Eastern Mediterranean University

Department of Mechanical Engineering

Introduction to Capstone Design

MECT/MENG 411

Name of Project: *CORROSION TEST APPARATUS*

Group Name: CTA GROUP

Group Members:

16701819	GHALEB BANI JABER
16701104	*MOMEN ABUMUHSEN*
18700746	*AHMED ALASWAD*
17700858	*ABDULAZIZ ALAMOUDI*
16701670	*ABDULLAH MOHAMMED BAKRAN*

Supervisor: *ASSIST. PROF.DR. Mohammed Bsher A. ASMAEL*

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ABSTRACT

Corrosion is an electrochemical process resulting in the deterioration of metals working in reactive environments and loss of material over time. Corrosion is affecting materials’ mechanical properties and is ultimately leading to dysfunctional equipment components. To test materials’ ability to withstand corrosion and find methods to enhance their resistance, commercial testing equipment are available that can create accelerated corrosion conditions; however, the industrial large-sized equipment and high price associated with it preclude their use in a small university lab. The corrosion research aims at determining the durability of metallic structures under operational conditions (e.g., oil and gas pipelines, tanks) and revealing the mechanisms of the corrosion process. This mechanism can be chemical, electrochemical, or mixed.

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LIST OF SYMBOLS and ABBREVIATIONS

Table 1: Symbol Meaning

Symbol	Meaning
$T1$	**1st emperature**
$T2$	**Second emperature**
$P1$	**Entering air pressure**
$P2$	**Existing air pressure**
$T2$	**Exiting temperature**
$T1$	**Entering temperature**
k	**Ideal gas: air constant**
$\dot{m}e$	**Existing mass flow**
$\dot{m}i$	**Entering mass flow**
$h e$	**Exiting temperature enthalpy**
$h i$	**Entering temperature enthalpy**
$\dot{Q}$	**Heat**

Symbol	**Value**
P1	**83 kPa**
P2	**/**
T2	**319 k**
T1	**298k**
T1	**298k**
T2	**319k**
m˙e	**/**
m˙i	**/**
h e	**298.15kg/kj**
h i	**319.57kgkj**

CHAPTER 1 – INTRODUCTION

1.1 Detailed definition of the project

Corrosion is a characteristic and expensive procedure of destruction like earthquakes, tornados, floods, and volcanic ejections, with one significant contrast. While we can be just a quiet onlooker to the above procedures of annihilation, corrosion can be forestalled or possibly controlled. Corrosion is the aftereffect of cooperation between a metal and conditions which brings about its progressive decimation. Corrosion occurs when metallic material is exposed to a specific environment and is defined as the loss of material during the deteriorative process. As a result, the strength, ductility, and surface appearance of a metal specimen is compromised. Engineers are developing methods of metal treatment that can resist the damaging effects of corrosion. For example, using additional chromium alloying in steels to create stainless steels or using surface treatments to achieve a higher corrosion resistance for the metallic specimens. High corrosion resistance property is especially important in naval and offshore applications as the exposure to saltwater and high winds create an extremely corrosive environment. To test the corrosion resistance of metals and various surface coatings, the Japanese Industrial Standards Method of anodic corrosion curves measurement for stainless steel Preface This standard incorporates recent advances in measuring equipment. It was revised because it is necessary to improve the experimental efficiency and to improve the consistency and description of the test piece surface finish with the related standards of the stainless steel corrosion test method

1.2 Significance of the project

The causality of the electrochemical test is that it avoids failure in the mechanism at all machines majorly at industries as it allows normal interval of time checkups on the machines to make sure it is at the optimal condition at all times, add to that it avoids chemical reactions other than corrosion suck as skin infections … etc. If this is used around all industries, this will allow the decrease the loss of expenses of fixation and repair of machines as the company/government is notified with the machine status thus helps increase the outcome leading to a better monetary condition in this matter.

1.3 Detailed project objectives

The main objective of this project is the study and understand the behavior of corrosion on Aluminum and steel and the effects in different environments. The project illustrations are detailed below.

1.3.1 Design for cost

Design for the cost is the cognizant application of engineering technology to manufacture a material using economic designs and manufacturing whilst still maintaining high-quality performance. This is attained by using low-cost designs and manufacturing processes. For instance, in this project lightweight aluminum is utilized to reduce cost-effectively.

1.3.2 Design for safety

In this project, the safety of personnel and working environments is a priority. We ensured to use coatings as precautions to high corrodible materials. With the reduction in corrosion, lives are at fewer risks be-cause materials used in construction are more durable and reliable. Also, we tried to use to avoid the use of highly corrosive material; like using metallic alloys as replacements because they have higher corrosive resistance.

1.3.3 Design for assembly

Design for assembly explains the scope of ease at which the product is assembled. Also, it helps in making the design process simpler. The manufacturing process of our products is normal except for implementing a more reliable layout that complies with the other design processes. Some of the highlighted measures were:

- Using less corrosive materials like metallic alloys.
- Using anti-corrosion coatings on highly corrosive materials if required.
- Considering less reactive materials depending on the environmental condition at which our product is used.
- Avoiding the usage of heavy materials to make assembly easier.

1.3.4 Design for performance

Our design process included elements that make our product very comfortable to use in different environmental conditions. This includes the coatings used on high corrosive materials that make them usable in dry and moist conditions whilst still maintaining their high durability level.

1.3.5 Design for environment

Design for the environment and its conditions was a very thoughtful and careful design. The most important being that it reduces wastage of the material to the bare minimum. There is a reduction in the contamination of products in their surroundings if corrosion happens. generally, the design of our products maintains a level that does not cause harm to both humans and inanimate objects in their surroundings.

1.4 Detailed project constraints

The six main constraints facing this project are Quality, Time, Cost, Scope, Benefits, and Risks:

1.4.1 Quality:

Quality is one of four major constraints of every project, as depicted in the classic triangle, which also includes scope, time, and cost, Quality sits slightly apart from the other three, appearing inside the triangle because it is almost always affected by any change to the other three. At the same time, changing quality expectations will most certainly affect the project's time, scope, and cost. Most importantly, all constraints within the classic triangle are interrelated, so a strain on one will affect one or more of the others.

1.4.2 Time:

One of the most important stakeholder considerations, project time (how long it will take to deliver), is a vital measure of project success. Your task is to estimate project time as accurately as possible, which requires a blend of research and experience.

1.4.3 Cost:

Equally important to stakeholders is how much a project will cost. As with time constraints, your budget estimates need to be presented in a range. Some key research will lead you to accurate numbers:

- Estimate costs with thoroughly researched market rates for goods and services you need
- Estimate costs with vendor bids and ranges
- If providing hourly cost estimates, be sure to estimate your time accurately in the first place

- Estimate your budget by considering all costs: labor, material, factory, equipment, administrative, software, contractors, etc.
- Look at costs and budgets for similar past projects inside and outside your organization
- Look carefully at change orders that affected past project budgets

Controlling your costs will be an ongoing project management task. You'll want to stick very closely to your proposed budget while keeping an open mind about changes that may affect costs.

1.4.4 Scope:

Since project scope is not an estimate but a guaranteed set of deliverables, it's difficult to imagine creating a range for this constraint. However, you can consider that stakeholders may be invested in scope risk and scope tolerance ranges.

1.4.5 Benefits:

The projected benefits of any project should be spelled out in a business case during the very early stages of project planning. To put it simply, a project's value must be determined early and fully agreed upon before launch. Therefore, your business case should articulate the project's justification and what set of measures will be used to assess its benefits to the organization.

1.4.6 Risks:

We usually think of threats—what might go wrong when we plan for risks. A PM must be able to reasonably foresee failures at every step of a project and prepare for them accordingly. This can involve playing out what-if scenarios and formulating contingency plans:

- What if a supplier fails to deliver?

- What if we lose any number of resources due to illness or transfer?
- What if the market takes a huge swing?
- What if our competitor launches a similar product at the same time?

When managing risks as a constraint, you must find the zone of risk tolerance in your organization and stakeholders, which means determining a tolerable range of responses within appropriate limits.

1.5. Report Organization

the following report contains five chapters; every chapter is divided into subsections.

The 1st chapter is the introduction, which consists of five sections that are: the detailed definition of electrochemical corrosion testing, the significance of the plastic electrochemical corrosion testing, the detailed project objectives, the detailed project constraints, and finally the structure of the report.

The 2nd chapter, literature review consists of the background of the electrochemical corrosion testing machine, types of metals and coatings, and the other sections consist of the concurrent solutions which show other types of tests, that are compatible with our test, the comparison of these concurrent solutions and finally the engineering standard used.

The 3rd chapter, design, and analysis consist of selected designs, which states why the components used are the most relevant to our design. The other sections include the engineering standards used, design calculations, and finally the cost analysis.

The 4th chapter, manufacturing processes contains two sections, manufacturing processes selection where all the types of manufacturing processes are described, while the other section describes detailed manufacturing processes that have been mentioned beforehand.

The 5th chapter, is the last chapter that includes the product testing plan, which the plan is done, to reach our objectives, as well as the verification plan of how to apply these engineering standards.

CHAPTER 2 - LITERATURE REVIEW

2.1. Background information

Since the corrosion behavior of metals is directed by complex interactions involving many different parameters, it often unexpectedly manifests itself. Therefore, corrosion resistance is not a basic property of a certain metal, yet a system property. The same metal is more likely to corrode in certain environments, while in other environmental conditions it can be stable. From a more vital point of view, the corrosion resistance of metals is essentially determined by the reactivity of the metal-environment interface.

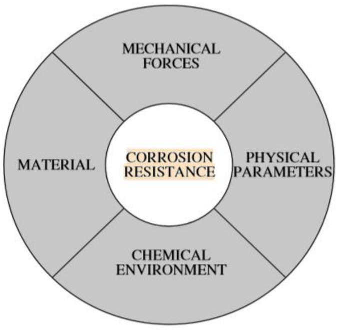

Figure 1: Corrosion Resistance

2.1.1 Factors Affecting Corrosion:

There are our elements that need to be present for corrosion to occur and are collectively referred to as the corrosion cell: an anode (+), a cathode (-), a metallic conductor, and an electrolyte. Changing the potency of the electrolyte affects the corrosion ratio of the material. Corrosion rates are determined by a variety of factors; however, five factors do play an overwhelmingly important role in determining corrosion rates.

- Oxygen: Like water, oxygen increases the rate of corrosion. Corrosion could also take place in an oxygen-deficient condition, but the rate of the degrading of the metal corrosion is at a much slower rate. In immersed conditions, if an electrolyte is in contact with one area of metal-containing more oxygen than the electrolyte, the higher oxygen-concentration area is cathodic relative to the remaining surface. An oxygen concentration cell then forms, which results in rapid corrosion.

- Temperature: Corrosion reactions being electrochemical are normally hastened in rather hotter or increasing temperatures. Therefore, the corrosion ratio increases faster in warmer conditions.
- Chemical Salts: Chemical salts increases the corrosion ratio by increasing the conductive efficiency of the electrolyte. The most widely used chemical salts are not limited to sodium chloride, a major element of seawater. Sodium chloride deposited on atmospherically exposed surfaces also acts as a hygroscopic material (it extracts moisture from the air), which then increases the corrosion in non-immersed areas.
- Humidity: Humidity and time-of-wetness involve largely in propagating and accelerating corrosion rates. Time-of-wetness is defined as the length of time an atmospherically exposed substrate has sufficient moisture to support the corrosion process. The wetter the environment, the more corrosion is likely to occur.
- Pollutants: Acid rain which is a chemical by-product from manufacturing and processing plants, and chlorides (in coastal areas) enhances corrosion. Acid gases, such as carbon dioxide, when the metal is exposed to such gases they dissolve on its surface creating a film of moisture.

2.1.2 Corrosion Resistance:

When it comes to environmental factors corrosion resistance of pure metals in different atmospheres can be described in the following table. It brings out the fact that depending on the environment, one or another metal has higher corrosion resistance. This proves that corrosion resistance is very dependent on the metal-environment system and not just on the metal itself.

Table 2: Corrosion Resistance Of a Few Pure Metals

	Fe	Cr	Ni	Cu	Al	Zn	Ti	Ta
Humid air	-	+	+	+	+	m	+	+
Cold aerated water	m	+	+	+	-	+	+	+
Seawater	-	+	+	m	m	-	+	+
Non-oxidizing acid	-	m	m	-	-	-	+	+
Oxidizing acid	-	+	m	-	-	-	+	+
Acid + Cl^-	-	+	m	-	-	-	m	+
Base + O_2	+	+	+	+	-	-	+	m
High-temperature oxidation	m	+	+	-	-	-	m	-

The table above shows the corrosion resistance of certain pure metals; we must mention that alloys corrosion resistance resembles that of its principal component. That is to be determined by the humidity of air or the aqueous solution, depending on the pH concentration of the solution. At low pH, proton reduction takes place, and the corrosion rate increases as the pH get lower. In a neutral solution, oxygen carriage controls the rate of corrosion, which therefore does not change accordingly with pH. the corrosion resistance depends on the crystal structure of these alloys and the chemical composition. Nevertheless, corrosion-resistant alloys are only used when the corrosive conditions prohibit the use of carbon steels and protective coatings provide insufficient protection since these metals are economically not feasible. If the conditions allow for coated metals to be used, they prove their efficiency while being an economical solution while the atmospheric conditions are not very severe.

- **Stainless steel:**

The corrosion resistance of stainless-steel alloys increases with the amount of chromium content. Nevertheless, stainless steel with relatively high chromium percentage is very hard to work (machining, welding), while being economically not feasible compared to ordinary stainless steel, the most widely used stainless steels are (AISI 430), (AISI 304), and (AISI 316), and they each contain from 13% to 18% chromium. Some other substances can be added to stainless steel to improve its corrosion resistance towards certain factors; for example, when it comes to pitting corrosion, adding molybdenum and nitrogen to stainless steel will improve the resistance towards pitting corrosion, while adding sulfur will increase pitting corrosion. On another hand, intergranular corrosion risks decrease with the decrease of carbon concentration in the alloy. The presence of Ti, Nb, Ta in small amounts makes the alloy more stable and corrosion-resistant because these elements are added in the form of stable carbides.

- **Nickel alloys:**

Nickel displays good corrosion resistance in neutral, alkaline solutions and the atmosphere. However, it corrodes in strongly oxidizing acids. Chloride-containing environments cause pitting corrosion, especially in commercial-grade nickel that contains sulfide inclusions. Pure nickel is quite soft and is used mostly as a coating. Few nickel alloys, in particular those based on copper, chromium, or iron, provide good mechanical properties and high corrosion resistance. Copper, in particular, improves the resistance against oxidizing acids, while molybdenum improves the resistance towards non-oxidizing acids and chloride containing environments. The different nickel alloys are labeled by numbers or letters, such as Inconel 600 or Hastelloy C. These alloys have relatively high prices, hence the use of these materials is limited to those applications that require a better corrosion resistance than stainless steel alloys can provide.

- **Copper alloys:**

Copper provides good corrosion resistance in air, as well as hot and cold water, as long as the flow velocity does not exceed a certain value. Copper can be corrosion resistant in acid environments if oxygen is absent because copper is nobler than hydrogen. Strong oxidizing medians that have higher standard potential than copper readily attack the metal. As a consequence, copper corrodes in HNO and aerated sulfuric 3 acids. It is rapidly attacked by solutions of FeCl,

Bronzes are copper-tin alloys which upon extended contact with the atmosphere form a dark coating that is much appreciated in the art world. In presence of certain pollutants such as chloride, the dark coatings eventually turn green.

