CZECH TECHNICAL UNIVERSITY, PRAGUE
FACULTY OF MECHANICAL ENGINEERING
DEPARTMENT OF PROCESS ENGINEERING

OPTIMIZING OF THE SEQUENTIAL LINE

DIPLOMA THESIS

2017

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FACULTY OF MECHANICAL ENGINEERING CTU IN PRAGUE

MASTER THESIS ASSIGNMENT

I. PERSONAL AND STUDY INFORMATION

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Study field:	**Process Engineering**

II. MASTER THESIS SPECIFICATION

Master thesis title (in Czech):

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Master thesis title (in English):

Optimizing of the sequential line

Elaboration guidelines:

Cílem této práce bude optimalizace taktové linky pro nanášení povlaků. Optimalizace se zaměří na kvalitu přilnavosti povlaků a řešení minimalizace spotřeby chemikálií a energií. Hlavním úkolem bude identifikovat úzká místa linky a navrhnout řešení pro zvýšení kapacity produkce. Pro práci budou poskytnuta průmyslová data.

Literature resources:

Almeida E., Alves I., et al., Cataphoretic and autophoretic automotive primers A comparative study , 2003, Progress in Organic Coatings 46, p.8?20

Merlo L., Application methods: Electrocoating, 2012, PPG industries Inc., Springdale, Pa.

Oravitz J., Electrocoating, 2010, PPG industries Inc., Springdale, Pa.

Industrial data.

Name and affiliation of the thesis supervisor:

Ing. Michal Netušil Ph.D.,	**Department of Process Engineering FME CTU in Prague**

Consultant:

-

Assignment issue date:	**10th April 2017**	Thesis due date:	**6th June 2017**

Validity of assignment: -

_____	_____	_____
Thesis Supervisor	Head of the Department	Dean of the Faculty

III. THESIS ASSIGNMENT RECEIVED

The student is aware that the thesis has to be accomplished through an independent and unassisted student's work, supported only by recognized consultations. Literature and other information resources as well as consultants' names have to be acknowledged in the thesis.

2 4 -04- 2017	
_____	_____
Date	Student

DECLARATION:

I declare that this diploma thesis entitled "OPTIMIZING OF THE SEQUENTIAL LINE" is my own work performed under the supervision of Ing. Michal Netušil, Ph.D, with the use of the literature presented at the end of my diploma thesis in the list of references.

In Prague:………….   Signature:…………………

ACKNOWLEDGEMENT:

I would first like to thank god for all things which I have in life, and I would like to thank my teacher and colleagues who are all helpful in so many ways in completion of my master thesis program. And I would like to thank my thesis supervisor Ing. Michal Netušil Ph.D., of the Czech technical University, Faculty of Mechanical Engineering, and Department of Process Engineering.

The door to Mr. Michal Netušil office was always open whenever I ran into a trouble spot or had a question about my research or writing. He consistently allowed this paper to be my own work, but steered me in the right direction whenever he thought I needed it.

My deepest thanks to my thesis advisor Ing. Michal Netušil Ph.D, who has been a major source of continuous support, patience, motivation, informative and advice. His guidance and knowledge led myself to acquire curios interest in Electro coating and to complete my thesis in correct direction.

Finally, I must express my very profound gratitude to my family and to my friends for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

Thank you.

2017   YUVAPRABHU MANOHARAN

ANNOTATION SHEET:

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Tutor:

Submitter: Czech Technical University in Prague,

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ANNOTATION: I have done literature research on Electro Coating in Industries. These scientific researches focused on Electro Coating Technology, Electro-painting, chemical, energy and waste in industries to increase the production. Based on the literature research, I have selected Sequential step and chemical used during coating process. After selection of primary material, I have made industrial design of line diagram of industry layout, Electro coating layout, construction work, Technological scheme – line disposition, Technology Scheme P&ID 1 and 2 pretreatments with a removing of sewage sludge, waste disposal and phosphate bath in design. According to the calculation we can conclude that, by the process of electro coating in industry, production is increased and price of chemical, energy and waste is reduced.

KEYWORDS: **Optimization, Electro coating, Sequential line, Technology P&ID, Painting, Energy and waste reduction - AutoCAD 2D Design.**

TABLE OF CONTENTS:

1. INTRODUCTION:

Electro Coating is a method of giving a metal by an organic finish by using electrical current to deposit the paint in the material. The process works on the principle of 'opposites attract'. An electro coat system applies a DC charge to a metal part immersed in a belt of oppositely charged paint articles. The paint articles are drawn to the metal part and paint is deposited on the part forming an even continuous film over every surface, in every crevice and corner until the coating attains the desired thickness. At that thickness, the film insulates the part and the attraction of paint particle stops and electro coating is complete. There are two types anodic or cathodic current to apply paint on metallic substrates. These types are mostly popular in industries due to its excellent corrosion resistance and great covering ability on complex metallic components. However, it requires precise electrical control and expensive bath maintenance. [1]

In coating industry has changed greatly in the past dozen years. Electro coating was the widely accepted method in fastener production until it was discovered that bulk electrocoating on trays or in baskets provided better corrosion protection along with a tightly controlled film thickness and, therefore, greatly reduced paint usage. In addition, e-coat eliminated head fill, clogged threads and minimized clumping during the curing process. As a result, electro coating was quickly relegated to batch colors while e -coat became the coating of choice for high volume products. This usually meant one, two or – at the very most – three colors applied by the same system [1]. A noted fastener manufacturer sought ideas on an electrocoating system able to provide high output in any one of five colors, with a future option for a sixth color. Besides color, the product also varied by fastener type, length, diameter and thickness design is drawn.

In electro coating bath, operating parameters can result in more consistent workpiece quality as well as longer bath life. This strategy is simple: determine critical operating parameters and maintain them within the acceptable limits. The first step in this process is to determine optimum operating parameters for the process. The next step is to ensure regular monitoring of bath chemistry, which is essential in determining the proper amount of chemicals to add to maintain efficient operating parameters. Determining operating parameters on an individual

plating line basis is important because suppliers sometimes set concentration specifications for levels higher than is required for effective operation. Higher concentrations mean increased drag out and waste generation.

Currently, automotive paint manufacturers are not able to easily assess the economics of painting. As they have mainly been involved with supplying paint, they have not experienced a need to understand the economics of the actual painting process. In situations where they are beginning to get involved in the painting process, they are typically relying on cost estimation techniques which have historically been set up for traditional accounting purposes. These techniques are not useful in assessing the cost implications of process changes or the contribution of various steps to the total painting cost [2].

According to literature research, this thesis renders an economic analysis of the automotive painting process via the construction and use of a process based cost estimation model. The thesis also examines other strategic factors that are key to being competitive in this industry. In Coating industries chemical are wasted nearly about 40 %, Energy 20%, water is wasted about 45% in year. Due waste of chemical and energy production is wasted and cost of the money are reduced. My project shows that during the electro coating Sequential lining process - chemicals, energy and waste are reduced and to increase the production. Consideration will be given to system layout, concerns about paint contamination, material handling automation, load tracking, paint handling and wastewater disposal [2]. To reduce the cost, waste and energy complication and coating defects associated with the application of current, it would be ideal to have an E-coating that can self-deposit alloys. One of the possible solutions to this problem is the application of a low cost, temporary protective coating that can prevent the dissolution of in the phosphating bath and be compatible with the subsequent normal E-coating process Further to the establishment of the new E-coating theory and technique, it is important to investigate if the coating is feasible in practical production conditions. For this purpose, this project compares the corrosion performance of the E-coating on various chemical, energy waste is reduced and production is increased according to the design and calculation. Further, the model can evaluate the chemicals and energy to implications of alternative painting technologies.

2. LITERATURE RESEARCH:

2.1 Overview of Electro coating sequential lining:

2.1.1 Types of electro coating:

The E-coat process is best described as a cross between plating and painting. It is a process where a metal part is immersed in a water-based solution containing a paint emulsion. An electric voltage is applied to the part causing the paint emulsion to condense onto the part. A part can be painted both inside and out, wherever the liquid is able to reach a metal surface. The coating thickness is limited by the applied voltage. As areas of high voltage build a coating they become insulators thus allowing lower voltage areas to build up. Finally, the interior of a part can be coated since the exterior is fully insulated by the coating. There are two types of electro coating process:

- Continuous Electro coating process
- Sequential Electro coating process.

In continuous electrocoating process, process is done continuously in several stages and it is shown in figure (1).
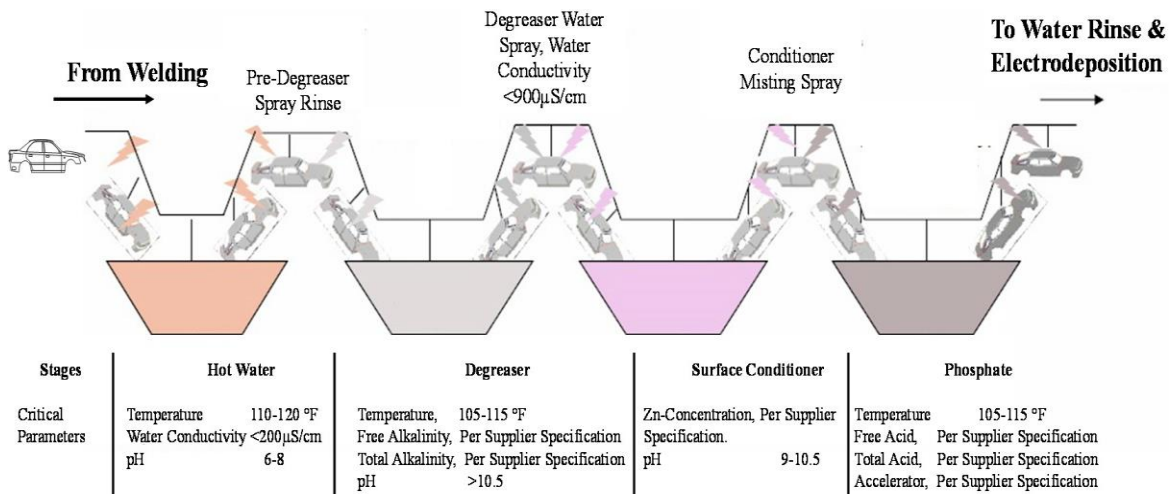

Figure 1: Continuous Electro Coating process

In Sequential line process, it has several stages and it is shown in figure (6). These papers focus only about the sequential lining process. In sequential Lining process, there are 5 important stages for coating are detailed explained below:

- Pre-cleaning
- Rinsing
- Zinc-phosphating
- Electro coating
- post rinse
- bake oven.

2.1.2 Pre-Cleaning:

In the typical metal finishing process, the alkaline cleaning tanks are first in line and take the bulk of the dirt load. Whether the tanks are soak cleaners, ultrasonic assisted cleaners, or electro cleaners, their purpose is to remove oils, grease, wax, polishing compound, particulates, and light oxides from the part surfaces [2]. Depending on the detergent additives in these tanks, the tanks could build up surface oil, oil emulsions, suspended solids, or sludge at the bottom of the tank or any combination of these contaminants. As with acids, the cleaning chemicals are consumed in the process of removing and preventing redeposit ion of the contaminants. The first sequence in preparing the for sequential coating is pretreatment—see figure (6). Pretreatment consists of cleaning the body surface to remove remaining oils from the stamping process and welding residues through three primary liquid dip processes of degreasing, conditioning, and phosphating. An additional pretreatment cleaning that employs ~pH 9 hot water can also be used. Pretreatment helps the primer to bond onto the metal. A phosphate treatment applies an inert layer of metal phosphate.

The next sequence is surface conditioning (also called activation), which creates nucleation sites for phosphate crystal growth. It increases the number of crystallization nuclei on the metal surface that enhance bonding mechanisms for the subsequent phosphate sequence. In conditioning, an aqueous dispersion of titanium orthophosphate with pH between 8 and 10 is typically used. Finally, the liquid dip phosphate solution is composed of phosphoric acid, phosphate ions, nitrate ions, zinc and other divalent metal ions, hydrogen ions, and an accelerating

compound [3]. The free acid etches the steel surface, causing hydrogen to be released while metal phosphate ions are precipitated onto the surface in a crystalline form. The primary objective during phosphating is to deposit a thin, dense and uniform conversion layer on the cleaned and prepared metal surface.

2.1.3 Rinsing:

Rinsing is critical in the metal finishing process but more water use does not necessarily mean better rinsing. Best practices for producing effective rinsing are double counter flow immersion rinse tanks between process tanks Reactive rinsing for the appropriate process chemistry combinations rinse controls such as automatic valves controlled by timers or water conductivity limits Immersion rinse efficiency model Often, when the rinse appears to be inadequate, However, rinse flow rates can be deceptive in that high flow rates may not be as helpful as expected. The initial conditions are 100-gallon rinse tank Incoming solution concentration of 100 grams/gallon Drag out volume per rack of 0.05 gallons. It is apparent from that the rinse tank does not dilute the dragged in chemical very rapidly. Even the 25 gpm flow rate takes approximately 5 minutes to drop the concentration from 5% to 2.5%. The main point is that a single rinse tank is relatively ineffective at providing critical rinsing. More importantly, increasing the flow rate in a rinse tank does not necessarily improve rinsing unless extremely high and costly flow rates are used [3].

2.1.4 Zinc – Phosphating Rinse:

In the pretreatment process, metal surfaces are cleaned and prepared for electrocoat paint application. Oils and other contaminants are removed from the part. Existing rust spots may be removed and a phosphate or conversion coating is applied. The pretreatment process is necessary to improve electrocoat performance, ensure a high quality electrocoat finish and to keep the paint bath clean of unwanted contaminants [3]. The number and type of pretreatment stages depends greatly on the type and condition of metal being introduced to the system. It also depends on the part configuration and the overall performance requirements of the phosphate or conversion coating.

$$2H_3PO_4 + 3Zn \rightarrow 3H_2 + Zn_3(PO_4)_2$$

$$2H_3PO_4 + Fe + 2Zn \rightarrow 3H_2 + FeZn_2(PO_4)_2$$
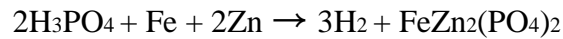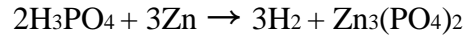
These equation is taken from the reference [4]. Zinc and iron phosphates are the most widely used conversion coatings in the electrocoat industry. These are pretreatment choices in the electrocoat industry because it provides the best corrosion resistance and paint adhesion. Iron phosphating has had a long history of being the process of choice for applications where overall cost considerations override performance requirements. Although iron phosphates provide reduced corrosion resistance in comparison to a zinc phosphate process, it is less expensive to install and operate for the next electro coating process. This treatment leads to a marked improvement in corrosion resistance, both directly and by helping the paint to stick. Phosphating and painting together offer 75 - 90% of the total corrosion resistance and increase the life of the material by 5 - 10 years.
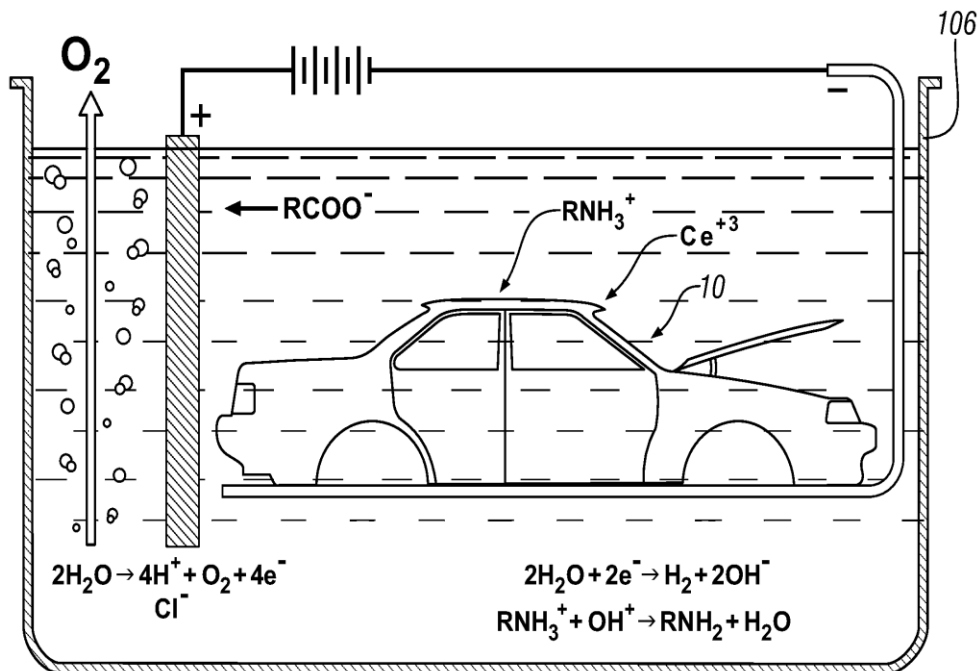

