods in the beginning of the investigations.

Figure 5.4 Sand blasting machine with gun (short nozzle) and sand container.

5.5. Ultrasonic stripping of paint

The ultrasonic method is well known for being effective for smaller pools in many different cleaning cases. The information we get from supplier was that it's hard for the ultrasonic sound to penetrate the hardened paint surface and therefore it is not effective to be used in this application. Process time will be too long. No supplier could present a reference installation big enough for testing our mix of objects either. Practical tests are mandatory for Volvo. More info about this method in chapter 5.9 Ultrasonic cleaning off ash after pyrolysis.

Figure 5.5 Big ultrasonic cleaning machine

5.6. Fluidizing bed for cleaning of paint

One supplier suggested to use the method fluidizing bed. The principle is to dip the objects in to hot (+420°C) fine-grained swiveling/floating sand. The swiveling is created by blowing in air thru holes from the underside of the tank. The heat comes from burning gas from nozzles underside and from the volatile organic compounds (VOC) that leave from the objects when heated. The sand gently grinding the objects clean in high temperature. This method is effective and have short cycle times (< 45min). But after cleaning the objects must be cooled down from ~420°C, flushed with water and dried. This method has limitations due to the depth of the sand bed. The maximum height of the bed we found was 1,5m. Most of the suppliers have a maximum depth of 1,2 to 1,3m. This is due to physical restraints. Which means that most of our big volume fixtures can’t be cleaned. Cooling down, flushing of sand with water, drying also mean longer lead time & manpower and more needed floorspace and investments.

Figure 5.6a Fluidizing bed cleaning machine with mechanism and lid.

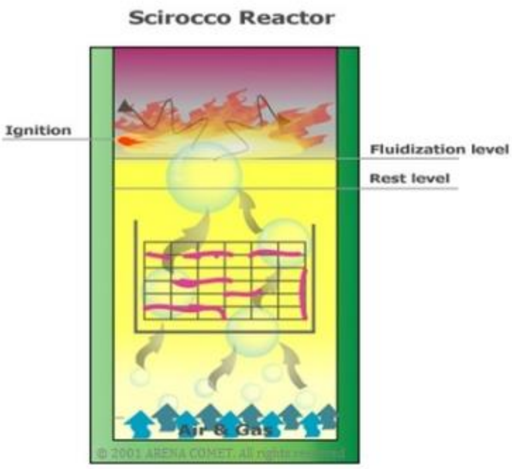


Figure 5.6b Principles fluidizing bed

5.7. Pyrolysis ovens (furnaces) for cleaning off paint

For our needs, we think the only reasonably method to clean off the paint is to use a pyrolysis process. That has to do with our mix of sizes and complicated form of our objects. We have done an evaluation including many different methods which are all presented in this report. The pyrolysis method is enclosing and reach every point on objects. In **Appendix 9.2** there is presentation that show the principle for this method. Pyrolysis is a thermal degradation av material in oxygen free or very low oxygen level (<8% oxygen) environment. (Breathing normal air contains ~18% oxygen) If oxygen level is too high inside things can start to burn and then so-called hot spots can occur that potentially could damage the gods inside. A solid content remains on the surface after the process is done, it’s ash. In our case the ash contains titanium oxide and other solids from the paint content. The recommend temperature for our pyrolysis process is around ~420°C. The rest of the paint content go from solid to gas form with help from the heating and get burnt in the afterburner. These gases called VOC which is short for Volatile Organic Compounds. These VOC gases contain energy that also help increase the temperature in the afterburner. The temperature must be + 900°C in the afterburner to maintain the oxidation process of the different VOC gases to CO_2. From the smoke chimney should only smell free CO_2 come if the process is correct adjusted. In our case we also let the smoke to pass a heat exchanger. Heat return can be done in many ways. For Volvo it's mandatory. The most use way is to heat up water. Heat exchanger affects the pyrolysis process so they must be developed together with the oven and adjusted together. One heat exchanger cost ~1 MSEK. Some ovens have 2 smoke chimneys so it will then need two heat exchangers.

The process inside the oven is divided in steps:

1. Heating up in steps to ~420°C, (time space depends on loaded steel weight and a how good the heat spreading are inside the oven).
2. Hold time (~420°C, (this depends mostly on the weight of the paint dirt on the objects).
3. Cooling down time, (slower decrease inside oven and much faster outside oven).

Heating up to fast means the VOC leaves the objects to fast and its risk for fire inside or too high temperature in the afterburner that can be damaged. Sensors and water nozzles inside are used to spray water to cool down the process and extinguish fires inside. Sensors for temperature, oxygen and VOC are used to steer the process. Outside oven it's possible to follow and steer the process in a PLC steering system on screen. Several run programs can be stored for different load cases. All brands seem to have the same possibilities. Oven supplier can offer different brands of PLC systems at extra cost, at Volvo we use and order Siemens.
Most of the heating medias used in ovens are bad for environment. But there are some alternatives that are little better, bio propane gas, natural gas and biodiesel that are possible to order CO_2 neutral. Today we already use propane gas in several applications in plant. We are looking for a possible switch to bio propane gas if possible and to electrical heating where it's possible. Volvo have not so far succeeded to secure enough deliveries of bio propane gas. The price level is also high and unstable. We have not been able to find any electrical driven pyrolysis oven on market. But to our attention have come that research have start up to see if it's possible to make ovens for industrial work. Expected lead time is ~4-5 years according to CEO of the company. The difficulty is to get the oxygen level down inside an electrical oven so a pyrolysis process can occur. That reduction of oxygen occurs natural in a gas driven oven when gas is burnt to produce heat.

