BASIC ENGINEERING PACKAGE FOR DEPROPYLENIZER UNIT

Submitted by:

Md Zunaid Ali

Enrolment No: R670209014

SAP ID: 500006973

M.Tech (Process Design Engineering)



College of Engineering

University of Petroleum and Energy Studies,

Dehradun, Uttarakhand, India

UPES - Library

DI1152

ALI-2011MT

MAY - 2011



BASIC ENGINEERING PACKAGE FOR DEPROPYLENIZER UNIT

A Thesis submitted to College of Engineering Studies for the partial fulfillment of Degree of Master of Technology

(Process Design Engineering)

Guided by:

Sanjay D. Dalvi

Assistant Professor
College of Engineering
University of Petroleum & Energy Studies
Dehradun – 248 006

Submitted by:

Md Zunaid Ali

Enrolment No: R670209014 SAP ID: 500006973

Approved by:

Dean (Dr. Shrihari)

College of Engineering

University of Petroleum and Energy Studies,

Dehradun, Uttarakhand, India

MAY - 2011



UNIVERSITY OF PETROLEUM & ENERGY STUDIES

(ISO 9001:2000 Certified)

CERTIFICATE

This is to certify that the work contained in this thesis titled "Basic Engineering Package for Depropylenizer Unit" has been carried out by Mr. Md Zunaid Ali under my supervision and has not been submitted elsewhere for a degree.

Sanjay D. Dalvi

Assistant Professor
College of Engineering
University of Petroleum & Energy Studies
Dehradun – 248 006

Date: 14/04/2011

ACKNOWLEDGEMENT

I want to render my sincere thanks to **Dr. Shrihari**, Dean College of Engineering, University of Petroleum & Energy Studies (UPES), Dehradun, for giving me this opportunity to perform major project at University campus.

I owe a deep sense of gratitude to my project guide Mr. Sanjay D. Dalvi, Assistant Professor, for providing the vital and effective information and required resources and for his valuable guidance and constant encouragement which helped me in successful completion of my work.

I sincerely thank **Prof. Vasdev Singh**, H.O.D of Chemical Engineering and **Mr. G. Sanjay Kumar**, course co-ordinator, M.Tech Process Design, for helping me throughout in making this thesis.

My special thanks to Mr. Alok Saxena for his support and suggestion throughout the project.

I would also like to thank the faculty member of the Chemical Engineering department, U.P.E.S, and all my friends for helping me in any possible way to complete this project.

ABSTRACT

This project aims to develop Basic Engineering Package of Depropylenizer unit which separates mixed C_3/C_4 feed into Polymer Grade Propylene as overhead, C_4 Recycle as side draw and C_4 + Purge as bottom product.

The unit is designed to produce 165 KTA of Polymer Grade Propylene in 8,000 operating hours a year when processing the design feed stocks during the normal operation while composition of the Feed and Products is supplied by the client.

Process Flow Diagram (PFD) for the Unit is developed and Control Philosophy for the process is decided.

To obtain Polymer grade Propylene with the specified specification from the given feed streams, the process is designed and simulated using software PRO-II. Optimization of the Unit is done to meet the optimum operating and installation costs.

Based on Material Balance generated by PRO-II, Data Sheet for all the Process Equipments and Line Sizing has been done.

Piping & Instrumentation Diagram (P&ID) of the unit is also prepared.

TABLE OF CONTENTS

1.	Introductio	On	1
2.	General De	escription of the Depropylenizer Unit	2
3.	Process Flo	ow Diagram	3
	3.1	Process Description	
	3.2	Equipment List	
	3.3	Control Philosophy	
4.	Pressure Pi	rofile	4
5.	Simulation	of Depropylenizer Unit	5
	5.1	Simulation Steps in Pro-II	
	5.2	Simulation Data	
6.	Optimization	on of Depropylenizer Unit	11
7.	Reflux Dru	m Design	12
	7.1	Design Basis for Accumulator Sizing	
	7.2	Procedure for Sizing Accumulators	
	7.3	Data Sheet for Reflux Drum	
8.	Column Des	sign	16
	8.1	Design Basis for Column Sizing	
	8.2	Procedure to Calculate Column Diameter	
	8.3	Procedure to Calculate Column Height	
	8.4	Data Sheet for Depropylenizer Tower	
) .	Design of Co	ondenser E-101	23
	9.1	Design Basis	
	9.2	Inputs to HTRI	
	9.3	Output Summary	
	9.4	TEMA Sheet	
	9.5	Rating Data Sheet	
	9.6	Vibration Analysis	
	9.7	Final Results	
	9.8	Tube Layout and Drawing	

10.	Design of C	ooler E-103	33
	10.1	Design Basis	
	10.2	Inputs to HTRI	
	10.3	Output Summary	
	10.4	TEMA Sheet	
	10.5	Rating Data Sheet	
	10.6	Vibration Analysis	
	10.7	Final Results	
	10.8	Tube Layout and Drawing	
11.	Design of C	ooler E-104	42
	11.1	Design Basis	
	11.2	Inputs to HTRI	
	11.3	Output Summary	
	11.4	TEMA Sheet	
	11.5	Rating Data Sheet	
	11.6	Vibration Analysis	
	11.7	Final Results	
	11.8	Tube Layout and Drawing	
12.	Design of Re	eboiler E-102	51
	12.1	Design Basis	
	12.2	Inputs to HTRI	
	12.3	Output Summary	
	12.4	TEMA Sheet	
	12.5	Rating Data Sheet	
	12.6	Final Results	
	12.7	Reboiler Piping Details	
	. 12.8	Tube Layout and Drawing	
13.	Line Sizing		61
	13.1	Procedure to Size Liquid Phase Line	
	13.2	Some Recommended Value for Liquid Line Sizing	
	13.3	Procedure to Size Vapour Phase Line	
	13.4	Some Recommended Value for Vapour Line Sizing	
	13.5	Line List	

- 🛁

14.	Column T-101 Summary	65
15.	Detailed Material Balances	67
	15.1 Component Rates	
	15.2 Total Stream Properties	
16.	Annexure-1:	75
	Feed Stock Composition	
17.	Annexure-2:	76
	Products Composition	
18.	Annexure-3:	77
	Utilities Condition	
19.	Annexure-4:	78
	Battery Limit Conditions	
20.	Annexure-5:	79
	Process Flow Diagram	
21.	Annexure-6:	80
	Equipment List	
22.	Annexure-7:	81
	Process Flow Diagram with Control Scheme	
23.	References	82
24.	Piping and Instrumentation Diagram (P & ID)	

LIST OF FIGURES

6.1	Optimization Graph	1
9.9	Variation of Heat Flux across the Length of E-101	3
9.10	Variation of MTD across the Length of E-101	31
9.11	Enthalpy Curve of E-101	32
9.12	Flow Regime of E-101	32
10.9	Variation of Heat Flux across the Length of E-103	41
10.10	Variation of MTD across the Length of E-103	41
11.9	Variation of Heat Flux across the Length of E-104	50
11.10	Variation of MTD across the Length of E-104	50
12.9	Variation of Heat Flux across the Length of E-102	59
12.10	Variation of MTD across the Length of E-102	59
12.11	Enthalpy Curve of E-102	60
12.12	Pressure Variation across Tube Length of E-102	60
14.1	Temperature Variation across Column	66
14.2	Liquid and Vapour Flow Rate across Column	66
20.0	Process Flow Diagram	79
22.0	Process Flow Diagram with Control Scheme	81

LIST OF TABLES

4.0	Pressure Profile	4
5.2	Simulation Data	10
7.3	Data Sheet for Reflux Drum	15
8.4	Data Sheet for Depropylenizer Tower	22
13.2	Some Recommended Value for Liquid Line Sizing	62
13.4	Some Recommended Value for Vapour Line Sizing	64
13.5	Line List	64
14.0	Column T-101 Summary	65
15.1	Component Rates	67
15.2	Total Stream Properties	71
16.0	Feed Stock Composition	75
17.0	Products Composition	76
18.0	Utilities Condition	77
19.0	Battery Limit Conditions	78
21.0	Equipment List	80

NOMENCLATURE

G = Vapour flow rate

U_f= Flooding velocity

 F_{HA} = Fractional Hole Area

H_R = Height of Rectifying section

H_T= Total Height of column

A = Cross Sectional Area

Re = Reynolds Number

KTA = Kilo Ton per Annum

Kg = Kilogram

Kcal = Kilocalories

L = Length

V = Volume

C.S = Carbon Steel

MTD= Mean Temperature Difference

f = Percentage Flooding

 $P_g = Vapour density$

 $A_h = Hole Area$

H_S = Height of Stripping section

Q_L= Volumetric Flow Rate

V = Velocity of liquid

 ΔP = Pressure Drop

LLL = Low Liquid Level

⁰C = Degree Centigrade

CW = Cooling Water

D = Diameter

fhv = Fraction of vessel head

HLL = High Liquid Level

MPS = Medium Pressure Steam

1. INTRODUCTION

Process Design Engineers are concerned with Development of new process and modification of existing process. They develop a lab based process to production scale with minimum production cost.

A process design engineer has to design a plant or a part of it. He may have to design a complete complex plant or unit operation or a unit process or a system. The task of a process engineer is to convert the research and development effort into industrial reality. The important aspect is that it must work and operate reliably and smoothly. The unit is to be designed for a commercial purpose and hence, it has to be economical and cost effective. A good process design engineer has to have a good knowledge and understanding of process, technology and behaviour of process under given operating condition & changing operating condition must be known for process design. So, Process design can be called as an art which comes through years of experience.

The Role of Process Design Engineer starts right from the Project Concept. The Project concept is like the preface of project giving idea that is there to be done in project. It is like a proposal based on client or Bidder requirement. It is mainly prepared for the confirmation of service and the order from the customer with relevant details for design. The project concept is based on the information provided by customers as Raw material specification, Finished Product Specs, Expected Capacity, Environmental data, Site location, Level of Automation and many more.

The aim of the project is to develop Basic Engineering Package of Depropylenizer unit which separates mixed C_3/C_4 feed into Polymer Grade Propylene, C_4 Recycle and C_4+ Purge.

During the course of the preparation of the package, I utilized my Basic Process Engineering knowledge and usage of the software tools learnt during my Post Graduation and also got hands on feel of the work related to Process Design Engineering.

The unit is designed to produce 165 KTA of Polymer Grade Propylene in 8,000 operating hours a year when processing the design feed stocks during the normal operation. Composition of the Feed and Products was supplied by the client.

2. GENERAL DESCRIPTION OF THE DEPROPYLENIZER UNIT

FUNCTION:

The Depropylenizer Unit is designed to separate feed into Polymer Grade Propylene, C_4 recycle and C_4 + purge. The processing scheme shall be as shown in Process flow diagram.

CAPACITY:

The unit is designed to produce 165 KTA of Polymer Grade Propylene in 8,000 operating hours a year when processing the design feed stocks during the normal operation.

FEED STOCKS:

The unit is designed to process the following feedstock during normal operation to produce required amount of Propylene. Complete composition of the feed stock is given in ANNEXURE-1

PRODUCTS:

- a) Polymer Grade Propylene (high purity)
- b) C₄ Recycle
- c) C₄+ purge

Composition of product streams can be referred from ANNEXURE-2

TURNDOWN:

Plant shall be designed to operate at 50% of normal capacity.

UTILITIES:

- a) Cooling water
- b) Steam
- c) Power

Condition and characteristics of utilities used can be referred from ANNEXURE-3

BATTERY LIMIT CONDITION:

Battery limit conditions for feedstock and products can be referred from ANNEXURE-4

3. PROCESS FLOW DIAGRAM

A process flow diagram for the process has been attached as ANNEXURE-5

3.1 PROCESS DESCRIPTION

The purpose of Depropylenizer unit is to separate feed into three products:

- a) Polymer Grade Propylene (Overhead)
- b) C₄ Recycle (Side draw)
- c) C₄+ (Bottoms product)

Mixed C_3/C_4 feed from Deethylenizer is sent to the Depropylenizer tower. The tower operates at a pressure which permits total condensation of Depropylenizer overhead against cooling water. Part of the Distillate is used as Reflux and the net Polymer grade Propylene product is pumped to the OSBL storage. Reboiler heat to the Depropylenizer is supplied by MP steam. C_4 Recycle is taken as side draw from the Depropylenizer tower and cooled against cooling water (cooler outlet temperature of C_4 recycle is 40° c) and sent to the fresh recycle C_4 surge drum. The Bottoms from Depropylenizer containing C_4 + and heavier material is cooled against cooling water and pumped to the Ethylene plant outside the battery limit.

3.2 EQUIPMENT LIST

A list of Equipments with Name and their Notation used in the PFD has been attached as ANNEXURE-6

3.3CONTROL PHILOSOPHY

A process flow diagram with control philosophy for the process has been attached as ANNEXURE-7

Column overhead pressure is controlled by coolant flow rate and column temperature is controlled by cascading the temperature controller with steam flow controller.

To control liquid level in the bottom of the column, a level controller is cascaded with bottom product flow controller. Reflux to the column is controlled by a fixed flow controller.

Side draw product flow is controlled by a fixed flow controller which is cascaded with the level controller located on the side draw product removal tray.

To control the liquid level in the reflux drum, a level controller is cascaded with the flow controller of the propylene product.

4. PRESSURE PROFILE

Since this unit is expansion of an existing plant, the actual plant layout is known. Plant layout is necessary in order to know elevation of equipments, length of the pipes on which the frictional loses depends. In order to do preliminary pressure calculations, reasonable frictional loses, pressure drop per tray, pressure drop across Cooler, Control valve pressure drop are assumed which will not bring much error in the final calculations.

a) Tower bottom tangent line from grade: 8m

b) Reflux drum tangent line from grade: 3m

c) Pressure drop across Cooler: 0.14 kg/cm²

d) Control valve pressure drop: 0.7 kg/cm²

e) Losses in each line segment: 0.07 kg/cm²

f) Pressure drop per tray: 0.01 kg/cm²

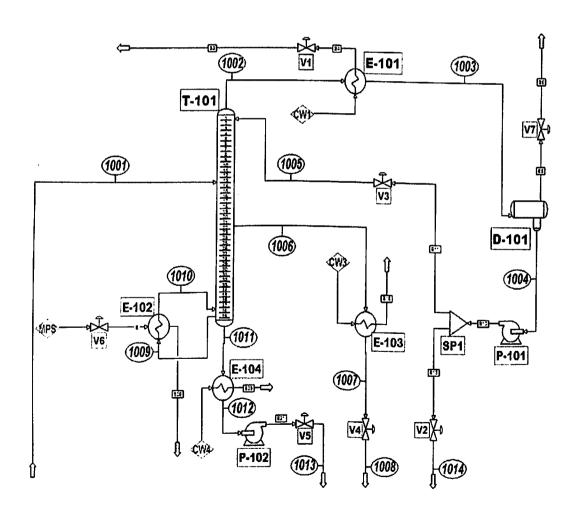
Name	Pressure (kg/cm ²)	F	ressure Drop (kg/cm²)	Static Head (kg/cm²)	Height (m)	
		Line loss	Equipment	CV		
T-101 top tray	18.56					
E-101 inlet	18.49	0.07				
E-101 outlet	18.35		0.14			26
Reflux drum	18.56	0.282		0.7	-1.193	3
P-101-suction	18.63	0.07		-	-0.1434	
P-101-discharge	36.63					
C4 Recycle Tray	18.85					11
E-103 inlet	19.281	0.17			-0.601	
Bottom tray	18.92					8

5. SIMULATION OF DEPROPYLENIZER UNIT

In order to obtain Polymer grade Propylene with the specified specification (ANNEXURE-2) from the given feed streams, the process was designed and simulated using software PRO-II. The propylene flow rate in the Distillate and composition in the Bottom are almost kept constant at 20,625 kg/hr and 500 wt ppm respectively. It was also ensured that the composition (mole %) of cis-2-Butene and trans-2-Butene in the C₄ Recycle product stream matches with the Estimated Product specifications.

5.1 SIMULATION STEPS IN PRO-II

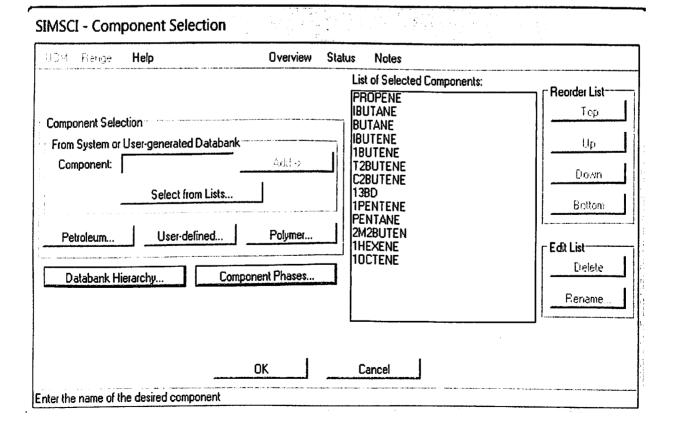
1. Build flow sheet



2. Check units of measure

earth sana Help					
asis: Metric				Initialize from UOM Libra	ary
Default Units of Measure I	or Problem Data Input		The state of the s	**************************************	
Temperature:	Celsius		Energy:	Kilocalorie	₹
Pressure:	Kilogram/centimeter^2	I	Duty:	Energy/Time	¥
Time:	Hour	Ī	Work:	Kilowatt	Ţ
Weight (wt.):	Kilogram	₹	Length:	Meter	Ţ
Liquid Volume:	Meter^3	┰	Fine Length:	Millimeter	
Vapor Volume:	Meter^3	·	Heat Trans. Coefficient:	Kilocalorie/hour-m^2-K	-
Specific Liquid Volume:	Liquid volume/Molar wt.	$\overline{\mathbf{x}}$	Fouling Coefficient:	Hour-meter^2-C/kcal	T
Specific Vapor Volume:	Vapor volume/Molar wt.	T	Viscosity:	Centipoise	-
Liquid Density:	Weight/Liquid volume		Kinematic Viscosity:	Centistoke	Ī
Vapor Density:	Weight/Vapor volume	Ŧ	Thermal Conductivity:	Kilocalorie/hour-m-C	T
Petroleum Density:	same as liquid density	I	Surface Tension:	Dyne/centimeter	¥
Pressure Gauge Basis:	1.0332 kg/cm ²				
Standard Vapor Con	ditions			TVP and RVP Conditions	
			THE ACT IS NOT THE REAL PROPERTY OF THE PARTY OF THE PART		
	ÖK	\neg	Cancel		

3. Define components



4. Select Thermodynamic Package

Column - Thermodynamic Systems

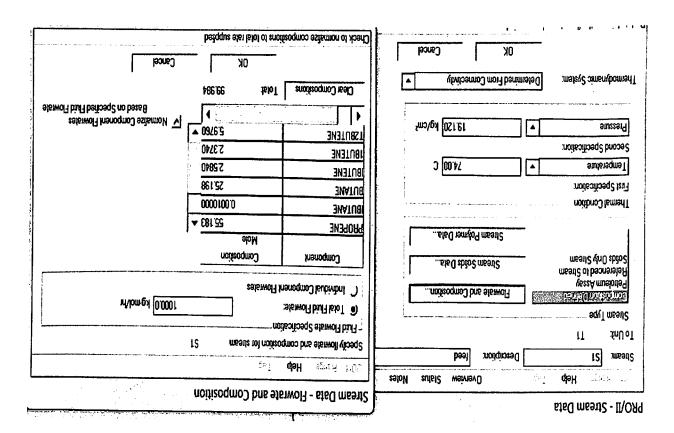
syent Balvino BABV totalot 🗍 BULY of BLV mort omen't lepimen'D sprend ประส_ิ heart Systems for Individual Sections Dewn to End Tray ត៌ឡ เหล่วห์ดี ดเกอกไ ₽u∃ SBKOI umuloù eistqmoù 🍑 Thermo for Individual Sections Thermodynamic System Specification weiview dlэН

Cancel OK matrick constit 344. 9 เหตินอนุร ณ Þ Ayea to recinal can eller!