Figure 2: Zinc Phosphating

2.1.5 Electro coating:

The most important for the electro coating is electroplating the application of a metal coating to a metallic or other conducting surface by an electrochemical process. The article to be plated (the work) is made the cathode (negative electrode) of an electrolysis cell through which a direct electric current is passed. The material of coating part is immersed in an aqueous solution (the bath) containing the required metal in an oxidized form, either as an equated cation or as a complex ion. The anode is usually having electro coating of macro molecules it has charged particle, Paint particle and resin. Depending on the polarity of the part and paint particles, electrocoating is classified as either anodic or cathodic.
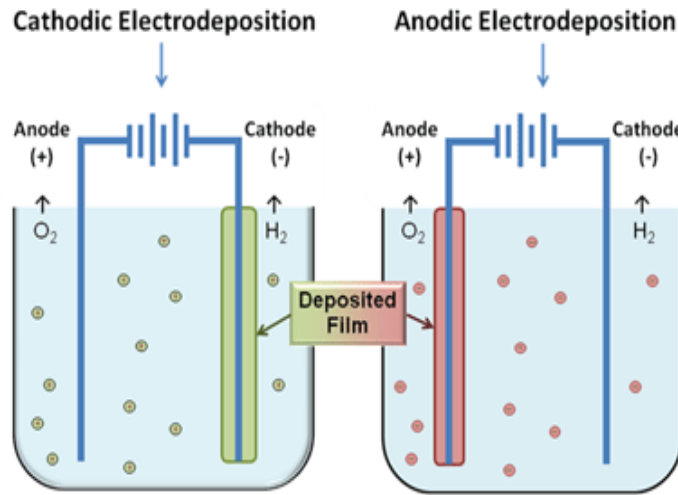
Figure 3: cathodic & Anode process

Anode process: the part to be coated is the anode with a positive electrical charge which attracts negatively charged paint particles in the paint bath. During the anodic process, a small amount of soluble iron can migrate away from the part and into the paint film which results in a reduction of the performance properties of these systems. Although most anodizing involves immersion of racked parts in tanks, continuous anodizing is done on large coils of aluminum in a manner like continuous electroplating. For aluminum parts, the formation of the oxide occurs when the parts are made anodic in dilute sulfuric acid or dilute chromic acid solutions. The oxide layer begins formation at the extreme outer surface, and as the reaction proceeds, the oxide grows into the metal. The last formed oxide, known as the boundary layer, is located at the interface between the base metal and the oxide. The boundary is extremely thin and nonporous [3].

Cathodic process, the part to be coated is the cathodic with a negative electrical charge which attracts positively charged paint particles in the paint bath. By reversing the polarities used in the anodic process, the amount of soluble iron that enters the paint film during the cathodic process is greatly reduced and the corrosion resistance properties of the paint film are improved.

The electrocoat bath consists of 80-90% deionized water and l & 20% paint solids. The deionized water acts as the carrier for paint solids, which consist of resins, pigment, and small amounts of solvents. The resin is the backbone of the final paint film and provides properties such a corrosion protection and ultraviolet durability. Pigments provide color, gloss, and corrosion protection as well. Solvents help ensure smooth film appearance and application. During the electrocoat process, paint is applied to a part at a certain film thickness, which is regulated by the amount of voltage applied.

The coating material is lowered into the tank, and an electric current applied; the solution in the tank consists of 80%–90% deionized water and 10%–20% paint solids (consisting of resin, binder, and pigment). The deionized water acts as a carrier for the paint solids, which are under constant agitation. The resin is the backbone of the final paint film and provides corrosion protection, durability, and toughness. Pigments are used to provide color and gloss. To control paint performance during cathodic E-coating, purging of the paint and regulating the amount of applied voltage are essential. As the coating grows in thickness, it becomes more and more insulating, thereby causing the deposition process to slow. As an automobile body exits the tank, paint solids adhering to the surface but not bound to the surface are rinsed off to recover the ED solids via an ultrafiltration unit to ensure surface smoothness [4].

2.1.6 Post rinse:

The post rinses provide both quality and conservation. During the electrocoat process, paint is applied to a part at a certain film thickness, regulated by the amount of voltage applied. Once the coating reaches the desired film thickness, the part insulates and the coating process slows down. As the part exits the bath, paint solids cling to the surface and must be rinsed off to maintain efficiency and aesthetics. These excess paint solids are returned to the tank to create a coating application efficiency above 95%. [3]

2.1.7 Bake oven:
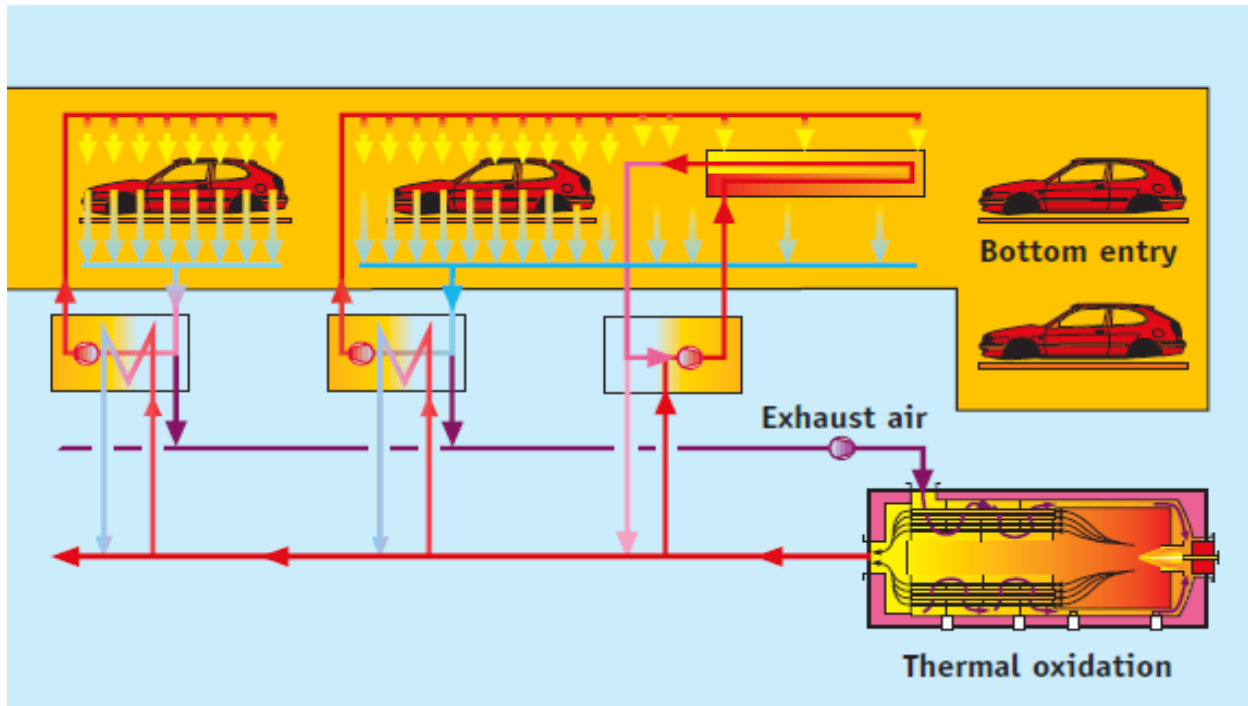
Figure 4: Baking oven Process

After exiting the post rinses, the electrocoated part enters the bake oven. The bake oven crosslinks and cures the paint film, making it hard and durable to assure maximum performance properties. Oven temperatures can range from 150°C to over 230°C, largely dependent on the paint technology being used and the time spent in the oven [13], Shown in figure (4). Although initial heating of the components and is therefore line-of-sight, heat is also conducted to other parts of the workpiece by the substrate. Careful angling of infrared sources can promote a better cure. Energy costs can be reduced, if the size of workpieces varies and smaller components are being cured, by switching off some of the panels of radiant systems or the elements of electric systems. This facility is not available with conventional ovens. The use of infrared heating can reduce staving times considerably. This allows smaller ovens to be used on conveyorized systems it will have capacity increase could be reached by enlargement of the oven in the finishing process.
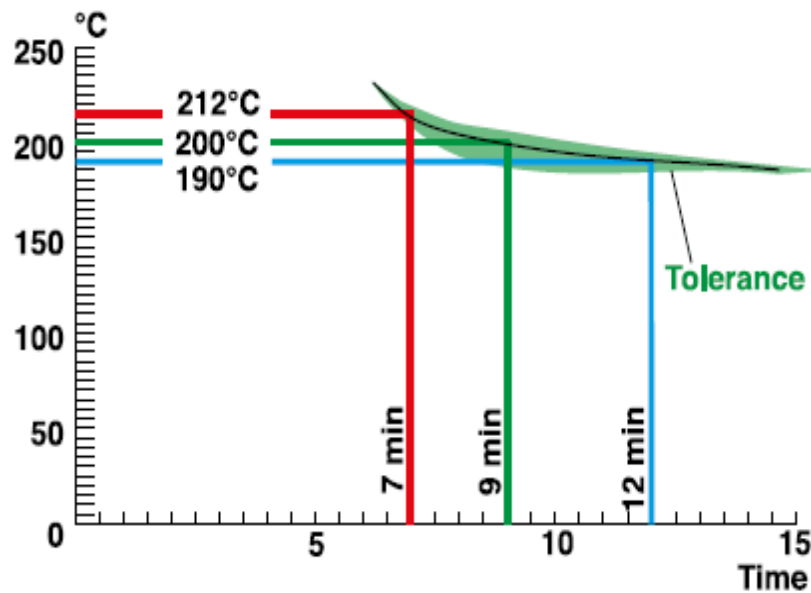
Figure 5: Temperature Range- Baking process

Most often, 20 minutes of metal temperature at a recommended temperature is specified to obtain full paint cure Figure (5). Because of their water based formulations, electrocoat paints have low volatile organic compound (VOC) and hazardous air pollutant (HAP) content. Ovens must be continuously exhausted to maintain the oven atmosphere below the lower explosion limit (LEL) and to prevent smoke buildup in the oven and plant. Often, the levels of VOC or HAP emissions are low enough that companies are typically permitted to exhaust ovens to the atmosphere without the use of air abatement equipment. [14]. Because the dry off and curing ovens used in the top coating process do not require high heat, the conveyor requires less lubrication. Throughout the top coating area, load bars remain disconnected from the power and free conveyor to make sure line workers have sufficient time to complete their tasks.

2.2 Consumption of Chemical energy and waste:

2.2.1 Step and coating Process:

Electro coating was the widely-accepted method employed in fastener production until it was discovered that bulk electrocoating on trays or in baskets provided better corrosion protection along with a tightly controlled film thickness and, therefore, greatly reduced paint usage. In addition, e-coat eliminated head fill, clogged threads and minimized clumping during the curing process. As a result, dip spin coating was quickly relegated to small batch colors while e-coat became the coating of choice for high volume products. A noted fastener manufacturer sought ideas on an electrocoating system able to provide high output in any one of five colors, with a future option for a sixth color. This usually meant one, two or – at the very most – three colors applied by the same system [13]. The challenge was to provide an electrocoating system that maximized product flow – preferably in more than one color at a time – with an automated material handling system to bulk load and unload fasteners and manage their trip through the coating process. There are many types of paint and coating failure for which the coatings or corrosion has little or no control over. If the coating system that is selected by the chemical is formulated inadequately, the coating will most likely to regardless of all efforts made in an optimal Sequential application. These ingredients chemical include the resins used, the pigments used, as well as the solvent formulation and are wasted. Several specific types are presented in Electro coating process system during process there are some effect of time limitation from these table (1). According to the figure (6), Sequential step are drawn for the e-coating process it has a several   appearances, causes, and problem prevention. The installed capacity of the plant is 1.39 sq. meters / second [5]. On this basis, the installed capacity is 444.8 sq. meters in 16 hours. The annual capacity is 133440 sq. meter [5]. After applying the efficiency factor of 90% the installed capacity works out to 120000 sq. meters. Plant and machinery are mentioned in Table (2) & Man power and consumption are showed in Table (3) & (4).
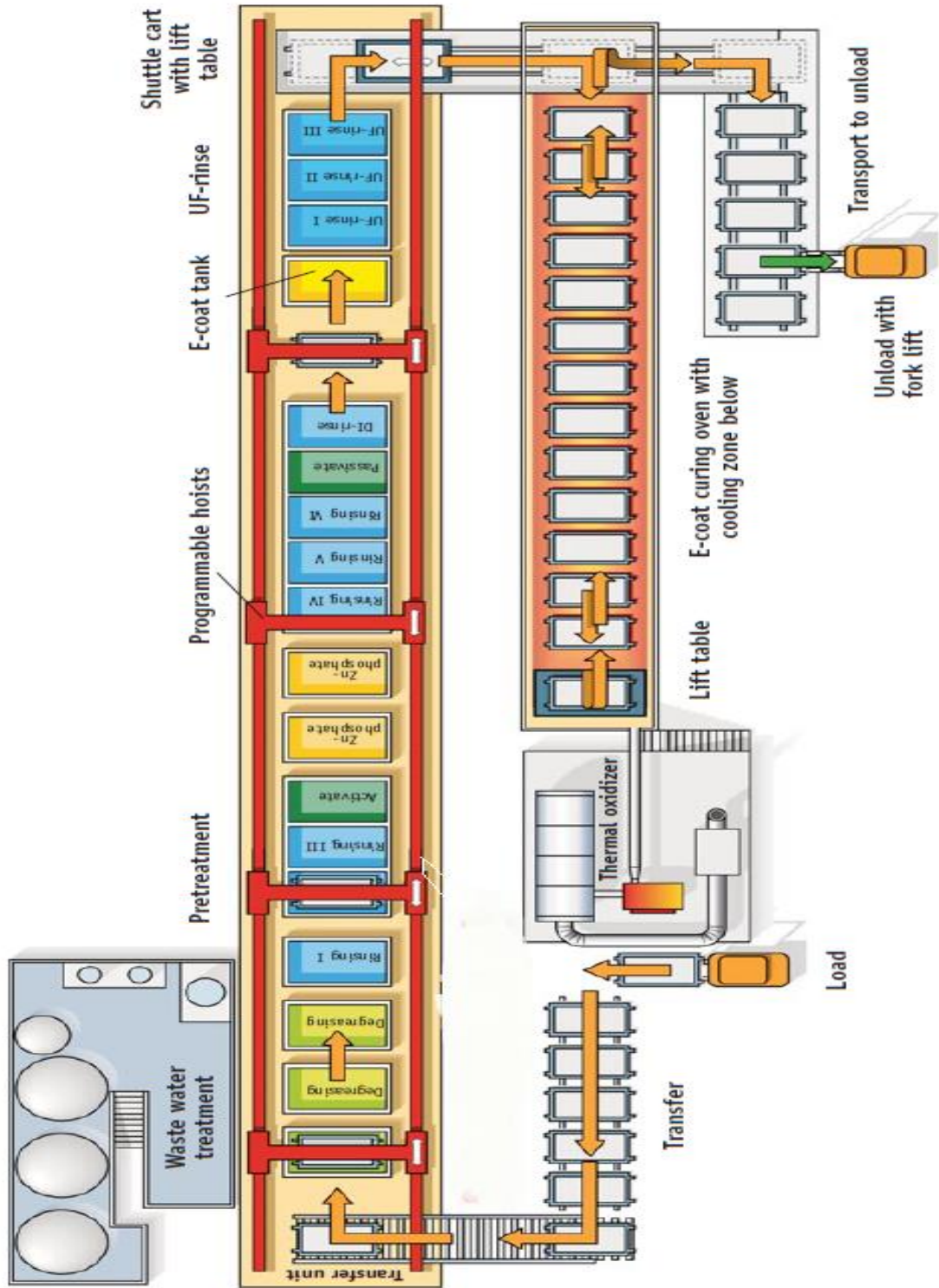
Figure 6: Electro coating Sequential line [6]