We have looked at different design principles for ovens that are possible for us to use for fulfilling the directive. Some lack the needed safety and capacity and some suppliers have warn us for run disturbances and increased maintenance for some designs. There is unfortunately only one oven design available that fulfills the directive in full at the time of writing this report. We have limited floorspace in the plant and in the space for the cleaning process. We also deal with uneven inflow of cleaning objects. This must be investigated closer in detail in the next step of the project, can it be leveled? The two types of ovens we have looked at is loading/unloading inside oven with a forklift truck **(type A)** and the other one is loading/unloading on a table outside the oven with a forklift truck and changed with a semiautomatic mechanism **(type B)**. Both types recommended by suppliers. Pictures of the two types of ovens can be seen in **Appendix 9.3** Two type of pyrolysis oven. The first one is the table design oven and comes with a semiautomatic cart to take out and put in a new already loaded table. This complete change process takes ~5 minutes to perform by one operator running the cart. That saves heating media. The motorized cart runs on rails. The table is placed on supports both inside and outside. No moving parts inside the oven. Hydraulics in the cart lifts and lowers the table. Loads between 5-30 tons possible to choose. The table can be loaded/unloaded at any position without being unstable. Door opening (hydraulic) temperature is 300°C for the oven **type B**. The principal layout for this **type B** oven is shown in figure 4.9a below. The operator that run the cart is fully protected from heat and accident risks when loading/unloading. Cooling inside oven is slow even with the fans running for blowing in cold air. Outside oven cooling is much faster and typical only 1h needed to go from 300°C to 80°C. (info from two suppliers when I asked).

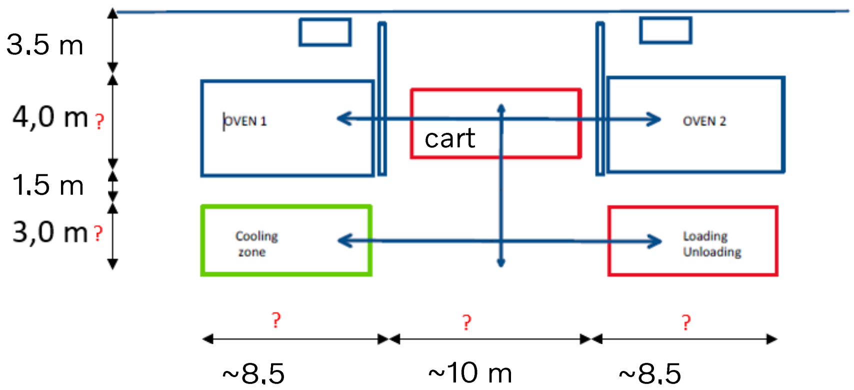


Figure 5.7a Principle set up for type B ovens.

Measurements comes from supplier. I ask for them because depth (11-12m) of oven footprint process is critical for us when creating a layout. The measurements for length set the capacity and the measurement for depth is fixed and don't need to be changed in the most likely set up for us. One supplier informed us that one meter extra or less is ~5% of the price for the oven. Read text for how to calculate the capacity. The figures shown for length could be too big comparing to what the real capacity setting will be. Steering cabinet can be placed optionally optimal for production. We have not done any practical test with ovens because we need to develop a whole concept for the cleaning.

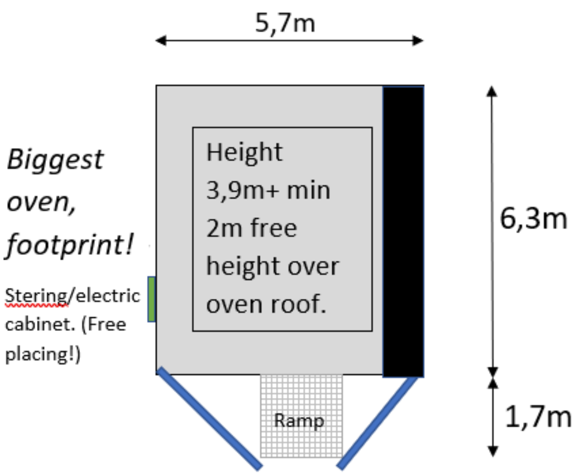


Figure 5.7b Oven **type A** with maximum size footprint (recommended by supplier.