- **Aluminum alloys:**

Aluminum exhibits good resistance to atmospheric corrosion and corrosion in neutral solution. Because in this pH range it is protected by a thermodynamically stable oxide coating. Yet in acidic and alkaline environments; this aluminum oxide coating dissolves and the metal corrodes rapidly, and when chloride ions are present, pitting corrosion occurs. Aluminum alloys show similar behavior to that of pure metal, yet this behavior may be altered depending on the alloy composition. The major alloying elements for aluminum are Fe, Si, Cu, Mg, Mn, and Zn. Among these elements, iron and copper tend to reduce the corrosion resistance, because intermetallic phases can precipitate at the grain boundaries during thermal treatment and promote sensitivity to intergranular corrosion and stress corrosion cracking.

3. Corrosion Prevention Methods:

We understand the importance of corrosion prevention. Rust and other corrosion forms can lead to safety issues and ruin the integrity of your equipment and supplies. Even routine maintenance to remove and repair corrosion can drive up costs. Fortunately, there are a variety of measures you can take to minimize corrosion. Here we'll highlight many of these methods:

● Barrier Coatings:

One of the easiest and cheapest ways to prevent corrosion is to use barrier coatings like paint, plastic, or powder. Powders, including epoxy, nylon, and urethane, are heated to the metal surface to create a thin film. Plastic and waxes are often sprayed onto metal surfaces. Paint acts as a coating to protect the metal surface from the electrochemical charge that comes from corrosive compounds. Today's paint systems are a combination of different paint layers that serve different functions. The primer coat acts as an inhibitor, the intermediate coat adds to the paint's overall thickness, and the finish coat provides resistance to the environmental factors.

● Hot-Dip Galvanization:

This corrosion prevention method involves dipping steel into molten zinc. The iron in the steel reacts with the zinc to create a tightly-bonded alloy coating which serves as protection. The process has been around for more than 250 years and has been used for corrosion protection of things like artistic sculptures and playground equipment. Compared to other corrosion prevention methods, galvanization is known for lower initial costs, sustainability, and versatility.

● Cathodic Protection:

Cathodic protection protects against galvanic corrosion, which occurs when two different metals are put together and exposed to a corrosive electrolyte. To prevent this, the active sites on the metal surface need to be converted to passive sites by providing electrons from another source, typically with galvanic anodes attached on or near the surface. Metals used for anodes include aluminum, magnesium, or zinc. Cathodic protection is used for steel pipelines carrying water or fuel, water heater tanks, ship hulls, and offshore oil platforms.

- **Anodic Protection:**

  Anodic protection involves coating the iron alloy steel with a less active metal, such as tin. The tin will not corrode, so the steel will be protected as long as the tin coating is in place. This method is known as anodic protection because it makes the steel the anode of an electrochemical cell. Anodic protection is often applied to carbon steel storage tanks used to store sulfuric acid and 50% caustic soda. In these environments, cathodic protection is not suitable due to the extremely high current requirements.

2.1.3 Effect of coating on corrosion testing:

The effects of the coating during the test defer depending on many variables, yet mainly on the method used for coating and the testing type of the corrosion testing type. For instance, Electrochemical impedance spectroscopy (EIS) methods enable conversion coated metals to be evaluated more quickly and quantitatively than exposure test methods such as salt spray.

To be clear, the results expected from both tests are different, EIS test gives us values depending on the corrosion current delivered, we can convert that to corrosion resistance coefficient, and with a further visual inspection, we can determine how corroding resistance is a certain alloy with certain coating. Meanwhile in spat spray tests the results to be expected only follow visual inspection as a parameter to determine the suitability of coatings, paints, and metals to resist corrosion or exposure to the environments.

2.2. CONCURRENT SOLUTIONS

When it comes to corrosion testing, there are plenty of methods used to determine the corrosion rate in metals, therefore there are plenty of methods to express the corrosion rate. and also There are many techniques used for electrochemical corrosion testing.

2.2.1 Weight-loss corrosion Test

One of the cheap, easy, and most widely recognized strategies to explore the corrosion rate. Many researchers have used immersion test followed by weight loss method. The mass loss experiment procedure is given in the ASTM G31 standard. ASTM G1 standard method gives the general procedure to clean the material samples. A technique to examine the corrosion of biodiesel by mass loss strategy is as per the following:

1- The samples have to be polished with emery paper and then cleaned with acetone solvent. The polished samples should be weighted before being immersed in biodiesel fuel for a specific period.

2- After a certain period of immersion, the materials have to be removed from biodiesel. Then the excess amount of biodiesel is removed by sodium hydroxide followed by water washing.

Several pieces of data must be collected to calculate the Weight-loss corrosion rate for any given metal:

- The weight lost (the decrease in weight of the metal during the period of reference).
- The density of the metal.
- The total surface area initially present.
- The time is taken for the metal to corrode.

The CR is calculated as follows:

$$\boldsymbol{CR} = (\boldsymbol{k} \times \boldsymbol{W})/(\boldsymbol{D} \times \boldsymbol{A} \times \boldsymbol{T})$$

where k = a constant, W = total weight lost, T = time taken for the loss of metal, A = the surface area of the exposed metal, D = the metal density in g/cm³.

The Weight-loss corrosion rate is best expressed in terms of the thickness or weight loss where the surface of the metal corrodes uniformly across an area. This method involves the exposure of a weighed piece of test metal or alloy to a specific environment for a specific time. This is followed by a thorough cleaning to remove the corrosion products and then determining the weight of the lost metal due to corrosion. The rate may different if the rate expressed by the formula above is used in the comparison of the corrosion rates for a period lengthier than one year with rates computed over a short time. This is since short-term periods have prone to varying environmental changes from day to day as well as from season to season The results from laboratory weight-loss studies have been used to determine the relative corrosiveness of different operating parameters (amine type or concentration, steel type, vapor versus liquid phase.

There are some potential sources of errors in this measurement. The area of the coated material needs to be accurately measured as it is by using the coating weight and knowing the area of the sample, the coating thickness can be calculated. This will be the theoretical thickness assuming a fully dense coating; however, we know that evaporated coatings may contain trapped gas and there may be voids due to less than perfect packing and so we need to make an educated guess about the true density of the coating.

Another possible source of error can be caused by some of the liquid, which is used to dissolve the coating of the substrate, being absorbed into the substrate. This would increase the weight of the substrate and the difference would be reduced and so the estimated coating thickness would be reduced. The longer the time the substrate is left in the liquid the higher the chance of the liquid being absorbed into the substrate. It is possible to weigh a larger sheet of the substrate material and produce an average weight per unit area

2.2.2 Tafel Analysis

Tafel analysis is a conventional dc technique in which larger, applied potentials are used. This produces larger, measurable currents, but the current – potential relationship is non-linear, so a semi-log plot is used, which is called a “Tafel” plot (Figure). The Tafel plot shows an anodic branch for the oxidation reaction and a cathodic branch for the reduction reaction. Each branch shows a linear portion and extrapolation to the free corrosion potential provides the corrosion current at the free corrosion potential. The slopes of the anodic and cathodic lines are the Tafel coefficients. The problems with this approach are that large potentials can sometimes drive unwanted reactions that obscure the linear portion of the anodic or cathodic branch, making extrapolation inaccurate, and irreversibly altering the electrode surface.

- DC methods like linear polarization and Tafel analysis are easy to perform, but they have additional severe limitations when the corrosion rate is very low, the electrolyte has low electric conductivity, or when an electrically insulating coating is used. The next Figure helps explain why these limitations exist. The corroding metal in an electrochemical test is part of an equivalent, an electric circuit that contains contributions from the resistance of the solution (or an electrically insulating coating) and from the double layer capacitance that forms from the accumulation of ions at the surface of the electrode, in addition to the polarization resistance, R_p, that is related to the corrosion rate. The electric current that is measured contains a component that comes from V/R_{solution} and that is appreciable if the solution is large, and a component that comes from charging of the capacitance, if present, both of which have nothing

2.2.3 III- Electrochemical Impedance Spectroscopy

electrochemical impedance spectroscopy (EIS) is exploited to obtain a more accurate measure of the corrosion current by using an AC potential excitation rather than a DC potential excitation, and by measuring the relationship between the AC and the applied AC potential for a variety of frequencies. The data from this approach allows for the construction of an equivalent circuit model, including determination of the values of the various elements of the model of the electrochemical system, such that a value of R_p is obtained that is related only to the corrosion current. For example, electrochemical impedance spectroscopy with equivalent circuit modeling is very instructive about the degradation of paint coatings on metal surfaces. Paint coatings typically go through several stages as shown in the following Figure, and these stages can be identified and quantified by equivalent circuit modeling. Although very powerful, the instrumentation for electrochemical impedance spectroscopy is more complex, the mathematics is more sophisticated, there is a multitude of models, it takes experience to identify the correct model, and extensive modeling is required. Nonetheless, when done properly, EIS provides superior, often unique insight about the corrosion rate and mechanism.

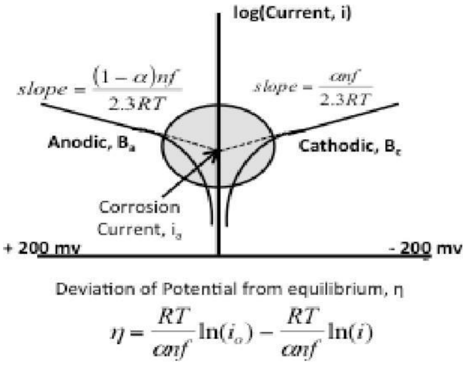

Figure 2: Tafel Analysis

2.3. Comparisons of the concurrent solutions

Table 3:criteria matrix for method of corrotion

`					
Method	**Cost**	**Time**	**Complexity**	**Reliability**	**Total**
Weight-loss corrosion Test	9	7	8	7	**31**
Linear Polarizatin and Tafel	6	3	7	6	22
Electrochecl Impedance Spectroscope	2	5	2	4	13

2.3.1 AASS AND CASS TEST:

There are two distinct test methods in ISO 9227: the neutral salt spray (NSS), the acetic acid salt spray (AASS), and copper-accelerated acetic acid salt spray (CASS). The acetic acid salt spray (AASS) test is especially useful for testing decorative coatings of copper + nickel + chromium, or nickel + chromium. It has also been found suitable for testing anodic and organic coatings on aluminum. The second test is the copper-accelerated acetic acid salt spray (CASS) test is useful for testing decorative coatings of copper + nickel + chromium, or nickel + chromium. It has also been found suitable for testing anodic and organic coatings on aluminum Neutral Salt

Spray testing is a common accelerated corrosion test method that exposed metallic and non-metallic materials to a highly corrosive environment, over an extended period, to assess their relative corrosion resistance The choice of the test for your product(s) should be based on the type of material/coating. Indeed, AASS and CASS are mostly used for electrodeposited copper/nickel/chromium coatings, nickel/chromium coatings, and sometimes anodic coatings on aluminum. whereas the NSS test, offering neutral salt spray conditions with a pH ranging between pH 6.5 to 7.2 applies for metals and their alloys, most metallic coatings, anodic oxide coatings, organic coatings, and metallic materials. The AASS and CASS methods are much more corrosive than the ordinary salt spray method (NSS) and are very useful in enhancing electroplated parts is quality. For a better comparison of these tests.

2.4. Engineering standards of the concurrent solutions

1) ASTM G31 Corrosion analysis applies to a wide range of conditions, allowing you to rapidly assess the corrosion rate of your materials and solutions. We run these tests over a wide range of temperatures and test parameters and can tailor every test to meet your specific needs.

2)A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless steels

3) D 1193 Specification for Reagent Water

4) D 1384 Test Method for Corrosion Test for Engine Coolants

5)D 2776 Test Methods for Corrosivity of Water in the Absence of Heat Transfer (Electrical Methods)

6)G 15 Terminology Relating to Corrosion and Corrosion Testing

7) G 16 Guide for Applying Statistics to Analysis of Corrosion Data

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9)G 33 Practice for Recording Data from Atmospheric Corrosion Tests of Metallic-Coated Steel Specimens

10)G 46 Guide for Examination and Evaluation of Pitting Corrosion

11)G 50 Practice for Conducting Atmospheric Corrosion Tests on Metals

12)G 78 Guide for Crevice Corrosion Testing of Iron Base and Nickel-Base Stainless Alloys in Seawater and Other Chloride-Containing Aqueous Environments

CHAPTER 3 -DESIGN and ANALYSIS

3.1. Proposed/Selected design

The Weight-loss test, in which specimens are exposed to a salt solution, has different valuable purposes when used with full recognition of its defects and limitations. Initially proposed as a fast-tracked laboratory corrosion test simulating the impacts of atmospheres on metals, inclusive of protective coating and in some cases, without them.

Some theory of the approximate service life and characteristics of several samples of the same (or closely related) metals or of protective coating-based metal mixtures in marine and exposed seacoast locations can be gained using the test. the salt test chamber is utilized for reliability and quality analysis and corrosion resistance test of a variety of materials, including metal plating, metal, electronic components, chemical coatings, paint, automobiles, motorcycles, metalware, screws, springs, magnetic materials, organic and inorganic coating, anodizing, anti-rust oil industry, etc. after the surface treatment. modular design gives the privilege of including additional features, relative ion the number and type of tests required. Our system uses multiple command solenoids into modifying the water volume/Temperature. A holding tank prepares the water to the desired temperature if needed. A pump makes ensure the water is conveyed in the appropriate pressure range. the water is fed to a motorized manifold that rotates arms. each arm has a changeable valve to allow easier control. the blueprint is modeled after and does not contrast greatly. in the requirements.

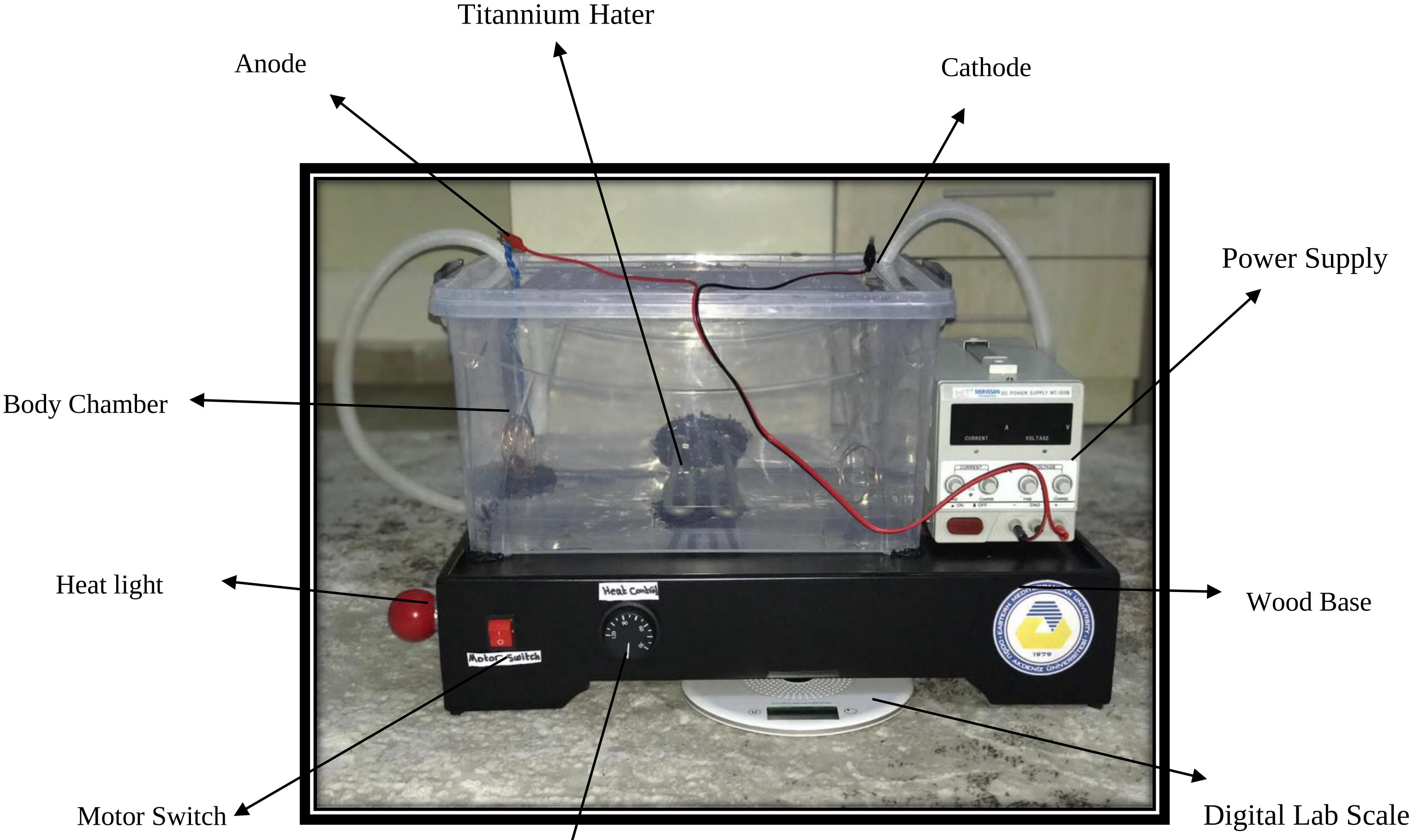


Figure 3: Structure of Machine

3.1.1 Chamber Body

The chamber and all accessories shall be made of a material that will not affect the corrosiveness of the salt atmosphere, such as glass, hard rubber, or plastic. All parts of the test setup that come in contact with test specimens shall be of materials that will not cause electrolytic corrosion. The chamber and accessories shall be so constructed and arranged that there is no direct impinging of the spray or dripping of the condensate on the specimens so that the atmosphere circulates freely about all specimens to the same degree, The chamber shall be properly vented to prevent pressure build-up and allow uniform distribution of salt spray. The chamber shall have a suitable means of heating and maintaining the required test temperature which will hold the other components of the corrosion equipment.