ξ

5. Supply stream data

Push this button to accept data entry.



6. Provide process condition

PRO/II - Column

Column - Pressure Profile

255 Lethe hange	Help	Overview							
Pressure Specification M	lode			Individua	al Tra	y Specifica	ation		
Overall				Cut		Tray	Pressure		
By Individual Trays				Сору			itg/cm²		
Overall Specification			_ _	Paste	1	1 20			
Top Tray Pressure:	18.50	60 kg/cm²		Insert Reset	3	39		:	
Pressure Drop		-	7		4				
(Per Tray:	0.01000	00 kg/cm²			5				
C Column:	0.0500	00 kg/cm²							
	ŌK			Cancel					
Exit the window after saving	ı all data								

Column - Condenser

JOM Define Range Help	Overview	
Column with Condenser		
Condenser Type	Condenser Data	
C Partial	Pressure:	18.350 kg/cm²
Bubble Temperature	Temperature Estimate:	с
C Subcooled,	Fixed Temperature:	<u> </u>
Fixed Temperature	Degrees Subcooled:	ŗ,
C Subcooled, Fixed	Duty:	x 10° Kcal/hr
Temperature Drop		
To person the second section of the section o	iovi c l	1
	DK Cancel	
it the window after saving all data		

Column - Reboiler

ULLEM	Destroc	Farge	Help	Overview
しゅししし	ermosiphon Return Liqu Return Vap Temperatu Temperatu Rate:	uid: por: re:	pecification	Mode transition 0.3000 Mole fraction F. C. kg-mol/hr
Duty		Ok	<u> </u>	Mole Fraction kg-mol/hr x 10° Kcal/hr Cancel
Exit the	window after	er saving al	l data	

7. Run and view results

5.2 SIMULATION DATA

The data is being collected by varying the following things of the tower to ensure that the composition (mole %) of cis-2-Butene and trans-2-Butene in the C₄ Recycle product stream matches with the Estimated Product specifications.

- a) No. of stages
- b) Position of feed stream to the column
- c) Position of C₄ Recycle product stream

From the simulation data collected, the Most Optimum Data for a Particular Number of Stage is being chosen and the useful data is being listed below:

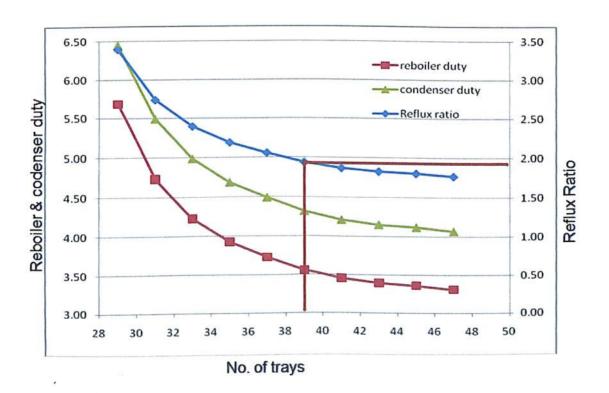
No. of Stages	Feed at	C ₄ Recycle	Condenser Duty	Reboiler Duty	Reflux Ratio	C2B Mol%	T2B Mol%
Stuges	No.	Stream Tray no.	*10 ⁶ kcal	*10 ⁶ kcal	1.41.0	110176	110170
29	18	21	-6.4484	5.6884	3.3909	7.083	12.13
31	19	23	-5.4922	4.7317	2.7392	7.081	12.12
33	20	25	-4.9868	4.2265	2.3951	7.074	12.12
35	21	27	-4.6844	3.9249	2.1893	7.070	12.10
37	22	29	-4.4875	3.7289	2.0552	7.065	12.09
39	24	31	-4.3147	3.5570	1.9376	7.061	12.09
41	26	33	-4.2105	3.4537	1.8666	7.056	12.08
43	28	35	-4.1495	3.3939	1.8260	7.053	12.08
45	30	37	-4.1176	3.3633	1.8033	7.047	12.08

6. OPTIMIZATION OF DEPROPYLENIZER UNIT

The data in the above table is approximate which is used to judge the best column among the above cases. As mentioned earlier, the operating and installation costs are the due to Condenser duties, Reboiler duties, Reflux ratio and Number of trays. A plot of Condenser duty, Reboiler duty and Reflux ratio v/s Number of stages is given below was used to decide the Optimum Number of Theoretical stages from the above tabulated cases. In order to meet operating and installation costs, the case with 39 Number of Theoretical Stages is being selected.

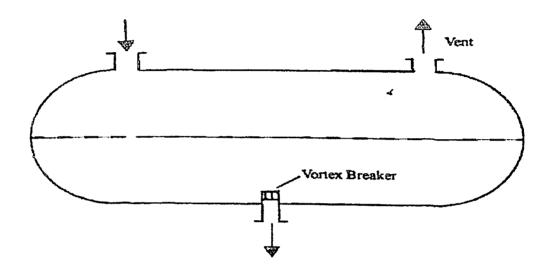
6.1 OPTIMIZATION GRAPH

A plot of Condenser duty, Reboiler duty and Reflux ratio v/s Number of stages is given below was used to decide the Optimum Number of Theoretical stages from the above tabulated cases. In order to meet the optimum operating and installation costs, the case with 39 Number of Theoretical Stages is being selected.



7. REFLUX DRUM DESIGN

An accumulator is placed after the condenser to provide reflux to the fractionators and prevents column fluctuations in flow rate from affecting downstream equipment.



Accumulators are not separators. In this application the accumulator is called a reflux drum. A reflux drum is shown in the above figure. Liquid from a condenser accumulates in the drum before being split into reflux and product streams. At the top of the drum is a vent to exhaust noncondensable gases that may enter the distillation column. The liquid flows out of the drum into a pump. To prevent gases from entering the pump, the drum is designed with vortex breaker at the exit line.

The total volume of an accumulator is calculated using a residence time, also called surge time, which is obtained from experience, according to the type and degree of the process control required. Commonly it is recommended that to take residence time of 5 to 10 minutes. Once a residence time is selected, accumulator is sized for half-full operation to accommodate either increase or decrease in liquid level.

7.1 DESIGN BASIS FOR ACCUMULATOR SIZING

Holdup time

7 minutes of holdup on Reflux flow quantity or 10 minutes on liquid product, whichever is greater.

Heads

Pressure
$$\geq 10 \text{ kg/cm}^2 \text{ g}$$

Length to diameter ratio

$$L/D = 3$$

nearest 5°C.)

For Design Pressures from 7 Kg/cm²g -
$$21$$
kg/cm²g L/D = 4

Design pressure

Maximum design pressure for any pressure vessel shall be Maximum normal operating pressure plus $2.0\ kg/cm^2$

The minimum design pressure for any pressure vessel shall be 3.5 kg/cm²g.

Design temperature

In general the design temperature of pressure vessels is dependent upon the operating temperature range as follows:

No maximum design temperature will be set less than 65°C.

Operating Temp Range, (°C)	Design Temp, (°C)
T < 50	Minimum anticipated operating
	temperature margin to be
	determined by metallurgical
	limits
50 < T < 400	Maximum anticipated operating
	temperature + 15°C (round up to

T > 400*

Maximum anticipated operating temperature 10% minimum margin

Round off

The calculated diameter and length of the vessel is rounded off to match the standard size available in the market to control the cost.

Diameter Round off in increment of 6 inch

Length Round off in increment of 3 inch

Limitations

The maximum vessel diameter is limited to about 4.11 meters because of shipping limitation by rail and truck and minimum vessel diameter is limited to about 0.762 meters for economic purpose.

7.2 PROCEDURE FOR SIZING ACCUMULATORS

- 1) Select Residence time or Holdup time
- 2) Calculate accumulator volume using formula

3) Also we know

$$V = \{(3.14 * D^2 * L) / 4\} + \{2 \text{ fhv } * D^3\}$$

Where fhv = fraction of vessel head

fhv = 0.1309 for Ellipsoidal head

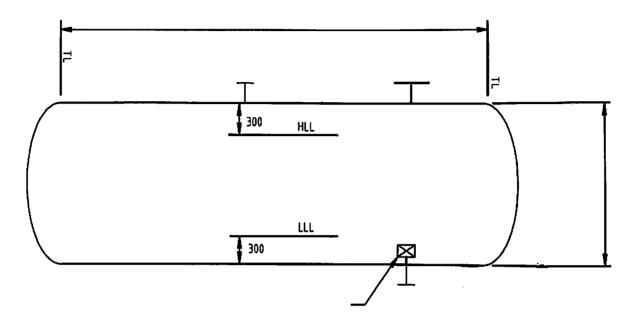
fhv = 0.778 for Torispherical head

- 4) Select Vessel Head and L/D ratio based on the operating pressure
- 5) Calculate Vessels Diameter and round off "D" in 6 inch increment
- 6) Calculate length and round off "L" in increment of 3 inch

7.3 DATA SHEET FOR REFLUX DRUM

ITEM NUMBER: D-101

ITEM NAME: Depropylenizer Reflux Drum



VESSEL NO.	D-101
VESSEL NAME	DEPROPYLENIZER REFLUX DRUM
Diameter	2134 MM (84")
Horizontal Length(T/T)	8534 MM(336")
Operating Temperature	43°C
Operating Pressure	1.74 MPAG
Liquid Density	474 KG/M3
Design Temperature	65°C
Design Pressure	1.91 MPAG
Head	ELLIPSOIDAL
Shell Material	C.S
Corrosion Allowance Shell	3 MM

8. COLUMN DESIGN

The sizing of columns is critical. Almost all of the mass transfer operations occur in columns. As a thumb rule, the diameter of the column directly relates to the flow rate to be handled and the height to the degree of separation to be achieved.

8.1 DESIGN BASIS FOR COLUMN SIZING

Tray Type

Depropylenizer will be provided with all Valve Trays.

Tray Efficiency

Tray efficiencies and hydraulic criteria to be used for these towers are summarized below:

	Tower	% Tray Efficiency	
1	Depropylenizer	Above Feed	55%
		Below Feed	65%

Tray Spacing

Above Feed 500 mm

Below Feed 600 mm

Tower and their Behaviours

Tower Behaviour

Depropylenizer Non Foaming

Debutanizer Non Foaming

Demethanizer Moderate Foaming

Caustic Tower Severe Foaming

Design pressure

Maximum design pressure for any pressure vessel shall be Maximum normal operating pressure plus $2.0\ kg/cm^2$

The minimum design pressure for any pressure vessel shall be 3.5 kg/cm²g.

Design temperature

In general the design temperature of pressure vessels is dependent upon the operating temperature range as follows:

No maximum design temperature will be set less than 65°C.

Operating Temp Range, (°C)	Design Temp, (°C)
T < 50	Minimum anticipated operating temperature margin to be determined by metallurgical limits
50 < T < 400	Maximum anticipated operating temperature + 15°C (round up to nearest 5°C.)
T > 400*	Maximum anticipated operating temperature 10% minimum margin

Manholes

Vessels with trays shall be provided with the following number of manholes:

Number of Trays	Number of Manholes
1 to 25	2
26 to 41	3
42 to 61	4
62 to 80	5
81 to 100	6

Basic Engineering Package

101 to 120	7
121 to 150	8
151 to 175	9
176 to 200	10

Manholes shall be provided above the top tray, and below the bottom tray. Where manholes are provided between trays, the minimum tray spacing should be as follows:

Manhole Size	Min. Tray Spacing
20 inch	36 in (900 mm)
24 inch	40 in (1000 mm)

For towers, unless there are special considerations, manhole sizes shall be as follows:

Tower Diameter, ID, mm	Size, Inches
< 900	18
900 < D < 3000	20
> 3000	24

Miscellaneous

Trays shall be numbered from the top down, that is, tray No. 1 shall be the top most tray.

8.2 PROCEDURE TO CALCULATE COLUMN DIAMETER

1. Calculate Column diameter by using Formula

$$D_{T} = \left(\int_{f \times u_{f} \times \pi \left(1 - A_{D}/A_{T}\right) \times \rho_{G}}^{4G} \right)$$

Where

G Vapour flow rate

F Percentage Flooding

U_f Flooding velocity

P_g Vapour density

D_T Tower Diameter

A_D Downcomer area

 A_T Total cross sectional area

- 2. As a thumb rule take percentage flooding from 70% to 90%
- 3. Flooding velocity is calculated using formula

$$u_f = C_{SB} \times (\frac{\sigma}{20})^{\wedge} 0.2 \times F_F \times F_{HA} \times \sqrt[3]{\frac{\rho_L - \rho_G}{\rho_G}}$$

F_F 1 Foaming 0.6 Nonfoaming

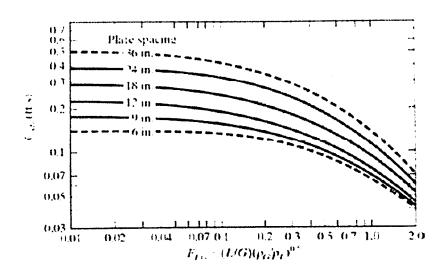
4. Fractional Hole Area (F_{HA}) is function of ratio of Hole Area (A_h) and Tray Active Area (A_a) and calculated using correlation

$$F_{HA} = \begin{cases} 1 & \frac{A_h}{A_a} \ge 0.1 \\ 5\left(\frac{A_h}{A_a}\right) + 0.5, & 0.06 \le \frac{A_h}{A_a} \le 0.1 \end{cases}$$

As thumb rule

Type of Service	A_h/A_a (%)
Pressure	6 - 10
Atmospheric	8 - 12
Vacuum	10 - 16

5. CSB is function of Plate spacing and ratio of gas liquid flow, calculated using correlation



8.3 PROCEDURE TO CALCULATE COLUMN HEIGHT

1. Calculate Height of Rectifying section using formula

 $H_R = [(No. Of trays)*(Tray spacing)] + [Disengagement height] + [Manhole spacing]$

As a Thumb rule take Disengagement height = 4 ft

As a Thumb rule take Tray spacing = 500 mm

2. Calculate Height of Stripping section using formula

 $H_S = [(No. Of trays)*(Tray spacing)] + [Sump height] + [Manhole spacing]$

As a Thumb rule take Sump height = 10 ft

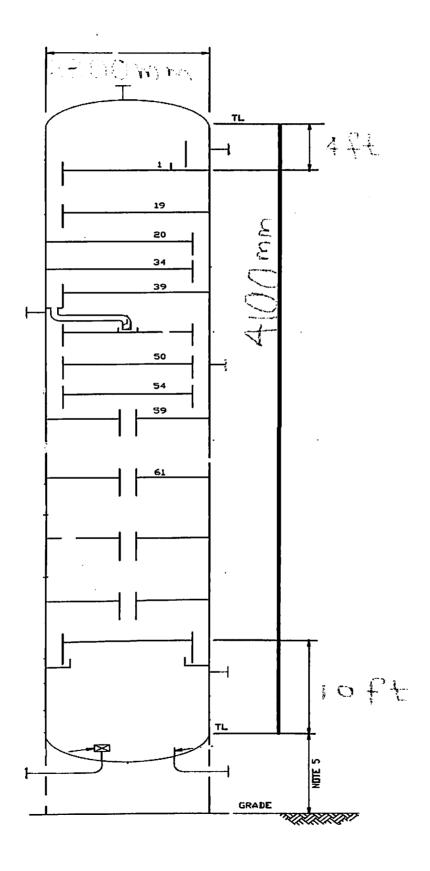
As a Thumb rule take Tray spacing = 600 mm

3. Total Height of column is given by

$$H_T = H_R + H_S$$

ITEM NUMBER: T-101

ITEM NAME: Depropylenizer Tower



8.4 DATA SHEET FOR DEPROPYLENIZER TOWER

ITEM NUMBER: T-101

ITEM NAME: Depropylenizer Tower

VESSEL NO.	T-101
VESSEL NAME	DEPROPYLENIZER TOWER
Inside Diameter (Rectifying Section)	2300 MM
Inside Diameter (Stripping Section)	2300 MM
Vertical Height (T/T)	4100 MM
No. Of Trays above Feed Tray	40
No. Of Trays below Feed Tray	24
Feed Tray Location	41 th
Operating Temperature (TOP)	43.7 °C
Operating Temperature (BOTT)	143.3 °C
Operating Pressure (TOP)	1.74 MPAG
Operating Pressure (BOTT)	1.80 MPAG
Liquid Density (TOP)	474 KG/M³
Liquid Density (BOTT)	467 KG/M ³
Design Temperature	160°C
Design Pressure	1.91 MPAG
Shell Material	C.S
Corrosion Allowance Shell	3 MM

9. DESIGN OF CONDENSER E 101

9.1 DESIGN BASIS

Design pressure

Maximum design pressure for any pressure vessel shall be Maximum normal operating pressure plus 2.0 kg/cm²

The minimum design pressure for any pressure vessel shall be 3.5 kg/cm²g.