The **type A** oven have an electrical programed lock for doors to fulfill the negotiated safety demands. At Volvo cars the doors can be opened when temperature inside oven is below 80°C. Studying the two types of ovens it's easy to see the differences. Even spread of heat is important for a quick heat up phase. The oven **(type B)** that have only one fan on the short side blowing in the heat in tunnel placed on the floor in the middle of the oven and thru the whole length of the oven, have the better spreading of the heat compared to oven **type A**. The heat is let out from holes in the tunnel on low floor level. Small holes close to fan and bigger holes away from the fan. All calculated for an even and quick spread of the heat. The **type A** ovens have two fans placed on one of optional long sides at floor level. One fan in each end. Spreading heat true wholes between the two fans at floor level. This takes up valuable floorspace capacity and the spread of heat are probably not as good compared to **type B**.
In **Appendix 9.4** There is a compare chart of the two ovens.
It's important to get the dimensioning of the capacity right. The dimensioning parameters to look after is the size, shape (measurements) of the floor inside the oven and ovens cycle time. In our case we must use a forklift truck to load and unload. Inside measures of the floor must have the best fit possible to what we load in order to save space. The footprint measures of the forklift packages must fill up the floorspace as much as possible. That will save running cost and heating media. To consider are also possible fork directions of the packages when loading/unloading. Is it possible to stack packages in the oven, full or partly to increase the density? In **Appendix 9.7** A check for 3rd shift capacity (+20%) is done.

Figure 5.7c+d below show difference between the two oven types when it comes to "footprint" after loading. Suppliers recommend splitting the load to two ovens 50/50 for redundancy. And for to lower the manufacturing cost with two equal ovens. For the oven type A there is a maximum size for the oven type and if that maximum is passed more ovens are needed. For type B it's possible to do a deeper oven inside for more capacity. But then the cart system also needs the same increase in size. **Type B** can use different sizes in depth measurements for the two ovens. Total steel load in pre-study calculation was 5400kg.

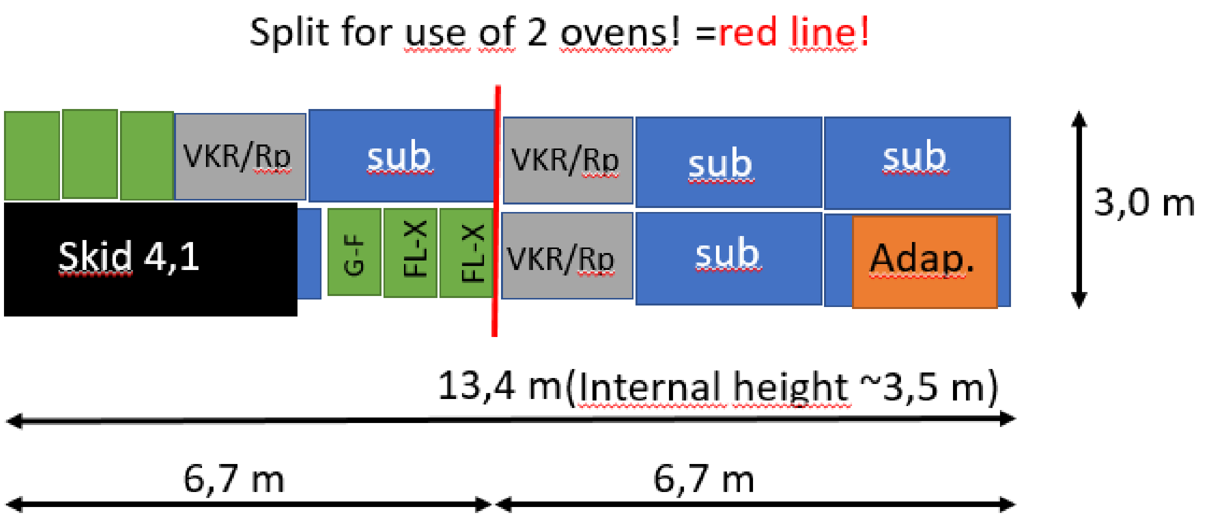


Figure 5.7c (Type B oven example)

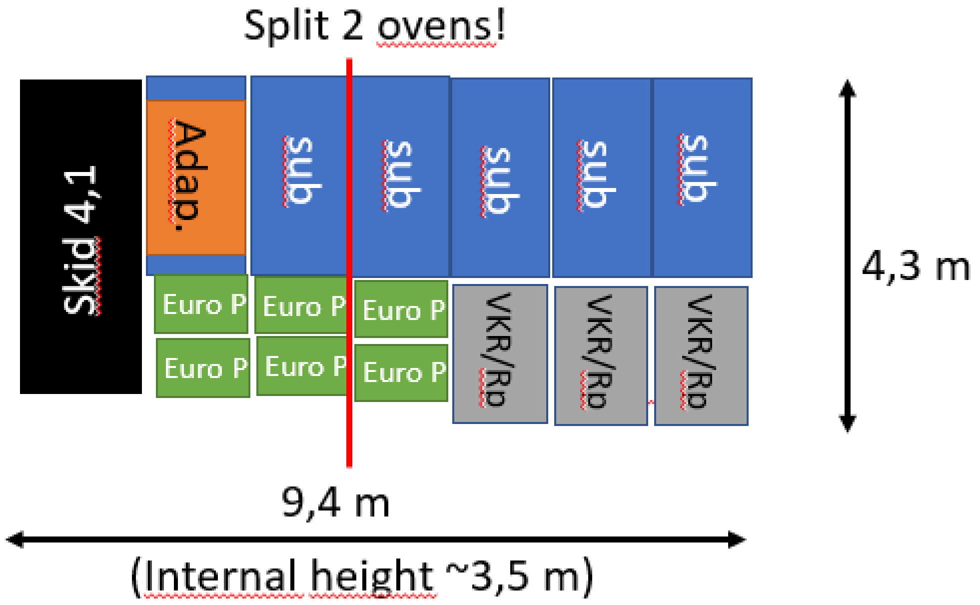


Figure 5.7d (Type A oven example)