The chamber body material was chosen knowing the chamber is subjected to a corrosive salt environment and elevated temperatures necessary, the body was constructed from a P.V.C polyvinyl chloride, The inner walls and outer shell of the cooler are made of polyurethane plastic, materials with good corrosion resistance Between these two shells there is enough thick that is providing temperature insulation

Figure 4:Chamber Body

Table 4:Critical matrix for chamber

	Price	trength	Ease of manufacture	vailability
Plastic	+ + +	++	+++	+++
Glass	+	+	+ +	+ + +
Stone	−	++ +	− −	+ +

3.1.2 Salt Solution.

The salt used shall be sodium chloride (NaCl) containing on a dry basis not more than 0.1 percent of sodium iodide, and not more than 0.5 percent of total impurities. Do not use sodium chloride (NaCl) containing anti-caking agents because such agents may act as corrosion inhibitors. Unless otherwise specified, the salt solution concentration shall be 5 ±1 percent. The 5 percent solution shall be prepared by dissolving 5 ±1 parts by weight of salt in 95 parts by weight of distilled or deionized water. Water used in the preparation of solutions shall contain no more than 200 parts per million of total solids. The salt solution shall be kept free from solids by filtration. The solution shall be adjusted to and maintained at a specific gravity by figure 101-1. The pH shall be maintained between 6.5 and 7.2 when measured at a temperature of 95°F ±5°F (35°C ±3°C). Only dilute cp grade hydrochloric acid or sodium hydroxide shall be used to adjust the pH. In our test, we use water sea because all properties the same as the salt solution required.

Figure 5: Salt Solution.

3.1.3 Power supply

Electrical device that converts the electric current that comes in from a power source, such as the power mains, to the voltage and current values necessary for powering a load, such as a motor or electronic device. The objective of a power supply is to power the load with the proper voltage and current. The current must be supplied in a controlled manner — and with an accurate voltage — to a wide range of loads, sometimes simultaneously, all without letting changes in the input voltage or other connected devices affect the output. A power supply can be external, often seen in devices such as laptops and phone chargers, or internal, such as in larger devices such as desktop computers. A power supply can either be regulated or unregulated. In a regulated power supply, the changes in the input voltage do not affect the output. On the other hand, in an unregulated power supply, the output depends on any changes in the input. The one thing all power supplies have in common is that they take electric power from the source at the input transform it in some way and deliver it to the load at the output.

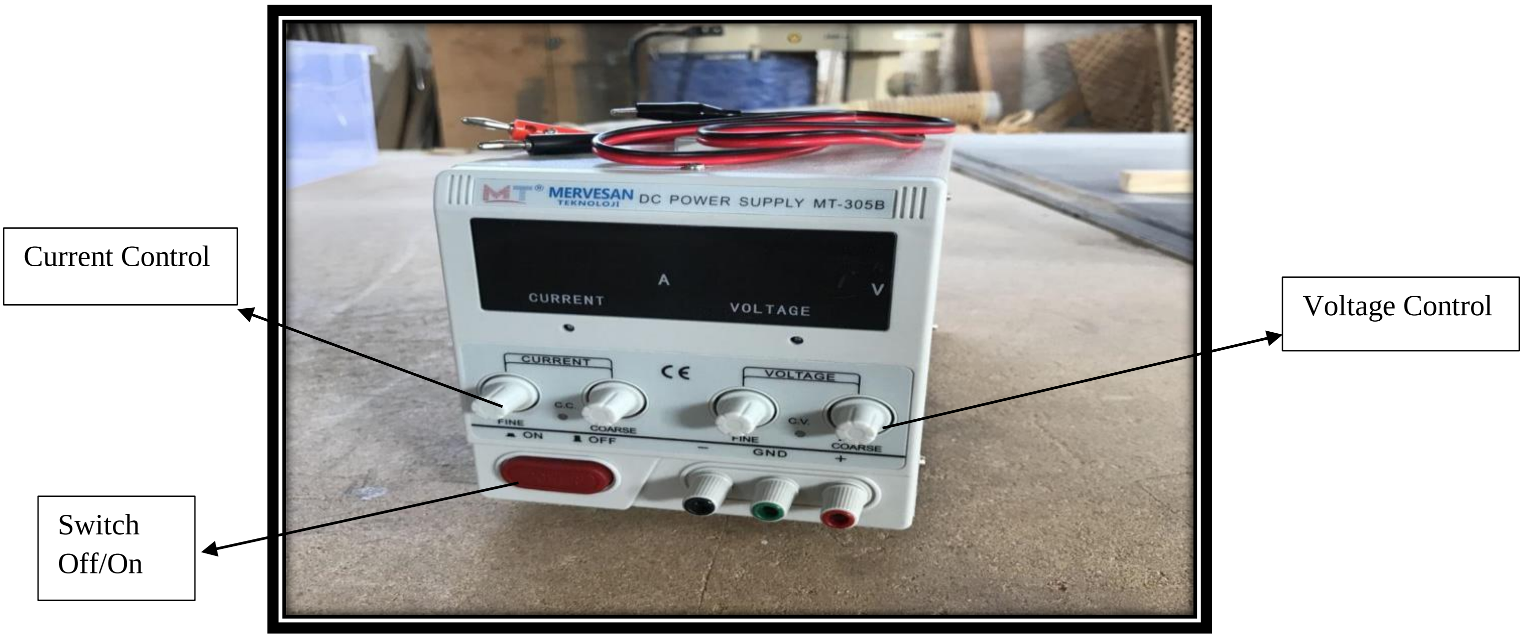
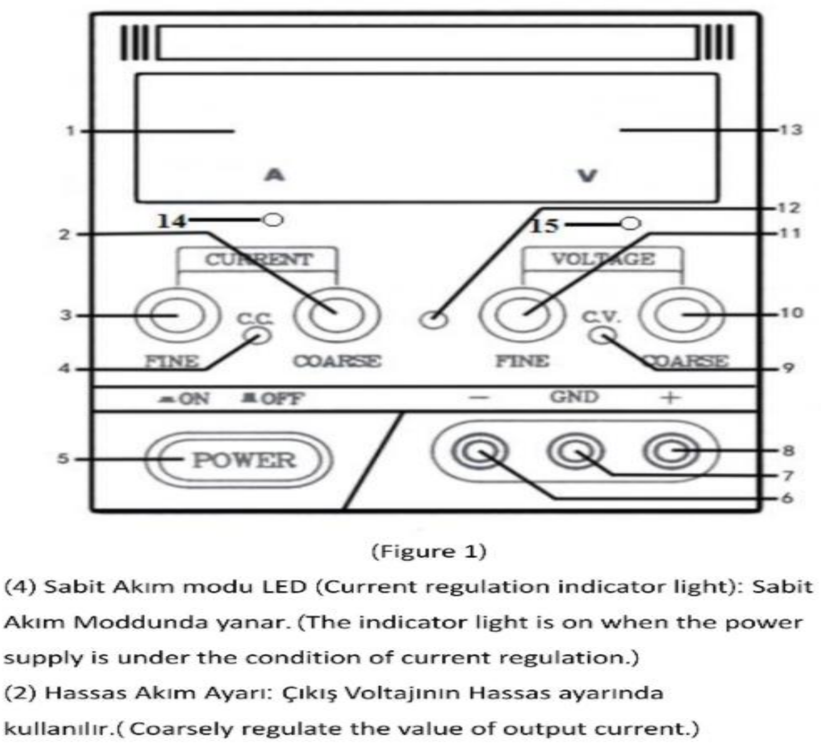


Figure 6:Power Supply



(Figure 1)

(4) Sabit Akım modu LED (Current regulation indicator light): Sabit Akım Moddunda yanar. (The indicator light is on when the power supply is under the condition of current regulation.)

(2) Hassas Akım Ayarı: Çıkış Voltajının Hassas ayarında kullanılır.(Coarsely regulate the value of output current.)

Figure 7: Power Supply Structure and Details

(11)Voltaj Hassas Ayarı: Çıkış voltajının Hassas ayarında kullanılır. (Finely regulate the value of output voltage.)

(9) Sabit Voltaj LED (Voltage regulation indicator light):Sabit Voltaj çalışma şartşlarında aktifdir. (The indicator light is on when the power supply is under the condition of voltage regulation.)

(10) Voltaj Ayarı: Çıkış voltajının ayarında kullanılır. (Coarsely regulate the value of output voltage.)

(5) Güç Anahtarı (Power supply switch)

(6) "-" Çıkış Terminali (output terminal): Eksi Çıkış (Negative polarity (black))

(7) "GND" Toprak terminal: Ground terminal (green)

(8) "+"Çıkış Terminali (output terminal): Artı Çıkış (Positive polarity (red))

3.2 Arka Panel (**Back panel**)

(17) Power Fiş (Power socket)

(16) AC voltaj Anahtarı (AC voltage selection switch)

3.1.4 Drainage motor

mainly composed of a miniature synchronous motor, a variable speed gear, a traction wire rope, and a stroke switch. When draining, the controller supplies power to the miniature synchronous motor of the drainage motor. The synchronous motor rotates, and the low-speed rotation through the gear speed change will The steel wire is entangled in the rotary drainage motor, and the steel wire rope pulls the connecting arm, and the connecting arm pulls the drain valve plug to overcome the elastic force of the valve spring to drain, and at the same time pull the clutch brake arm, when the wire is wound, the stroke switch acts, Keep this state. When the drain motor is de-energized, the drain valve plug is reset by the elastic force of the valve spring to stop the drain, and the drain motor wire is pulled out.

Figure 9 A: Motor Front Side

Figure 8 B: Motor Top Side

3.1.5 Control System

The Control system for the salt machine will include temperature controllers

To accurately control process temperature without extensive operator involvement, a temperature control system relies upon a controller, which accepts a temperature sensor such as a thermocouple as input. It compares the actual temperature to the desired control temperature, or setpoint, and provides an output to a control element.

A Temperature Sensor measures the temperature of a location where temperature control is required. It converts the temperature to a physical quantity of a voltage or resistance and outputs that. The selected temperature sensor for this project is a Capillary Thermostats

3.1.6 Capillary Thermostats

This thermostat functions as maintaining adjusted temperature by measuring the external and internal temperature of the equipment as an expanding-liquid thermostat. If the sensor detects the heat, the liquid expands and extends the space of the diaphragm, and that power enables making and breaking contact points of the switch. It is an automatic reset product that repeats going up and down within the range of adjusted temperature

Specifications

Capillary : 1,000mm (250mm to 2,000mm) Knob (Dial) : R or B Stuffing Bolt : PT1/4, M12, M14 Mounting Distance : 28mm Electric Rating : 20A / 250V Switch Action : SPST / SPDT Shaft Range : 270 Ambient Temp. : 120°C Tab Terminal : Straight, 90°

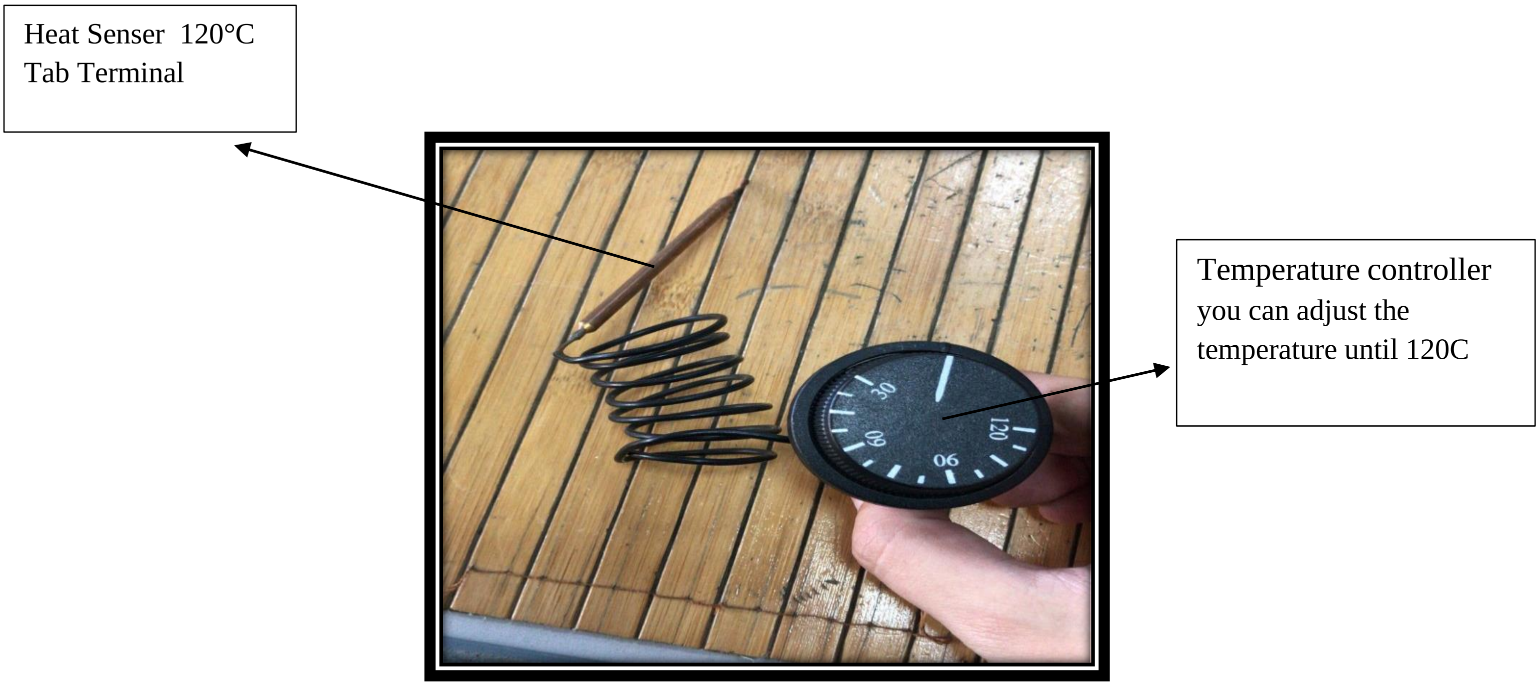


Figure 10: Temperature Controller

3.1.7 Digital Lab Scale

digital lab scale with high precision, ease-of-use, and durability! A high-quality electronic balance or counting scale is a useful piece of lab equipment to add to any classroom lab. This compact digital platform scale has a large 300 g capacity, provides very accurate 0.01 g sensitivity, and is incredibly easy to use. Overall, it's much easier and faster to use a digital balance rather than a mechanical balance; with an electronic scale or lab balance like this one, both preparation and lab time are can be greatly reduced Due to its high accuracy and high capacity, this multifunctional digital laboratory scale is ideal for middle school and high school science courses, including advanced chemistry. This high-precision scale features a 10 cm (4") square stainless steel weighing surface, a large high-contrast LED display (providing better quality than LCD lighting), a backlight, an automatic tare feature, keypad calibration, and protective covers that double as weighing trays. Its power supply consists of two AA batteries (included), making it an excellent portable balance and weight scale for you experimenting and weighing needs This digital platform scale weighs in grams, ounces, troy ounces, pennyweight carats, and grains.