Table 1: Technological process- Electro Coating

Sr. No.	Stages	Chemical Name	Make up per 1000 LTR (Kgs)	Testing Parameters	Temp °C	Time (sec.)	Process Kg. cm²	Remarks
1.	Hot Water	--	--	pH = 8.0 – 9.5	50 – 55	45	1.5 – 2.0	Frequent Renewal
2.	Degrease (Electro coat)	Nipaklin 4460 A Nipaklin 4460 B1	4460 A = 20 4460 B1 = 12	Qahtani Pipe Coating (AL) = 16 - 19 PTS	50 -55	60	1.5 – 2.0	Permissible Oil Content in the in the = 4.0 G/L Max.
3.	Degrease (DIP)	Nipaklin GN 4460 A Nipaklin GN 4460 B1	4460 A = 20 4460 B1 = 12	AL. = 16 - 19 PTS	55 – 60	150	--	
4.	Water Rinse (Electro coat)	Industrial Water	---	Tal = Max .5.0 PTS	R.T.	90	1.0 – 1.5	Continuous Overflow
5.	Water Rinse II (DIP)	Industrial Water	---	TAL = MAX .3.0 PTS	R.T.	45	--	CASCADE to WRI
6.	Surface Conditioning (DIP)	– X Additive GN 4977 Additive GN 4977B	PL – X = 3 4977 = 0.6	Coating = 2.6– 3.9 pH = 9 – 10 pts	R.T.	45	--	Discard Every 4 Months

7.	Phosphate (DIP) SS tank	Nipaphos GN 3020 M Nipaphos GN 3020 R Additive E GN 4813 Additive GN 4856 Neutralizer GN 4055 Nipacel GN 4704	3020 M = 48 3020 R = -- 4813 = 5 4856 = 17 4055 = 8.6 4704 = 0.42	TA = 22 - 24 PTS	40 – 45	120	--	Make up & Replenish Chemicals are Different
8.	Water Rinse III (Electro coat) MS FRP tank	Industrial Water	---	TA = MAX. 5.0 PTS	RT	45	1.0 – 1.5	Continuous Overflow
9.	Water Rinse IV (DIP)MS FRP tank	Industrial Water	---	TA = MAX. 3.0 PTS	RT	45	--	CASCADE to W.R. III
10.	DM Water Recirculate (DIP) MS FRP Tank	DM Water	---	pH = 6.5 – 7.5 EC < 30 µS/CM	RT	45	--	CASCADE to Stage 4
11.	DM Water Fresh (Electro coat)	DM Water	---	pH = 6.5 – 7.5 EC < 10 µ	RT	pass	0.8 –1.2	CASCADE stage 10

2.2.2 Plant & Machinery:

Plant & Machinery items are considering by the sequential step for the Electro coating process from these Table (2). Plant and machinery price is calculated according to the Czech national bank Currency conversion. The Price are from the year 2011 [23].

Table 2: Plant and machinery [5]

Particulars	Qty (No)	Value (€)
Pre-treatment Line-seven Tank process	1	6000
Electro coat system	1	4400
Baking Oven	1	2000
Total	3	12400

The land and building will have required area about -1000 sq m. This can be arranged on lease basis. Rent assumed. The total power requirement of the unit will be 52 kW. Water requirement is about 500 liters per day (ionized water) which can be purchased.

2.2.3 Man, power consumption:

Man, power consumption in elector coating plant with annual income only for the country Czech Republic at the year of 2014 shown in table (3) [6].

Table 3: Man, power consumption – Electro coating process [5]

Category	Nos	Salary / monthly (€)	Annual Salary (€)
Supervisors	1	1400	16800
Operators	8	1350	16200
Security	1	1300	15600
Total	10	1050	24600
Add 20%benefits			2600
Total			75800 (€)

Total Electro Coating Installation Assumption in year (2014):

Table 4: Assumption for Installing the plant Total cost [17]

Electro coating plant - Installed capacity per annum	
Capacity utilization- Year -1	60%
Year -2	70%
Year -3	80%
Selling price per unit	Electro Coating – (€) 30 /sq. m.

2.2.4 Zinc – Phosphating:

A substantial percentage of paint and coating are related to the substrate to be coated and its proper preparation prior to coating. To eliminate this class of paint and coating failure, it is imperative that the painters and coating applicators take great care in following specified method of surface preparation. There is no substitute for proper surface preparation if long service lifetime is expected from the paint or coating [3]. Several specific types of substrate-related failures are presented in, as well as appearances, causes, and problem prevention. They include previously used steel; galvanized or metallic zinc surface, aluminum, copper, wood; and concrete.

The phosphating baths for phosphating conversion treatment, if they are suitable for the deposition of a crystalline zinc phosphate layer at least on the uncovered ferrous and zinc surfaces of the component According to the invention, ferrous surfaces include surfaces of steel, while zinc surfaces also include, in addition to galvanized steel surfaces, surfaces of alloy-galvanized steel and zinc alloy. The phosphating solutions which should preferably be used are those which can be applied by Electro coating or dipping and which contain 0.2 to 3 g/l of zinc ions and 3 to 50 g/l of phosphate ions, the weight ratio of phosphate ions to zinc ions amounting to at least 3.7, as well as one or more accelerators selected from [3].

- 0.3 to 4 g/l of chlorate ions,
- 0.01 to 0.2 g/l of nitrite ions,
- 0.05 to 2 g/l of m-nitrobenzene sulfonate ions,
- 0.05 to 2 g/l of m-nitrobenzoate ions,
- 0.05 to 2 g/l of p-nitrophenol,
- 0.005 to 0.15 g/I of hydrogen peroxide in free or bound form,
- 0.1 to 10 g/l of hydroxylamine in free, ionic or bound form,
- 0.1 to 10 g/l of a reducing sugar
- 0.05 to 4 g/l of an organic N-oxide, preferably N-methyl morpholine,
- 0.5 to 5 g/l of an organic nitro compound selected from nitroguanidine, nitroarginine and methyl, ethyl or propyl esters thereof and from nitro butylidene diacetate.

2.2.5 Zinc phosphate – Pretreatment Process:

The post-treatment on the one hand heals defects in the phosphating and, on the other hand, should be used and does not result in homogeneous, continuous phosphating of the aluminum surface of the component with a layer weight of at least 0.5 g/m² of zinc phosphate. The passivating post-treatment of the component after phosphating and before electro-dip coating in is preferably carried out by means of an acidic composition containing flour complexes of the metals zirconium and/or titanium, the proportion of flour complexes relative to the elements zirconium and/or titanium particularly preferably being in the range from 50-1000 ppm [3].

A further aspect of the present invention relates to the use of a metallic component, which has been treated in accordance with the method according to the invention for avoiding "mapping", in a process for the application of a multilayer system, preferably consisting of organic coating materials, in industrial surface finishing. Metallic components treated according to the present invention are furthermore used in the construction industry and architectural sector, and to produce vehicle bodies in automotive manufacture and to produce "white goods" and electronic housings. A typical processing sequence for anticorrosion treatment of metallic components of the type provided by the present invention consists of the following process steps [4].

Method A:

- 1) Degreasing in Ridoline 1565® (Henkel AG & Co. KGaA) by dipping
    - Formulation: 3.0% Ridoline® 1565 A and 0.3% Ridosol® 1270 in tap water
    - pH value: 10.8
    - Temperature: 56-57° C.
    - Duration: 5-6 min
- 2) Rinsing with deionized water
    - Temperature: Room Temperature
    - Duration: 1-2 min
- 3) Activation with acidic aqueous dispersions by dipping
    - Formulation: 0.14 g/l of insoluble phosphate measured as PO_4 4.9 g/l of soluble phosphate measured as PO_4 produced by addition of a solution of 27.4% of H_3PO_4 and 10.4% of Naho in deionized water (pH 2.9) to a dispersion of 0.6 g/l of $Zn_3(PO_4)_2.4H_2O$ in deionized water until a pH value of 4.3 is established.
    - Temperature: RT
    - Duration: 30 - 60s
- 4) Phosphating with Grenadine® 952 (Henkel AG & Co. KGaA) by Electro coating
    - Formulation: Grenadine® 958 Atoner® C 16+Toner® 338
    - Free acid: 1.6 points at pH 3.6
    - Total acid: 22.0-23.0 points at pH 8.5
    - Zn^{2+}: 1.1 g / l
    - Free fluoride: 120-145 mg/l
    - Accelerator: 1.8-2.0 gas points
    - Electro coat pressure: 0.7 bar
    - Temperature: 51° C.
    - Duration: 3 min
- 5) Rinsing with deionized water
    - Temperature: RT
    - Duration: 30-60 s
- 6) Drying with compressed air

- 7) Coating with cathode dip coat, Cath Guard® 500 (BASF AG) and staving of the coating material at 175° C. for 25 min in an oven.

Method B:

The phosphating zone during vehicle body manufacture was simulated by syringing a few drops of phosphating solution after activation onto pyrophosphate galvanized sheet steel (ZE, pyrophosphate) and phosphating by Electro coating after an exposure time of approx. 20 s. "Mapping" occurred in the form of "curtaining" due to initial wetting with the phosphating solution in the case of a conventional activating pretreatment with Fixodent® at a pH value of 8.5. It is apparent Method A & B that activation with an acidic aqueous dispersion containing insoluble and soluble phosphate in the method (A) according to the invention is capable of suppressing "mapping" effects.

Table 5: Sheet metal Layer weight during zinc phosphating [3]

Zinc – phosphating			
Occurrence of "mapping" on heat-treated pyrophosphate ZE sheet metal as a function of the activating pretreatment method			
		Layer weight*	
Sheet metal	Method	in g/m²	Mapping[#]
Steel (CRS)	A	1.4	—
	B	1.7	—
	A	1.5-1.7	no curtaining/marks
THAT,	B	1.5-1.7	curtaining/marks clearly
pyrophosphate			evident

It is additionally clear that the film thickness of the dip coat (Cath Guard®) is thinner at those points at which "mapping" occurs than in the other areas. On cross-sections, which were prepared by microtome, it was possible determine on pyrophosphate ZE sheet metal, which was treated according to method (B) and on which marks in the form of curtaining were consequently present, that the average film thickness after 5-fold measurement was 20.6 μm, while that away from the marks was 24.7 μm [4].

It is additionally clear that the film thickness of the dip coat (Cath Guard®) is thinner at those points at which "mapping" occurs than in the other areas. On cross-sections, which were prepared by microtome, it was possible determine on pyrophosphate ZE sheet metal, which was treated according to method (B) and on which marks in the form of curtaining were consequently present, that the average film thickness after 5-fold measurement was 20.6 μm, while that away from the marks was 24.7 μm. Layer thicknesses were determined by measuring the microtome cross-sections by scanning electron microscopy. [4]. According to the method A zinc-phosphate process is calculated in these papers.

2.2.6 Physical Method-Related:

Many specific types of physical defects have been categorized and studied by the paint and coatings industry and by coatings and corrosion engineers. Many of these physical defect-related types overlap with the formulation-related and substrate-related during the coating process types discussed above. However, these physical defect types and their nomenclature as discussed here are traditionally considered by the paint and coatings industry, and they merit a separate category. Several specific types of physical defect-related failures are presented in [4], as well as appearances, causes, and problem prevention. They include blisters; bubbles and craters; color mismatch; dirt; fisheyes; gloss variations; mottle; orange peel; runs, sags, and curtains; paint adhesion loss; soft paint films; solvent popping, boiling, and pinholes; and solvent wash. From Table (6) the installed capacity of the plant electro coating shows that in each steps materials chemicals and types of methods are used during the process.

Table 6: Physical Technological method -Related

Sr. No.	Stage	Temp. Process time	Circulation Rate	Chemical	Temp	Dosing system	Material	Cascading
1.	Electro deposition coating tank(ED)	3 mins.	6~8 circulation turn overs/hr. by volume	ED bath Paint	28 ~32 °C	diaphragm pump for paint feeding	Mild steel tank with FRP lining, PVC piping in the tank, SS304 piping outside the tank. Educator nozzles inside the tank for circulation	Overflow of UF rinse I tank to ED tank by gravity or by pump other than Electro coat pump
2.	Ultra-filter (UF)Rinse I	0.5 min.	0.5 ~1.5 Kg/cm² Electro coat pressure	Re circulated UF permeate	< 30°C	(Provision for deionized water Water addition)	MS tank with FRP lining, SS 304 piping & Electro coat nozzles.	Overflow of UF rinse II tank to UF rinse I tank

3.	UF Rinse II Dip	0.5 min.	3~4 circulation turn overs/hr. by volume	Re circulated UF permeate	< 30°C	(Provision for Demineralized water addition)	MS tank with FRP lining, SS 304 piping, Educator nozzles inside the tank for circulation	Overflow of UF rinse III tank to UF rinse II by gravity or by pump other than Electro coat pump
4.	UF Rinse III Electro coat	0.5 min.	0.5 ~1.5 Kg/cm² Electro coat pressure	Re circulated UF permeate	< 30°C	(Provision for Demineralized water addition)	MS tank with lining, SS 304 piping & Electro coat nozzles.	Exit mist Electro coat with fresh permeate. 10 lpm
5.	dip rinse	0.5 min.	3~4 circulation turn overs/hr. by volume	Re circulated DM Water	Ambient	(Provision for DI Water addition)	MS tank with lining, SS 304 piping, Educator nozzles inside the tank for circulation	Exit Electro coat with fresh DI Water. 2 Lit/M²

6.	Fresh DM Electro coat	Pass time	0.5 ~1.5 Kg/cm² Electro coat pressure	Fresh Demineralized water (DM)	Ambient	--	MS tank with FRP lining, SS 304 risers	Cascade in coating bath
7.	Flash off	5~10min	---	---	Room Temp.	---	---	3 min flash off
8.	Baking	(30~40Min)	---	---	160°C/10 min. or 150°C/20 min	---	---	---

2.2.7 VOC waste gas:

The official definition of a VOC states that it is any organic compound that participates in an atmospheric photochemical reaction. VOC content for coatings is determined by EPA Reference [13], which in turn uses four ASTM methods: 1. ASTM D 1475 to determine the coating's Density, 2. ASTM D 2369 to determine the weight percent of volatiles ,3.ASTM D 3792 to determine the water content (if applicable) using a gas chromatograph (GC) ASTM D 4017 to determine the water content (if applicable) by following the Karl Fischer (KF) analysis One of the most important tests is ASTM D 2369, in which all of the volatiles (solvents and water) are driven off by heating a coating sample to 230°F for 1 hour [7]. The volatile content is determined by weighing the sample before and after heating. Note that in this test, one cannot differentiate for between the water and solvent, since both will evaporate at 230°F. To make the necessary differentiation, the water content is determined by following either ASTM D 3792 or ASTM D 4017. In most cases, it is too inaccurate to analyze directly for the VOC content, because the concentrations are low and several organic compounds might be in the VOC mixture. Since Reference Method 24 requires that the water content be determined, VOC content is calculated by subtracting

water from the total volatiles:

$$VOC \ (g/L) = TV \ (g/L) - WC \ (g/L)$$

where TV is total volatiles and WC is water content. [8]

The test methods for measuring water content provide accuracies of approximately +3.0%. While this seems reasonable for most solvent-borne coatings with small amounts of water, and has been adequate, it is unacceptably high when the ratio between water and VOC in the coating is very large [8]. This is a problem with new generation waterbombs, such as the new electrocoating's, for which the VOCs are minimal (often near zero) [7]. The VOCs being Oxidized to carbon dioxide and water. The operating costs of thermal systems such as incinerators are high, especially with the low concentrations of VOCs typical of emissions. Particulate removal prior to incineration of the VOC-containing waste stream may also be necessary. Running costs can be reduced by using heat recovery or catalysts to reduce energy consumption.

