A novel acrylic acid storage reservoir design and manufacture to inhibit a Polymerization Challenge

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Abstract: This manuscript proposed a novel design and manufacture of 30,000 liters of acrylic acid storage reservoir according to construction code EN 5500:2009. particularly because the first alternative is limited storage with a volume of 100 liters and does not fulfill the demand of the plant or public safety standards.The proposed design has the ability to encounter all the challenges related to storing acrylic acid in terms of environmental and health risks, flammability, and unexpected Polymerization. All design steps, measurements, and calculations are described in detail in this manuscript.

Key-Words: - Polymerization, Acrylic acid, storage reservoir, Portable reservoir, specific dangers, flammability

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1. Introduction

Acrylic acid ($C_3H_4O_2$) has no color, destructive solvent with an overpowering fragrance that is typically made by oxidizing acrolein [1-4]. If acrylic acid is not sufficiently restrained, it can quickly polymerize. Pollutants or unnecessary warmth can induce Polymerization even though it is correctly prevented. Unmanaged Polymerization is fast which could be very strong and intense, producing a lot of heat and raising the pressure. If the pressure rises, heated vapor and polymer are ejected, which can self-ignite. Unregulated Polymerization of acrylic acid has resulted in detonations [5].

2. Design Challenges and Potential Hazards

There are many challenges facing the process of storing and preserving a dangerous liquid of Acrylic acid. It can be summarized as follows [6-8]

2.1. Polymerization

The huge amount of the availability of free radicals is a well noticeable property of acrylic esters. Fire, illumination, or X-ray irradiation will produce free radicals, stimulating radical formation components. Many materials, like peroxides producing substances, are considered to quickly facilitate Polymerization (aldehydes, amines, ethers, nitric acid). Polymerization may also be initiated by the reactions of redox with polyvalent intensive metal ions or metal hydrolysis with solid metallic acids. Humidity and dampness increase the possibility of Polymerization. The two most important reasons for the leading of a Polymerization problem are:

2.1.1. Overheating

High temperature has to be the most common leading risk factor for Polymerization (e.g., keeping close to a heat provenance). The acrylic esters can be stored at an ultimate temperature of 35°C. Increasing Thermal energy can cause the stabilizer system (comprising regarding to hydroquinone-mono-methyl-ether MEHQ or oxygen) to consume more quickly, resulting in inadequate Polymerization.

2.1.2. Oxygen Reduction

Keeping or treating Acrylic esters cannot ever be exposed to a static ambiance. The existence of oxygen is needed for the balance to perform correctly. Oxygen in the water transforms carbon-settled free radicals into oxygen-settled primary radicals. To regulate the acrylic ester, the MEHQ traps those based cores of oxygen radicals. Voidness containing appropriate air must always be maintained on top of the monomer to ensure resistor effectiveness.

Dissolved oxygen participates in the interaction of activation and is gradually absorbed. The concentration of dissolved oxygen must be supplemented regularly, which can be completed by full aeration of the liquid form (e.g., Redistribution material in a reservoir or stirring tanks with spinning blades with rotational motion).

2.1.3. Radioactive contaminants

Proper domestic duties and extra precautions must be made to eliminate any toxins out of a reservoir. Many compounds have been identified which can react quickly with acrylic esters. Substances competent of causing uncontrolled polymerizations, such as peroxides, peroxide forming additives, or azo compounds, pose a significant risk. In such situations, initiating radicals can be generated also by polyvalent intensive metallic ions involved in redox reactions.

Copper, cobalt, nickel, chromium, and iron are examples of metal ions. Limited amounts of nitric acid can also initiate Polymerization.

Containers must be safe from being filled by accident with other products or Rebound from other processing reservoirs. This is ideally accomplished by using specific charging and discharging track with good marking.

Containers, tubes, and Containers used for transportation should be tested for polymer-forming regularly since the polymer may provide assistance as a source for moreover Polymerization. Ester polymers are mostly dissolved in the monomer.

2.2. Flammability and Detonation Dangers

Except for 2-Ethylhexyl acrylate, whole acrylic esters emit easily extremely flammable vapors at the room's temperature. In the presence of combustible materials and oxygen on top of the LOC, an explosion can happen. Sparkles release from charged particles or poorly grounded and bonded reservoirs, also the typical causes of spark, should be examined.

