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# Wall Thickness Analysis of Vapour Liquid Separator

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**Abstract**: Objective of this work is design and modification in vapour liquid separator (VLS) used in distillery plant. The study of distillery wastewater consists of different types of wastewater from different sources and zero discharge system of distillery. Then study of membrane technology is done, which is used for purification of distillery wastewater. This study describes types of membrane, membrane modules, types of membrane techniques, and also effect of membrane bioreactors which are helpful for treatment of distillery wastewater. Membrane distillation technology is more costly, less efficient and requires frequent maintenance. By making changes in design of vapour liquid separator (VLS) wall thickness and modifying shape of the same system gives sufficient allowable design stresses. These results are validated using ANSYS software and objectives of this work are obtained.

**Keywords:** Distillation process, vapour, VLS, wall thickness, stresses, vessel, etc…..

## I. INTRODUCTION

### A. Vapour Liquid Seperator of Distillary PlantFermentation Section

**1. Molasses Handling and Distribution:**

Molasses from bulk storage is transferred to molasses receiving tank and molasses is weighed. Weighed molasses is distributed to cell mass propagation, fermentation and yeast activation section.

**2. Yeast Propagation:**

Yeast is grown in laboratory during plant start up. Yeast propagation section comprises of molasses diluter and hygienically engineered yeast vessels equipped with heating, cooling and air sparging facility. Dilute molasses media are prepared in yeast vessel by recirculating media through molasses diluter. Laboratory propagated cell mass is scaled up in series of yeast vessels. Sterile air is sparged in pasteurized and cooled dilute molasses medium for optimum growth of yeast. Temperature is maintained at 30-32°C by recirculation cooling water through jacket of yeast vessels. Cell mass from Yeast vessel is transferred to Prefermentors to build up cell mass required for fermentation transferred by cell mass transfer pump.

**3. Fermentation:**

At steady state, activated cell mass from Prefermentors is transferred to fermentors. Feed (Molasses), process water is also added. As ethanol fermentation is exothermic process, optimum temperature required for yeast activity is maintained by forced recirculation through fermentor wash coolers. Fermented wash from Fermentor is sent to wash holding tank and pumped to distillation section.

**4. Auxiliaries:**

Auxiliary system comprises of dosing system for nutrient, antifoam, acid, Caustic as well as sterile air supply system for yeast activation and yeast propagation (during start up) section.

**5. Utility:**

Cooling water is supplied to fermentation section. Cooling water return from fermentation is sent to cooling tower. Process water pumps supplies process water required for dilution of molasses in fermentor and prefermentors.

### B. Distillation Section

**1. Wash to Rectified Spirit (RS) Mode:**

Following columns will be under operation

i. Analyser Column (Vacuum)
ii. Degasifying Column (Vacuum)
iii. Rectifier cum Exhaust Column (Pressure)
iv. Recovery Column (Atmospheric)

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Pre-heated fermented wash will be fed to Degasifying column. Fermented wash is stripped off alcohol by ascending vapours in Analyser column. Rectifier vapours provide energy to Analyser column through a Thermosiphon reboiler. Vapours of Degasifying column are condensed and taken to Recovery Feed Tank. Analyser vapours are condensed in the Falling Film Evaporators in the Integrated Evaporation Section. The condensed Analyser vapours are taken to Rectifier Feed Tank. Rectifier column, which operates under pressure, concentrates the condensate to 95% concentration. Condensing steam provides energy to rectifier column through a vertical Thermosiphon reboiler. Fuel Oil Draws are taken from appropriate trays and fed to Recovery Column. Recovery Column concentrates the fuel oil streams and Degasifying condensate to 95% concentration. An impure spirit cut of about 2-3% of total spirit production is taken out from the top of the recovery column. Rectified Spirit draw of 95% is taken out from the upper trays of Rectifier Column.