Oven sizes are limited when it comes to transport dimensions. Height and width are limited on domestic roads. Some suppliers can offer a split delivery at an extra cost. For **Type A** it's a practical maximum depth because of the rest heat inside the oven. To go deep inside a still hot 80°C oven for operators is not a good work environment. A Swedish supplier have received complaints from several customer about this. He doesn't recommend deep ovens! Waiting for complete cooling down increase the cycle time a lot. It also increases the cost for heating media.

To figure out a preliminary oven sizes for suppliers cost estimations we used this method to calculate.

- Use the latest year cleaning statistics per cleaning object and produced cabs out from paint shop. Then we are sure that we consider all improvements/changes in the paint process to reduce or increase the cleaning and new and old objects changes in production.

- A future look what's coming in the ongoing projects in 2-3 years ahead that will probably change the capacity for cleaning. This must be more investigated and more precise estimated and decided in the next project phase.

- The number of cleanings per object will then after being recalculated in proportion to the plants demanded installed volume according to directive (75000pc. in 2-shift and +20% = 90000pc. in 3-shift) with OEE and other considerations to count in. Exceptions are objects that are on a scheduled cleaning, for example grid floor that are picked out for cleaning every weekend regardless of shift form.

- Next step is to divide them to racks, frames, pallets and skids that is possible to handle with a forklift truck. One package is the normal what a forklift truck can handle. **Figure 5.9c** show the number of packages per object to be cleaned. In the picture forklift packages are called "trolley packages".

- Next step is to divide to amount of forklift packages to be handled every shift. That is the demand in the directive = follow shift! One week are 9 shifts for 2-shift and its 45 weeks in a year. 2-skift run total 18,2h per day and nightshift run 5,8h per day Monday to Thursday and 7,3h Sunday to Monday.

Fixtur	Cleaned singel fixtures per year	Cleaned full racks or pallets per year	Racks or pallets per shift	Racks or pallets per day*	Racks or pallets per week	2-skift Trolley Amount of packages /skift	2-skift Amount of packages rounded /skift	3-skift Trolley Amount of packages /skift	3-skift Amount of packages rounded /skift	Foot print size & height meter WxLxH	
Sub 1X	2237	447	1,10	2,21	9,94					1,3x2,4x2,6	
Sub 2X	3493	582	1,44	2,87	12,94					1,3x2,4x2,6	
Sub 3X	1321	220	0,54	1,09	4,89					1,3x2,4x2,6	
Sub 4X	3219	536	1,32	2,65	11,92					1,3x2,4x2,6	
Sub 5X	4167	417	1,03	2,06	9,26					1,3x1,9x1,5	
SUM:				10,88	48,95	5,44	6,0	6,53	7,0		
FH adapter*F	320	46	0,11	0,23	1,02					1,3x,1,95x 1,6	Stacked
FM Adapter*P	136	34	0,08	0,17	0,76					1,4x1,9x 1,5	Stacked
XXL adapter	5	singel	singel	singel.						singel	
SUM:				0,40	1,78	0,20	0,2	0,24	0,2		
FH24 frontlid fixture	7639	387	0,95	1,91	8,59					0,8x1,2x1,8	
FM24 frontlid fixture	2966	247	0,61	1,22	5,49					0,8x1,2x1,6	
SUM:				3,13	14,08	1,56	1,6	1,88	2		
Skid 4,1	314	62,7	0,15	0,31	1,39					1,6x4,2x2,4	Stacked 5
SUM:				0,31	1,39	0,15	0,2	0,19	0,2		
Vkr/Rp frame	1133		2,80	5,59	25,18					1,2x1,85x2,7	
SUM:				5,59	25,18	2,80	3,0	3,36	3,4		
ED bur CKD	4	singel	singel		????					2,4x2,4x2,4	
Grid floor big	1800	90	0,22	0,44	2,00					0,8x1,2X1,30	
Grid floor small	6480	162	0,40	0,80	3,60					0,8x1,2x1,30	
RP nr 1frames*F	382	26	0,06		0,58					0,8x1,2x0,5	
Vind deflector*F	2736	114	0,28	0,56	2,53					0,8x1,2x0,5	
SUM:				1,81	8,71	0,97	1,0	1,16	1,2		
					"Trolley packages" SUM;	11,1	12,0	13,3	14,0		

"Trolley packages" = Packages to be handled by forklift on and of trolley or in or out from oven

Figure 5.7d Forklift packages calculation.

Cycle time per oven type also have a great impact to fulfil the capacity demand in the directive. To show how that impact we made this **Figure 5.9d.** This is based on the amount and mix we have today. We already know that the number of fixtures will increase.