2.3. Considerations Affecting Safety and Health

Acrylic esters have the potential to irritate human tissues and mucoid overlay. Erythematous or superficial reddening of the skin may occur when cutaneous tissue is exposed to liquids or massive condensation of vapors for a long duration. Pustule formation is also being found in exceptional instances following exposition for a long time to liquid esters. The vast majority of the esters have been shown to cause skin sensitization in humans.

Inhaling condensed gases and haze may cause mild to extreme lung tissue excitement. Higher condensation can cause pulmonary edema, although lower condensations can cause nose and larynx inflammation. After sniffing, lachrymation of the pupils is also possible. The gasses of lighter esters have a narcotic effect, causing sleepiness or unconsciousness in few situations.

While gulping acrylic esters isn't a common option of usual human doings, it can cause serious agitation or damages to the mouth, nose, oesophagus, and stomach.

There have been no reports of adverse health consequences in humans who have been unsafe against a small dosage of acrylic esters for one time or twice.

3. Storage Reservoir Design Requirements

To design the acrylic acid storage reservoir, the following requirement must be taken [5-6, 9-11]:

3.1.Temperature Control`

Hot temperatures are a big problem when storing acrylic esters. Temperatures above 35 °C must be prevented because they could cause the inhibitor mechanism to degrade prematurely. Acrylic esters must typically be kept at room temperature.

The first significant constraint for external reservoirs is to keep the temperature below 35 degrees Celsius, allowing enough time to deal with any temperature rise caused by polarization or combustion.

In such instances, a heat exchanger, which is a very common piece of equipment, may extract the heat produced by the pump or provide conditioning in high temperatures.

Internally or externally, cooling-heating coils may also be used to hold the temperature between 15 and 35 ℃.

- Heat exchanger interior surfaces and inner coil out surfaces must be cleaned regularly.
- Using steam in warming or acrylic acid is often allowed.
- The internal container must be aperture to the outside to have good ventilation.
- In the case of internal process materials, a characteristic firefighting system should be mounted.

3.2.Storing Timeframe

While preservation, the inhibitor mechanism, which consists of MEHQ and oxygen, is steadily depleted. As a result, oxygen can be replenished regularly by inciting the monomer and getting it into near exposure to air in the container's headspace. The required oxygen condensation in tankers is better preserved by periodically rotating the tank fluids or materials for a few hours monthly. While soluble oxygen degrades faster than MEHQ, an analytical calculation of the repression efficiency is also advised if the substance is stored for even more than two months. The average of tank temperature range primarily determines the level of inhibitors and oxygen intake. However, the inhibition reaction (monomer plus oxygen) produces greater radical form content levels over time. This can have an adverse impact on the reactions of the monomer in regular use. Large amounts of radical-creating content can make Polymerization more complicated. Consequently, the substance's temperature will not rise above 35 Celsius, and the inhibitor dosage is controlled correctly; stable preservation for one year can be anticipated.

3.3.Dissolving Iced Acrylic Acid

Acrylic acid cannot be frozen (its freezing temperature is 13 ℃), so melting it could be highly dangerous. As acrylic acid freezes, the first crystals form along the reservoir's internal surface. The inhibitor is contained in the existing solvent since there is a very little inhibitor in the crystalline form of acrylic acid.

Freezing concentrates all non-acrylic acid elements in the liquid form, potentially depleting the crystalline layer of MEHQ inhibitor and thawed oxygen. Fast Polymerization can also be happened by defrosting conditions like localized regions of fire. If we have to avoid freezing, it is best to use heated water trace and isolated tubes.

The acid's temperature can be held between 15 and 25 Celsius, with low and high-temperature warnings. The maximum level of 25 Celsius is intended to slow dimer development, which has an effect on product goodness, but it isn't a safety concern. Temperatures over 45°C (113°F) will cause uncontrolled Polymerization; hence, the temperature that used in melting acrylic acid shouldn't be above 35-45°C (95-113°F). If freezing does happen, the next steps are recommended.