Capture techniques on being able to remove solvent vapors from the exhaust air stream and return them to the liquid state

- by direct cooling of the airstream to condense the vapors.
- by using an agent such as activated charcoal to adsorb the VOCs [8].
- Bio filter with organism which are mostly used in these method for consuming the VOC.

The capture and recovery of the mixed, relatively low value solvents commonly found in paint shops are not currently cost-effective, but may offer potential benefits in comparison to the other VOC abatement options [8].

2.2.8 Waste Recovery:

Traditional rinsing methods include independent rinse tanks, with rinse water flowing in and out of each tank, and countercurrent rinsing, with relatively clean rinse water flowing from the second rinse tank to the more contaminated primary rinse tank. The figure (8) shows a typical rinse system with four independent rinse tanks; and the bottom diagram depicts a reduced flow rinse scheme [9].

Waste disposal regulations require to ensure that all wastes are correctly disposed of from coating tanks. This means that all wastes containing solvents, spent cleaning fluids, waste paints and thinners and dirty wash, must be sent to registered waste disposal, that can either recover the

solvent or dispose of it in a proper manner. A few small solvent recoveries availed to clean the waste about 70%. The solvent waste is put in the machine's waste tank and the machine switched on. These distillation machines are automatic; they can be set running and left to get on with the job. They typically take 12 or 25 liters of waste solvent at a time and need about eight hours to treat one batch of waste. Larger units can be made to order [8].

The recovered solvent is not high quality, but can often be used as gun wash or as a low-grade cleaning solvent. A small amount of residue is left in the waste tank. This is often solid and can be disposed of with other non-hazardous solid waste. If the residue is liquid, it may have to be stored and sent for specialist disposal - however, the volume will be much smaller than before. Consumption 0f waste water overall in process about 80 – 90% Shown in figure (7).
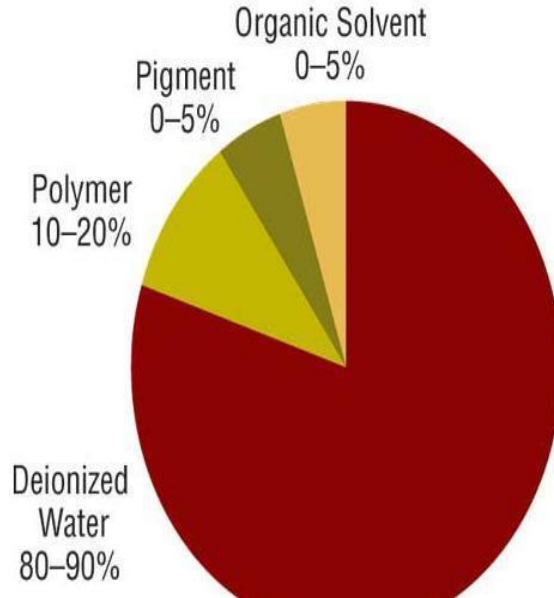

Figure 7: Consumption of Waste [8]

Acidic or alkaline chemicals are used as cleaning agents. The subsequent rinsing are the primary sources of wastewater from metal finishing facilities. In recent discussions with industry. The environmental protection agency learned that cleaning and rinsing operations may be conducted over other rinse tanks or plating baths to collect and reuse the wastewater. Facilities have also implemented countercurrent rinse cycles to reduce the replacement frequency of the rinse water used in rinsing operations [9].

The growing use of "integrated profitable pollution prevention" techniques by metal finishers to reduce water use and chemical consumption [9]. That study identified by a method of cleaning and rinse process control method that uses a two-layered hierarchical dynamic optimization technology to conserve chemical and water use. The lower layer adjusts local control variables, such as chemical concentration and water flow rate, to optimal settings. The upper layer uses the optimal processing time in all the cleaning and rinse tanks to achieve the desired surface characteristics. The two layers, when used together, maximize cleaning and rinsing efficiency, thereby minimizing chemical use and conserving water.

Re-designing water flow patterns through a rinsing system to optimize flow rates. The water flow patterns can be switched during operation (based on current use) to maximize water reuse while maintaining rinse water quality. A sludge reduction method to classify sludge as avoidable or unavoidable. The method determines the amount of avoidable sludge and reduces it by altering the chemical use and identifying unnecessarily long cleaning times. A model-based design and operation strategy to derive an optimal reversed drag out network system to recover chemical losses from cleaning and plating systems. A dynamic hoist scheduling algorithm to generate a production schedule based on waste generation, chemical consumption, and energy use.

To demonstrate the effectiveness of Wastewater, technologies, the researchers also described a manually operated bronze cyanide plating line at a facility that implemented a near-zero chemical and metal discharge system, intended to reduce chemical consumption and water use [9]. Figure (8) presents the original configuration of the bronze cyanide plating line. Each rack of parts is first cleaned (soak cleaning and electro cleaning or de-rusting) and then rinsed. As shown in the diagram, the initial cleaning and rinsing are followed by an acid clean step, followed by another rinse before the actual copper and tin plating [9].
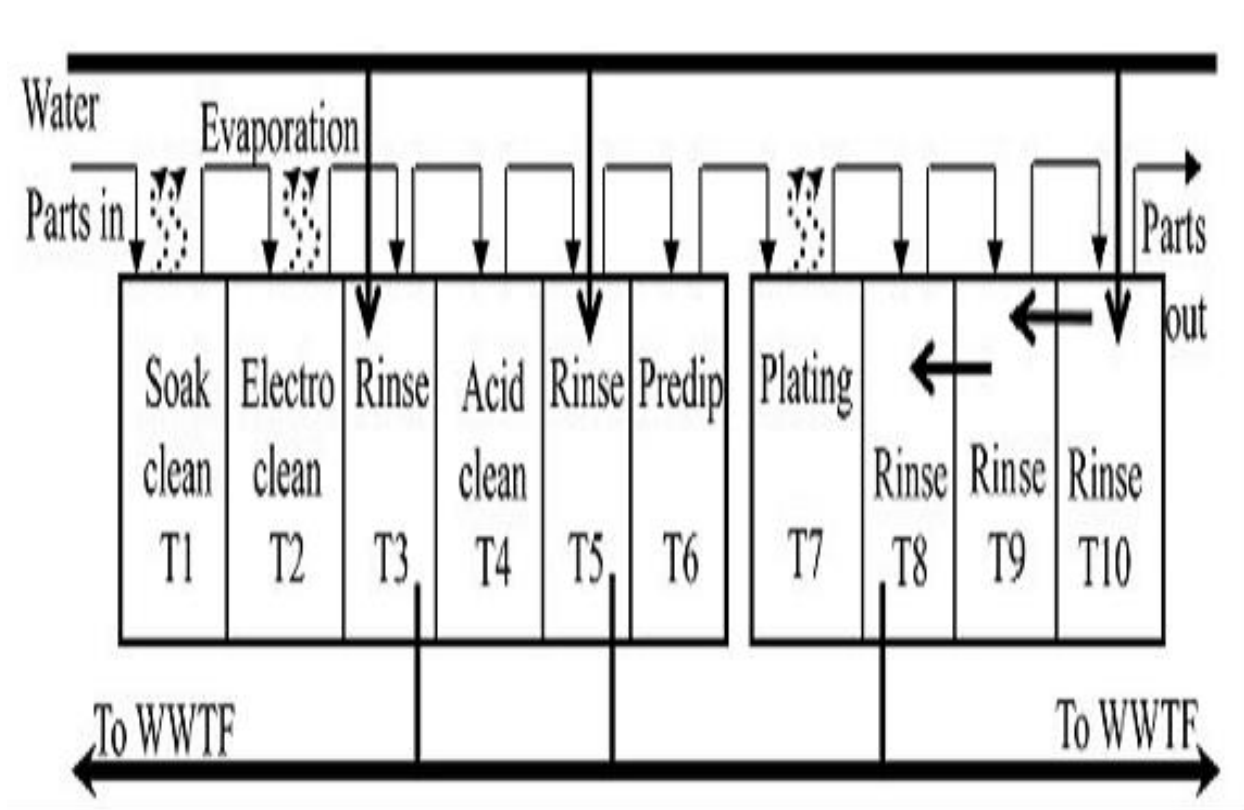
Figure 8: Original Process of Waste Water Treatment – coating [9]

Figure (9) presents a revised rinsing configuration. The facility installed a new rinse tank 11 so chemical solvent from the soak clean and electro clean steps, accumulated in Rinse Tank 3, could be recovered and reused. The tank before New Rinse Tank 11 is charged for static rinse, and New Rinse Tank 11 is for flow rinse. Rinse Tank 8 is also charged for static rinse, while Rinse Tanks 9 and 10 are countercurrent rinse tanks. Two pumps are added to the system, one to pump the solution from Rinse Tank 3 to the electro cleaning tank, and one to pump water back to the plating tank from Rinse Tank 8.
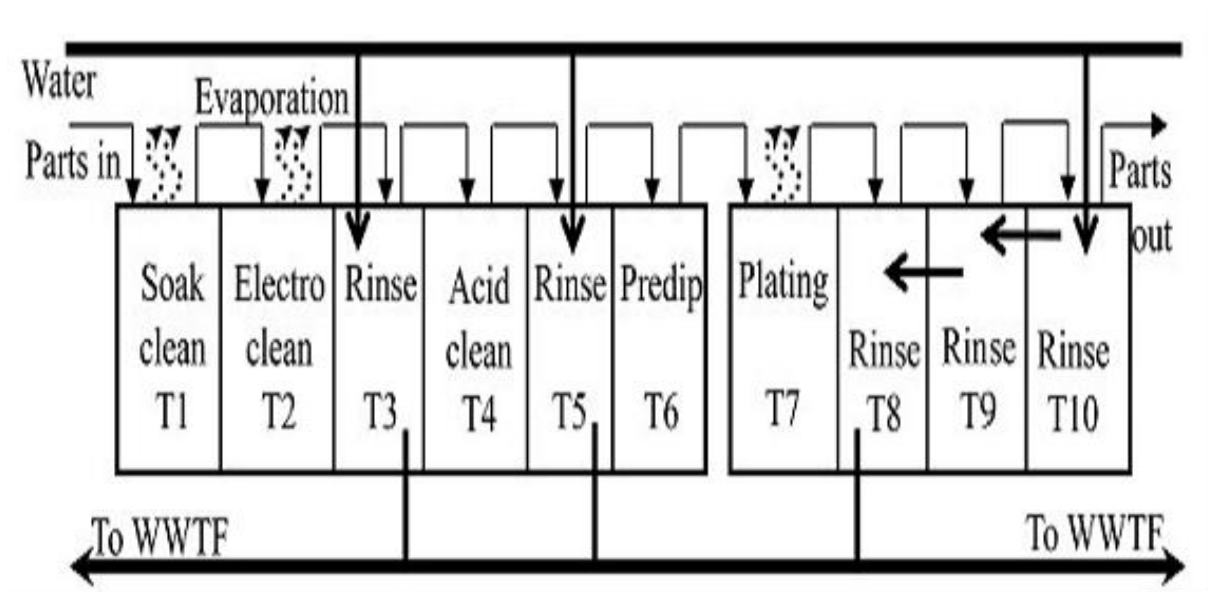
Figure 9: New Process Waste water treatment - Plating Facility [9]

After making these changes figure (9), facility reduced use of the dedusting chemicals (used in the electro clean and acid clean steps) by 40 percent, the soak cleaners by 100 percent, and the acid by 8 percent. Rinse water costs were reduced by 40 percent and wastewater treatment costs were reduced by 70 percent. According to the study authors, implementation of profitable pollution prevention techniques typically involves slight modifications of processes, which require little capital investment but can increase efficiency and reduce waste [9]. The Table (7) shows that overall consumable cost for chemical, energy and waste in electro coating industry.

*Table 7: Overall Consumable cost for chemical, Energy and wastage Approximately [5]*

Consumables cost at 100%	Qty (including wastage)	Cost/kg (€)	Value (€)
Rinsing chemicals	11850.kg	4.2	2200
Coating chemicals	9230.4 kg	6.7	3700
Phosphating chemicals	4569.8 kg	3.6	3500
Waste	1700 (l/h)	1.3	1000
Energy	1500 MWh/y		2000
Total			12400 (€)

2.2.9 Overall Technology - Electro Coating System:

In addition, e-coat eliminated head fill, clogged threads and minimized clumping during the curing process. As a result, dip spin coating was quickly relegated to small batch colors while e-coat became the coating of choice for high volume products. This usually meant one, two or – at the very most – three colors applied by the same system. A noted fastener manufacturer sought ideas on an electrocoating system able to provide high output in any one of five colors, with a future option for a sixth color. Besides color, the product also varied by fastener type, length, diameter and thread configuration (Figure 6). The manufacturer had limited floor space available; packaging equipment and warehousing space already claimed a large portion of the facility. Fastener "nesting" should be minimized and cross contamination of different products with one another non-existent. Due to the limited facility area available for the system, special consideration was given not only to the size of the system itself, but also to auxiliary equipment. To maintain consistent throughput during color changes, each paint color would require its own rectifier, ultrafilter skid and storage tank. Room was also required for pretreatment storage tanks and a wastewater treatment system.

Based on the available footprint, a full immersion, five color monorail system would have been impractical. Belt processing lines would also have been too long, and required several systems for multiple color processing [12]. Due to flexibility requirements for running various colors and fastener types, a square transfer system was chosen with dual processing lanes – each capable of applying three colors. The square transfer concept greatly reduces floor space requirements because loads enter and exit the process tanks vertically. The use of baskets maximizes throughput and makes bulk electrocoating feasible by increasing load size. Because tanks are smaller, a square transfer system allows immersion pretreatment for more thorough cleaning and phosphating in a limited footprint. Tank charge costs are lower, as less paint and chemicals are needed to fill tanks at startup. The cure oven and cooldown zone are located above the process tanks, further minimizing system footprint. The square transfer layout also allowed the two adjacent processing lanes to share common pretreatment tanks, oven and cooling tunnel. The design saves on capital expenses and costs of maintaining two pretreatment systems, two ovens and two cooling tunnels. Shown in Figure (10).
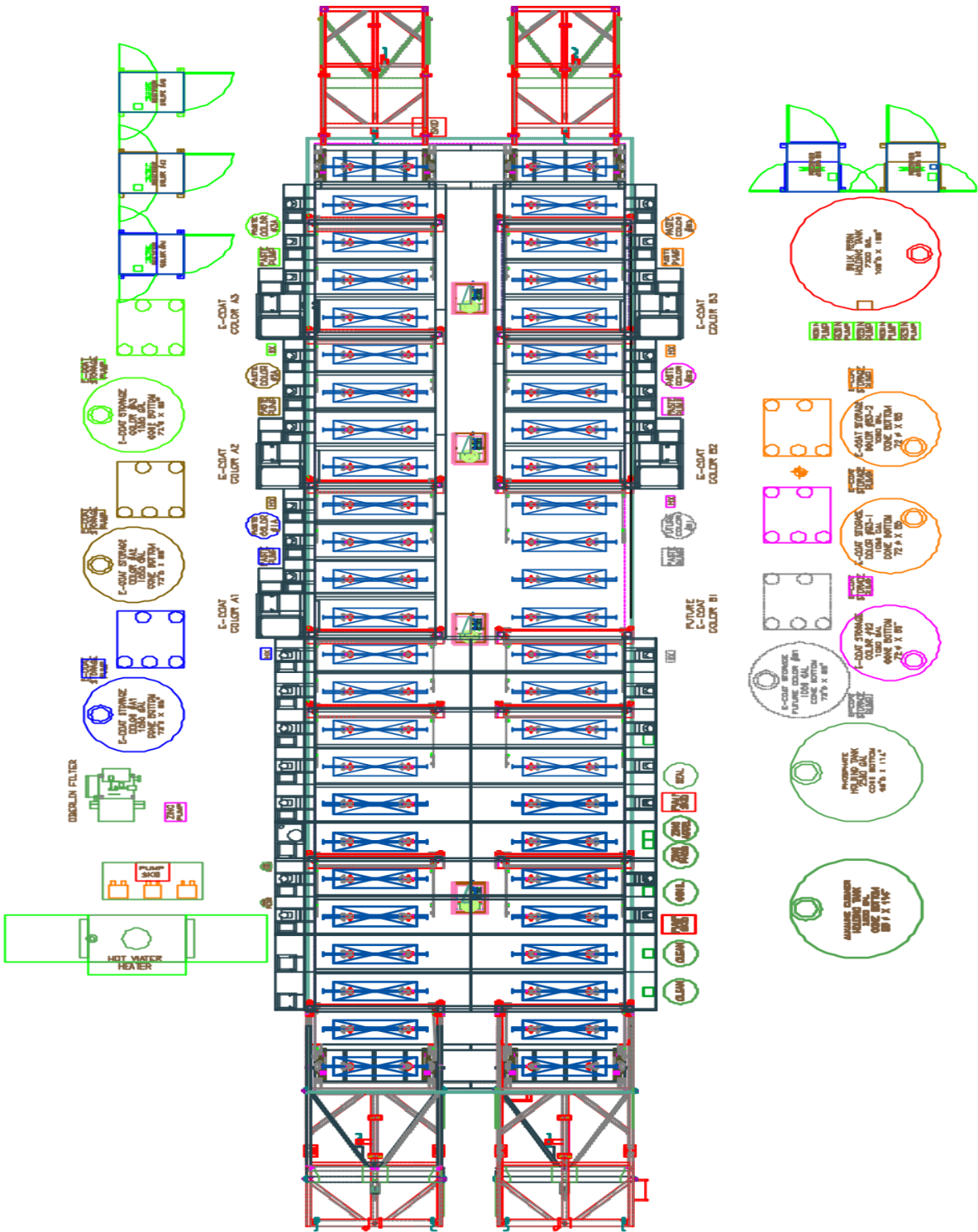
Figure 10: Technological construction - Electro coating