**2. Wash to extra neutral alcohol (ena) mode:**

Following Columns will be under operation

1. Analyser Column (Vacuum)
2. Degasifying Column (Vacuum)
3. Pre-Rectifier cum Exhaust Column (Pressure)
4. Extractive Distillation Column (Vacuum)
5. Rectifier cum Exhaust Column (Pressure)
6. Recovery Column (Atmospheric)
7. Simmering Column (Atmospheric)

Pre-heated fermented wash will be fed to Degasifying column. Fermented wash is stripped off alcohol by ascending vapours in Analyser column. Rectifier vapours provide energy to Analyser column through a Thermosiphon reboiler. Vapours of Degasifying column are condensed and taken to Recovery Feed Tank. Analyser vapours are condensed in the Falling Film Evaporators in the Integrated Evaporation Section. The condensed Analyser vapours are taken to Pre-Rectifier Feed Tank. Analyser Condensate is concentrated in Pre-Rectifier column, which operates under pressure. Condensing steam provides energy to pre-rectifier column through a vertical Thermosiphon reboiler. A Technical Alcohol cut of about 1-2% of total spirit is taken from the Pre-Rectifier column.

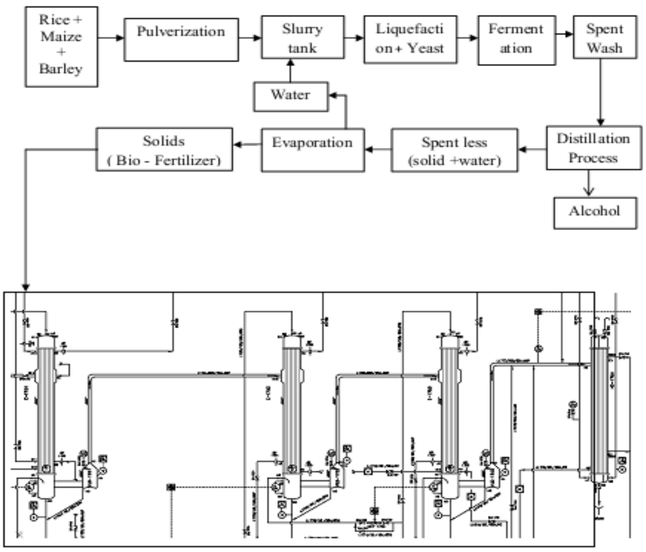


Fig. 1 Process Layout of Distillary plant

Concentrated alcohol draw from Pre-Rectifier column is fed to Extractive distillation column for purification. Dilution water in the ratio of 1:9 is added in this column for concentrating higher alcohol at the top. Top of this column is condensed in its condensers and fed to recovery feed tank while bottoms are fed to Rectifier cum Exhaust Column for concentration. Rectifier Column operates under pressure and condensing steam provides energy to this column through a vertical Thermosyphonreboiler. Technical Alcohol cut is taken out from the top of this column while ENA draw is taken out from appropriate upper trays and fed to Simmering Column after cooling. Fusel Oil build up is avoided by taking fusel oil draws from appropriate trays. These fusel oils along with the condensate of Degasifying & Extractive Distillation columns are fed to recovery column for concentration. A technical alcohol cut is taken out from the top of this column. Simmering Column is operated under high reflux for better separation of methanol and di-acetyls. Final ENA product draw is taken from the bottom of this column.

### 3. The Process of Alcohol Fermentation:

The basic equation for alcohol fermentation shows that yeast starts with glucose, a type of sugar, and finishes with carbon dioxide and ethanol. However, to better understand the process, we need to take a look at some of the steps that take us from glucose to the final products. The process of alcohol fermentation can be divided into two parts. In the first part, the yeast breaks down glucose to form 2 pyruvate molecules. This part is known as glycolysis. In the second part, the 2 pyruvate molecules are converted into 2 carbon dioxide molecules and 2 molecules of ethanol, otherwise known as alcohol. This second part is called fermentation.

## II. LITRATURE REVIEW

**1. Jung Yoon & Tae-ho Lee (2015)** has worked on the gas-liquid separator for the separation of gas and sodium particle dumped the Stairmand's model which has high performance among standard cyclone separator model. The body diameter is determined, and other dimensions are determined due to the ratio about the body diameter. Shepherd &Lapple's model is selected as the pressure drop calculation model considering the conservation.