Figure 11: Digital Lab Scale

3.1.8 Titanium Heater

Aluminum is not compatible with water, and stainless steel heat pipes typically generate large amounts of non-condensable gas. To prevent corrosion, Anderson, Dussinger, and Sarraf (2006) have shown in the Table that commercially pure (CP) titanium, titanium alloys, Monel 400, and Monel K500 are all compatible with water at temperatures up to 550 K. A titanium LHP would have a lower mass than a Monel LHP, so titanium was selected for the heat exchanger CP-titanium was used, due to its greater availability compared with titanium alloys. The heat exchanger was designed to operate at 400-500K and a thermal load of 500W. The heat exchangers were made from Commercially Pure 2 (CP-2) grade titanium, to avoid any incompatibility problems with water and two dissimilar metals. This includes the evaporator, evaporator wick, transport and condenser lines, and compensation chamber. The working fluid was water. In chemical processes, the use of Titanium Heat Exchangers is a cost-effective method of resisting leaks from corrosion on a process line.

Titanium Heat Exchangers can:

- Provide an extended service life compared to other materials of construction
- Eliminate expensive downtime due to equipment failure
- Do away with the requirement for spare parts inventory
- Provide superior corrosion resistance
- Deliver high heat transfer efficiency
- Accommodate high steam pressure to reduce the required surface area
- Eliminate breakage during handling, installation, and operation due to fully-welded metal construction

Therefore, the heating system adopts the direct heating method. The heating speed is fast and the standby time is reduced, when the temperature richer. The constant temperature state automatically switched .the temperature is accurate. Also, power consumption is low.

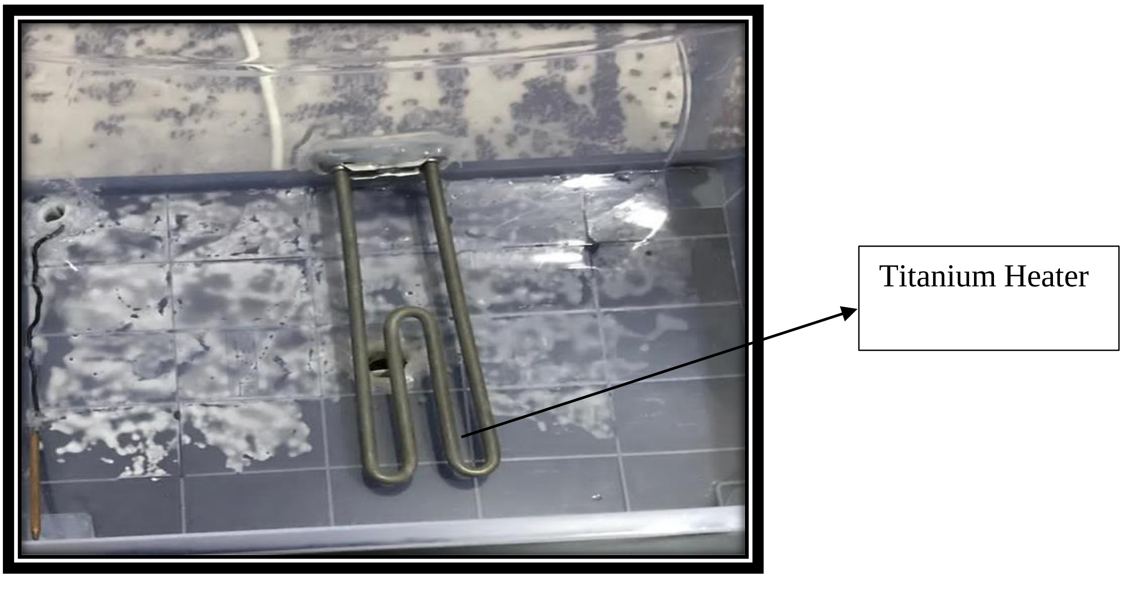


Figure 12: Titanium Heater

Table 5: Anderson, Dussinger, and Sarraf Table

Quantity	**Wall Material**	**Endcap/Fill Tube**	**Work**	**Operating Temperature**	**Operating Hours 6 June 2006**
4	Monel K 500	Monel 400	200x200 Monel 400 Screen 0.064 mm wire	550&500K	17.376 hours
4	CP-2 Ti	CP-Ti	150x150CP-Ti Screen 0.069 mm wire	550&500K	17.376 hours
4	CP-2 Ti	CP-Ti	Sintered Titanium -35+60 Mesh CP-2	550K	8.933 hours
2	CP-2 Ti	CP-Ti	100x100 CP-Ti Screen 0.05 mm wire	550K	1996/6248 hours
2	CP-2 Ti 21 S Foil Inside	CP-Ti	100x100 CP-Ti Screen 0.05 mm wire	550K	8.933 hours
2	Grade 5 Ti	CP-Ti	100x100 CP-Ti Screen 0.05 mm wire	550K	8.933 hours
2	Grade 7 Ti	CP-Ti	100x100 CP-Ti Screen 0.05 mm wire	550K	8h 5m 34s 800ms
2	Grade 9 Ti	CP-Ti	100x100 CP-Ti Screen 0.05 mm wire	550K	4.776 hours
2	Monel 400	Monel 400	120x120 Monel 400 Screen 0.05 mm wire	550K	4.272 hours
2	Monel K 500	Monel 400	120x120 Monel 400 Screen 0.05 mm wire	550K	3.432 hours
2	Monel 400	Monel 400	-100+170 Mesh Monel 400 Powder	550K	2.184 hours

3.2. Engineering standards

Weight loss test testing provides a controlled accelerated corrosive environment to evaluate the relative corrosion resistance of the coating, substrate, or part itself. Parts or panels are placed inside a chamber and exposed continually for a specified time, then evaluated for corrosion resistance. For this, we must follow several standards as follows:

1) ASTM G31. We run these tests over a wide range of temperatures and test parameters, and can tailor every test to meet your specific needs.

2)A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless teels.

3) D 1193 Specification for Reagent Water

4) D 1384 Test Method for Corrosion Test for Engine Coolants

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12)G 78 Guide for Crevice Corrosion Testing of Iron Base and Nickel-Base Stainless Alloys in Seawater and Other Chloride-Containing Aqueous Environments

Auxiliary Evaluations:

13)**ASTM D1654**, (Scribing and scribe creep evaluation).

14) **ASTM D610**, (Degree of rusting).

15) **ASTM D714**,(Degree of paint blistering).

16) **ASTM D7408**, (Standard Specification for Non-Reinforced PVC (Polyvinyl Chloride))

17) **OS950**, plastic optical level sensor is made from a polysulfone polymer and is well-suited for sterile applications like dialysis machines, washers, and other medical appliances.

18) **DIN/IEC 60751**. Industrial platinum resistance thermometers and platinum temperature sensors

3.3. Design calculations

In this section, procedures given are designed to remove corrosion products without significant removal of base metal. This allows an accurate determination of the mass loss of the metal or alloy that occurred during exposure to the corrosive environment, in some cases, may apply to metal coatings. However, possible effects from the substrate must be considered.

3.3.1 Chemical reaction :

Fe^0 + 2 H+ ⇒ Fe^2+ + H^2 **(1)**

(1a) Fe^0 + 2 H2O ⇒ Fe(OH)^2 + H^2 **(2)**

4 Fe^2+ + O2 + 4 H^+ ⇒ 4 Fe^3+ + 2 H^2O **(3)**

4 Fe(OH)2 + O2 + 2 H2O ⇒ 4 Fe(OH)3 **(4)**

Fe(OH)2, Fe(OH)3 ⇒ Fe O, Fe3O4, Fe2O3, Fe OOH **(5)**

Fe0 + H2O + (O2) ⇒H2 + iron hydroxides and oxides **(6)**

In summary, Equation (4) recalls that immersing a reactive Fe0 in water can be universally used to generate H2, Fe2+ and various Fe II, Fe III and Fe II/Fe III hydroxides and oxides. Equation (1) demonstrates that Fe0 is a scavenger of humidity (H2O), while Equation (2) demonstrates the O2 scavenging nature of Fe0 . These two scavenging characteristics have been exploited in several industrial applications .For example, Fe0 is used as desiccant in food packaging [81]. In the Fe0 remediation literature, the best illustration for the nature of the Fe0 /H2O system as generator of FeCPs is perhaps the excellent research article by Furukawa et al.. These authors used several analytical tools to demonstrate the presence of ferrihydrite, green rust, magnetite and lepidocrocite in an Fe0 /H2O system. More importantly, they conclude that an Fe0 /H2O system is a temporally and spatially heterogeneous geochemical environment. Concerning the spatial heterogeneity, Furukawa specified that magnetite (Fe3O4) is generated Water 2020, 12, 641 5 of 26 in the vicinity of Fe0 , whereas ferrihydrite (Fe(OH)3) precipitates away from the Fe0 surface. This conclusion corroborates ancient findings and recalls that even under oxic external conditions, there is a progressive O2 depletion culminating into anoxic conditions in the vicinity of Fe0 . In this context, Stratmann and Müller clearly demonstrated that oxygen is reduced by Fe II species within the oxide scale (chemical reaction), while Fe0 is oxidized by water (electrochemical reaction)

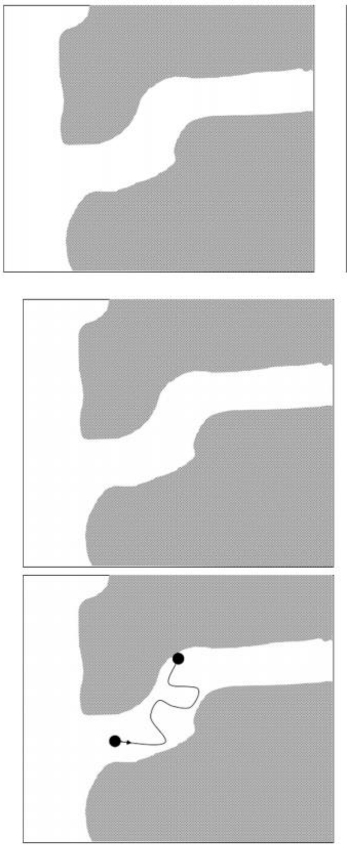


Figure 13:Pure adsorbent

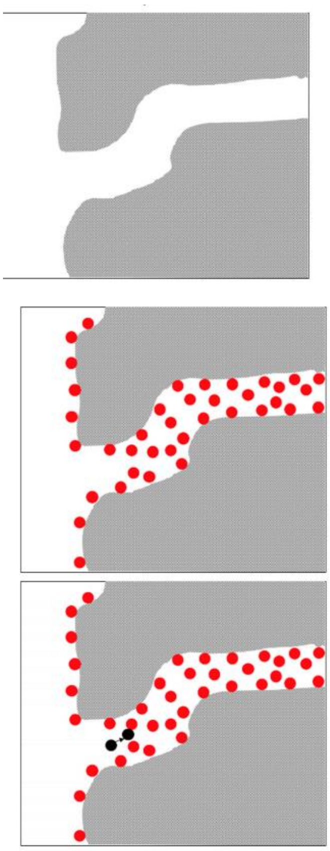


Figure 14Fe0/sand

Schematic diagram comparing the interactions of contaminants (black points) with solid phases in a pure adsorbent system (left) and the Fe0 -based system (right). The red points represent iron corrosion products (FeCPs) which are either coated on solids or suspended in the pore solution.

3.3.2 Corrosion rate

The initial total surface area of the specimen (making corrections for the areas associated with mounting holes) and the mass lost during the test are determined. The average corrosion rate may then be obtained as follows:

$$\boldsymbol{CR = (k \times W)/(D \times A \times T)}$$

where: K = a constant, T = time of exposure in hours constant 1hour 30 min, A = area in cm2, W = mass loss in grams, and D = density in g/cm3 . the corrosion rate can be calculated in a variety of units with the following appropriate value of K:

Corrosion Rate Units Desired	**Constant (K) in the Corrosion Rate Equation**
mils per year (mpy)	3.45 3× 10^6
inches per year (ipy)	3.45 3 ×10^3
inches per month (ipm)	2.87 3 ×10^2
millimetres per year (mm/y)	8.76 3 ×10^4
micrometres per year (um/y)	8.76 3 ×10^7
picometres per second (pm/s)	2.78 3 ×10^6
grams per square meter per hour (g/m2 ·h)	1.003×10^4
milligrams per square decimeter per day (mdd)	2.40 3×10^6
micrograms per square meter per second (µg/m2 ·s)	2.78 3 10^6

In the case of sacrificial alloy coatings for which there is preferential corrosion of a component whose density differs from that of the alloy, it is preferable to use the density of the corroded component (instead of the initial alloy density) for calculating average thickness loss rate by use of Eq.

This is done as follows: (1) cleaning to remove corrosion products only and determine the mass loss of the corroded component; (2) stripping the remaining coating to determine the mass of the uncorroded component, (3) chemical analysis of the stripping solution to determine the composition of the uncorroded Component, (4) performing a mass balance to calculate the composition of the corroded component,(5) using the mass and density of the corroded component to calculate the wight loss rate.