(APPENDIX A- A3 format at end of the report)

And the figure (11) shows the working process of coating technology. The layout of the system is such that three colors can be sequenced in each processing line. Each electrocoating bath has three dedicated post-rinses behind it. Colors are aligned from lightest to darkest to minimize potential contamination from drag out. Anodes in the e-coat tanks are arrayed horizontally. instead of the normal vertical orientation for even throw power across the entire width of the tank.
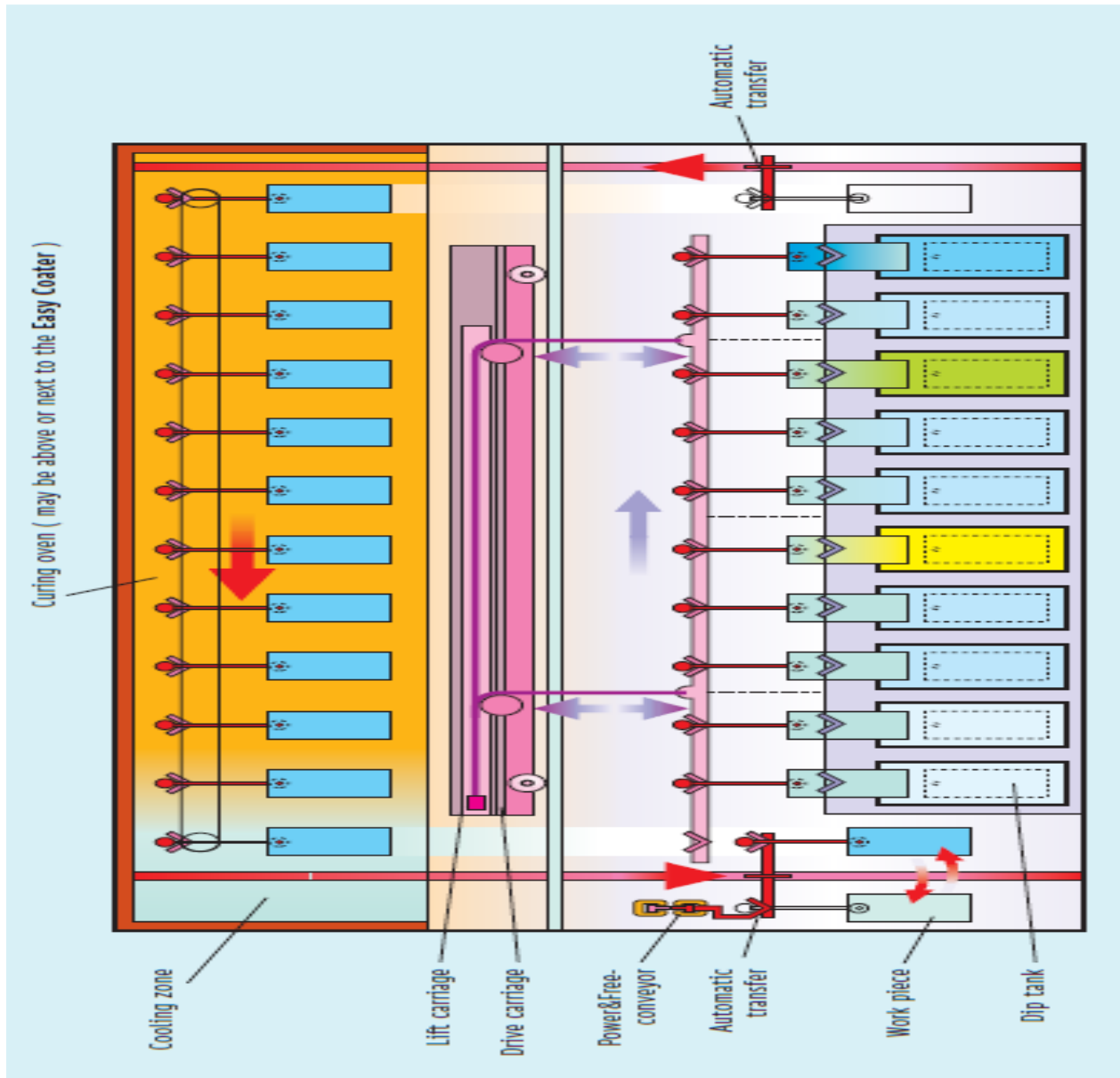

Figure 11: Working process – 2D view

The transfer concept allows for maximum throughput of different fasteners in different color tanks with the use of holdups. The line operator enters the process parameters for each load into the Programmable Logic Controller (PLC) [2]. Baskets are then dipped into the correct color e-coat tank and subsequent post-rinses, and held up over the other e-coat and post rinse tanks. Unlike a programmed hoist, each processing cycle will deliver a completed load to the unload station – or in this case, one load from each processing lane. It is possible for other methods to be employed for multiple color application on square transfer systems. For instance, the e-coat tank and subsequent rinses may be transferred sideways out of the process line and a new color tank and post rinses slid into place. The drawback of this method is that painting can only be done in one color at a time on a batch basis. The same paint and post rinse tanks could be used for different colors by pumping their contents into holding tanks, rinsing the process tanks and then refilling with another color paint and solution from other holding tanks. Obviously, this would-be time and labor consuming, greatly reduce throughput and still only offer single color processing at any one time. Both alternate methods limit flexibility.

3. TASK:

Optimization of the sequential line for coatings. To focus on the coating lines and solutions for minimizing the consumption of chemicals, waste and energy. The result shall be a solution for the production capacity increase.

Scope of project:

Most of research shows the method to reduce the chemical and energy waste and to increase the production during E–coating process. The aim of this research is about detail description of design, Chemical, Energy and waste to reduce.

- To review working principle of coating with technological work, chemical and energy.
- To make critical literature research about utilization of chemical during the process.
- Based on literature research, Technology, chemical and paint cost is calculated. In the same way to create the waste water reduction and waste gas reduction.
- AUTOCAD Design: Line diagram of industrial layout, Electro coating industry layout, Line for Surface Treatment, Technological scheme P&ID 1&2.
- Create an excel file for Paint process, Technology, chemical, energy and waste water and waste gas.
- To show that how much of chemical and waste of amount is reduced.
- The result shall be a solution for the production capacity increase.

4. PRATICAL PART:

4.1 Building construction - Electro coating:

4.1.1 Line diagram of industry layout - Electro coating:

According to the literature search [10], electro coating industry plant is designed by using **AUTOCAD 2013** software. In figure (12) shows that line diagram-electro coating industry. The overall building dimension is consisting of 53.29m * 60m. According to dimensions, the electro coating building is constructed and electro coating plant is placed and shown in figure (12).
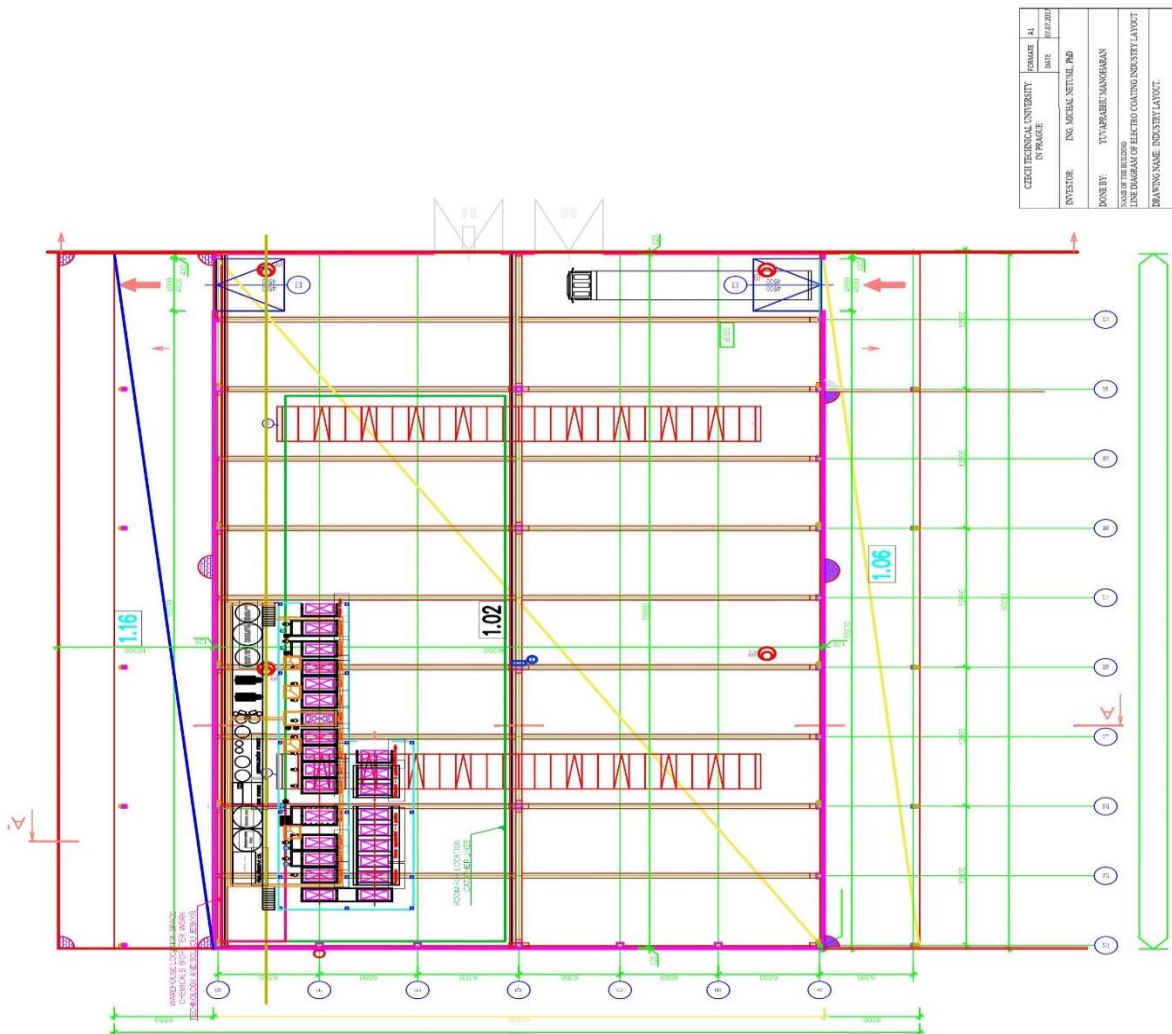

Figure 12: Line Diagram of Industrial Layout- AUTOCAD Design

(APPENDIX -B - A3 format at end of the report)
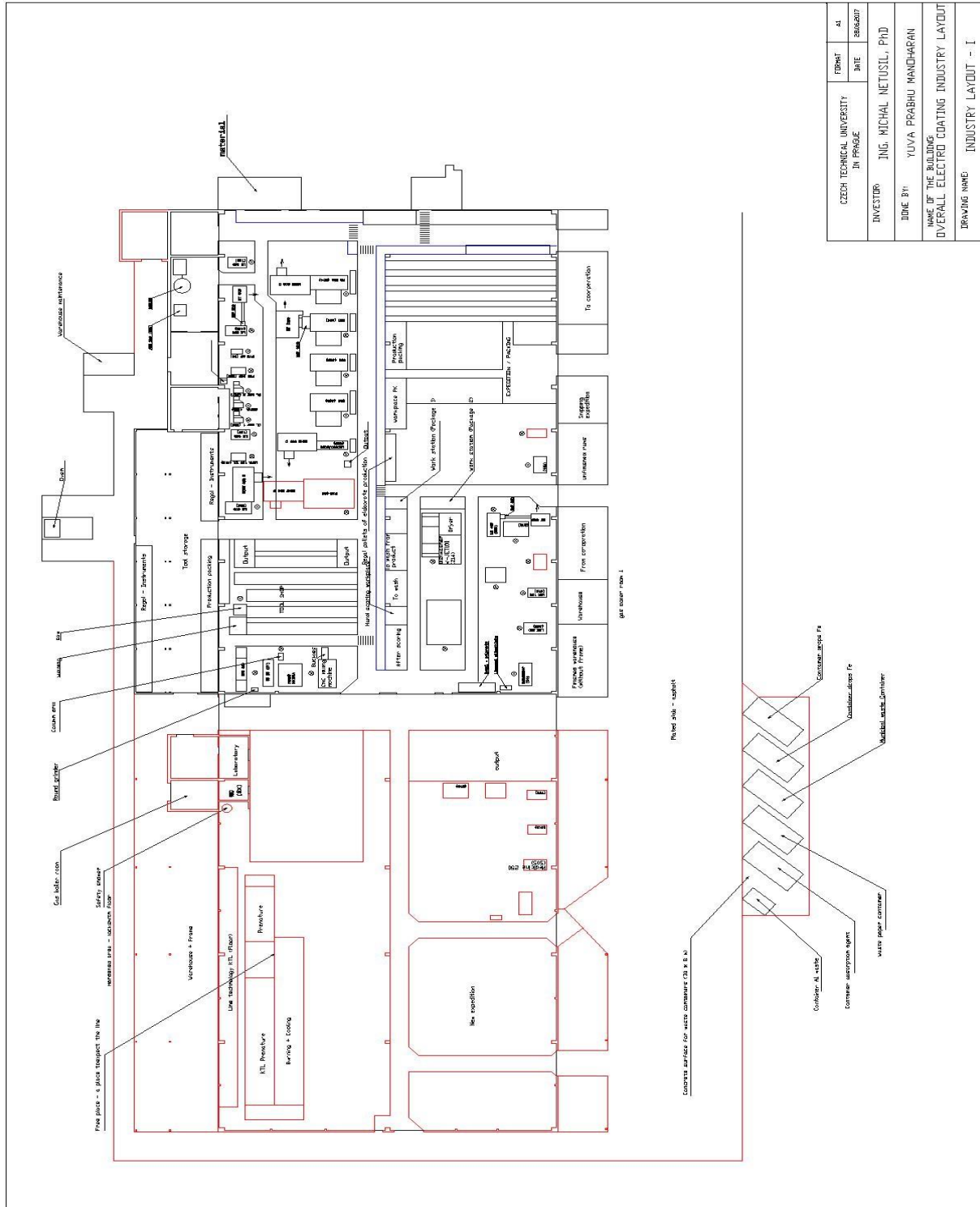
4.1.2 Electro Coating Industry Layout:

Figure 13: Electro Coating Industry Layout- AUTOCAD Design

(APPENDIX -C- A3 format at end of the report)

According to the literature search [10] and from line diagram figure (12). The figure (13) has been designed, it shows that overall electro coating industry layout. The electro coating treatment is placed is corner of the design and its look like U-shape, is mainly to reduce the space in the working environment. On the one side, from the stage 01 – stage 15 tank will have ware house, chemical storage tanks, ultrafiltration tank, accessory and waste water treatment to remove the waste easily during the process. On the other side stage 16 - stage 17 Oven and cooling zone is placed to get the final finished product. Stage 16 and 17 is also reason for U-shape because the cooling zone should not act with previous stages. The most important part of coating industry is coating line technology, ware house frame, tool storage, water storage, ware house maintenance, packing station, work station, shipping process etc., detailed shown in figure (13).