**2. Jack Besse& Danielle Dechaine (2014)** did their work on project to provide the owner of Amherst Farm Winery with an operable distillery design within a tight budget. A growing craft spirits market influenced the owner to pursue a new revenue stream by starting Amherst Farm Distillery, LLC, a locally sourced micro-distillery located in western Massachusetts.

**3. Prof. Apte S. S. & Prof. Hivarekar S. B. (2014)** have worked on Distillery condensation & generated by-product of Multi-Effect Evaporation of spent wash generated as wastewater stream from alcohol production process. So they deals with the treatment process which was selected and the observed results and problem troubleshooting.

**4. Prof. Saidpatil& Prof. Thakare (2014)** have worked on Finite Element Method is a mathematical technique used to carry out the stress analysis to carry out detailed design & analysis of Pressure vessel used in boiler for optimum thickness, temperature distribution and dynamic behavior using Finite element analysis software. FEA Model like material, thickness, etc. The model is then analyzed in FE solver.

**5. Mark Bothamble& JM Campbell (2013)** have worked on two-phase and three-phase separators in the oil and gas industry continue to underperform. They observed sometimes, the wrong type of equipment was selected, or the correct type of equipment was selected, but the sizing methodology was inadequate.

## III. METHODOLOGY

Methodology consists of application of scientific principles, technical information and imagination for development of new or improvised Vapor Liquid Separator to perform a specific function with maximum economy and efficiency.
This project work will relate to Optimization of stresses in an thin wall portion of VLS including :
1. Measurement of stress developed in thin wall pressure vessel.
2. Development of finite element model using ANSYS software.
3. The influence of opening location and geometry on
thermal performance of pressure vessel.

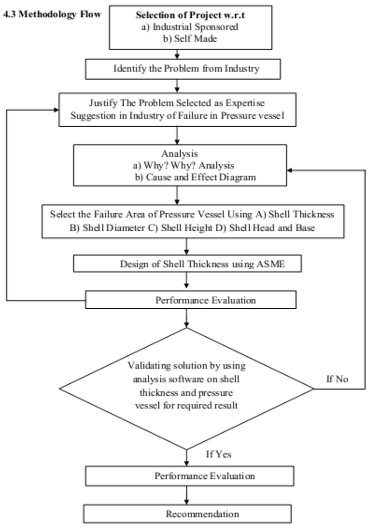

Fig.2 Flow Diagram of Methodology

**A. Methods to be used**

**1. Mathematical modelling:**

Vessel Height = Shell OD
Shell OD = 1000 mm
So vessel height also 1000 mm
Height for static Head calculation
Height for static Head = vessel Height. + Top Nozzle projection + Bottom Nozzle Projection
=1000+150+150
=1300 mm
Maximum Possible Static Head , H ( mm) = 1500 mm
( rounded , considering all (Max. Distance Between Topmost and Bottom Most Pressure Parts.)

**Cylindrical Shell Thickness**

Internal Design Pressure (Pi) = 0.499 MPa
Circumferential Stress (Longitudinal joint):

$$t = \frac{P \times R}{S \times E - 0.6 \times P}$$

$$t = \frac{0.49 \times 44.5}{(815.2 \times 2) - (0.6 \times 0.49)}$$

t = 0.27 cm
t = 2.7 mm

$$P = \frac{S \times E \times t}{R + 0.6 \times t}$$

$$P = \frac{0.49 \times 1 \times 0.27}{44.5 + 0.6 \times 0.27}$$

P = 4.92 Kg/ $cm^2$
Hence Internal Design Pressure (Pi) = 4.92 Kg/ $cm^2$ = 0.483 MPa
The symbols defined below are used in the formulas of this paragraph.

- E = Joint Efficiency for, or the efficiency of, appropriate joint in cylindrical or spherical shells, or the efficiency of ligaments between openings, whichever is less.
- For welded vessels, use the efficiency specified in 1.00.