	Type A*	Type B	Present supplier oven
Cycle time	~11,5h	~5h	?
2-skift, number of ovens to fullfil directive	3	2	0
3-skift, number of ovens to fulfill directive	4	2	0
Enough space in assigned room Emred 3-skift	NO	YES	0

*** = Maximum size and all Volvo work environment demands fullfiled**

Figure 5.9d Compare the number of ovens needed to fulfill directive

5.8. Water flushing (water jetting) ash cleaning after pyrolysis

The as-is process, at the supplier, is flushing by hand using high pressure water with an aggressive "turbo nozzle". The machines used are of the same type that are used in homes for cleaning cars and buildings. But they are more robust and have higher pressure capacity, typical 250 bar, and are made for daily use. Low investment, around 50 000 SEK for one machine. A pool for collecting the water and reuse it after separate the ash in a dryer process. Sludge suction can also be used to send the ash for deposition or to own treatment plant. Sludge suction in our case is estimated to two times per year by local company. A separate ventilated house inside the building with rolling doors are needed to be set up around the process for an acceptable inhouse environment. If the parts are heavy, lifting aids and manipulators are needed for fulfilling environment regulations and laws. In our project we need it all. All manipulators and lifting aids must be protected from water. This method was a backup (plan B) for us but was closed by the management due to the unwanted/ not attractive environment and expected high investments in a multistep process that also demand higher manning to run. It also demands “a house in the house” that are both separate ventilated. The cost is estimated to be high for this method.

Suppliers was asked about machines for doing the job. The ones that manufacture low pressure and high flow machines say that they could not help us. The ones that sell high pressure machines say no due to size of our parts and that they don’t believe it will work either. A visit was paid during a business trip to a production company in Germany where they have installed a cabinet high pressure water machine. They informed us that the machine didn’t give clean parts out after the pyrolysis process. We got the tip to use a wheel blasting machine instead.

Talking with manual water jetting operators at production facilities they informed us about the necessity that the water beam hit every square centimeter for reaching a result that leaves no ash remaining on the object. Enough impact energy must be achieved from the water beam. Meaning the spray nozzle must be close to the object and the water pressure must be high enough. An aggressive nozzle must be used. If the paint is not processed in the pyrolysis process long enough it will take longer time to clean off the ash.

5.9. Ultrasonic ash cleaning after pyrolysis

Cavitation is a phenomenon where rapid pressure changes occur in a liquid which leads to creation of small bubbles filled with steam in the liquid. It normally occurs where the pressure is lower than the surrounding liquid. Because the content in the bubbles is nothing they implode. That creates a force that hit the surface and the dirt to chip off. A lot of bubbles need to be created. It can be a very powerful effect that can be used for cleaning off dirt. To make it happen, sound with a sound frequency (and high power) in the range of 20-60 kHz are used to keep the process going.

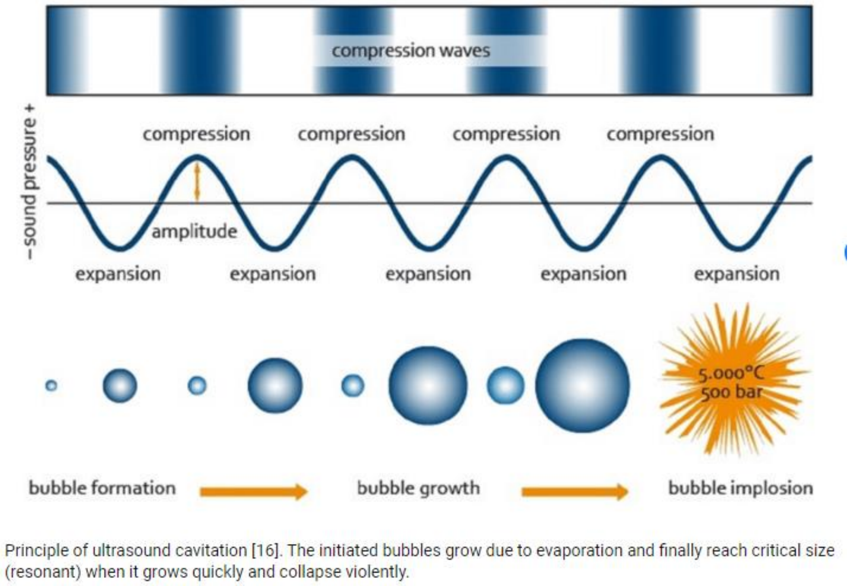


Figure 4.11 The working principle for ultrasonic cleaning

One supplier answered our Request for proposal, RFP with presenting a facility for cleaning off ash for our mix of objects with ultrasonic cleaning. The design measurements: length: 32m, with: 25m, height: 15m. Drawing in **Appendix 9.5** Ultrasonic facility. An earlier price estimate before this design was developed and sent to us was 17miljon SEK. No new price given for this new design from supplier. But the design is far too big for our assigned area. No supplier could present a reference installation big enough where we can do practical tests with this method. And the test will be tough to accept for being valid due to all the parameters involved. But practical testing is mandatory for Volvo. This method of cleaning has parameters and adjustments that must be looked after due to how the method is functioning. There are risks for uncleaned spots. To mention some of them are placing of the generators in the pool and the distance from wave generators to object and to reach all spots and angels on objects. This method is also big power demanding. A rule of thumb is ~25kW per 1000 liter of fluid. This method always needs chemicals in the fluid to work properly which always means that rinsing and drying of the objects must be done. The ash in the fluid must be dried out and sent for deposition. There are a lot of types of chemicals used for different purposes that must be handled in a secure way. Normally it's a chemical that lowers the surface tension in the fluid. Sometime a separate special machine must be used to get rid of bubbles inside the fluid because it reduces the cleaning power. Or simply to change the fluid. The ash must be filtered out from the fluid and sent for deposition. The ash is not environmental harmful. The fluid most also be taken care of in a proper way normally in a treatment plant.