Design temperature

In general the design temperature of pressure vessels is dependent upon the operating temperature range as follows:

No maximum design temperature will be set less than 65°C.

Operating Temp Range, (°C)	Design Temp, (°C)
T < 50	Minimum anticipated operating temperature margin to be determined by metallurgical limits
50 < T < 400	Maximum anticipated operating temperature + 15°C (round up to nearest 5°C.)
T > 400*	Maximum anticipated operating temperature 10% minimum margin

Fouling Factors

Fouling factors shall be specified as follows:

<u>Utility Services</u>	m ² -°C-h/kcal
Steam (all levels)	0.0001
Cooling Water	0.0004

Basic Engineering Package

Process Streams

m²-°C-h/kcal

Depropylenizer Overhead

0.0001

Depropylenizer bottoms

0.0004

Corrosion Allowance

Utility Services

Corrosion Allowance

Steam (all levels except SHP)

3 mm

Steam Condensate

1.5 mm

Cooling Water

3 mm

9.2 INPUTS TO HTRI

Rating	C Simulation	C Design									
Exchanger Configu											
Exchanger service Generic Shell and Tube											
Process Conditions											
Flow rate	Hot Shell	17.0689	Cold Tube	9		kg/s					
Inlet/outlet Y	1 /	0	0	1	O	Weight	raction vapor				
Inlet/outlet T	43.75 /	43	33	1	38	С					
Inlet P/allow dP	1820.11 /	19.613		1	68.647	kPa	/ kPa				
Fouling resistance	0.000086		0.000086			m2-K/W					
Shell Geometry Baffle Geometry											
TEMA type	A ▼ E ▼	L	Type		Single s	egmental	▼				
ID	1600 mm		Orientatio	n	Parallel		▼				
Orientation	Horizontal	-	Cut		20		%ID				
Hot fluid	Shellside	J	Spacing		500		mm				
Tube Geometry							Jan Salaman (1975) - Paper one decision in 1985 and decisions (1986)				
Туре	Plain	⊻	Wall thick	nes	s 2.108	≛	mm				
Length	6.096	m	Layout ar	ngle	30	~	degrees				
Tube OD	31.75 v mm		Tubepasses		4	▼					
Pitch	39.6875	mm	Tubecou	nt							

9.3 OUTPUT SUMMARY

Process Conditions		Hot Shellside		Cold Tubeside					
 Fluid name		Propylene		Water					
Flow rate	(kg/s)		17.0690		259.572				
Inlet/Outlet Y	(Wt. frac vap.)	1.000	0.000	0.000	0.000				
Inlet/Outlet T	(Deg C)	43.75	43.00	33.00	38.00				
Inlet P/Avg	(kPa)	1820.14	1816.71	0.000	0.000				
dP/Allow.	(kPa)	6.856	19.614	32.641	68.648				
Fouling	(m2-K/W)		0.000086		0.000086				
Exchanger Performance									
Shell h	(W/m2-K)	1656.22	Actual U	(W/m2-K)	972.71				
Tube h	(W/m2-K)	5727.33	Required U	(W/m2-K)	925.02				
Hot regime	()	Gravity	Duty	(MegaWatts)	5.1016				
Cold regime	()	Sens. Liquid	Area	(m2)	755.539				
EMTD	(Deg C)	7.3	Overdesign	(%)	5.16				
	Shell Geometry		Baffle Geometry						
TEMA type	()	AEL	Baffle type	()	Single-Seg.				
Shell ID	(mm)	1600.00	Baffle cut	(Pct Dia.)	20.00				
Series	()	1	Baffle orient	ation ()	Parallel				
Parallel	()	1	Central space	ing (mm)	500.000				
Orientation	(deg)	0.00	Crosspasse	s ()	11				
	Tube Geometry	•	Nozzles						
Tube type	()	Plain	Shell inlet	(mm)	258.877				
Tube OD	(mm)	31.750	Shell outlet	(mm)	205.004				
Length	(m)	6.096	Inlet height	(mm)	83.144				
Pitch ratio	()	1.2500	Outlet heigh	t (mm)	29.369				
Layout	(deg)	30	Tube inlet	(mm)	387.351				
Tubecount	()	1286	Tube outlet	(mm)	387.351				
Tube Pass	()	4		(,					
14001400		Velocitie	s, m/s	Flow Fractions					
Shell	58.73	Shellside	0.85	A	0.151				
Tube	19.59	Tubeside	1.37	B	0.522				
Fouling	18.01	Crossflow	1.33	C	0.062				
Metal	3.673	Window	1.43	E	0.205				
				F	0.060				

9.4 TEMA SHEET

Plant Location					Date	08-03-2011	Rev
Service of Unit					Item No.		-
	1600 00	x 6095.93 mm	Type AEL	Horz.	Connected In	1 Parallel	1 Series
Surl/Unit (Gross/Eff			Shell/Unit	1	Surf/Shell (Gro	ss/Eff) 781.94 / 755.54 m2	2
Out of it (Gloss Eli	1 101.5	1. 100.011112	PERFORMANC				
Fluid Allocation		- -		II Side		Tube	Side
Fluid Name			Propylene	Orac		Water	
				448.3		934	459
Fluid Quantity, Tota	!	kg/hr		1 440.3		301	100
Vapor (In/Out)			61448.3	-	011100	024450	934459
Liquid					61448.3	934459	304408
Steam							
Water							
Noncondensables							
Temperature (In/Ou	t)	С	43.75		43.00	33.00	38.00
Specific Gravity					0.4247	0.9952	0.9934
Viscosity		mN-s/m2	0.0103		0.0516	0.7491	0.6783
Molecular Weight. \	/apor						
Molecular Weight, N		iensables					
Specific Heat		kJ/kg-C	2.0615		3.2747	3.9151	3.9504
Thermal Conductivi	tv	W/m-C	0.0193		0.0773	0.6206	0.6281
Latent Heat	<u> </u>	kJ/kg	297.425		297.429		-
Inlet Pressure		kPa		20.14		† · · · · · · · · · · · · · · · · · · ·	
Velocity		m/s		0.85		1	37
	O_I		19.614	1.55	6.856	68.648	32.641
Pressure Drop, Allo		m2-K/W		100086	0.030		0086
Fouling Resistance			0.0		Corrected)	7.3 C	0000
Heat Exchanged V		5101550	1111 - 11				972.71 W/m2-K
Transfer Rate, Sen	/ice	925.02	W/m2-K Clean		186.40 W/m2-k		
		CONSTRUCT	ION OF ONE SHELL			Sketch (Bundle/N	lozzle Orientation)
			Shell Side		Tube Side	4	
Design/Test Pressu	ıre	kPaG	1930.03 /	1000.0		亅 ͺ╬ͺ	<u> </u>
Design Temperatur	re	С	140.00		65.00		
No Passes per She			1		4	_	talken
Corrosion Allowand		mm				▔▎▐ [╟] ┯┯┃ <u>╟</u> ╦╵┸╌┸╌┸╼┸╾┸	┸┸┸┈╢┈╢┈┵
Connections	lh	mm	1 @ 258.877	1@3	87.351	T + 1743	
Size &	Out	mm	1 @ 205.004	1@3	87.351	1 '	
Rating	Interme		@	a a		1	
Tube No. 1286		31.750 mm	Thk(Avg) 2.108 mm		Length 6.096	m Pitch 39.687 m	nm Layout 30
	Plain	01.70011111	Tracking, 2.100 time		Material CAP		
Tube Type		0.00 mm	OD	mm	Shell Cover	IDOITOTELL	
Shell		U.UU IIIIII			Channel Cove	er	
Channel or Bonnet					Tubesheet-Flo		
Tubesheet-Stationa					Impingement I		
Floating Head Cov	er		E000 40 11	(Diago) A	_1		L. 205 710
Baffles-Cross		Type SINGL		(Diam) 20	J.U Spacing	(c/c) 500.000	Inlet 735.718 mm
Baffles-Long			Seal T				
Supports-Tube			U-Ben			Туре	
Bypass Seal Arran	gement		Tube	Tubeshee	t Joint		
Expansion Joint			Туре				
Rho-V2-Inlet Nozzl	e	2730.67 kg/	m-s2 Bundle	Entranc	512.58	Bundle Exit 159.22	kg/m-s2
Gaskets-Shell Side			Tube S	Side			
-Floating Head							
Code Requirement						TEMA Class	
			Filled with Water 435	86.2		Bundle 15018.5	kg
Weight/Shell 286	40.0		,				-
Remarks:							
				-			
L						Dondo	ted with Permission (v5)
						перш	AND THE PERSON (40)

9.5 RATING DATA SHEET

Type AEL		Orientation Horizontal	Connected	In 1 Parallel 1 Se	nies	
Surt/Unit (Gross/E	ff) 781.94 / 755.54 m2		Surf/Shell (Gross/Eff) 781.94 / 755.		
FI ' I AD		PERFORMANC	E OF ONE UNIT			
Fluid Allocation			l Side		Tube Side	
Fluid Name		Propylene		Water		
Fluid Quantity, Tot			0690		259.572	
Vapor (In/Out)	wt%	100.0	0.0	0.0	0.0	
Liquid	wt%	0.0	100.0	100.0	100,0	
Temperature (In/O		43.75	43.00	33.00	38.00	
Density	kg/m3	38.511	424.46	994.72	992.98	
Viscosity	mN-s/m2	0.0103	0.0516	0.7491	0.6783	
Specific Heat	kJ/kg-C	2.0615	3.2747	3.9151	3.9504	
Thermal Conductiv		0.0193	0.0773	0.6206	0.6281	
Critical Pressure	kPa					
Inlet Pressure	kPa	1820	0.14			
Velocity	m/s		0.85		1.37	
Pressure Drop, Allo	w/Calc kPa	19.614	6.856	68.648	32.641	
Average Film Coeff		1656	5.22		5727.33	
Fouling Resistance	(min) m2-K/W	0.000		0.000086		
Heat Exchanged	5.1016	MegaWatts MTD (Corrected) 7.3 C		Overdesign 5.16 %		
Transfer Rate, Service 925.02		W/m2-K Calculated 972.71 W/m2-K			6.40 W/m2-K	
	CONSTRUCT	ION OF ONE SHELL			e/Nozzle Orientation)	
		Shell Side	Tube Side	Onoton (Duna)	O HOLZIO OTICINATION	
Design Pressure	kPaG	1930.03	1000.02	7 1	1	
Design Temperature	C	140.00 65.00		╼╡⋒ [┸] ╬╬╌┰┯┰┰┯		
lo Passes per Shel		1 4				
low Direction		Downward Upward				
Connections	ln mm	1 @ 258.877	1 @ 387.351		· ·	
Size &	Out mm	1@205.004	1 @ 387.351	-		
Rating	Liq. Out mm	@	@	-		
ube No. 1286 (OD 31.750 mm	Thk(Avg) 2.108 mm	Length 6.096	m Disch 20 co	7 1	
ube Type Plain		Material CARBON STEE	201947 0.000	Pairs seal strips		
hell ID 1600.00		Kettle ID m		Passlane Seal Rod N	0	
ross Baffle Type F	PARALLEL SINGLE-S					
pacing(c/c) 500.00		nlet 735.718 m		Impingement Plate	Circular plate	
ho-V2-Inlet Nozzle	·	Shell Entra		No. of Crosspasses	11 5. hadaa ah	
			rance 512.56	Shell Exit 1152.3 Bundle Exit 159.22		
eight/Shell 2	8645.6		3586.2	Bundle Exit 159.22 Bundle 15018.		
otes:			ermal Resistance, %		Flow Fractions	
		SH	rell 58.73			
				Tubeside 1.37		
		Fo	uling 18.01			
		יון יי	0	0100311011 1.00		
		Me		Window 1.43		

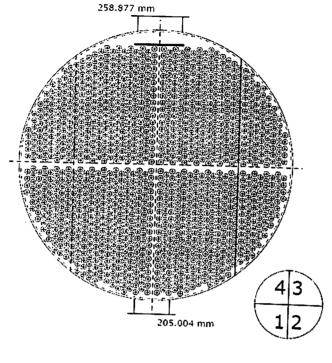
9.6 VIBRATION ANALYSIS

Shellside condition		Cond. Vapor	1(1 aval 0 0)	
Axial stress loading	(Mpa)	0.000	(Level 2.2)	
Beta	(wpa)	4.000	Added mass facto	г 1.761
Position In The Bund	dle	Inlet	Combon	
Length for natural frequency	(m)	1.236	Center	Outlet
Length/TEMA maximum span	()	0.553	1.000	1.154
Number of spans	()	0.555	0.447	0.516
Tube natural frequency	(Hz)	75.9	6	6
Shell acoustic frequency	(Hz)	64.0 +	74.9	68.0 4
Flow Velocities		Inlet		
Window parallel velocity	(m/s)	2.51	Center	Outlet
Bundle crossflow velocity	(m/s)	1.17	1.21	0.23
Bundle/shell velocity	(m/s)	1.27	0.83	0.12
Fluidelastic Instabilit	y Check	inlet	0.90 Center	0.13
Log decrement	HTRI	0.030	i	Outlet
Critical velocity	(m/s)	11.22	0.070	0.044
Baffle tip cross velocity ratio	()	0.120	18.37	5.22
Average crossflow velocity ratio	()	0.120	0.052	0.027
Acoustic Vibration Cl		Inlet	0.045	0.023
Vortex shedding ratio	()	0.230	Center	Outlet
Chen number	()	79899		
Turbulent buffeting ratio	()	0.171		
Tube Vibration Check	/	Inlet	0	
Vortex shedding ratio	()	0.099	Center	Outlet
Turbulent buffeting ratio	()	0.161	0.070	0.010
Parallel flow amplitude	(mm)	0.000	0.114	0.016
Crossflow amplitude	(mm)	0.006	0.000	0.000
Turbulent buffeting amplitude	(mm)	0.001	0.003	0.001
Tube gap	(mm)	7.938	0.001	0.000
10 7	(g/m-s2)	· -	7.938	7.938
Bundle Entrand	o/Evit	52.50	54.82	6.02
(analysis at first t			_	
Fluidelastic instability ratio	abe low)	٠. ١	Entrance	Exit
Vortex shedding ratio		()	0.400	0.144
1		()	0.310	0.052
Crossflow amplitude Crossflow velocity		(mm)	0.06251	0.01340
•		(m/s)	3.65	0.61
Turbulent buffeting amplitude		(mm)	0.015	0.001
Tubesheet to inlet/outlet support		(mm)	None	None
Shell Entrance/Exit Pa	rameters		Entrance	Exit
Impingement plate		l	Yes	
Flow area		(m2)	0.063	0.024
Velocity		(m/s)	7.00	1.65
RHO-V-SQ		(kg/m-s2)	1888.01	1152.35
Shell type AEL		affle type		Single-Seg.
Tube type Plain Pitch ratio 1.2500	Ba	affle layout		Parallel
	Γι ~-	be diameter, (mm)		31.750
Layout angle 30		ibe material		Carbon steel
	Sı	ipports/baffle space)	

9.7 FINAL RESULTS

Process Data		He	ot Shellside	T 0:1	
Fluid name			A Stietiside		d Tubeside
Fluid condition		Propylene	0	Water	
Total flow rate	(ka/c)	•	Cond. Vapor	;	Sens. Liquid
Weight fraction vapor, In/Out	(kg/s)		17.0690		259.572
Temperature, In/Out	()	-	0.000	0.000	0.000
Temperature, Average/Skin	(Deg C)	43.75	43.00	33.00	38.00
Wall temperature, Min/Max	(Deg C)	43.4	38.79	35.5	37.21
Pressure, In/Average	(Deg C)	36.29	39.67	35.96	39.48
	(kPa)	1820.14	1816.71	0.000	0.000
Pressure drop, Total/Allowed	(kPa)	6.856	19.613	32.641	68.647
Velocity, Mid/Max allow Mole fraction inert	(m/s)	0.85	1	1.37	00.047
	()		0.000		1
Average film coef.	(W/m2-K)		1656.22		5727.33
Heat transfer safety factor	()		1.000		1.000
Fouling resistance	(m2-K/W)		0.000086		0.000086
•		Performance	Data		0.000,000
Overall coef., Reqd/Clean/Acti	ıal	(W/m2-K)	925.02 /	1186.40 /	070.74
Heat duty, Calculated/Specifie	d	(MegaWatts)	5.1016 /	1186.40 /	972.71
Effective overall temperature d	lifference	(Deg C)			
EMTD = (MTD) * (DELTA) * (F	/G/H)	(Deg C)		1.0000 •	1.0000
		. 0 -/		1.0000	1.0000
		1			
			T-1	 	
		1111 1111 1			-
Exchanger Fluid Volu	mac	101 111 1	11111	1 1 1111 1111	term or man
Approximate shellside (L)		╙┸ ╌ ┸╢ ╌ ┸	- - - - - - - - - - 		
	5721.4		604 m		
Approximate lubeside (L)	9229.0				
TERIA -1 II de un -		truction infor	mation		
TEMA shell type	AEL	She	ell ID	(mm)	1600.00
-	l Parallel 1		al area	(m2)	781.939
	Tube 4	Eff.	area	(m2/shell)	755.539
Shell orientation angle (deg)	0.00			····	, 00.005
mpingement present	Circular plat	e Imp	ingement diame	eter/nozzle	1.1
Pairs seal strips	0		slane seal rods	/mm) 31 750	No. 10
Shell expansion joint	No	Rea	r head support	plate No	140. 10
Veight estimation Wet/Dry/Bun	dle	43586 /	28646 /		a.b. = U\
		e Information		15018 (kg/	snell)
ype Parallel	Single-Seg.				
crosspasses/shellpass	5///gie-5eg. 11	Dali	le cut (% dia) 2		
Central spacing (mm)		4		nm) to C.L	
nlet spacing (mm)		1	15.10	480.000	
No. At 1		2	0.00	0.000	
- 641					
attle thickness (mm)	15.875				
-	Tube	Information			
ube type	Plain		ecount per shell	ı	4000
	6.096	Dot +	inper toward	(hoth)	1286
verali length /m\		rul l	ubes removed (2.26
verall length (m) ffective length (m)		△	ido diamete-		
ffective length (m)	5.890		ide diameter	(mm)	31.750
ffective length (m) otal tubesheet (mm)	5.890 205.813	Wall	thickness	(mm)	2.108
ffective length (m) otal tubesheet (mm) rea ratio (out/in)	5.890	Waii Pitch	thickness	• •	