4.1.3 Line diagram for surface treatment - Electro coating:

According the figure (10) and literature search [10] electro coating is designed. In these design, the most important item of 5 legend are used, for removing the waste in tank during process

Legenda:

    01- degreasing waste sump
    02- waste water sludge
    03- phosphate bath
    04- waste disposal activates
    05- waste node

The Legenda 01- degreasing waste sump collector has been kept between the Stage 2 and Stage 3 for removing the waste during the rising process shown in figure (14). The Legenda 02 - waste water sludge collector is kept between the (Stage 4 and Stage 5), for removing the waste in Stage 4 rinsing process. In these stage 6, legenda 03 - is used to remove the waste in phosphate bath shown in figure (14). The 04-waste disposal activate tank is kept between Stage 7 and Stage 8. The next stage is waste disposal activate (Stage 7 and Stage 8). The legenda – 05 is called waste node which is kept in the stage 11 and 12 for removing the coating waste from the coating bath and rinse stage 12. The next stage is ultra-purification (Stage 12 and Stage 13). The next Stage 14 is demi rinse Tank. All the dimension is detailly shown in figure (14).
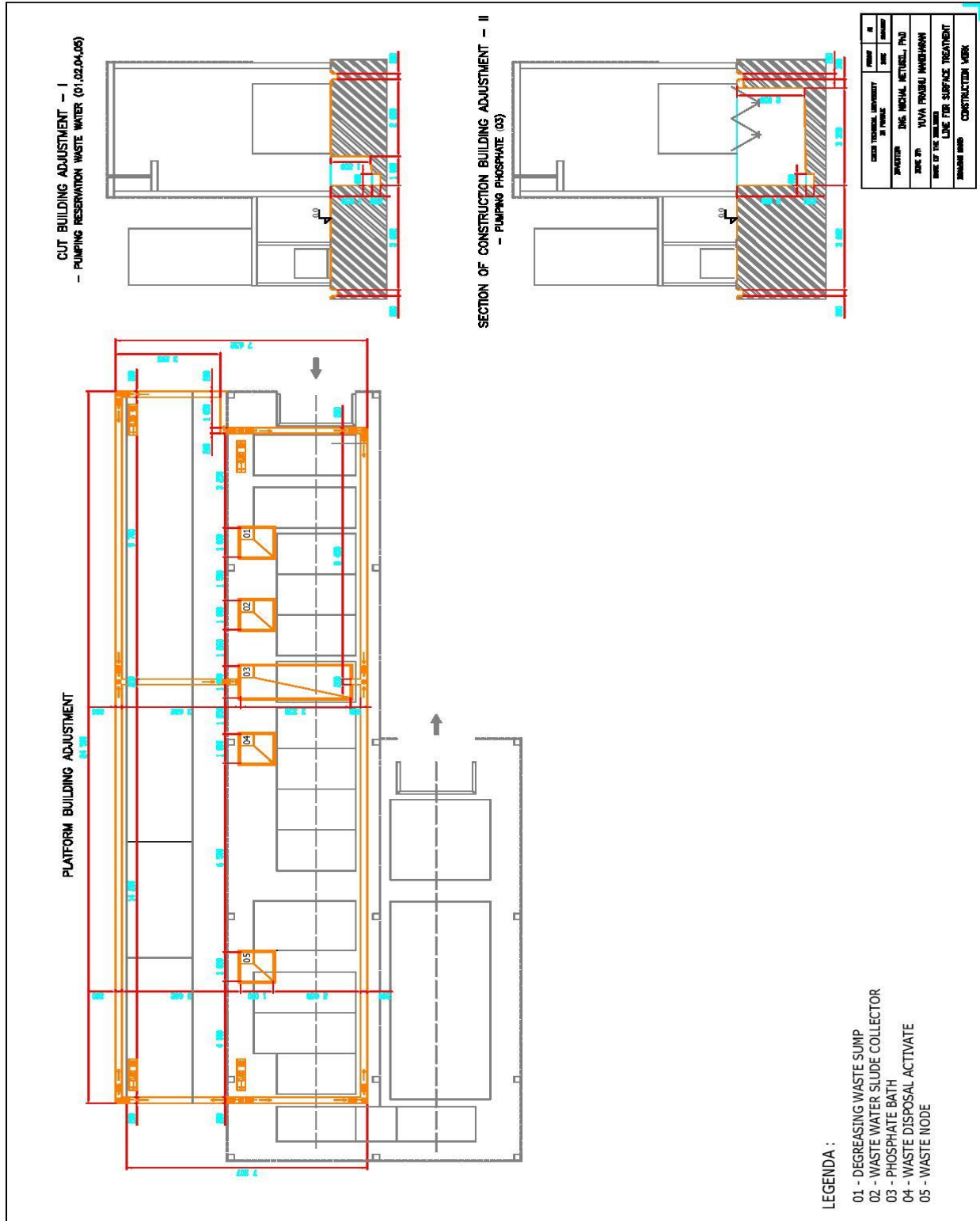
Figure 14: Line for surface treatment- AUTOCAD Design

(APPENDIX -D- A3 format at end of the report)

4.2 Technological scheme:

According to the literature search [17], the technology scheme is designed and calculated. There are 17 stages during the process to increase the production capacity.

4.2.1 Stage 1: Entrance workplace.

The work piece of the welded material is passed over through the conveyor for the next stage of coating submersible degreasing process.

4.2.2 Stage 2 & 3: Submersible degreasing.

From the previous stage, the work piece from the conveyor is dipped in the degreasing solution, is dipped in the solution Alkaline 300 - 400 sec (5 minutes) [10] to remove the dust particle from the work piece. And the bath is about 5.2 m³, temperature is around 60 – 70 °C. In these stage power consumption is around 150kW. In these stage chemical is used is tank is in stage 2- (Alkaline cleaner) [6] it contains about 250 kg of solution and stage 3- (Alkaline cleaner) 25 kg of solution Shown in table (12).

4.2.3 Stage 4 to 7: Rinsing process and activating:

From the previous stage, work piece dipped in the Rinsing process, is dipped in the solution Drinking water for 180 - 240 sec (3 -4 minutes) [10] for removing the dust from the material. And the bath is about 4.75 m³, temperature is around 60 – 70 °C. In these stage power consumption is around 150kW. And the chemical used are explained in the table (12).

4.2.4 Stage 8: Zinc phosphating:

From the previous stage, work piece is dipped in the zinc phosphate solution for 204 - 300 sec (5 minutes) [10] table [8]. And the bath is about 6.5 m³, temperature is around 50 - 60 °C. In these stage power consumption is around 150kW. In these stage chemicals used is BONDERITE M-ZN 4551 is about 250 kg of solution shown in table [12]. BONDERITE M-ZN 4551 [6] these chemicals are mostly used for zinc phosphating bath – formulated for dipping application for steel, Electro galvanized steel, zinc steel, zinc alloy coated steel and aluminum.

4.2.5 Stage 9 to 11: Rinsing process:

From the previous stage, work piece is dipped in the Rinsing process for 180 - 240 sec (3 -4 minutes) table (8). And the bath is about 4.75 m³, temperature is around 60 – 70 °C table (8). In these stage power consumption is around 150kW. In these step chemicals are used is BONDERITE M-AD 130 [6] solution is about 25 kg because it has chemical conversion for coating agent which is added to tank.

4.2.6 Stage 12: Electro coating:

From the previous stage, material is dipped in the electro coating bath about 180 – 420 sec (3 – 7 minutes) table (8) is dipped in the solution color painting. And the bath is about 6.75 m³, temperature is around 32 - 35 °C. In these stage power consumption is around 2*20 kW. In these stage pigment paste CP 471A [6] is used about 250 kg of solution is used in these tank for coating purposed. CP 471A mostly used for coating of workpiece during the process.

4.2.7 Stage 13 to 15: Ultra purification Rinse.

From the previous stage, material is dipped in the Rinsing tank for 60 – 180 secs (1 - 3 minutes) [10] is dipped in the solution Permeate. And the bath is about 5.2 m^3, temperature is around 60 – 70 °C. In these stage power consumption is around 150kW. In these stage Butyl glycol CA 101E [21] is used about 90 kg of solution during process. At stage 15 Methoxy propanol CA141E is used it contain about 25 kg of solution in the tank. Methoxy propanol CA141E it has 1-methoxy-2-propanol is a colorless liquid. It can avoid rough ness in material and keep it very smooth. Used as a solvent and as an antifreeze agent.

4.2.8 Stage 16: Baking oven:

From the previous stage, workpiece is pass over through oven for heating, which has the temperature is around 150 - 200°C table (8).

4.2.9 Stage 17: cooling:

From the previous stage, from oven is passed to cool air which has circumference of air flow around 10000 m³/h. power is about 12 kW.
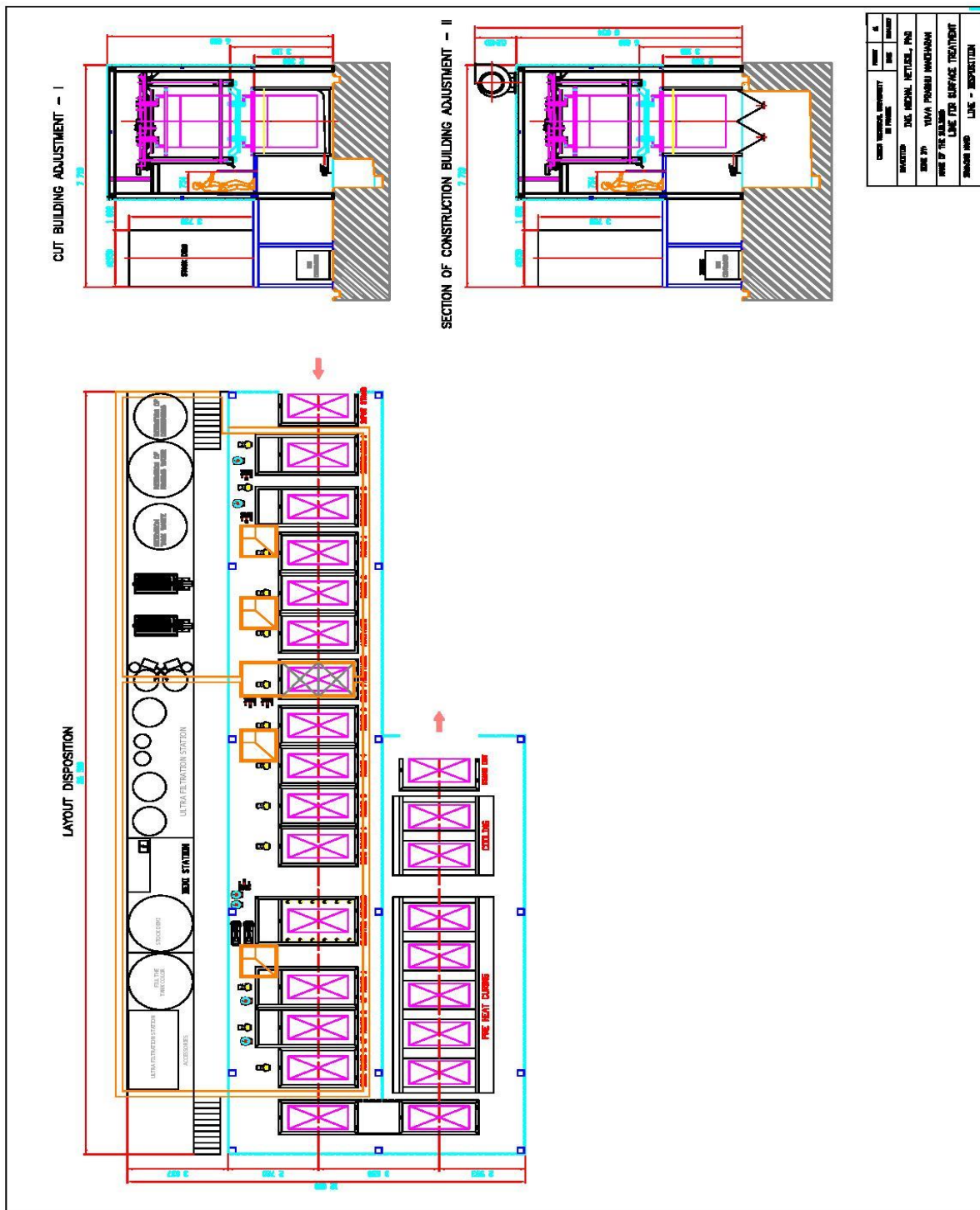
Figure 15: Technological scheme – line disposition - AUTOCAD Design

(Appendix -E- A3 format at end of the report)

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Table 8: Calculation for Technological scheme 1 & 2

Sn.o	Operation	Environment	Functional time of operation (s)	Bath(m³)	Temperature (°C)	Circulation rate (m³/h)	Medium	Power (kW)
						TECHNOLOGY		
1	Entrance workplaces							
2	submersible degreasing 1	Degreasing solution	300-420	5.2	60-70	25	Hot Utility water 85°C	150
3	submersible degreasing 2	Degreasing solution	300-420	5.2	50-60	25	Hot utility water 85°C	150
4	Rinse1	Drinking water	60-180	4.75	operating	15		
5	Rinse2	Activating solution	60-180	4.75	operating	15		
6	Activation	Activating solution	60-180	4.75	operating	15		
7	Zn-phosphate	Phosphate solution	240-300	6.5	50-60	25	Hot utility water 85°C	2x150
8	Rinse	Drinking water	60-180	4.75	operating	15		
9	Rinse	Drinking water	60-180	4.75	operating	15		
10	Rinse - Passive	Drinking water	60-180	4.75	operating	15		
11	Rinse the demi	demineralized water 60-180	60-180	4.75	operating	15		
12	lacquer	color	180-420	6.7	32-35	40	Cooling	2x20
13	UF Rinse	permeate	60-180	5.2	operating	18		
14	UF Rinse	permeate	60-180	5.2	operating	18		
15	Rinse the demi	permeate	60-180	4.75	operating	18		

16	polymeriza tion furnace	air			150-200			
17	cooling	air				10,000	Air	12
18	Accessible workplace							

4.3 Technological scheme for maximum production:

According to the literature search [17] and table (8). According to the size of work pieces 3 m x 1.5 and 2m x 1.8 m and less than 5m², average is of line, capacity of the load, Thickness of the material, Time, varnished area is chosen for increasing the production capacity and calculated shown in the table (9). To increase Maximum production is calculated by according number of working days in year. According to the size of materials is detailed explained in the table (9) to have maximum production capacity in an hour / year.