- In no case should steam has been used to raise the temperature or melt acrylic acid.
- Electrical temperature traceability cannot be used on piping devices, including (filters, valves, and pumps) or containers in acrylic acid operation, before checking that the overall electrical tracing temperature during warming or melting does not exceed 35-45°C (95-113°F).
- Due to advanced updates, self-limiting or constant wattage electrical heat trace

restricted to temperatures under 65°C (149°F) and embedded to monitor at 35-45°C is suitable for this operation. An isolated high-temperature stop at 35-45 C (95-113°F) can also be used as an additional protection feature to protect against tracing device failure. Thawing is best accomplished by recirculating the liquid that has not been frozen into a heat exchanger with heated water as a medium that can transfer heat. This both warms the combination and redistributes the inhibitor and dissolved oxygen.

- The temperatures of water and the dissolved acrylic acid should be carefully regulated and monitored.
- To Distribution the inhibitor again and replenish the dissolved oxygen, thoroughly mix the acrylic acid.
- The temperature of the acrylic acid must be held in a range of 15 to 25 degrees Celsius. Never drain liquid from an incompletely thawed acid container while it is already dissolved; the residual fluid could be severely under-inhibited. Frozen content left in a container after unloading will produce a perilous situation.

3.4.Pumps Overheating

When a pump overheats, a strong polymerization may happen, resulting in severe injury or property damage or both of them.

There are several options that will help protect the pump from getting too hot below:

- A pump with an internal sensing element to control the temperature , a warning, and a wholly closed option may be used
- A temperature sensor with a warning and shutdown choice can be installed on the outlet port.
- A power meter indicator with a warning and a stop button may be used; an abrupt decrease in power usage happens due to the discharge line closure or deadheading in the centrifugal engine, which quickly overheats the pump the acrylic acid.
- A flow monitoring feature on the discharge port reads low flow and is linked to a warning and a disconnect switch.
- Fluid indicators in the suction line prevent the pump from running dry by detecting the liquid and triggering the warning and disconnect switch.
- There must be two distinct types of sensors given.
- A Centrifugal pump with a double mechanical seal and a magnetic motor is recommended. (Equipment interlocks are needed to avoid overheating during oversized loads.)
- Pump with a midriff that is operated by air.
- Mechanical parts connected with acrylic acid (such as seals and bearings) must be cleaned, lubricated, and adequately cooled, as high temperatures can allow polymer particles to grow.
- To prevent the truck-installed pump from getting too hot, discharge from the truck to the reservoir should be accomplished by gravity force.

3.5.Detection of a potentially dangerous situation on the inside

Daily review is required on the inside to ensure the polymer does not cover critical safety equipment. It is strongly advised that two separate temperature monitors be attached to an alert in the control room, which can also track the amount at which the temperature changes. Diligent monitoring would provide enough time for emergency preparedness.

3.6.Protection for Ventilation Nozzles and Tubes from Polymer Creation

Acrylic esters extracted from vapor lack MEHQ stabilizer and are able to Polymerization, which can clog critical pressure and vacuum relief valves.

Some considerations can be applied:

- Drain the accumulated liquid by sloping the ventilation duct.
- A sluggish tank is given for the liquid drain.
- Based on the acrylic ester employed, electric detection can be utilized to warm the ventilation duct.

3.7.Indoor Storage facilities

Consider the following:

- Local standards and rules must be followed.
- A leakage monitoring system should be mounted.

- Tracking for spills
- A Good ventilated environment prevents vapor build-up in the structure's lower levels, which is thicker than air.
- A foam unit must be utilized to eradicate the acrylic ac explosion or blaze.

3.8.Other Considerations

Any consideration needs to be given to building a container with the necessary supplementary equipment. Often have an embanked area ready to install the outside reservoir and pump. This area should be wide enough to accommodate the enormous reservoir capacity (the needed 30,000 litters capacity of Acrylic acid), as seen in figure 2.

4. Material and Method

An Innovative Construction material manufacturer as concrete admixtures, adhesives, waterproofing, constrains of storage this material in tanks with 30,000 letters capacity, the required auxiliary systems according to guide line in EN 5500:2009. The script begins with an introduction that describes the Acrylic acid considered in our design, then deals with particular dangers in an appropriate manner comprising health and flammability, environmental risk, and the potential untimely polymerization, followed with required calculations to design the storage tank part.

4.1.Load considerations [13-14]

The accompanying loads must be taken into consideration in the construction of a chamber, if applicable.