9.8 TUBE LAYOUT AND DRAWING

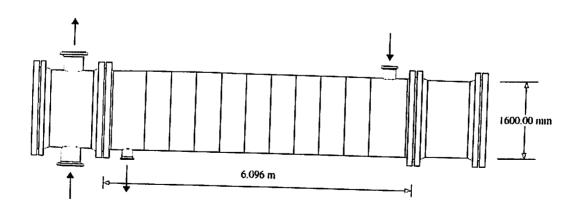


Item number	
TEMA type	AEL
Shell diameter	1600.00 mm
Outer tube limit	1580.61 mm
Height under inlet nozzle	83.144 mm
Height under outlet nozzle	
Tube diameter	
Tube pitch	
Tube layout angle	39.687 mm
Number of tubes (specified)	30
Number of tubes (calculated)	1286
Number of tie rods	1286
Number of seal strip pairs	12
Number of passing pairs	0
Number of passiane seal rods	10
Number of passes	4
Parallel passiane width	22.225 mm
Perpendicular passiane width	22.225 · mm
Baffle cut % diameter	20

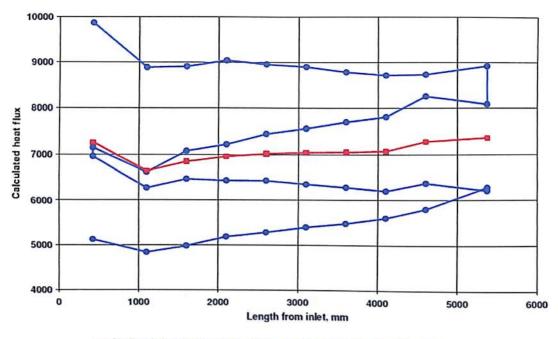
TUBEPASS DETAILS

Pass	Rows	Tubes	Plugged
1	37	323	
2	37	323	0
3	35		0
4		326	0
4	35	326	0

- SYMBOL LEGEND
 O Tube
 Plugged tube
 Tie rod
 Impingement rod
 Oummy tube
 Seal rod
 Seal strip/Skid bar

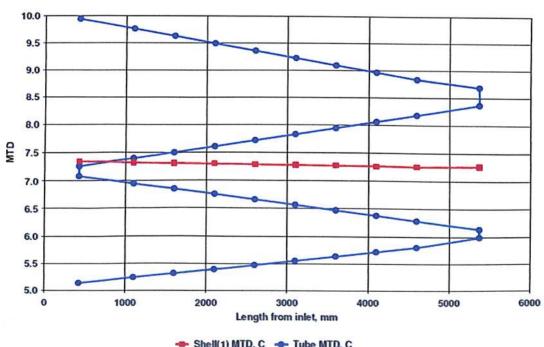


9.9 VARIATION OF HEAT FLUX ACROSS LENGTH



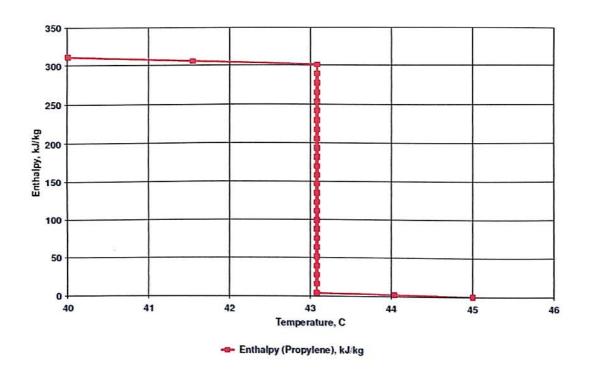
- Shell(1) Calculated heat flux, W/m2 - Tube Calculated heat flux, W/m2

9.10 VARIATION OF MTD ACROSS LENGTH



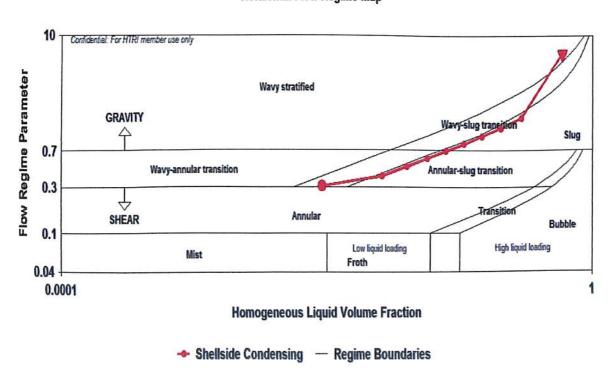
Shell(1) MTD, C - Tube MTD, C

9.11 ENTHALPY GRAPH



9.12 FLOW REGIME

Horizontal Flow Regime Map



10. DESIGN OF COOLER E-103

10.1 DESIGN BASIS

Design pressure

Maximum design pressure for any pressure vessel shall be Maximum normal operating pressure plus 2.0 kg/cm^2

The minimum design pressure for any pressure vessel shall be 3.5 kg/cm²g.

Design temperature

In general the design temperature of pressure vessels is dependent upon the operating temperature range as follows:

No maximum design temperature will be set less than 65°C.

Operating Temp Range, (°C)	Design Temp, (°C)
T < 50	Minimum anticipated operating temperature margin to be determined by metallurgical limits
50 < T < 400	Maximum anticipated operating temperature + 15°C (round up to nearest 5°C.)
T > 400*	Maximum anticipated operating temperature 10% minimum margin

Fouling Factors

Fouling factors shall be specified as follows:

<u>Utility Services</u>	m²-°C-h/kcal
Steam (all levels)	0.0001
Cooling Water	0.0004

Process Streams

m²-°C-h/kcal

Depropylenizer Overhead

1000.0

Depropylenizer bottoms

0.0004

Corrosion Allowance

Utility Services

Corrosion Allowance

Steam (all levels except SHP)

3 mm

Steam Condensate

1.5 mm

Cooling Water

3 mm

10.2 INPUTS TO HTRI

Rating	C Simulation	Design			
- Exchanger Con	figuration ————				
Exchangersen	vice Generic Shell ar	nd Tube	$\overline{\cdot}$	-	
Process Conditi	ons				
Flow rate	Hot Shell	27078.5	Cold Tube		kg/hr
Inlet/outlet Y	0 /	0	0 /	0	- Weight fraction vapor
Inlet/outlet T	100 /	40	33 /	40	C
Inlet P/allow dP	/	0.7		0.7	kPa / kgf/cm2
Fouling resistan	ce 0.000344		0.000086	,	m2-K/W
Shell Geometry			Baffle Geometr	V	
TEMA type	A ▼ E ▼		Туре	Single se	
ID	mm		Orientation	Parallel	→
Orientation	Horizontal -]	Cut	30	% ID
Hot fluid	Shellside]	Spacing		mm
Tube Geometry				· · · · · · · · · · · · · · · · · · ·	
Туре	Plain	•	Wall thickness	2.108	▼ mm
Length	1.829 w		Layout angle	30	▼ degrees
Tube OD	19.05 w	m	Tubepasses	2	▼
Pitch	25 mr	n	Tubecount		

10.3 OUTPUT SUMMARY

Process	Conditions	Hot SI	nellside	0-143	
Fluid name	o inditioning		ieliside	1	Tubeside
Flow rate	lkalo	propylene `	===	water	
Inlet/Outlet Y	(kg/s) (Wt. frac vap.)		7.5218		46.6670
Inlet/Outlet T	(Deg C)		. 1	3.000	5.555
Inlet P/Avg	(kPa)			1	40.00
dP/Allow.	(kPa)		1 3,500	1	0.000
Fouling	(m2-K/W)		0.000344		68.648
			Performance		0.000086
Shell h	(W/m2-K)		ı	8441 - 40	
Tube h	(W/m2-K)		1	(W/m2-K)	490.39
Hot regime	()	Sens. Liquid	1 4	(**************************************	465.83
Cold regime	()	Sens. Liquid	Area	(MegaWatts)	1.2863
EMTD	(Deg C)	19.8	Overdesign	(m2) 1 (%)	139.596
	Shell Geometry	/		Baffle Geomet	5.27 rv
TEMA type	()	AES	Baffle type	()	•
Shell ID	(mm)	715.000	Baffle cut	(Pct Dia.)	Single-Seg.
Series	()	1	Baffle orient		35.00 Parallel
Parallel	()	1	Central space	` '	400.000
Orientation	(deg)	0.00	Crosspasse	•	7
	Tube Geometry			Nozzles	
Tube type	()	Plain	Shell inlet	(mm)	154.051
Tube OD	(mm)	15.875	Shell outlet	(mm)	154.051
Length	(m)	3.048	Inlet height	(mm)	24.522
Pitch ratio	()	1.2500	Outlet height		24.522
Layout	(deg)	30	Tube inlet	(mm)	154.051
Tubecount	()	950	Tube outlet	(mm)	154.051
Tube Pass	()	2		(*******)	104.001
Thermal Resi	Thermal Resistance, % Velocities			Flow Fra	ctions
Shell	62.29	Shellside	0.16	A	0.127
Tube	13.03	Tubeside	0.93	B	0.127
ouling	22.60	Crossflow	0.21	Č	0.121
<i>l</i> letal	2.081	Window	0.21	Ē	0.113
				F	0.127

10.4 TEMA SHEET

Camies afti.					Date	22-01-2011	Rev
Service of Unit					Item No.		UGA
Size	715.000 x 30	047.96 mm	Type AES	Horz.	Connected In	1 Paralle	
Surf/Unit (Gross	Eff) 144.41 / 13	39.60 m2	Shell/Unit	1	Surf/Shell (Gr	oss/Eff) 144.41 / 139.60	1 Series
			PERFORMAN	CE OF ON	VE UNIT	000 Ett/ 144.417 109.00	1112
Fluid Allocation				rell Side		T.	- C11
Fluid Name		pr	opylene			water	be Side
Fluid Quantity, T	otal kg/h	nr		7078.7			20004
Vapor (In/Out)				7			58001
Liquid			27078.7	+	27078.7		
Steam			27010.1	+	21016.1	168001	168001
Water				+-			
Noncondensabl	es						
emperature (In/	Out) C		99.40	 -	40.00		
Specific Gravity		-+	0.4119		40.00	33.00	40.00
/iscosity	mN-	s/m2		-	0.5207	0.9952	0.9927
Aolecular Weigh	Vanor	3/11/2	0.0504	——	0.0875	0.7491	0.6532
Aolecular Weight		Noc					
pecific Heat	kJ/kg		0.0767	↓ _			
hermal Conduct	vity W/m		3.3797		2.5634	3.9151	3.9649
atent Heat			0.0709		0.0973	0.6205	0.6309
	kJ/kg	-					V.W003
let Pressure	kPa	_					
elocity	m/s			.16			93
ressure Drop, Al	ow/Calc kPa		68.648		1.277	68.648	
ouling Resistanc	e (min) m2-K	W_	0.00	0344			14.492
eat Exchanged		6295		MTD (Co	prected)	19.8 C	0086
ansfer Rate, Ser		465.83 W/n	n2-K Clean		33.67 W/m2-K		
	CONS	TRUCTION	OF ONE SHELL		30.07 Williz-IX	Actual	490.39 W/m2-K
			Shell Side	T	ıbe Side	Sketch (Bundle/N	ozzle Orientation)
sign/Test Press	re kPaG	1930	0.03/	1000.02		1	
sign Temperatu		— ····	130.00		35.00	m = 101	
Passes per She			1	 	2		
rrosion Allowand			'	 			} ::''à
Connections	In mm	10	154.051	10151		, a.	
Size &	Out mm		154.051	1 @ 154.		1	
Rating	Intermediate		154.051	1@154.	051		
pe No. 950		@	<u> </u>	@			
pe Type	Plain	im /hk//	Avg) 2.108 mm		ength 3.048 m		n Layout 30
					laterial CARBO	ON STEEL	- Cayour oo
	ID 715.000 mm		OD	mm S	hell Cover		
annel or Bonnet					hannel Cover		
esheet-Stationa					ubesheet-Floati	na — — —	
iting Head Cove					npingement Plat		
les-Cross	Type S	INGLE-SEC	i. %Cut (Dia	m) 35.0	Spacing(c/c	1 100 000	
les-Long			Seal Type		- Spacing(tr	s) 400.000 Ini	et 532.625 mm
ports-Tube			U-Bend				
ass Seal Arrange	ment		Tube-Tube	anhact Isla		уре	
ansion Joint				soneer Joh	<u> </u>		
V2-Inlet Nozzle	395 58	kg/m-s2	Type Bundle En	trans- C	140	u 6.	
ets-Shell Side	- 555.56	rightin SE			.42 B	undle Exit 107.90 kg	ym-s2
Floating Head			Tube Side				
Requirements							
ht/Shell 4492.0	<u> </u>	g=414 ·	10. 342			MA Class	
arks:	5	Filled y	vith Water 5861.98		Bu	ındle 2311.32 kg	
uinə.							

10.5 RATING DATA SHEET

Type AES		Orientation Horizonta	Connected	I In 1 Parallel 1 S	eries
Surt/Unit (Gross/Eff) 14	14.41 / 139.60 m2		Surf/Shell	(Gross/Eff) 144.41 / 139	60 m2
FI : I AU		PERFORMANO	E OF ONE UNIT	, , , , , , , , , , , , , , , , , , , ,	.oo me
Fluid Allocation		She	Il Side		Tube Side
Fluid Name		propylene		water	
Fluid Quantity, Total	kg/s	7.	5218		46.6670
Vapor (In/Out)	wt%	0.0	0.0	0.0	0.0
Liquid	wt%	100.0	100.0	100.0	100.0
Temperature (In/Out)	С	99.40	40.00	33.00	40.00
Density	kg/m3	411.68	520.48	994.70	992.22
Viscosity .	mN-s/m2	0.0504	0.0875	0.7491	0.6532
Specific Heat	kJ/kg-C	3.3797	2.5634	3.9151	3.9649
Thermal Conductivity	W/m-C	0.0709	0.0973	0.6205	0.6309
Critical Pressure	kPa				
Inlet Pressure	kPa				
Velocity	m/s		0.16		0.93
Pressure Drop, Allow/Cal		68.648	1.277	68.648	14.492
Average Film Coefficient		787	.53		5121.30
Fouling Resistance (min)	m2-K/W	0.000)344		0.000086
Heat Exchanged	1.2863		rrected) 19.8 C	Overdesign	
Transfer Rate, Service			d 490.39 W/m2-K	Clean 633.	
	CONSTRUCT	ON OF ONE SHELL	100.00 11/11/2 11		
		Shell Side	Tube Side	OKERTI (DURU)	e/Nozzle Orientation)
Design Pressure	kPaG	1930.03	1000.02	- 	1
Design Temperature	C	130.00	65.00	╼┨╓ ┋ ╓╌┯╼┰	─┬─ [₹] -⋒─┐ —
No Passes per Shell		1	2	-	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
low Direction		Downward	Upward	╼┦╟╀┼┫╟╤┰┸╌┸╌┸	
Connections In	mm	@ 154.051	1 @ 154.051	- I I I I I I I I I I I I I I I I I I I	
Size & Out			1 @ 154.051	┦ ' '	•
Rating Liq. Ou		@	@	-[
ube No. 950 OD 1	5.875 mm T	hk(Avg) 2.108 mm	Length 3.048) m Dish 4004	
ube Type Plain		laterial CARBON STEE	Longur 5.040	Pitch 19.844	
hell ID 715.000 mm		ettle ID m		Pairs seal strips	2
ross Baffle Type PARAL				Passlane Seal Rod N	
pacing(c/c) 400.000		let 532.625 mi		Impingement Plate	None
no-V2-Inlet Nozzle 395.5		Shell Entra		No. of Crosspasses	7
12 811011102210 000.00	- 1.3.11.02			Shell Exit 463.77	kg/m-s2
eight/Shell 4492.08) <u>[</u>		rance 82.42	Bundle Exit 107.90	kg/m-s2
otes:	, FR		861.96	Bundle 2311.32	
noo.	· · · · · · · · · · · · · · · · · · ·	Sh	ermal Resistance, %	At 11 1	Flow Fractions
	<u></u>	Tul			
			ling 22.60	V.2.1	C 0.121
		Me	lal 2.08	Window 0.21	
		<u></u>			F 0.127