3.3.3 Test result :

$$\boldsymbol{CR = \frac{k \times W}{D \times A \times T}}$$

K = a constant

K= $1.003 \times 10^4 g/m^2h$ $\quad$ $1.003\ g/cm^2h$

W = mass loss in grams

W= (184 -182) = 2g

D = density in g/cm3

D= 8.05 g/cm^3

A = area in $\boldsymbol{cm^2}$

A= 87.96 cm^2

T = time of exposure in hours

T= 1 hour 30 min

$$\boldsymbol{CR} = \frac{1.003 \times 2}{8.05 \times 87.96 \times 1.5} = \boldsymbol{0.00188 \frac{g}{h^2cm}}$$

Table 6: Result

Number Of Speciment	**Area of the Speciment**	**Weight Before Test**	**Weight After Test**	**Average Weight**	**Voltage**	**Amphere**	**Duration**	**Corrosion Rate**
1	87.96 cm^2	184 g	182 g	2g	8V	2A	1 houre 30min	0.00188
2	75.39 cm^2	220g	218g	2g	10 V	2A	1 houre 30min	0.00220
3	42.32cm^2	104g	101g	3g	12V	2V	1 houre 30min	0.00588
4	16.8 cm^2	106g	102g	4g	8V	3A	1 houre 30min	0.01976
5	30.6 cm^2	47g	46g	1g	10V	3A	1 houre 30min	0.00271
6	28.3 cm^2	77g	76g	1g	12V	3A	1 houre 30min	0.00293
7	301.59 cm^2	658 g	652 g	6g	8V	4A	1 houre 30min	0.00526
8	100.53cm^2	48g	46g	2g	10V	4A	1 houre 30min	0.00165
9	80.4 cm^2	368g	358g	10g	12V	4A	1 houre 30min	0.01032

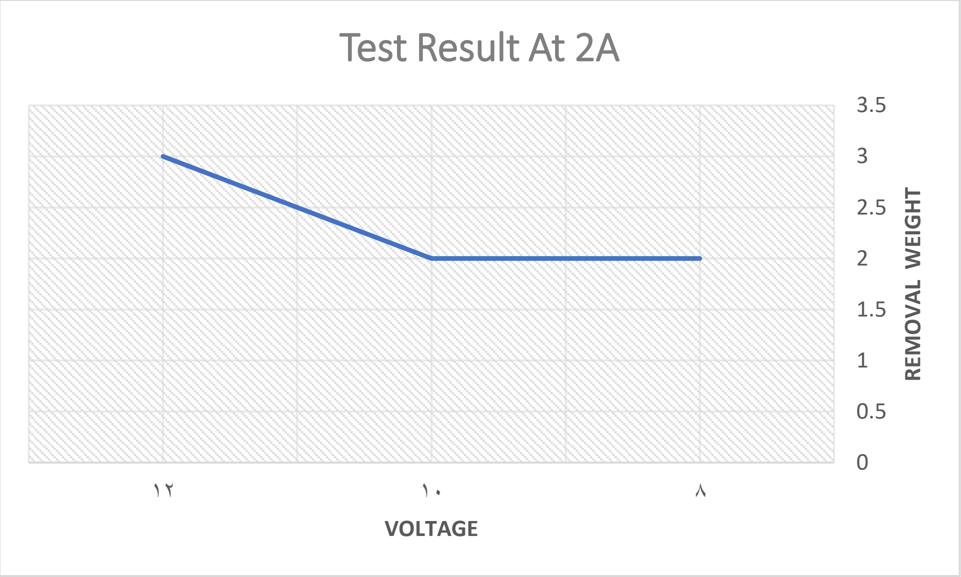


Figure 15: Result at 2A

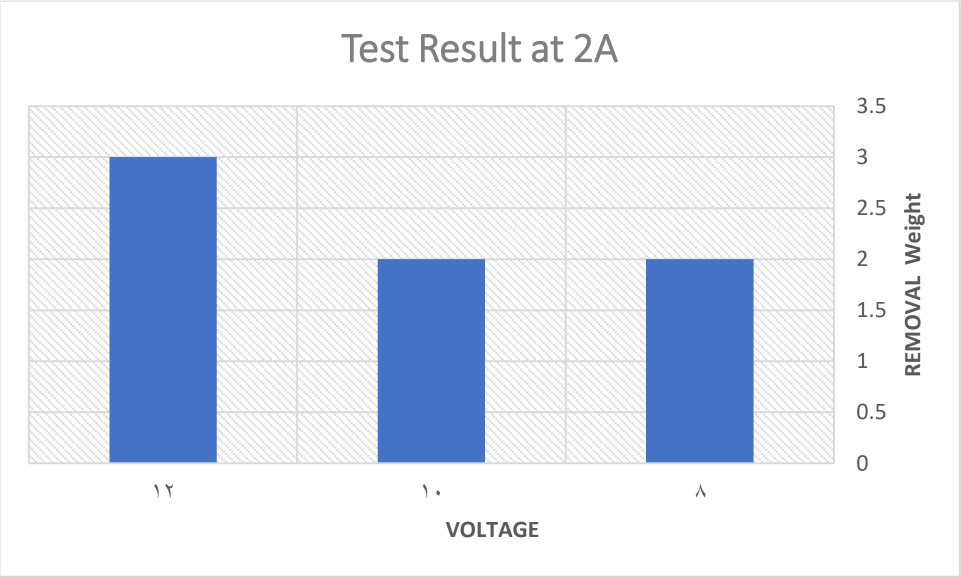


Figure 16: Result at 2 A

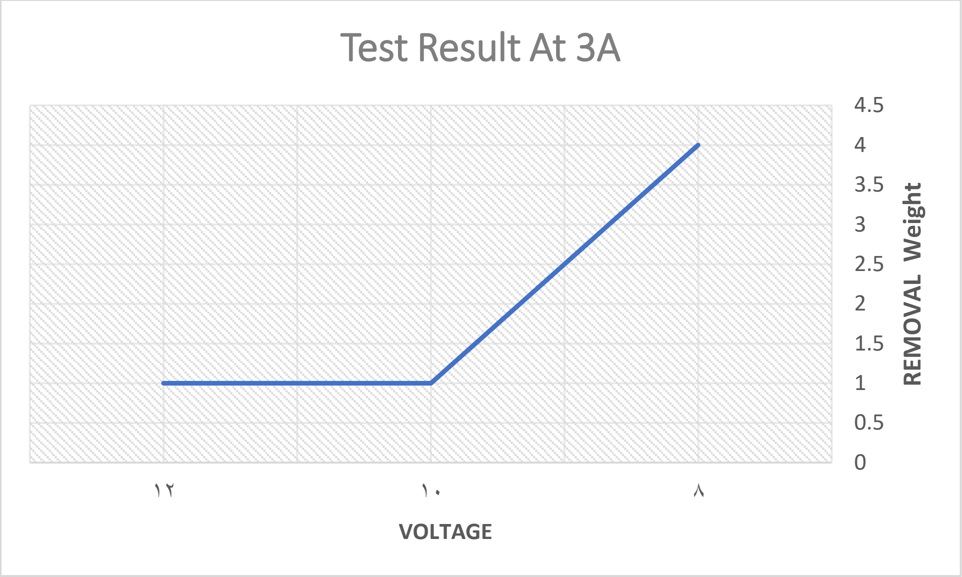


Figure 17: Result At 3A

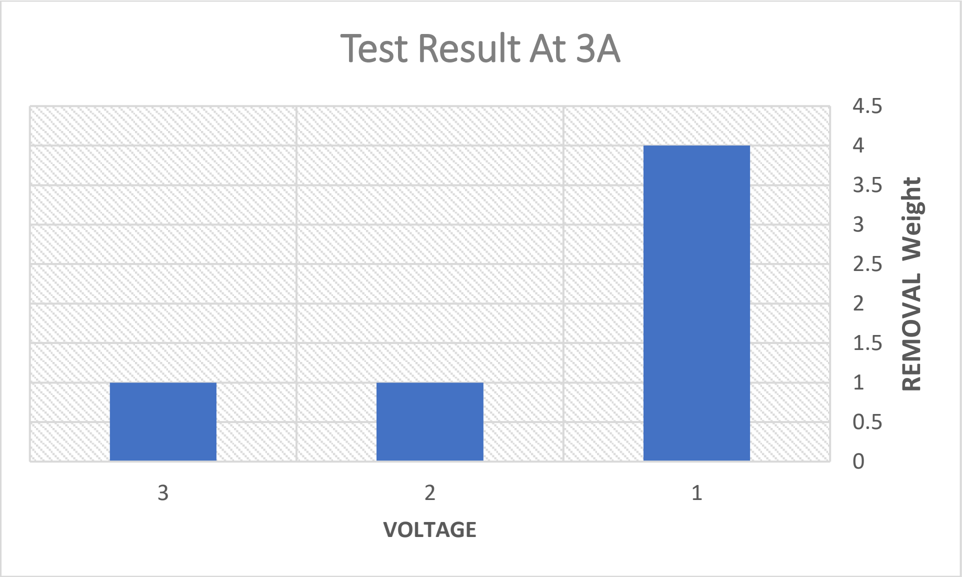


Figure 18: Result at 3A

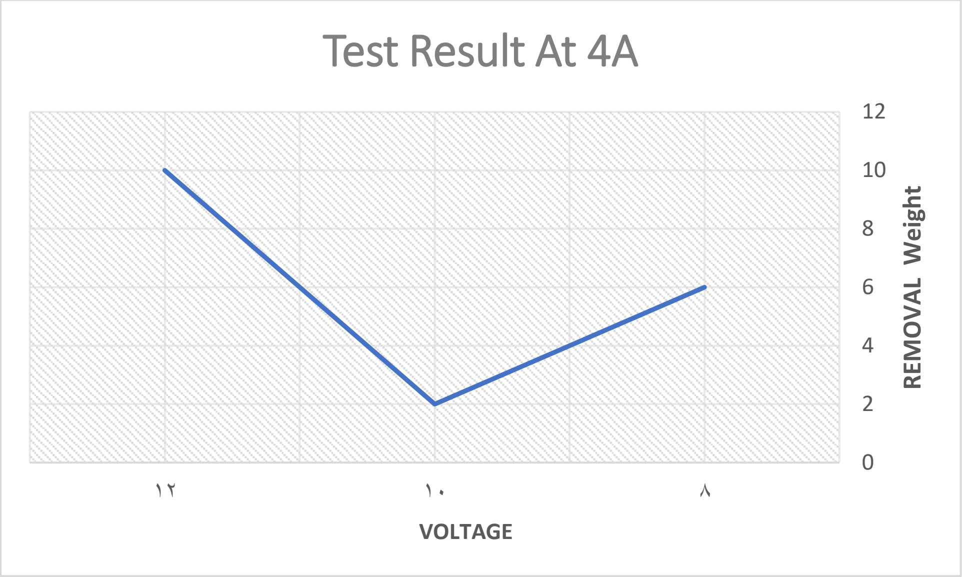


Figure 19: Result at 4A

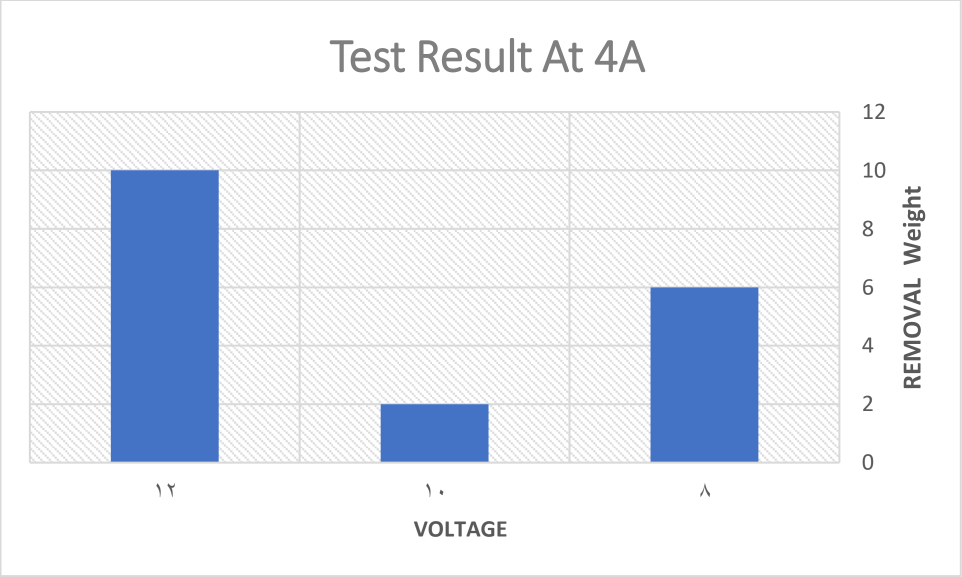


Figure 20: Result at 4A

	Before	After
Voltage 8V **Current 2A**	 	 
Voltage 10V **Current 2A**	  	  

Voltage 12V **Current 2A**	 	 

	Before	**After**
Voltage 8V **Current 3A**	 	 

Voltage 10V **Current 3A**	 	 
Voltage 12V **Current 3A**	 	 

	Before	After
Voltage 8V Current 4A	 	 
Voltage 10V Current 4A	 	 
Voltage 12V Current 4A		

3.4. Cost analysis

3.4.1. Financial and administrative equipment and expenses.

Table 7:Capital investment

	Quantity	**Unit price**	**Total**
Vernier caliper	1	$12	$12
Gloves	5	$3	$15
Safety glasses	5	$3	$15
Spammer set	1	$10	$10
Hammer	1	$5	$5
Screw drivers set	1	$7	$7
Allen keys set	1	$6	$6
#	#	#	Total:70$

Table 8:Other expenses.

Category	**Cost**
Food	$173
Transportation	$80
Shipping	$350
#	Total:603$

3.4.2. Bill of materials:

Table 9:Bill of materials

Item #	Part #	Quantity	Name	Material	Source	Cost	Picture
1	1-1	1	Power Supply MT-305B 0-30 Volt 5 Amper	Plastic	https://www.kartalotomasyon.com.tr	$150	
2	1-2	1	Digital Platform Scale	Plastic	https://stilevs.com.tr/	$13	
3	1-3	1	Chamber Body	Plastic	Park CO. LTD Cyprus Famagusta.	$10	
4	1-4	5	Titanium Heat	Titanium	https://www.alibaba.com	$19	

5	1-5	1	Capillary Thermostats	Plastic and Steel	https://www.ayfastore.com	**$12**	
6	1-6	2	Drainage motor	Plastic	i https://ar.aliexpress.com	$20	
7	1-7	2	Plastic Switch	Plastic	Electrical equipment store Cyprus Famagusta	$5	
8	1-8	1	Heat Light	Glass	Electrical equipment store Cyprus Famagusta	$75	
9	1-9	1	Wire	Steel	Electrical equipment store Cyprus Famagusta	98$	

10	1-10	1	Wood Base	Wood	https://www.amazon.ca	30$	
11	1-11	1	Plastic Pipe	Plastic	Building materials store	7$	
12	1-12	1	Silicones	Polysiloxanes	Building materials store	10$	
#	#	#	#	#	#	Total: $	# 449$

CHAPTER 4 – MANUFACTURING PLAN

This section will discuss the manufacturing process that is going to be produced while manufacturing the final unit. It begins with the selection of materials and components and passing it through manufacturing processes to achieve the required part. These processes include drilling, fastening, Fitting parts, Electricity Connection, and many more in which the appropriate process will be selected

4.1. Manufacturing process selection

According to Groover, a manufacturing process is a procedure designed to make physical changes to a starting work material to increase the value of that material (Groover, 2010). For this project, most of the parts will be assembled and connected with electrical wires, in a way that will contribute to ensuring that the project objectives are met.

4.1.1 Chamber Body

We choose in our test specific chamber that manufactured with A material that will not impact greatly the corrosiveness of the salt atmosphere The chamber body material was chosen knowing the chamber is subjected to a corrosive salt environment and elevated temperatures the body was constructed from P.V.C polyvinyl chloride materials with good corrosion resistance and enough thick that is providing temperature insulation. shown in Table the criteria's considered when comparing the given many types of material, and we find the plastic is the best choice.

Chamber Body cover, We make 24 holes with 5mm on top of the cover because during the test some of the water will evaporate in this case to avoid the moisture we have to make a small hole to transfer the moisture to the outside the chamber.