- Configuration of pressure from inside and outside.
- Within working conditions, the upper limit of the static head of the stored fluid.
- The reservoir weights.
- Within normal operating conditions, the weight limit of the components is.
- Wind loads.
- Earthquake and disaster loads.
- Other weights that support or react to the reservoir.
- Transport system and final location controlling.
- Test pressure is required. Where a design review and inspection are needed, apply experiment pressure.

  It is impossible to show the appropriateness of this project, e.g., by analogy with the action of other reservoirs, consideration must be given to the impact of the subsequent loads [16-17]:
- Regional stresses induced by reinforcing lugs, ring girders, saddles, inner supports, or linking piping, or deliberate middle line offsets in close ingredients.
- Shock forces are generated by hammering water or rushing container materials.
- Bending moments induced by the strangeness of the center of gravity due to the container's centerline (neutral axis).

- Temperature fluctuations, like movement situations and variations in the thermal expansion coefficients, create stress.
- the variations of temperature and Pressure.

4.2.Design Reservoir Pressure: [15-18]

The required computed pressure must not be less than:

- The pressure that will leave the container as the pressure freeing valve begins to release, or the pressure freeing instrument's fixed pressure, whichever is greater.
- The highest pressure can be achieved in operation if a releasing system does not constrain it. Where appropriate, the design pressure must contain the static head.
- Containers exposed to exterior pressure must be built to withstand the whole pressure difference to be subjected to operation.

  It is advised that vacuum containers be equipped for 1 Mpa except if the vacuum brake valve or equivalent system is available, in which situation the min design pressure could be used through consensus with the producer, customer, and the agency which gives certifications after testing.

4.3.Design Maximum Temperature

The max limit of allowable temperature applied to assess the required nominal design intensity for the chosen materials to achieve design must not be below the highest expected average metal temperature in use. (Above 925 C for grade 304 or 1095C for grade 309)

The lowest material temperature required in operation shall be used to assess the appropriateness of the material to withstand ductile failure at the minimum design temperature. Many carbon steels with a proper MDMT rating of -20 F cannot meet this transition range until temperatures fall below -20 F. The substance remains completely ductile until temperatures of -20 F or below are achieved.

4.4.Design Thermal Loads

To prevent undue thermal pressures, requirements must be created in the structure to allow for thermal expansion and shrinkage.

4.5.Erosion and Corrosion: [20]

The required thickness identified in addition to that needed for design condition must be sufficient to cover the cumulative amount of corrosion anticipated on one or both sides of the container. The purchaser must give it in the purchasing requirements.

It must be at minimum equivalent to the predicted corrosion wasteful spending during the reservoir's identified life. It must be no less than one millimeter unless a secure layer is used.

4.6.Stresses build-up types [20]

The proposed design was followed the below specifications:

- At the design temperature, the strength of design for components must not surpass the required design strength for the needed components.
- The new building elements are (grade 304 of Austenitic stainless steel),
- Regardless of the direction of the primarily welded seams, the following specification stress restrictions must be adhered to: (i) Carbon manganese steel and Carbon; and (ii) The structure stress must not be greater than R m /5. The Categories of construction are available in the code [2]

4.7.Austenitic [21-24]

The structure stress must not be greater than 120 N/mm^2 or 120*(450/400+t), where t is the design temperature.
The design stress must be multiplied by 0.8 if the required lowest yield strength is less than 230 Pascal.

4.8.Strength of Nominal Design

The nominal project strength (fN) was calculated as follows:

- The lower of fF & fE were obtained from adding protection factors through the following two sections.
- Project strength that not changes over time
- If the substance with defined higher temperatures numbers: equivalent to 50 degrees Celsius, the below strengths is fE= Rm/2.5 or Re/1.5, Just whatever has the lowest value.
- In case of design strength that changes over time, the below strengths is fF=Srt/1.3
- In this situation, the reservoir will be mounted in a skirted or covered field, then no wind load (overthrow stability) will be considered when computing the uplift force, and the reservoir will never be grounded. As a result, we will be using the minimum permissible plate thickness with regards to API 650 Articles to assess the bottom plate thickness: shell thickness exceeds 19 millimeters, minimum plate thickness equals 6millimeters.
- All ground plates must have an eroded thickness of not lower than 6 millimeters [49.8 kg / m^2], Except otherwise accepted by the Customer, both the nominal width of the rectangular and sketch plates should be at least one thousand and eight hundred millimeter
- Request base plates of an adequate size such as shortened, at least a 50-millimeter diameter projects beyond the case.
- The base plates must be fastened by welding.
- The thicknesses of the circumferential base plates must not be below the larger calculated thickness for product design (and furthermore, any required corrosion recompense) or design of the hydrostatic analysis. Above the height of H x G=23 m, an elastic inspection should be performed to assess the thickness of the ring-shaped plate. The (SI) circular base-Plate Thicknesses (tb) are avialbe in [API standard 650] [3]