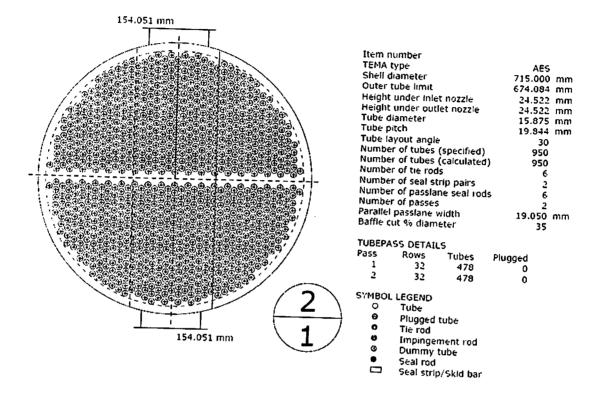
10.6 VIBRATION ANALYSIS

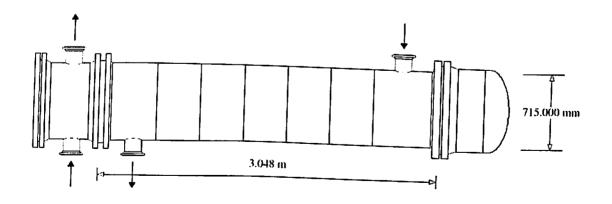
Shellside condition		Sens. Liquid	(Level 2.2)	
Axial stress loading	(Mpa)	0.000	Added mass factor	.
Beta	•	4.000	Added mass racti	or 1.761
Position In The Bun	dle	Inlet	Center	Outlet
Length for natural frequency	(m)	0.933	0.800	Outlet 0.814
Length/TEMA maximum span	()	0.693	0.594	
Number of spans	()	4	0.534	0.604
Tube natural frequency	(Hz)	61.1	60.1	500
Shell acoustic frequency	(Hz)	V 1.1	00.1	59.9
Flow Velocities		Inlet	Center	Outlet
Window parallel velocity	(m/s)	0.23	0.19	Outlet
Bundle crossflow velocity	(m/s)	0.15	0.19	0.18
Bundle/shell velocity	(m/s)	0.10	0.10	0.15
Fluidelastic Instabilit	y Check	Inlet	Center	0.10
Log decrement	HTRI	0.038	ľ	Outlet
Critical velocity	(m/s)	2.26	0.038	0.038
Baffle tip cross velocity ratio	()	0.066	2.82	2.69
Average crossflow velocity ratio	()	0.066	0.057	0.056
Acoustic Vibration Cl		Inlet	0.057	0.056
Vortex shedding ratio	()	unet	Center	Outlet
Chen number	()			
Turbulent buffeting ratio	()			
Tube Vibration Check		Inlet	0	
Vortex shedding ratio	()	0.028	Center	Outlet
Turbulent buffeting ratio	()	0.028	0.031	0.029
Parallel flow amplitude	(mm)	0.000	0.050	0.046
Crossflow amplitude	(mm)	0.000	0.000	0.000
Turbulent buffeting amplitude	(mm)	1	0.001	0.001
Tube gap		0.000	0.001	0.001
Constitution Dispose	(mm)	3.969	3.969	3.969
Bundle Entranc	g/m-s2)	8.77	12.69	11.50
		ł		
(analysis at first to	lbe row)		Entrance	Exit
Fluidelastic instability ratio		()	0.244	0.208
Vortex shedding ratio		()	0.086	0.208
Crossflow amplitude		(mm)	0.01478	0.01121
Crossflow velocity		(m/s)	0.45	0.01121
Turbulent buffeting amplitude		(mm)	0.007	
Tubesheet to inlet/outlet support		(mm)	None	0.009
Shell Entrance/Exit Par	ameters	(*****)		None
Impingement plate	-		Entrance	Exit
Flow area		(m2)	No	
Velocity		(m/s)	0.015	0.015
RHO-V-SQ		(III/S) (kg/m-s2)	1.19	0.94
Shell type AES	Raffl	e type	586.32	463.77
Tube type Plain		e layout		Single-Seg.
Pitch ratio 1.2500		diameter, (mm)		Parallel
_ayout angle 30	Tube	material		15.875
		orts/baffle space		Carbon steel
	Supp	orranname space		

10.7 FINAL RESULTS

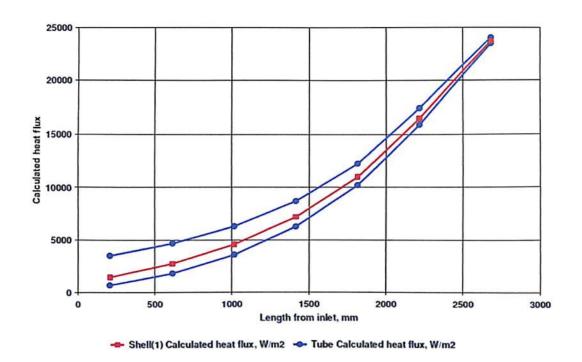
Process Data	<u>-</u>	Hot	Shellside	Co	ld Tubeside
Fluid name		propylene		1	4062106
Fluid condition			ens. Liquid	water	0
Total flow rate	(kg/s)	•	7.5218	1	Sens, Liquid
Weight fraction vapor, In/Out	()		0.000	0.000	46.6670
Temperature, In/Out	(Deg C)	99.40	40.00	33.00	0.000
Temperature, Average/Skin	(Deg C)	69.7	44.79	36.5	40.00
Wall temperature, Min/Max	(Deg C)	34.43	49.15	34.30	39.49
Pressure, In/Average	(kPa)	0.000	0.000	0.000	47.99
Pressure drop, Total/Allowed	(kPa)	1.277	68.647	14.492	0.000
Velocity, Mid/Max allow	(m/s)	0.16	00.047	0.93	68.647
Mole fraction inert	()	,		0.93	1
Average film coef. (V	V/m2-K)		787.53		5121.30
Heat transfer safety factor	()		1.000	1	1.000
Fouling resistance (n	<u>n2-K/W)</u>		0.000344		0.000086
	Overall	Performance I			0.00000
Overall coef., Reqd/Clean/Actual		(W/m2-K)	465.83	/ 633,67 /	490.39
Heat duty, Calculated/Specified		(MegaWatts)	1.2863		490.39
Effective overall temperature differe	nce	(Deg C)	19.8		
EMTD = (MTD) * (DELTA) * (F/G/H)		(Deg C)	21.40	0.9245	1.0000
	 ,				
		1		1	
		<u> </u>		╶┑	T -
		1111 11111 1	1 1 1	1 1 1111	715 000 mm
Exchanger Fluid Volumes			_1 1 1	1 1 0011	
pproximate shellside (L)	632.9		1016	╌┵╼╌╵╌╾╴╢╟┖	1 ∕ — ♣
pproximate tubeside (L)	737.9				
Sh	ell Cons	truction inform	ation		
EMA shell type AES	3	Shell	ID	/mm)	745 000
hells Series 1 Par		Total		(mm)	715.000
asses Shell 1 Tub	_	Eff. a		(m2) (m2/shell)	144.409
hell orientation angle (deg) 0.00)			(1112/311611)	139.596
npingement present No airs seal strips					
kan kan		Passi	ane seal rod	s (mm) 15.875	No. 6
nell expansion joint No		Hear	head suppor	t plate No	140. 0
eight estimation Wet/Dry/Bundle		5862.0 /	4492.1 /	2311.3 (kg/	shell)
	Baffle	Information			oricii)
pe Parallel Single	-Seg.	Baffle	cut (% dia)	25.00	
osspasses/shellpass	7	No. (P	ct Area) (mm) to C.L	
	0.000	1	32.57	107.250	
et spacing (mm) 53	2.625	2	0.00	0.000	
***	3.745			0.000	
ffle thickness (mm)	6.350				
	Tube	Information			
pe type	Plain				
oe lybe	- 14111	Tubeco	ount per she	I	950
	2 042		oc romana	(both)	0.11
erall length (m)	3.048 2.046	PCI IUD	es removed	(404.7)	V. 1 1
erall length (m) 3 ective length (m) 2	2.946	Outside	e diameter	(mm)	15.875
erall length (m) 3 ective length (m) 2 al tubesheet (mm) 101	2.946 1.600	Outside Wall th	e diameter ickness	(mm) (mm)	
erall length (m) 3 ective length (m) 2 al tubesheet (mm) 10	2.946 1.600 3616	Outside Wall th Pitch (n	e diameter ickness	(mm)	15.875

10.8 TUBE LAYOUT AND DRAWING

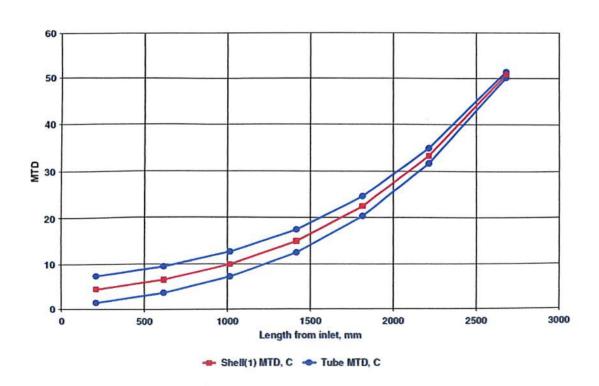




10.9 VARIATION OF HEAT FLUX ACROSS LENGTH



10.10 VARIATION OF MTD ACROSS LENGTH



11. DESIGN OF COOLER E-104

11.1 DESIGN BASIS

Design pressure

Maximum design pressure for any pressure vessel shall be Maximum normal operating pressure plus $2.0\ kg/cm^2$

The minimum design pressure for any pressure vessel shall be 3.5 kg/cm²g.

Design temperature

In general the design temperature of pressure vessels is dependent upon the operating temperature range as follows:

No maximum design temperature will be set less than 65°C.

Minimum anticipated operating temperature margin to be determined by metallurgical limits
Maximum anticipated operating temperature + 15°C (round up to nearest 5°C.)
Maximum anticipated operating temperature 10% minimum margin

Fouling Factors

Fouling factors shall be specified as follows:

<u>Utility Services</u>	m²-°C-h/kcal
Steam (all levels)	0.0001
Cooling Water	0.0004

Process Streams

m2-OC-h/kcal

Depropylenizer Overhead

0.0001

Depropylenizer bottoms

0.0004

Corrosion Allowance

Utility Services

Corrosion Allowance

Steam (all levels except SHP)

3 mm

Steam Condensate

1.5 mm

Cooling Water

3 mm

11.2 INPUTS TO HTRI

Rating	C Simulation © Desig	n	
Exchanger Conf	figuration —		
Exchangerserv		▼	
Process Conditi	ons		
Flow rate	Hot Shell 2124	Cold Tube	kg/hr
Inlet/outlet Y	0 / 0	0 /	0 Weight fraction vapor
Inlet/outlet T	143 / 40	33 ,	40 C
Inlet P/allow dP	/ 0.7		0.7
Fouling resistant	J	0.000086	w./ kPa / kgf/cm2 m2-K/W
Shell Geometry		Baffle Genmetry	
TEMA type	A ▼E ▼S ▼	Туре	Single segmental ▼
ID	mm	Orientation	Parallel •
Orientation	Horizontal 🔻	Cut	20
Hot fluid	Shellside 🔻	Spacing	30 % ID mm
Tube Geometry—			1
Туре	Plain ▼	Wall thickness	2.108 v mm
Length	1.829 ▼ m	Layout angle	30
Tube OD	12.7 mm	Tubepasses	2
Pitch .	15.875 mm	Tubecount	

11.3 OUTPUT SUMMARY

Process	Conditions	Hot S	Shellside		Cold Tu	thacida
Fluid name		C4+ Product				ine2id6
Flow rate	(kg/:		0.590		ater	
Inlet/Outlet Y	(Wt. frac vap				0.000	5.9239
Inlet/Outlet T	(Deg C		- 1 0.00	ľ	33.00	0.000
Inlet P/Avg	(kPa		, ,,,,	- 1	0.000	40.00 0.000
dP/Allow.	(kPa) 1.31		·	1.358	19.614
Fouling	<u>(m2-K/W</u>)	0.00034		1.000	
		Exchanger	Performance)		0.000000
Shell h	(W/m2-K				///////////////////////////////////////	
Tube h	(W/m2-K)		.	11	(W/m2-K) (W/m2-K)	263.98
Hot regime	()	Sens. Liquio			egaWatts)	247.54 0.1633
Cold regime	()		Area	,,,,	(m2)	19.102
EMTD	(Deg C)	- 110	Overdesig	n	(%)	6.64
ı	Shell Geometr	у		Baff	le Geometry	
TEMA type	()	AES	Baffle type		()	Cinalo Com
Shell ID	(mm)	360.000	Baffle cut		(Pct Dia.)	Single-Seg.
Series	()	1	Baffle orie		•	28.00
Parallel	()	1	Central spa		()	Parallel
Orientation	(deg)	0.00	Crosspass	_	(mm)	160.000 9
T	ube Geometry				()	9
Tube type	()	Plain	Shell inlet	ı	Vozzies	
Tube OD	(mm)	15.875	ſ		(mm)	52.553
Length	(m)	1.829	Shell outlet		(mm)	26.645
Pitch ratio	()	1.2500	Inlet height		(mm)	18.273
ayout		30	Outlet heigh	nt	(mm)	18.273
Tubecount	(deg)	j	Tube inlet		(mm)	77.927
Tube Pass	()	218	Tube outlet		(mm)	77.927
	()	1				
Thermal Resis		Velocities	, m/s		Flow Fraction	ons
ihell ube	61.90	Shellside	5.041e-2	Α		0.245
ouling	24.87 12.08	Tubeside	0.26	В		0.426
letal	1.156	Crossflow Window	7.255e-2	C		0.175
	1.130	**INUUW	7.235e-2	E		0.154
				F		0.000

11.4 TEMA SHEET

Plant Location Service of Unit		Date	24-01-2011	Rev
Size 360.000 x 1828.98 m	m Type AES	Item No.		
Surf/Unit (Gross/Eff) 19.89 / 19.10 m2	Shell/Unit	Horz. Connected In		1 Series
	PEDECIDATAN	CE OF ONE UNIT	oss/Eff) 19.89 / 19.10 m2	
Fluid Allocation	TETH ONWAIN	ell Side		
Fluid Name	C4+ Product	ell Side	Tube	Side
Fluid Quantity, Total kg/hr		<u> </u>	Water	
Vapor (In/Out)	21	24.01	2132	6.2
Liquid	21212			
Steam	2124.01	2124.01	21326.2	21326.2
Water				21020.2
Noncondensables				
Temperature (In/Out) C				
Specific Gravity	141.53	40.00	33.00	40.00
1.0	0.4092	0.5606	0.9952	0.9927
Viscosity mN-s/m2 Molecular Weight, Vapor	0.0495	0.1112	0.7491	0.6532
Molecular Weight, Noncondensables				0.0332
norky'O	3.3290	2.3601	3.9151	0.0040
	0.0615	0.1079	0.6206	3.9649
Latent Heat kJ/kg			0.0200	0.6309
Inlet Pressure kPa				
Velocity m/s	5.04	1e-2	0.00	
Pressure Drop, Allow/Calc kPa	19.614	1.312	0.26	
Fouling Resistance (min) m2-K/W	0.000		19.614	1.358
Heat Exchanged W 163283		MTD (Corrected)	0.00008 34.5 C	36
Transfer Rate, Service 247.54 V	V/m2-K Clean	300.20 W/m2-K		
CONSTRUCTION	ON OF ONE SHELL	300.20 Willi2-IV	Actual 26	3.98 W/m2-K
	Shell Side	Tube Side	Sketch (Bundle/Nozz	le Orientation)
Design/Test Pressure kPaG 11		1000.02/		1
Design Temperature C	160.00	65.00	M-M	╧┷╬╌╴╶┰
vo Passes per Shell	1	05.00	~¶ N]]] → ×ça
Corrosion Allowance mm			UP	
Connections In mm 1	@ 52.553	1 @ 77 007		
		1 @ 77.927		
	<u>a</u>	0 77.927		
	k(Avg) 2.108 mm	@		
ube Type Plain	Altry 2.100 mm	Length 1.829 m	Pitch 19.844 mm	Layout 30
hell ID 360,000 mm	OD	Material CARBO	NSTEEL	
hannel or Bonnet	<u> </u>	mm Shell Cover		
besheet-Stationary		Channel Cover		
pating Head Cover		Tubesheet-Floatin	g	
		Impingement Plate	None	
iffles-Cross Type SINGLE-Siffles-Long		n) 28.0 Spacing(c/c)		105.772 mm
pports-Tube	Seal Type		inet -	105.772 INIT
	U-Bend	Tv	pe	
pass Seal Arrangement	Tube-Tubes	heet Joint		
pansion Joint	Type			
o-V2-Inlet Nozzle 180.91 kg/m-s2	Bundle Entre	ance 2.36 Bu	ndle Exit 6.35 kg/m-	-0
skets-Shell Side	Tube Side	Du	ndle Exit 6.35 kg/m-	SZ
-Floating Head				
de Requirements		TE	MA Class	
ight/Shell 983.28 Filler	with Water 1201.46		H	
narks:		Bui	ndle 329.78 kg	
				Permission (v5)