Table 9: Calculation - Technological scheme for maximum production

S.no	Maximum production			
1	Size of material	3m x 1.5 m	5 m x 1.8 m	units
2	Coating line	12	10	min
3	An average area in line	15	15	m²/s
4	Maximum disposal area coating	25	20	m²/s
5	capacity	75	60	m²/hour
6	capacity maximal	125	90	m²/hour
7	load capacity of conveyor max.	450	500	kg
8	Thickness of the color layer	15 - 35	15 - 35	microns
9	Working time fund	8000	8000	hour/year (240 days with 3 shift)

According to the table (9), and technological design figure (15) we calculate that number working days in industry is along with shift length of coating line is calculated to show the maximum area of coating of a piece in a day.

Table 10: Maximum piece production in a day/year

s.no	description	Value	Working norms
1	Number of working days	240	day / year
2	Number of shifts in Coating line	3	shift / day
3	Shift length	7.5	h/shift
4	Max area in coating	5,400	day/year

From the literature search [17], Maximum area of the coating is calculated shown in table (10).

= Number of working day (day/year) * coating line (shift/day) * Average shift length (h/shift)

= 240 * 3 * 7.5.

= 5400 day/year.

Figure 16: Technological scheme 1 P&ID -AUTOCAD Design
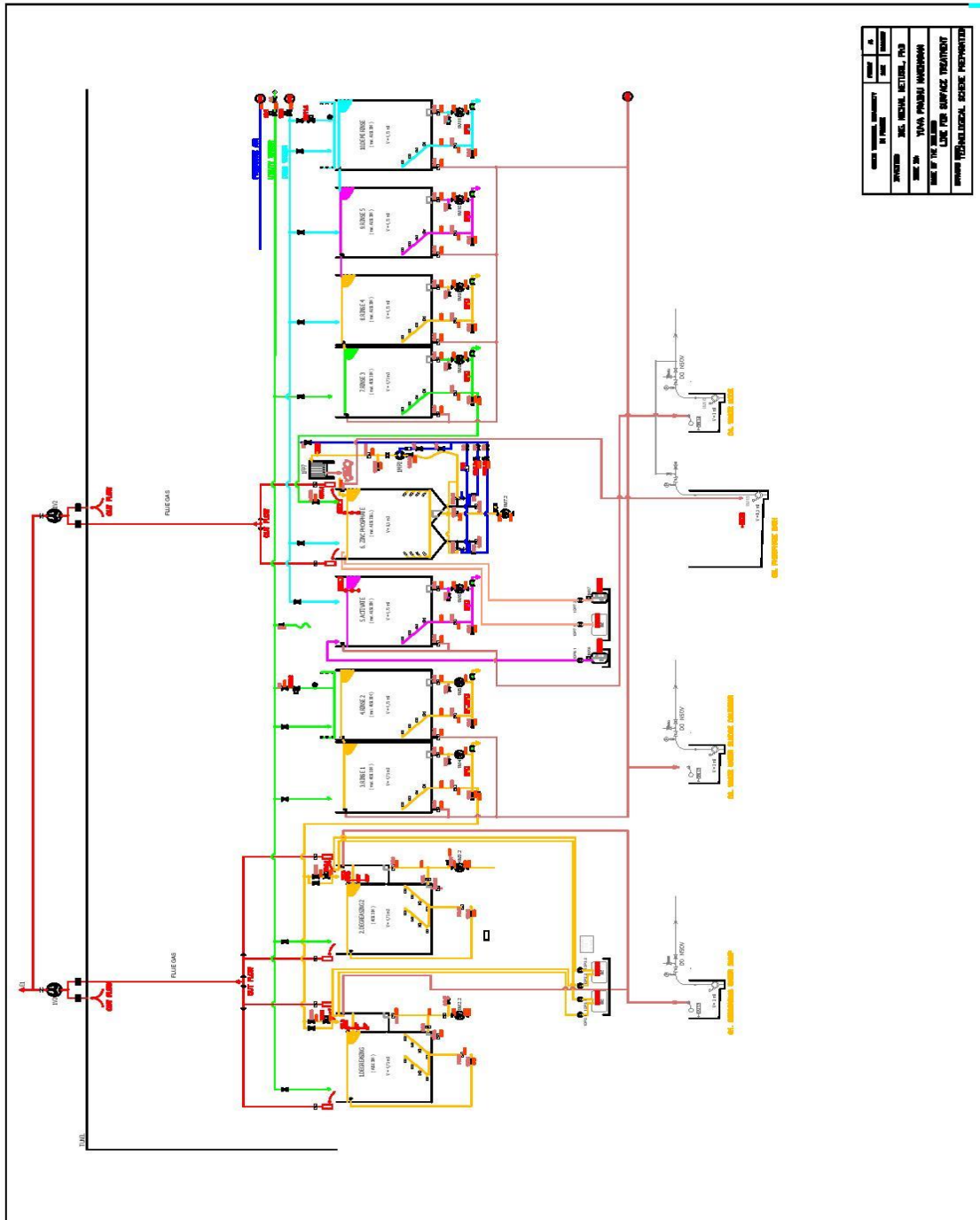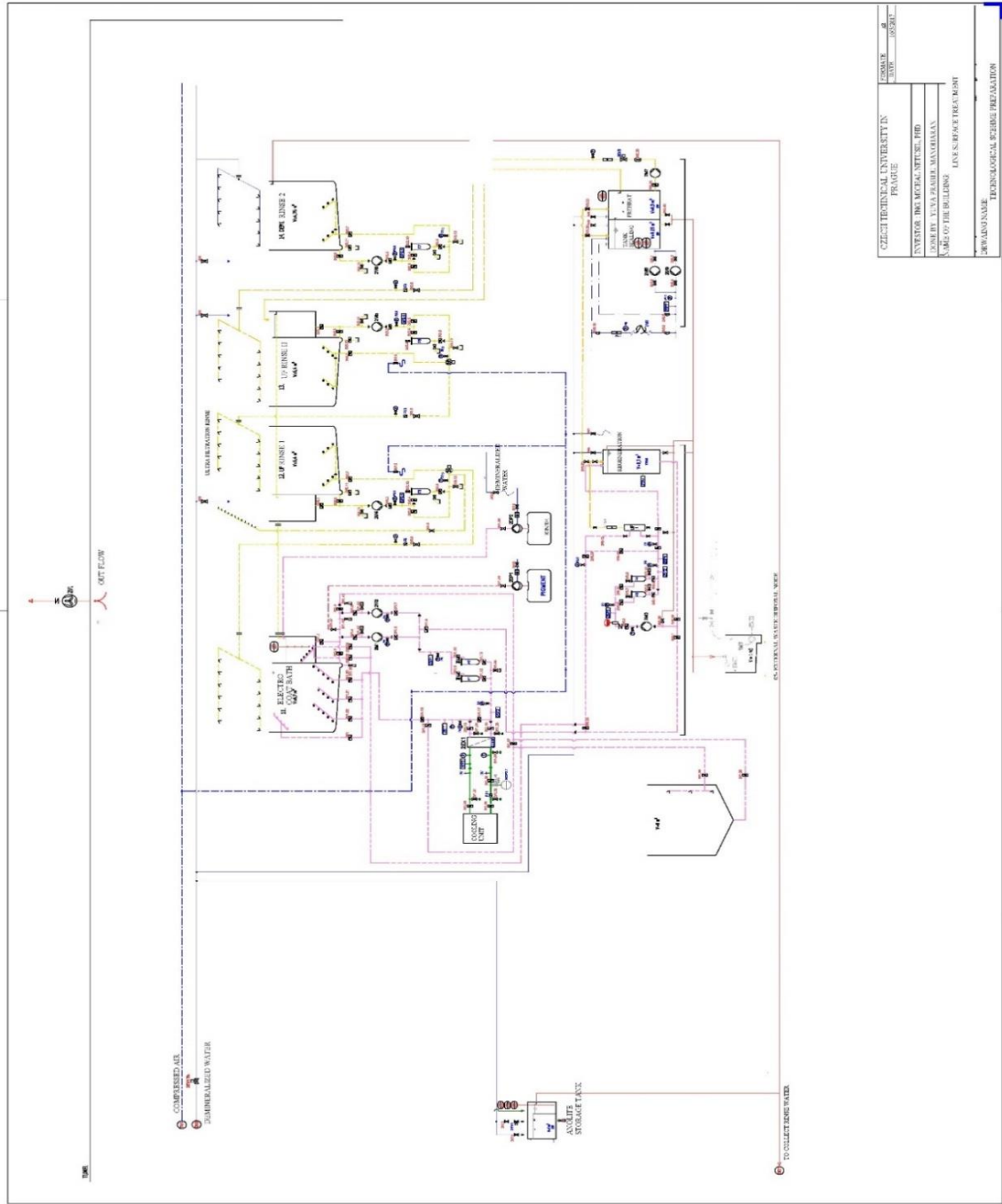
(Appendix -F- A3 format at end of the report)

Figure 17: Technological scheme 2 P&ID -AUTOCAD Design

(APPENDIX -G- A3 format at end of the report)

4.4 Paint price:

Paint process is calculated according to literature search [6]. Paint process is chosen according to each stage during coating process. Price of paint cost is calculated in euro (€). The Price Paint with VAT (value add tax) - Prediction 2017: 27.76 EUR / MWh net of VAT [25]. I have chosen the exact amount and price for paint and water, it is calculated detailed in table (11). Painting price is calculated according to the Czech national bank Currency conversion [23].

Table 11: Calculation of Process price

Paint Processing			
Parameter	**Value**	**Units**	**Note**
Length of the clock	10	Min	
Number of bars	14	Clocks	
Time Chem. + coat	140	min	
Part area	0.2	m³	
The number of parts per batch	60	Piece/batch	
Disposable area in the coat bath	13	m²	
Energy loss factor	0.98		Maximum energy loss [6]
Price incl. VAT	0.022	(€)/kWh	Prediction 2017: 27.76 EUR / MWh net of VAT [25]
LPG price with VAT	0.041	(€)/kWh	Offer 26.12.2016
Total batch consumes	104.1	kWh	
Energy from NG	55.0	kWh	
. Energy	2.28	(€)/batch	
Energy per unit	**0.043**	**(€)/pc**	
Price of water without VAT	1.558	(€)/m³	http://www.scvk.cz/aktuality/cena-vody-2016/ [25]

Total batch consumes	0.28	m³/batch	Cascade 3-4 L/ m2 / h (2 cascades + 0.5 rinses per coat)
Price for water	0.483	(€)/batch	
Water price per unit	**0.076**	**(€)/pc**	
Waste disposal cost	0.048	(€)/kg	free waste solutions
Every day without VAT	1.58	(€)/m³	http://www.scvk.cz/aktuality/cena-vody-2016 [25]
Volume of concentrated waste	0.028	m³/batch	Estimation of waste production 10% of water consumption
volume	0.25	m³/batch	
Waste disposal cost	1.78	(€)/batch	
The price for waste disposal per	**0.026**	**(€)/pc**	
Maintenance cost	0.175	(€)/batch	
Neutralization stations	0.0153	(€)/batch	
Membranes for UF production	0.175	(€)/batch	
Membranes for DM production	0.048	(€)/batch	module should last for 3/4 years
Maintenance cost per unit	**0.008**	**(€)/pc**	
Chemical pretreatment price	0.94	(€)/m²	Henkel Source 17.06.2016 [6]
total price	2.334	(€)/batch	Phosphate 0.08 - 0.18 €/m2. Influence of transmissions and shape composition. Part.
Price of chemist pre-treatment	**0.0396**	**(€)/pc**	Considered 0.2 €/m2. € = 27kč.

coat lacquering price	0.776	(€)/m²	
total price	9.35	(€)/batch	Colors 3.5-5x more expensive than before. Influence of component complexity and thickness. Lacquer
Coat lacquer price per piece	**0.094**	**(€)/pc**	
Cost of labor	180	(€)/shift	Hanging, hanging, line service, lab.
Number of operators	5	persons	4 agencies + technologist
Length of work 1 shifts	450	min	Lunch - 30min
Number of varnished batches	30	batch/shift	
The cost of the work	**0.1007**	**(€)/pc**	
Annual time fund	5400	h/year	
Factor of outages and approach	0.95		
Net working hours	5130	h/year	
Batch per year	20520	batch/year	
Depreciation	3.345	(€)/batch	Price / (years * fund) * length of shift / batch
Depreciation price per unit	**0.056**	**(€)/pc**	240 days with 3 shifts
Total	**0.443**	**(€)/pc**	

Painting process is calculated according to the formula [6]:

- Energy per unit = $\dfrac{\text{(Energy / number Parts in batch)}}{\text{Energy loss factor}}$

- Water price per unit = $\dfrac{\text{(Price for water /number Parts in batch)}}{\text{Energy loss factor}}$

- Price of waste water disposal = $\dfrac{\text{(Waste disposal cost /number Parts in batch)}}{\text{Energy loss factor}}$

- Maintenance cost per unit:

  = $\dfrac{\text{(Maintenance cost + Neutralizing station + Member for UF Production / no parts in batch)}}{\text{Energy loss factor}}$

- Price of chemist pre-treatment per part = $\dfrac{\text{(Total price of chemical / number Parts in batch)}}{\text{Energy loss factor}}$

- Coat lacquer price per piece = $\dfrac{\text{(Total price coating / Total use of consumption)}}{\text{Energy loss factor}}$

- cost of the work = $\dfrac{\text{cost of labor}}{\text{(Number of varnished batches* number Parts in batch)}}$

- Depreciated price per unit = $\dfrac{\text{Depreciation}}{\text{number Parts in batch}}$

- Energy loss is one of the main factor in each stage like coating line, energy, waste water disposal and chemical, so energy losses factor it is used for calculation [14].

Total sum of price is calculated and shown in table (11)

= Energy per unit + Water price per unit + Price water disposal at minutes + Maintenance cost per unit + Price of chemist pre-treatment per part + Coat lacquer price per piece + cost of the work + Depreciated price per (240 days at 3 times).

Total sum of price = 0.443 (€)/pc.

4.5 Chemicals:

According to the literature search [6], Chemicals are chosen and calculated. During the coating process, the chemicals are used in each stage and detailed shown in the table (12). In each stage has different chemical solution capacity (g/m²) in the tank and its shown in the table (12).

Table 12: Chemical used in each Stage

CHEMICAL						
S.no	**Operation**	**preparation**	**g/m²**	**Spending kg/year**	**Volume kg**	**type**
1	Degreasing	BONDERITE C-AK1574	10.00	4,860	*250*	Barrel
2	Degreasing	BONDERITE C-AD 0570	1.00	55	*25*	Bag
3	Activation	FIXODINE X	1.00	486	*25*	Canister
4	Phosphate	BONDERITE M-ZN 4551	15.00	7,290	*250*	Barrel
5	Phosphate	BONDERITE M-AD 130	0.52	253	*25*	Canister
6	Phosphate	BONDERITE M-ZN 565	0.07	34	*25*	bag
7	Phosphate	BONDERITE M-ZN 3102	0.09	44	*25*	bag
8	lining E-Coat	Resin CR 691K	67.00	32,562	1000	Returnable container
9	lining E-Coat	Pigment paste CP 471A	12.00	5,832	250	Barrel
10	lining E-Coat	PH regulator CA 146E	0.15	72	*25*	Bag
11	lining E-Coat	Butyl glycol CA 101E	1.98	960	90	Barrel
12	lining E-Coat	Hexyl glycol CA 114E	1.98	960	90	Barrel
13	lining E-Coat	Methoxy propanol CA141E	0.99	480	*25*	Canister

Table 13: Overall Chemical calculation during process:

S.no	operation	preparation	ware house of the day	Amount of storage	Number of packages	Total stock kg
1	Degreasing	BONDERITE C-AK1574	56	764	4	1000
2	Degreasing	BONDERITE C-AD 0570	56	9	1	25
3	Activation	FIXODINE X	56	76	4	100
4	Phosphate	BONDERITE M-ZN 4551	56	1,147	5	750
5	Phosphate	BONDERITE M-AD 130	56	40	2	50
6	Phosphate	BONDERITE M-ZN 565	56	5	1	25
7	Phosphate	BONDERITE M-ZN 3102	56	7	1	25
8	line E-coat	Resin CR 691K	30	2,782	3	0
9	line E-coat	Pigment paste CP 471A	30	498	2	0
10	line E-coat	PH regulator CA 146E	30	6	1	25
11	line E-coat	Butyl glycol CA 101E	30	82	1	90
12	line E-coat	Hexyl glycol CA 114E	30	82	1	90
13	line E-coat	Methoxy propanol CA141E	30	41	2	50
		Total				**2230 kg/year**

The total sum of chemicals used in all stage for coating process is about 2230 kg/year.