5.10. Blasting machines for cleaning of ash after pyrolysis

On a business trip to Germany, we got interested in flywheel blasters for a solution to clean of ash. They are frequently used for different cleaning purposes in the industry today. There are some different types to choose from. They are all built around different numbers of flywheels inside. They are all flexible in use. They seem to be divided in 3-4 different type groups from the big manufacturers. Its standard machines. Unfortunately, some of the types need a foundation in the cellar level, meaning we must cut the floor open and make the foundation. And some are so big so we can't fit them in the assigned room together with the other processes. We have also concluded that we probably need a special machine to fulfil our

demands. So far, we have not find a supplier that say they can help us. We still need to do the practical testing after they have presented a solution. We are waiting for some answers from a supplier when this is written. The most important thing is that we must be able to handle all objects with a forklift in and out from the machine. The machine must fit in the room together with the other processes needed. Wheel blasters work with a high amount of blasting media that are blast on the surface of the gods with an air pressure that can be regulated. The normal spray pattern from a blaster is a triangular shaped beam. The media could often be round steel balls in different sizes and hardness. In our case recommendations have been 0,2-0,8 mm soft steel balls. There are many types of blaster media to choose from to optimize. The supplier will help us this with optimization. Normally the hardness of the media should be softer than the hardness of the object to avoid damages on the surface. This blasting method use the impact energy to clean off the ash and is a “soft method” meaning it’s not aggressive to the substrate. The media is bouncing around and because of the ricochet effect it creates a good cleaning result. The object rotates or the blaster wheels are placed in angels so all surfaces on the object are covered. The media is filtered out and reused again and again until it is too small and got stuck in the air filter. Refilling to be done every now and then to keep an effective mix of bigger and smaller media parts. Filters for our type of use are long lasting and changed ~two times per year. All machines can deliver dust free objects out and the air the machine use go through the same type of hepa classed filter that are used in home vacuum cleaners. And back to room. The already warmed up air stays on the inside of the plant.
The machine we think can help us is a special made hook blaster with the possibility to load and unload with a forklift truck. Cycle time ~5-10 minutes. Price estimate 9,5 MSEK. Needed total power between 80 and 200 kW. One single wheel blaster needs between 12-15 kW. None is yet verified and we lack info about cycle times, price, size, delivery times etc. Below there are three common types of blasters presented. Unfortunately, some of them needs a hole in the floor and a fundament in the basement to stand on. Some of them have dimensions that is too wide and long and can’t be fitted in the room we have been assigned. Below pictures of some of the most common types of blasting machines.

Figure 5.10a Pass thru blaster example.

Figure 5.11b Hook blaster example

Figure 5.11c Table blaster example

5.11. Recommended concept

Due to technical limitations to handle the scope of objects, cycle time etc in all but one concept, the recommendation, in the time of writing, is to use Pyrolysis oven combined with flywheel blasting for cleaning of the ash. But still more investigation, development testing is needed of the blasting machine to evaluate the needed process set up.

6. Evironmental impact & sustainability potential

6.1. Potential environmental savings from reduced transport

There are, with current volumes, 10 transports of objects to be cleaned per week. Transport distance is 3km, one way. That gives a total transport distance of 2700km /year. The transport vehicles consume 0,6 liter/km on average. Total of 0,6x2700= 1620 liter diesel/year. Equals to approximately 4860 kg CO_2 in savings from transport reduction.

6.2. Potential environment savings from changed process

With the recommended concept, pyrolysis and blasting of ash, the potential environmental savings can be

- Less use of propane with change of oven type. Even lower after full trimming in.
- Change to fossil free biopropane gas
- Change to electrical pyrolysis ovens. Technology not yet mature for large scale objects
- Optimized logistic flow to reduce internal transports in the plant
- Less transport of propane gas with big tank instead of single bottles
- Heat recovery system

7. Financial and business impact

Investments for the recommended concept, including civil works and relocation of current process to accommodate required floor space, is estimated to be significantly over budget. Technical life span for the equipment is expected to 20 years.
A possibility is that we can run the whole cleaning process with only one operator depending on the process cycle times.
If the most efficient oven is chosen there is a potential to reduce the cost for propane due to less consumption. If installing new ovens in the plant we can use propane with lower price than the supplier has today, it's a big difference in price. That is due to the change from bottled gas to gas in a big tank that already use today for other ovens in the plant.
Internal transports at Volvo plant can be reduced when most of our fixtures only are transported inside the plant and the logistic is optimized.
Further investigation and concept selection is needed to fully understand the complete business case. The conclusion now is to halt the project due to big discrepancy of initial budget and forecast of investment cost.