11.5 RATING DATA SHEET

	ES	Orientation Horizont	al Connecte	ed In 1 Parallel 1 Serie	<u> </u>
Surf/Unit (Gro	ss/Eff) 19.89 / 19.10 m/		Surf/Shel	(Gross/Eff) 19.89 / 19.10 m	; <u>s</u>
Child An			CE OF ONE UNIT	(10.00 / 10.10 III	
Fluid Allocation	1	St	ell Side	Tul	be Side
Fluid Name	T	C4+ Product		Water	
Fluid Quantity.			.5900		9239
Vapor (In/Out		0.0	0.0	0.0	0.0
Liquid	wt%	100.0	100.0	100.0	100.0
Temperature (I		141.53	40.00	33.00	40.00
Density	kg/m3	408.97	560.40	994.72	992.23
Viscosity	mN-s/m2	0.0495	0.1112	0.7491	
Specific Heat	kJ/kg-C	3.3290	2.3601	3.9151	0.6532
Thermal Condu		0.0615	0.1079	0.6206	3.9649
Critical Pressure	10.00			0.0200	0.6309
Inlet Pressure	kPa				
Velocity	m/s		5.041e-2		0.00
Pressure Drop,		19.614	1.312	19.614	0.26
Average Film Co	pefficient W/m2-K	42	6.14		1.358
Fouling Resistan	ce (min) m2-K/W		0340		7.46
Heat Exchanged		3 MegaWatts MTD (Co	arrected) 24 E C	0.00	
Transfer Rate, S	ervice 247.5		ed 263.98 W/m2-K	Overdesign 6.6	
		TION OF ONE SHELL	203.30 VY/MZ-K	Clean 300.20	
		Shell Side	Tube Side	Sketch (Bundle/No	ozzle Orientation)
Design Pressure	kPaG	1863.29		_	1
Design Temperat		160.00	1000.02	<u> </u>	_
No Passes per SI		100.00	65.00	· ┛┪╫╟╏╏╏]]
Flow Direction		Downward	<u> </u>		——₩ <i>1</i> / — L
Connections	ln mm	1 @ 52.553	1 @ 77 007	-	
Size &	Out mm	1 @ 26.645	1 @ 77.927 1 @ 77.927	-1	
Rating	Liq. Out mm	@		4	
	3 OD 15.875 mm	Thk(Avg) 2.108 mm	@		
ube Type Plain			Length 1.829		n Layout 30
v · / pv · i (uii)	10 mm	Material CARBON STEL		Pairs seal strips 2	
	07 11111		m	Passlane Seal Rod No. 0	
hell ID 360.00		CEC ALC LIES		- applicate open 1100 140. O	
hell ID 360.00 ross Baffle Type	PARALLEL SINGLE-S				one
hell ID 360.00 ross Baffle Type pacing(c/c) 160.	PARALLEL SINGLE-S	Inlet 405.772 m	m) 28.0 m	Impingement Plate N	one
hell ID 360.00 ross Baffle Type pacing(c/c) 160.	PARALLEL SINGLE-S	Inlet 405.772 m Shell Entra	m) 28.0 m nce 71.33	Impingement Plate N No. of Crosspasses 9	one
hell ID 360.00 ross Baffle Type pacing(c/c) 160.0 ho-V2-Inlet Nozzl	PARALLEL SINGLE-S 000 mm e 180.91 kg/m-s2	Inlet 405.772 m Shell Entra Bundle Ent	m) 28.0 m	Impingement Plate N No. of Crosspasses 9 Shell Exit 231.82 kg	one v/m-s2
hell ID 360.00 ross Baffle Type pacing(c/c) 160.0 no-V2-Inlet Nozzlo eight/Shell	PARALLEL SINGLE-S 000 mm e 180.91 kg/m-s2	Inlet 405.772 m Shell Entra Bundle Ent	m) 28.0 m nce 71.33	Impingement Plate N No. of Crosspasses 9 Shell Exit 231.82 kg Bundle Exit 6.35 kg	one
hell ID 360.00 ross Baffle Type pacing(c/c) 160.	PARALLEL SINGLE-S 000 mm e 180.91 kg/m-s2	Inlet 405.772 m Shell Entra Bundle Ent Filled with Water 1	m) 28.0 m nce 71.33 rance 2.36 201.46	Impingement Plate N No. of Crosspasses 9 Shell Exit 231.82 kg Bundle Exit 6.35 kg Bundle 329.78 kg	one ym-s2 ym-s2
hell ID 360.00 ross Baffle Type pacing(c/c) 160.0 no-V2-Inlet Nozzlo eight/Shell	PARALLEL SINGLE-S 000 mm e 180.91 kg/m-s2	Inlet 405.772 m Shell Entra Bundle Ent Filled with Water 1	m) 28.0 m nce 71.33 rance 2.36 201.46 ermal Resistance, %	Impingement Plate N No. of Crosspasses 9 Shell Exit 231.82 kg Bundle Exit 6.35 kg Bundle 329.78 kg Velocities, m/s Fig	one ym-s2 ym-s2 ow Fractions
hell ID 360.00 ross Baffle Type pacing(c/c) 160.0 ho-V2-Inlet Nozzlo eight/Shell	PARALLEL SINGLE-S 000 mm e 180.91 kg/m-s2	Inlet 405.772 m Shell Entra Bundle Ent Filled with Water 1 Th	m) 28.0 m nce 71.33 rance 2.36 201.46 ermal Resistance, % ell 61.90	Impingement Plate No. of Crosspasses 9 Shell Exit 231.82 kg Bundle Exit 6.35 kg Bundle 329.78 kg Velocities, m/s Flo Shellside 5.041e-2 A	one y/m-s2 y/m-s2 ow Fractions 0.245
hell ID 360.00 ross Baffle Type pacing(c/c) 160.0 ho-V2-Inlet Nozzlo eight/Shell	PARALLEL SINGLE-S 000 mm e 180.91 kg/m-s2	Inlet 405.772 m Shell Entra Bundle Ent Filled with Water 1 Th Sh	m) 28.0 m nce 71.33 rance 2.36 201.46 ermal Resistance, % ell 61.90 be 24.87	Impingement Plate No. of Crosspasses 9 Shell Exit 231.82 kg Bundle Exit 6.35 kg Bundle 329.78 kg Velocities, m/s Flo Shellside 5.041e-2 A Tubeside 0.26 B	one ym-s2 ym-s2 ow Fractions
hell ID 360.00 ross Baffle Type pacing(c/c) 160.0 ho-V2-Inlet Nozzlo eight/Shell	PARALLEL SINGLE-S 000 mm e 180.91 kg/m-s2	Inlet 405.772 m Shell Entra Bundle Ent Filled with Water 1 Th Sh Tu	m) 28.0 m nce 71.33 rance 2.36 201.46 ermal Resistance, % ell 61.90 be 24.87 uling 12.08	Impingement Plate No. of Crosspasses 9 Shell Exit 231.82 kg Bundle Exit 6.35 kg Bundle 329.78 kg Velocities, m/s Flot Shellside 3.041e-2 A Tubeside 0.26 B Crossflow 7.255e-2 C	one y/m-s2 y/m-s2 ow Fractions 0.245
hell ID 360.00 ross Baffle Type pacing(c/c) 160.0 ho-V2-Inlet Nozzlo eight/Shell	PARALLEL SINGLE-S 000 mm e 180.91 kg/m-s2	Inlet 405.772 m Shell Entra Bundle Ent Filled with Water 1 Th Sh	m) 28.0 m nce 71.33 rance 2.36 201.46 ermal Resistance, % ell 61.90 be 24.87 uling 12.08	Impingement Plate No. of Crosspasses 9 Shell Exit 231.82 kg Bundle Exit 6.35 kg Bundle 329.78 kg Velocities, m/s Flo Shellside 5.041e-2 A Tubeside 0.26 B	one y/m-s2 y/m-s2 ow Fractions 0.245 0.426

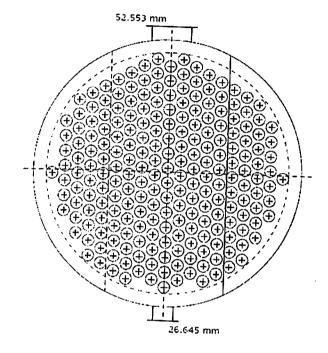
11.6 VIBRATION ANALYSIS

Shellside condition Axial stress loading	49.0	Sens. Liquid	(Level 2.2)	
Beta	(Mpa)	0.000	Added mass facto	^{)r} 1.761
Position In The Bun	dia I	4.000		1.70
Length for natural frequency		inlet	Center	Outlet
Length/TEMA maximum span	(m)	0.566	0.320	0.391
Number of spans	()	0.420	0.238	0.291
Tube natural frequency	()	5	5	5
Shell acoustic frequency	(Hz)	188.4 +	351.1	349.5
Flow Velocities	(Hz)			
Window parallel velocity	(77/2)	Inlet	Center	Outlet
Bundle crossflow velocity	(m/s)	7.182e-2	5.491e-2	5.242e-2
Bundle/shell velocity	(m/s) (m/s)	2.611e-2	5.063e-2	3.344e-2
Fluidelastic Instabilit	V Chock	1.832e-2	3.552e-2	2.346e-2
Log decrement		Inlet	Center	Outlet
Critical velocity	HTRI	0.038	0.038	0.038
Baffle tip cross velocity ratio	(m/s)	7.12	19.90	13.06
Average crossflow velocity ratio	()	0.004	0.003	0.003
Acoustic Vibration Ch	()	0.004	0.003	0.003
Vortex shedding ratio		Inlet	Center	Outlet
Chen number	()	1		
Turbulent buffeting ratio	()			
Tube Vibration Check	()			
ortex shedding ratio	1	Inlet	Center	Outlet
Turbulent buffeting ratio	()	0.002	0.003	0.002
Parallel flow amplitude	()	0.003	0.005	0.002
Crossflow amplitude	(mm)	0.000	0.000	0.000
	(mm)	0.000	0.000	0.000
urbulent buffeting amplitude ube gap	(mm)	0.000	0.000	0.000
Na () - DUO 14	(mm)	3.969	3.969	3.969
	7/m-s2)	0.28	1.37	0.63
Bundle Entrance	e/Exit			0.03
(analysis at first tu	ibe row)		Entrance	Evia
uidelastic instability ratio		()	0.013	Exit
ortex shedding ratio		()	0.005	0.010
rossflow amplitude		(mm)	0.00006	0.007
ossflow velocity		(m/s)	7.602e-2	0.00004
rbulent buffeting amplitude		(mm)	1	0.11
besheet to inlet/outlet support		(mm)	0.000	0.000
Shell Entrance/Exit Para	ameters	(11111)	None	None
pingement plate	4111G (C) S		Entrance	Exit
ow area		(No	
locity		(m2)	3.454e-3	1.637e-3
<u>IO-V-SQ</u>		(m/s)	0.42	0.64
ell type AES	Baffle	(kg/m-s2)	71.33	231.82
be type Plain	Daille Raffla	layout		Single-Seg.
ch ratio 1,2500		diameter, (mm)		Parallel
out angle 30	Tuhe	material		15.875
	1000	וומנסוומו		Carbon steel

11.7 FINAL RESULTS

Process Data	H	ot Shellside		
Fluid name		0		i Tubeside
Fluid condition	C4+ Product		Water	
Total flow rate	(kalo)	Sens. Liquid	8	Sens. Liquid
Weight fraction vapor, In/Out	(kg/s)	0.5900		5.9239
ITemporature Into	() 0.000	0.000	0.000	0.000
Temperature Average (C	eg C) 141.53 •	40.00	33.00	40.00
Moli tomor anni.	eg C) 90.8	49.34	36.5	44.49
Pressure In/Augusta	eg C) 34.90	62.73	34.83	61.75
Proceuro dron Tabellan	(kPa) 0.000	0.000	0.000	0.000
Velocity, Mid/Max allow	(kPa) 1.312	19.613	1.358	19.613
Mole fraction inert	(m/s) 5.041e-2		0.26	19.013
Assessed films 4	()	•	0.20	I
Heat transfer safety factor	m2-K)	426.14		1447.46
I Caralinan na - : - :	()	1.000		
m2-	K/W)	0.000340		1.000
o	verall Performance	Data		0.000086
Overall coef., Read/Clean/Actual	(W/m2-K)		000.00	
Heat duty, Calculated/Specified	/Manal41-4-i	0.1633 /	300.20 /	263.98
Effective overall temperature difference	e (Deg C)			
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	37.65	0.9171 •	
			0.9171 •	1.0000
			1	
		TITT		\
	→ -	11111	!	P- Magness
Exchanger Fluid Volumes	╼╾┦ ╙ ╸ ╢ ╴ ╌		┸╌┸╌╌╌╣╟╌╏	Γ
Approximate abolitis is	مم ا	1520 m		
Ammunistanna a distribution de la l	02.3 16.0		•	
FC 14 4 4 6 4 11 4 4	Construction Infor			
	She	ll ID	(mm)	360.000
Dooree Ohell		ıl area	(m2)	19.885
Shall ariantation	1 Eff. a	area (m2/shell)	19.102
mningement		`		19.102
Poiro poel stains				
hall aumanaian tait a	Pass	slane seal rods (mm) 0.000 N	
Veight estimation Wet/Dav/Dav	Rear	head support p	late No	0. 0
Veight estimation Wet/Dry/Bundle	1201.5 /	983.28 /	329.78 (kg/sl	nott)
	Baffle Information		JES.10 (KU/SI	ieil)
ype Parallel Single-Si		e cut (% dia) 28	00	
rosspasses/shellpass				
entral spacing (mm) 160.0	00 1	25.88	n) to C.L	
let spacing (mm) 405.7		0.00	79.200	
utlet spacing (mm) 231.2		0.00	0.000	
affle thickness (mm) 3.1				
	Tube information			
ibe type Pla	in Tuber	count per shell		
verall length (m) 1.82	29 Pct tu	bes removed (b	nėh)	218
		de diameter	•	45.05-
rective length (m) 1.75	" Onsi		(mm)	15.875
Tective length (m) 1.75 Ital tubesheet (mm) 72.00		hickness		i i
fective length (m) 1.75 fal tubesheet (mm) 72.00 ea ratio (out/in) 1.361	00 Wall ti	hickness	(mm)	2.108
Tective length (m) 1.75 ofal tubesheet (mm) 72.00	00 Wall ti 6 Pitch (hickness		i i

11.8 TUBE LAYOUT AND DRAWING



Item number	
TEMA type	AES
Shell diameter	360.000 mm
Outer tube limit	335 544
Height under Inlet nozzle	
Height under austra	18.273 mm
Height under outlet nozzle	18.273 mm
Tube diameter	15.875 mm
Tube pitch	19.844 nim
Tube layout angle	30
Number of tubes (specified)	
Number of tubes (calculated)	218
Number of tie rods	218
Minutes of the tods	4
Number of seal strip pairs	2
Number of passes	1
Baffle cut % diameter	
	28

TUBEPASS DETAILS

Pass	Rows	Tubes	Plugged
1	32	222	0

SYMBOL LEGEND

Tube

Plugged tube

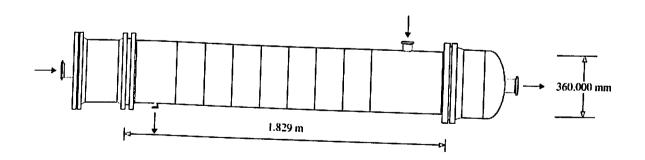
Tie rod

Impingement rod

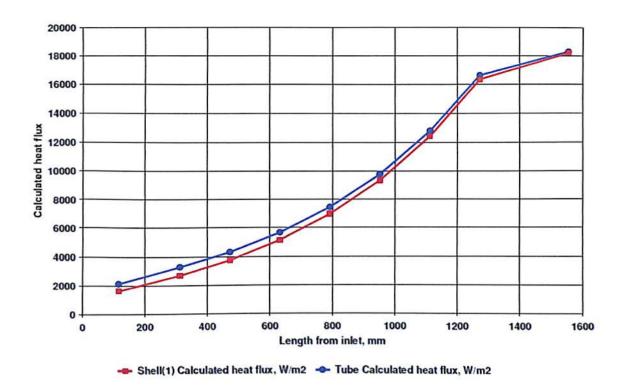
Dummy tube

Seal rod

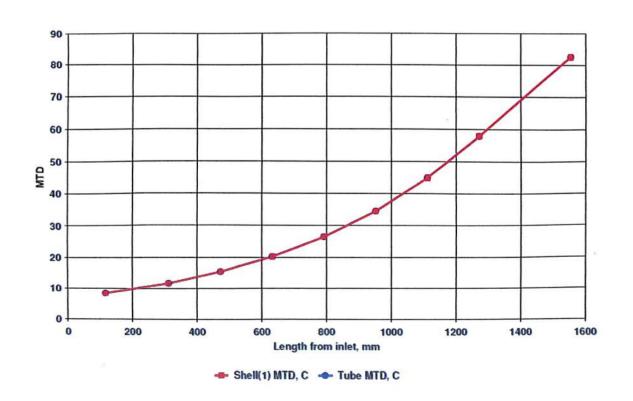
Seal strip/Skid bar



11.9 VARIATION OF HEAT FLUX ACROSS LENGTH



11.10 VARIATION OF MTD ACROSS LENGTH



12. DESIGN OF REBOILER E 102

12.1 DESIGN BASIS

Design pressure

Maximum design pressure for any pressure vessel shall be Maximum normal operating pressure plus $2.0\ kg/cm^2$

The minimum design pressure for any pressure vessel shall be 3.5 kg/cm²g.

Design temperature

In general the design temperature of pressure vessels is dependent upon the operating temperature range as follows:

No maximum design temperature will be set less than 65°C.