According to the formula [14] and each step for chemicals is used during the process are calculated shown in table (13)

Formula:

- Operation: Degreasing
- Preparation: BONDERITE C-AK1574
- Ware house of the day = Number of working hours in day* Number days in a week

$$= 8 * 7$$

$$= 56.$$

- Amount of storage = $$\frac{\text{Kilo gram of solution}}{\text{ware house storage* No of days in a week}}$$

- Number of packages = $$\frac{\text{Spending kg / year}}{\text{ware house storage*number of days in year}}$$

- Total stock of chemicals = $$\frac{\text{Number of packing}}{\text{Kilo gram of chemicals}}$$

4.6 Energy:

From literature search [14], there are two types of energy are used in these projects. The first one is electrical energy is mostly used in coating purpose, cooling zone, exhaust system, neutralizing system, lighting and refrigeration and for operating appliances, computers, electronics, machinery and building purpose. And another energy is thermal energy can have converted to mechanical energy to provide power for industries, so it is used heating/cooling and domestic hot water, furnace, hot utility of water in heat exchanger which can warm the bath, building thermal mass, Phase Change materials in heat exchanger in process, and energy storage tanks. According to these two energies, are calculated for building construction, Technology, power and waste which are used in the coating process and chemicals in during the process [12].

Table 14: Overall Energy in Coating Process

ENERGY						
Consumption of energy per year						
Consuming	**Power kW**	**Time/T max**	**Power/power max**	**kWh**	**El**	**LPG/NG**
Healing system	380	0.80	0.40	122	0	122
Preparation	59.5	0.67	0.70	28	28	0
Coating knot	70.2	0.75	1.00	53	53	0
lining source	176	0.40	0.90	63	63	0
polymerization furnace with cooling zone	206	1.00	0.35	72	7	65
Handling system	37.4	0.60	0.90	20	20	0
Exhaust system	25.3	1.00	1.00	25	25	0
Reverse osmosis	6.8	0.80	0.80	4	4	0
Neutralizing Station	12.8	0.80	0.80	8	8	0
Total	**974**			**396**	**209**	**186**
Consumption of energy						
consuming	**Power kW**	**Time/ Time min**	**Power/power max**	**kWh**	**El**	**LPG/NG**
Healing system	380	8	0.40	20	0	20
prepare	59.5	23	0.70	16	16	0
Coating knot	70.2	8	1.00	9	9	0
lining source	176	4	0.90	11	11	0
polymerization furnace with cooling zone	206	25	0.35	30	2	29
Handling system	37.4	18	0.90	10	10	0
Exhaust system	25.3	10	1.00	4	4	0
Reverse osmosis	6.8	8	0.80	1	1	0
Neutralizing Station	12.8	8	0.80	1	1	0
Total	**974**			**102**	**53**	**49**

60

Heating water 85 c / 70 c for heating hot water					
consumption of gas new coating					
Top subscriptions - on ramps.					
Healing system *		380	kW		
polymerization furnace with cooling zone		200	kW		
``The power of the heater of new hall		170	kW		
Take off factor		0.4			
Number of hours airmail		500	h/year		
Annual consumption energy		**1,333**	MWh/year		
Consumption of energy for other purposes					
design is made in each of two HVAC unit 2*85 KW					
After production technology, we expect the production to be less than half.					
Final heating by gas overall					
Ivar earning		1,132	MWh/year		
Consumption of the hall + admin		356	kW		
The power of HAVC heater of the old S001halls		100	kW	2x50	
Heat output of office building		30	kW		
Energy needs soo2 technology, heat exchanger		580	kW		
Heat output of so2 heat exchanger		170	kW	2x85	
Power Heater future expansion 2017		100	kW	2x50	
Sum peak		1206	kW		
Conversion kW to MJ/ h		4342	MJ/h		

4.7 Waste water:

Waste are most important during the coating process. Waste are most important during the coating process. Waste are referring to the disposal cost of the two significant types of waste generated during painting: VOC and paint sludge. Paint sludge can be disposed as either hazardous or non-hazardous waste, depending on its content. In several plants, even though the sludge is non-hazardous it is disposed of as hazardous to limit liability in the future. In a few plants, including Chrysler, paint sludge is being recycled. However, recycling is not as prevalent as might be expected. Currently, the economics of treating sludge is such that it is cheaper to send it to landfills than to recycle it. Due to waste of paint and chemicals in process it can loss the production. To reduce the waste, here I have calculated table (15) the total number of waste leaked during the process according to design. According to the Technological scheme stage 1 to 17 waste are calculated and shown in table (15).

Table 15: Overall Waste During Coating Process

Waste Water					
Waste source	**Type**	**(m³)**	**weight (Week)**	**(l/h)**	**(m³/year)**
degreasing	Alkaline	5.2	8		34
degreasing	Alkaline	5.2	8		34
Rinse1	Rinsing	4.75	8	270	1,550
Rinse2	Rinsing	4.75	8		31
Activation	Alkaline	4.75	8		31
zn-phosphate	Phosphate solution	4.75	8		0
Rinse3	Rinsing	4.75	8	270	1,550
Rinse4	Rinsing	4.75	8		31
Rinse5	Rinsing	4.75	8		31
Rinse the demi	Rinsing	4.75	8		31
Coating color		7.5	8		0

anolyte	solution	0.5	8	45	253
Uf rinse 1	Ultrafiltration	5	8		0
Uf rinse 2	Ultrafiltration	5	8		0
Rinse the demi	Rinsing	4.75	8	270	1,550
Reverse osmosis	concentrate from RO			600	3,375
ultrafiltration	Reg>solution With Coating	0.5	4	Disposal exit	7
			Suma	**1455.2**	**8501**
Waste water			PD	620	3323

pointer		efficiency	Exit	note	
Zn		0%	X+200 mg/l	Min. Effectiveness the passage	
Nl		To 95 %	min 30 mg/l	Limitation output limit	
Zn2+		at pH 9	1 mg/l	Zn2 + up to the level of solubility of Zn, which is 1 mg / l at a pH of about 10	
PAL		cca 98 %		Depending on the NEL input (at high efficiency property up to 99.).	
Total		at pH 9	< 3 mg/l	Total: To the solubility level of calcium phosphate and phosphate	

Waste water is calculated according to the formula [9]:

Total waste water = SUM (Waste is all stage) + reverse osmosis [9]

$$= 5126 + 3375 = 8501 \text{ m}^3/\text{year}.$$

So, the total waste water is during process is about 8501 m³/year.

4.8 Waste Gas:

According to the chemicals technological scheme waste gases are calculated in these processes. In waste gas VOC are generated during paint dipping in the booths, baking in the ovens and from solvents used to clean equipment and flush paint lines. The air from coating booths goes through water scrubbers to remove overspray paints before being sent for incineration. For solvent borne paints, most solvents are not captured in the scrubber water because of their low solubility in water and high volatility. VOC concentrations in exhaust air from very low (50-200 ppm typically) because of the large volumes of air used. Treatment of this huge volume of air that has low VOC concentrations makes VOC removal very expensive. In general. the exhaust is incinerated at approximately 1400*F to destroy the VOCs. In some plants, activated carbon wheel absorbers are also used in VOC treatment. VOCs from large volumes of the booth exhaust air are adsorbed by carbon and then desorbed into a small amount of hot air, thus increasing the concentration of VOCs and decreasing the air volume to be incinerated. The current trend is to use a large incinerator rather than to use multiple small ones. According to [16] is have calculated VOC emission in these technology is about 160.3 g/year. And VOC released in Kiln (70) % is 112.2 g/year. Waste gas are calculated from the table (16).

Table 16: Overall VOC - Coating

Description	(m³)	weight (week)
Amount of suction air	14000	m³/h
Zn concentration in the drain	2	µg/ m³
Emissions of Zn per year	224	kg/year
Painted area	90	m²/h
Total VOC emissions	160.3	g/h
VOC released in the KTL tunnel (30%):	48.1	g/h
Exhausted air from the tunnel	3000	m³/h
VOC emissions from the tunnel exhaust	16.0	mg/m³

VOC released in the oven (70%):	112.2	g/h
Exhausted air from the furnace	3000	m³/h
VOC emissions from the exhaust furnace exhaust	37.4	mg/m³
VOC Legislative Limit	50	mg/m³

4.9 Overall Calculation – Chemical and waste:

For calculating overall cost, some of the materials are chosen from the literature [6] and from table (12) Chemical and table (15) waste result is taken and calculated shown in table (17). According to the cost/kg [6], The overall total chemical, and waste, amount is 10766 euro/year shown in the table (17). And the amount is calculated according to the Czech national bank Currency conversion [23].

Table 17: Total Price of chemical and waste in Year (2017)

Materials	Values	Cost/kg (€)	Total Amount	Currency/ year
Cleaning of heat exchangers + in coating process	580	5.2	3578.8	(€)/year
chemicals	2230 kg	1.2	2747.1	(€)/year
Tablet for DM water	500 (l/h)	1.3	693.53	(€)/year
Replacement of UF modules + waste	1455.2 (l/h)	2.6	3747.6	(€)/year
Total			**10766**	**(€)/Year**

5. CONCLUSION:

In view of our above approaches while pursuing by design and calculation, we can conclude point wise as follow:

➢ Based on literature research, we investigated that the electro coating process in each stage that how much of chemicals which are used is shown in table (1).

➢ From the Literature search [4], it shows that mechanical disintegration of chemical, energy, waste, plant and machinery are spending about 12400 euro/year for the production in a year shown in the table (7).

➢ After examination of the basic available parameters, I have made an Industry layout and technological scheme design for reduction chemical, energy, waste and man power consumption.

➢ According to the technological scheme chemical and energy is calculated for each coating stage from 1 to 17, which contain suitable machine and equipment for reduction.

➢ Main task: AUTOCAD Design - Line diagram of industrial layout, Electro coating industry layout, Line for Surface Treatment, Technological scheme – line disposition, Technological scheme P&ID 1&2.

➢ According to the literature search [6], and company like Henkel and PPG company, I have chosen quality of paint, energy and chemicals for the calculation. The overall Paint analysis is about 0.443 (€)/piece, and size of the pieces will be 3 m x 1.5 m and less than 5m² for example piece car bonnet and car bumper etc., is calculated and shown in the table (11).

➢ Overall chemicals which is used for coating process in all stages is about 2230 kg/year, is calculated and shown in table (13).

➢ According to figure (13), overall energy used in electro coating industry plant, annual consumption of energy is required for a plant is about 1333 MWh/year (2017), is calculated shown in the table (14).

➢ Total waste water is about 8501 m³/year, is calculated and shown in table (15).

➢ Waste gas- total VOC emission is about 160.3 g/h.

➢ According to the literature search [6] and from table (13) chemical and table (15) waste which have capacity of 416.5 m²/year, is calculated and amount is about 10766 euro/year, which is shown in the table (17).

➢ By the comparison of literature search, table (7) & particle part table (17), nearly about 1634 euro/year of amount is reduced in this project.

➢ At last figure (18) shows that the how much of chemicals, energy, waste are used paint process table (11) in electro coating industry in a year. The percentage in the figure (18) show overall calculation of paint, technology, chemical, waste and cost.
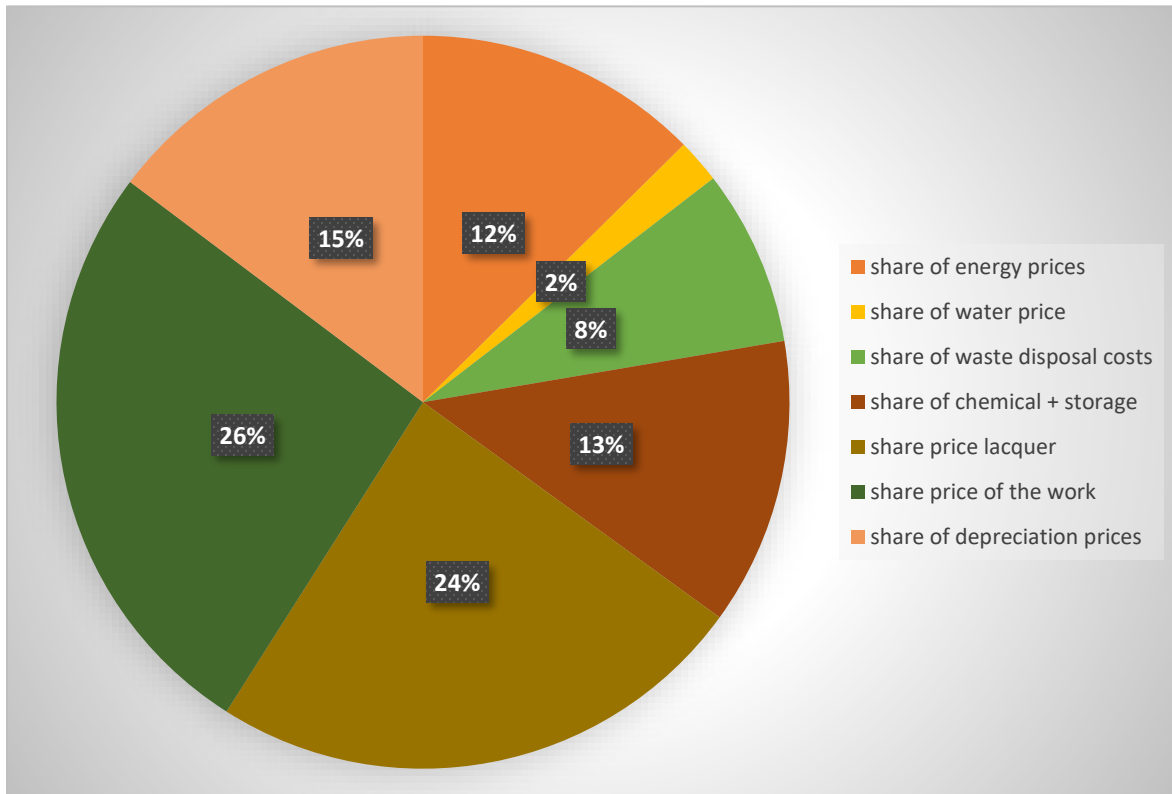

Figure 18: Overall percentage of paint, technology, chemical, waste in coating industry

➢ In conclusion, through this thesis work I have understood the concept of electro coating process which is used in industries.

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7. SUBSCRIPTS:

DC – Direct Current.

VOC – Volatile Organic compounds

FRC – Factory Reset Protection

PVC – Polyvinyl Chloride

UF – Ultra filtration

ASTM - American Society for Testing and Materials

PLC – Programmable Logic controller

HAP - Hazardous air pollutant

LEL- Lower explosion limit

VAT - Value add tax

HAVC – Heating Ventilation and Air conditioning.

ZPE – Zero-point Energy

HUV – Hot Utility water

PC – Pieces

AL - Qahtani Pipe Coating

TAL – Thickness Qahtani Pipe Coating

TA – Tantalum coating.

ED – Electro Deposition

UF – Ultra Filter

DM – Demineralized water

8. LIST OF TABLES:

9. LIST OF FIGURES:

10. APPENDIX:

Appendix A: Technological construction - Electro coating.

Appendix B: Line Diagram of Industrial Layout - AUTOCAD Design.

Appendix C: Electro Coating Industry Layout - AUTOCAD Design.

Appendix D: Constructional work - AUTOCAD Design.

Appendix E: Technological scheme – line disposition - AUTOCAD Design.

Appendix F: Technological scheme 1 P&ID -AUTOCAD Design.

Appendix G: Technological scheme 2 P&ID -AUTOCAD Design.

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