Where; a: Layer thickness mentions the thickness of the weared-out shell plate by corrosion for the product and the approximate thickness for hydrostatic testing.

b: The highest tension of the first shell sequence is the stress to be included (higher than the design stress or the hydrostatic examination stress).

The stress can be calculated by dividing the necessary thickness by the value in "a," then multiplying by the appropriate, permissible stress.

Design Stress = (td – CA/ weared out by corrosion t) (Sd)

Hydrostatic Test Stress = (tt/ nominal t) (St)

The thicknesses listed in the article are centered on the foundation supplying standardized protection over the recirculation plate's entire diameter. Settlement can cause further stresses in the ring-shaped plate unless the base is duly consolidated, which is basically inside a cement rings wall.

The following is a standard method for doing calculations of the end thickness of a tori spherical tank. [BSI-Pd 5500-2009]

1. Determine p/f using the model pressure and the needed material's design.
2. Start reading up to the suggested end shape's suitable he/D line, then over to e/D axis to the equivalent value of e/D .
3. To calculate the ended thickness, multiply by D.
   $p/f = 0.084361095/136.66 = 6.17 * 10^{-4}$
   $he/D = 320/ 2488 = 0.128$

Since the values of he/D and p/f in this scenario are less than the minimum, we used the standard constraint to calculate the tank thickness.

4.9.Shell Design

The necessary frame or the product's shell thickness is the larger specification frame thickness consisting of any permissible corrosion or the hydrostatic testing frame thickness. Still, it cannot be less than the next:

The following was taken in our design:

1. The actual container diameter must be the diameter of the top shell-course plates centerline, except as defined by the Customer.
2. The pinning specifications determine the defined thicknesses.
3. When the Customer specifies it, plates with a total thickness of 6 millimeters can be replaced for 1/4-inch plates.
4. The total thickness of the minimum shell tank must not be below 6 millimeters for dimensions below 15 meters but more than 3.2 meters.

5. Calculations

Both equations and calculations are done in accordance with British Standard [EN 5500:2009 [1-4]. All calculations were displayed in Table 1.

Table 1: Design parameters and specifications calculations.

Item	Calculation and Description
The Materials of Construction (M.O.C)	Stainless Steel 304, minimum Tensile Strength: 515 MPa, and the minimum yield strength is 0.2% with proof: 205 MPa.
Nominal design strength (fn)	fE=Re/1.5 =205/1.5 = 136.66. fE=Rm/2.5 = 515/2.5 = 206. Therefore, (fN)= 136.66
Design pressure	Liquid pressure inside a container x 1.3 = DensityXGXHX1.3 1050 Kg/m^3 * 9.81 meter/s^2 *6.3 m X 1.3 = 84361.09 Kg /m.s^2= 0.08436109 MPa.
Design temperature	Between 10 to 50 ℃
Acrylic acid vapor pressure @ at 20 ℃	0.000399 MPa= 0.00399 bar
Pressure for the release valve	0.002 bar
*Shell thickness	Minimum thickness for pressure loading e= pDi/2f-p Where: e: minimum thickness , p: pressure Di: inner diameter of shell,f: Nominal design stress e= pDi/2f-p = 0.77 mm
End-of-dish shaping	tori spherical as displayed in Fig. 1.

*However, according to API 650, and depending on a container diameter of below 15 m, the minimum acceptable shell thickness with corrosion tolerance is 4 mm + 1mm C.A.
The corrosion tolerance has been raised to 2mm in our situation, as negotiated with the customer, so the shell thickness selected is 6 mm.