Figure 21: Body Chamber

Table 10:Critical matrix for chamber

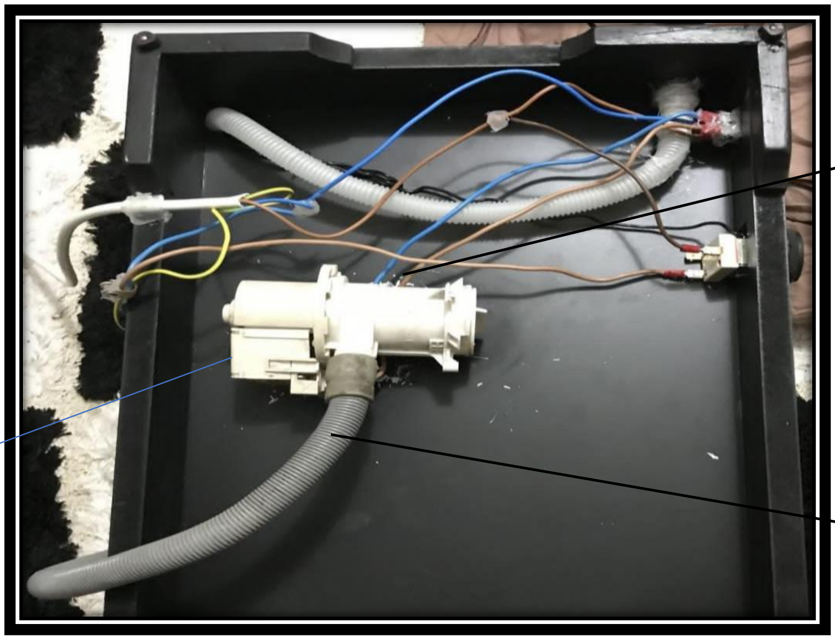
	Price	Strength	Ease of manufacture	vailability
Plastic	+ + +	++	+++	+++
Glass	+	+	+ +	+ + +
Stone	−	++ +	− −	+ +

Comment:

We choose plastic to manufacture the chamber since it is the most inflexible material in an item of cost, strength, ease of manufacture, and availability. is you can see that the manufacturing of plastic is the easiest between those three materials which make its cost lower than the others when you compare it with the glass or stone. also, although the stone has strength more than plastic choose plastic because we are looking for the weight too which make A. good point for plastic since it has good strength and lightweight it the same time, and also it is available and easy into finding it anywhere in the world.

4.1.2 Drainage motor

In our experiment, we need to rotate and stir the solution continuously and how to dispose of the solution after the completion of the experiment. The best way to do this is we used the motor when we searched for the motor, we found that the motor of the washing machines works the same mechanism that we need in our experience. We get a drainage motor and the fix under the base by silicon so that the solution would rotate and move continuously when the start button was pressed on the start button, the motor was connected to electricity and the power button was done by copper wires.



Two Copper Wires Connected with electricity and other one with switch bottom

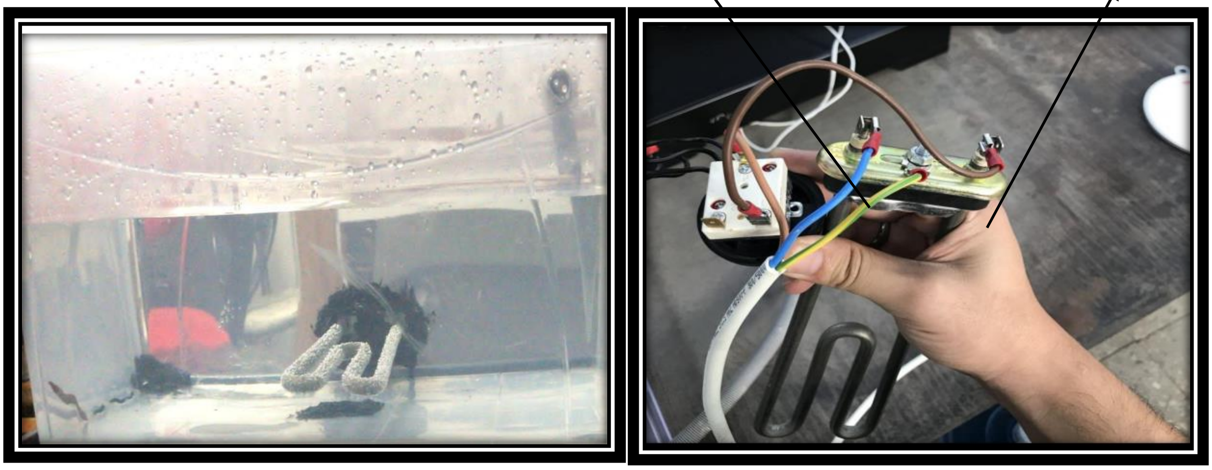
Drainage Motor fixed in hole by using silicon

Plastic pipe use to transfer rotate solution from down to up

Figure 21: Structure of Motor

4.1.3 Heat System

In the weight loss test, we found the best method to heat the solution is to use a heating system because it adopts the direct heating method. The heating speed is fast and the standby time is reduced, when the temperature richer. The constant temperature state automatically switched .the temperature is accurate. The heater was designed to operate at i400-500K and a thermal load of i500W. the heater was made from commercially pure i2 (CP-2) grade titanium, to avoid any incompatibility problems with water and two dissimilar metals. this includes the evaporator, e wick, transport and condenser lines and compensation chamber also eliminate expensive downtime due to equipment failure provide superior corrosion resistance deliver high heat transfer efficiency. In the Table shown the criteria are considered between different materials. So we fixed the heater in the body chamber by making a hole in the body chamber to placing the heater to do this step we fix the heater in the hole and we use silicon to fill up and close the hole from all side to avoid any liquid leaking, For adjust the temperature we connected the heater with Temperature control, also with electricity and switch to control the off and on prosses using copper wire.



Positive and native wire connected with electric to get energy and transfer it to heat

Copper wire which we connected with control temperature to adjected the heat temperature

Figure 22: Heat System

Table 11:Critical matrix Titanium Heater

	TITANIUM	**STEEL 1020**	**6061 aluminum**	**C268 copper**
Thermal Conductivity	1	3	5	7
Max. Service Temperature	10	4	2	6
Thermal Expansion	9	5	1	3
Cost	1	7	2	4
Total	21	19	10	20

4.1.4 Wood Base

In our test, we have to find a base that we can fix all the pieces on it. We did some research to choose the most appropriate base possible to do our test on it. We found that the wooden base is coated with a waterproof coating that is the best for our test for many reasons. Firstly, it is corrosion resistant this is the most important reason for choosing the wooden base. Secondly, its weight does not exceed 2kg. It can be easily carried thirdly the price Cheaper option compared to the others the table shown the criteria's considered. For the steps of how the parts were installed on the base first, we used silicone to fix the box in the middle of the base. Secondly, we made two holes in the front to fix the temperature controller, heat light, and the motor switch off /on, for heat light. We use a copper wire to connect light from the back with the temperature sensor and electric at the beginning of the experiment the light it w. will be turned on until the temperature reaches to the value which we adjected at the beginning by the temperature controller.

Heat light connected with temperature sensor

Figure 23: Wood Base

Figure 25: Wood Base after fixing

The hole for Temperature controller before we put it

Table 12:Critical matrix for Baes

	Price	Weight	Ease of Manufacture	Availability	Corrosion Resistant	Total 1\Best 10\ worse
Steel	8	9	9	5	9	40
Plastic	6	4	8	7	2	27
Wood	4	4	5	3	2	18

CHAPTER 5 - PRODUCT TESTING PLAN

5.1. Verification plan of the objectives of the project

Several tests will be conducted to validate the compatibility of the machine to the objectives of the design and ensure that the requirements and user expectations are met.

- The Demonstration will be performed to test if the designed height of the table and components are comfortable for the operator and that the controllers and the emergency stop switch are within reach when needed, as well as the movement around the machine is not restricted by the size and shape of the table.
- The main objective of the machine is to test the corrosion of the materials; this will be verified by allowing the machine to operate continuously for an extended period of time (a couple of hours) to test its ability in maintaining the salt spray on the materials without any issues. The main factor to be observed is the salt spray to see if there is any interruption or discontinuity in the spray, also the motor will be checked to see if any overheating is generated while the machine is continuously being operated.
- Due to the fact that the machine is capable to test the corrosion of materials, the Ability of the machine to operate smoothly with different materials and shapes will be tested by putting different shapes and different materials in terms of its strength, hardness and corrosion resistance in the machine and observing if there is any alteration in the performance when operating with it.
- The main idea of the machine is to know how much time that the material need to start to corrosion, so the capability of the machine to work without any mistakes will be by testing the air pressure, temperature, salt spray and defogging machine continuously at several time intervals (to check if there is any changes)

5.2. Verification plan of the applied engineering standards

In order to guarantee that the testing chamber operates under the specified standards of the ASTM B117, the following treats must be confirmed:

- For weight loss corrosion tests that simulate exposure to service environments, a commercial surface, closely resembling the one that would be used in service, will yield the most meaningful results.
- The temperature inside the chamber must be maintained at 30±1°C, therefor the humidifier must allow for 46°C, 47°C for given pressures 110, 124 kPa respectively
- The salted water pH must be evaluated before the test to be at 7±0.2, and that the salted solution contains 90% water and 10% NaCl. The purity of the salt must be that the other materials are less than 3% to not allow any of these other materials to work as corrosion inhibitors during the test.
- Electric engraving by means of a vibratory marking tool may be used when the extent of corrosion damage is known to be small. However, this approach to marking is much more susceptible to having the marks lost as a result of corrosion damage during testing
- Edge notching is especially applicable when extensive corrosion and accumulation of corrosion products is anticipated. Long term atmospheric tests and sea water immersion tests on steel alloys are examples where this approach is applicable.
- When it is undesirable to deform the surface of specimens after preparation procedures, for example, when testing coated surfaces, tags may be used for specimen identification. A metal or plastic wire can be used to attach the tag to the specimen and the specimen identification can be stamped on the tag. It is important to ensure that neither the tag nor the wire will corrode or degrade in the test environment. It is also important to be sure that there are no galvanic interactions between the tag, wire, and specimen

- Rinse thoroughly, hot air dry, and store in desiccator.
- When specimen preparation changes the metallurgical condition of the metal, other methods should be chosen or the metallurgical condition must be corrected by subsequent treatment. For example, shearing a specimen to size will cold work and may possibly fracture the edges.
- The clean, dry specimens should be measured and weighed. Dimensions determined to the third significant figure and mass determined to the fifth significant figure are suggested. When more significant figures are available on the measuring instruments, they should be recorded.
- Corrosion product removal procedures can be divided into three general categories: mechanical, chemical, and electrolytic.
- An ideal procedure should remove only corrosion products and not result in removal of any base metal. To determine the mass loss of the base metal when removing corrosion products, replicate uncorroded control specimens should be cleaned by the same procedure being used on the test specimen. By weighing the control specimen before and after cleaning, the extent of metal loss resulting from cleaning can be utilized to correct the corrosion mass loss
- The cleaning procedure should be repeated on specimens several times. The mass loss should be determined after each cleaning by weighing the specimen
- To minimize uncertainty associated with corrosion of the metal by the cleaning method, a method should be chosen to provide the lowest slope (near to horizont).

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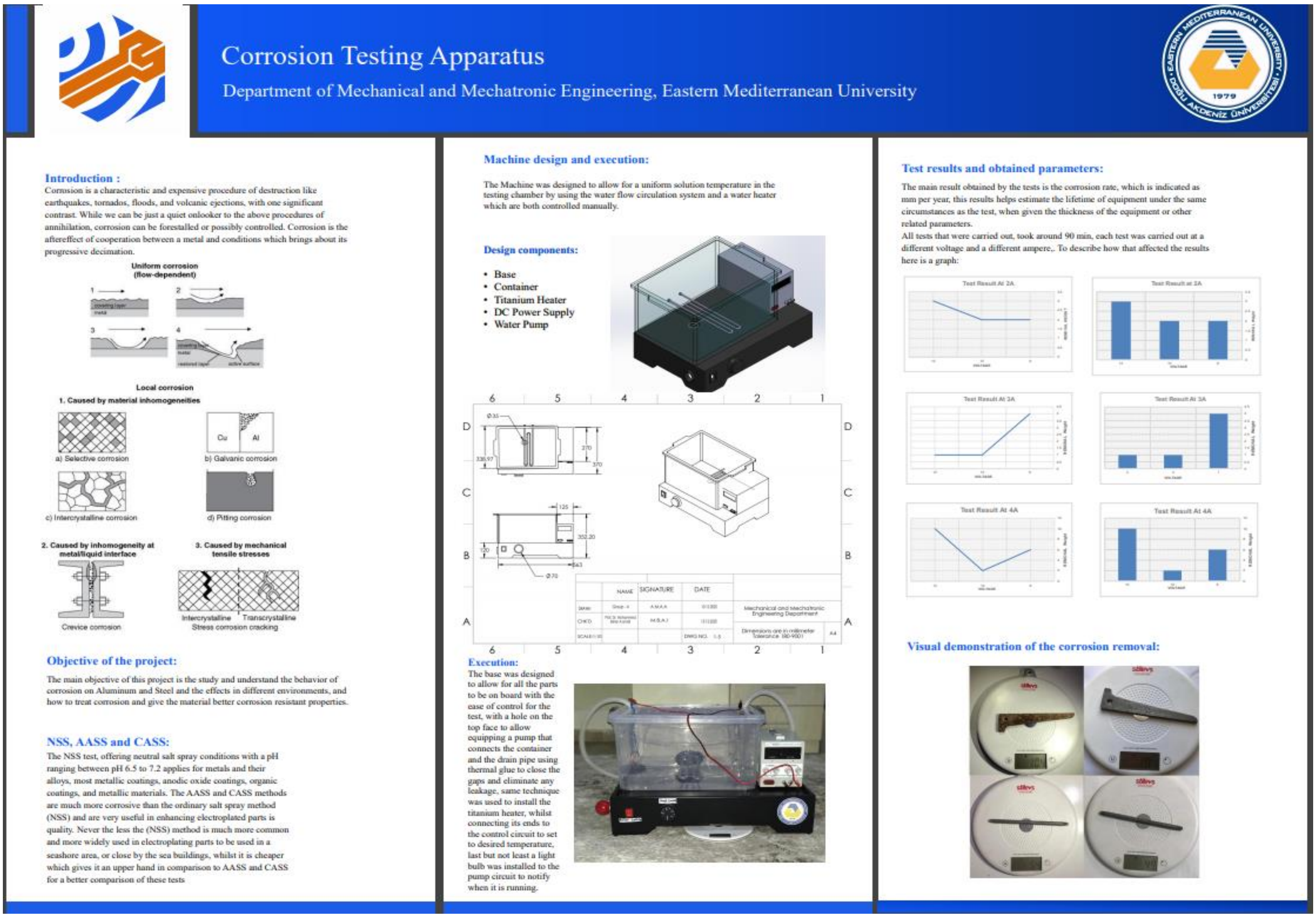
APPENDIX A: Electronic Media



Corrosion Testing Apparatus

Department of Mechanical and Mechatronic Engineering, Eastern Mediterranean University

Introduction :

Corrosion is a characteristic and expensive procedure of destruction like earthquakes, tornados, floods, and volcanic ejections, with one significant contrast. While we can be just a quiet onlooker to the above procedures of annihilation, corrosion can be forestalled or possibly controlled. Corrosion is the aftereffect of cooperation between a metal and conditions which brings about its progressive decimation.

Objective of the project:

The main objective of this project is the study and understand the behavior of corrosion on Aluminum and Steel and the effects in different environments, and how to treat corrosion and give the material better corrosion resistant properties.

NSS, AASS and CASS:

The NSS test, offering neutral salt spray conditions with a pH ranging between pH 6.5 to 7.2 applies for metals and their alloys, most metallic coatings, anodic oxide coatings, organic coatings, and metallic materials. The AASS and CASS methods are much more corrosive than the ordinary salt spray method (NSS) and are very useful in enhancing electroplated parts is quality. Never the less the (NSS) method is much more common and more widely used in electroplating parts to be used in a seashore area, or close by the sea buildings, whilst it is cheaper which gives it an upper hand in comparison to AASS and CASS for a better comparison of these tests

Machine design and execution:

The Machine was designed to allow for a uniform solution temperature in the testing chamber by using the water flow circulation system and a water heater which are both controlled manually.

Design components:

- Base
- Container
- Titanium Heater
- DC Power Supply
- Water Pump

Execution:

The base was designed to allow for all the parts to be on board with the ease of control for the test, with a hole on the top face to allow equipping a pump that connects the container and the drain pipe using thermal glue to close the gaps and eliminate any leakage, same technique was used to install the titanium heater, whilst connecting its ends to the control circuit to set to desired temperature, last but not least a light bulb was installed to the pump circuit to notify when it is running.