Operating Temp Range, (°C)	Design Temp, (°C)
T < 50	Minimum anticipated operating
	temperature margin to be
	determined by metallurgical
	limits
50 < T < 400	Maximum anticipated operating
	temperature + 15°C (round up to
	nearest 5°C.)
T > 400*	Maximum anticipated operating
	temperature 10% minimum
	margin

Fouling Factors

Fouling factors shall be specified as follows:

Utility Services	m²-ºC-h/kcal
Steam (all levels)	0.0001
Cooling Water	0.0004

Process Streams

m²-°C-h/kcal

Depropylenizer Overhead

0.0001

Depropylenizer bottoms

0.0004

Corrosion Allowance

Utility Services

Corrosion Allowance

Steam (all levels except SHP)

3 mm

Steam Condensate

1.5 mm

Cooling Water

3 mm

12.2 INPUTS TO HTRI

Case Mode —				
(Rating)	C Simulation © Design	1		
Exchanger Con	figuration —————————			
Exchanger sen	vice Generic Shell and Tube	▼		
Process Conditi	ons			
Flow rate	Hot Shell	Cold Tube	50.8328	kg/s
Inlet/outlet Y	1 / 0	0 ,	0.3	- Weight fraction vapor
Inlet/outlet T	1	143.3	<i>-</i>	C
Inlet P/allow dP	1471 / 176.52	1855.418		kPa / kPa
Fouling resistan	1	0.000344		m2-K/W
Shell Geometry		- Raffle Geometry		. ,
TEMA type	B V E V L V	Type	Single se	
ID	mm	Orientation	Parallel	gmental
Orientation	Vertical ▼	Cut	[·	
Hot fluid	Shellside 🔻	Spacing		% ID
Tube Geometry		opacing		mm
Туре	Plain 🔻	Wall thickness	2.108	▼ mm
Length	6.096 ▼ m	Layout angle	60	degrees
Tube OD	31.75 mm	Tubepasses	1	▼ deglees

12.3 OUTPUT SUMMARY

Process	Conditions	Hot S	hellside	Cold Tubeside				
Fluid name		steam		C4+	Oolu Tu	ineside		
Flow rate Inlet/Outlet Y Inlet/Outlet T	(kg/s (Wt. frac vap (Deg C	1.00	1 0.00	18 00	0.000	50.833 0.300		
Inlet P/Avg	(kPa		- 107.10	_	143.30	149.29		
dP/Allow.	(kPa			_ '	855.45	1843.92		
Fouling	(m2-K/W		0.00008		23.061	0.000		
			Performance			0.000344		
Shell h Tube h Hot regime Cold regime EMTD	(W/m2-K (W/m2-K) ()	9633.17 4621.56 Gravity Nucl	Actual U Required Duty Area	(W/ U (W/ (Megal	/m2-K) /m2-K) Watts) (m2)	1138.83 1058.08 4.2516 79.520		
	(Deg C)		Overdesic	ın	(%)	7.63		
ł	Shell Geometr	y		Baffle Geometry				
TEMA type	()	BEL	Baffle type	•	()	Single-Seg.		
Shell ID	(mm)	539.751	Baffle cut	(Pct	Dia.)	25.92		
Series	()	1	Baffle orie		()	Parallel		
Parallel	()	1	Central spa	acing	(mm)	197.953		
Orientation	(deg)	90.00	Crosspass	es	()	28		
	ube Geometry	•		Nozz	les			
Tube type	()	Plain	Shell inlet	(mm)	128.194		
Tube OD	(mm)	31.750	Shell outlet		mm)	77.927		
Length	(m)	6.096	Inlet height		mm)	42.136		
Pitch ratio	()	1.2500	Outlet heigh		mm)	40.720		
_ayout	(deg)	60	Tube inlet	•	nm)	457.000		
Tubecount	()	133	Tube outlet	Ť	nm)	457.000		
ube Pass	()	1		Į)	1411/	TU1.100		
Thermal Resis	itance, %	Velocities	, m/s	m/s Flow Fractions				
Shell	11.82	Shellside	3.93	A	W I IUQU			
ube	28.41	Tubeside	3.10	B		0.181 0.565		
ouling letal	54.98	Crossflow	5.58	Č		0.067		
iciai	4.795	Window	5.05	E		0.188		
				<u> </u>		0.000		

12.4 TEMA SHEET

Plant Location Service of Unit					Date	08-03-2011	Re	v	
Size	520	751 x 6095.79			Item No.				
Surt/Unit (Gross	/Eff. 80 :	27 / 70 52 mg	- 770 000	Vert.			allel	1 Ser	ies
- 3 0.11 (01053	LII/ 00.	91 1 1 9.52 M2	Shell/Unit	1	Surf/Shell (G	ross/Eff) 80.87 / 79.52	m2	. 001	
Fluid Allocation			PERFORMAN	CE OF C	ONE UNIT				
Fluid Name				nell Side			Tube Sid	e	
Fluid Quantity, T	otal	legila	steam			C4+			
Vapor (In/Out)	Ulai	kg/hr		854.37			182999		
Liquid			7854.37					5489	97
Steam					7854.37	182999		1280	
Water									
Noncondensabl	200								
emperature (In/	Duth	C							
Specific Gravity	July		197.35		197.35	143.30		149.2	9
/iscosity		mN-s/m2	 		0.8681	0.4059	_ _	0.401	
Nolecular Weight	Vanor	min-s/m2	0.0160		0.1362	0.0488	0.01		0.0
Aolecular Weight	Noncon	denochla-	 -				- ~~	- VIII	
pecific Heat	TEURICUM		 						
hermal Conducti	vilv	kJ/kg-C W/m-C	2.9498	+-	4.4825	3.3576	2.53	42 V/L	3.3
atent Heat	****		0.0430		0.6650	0.0602		75 V/L	0.0
let Pressure		kJ/kg kPa	1949.94		1949.94	214.369	0.02	211.52	
elocity		m/s		71.02			1855.45	211.32	<u>-</u>
ressure Drop, Al	ow/Cala	kPa		.93			3.10		
ouling Resistance	(min)	m2-K/W	176.523		17.303			23.061	
eat Exchanged	N	4251647	0.00	0086		0	.000344	20.001	
ransfer Rate, Ser			W/m2-K Clean		Corrected)	50.5 C			
unio, 7 1 1210, Oct	1100	OUNCTEN OF	W/m2-K Clean	2	529.01 W/m2-K	Actual	1138.8	3 W/m2).K
_		CONSTRUCT	ION OF ONE SHELL			Sketch (Bundle	/Nozzle	Orientatio	n)
esign/Test Press		kPaG	Shell Side		ube Side				***/
sign Temperatu		C	1369.70/	1754.12	2/			, 	
Passes per She		- — —		 		<u> </u>		[["]] ;	Piges
rrosion Allowand		mm	1	├ —	1	- 17k-			
Connections	in		1 @ 100 101					-	
Size &	Out		1 @ 128.194 1 @ 77.927	1@457					
Rating	Intermed		@ 77.921	1@457	.000				
			Thk(Avg) 2.108 mm	@					
	Plain	., 00 11111	TIK(AVG) 2.108 mm		Length 6.096 m	Pitch 39.687	mm	Layout	60
	D 539.7	il mm	00		Material CARBO	ON STEEL			
annel or Bonnet	000,1	71 111111	OD		Shell Cover				
esheet-Stationar					Channel Cover				
nting Head Cover	<u>, </u>				Tubesheet-Floati				
les-Cross		una CIMOLE	050	[mpingement Plai				
les-Long		ype SINGLE		m) 25.9	Spacing(c/c		Inlet 468	356 mm	
ports-Tube			Seal Type				11101 400	.000 111111	
			U-Bend		Ī	уре			
ass Seal Arrange ansion Joint	ment		Tube-Tube	sheet Jo	int				
V2-Inlet Nozzle		004.00 1	Туре						
cets-Shell Side	3	834.98 kg/m-s		rance 5	96.24 B	undle Exit 8.54	kg/m-s2		
Floating Head			Tube Side						
Requirements									
ht/Shell 3756.3	7					MA Class			
arks:	<u>'</u> _	Fil	led with Water 5439.19				kg		
							<u> </u>		

12.5 RATING DATA SHEET

Type BEL	()rientation		_	Connect		allel 1 S	eries		
Surf/Unit (Gross/Eff) 80.87 / 79.	52 m2		nell/Unit		Surf/She	ell (Gross/Eff) 8	0.87 / 79.52	2 m2		
Fluid Allocation		PEF		VCE OF O	NË UNIT		-			
Fluid Name			<u> </u>	hell Side				Tube Side		
F1 : 10		eam				C4+				
7.				2.1818				50.8331		
11 11		100		_	0.0		0.0		30.0)
7	<u>-</u>	0.			100.0		100.0	_	70.0	
		197			197.35		143.30		149.2	
		7.45			867.73		405.72	49.9	93 V/L	
****	s/m2	0.01			0.1362		0.0488		6 V/L	0.04
		2.94			4.4825		3.3576	 ;	2 V/L	3.394
6.11.16		0.04	30		0.6650		0.0602	0.027		0.058
								0.02.1	O VIL	0.000
10.4	_		14	71.02				1855.45		
					3.93			1000.40	3.10	
Pressure Drop, Allow/Calc kPa		176.5	23		17.303				23.061	
Average Film Coefficient W/m2			96	33.17				1601 60	23.VO	_
Fouling Resistance (min) m2-K		0.000086						1621.56		
leat Exchanged	4.2516 Me	gaWatts	MTD (C	orrected)	50.5 C	 ,	0.000344 Overdesign 7.63 %			
ransier Hate, Service	058.08 W/r	n2-K	Calculat	ed 1138 8	3 W/m2-K					
CONS	TRUCTION	OF ONE	SHELL		O WANE TO		lean 2529			
		Shell Si		Tul	e Side	- SKE	etch (Bundle	∀Nozzie O	ientatio	n)
lesign Pressure kPaG		1369.7	0		54.12	{			1	
esign Temperature C				 	01.12	——————————————————————————————————————		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	<u>-</u> 77 −	<u>.</u>
o Passes per Shell		1		 	1	╼┤┸╩╇	1502	шшшш		<u></u>
ow Direction		Downwa	rd	110	ward	 →			4	
Connections In mm	1@	128.194	<u> </u>	1 @ 457.0						
Size & Out mm		77.927		1 @ 457.0						
Rating Liq. Out mm	@			@ 437.0						
be No. 133 OD 31.750 mn		vg) 2.10	8 mm							
be Type Plain		ial CARE	ONI CTE	C) L(ength 6.09		ch 39.687	mm	Layout	60
ell ID 539.751 mm	Keltle					Pairs seal s	strips	2	-	
oss Baffle Type PARALLEL SING	H-SEC			m		Passlane S	eal Rod No	. 0		
acing(c/c) 197.953 mm		468.356		m) 25.9		Impingeme	nt Plate	Circular p	late	$\overline{}$
D-V2-Inlet Nozzle 3834.98 kg/m-s	2			m		No. of Cros	spasses	28		
TO MINETALLIO COO 1.00 NOTH 3	<u>-</u>		hell Entra		91.51	Shell Exit	49.08	kg/m-s2		
abi/CL-II 0750 07			undle Ent	rance 59	5.24	Bundle Exit	8.54	kg/m-s2		
ght/Shell 3756.37	Filled v	ith Water		439.19		Bundle	1466.94	_•		\longrightarrow
9S:			Th	ermal Res	stance, %	Velocities, m.		Flow Fract	ione	
			Sh	ell	11.82			A		.181
	_		Tu	be	28.41	Tubeside		B		
				uling	54.98					.565
			Me	<u> </u>	4.79	Window		<u>C</u>		067
					4.13	TTITIQOW	5.05	E	0.	188
			ı		Į.					000

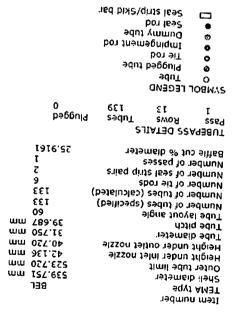
12.6 FINAL RESULTS

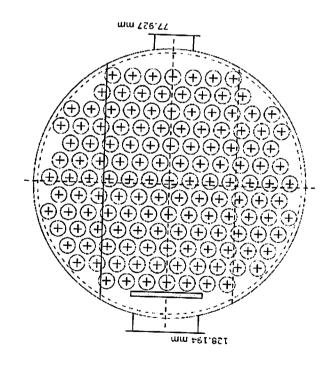
Pro	ocess Data		Но	t Shellside	Co	ld Tubeside
Fluid name			steam		l l	i anegide
Fluid condition				Cond. Vapor	C4+	Deller
Total flow rate		(kg/s)	`	2.1818		Boil. Liquid
Weight fraction va	ipor, In/Out	()		0.000	0.000	50.8331
Temperature, In/C)ut	(Deg C)	197.35	197.35	143.30	0.300
Temperature, Ave	rage/Skin	(Deg C)	197.4	191.35	146.3	149.29
Wall temperature,	Min/Max	(Deg C)	185.08	189.22	182.54	161.18
Pressure, In/Avera	ìge	(kPa)	1471.02	1462.37	1855.45	186.67
Pressure drop, To	tal/Allowed	(kPa)	17.303	176.520	23.061	1843.92
Velocity, Mid/Max	allow	(m/s)	3.93	110.020	3.10	
Mole fraction inert	Boiling range			0.000	3.10	15.7
Average film coef.		(W/m2-K)		9633,17		4621.56
Heat transfer safet	y factor	()		1.000		1.000
Fouling resistance		(m2-K/W)		0.000086		0.000344
			Performance	Data		0.000044
Overall coef., Require	1/Clean/Actua	1.	(W/m2-K)	1058.08 /	2529.01 /	1138.83
Heat duty, Calculat	ed/Specified	t	(MegaWatts)	4.2516 /		1130.03
Effective overall ter	inperature diff	erence	(Deg C)	50.5		
EMTD = (MTD) * (I Liquid static head,	JELIA) * (F/G	i/H)	(Deg C)	50.53 *	1.0000 •	1.0000
and ordine field,	required/Spe	cilled	(m)	6.72 /	0.00	1.000
See Runtime Mes	sages Report	l for				
warnings.	J map and			ПППППП		
				6,0% ra	<u> </u>	539,7 <u>\$1</u> mm
Exchanger	Fluid Volum	es	1 h	स्त अराज्य		ł
Approximate shellsi		731.1				•
Approximate tubesi	de (L)	952.9				
		Shell Cons	truction inform	nation		·
TEMA shell type		BEL	Shel			
Shells Series		Parallel 1		l area	(mm)	539.751
Passes Shell	17	Tube 1			(m2)	80.867
Shell orientation and	gle (deg) g	90.00	∟II. c	uea	(m2/shell)	79.520
mpingement preser	it (Circular plate	imnir i	adomont die		
Pairs seal strips	2			ngement diam	eter/nozzle	1.1
Shell expansion join	t h	No	Rear	head support	6 (mm) 0.000	No. 0
Veight estimation W	et/Dry/Bundie)	5439.2 /	3756.4 /		
			information	3730.4 /	1466.9 (kg/	shell)
уре	Parallel Sir			S #114 /0/ 11 / 1		
rosspasses/shellpa	ISS	28	baille '' ald	cut (% dia) 2		
entral spacing	(mm)	197.953		oct Area) (n	nm) to C.L	
let spacing	(mm)	468.356	1 2	22.40	129.993	
utlet spacing		379.064	2	0.00	0.000	
affle thickness	(mm)	4.763				
		Tube	Information			
ibe type		Plain	Tubec	ount per shell	1	100
verali length	(m)	6.096	Pct tul	bes removed ((both)	133
fective length	(m)	5.994	Outsid	le diameter	•	6.77
tal tubesheet		101.600	Wall th	nickness	(mm) (mm)	31.750 2.108
					11111111	c. 100
ea ratio	(out/in)	1.1531	Pitch (mm) 39	6875 Ratio	
ea ratio be metal		1.1531 on steel	Pitch (Tube p	mm) 39. Dattern (deg)	6875 Ratio	1.2500

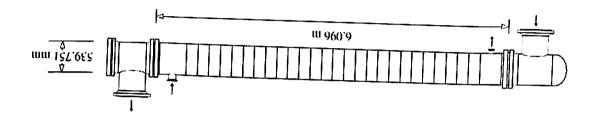
12.7 REBOILER PIPING DETAILS

*** Boiling Side Piping Data ***	T-	Inlot			
Total piping pressure drop	(kPa)	Inlet	Outlet		
Static pressure loss		0.270	3.424		
Exit pipe choke ratio	(kPa)	1	1.989		
Inlet valve pressure drop	(+-)	0.000	0.03895		
Main Pipe	(kPa)	0.000			
- Diameter	()				
- Number of lines	(mm)	457.000	457.000		
- Length	()	1	1		
1	(m)	5.000	5.000		
- Height above shell	(m)		0.000		
- Fitting allowance	(m)	31.076	15.538		
- Contraction loss from tower	(kPa)	0.178			
- Expansion loss into tower	(kPa)		0.613		
- Frictional loss in pipe	(kPa)	0.013	0.040		
- Frictional loss in fittings	(kPa)	0.079	0.782		
Header Pipe					
- Diameter	(mm)	0.000	0.000		
- Length	(m)	0.000	0.000		
- Fitting allowance	(m)	0.000	0.000		
- Height above shell	(m)		0.000		
 Contraction/expansion loss 	(kPa)	0.000	0.000		
 Frictional loss in pipe 	(kPa)	0.000	0.000		
- Frictional loss in fittings	(kPa)	0.000	0.000		
Nozzle Pipe		0.000	0.000		
- Diameter	(mm)	457.000	457.000		
 Number at each position 	()		457.000		
- Pipe length	(m)	0.000	2 200		
- Vapor RHO-V2	1	0.000	0.000		
- Exit vertical header height	(kg/m-s2)		172.89		
- Contraction/expansion loss	(m)		1.142		
- Frictional loss in pipe	(kPa)	0.000	0.000		
Exit Vertical Pipe Flow Regime (Estimated)	(kPa)	0.000	0.000		
- J.R. Fair flow map					
·					
- A.E. Dukler flow map Thermosiphon Process Conditions					
		Column / Inlet / C			
- Temperature	(C)	143.30 / 143.30 /			
- Weight fraction vapor	()	0.0000 / 0.000 / 0.300 / 0.3000			
- Pressure	(kPa) 1	828.96 / 1855.45 /	1832.39 / 1828.96		