** General constraints limitation [BSI-Pd 5500-2009]

ea < 0.002D, r < 0.06D , R > D

ea=0.002 X 2488 = 4.976 mm + 1mm C.A = 6mm

r= 0.06 X 2488 = 1492.8 mm

R=D=2488 mm, h=300mm

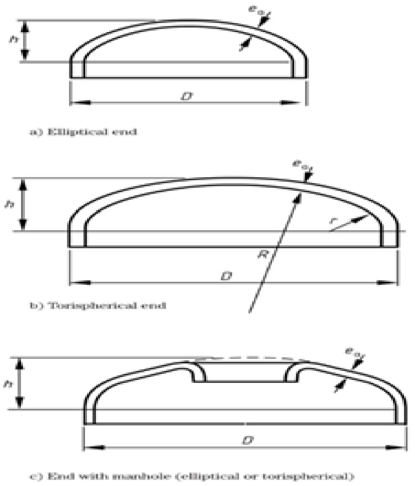

Figure 1: the tori spherical dish end

6. Manufacturing Steps

Transport of hazardous chemical liquid materials from Aqaba to Amman is extremely dangerous; standard safety procedures and specific technical limitations must be followed. These shipped liquid products are not produced in Jordan, and they are shipped in iso-containers [25].

Many companies use drum containers, as depicted in Fig.2, with capacities of 30, 50, and 100 liters to stores liquid material, and it is delivered via trucks to Amman, but this does not satisfy the requirements of the factories or the specifications, costing him extra needed workers and, at times, low efficiency.

Figure 2: 100 -liter drum reservoir

The primary goal of this article is to build a portable reservoir that is mounted over a container with a size of 30 thousand liters under British guidelines (BSI-Pd 5500-2009, EN 5500:2009).

It is the first industrial project in Jordan to introduce this idea by producing an industrial acrylic reservoir with a volume of 30 thousand liters, as seen in Figs. 3-5, to store hazardous liquid materials, particularly because the first alternative is limited storage with a volume of 100 liters and does not fulfill the demand of the plant or public safety standards.

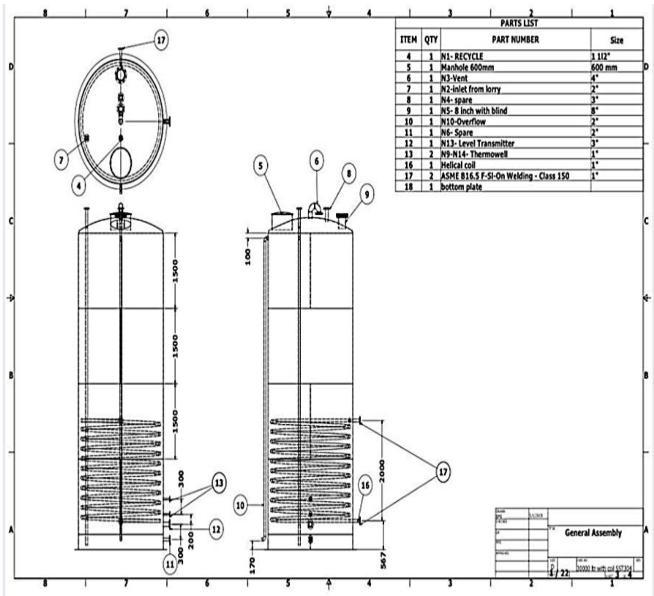

Figure 3: acrylic reservoir parts list (2-D skitch)

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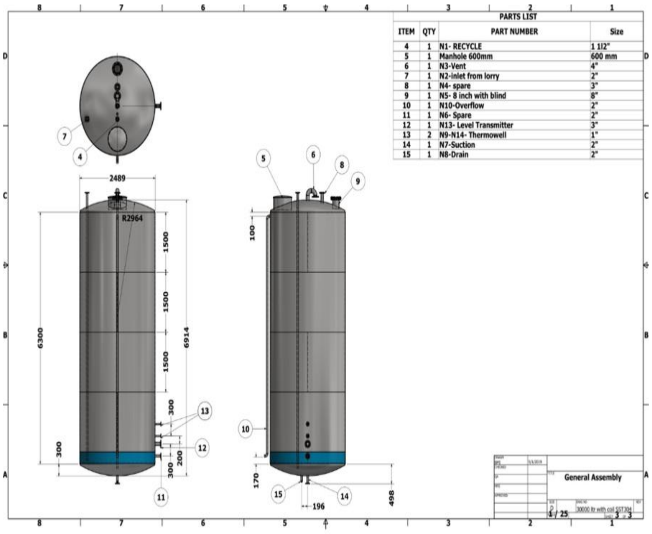