Test results and obtained parameters:

The main result obtained by the tests is the corrosion rate, which is indicated as mm per year, this results helps estimate the lifetime of equipment under the same circumstances as the test, when given the thickness of the equipment or other related parameters.

All tests that were carried out, took around 90 min, each test was carried out at a different voltage and a different ampere,. To describe how that affected the results here is a graph:

Visual demonstration of the corrosion removal:

- Also, there is a video for our machine that will be attached to the report.

APPENDIX B: Standards

Table 13:Project Standards.

Standards	Definition
ASTM D7408	(Standard Specification for Non-Reinforced PVC (Polyvinyl Chloride))
ASTM G78	Standard Guide for Crevice Corrosion Testing.
ASTM D1141-98	Standard Practice for the Preparation of Substitute Ocean Water.
OS950	a plastic optical level sensor is made from a polysulfone polymer
DIN/IEC 60751	Industrial platinum resistance thermometers and platinum temperature sensors
ISO 9227	Corrosion tests in artificial atmospheres.
D 1384	Test Method for Corrosion Test for Engine Coolants
ASTM G31.	We run these tests over a wide range of temperatures and test parameters, and can tailor every test to meet your specific needs
ASTM D1654	Scribing and scribe creep evaluation.
ASTM D610	Degree of rusting.
ASTM D714	Degree of paint blistering.

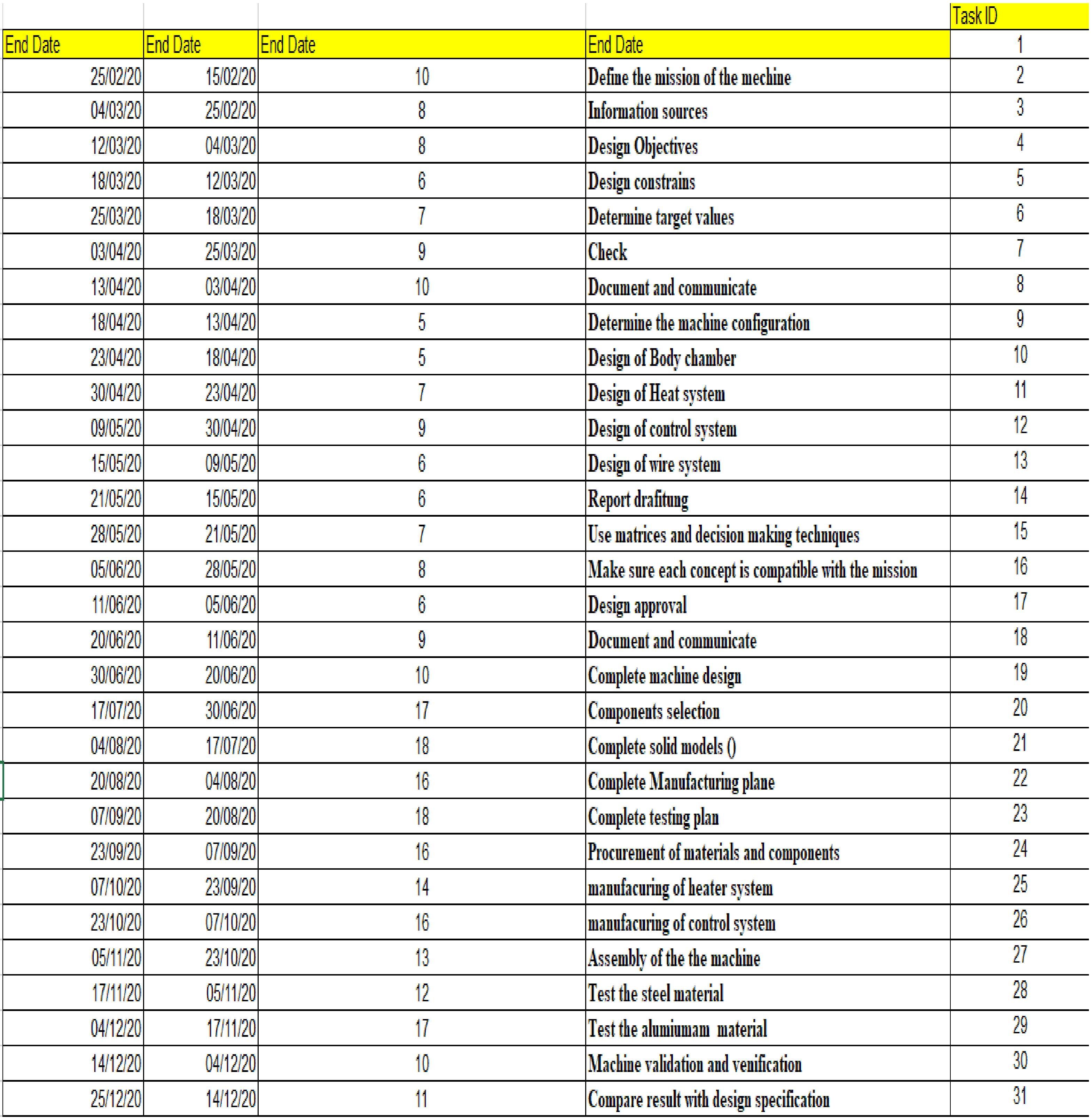
APPENDIXC: Constraints

Constraints	**Yes**	**No**
Economic	X	
Environmental	X	
Reliability	X	
Availability	X	
Manufacturability		X
Ethical	X	
Social	X	
Political		X
Health & safety		X
Efficiency	X	

APPENDIX D: Logbook& Project Timeline

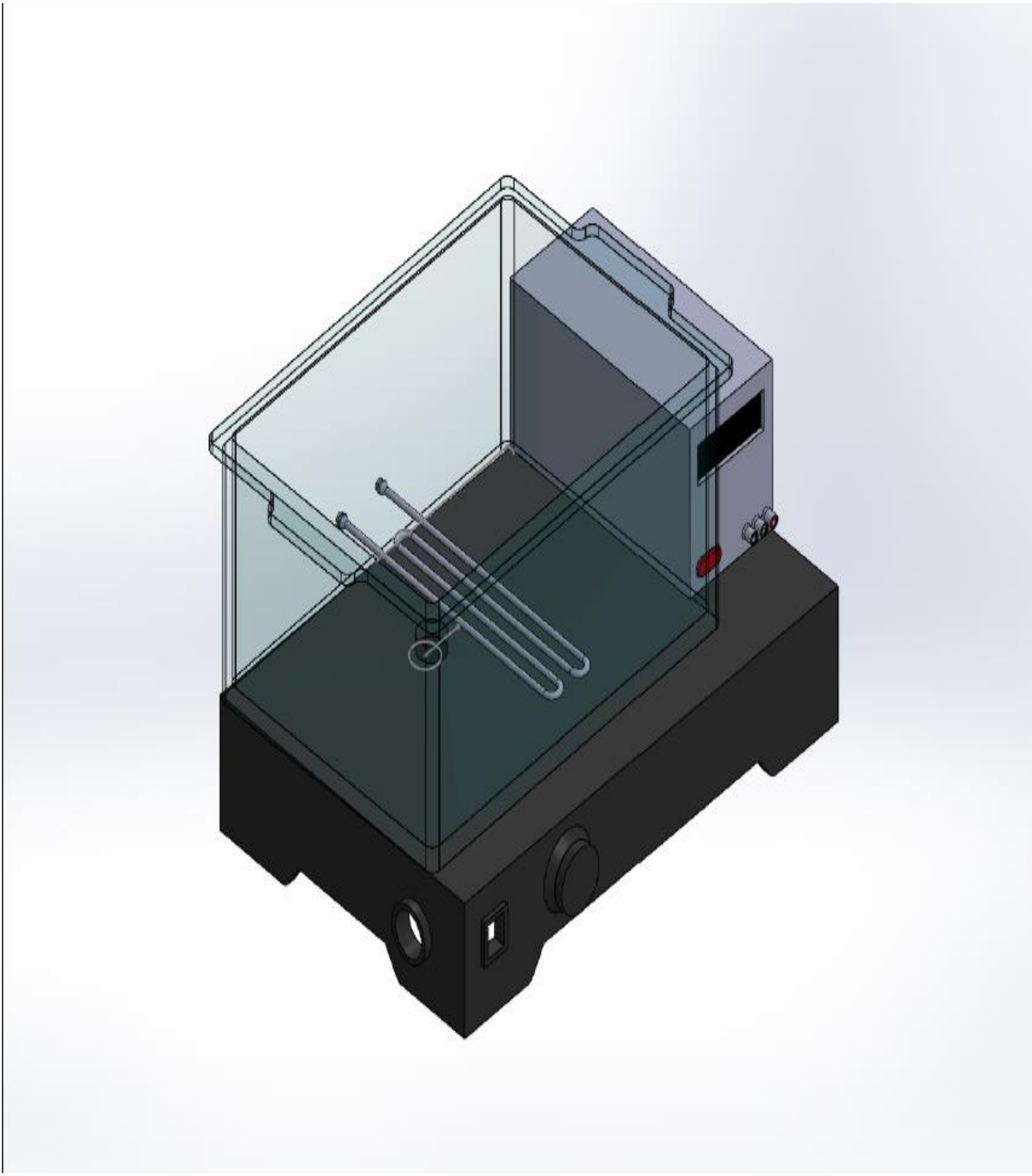
Date	Brief description of the performed work
27/2/2020	Team members meeting to discuss and share ideas about project redesign and development options. The task was assigned to each member.
10/3/2020	Meeting with the supervisor to propose and discuss ideas about project redesign and development options.
15/3/2020	Team members online meeting to discuss previous-report summary. Task was assigned to each team member.
22/3/2020	Team members meeting to discuss tasks assigned ion I(15/3). New task related to report writing was assigned.
26/3/2020	Team members meeting to further discuss tasks assigned ion I(15/3) and check the project progress.
1/4/2020	Team members meeting to discuss and iShares ideas about tasks assigned ion I(22/3). New tasks related to report writing were assigned.
14/4/2020	Meeting with the supervisor to discuss corrosion test machine I is election decisions and project progress.
4/5/2020	Team members meeting to discuss and share ideas about tasks assigned ion (1/4).
1/6/2020	Meeting with the supervisor to discuss project progress and updates about salt is pray corrosion test machine is election.

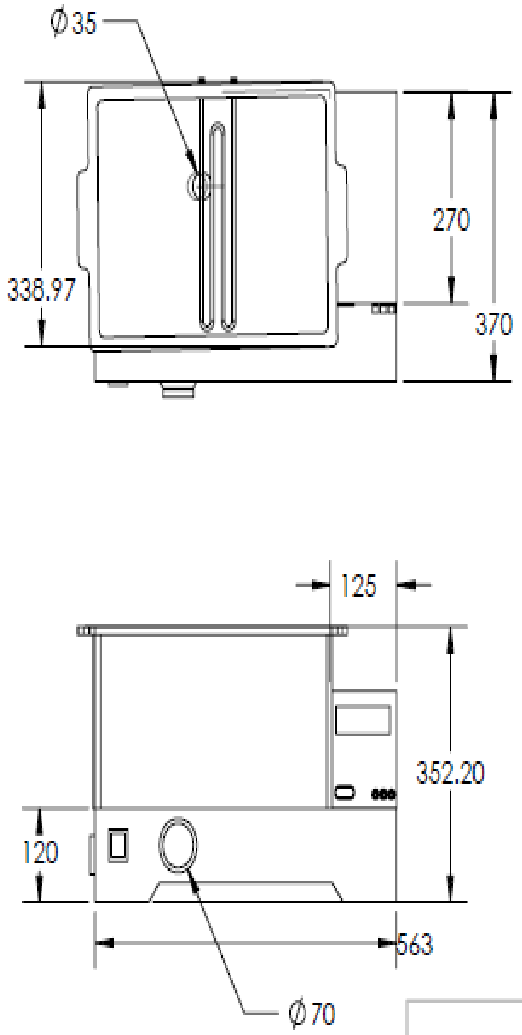

2021-01-30
2020-12-11
2020-10-22
2020-09-02
2020-07-14
2020-05-25
2020-04-05
2020-02-15
Define the mission of the mechine
Information sources
Design Objectives
Design constrains
Determine target values
Check
Document and communicate
Determine the machine configuration
Design of Body chamber
Design of Heat system
Design of control system
Design of wire system
Report drafitung
Use matrices and decision making techniques
Make sure each concept is compatible with the mission
Design approval
Document and communicate
Complete machine design
Components selection
Complete solid models ()
Complete Manufacturing plane
Complete testing plan
Procurement of materials and components
manufacuring of heater system
manufacuring of control system
Assembly of the the machine
Test the steel material
Test the alumiumam material
Machine validation and venification
Compare result with design specification

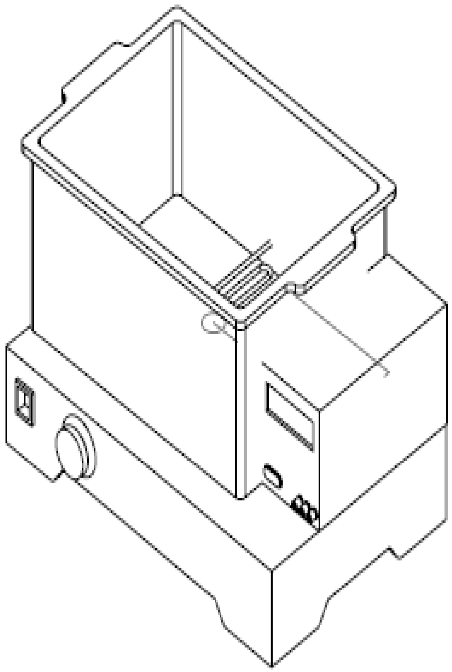


				Task ID
End Date	End Date	End Date	End Date	1
25/02/20	15/02/20	10	Define the mission of the mechine	2
04/03/20	25/02/20	8	Information sources	3
12/03/20	04/03/20	8	Design Objectives	4
18/03/20	12/03/20	6	Design constrains	5
25/03/20	18/03/20	7	Determine target values	6
03/04/20	25/03/20	9	Check	7
13/04/20	03/04/20	10	Document and communicate	8
18/04/20	13/04/20	5	Determine the machine configuration	9
23/04/20	18/04/20	5	Design of Body chamber	10
30/04/20	23/04/20	7	Design of Heat system	11
09/05/20	30/04/20	9	Design of control system	12
15/05/20	09/05/20	6	Design of wire system	13
21/05/20	15/05/20	6	Report drafitung	14
28/05/20	21/05/20	7	Use matrices and decision making techniques	15
05/06/20	28/05/20	8	Make sure each concept is compatible with the mission	16
11/06/20	05/06/20	6	Design approval	17
20/06/20	11/06/20	9	Document and communicate	18
30/06/20	20/06/20	10	Complete machine design	19
17/07/20	30/06/20	17	Components selection	20
04/08/20	17/07/20	18	Complete solid models ()	21
20/08/20	04/08/20	16	Complete Manufacturing plane	22
07/09/20	20/08/20	18	Complete testing plan	23
23/09/20	07/09/20	16	Procurement of materials and components	24
07/10/20	23/09/20	14	manufacuring of heater system	25
23/10/20	07/10/20	16	manufacuring of control system	26
05/11/20	23/10/20	13	Assembly of the the machine	27
17/11/20	05/11/20	12	Test the steel material	28
04/12/20	17/11/20	17	Test the alumiumam material	29
14/12/20	04/12/20	10	Machine validation and venification	30
25/12/20	14/12/20	11	Compare result with design specification	31