For ligaments between openings, use the efficiency calculated by the rules given
P = internal design pressure,
R = inside radius of the shell course under consideration,
S = maximum allowable stress value,
t = minimum required thickness of shell,
External Design Pressure (Pe) = 0.600 MPa
Material Designation is SA240 TP 304
Maximum Allowable Stress(S)

$$S = \frac{(P \times R) + (0.6 \times t)}{E \times t}$$

$$S = \frac{(0.495 \times 44.5) + (0.6 \times 0.27)}{1 \times 0.27}$$

S = 814.75 Kg/ $cm^2$
S = 79.95 MPa
Shell Inside Diameter ( Un Corroded) = 990.00 mm

$$\text{Inside Radius} = \frac{\text{Shell ID}}{2}$$

$$= \frac{990.00}{2}$$

Inside Radius (Ruc) = 445.00 mm
Corrosion allowance (CA) = 0.00 mm
Inside Radius ( Corroded) (R) = Ruc + CA = 495.000 + 0.000 = 495.00 mm
Provided Thickness ( Nominal ) = 5.00 mm

- Circumferential Stress ( Longitudinal Joints)

$$t = \frac{P \times R}{(S \times E) - (0.6 \times P)}$$

$$t = \frac{4.99 \times 44.5}{(815.2 \times 1) - (0.6 \times 4.99)}$$

t = 0.27 cm
t = 2.7 mm

$$P = \frac{S \times E \times t}{R + 0.6 \times t}$$

$$P = \frac{0.49 \times 1 \times 0.27}{44.5 + 0.6 \times 0.27}$$

P = 4.92 Kg/ $cm^2$
Longitudinal Joint Type is Type 1.
Joint Efficiency (E) = 1.00

Joint Efficiency Factor = **0.385SE**
= 0.385 X 80 X 1 = 30.80 MPa

Minimum Required Thickness = $t = \frac{P \times R}{(S \times E) - (0.6 \times P)}$ $t = \frac{4.99 \times 44.5}{(815.2 \times 1) - (0.6 \times 4.99)}$

t = 0.37 cm
**t = 3.7 mm**
Circumferential Joint Type.
Joint Efficiency (E) = 1.00

Joint Efficiency Factor = **1.25SE**
= 1.25 X 80 X 1 = 100 MPa

Minumum Required Thickness = $t = \frac{P \times R}{(2\,S \times E) + (0.4 \times P)}$ $t = \frac{4.99 \times 44.5}{(2 \times 815.2 \times 1) + (0.4 \times 4.99)}$

t = 0.137 cm
**t = 1.37 mm**

Minimum required thickness shall be > 2.5 mm ( 3/32 in.) excluding Corrosion Allowance is **2.50 mm.**
Governing thickness greater
t = Greater of (3.70 , 1.37 , 2.50 )

Governing thickness + Corrosion Allowance = 3.70 + 0.00 = **3.70 mm**
Req. Thickness = 3.70 mm< 5.000 mm (Provided) Thickness is safe…

**2. Finite Element Method:**
**Problem Dimensions**

| | |
|---|---|
| OD : | 1000 mm |
| Thickness : | 5 mm |
| Length : | 2500 mm |

**Material Specification**

| | |
|---|---|
| Material : | SS 304 TP 240 |
| Young's Modulus (E) : | 200 GPa |
| Poison's Ratio (μ) : | 0.3 |
| Density (ρ) : | 1200-1250 kg/$m^3$ |

**Other Specification**

| | |
|---|---|
| Process Fluid | Stick water |
| Test Fluid | Water |
| Gross Volume | 2.2 $m^3$ |
| Working Volume | 1.96 $m^3$ |
| Hydro Test Pressure | 2.5 kg/$m^2$ |
| Operating temp. | 80 $^oC$ |
| Design temp. | 120 $^oC$ |
| Operating pressure | 0.5 kg/$m^2$ |
| Design pressure | Full Vacuum kg/$m^2$ |