Figure 4: Acrylic reservoir parts list (3-D)

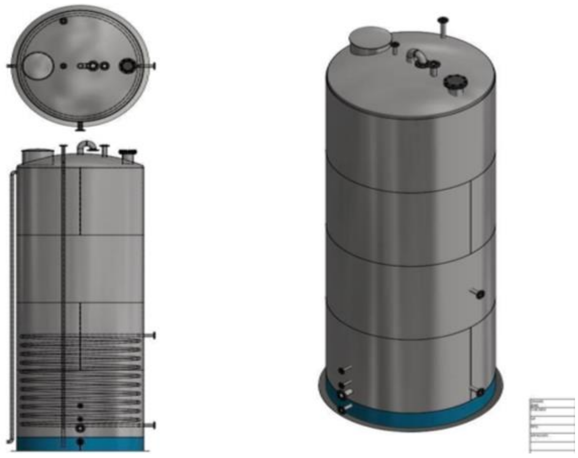

Figure 5: Acrylic reservoir parts list, with spiral heat exchanger (3-D)

First, place the spiral heat exchanger within the lower section of the acrylic reservoir, then complete the combination process, as depicted in Fig. 6.

Figure 6: spiral heat exchanger in the lowest section of the reservoir before combination

Skilled welders achieved the welding of all acrylic reservoir parts, the removable acrylic container was pressure checked, and no mechanical problems were discovered, as seen in Fig. 7.

Figure 7: an assembly of the 30,000-liter acrylic storage reservoir

After that, Fig. 8 depicts a section of the manufacturing plant infrastructure that was built in order to install the new reservoir within it.

Figure 8: Part of infrastructure inside the factory

7. Conclusion

The following conclusion erer deduced

- It was designed and manufactured a 30,000-liter removable reservoir to store volatile liquids under constraints that avoid the polymerization phenomenon caused by overheating.
- The calculations procedure were performed for vertical steel storage tank,
- The proposed design has the ability to encounter all the challenges related to storing acrylic acid in terms of environmental and health risks, flammability, and unexpected Polymerization,
- also it could use to transport diggetent chemical dangerous liquid

- The problem of possible sudden Polymerization caused by container overheating, environmental and health hazards, and the ability to produce the flame.
- A secure and controlled mechanical delivery system for liquid, dangerous compounds into a reservoir which is portable on a truck. As per manufacturing terms and conditions, it will transport 30,000 liters of acrylic acid from Aqaba to Amman. To avoid problems, set the temperature inside the reservoir at 15 °Cin the cold season and 25°Cin the hot days.
- the directions of future research in this area

Nomenclature

e: minimum thickness

p: Design pressure

Di: frame's inner diameter

fN: Design's strength

t: Design's temperature (celcios).

Dd: Dead Load

Pe: Design's Exterior Pressure

Pi: Design's interior Pressure

tb: the ring-shaped plate's thickness

H: max liquid design rate

G: liquid's specific gravity.

td: shell's thickness

tt: hydrostatic test shell's thickness in hydrostatic testing

D: reservoir diameter

H: liquid hight

Sd = permissible stress for tile design requirements

St = permissible stress for the hydrostatic testing requirements

Pmax: max design's pressure

M: a moment of wind overturns.

Rm: the particular min tensile strength at ambient conditions for the grade of material in question (which must be tested according to BS EN 10002-1)

Re: the min particular yield strength for the steel grade in question at temperature's room

ReL: the min defined yield strength (analyzed under BS EN 10002-5), as necessary;

Rp0.2: min indicated 0.2 percent prove stress for the grade of substance involved (tests performed under BS EN 10002-1) or temperature T (checked under BS EN 10002-5), as necessary

Rp0.1:min indicated 0.2 percent prove stress for the grade of substance involved at room temperature (tests performed under BS EN 10002-1) or temperature T (checked under BS EN 10002-5), as necessary SRt: The midst stress needed to cause a fracture

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