APPENDIX E: Engineerig Drowings







	NAME	SIGNATURE	DATE		
DRAWN	Group - 4	A.M.A.A	10-12-2020	Mechanical and Mechatronic Engineering Department	
CHK'D	Prof. Dr. Mohammed Bsher A.Ismail	M.B.A.I	15-12-2020		
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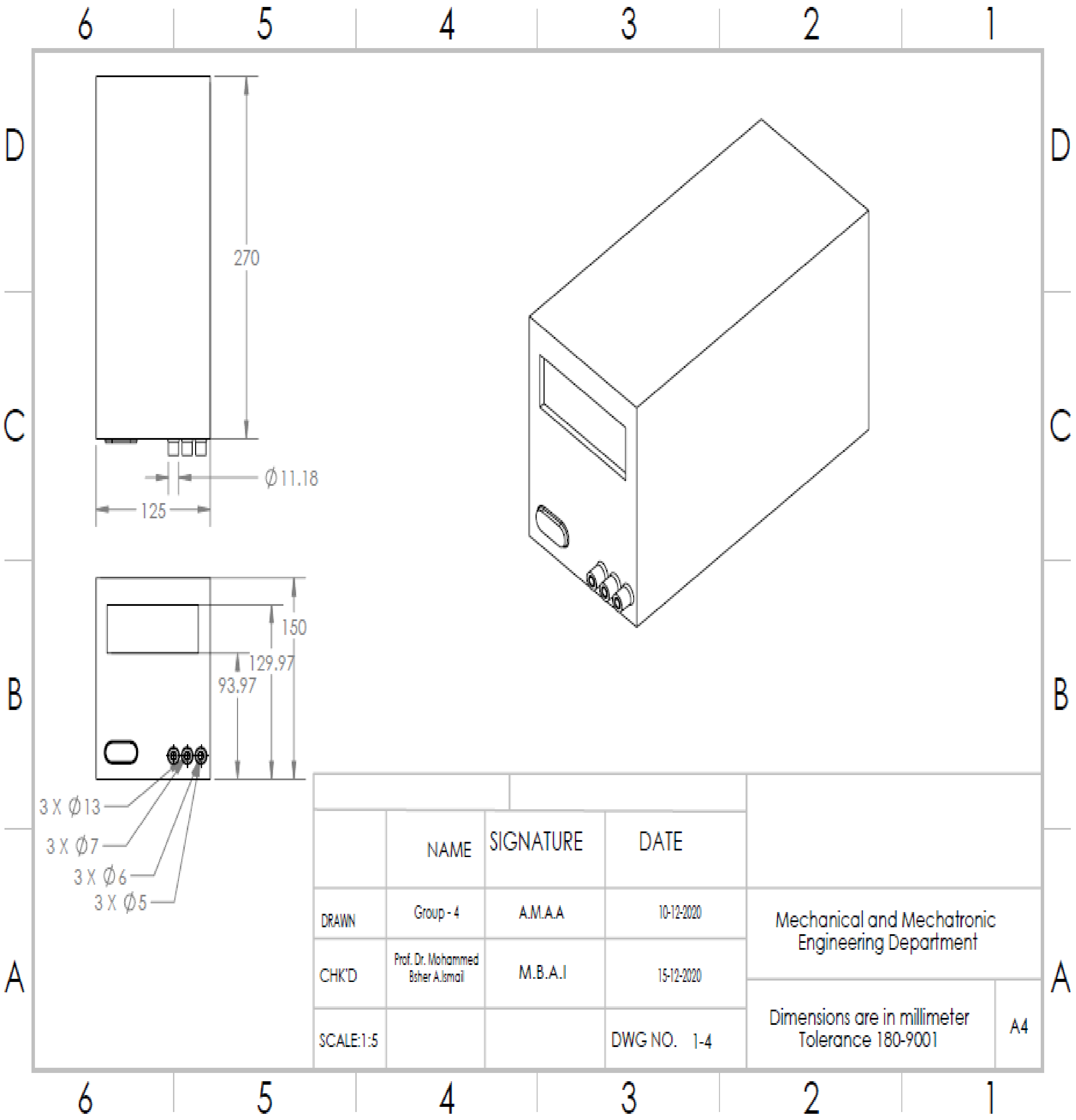

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CHK'D	Prof. Dr. Mohammed Bsher A.Ismail	M.B.A.I	15-12-2020	Dimensions are in millimeter Tolerance 180-9001	A4
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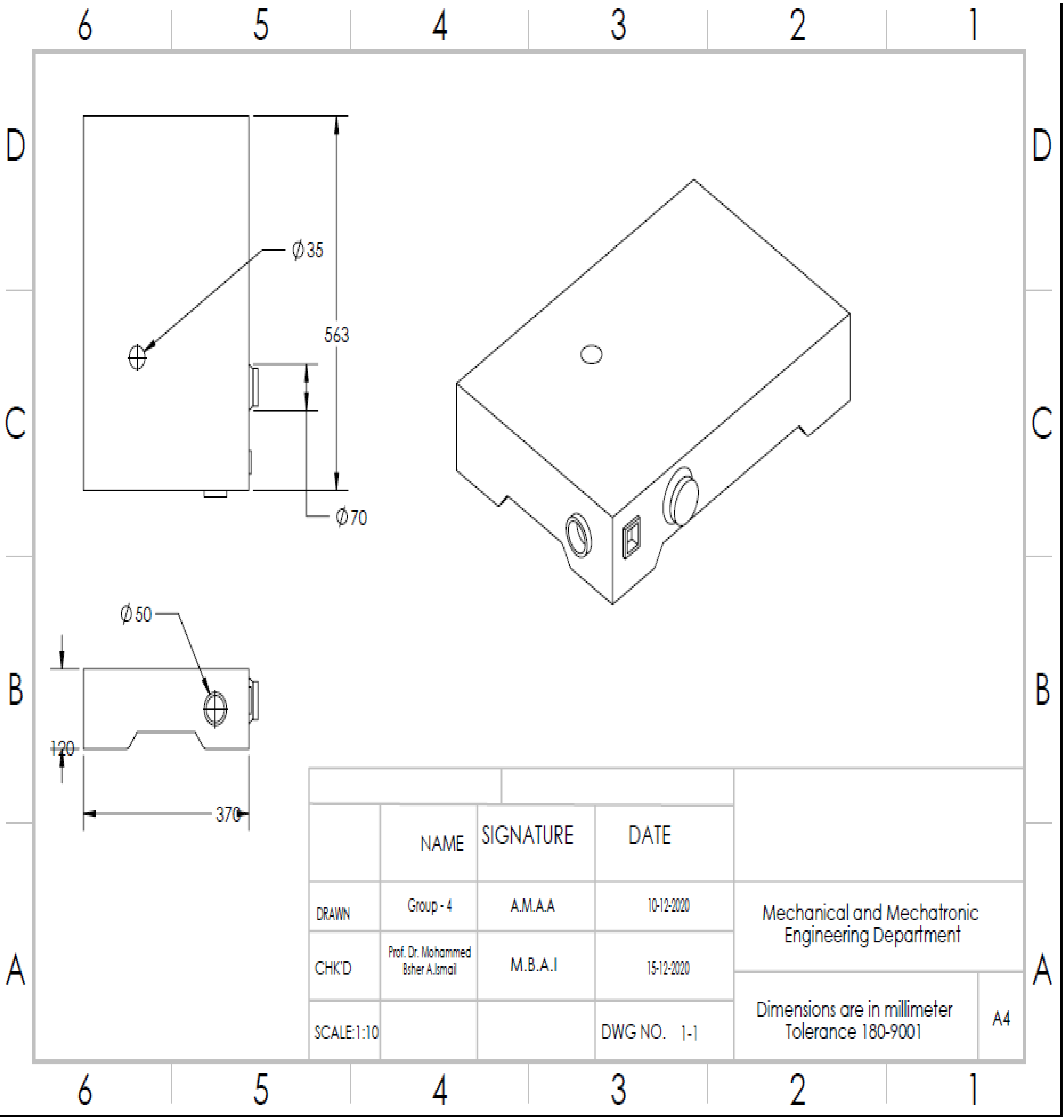
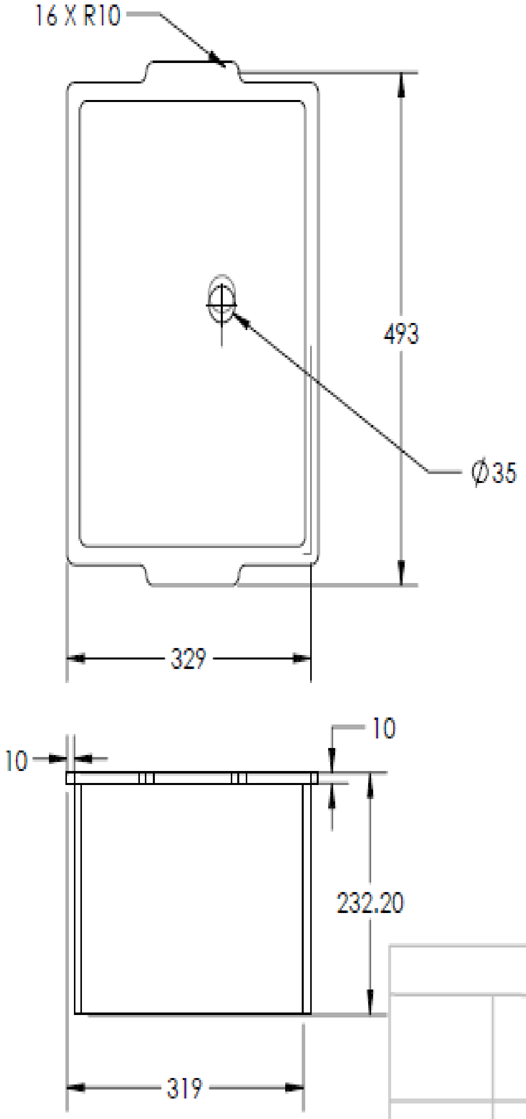
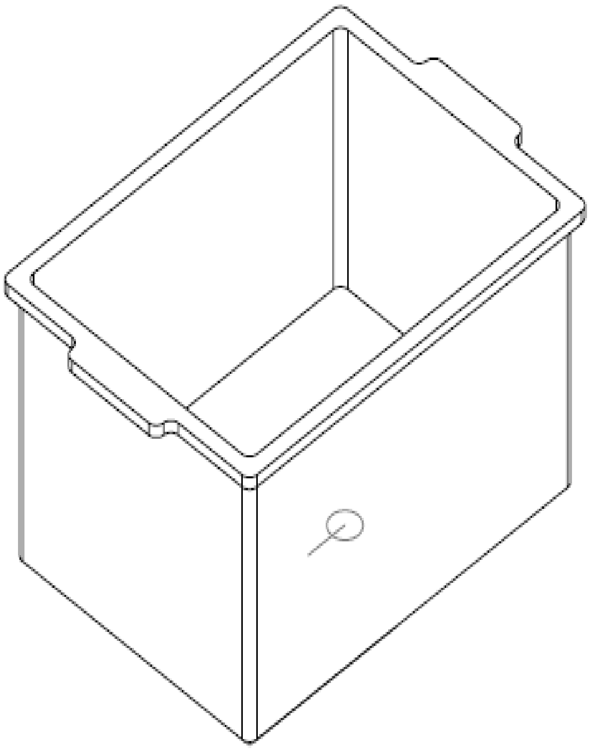
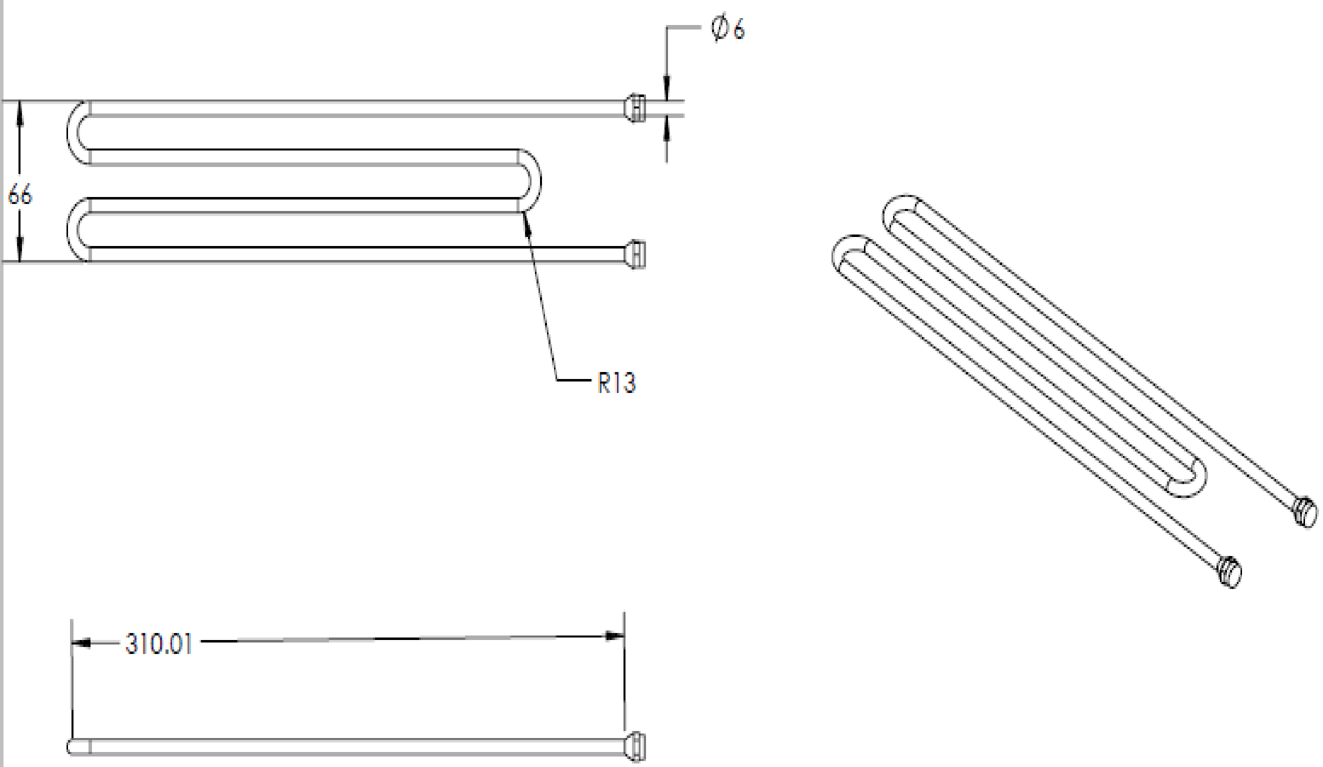


	NAME	SIGNATURE	DATE		
DRAWN	Group - 4	A.M.A.A	10-12-2020	Mechanical and Mechatronic Engineering Department	
CHK'D	Prof. Dr. Mohammed Bsher A.Ismail	M.B.A.I	15-12-2020	Dimensions are in millimeter Tolerance 180-9001	A4
SCALE:1:10			DWG NO. 1-1		





	NAME	SIGNATURE	DATE		
DRAWN	Group - 4	A.M.A.A	10-12-2020	Mechanical and Mechatronic Engineering Department	
CHK'D	Prof. Dr. Mohammed Bsher A.Ismail	M.B.A.I	15-12-2020		
SCALE:1:5			DWG NO. 1-2	Dimensions are in millimeter Tolerance 180-9001	A4



	NAME	SIGNATURE	DATE		
DRAWN	Group - 4	A.M.A.A	10-12-2020	Mechanical and Mechatronic Engineering Department	
CHK'D	Prof. Dr. Mohammed Bsher A.Ismail	M.B.A.I	15-12-2020	Dimensions are in millimeter Tolerance 180-9001	A4
SCALE:1:5			DWG NO. 1-3		