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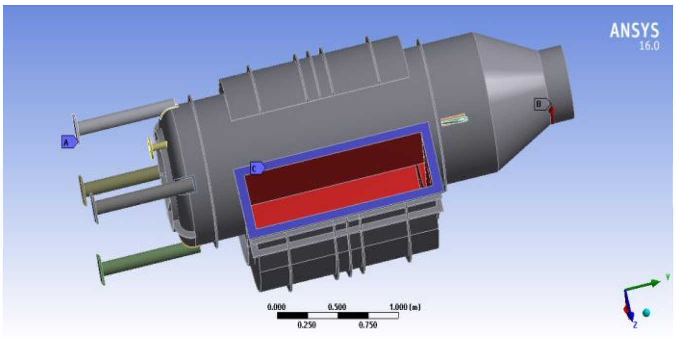

Fig.3 3D Model of VLS

**Mesh Size (without temp.)**

| | |
|---|---|
| Number of elements : | 65358 |
| Number of nodes : | 130652 |
| Size of element : | 0.003 m |

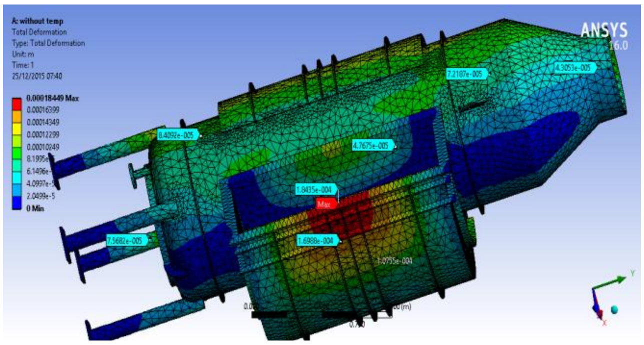

Fig. 4 Total Deformation for 5 mm shell wall thickness

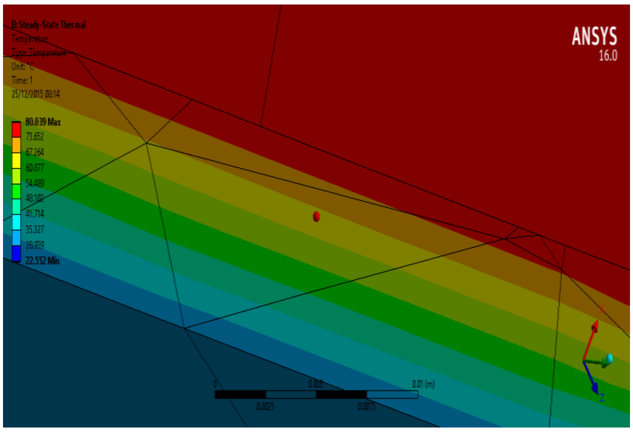

Fig. 5 Cut- section of Temp. Distribution for 5 mm shell wall thickness

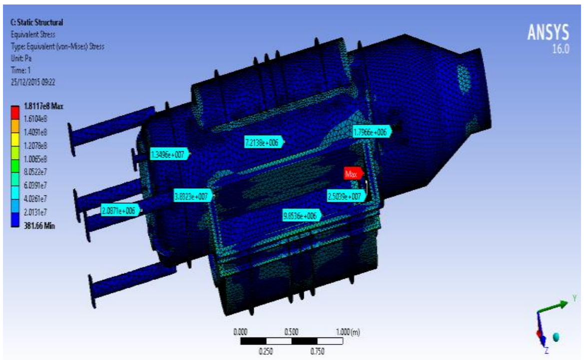

Fig.6 Steady state equivalent stress for shell

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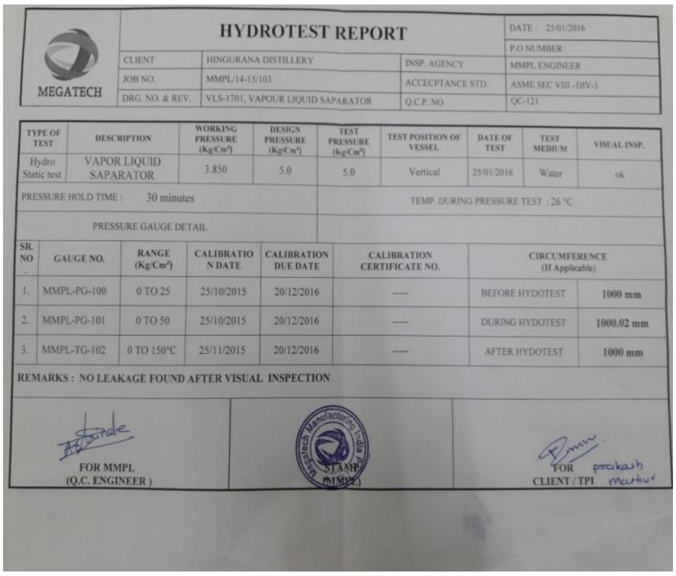
Table 1 Comparison in stresses induced in ANSYS