8. Conclusion

This report is part of the Viable business hub and to be shared for knowledge in the field of in-house paint stripping from process equipment used in paint shops.

No concept meets our requirements and are within the budget frame.

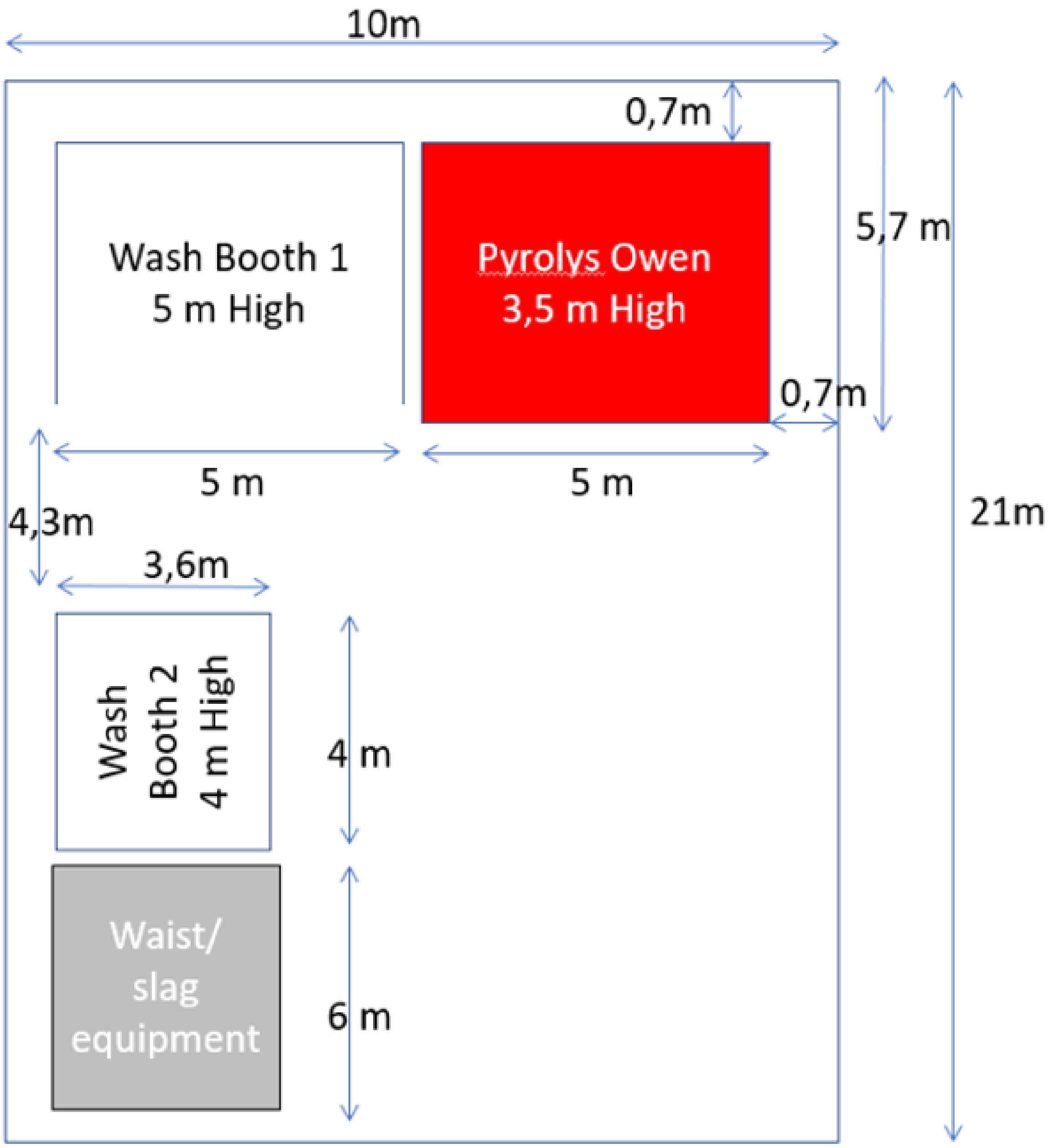
The project is in the concept study phase and are looking for concepts that can fulfill all the demands and prerequisites. It's about finding process solutions that work side by side in the floor space of our current industrial footprint. We have not been able to find a complete solution for the cleaning. The missing part is to clean of the ash after a pyrolysis process. (Pyrolysis, ash cleaning, logistic and ultrasonic ash cleaning for small parts that is not included in this project)

Next step, from an environmental perspective, could be to set up a testing facility for electro heated pyrolysis ovens. Start with smaller objects and continue, together with a supplier, develop ovens to cover the largest objects.

Another possibility is to narrow down the scope of the project and install a process inhouse to cover for part of the objects, e.g., high runners. For example, install one new oven in the plant that the can clean frames and fixtures and keep using the supplier for the big, long skids. This could potentially reduce the investment need by around 50%. By that create partly redundancy and better securing business continuity, decrease running cost, and decrease environmental impact both from reduced transportation but also, with a new modern oven, reduce use of propane gas. And use a heat recovering system to reduce overall energy consumption.