| Condition / Stresses | Without Temp (MPa) | | With Temp ($0^o$) | | Steady State (MPa) | | Clint condition | |
|---|---|---|---|---|---|---|---|---|
| | Max | Min. | Max | Min. | Max. | Min. | Max. | Min. |
| Von-Mises stress | 199.2 | 5.33 | - | - | 181.1 | 3.81 | 265 | - |
| Total Deformation | 0.1 | 0.0 | - | - | 0.2 | 3.81 | 2 | - |
| Steady State temp. | | | 80.3 | 22.5 | | | 90 | - |

**3. Experimentation:**
**Hydro Test Report**



MEGATECH

HYDROTEST REPORT

| | | | |
|---|---|---|---|
| CLIENT | HINGURANA DISTILLERY | DATE : | 25/01/2016 |
| JOB NO. | MMPL/14-15/103 | P.O NUMBER: | |
| DRG. NO. & REV. | VLS-1701, VAPOUR LIQUID SAPARATOR | INSP. AGENCY | MMPL ENGINEER |
| | | ACCECPTANCE STD. | ASME SEC VIII -DIV-1 |
| | | Q.C.P. NO | QC-121 |

| TYPE OF TEST | DESCRIPTION | WORKING PRESSURE (Kg/Cm²) | DESIGN PRESSURE (Kg/Cm²) | TEST PRESSURE (Kg/Cm²) | TEST POSITION OF VESSEL | DATE OF TEST | TEST MEDIUM | VISUAL INSP. |
|---|---|---|---|---|---|---|---|---|
| Hydro Static test | VAPOR LIQUID SAPARATOR | 3.850 | 5.0 | 5.0 | Vertical | 25/01/2016 | Water | ok |

PRESSURE HOLD TIME : 30 minutes

TEMP. DURING PRESSURE TEST : 26 °C

PRESSURE GAUGE DETAIL

| SR. NO. | GAUGE NO. | RANGE (Kg/Cm²) | CALIBRATION DATE | CALIBRATION DUE DATE | CALIBRATION CERTIFICATE NO. | CIRCUMFERENCE (If Applicable) | |
|---|---|---|---|---|---|---|---|
| 1. | MMPL-PG-100 | 0 TO 25 | 25/10/2015 | 20/12/2016 | ----- | BEFORE HYDOTEST | 1000 mm |
| 2. | MMPL-PG-101 | 0 TO 50 | 25/10/2015 | 20/12/2016 | ----- | DURING HYDOTEST | 1000.02 mm |
| 3. | MMPL-TG-102 | 0 TO 150°C | 25/11/2015 | 20/12/2016 | ----- | AFTER HYDOTEST | 1000 mm |

REMARKS : NO LEAKAGE FOUND AFTER VISUAL INSPECTION

FOR MMPL (Q.C. ENGINEER) | STAMP (MMPL) | FOR CLIENT / TPI prakash mathur

## IV. CONCLUSION

- By using stiffener, wall thickness of VLS decreases from 8mm to 5mm.
- Final stresses in VLS were reduced up to designed stresses as per ASME by modification of shape from torispherical to dishintorispherical. Thus failure in dishend is minimized.
- ANSYS result gives better reliability in the theoretical calculations and mathematical calculations.

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It is not possible to express the things in words what I feel, but here I tried to express my thoughts in the form of acknowledgement**.** It has been privilege for me to be associated with **Prof. D. S. Bajaj** my project guide.

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