9. Appendices

9.1. AS-IS process area and pictures



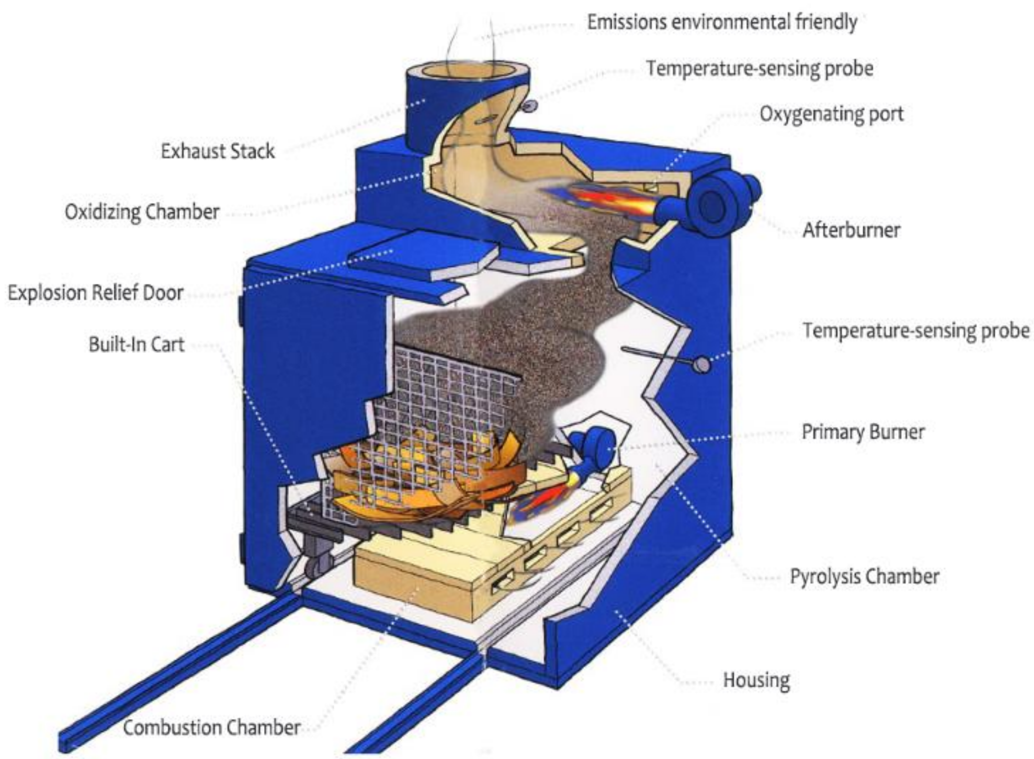
Photos see next pages…

AS-IS Storage of propane gas bottles (4 pieces) at supplier of cleaning.

AS-IS Machine for drying out ash at supplier of cleaning.

AS-IS Water jetting both and the pyrolysis oven at supplier of cleaning

9.2. Pyrolysis oven principle



9.3. Two type of pyrolysis oven

9.4. Compare of two oven types

Supplier:	Current supplier	Pyrox	Pump&pyrolysteknik	Arena comet
Oven type:	AS-IS, forklift truck and manual loading and unloading inside oven	Semiautomatic table loading/unloading oven	Forklift truck Load/unload inside oven	Forklift truck Load/unload inside oven
Compare attribute				
Cycletime total		5h	11,5h	11,5h
Cycle time oven	?	5h	10h	10h
Loading+unloading time inside oven, cycle time, estimated one oven	?	5min	1h	1h
Loading+unloading time outside oven, time, estimated		1h	N/A	N/A
Cleaning ash in oven, every run! time		N/A	0,3h	0,3h
Cleaning ash in oven, only weekends processcleaning needed! process team? Time		0,3h	N/A	N/A
Handling loading ramp with forklift truck for loading/unloading, every run, opening/closing doors		N/A	0,2h	0,2h
Open oven when <80°C inside	OK	N/A	OK	OK
Safe open oven when 300°C inside	NO	OK	NO	NO
Cooling time utside oven 300 --> <80°C (before ash cleaning step)		1h	0	0
3:rd skift +20% more output possible with 2 ovens		OK	NOK	NOK
Meet capacity demands in directive		OK	NOK	NOK
Price per oven		[redacted]	[redacted]	? Bundled prices
Price heating recovery per oven		[redacted]	[redacted]	N/A
Volvo TS demands		[redacted]	[redacted]	~1,0 MSEK
Transport & packing, CGN gasnorm, chimney work		[redacted]	[redacted]	?
Price semiautomatic change mechanism		[redacted]	[redacted]	N/A
Price per oven estimation		[redacted]	[redacted]	N/A
Total price estimation 2 ovens		[redacted]	[redacted]	?
Total price estimation 3 ovens		[redacted]	[redacted]	N/A
Total price estimation fullfiling directive		[redacted]	[redacted]	N/A

9.5. Ultrasonic facility