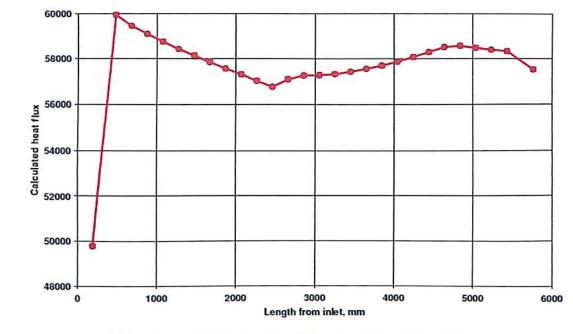
12.8 TUBE LAYOUT AND DRAWING





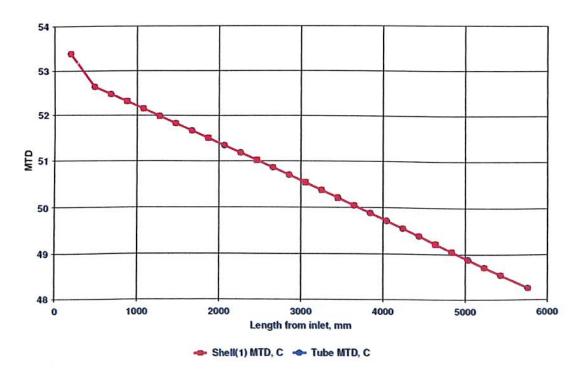


12.9 VARIATION OF HEAT FLUX ACROSS LENGTH

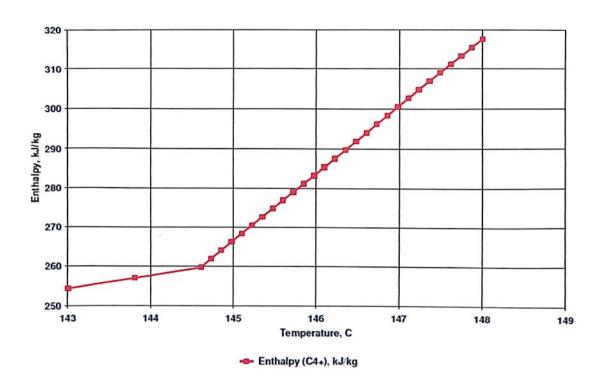


- Shell(1) Calculated heat flux, W/m2 - Tube Calculated heat flux, W/m2

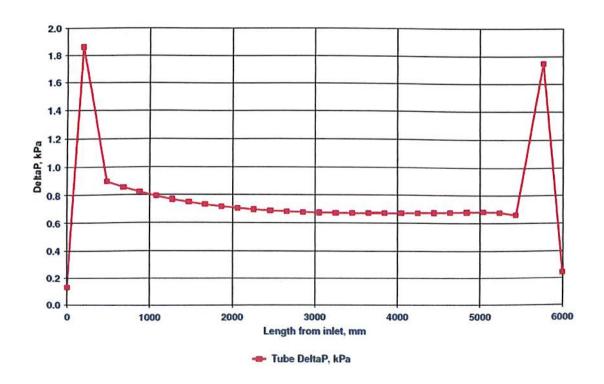
12.10 VARIATION OF MTD ACROSS LENGTH



12.11 ENTHALPY CURVE



12.12 PRESSURE VARIATION ACROSS TUBE LENGTH



13. LINE SIZING

13.1 PROCEDURE TO SIZE A LIQUID PHASE LINE

1. Assume Diameter

A standard diameter of line is assumed (D)

2. Calculate Velocity

Volumetric Flow Rate (QL)

=

 M_L/ρ_L

Cross Sectional Area (A)

=

 $\pi D^2/4$

Velocity of liquid (V)

=

 Q_L/A

3. Calculate Reynolds Number

Reynolds Number (Re)

=

 $D*V*\rho/\mu$

4.Calculate Friction Factor

If Re<=2000

Moody Friction Factor

=

64/Re

If Re>2000

Moody Friction Factor

=

4*f

5. Calculate Pressure Drop

$$6370 * \frac{Q_L^2 f d}{D^{\$}}$$

where

d

Specific gravity of liquid

D

Diameter in cm

f

Moody friction factor

 Q_L

Volumetric Flow Rate in m³/hr

6. Check Condition

If ΔP and V are not within the given conditions of maximum value, then go to step 1, else stop.

13.2 SOME RECOMMENDED VALUE FOR A LIQUID LINE SIZING

	Velocity	
Type of Service	(m/sec)	Max. Pressure Drop (kg/cm²/km)
General Recommendation	1.5 - 4.5	8.8
Laminar Flow	1.2 - 1.5	
Turbulent Flow		
Liquid Density (kg/m3)		
1600	1.5 - 2.5	
800	1.8 - 3.0	
320	3.0 - 4.5	
Pump Suction		
Boiling liquid	0.6 - 1.8	1 1
Non-boiling liquid	1.2 - 2.5	1.1
Pump Discharge (m³/hr)		2.2
0 - 55	1.8 - 2.5	10.0
55- 160	2.5 - 3.0	13.2
More than 160	3.0 - 4.5	8.8
Bottom Outlet		4.4
Reboiler Trapout	1.2 - 1.8	1.32
Liquid from condensor	0.3 - 1.2	0.33
Liquid to chillers	0.9 - 2.5	1.1
Refrigerant Lines	1.2 - 1.8	
Gravity run lines	0.6 - 1.2	0.88
	0.9 - 2.5	0.88
Liquid feed to towers	1.2 - 1.8	
Boiler feed	2.5 - 4.5	
Refinery Water Lines	0.6 - 1.5	5.5
Cooling Water	1.5 - 4.5	4.4
iquid with suspended solids	0.9 (Min)	
ipe carrying Phenolic Water	0.9	
ipe carrying conc. H₂SO ₄	1.2	
ipe carrying Salt Water	1.8	
ipe carrying Caustic Solution	1.2	
pe carrying CO ₂ rich amine liquid	3.0	

13.3 PROCEDURE TO SIZE A VAPOUR PHASE LINE

1. Assume Diameter

A standard diameter of line is assumed (D)

2. Calculate Velocity

Volumetric Flow Rate (Q_V)

- =
- M_V/ρ_V

Cross Sectional Area (A)

- =
- $\pi D^2/4$

Velocity of liquid (V)

- =
- Q_V/A

3. Calculate Reynolds Number

Reynolds Number (Re)

- =
- D*V*ρ/μ

4. Calculate Friction Factor

If Re<=2000

Moody Friction Factor

- =
- 64/Re

- If Re>2000
- **Moody Friction Factor**

- =
- 4*f

5. Calculate Pressure Drop

$$6370 * \frac{M^2 f}{D^5 d}$$

where

- ď
- Density of vapour
- D
- Diameter in cm
- f
- Moody friction factor
- Q_L
- Volumetric Flow Rate in m³/hr

6. Check Condition

If ΔP and V are not within the given conditions of maximum value, then go to step 1, else stop.

13.4 SOME RECOMMENDED VALUE FOR A VAPOUR LINE SIZING

Type of Service	Velocity (m/sec)	Max. Pressure Drop (kg/cm²/km)
General Recommendation		L (v.P. com / WIII)
Pressure level (kg/cm ² g)		
Above 35		A.5
14 - 35	$V = \frac{13.0 \text{ to } 24.0}{100000000000000000000000000000000000$	4.5
10 - 14	$V = \frac{1}{\rho^{1/3}}$	3.3
3.5 - 10	$\begin{cases} \rho^{-3} \end{cases}$	1.32
0 - 3.5	ļ	0.66
<u>0</u> 3.5	<u> </u>	0.33
Sub-atmospheric (vacuum)	where $\rho = \frac{1}{\text{density (kg/m}^3)}$	0.22
Gas lines within battery limits	7	
Compressor Piping Suction		1.1
Compressor Piping Discharge		0.25 - 0.6
Refrigerant Suction lines	4.5 - 10.7	1.0 - 2.2
Refrigerant Discharge lines	10.7 - 18.0	
Tower Overhead	100	
3.5 - 15 kg/cm ² g	12.0 - 15.0	1.5
0 - 3.5 kg/cm ² g	18.0 - 30.0	0.33
0 - 0.7 kg/cm ² a	40.0 - 60.0	0.11 - 0.22

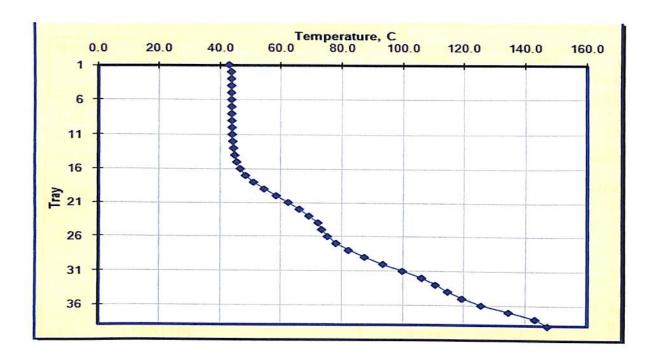
13.5 LINE LIST

LINE NO.	LINE SIZE (Inches)
1001	8
1002	12
1003	
1004	8
1005	8
1006	5
1007	5
1008	5
	5
1009	18
1010	18
1011	2
1012	2
1013	2
1014	4

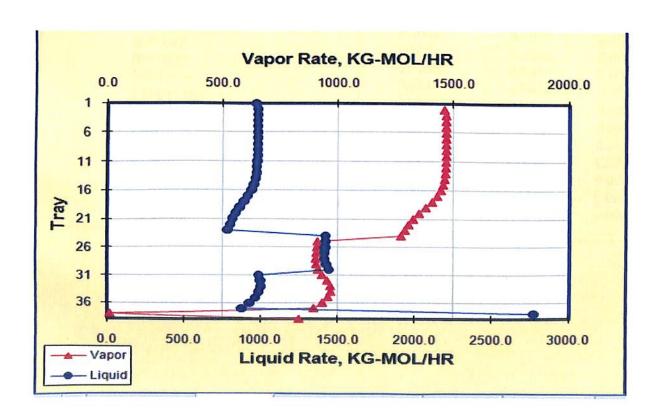
14. COLUMN T-101 SUMMARY

			Column	T-101 Su			
Тгау	Тошь	.	J		low Rates		
IIay	Temp.	Pressure	Liquid	Vарог	Feed	Product	Duties
1	C	KG/CM2		KG	MOL/HR		M*KCAL/HR
2	43.0	18.56	,			490.1	-4.391
3	43.7	18.56	1	1460.2			1.571
	43.8	18.57		1468.0			
4	43.8	18.58		1468.2			
5 6	43.8	18.59		1468.4			
7	43.8	18.60	978.5	1468.5			
8	43.9	18.61	978.6	1468.6		ĺ	
9	43.9	. 18.62	978.5	1468.7			
	44.0	18.63	978.3	1468.7			
10	44.0	18.64	977.8	1468.5		}	
11	44.1	18.65	976.8	1468.0		J	
12	44.3	18.66	974.9	1467.0]	
13	44.5	18.67	971.4	1465.0)	
14	44.9	18.68	965.4	1461.6			
15	45.6	18.69	955.4	1455.5		1	
16	46.8	18.70	939.7	1445.5		1	
17	48.5	18.71	917.5	1429.8			
18	51.1	18.72	890.1	1407.7		}	
19	54.6	18.73	861.1	1380.2			
20	58.5	18.74	835.4	1351.3		}	
21	62.5	18.75	815.2	1325.5		j	
22	66.1	18.76	799.4	1305.3			
23	69.3	18.77	782.8	1289.5		ĺ	
24	72.3	18.78	1422.0	1273.0	1000.0		
25	73.5	18.79	1419.8	912.2			
26	75.4	18.80	1417.1	909.9			
27	78.2	18.81	1415.1	907.2		ĺ	
28	82.3	18.82	1416.6	905.3			
29	87.5	18.83	1424.9	906.8			
30	93.6	18.84	1441.7	915.0			
31	100.0	18.85	984.8	931.8		450 -	1
32	106.3	18.86	998.4	954.4		479.5	
33	110.8	18.87	999.8	968.0		i	
34	114.8	18.88	988.2	969.4		1	ŀ
35	119.4	18.89	963.6	957.8		1	
36	125.7	18.90	926.3	933.2		1	1
37	134.6	18.91	875.4	895.8			1
38	143.3	- 1	2772.7	13.2		20.	
39	147.4	18.93		831.8		30.4	1
		==-,70		031.0			3.4758

14.1 TEMPERATURE VARIATION CURVE



14.2 LIQUID AND VAPOUR FLOW RATE



15. DETAILED MATERIAL BALANCES

15.1 Component Rates

	Compon	ent Rates		
Stream Name Description Phase		1001 FEED	1002 T-101 ovhd	100 To D10
Temperature	C	Mixed	Vарог	Liqui
Pressure	KG/CM2	74.000	43.742	42.98
Molecular Weight	KG/CMZ	18.780	18.560	18.35
Component Molar Rates	770 MOL 1115	49.827	42.081	42.08
PROPENE	KG-MOL/HR			
IBUTANE		551.919	1460.209	1460.20
BUTANE		0.010	0.000	0.00
IBUTENE		252.021	0.002	0.00
1BUTENE		25.844	0.008	0.008
T2BUTENE		23.744	0.003	0.003
C2BUTENE		59.770	0.000	0.000
13BD		35.166	0.000	0.000
1960 1PENTENE	•	0.010	0.000	0.000
PENTANE		24.684	0.000	0.000
2M2BUTEN		9.712	0.000	0.000
1HEXENE		5.041	0.000	0.000
10CTENE		10.612	0.000	0.000
Total		1.470		2.000
	KG-MOL/HR	1000.000	1460.222	1460.222
Component Mole Fractions				Z 100.22
PROPENE		0.5519	1.0000	1.0000
IBUTANE BUTANE		0.0000	0.0000	0.0000
IBUTENE		0.2520	0.0000	0.0000
1BUTENE		0.0258	0.0000	0.0000
T2BUTENE		0.0237	0.0000	0.0000
C2BUTENE		0.0598	0.0000	0.0000
13BD		0.0352	0.0000	0.0000
		0.0000	0.0000	0.0000
1PENTENE		0.0247	0.0000	0.0000
PENTANE		0.0097	0.0000	0.0000
2M2BUTEN		0.0050	0.0000	0.0000
1HEXENE		0.0106	0.0000	0.0000
10CTENE		0.0015	0.0000	0.0000

		Compone	ent Rates		
Stream	Name		1004	1005	100
	Description		TO P-101	REFLUX	SIDE DRAV
	Phase		Liquid	Mixed	Liqui
Temperatu	ire	С	43.000	43.741	99.97
Pressure		KG/CM2	18.561	18.560	18.85
Molecular '			42.081	42.081	56.47
Componen	t Molar Rates	KG-MOL/HR			
	PROPENE		1460.209	970.089	61.76
	IBUTANE		0.000	0.000	0.01
	BUTANE		0.002	0.002	244.89
	IBUTENE 1BUTENE		0.008	0.005	25.44
	· · · -		0.003	0.002	23.32
	T2BUTENE		0.000	0.000	57.89
	C2BUTENE 13BD		0.000	0.000	33.85
	19ENTENE		0.000	0.000	0.01
	PENTANE		0.000	0.000	17.62
	2M2BUTEN		0.000	0.000	6.528
	1HEXENE		0.000	0.000	3.095
	10CTENE		0.000	0.000	4.488
Γotal	TOCTENE	WG MOT GET			0.515
	Mala Ematin	KG-MOL/HR	1460.222	970.097	479.452
zomponem	Mole Fractions PROPENE				
	IBUTANE		1.0000	1.0000	0.1288
	BUTANE		0.0000	0.0000	0.0000
	IBUTENE		0.0000	0.0000	0.5108
	1BUTENE		0.0000	0.0000	0.0531
	T2BUTENE		0.0000	0.0000	0.0487
	C2BUTENE		0.0000	0.0000	0.1208
	13BD		0.0000	0.0000	0.0706
	1PENTENE		0.0000	0.0000	0.0000
	PENTANE		0.0000	0.0000	0.0368
			0.0000	0.0000	0.0136
	2M2BUTEN 1HEXENE		0.0000	0.0000	0.0065
			0.0000	0.0000	0.0094
	10CTENE				0.0011

		Component R	ates		
Stream	Name Description Phase		1007 FromE-103 Liquid	1008 C4 RECYCLE	101 BOTTOM
Temperatu	ire	С	40.000	Liquid	Liqui
Pressure		KG/CM2	19.141	40.009	143.29
Molecular '	Weight	110/01/12	56.478	18.441	18.92
	t Molar Rates	KG-MOL/HR	30.478	56.478	69.81
•	PROPENE	nd Mob/IIK	61.768	64.560	_
	IBUTANE		0.010	61.768	0.02
	BUTANE		244.898	0.010	0.00
	IBUTENE		25.443	244.898	7.12
	1BUTENE		23.326	25.443	0.39
	T2BUTENE		57.899	23.326 57.899	0.41
	C2BUTENE		33.852	33.852	1.87
	13BD		0.010	0.010	1.31
	1PENTENE		17.621	17.621	0.00
	PENTANE		6.528	6.528	7.06
	2M2BUTEN		3.095	3.095	3.18
	1HEXENE		4.488	4.488	1.94
	10CTENE		0.515	0.515	6.12
Γotal		KG-MOL/HR	479.452	479.452	0.95
Component	Mole Fractions			479.432	30.41
	PROPENE	J	0.1288	0.1288	0.000
	IBUTANE		0.0000	0.0000	0.000
	BUTANE		0.5108	0.5108	0.0000
	IBUTENE		0.0531	0.0531	0.234
	1BUTENE		0.0487	0.0487	0.013
	T2BUTENE		0.1208	0.1208	0.0133
	C2BUTENE	ĺ	0.0706	0.0706	0.0619
	13BD		0.0000	0.0000	0.0432
	1PENTENE	1	0.0368	0.0368	0.0000
	PENTANE		0.0136	0.0368	0.2322
	2M2BUTEN		0.0065	0.0065	0.1046
	1HEXENE		0.0094	0.0094	0.0640 0.2013
	1OCTENE		0.0011	0.0094	0.2013

			Component Ra	tes	
Stream	Name Description Phase		1012 FromE-104	1013 C4+ product	101 PROPYLENE PRODUC
Temperat			Liquid	Liquid	Liqui
Pressure	ure	C	40.000	40.267	45.44
Molecular	Maiche	KG/CM2	19.142	23.302	33.65
	nt Molar Rates		69.812	69.812	42.08
Componer	PROPENE	KG-MOL/HR			12.00
	IBUTANE		0.025	0.025	490.120
	BUTANE		0.000	0.000	0.000
	IBUTENE		7.122	7.122	0.003
	1BUTENE		0.399	0.399	0.003
	T2BUTENE		0.417	0.417	0.001
	C2BUTENE		1.871	1.871	0.000
	13BD		1.314	1.314	0.000
	1PENTENE		0.000	0.000	0.000
	PENTANE		7.063	7.063	0.000
	2M2BUTEN		3.183	3.183	0.000
	1HEXENE	· ·	1.946	1.946	0.000
	10CTENE	1	6.124	6.124	0.000
otal	TOCTENE	770 1400	0.955	<u> </u>	0.000
	Mal- P	KG-MOL/HR	30.419	30.419	490.125
	Mole Fraction	ıs			170.123
	PROPENE	1	0.0008	0.0008	1.0000
	IBUTANE		0.0000	0.0000	0.0000
	BUTANE	ļ	0.2341	0.2341	0.0000
	BUTENE		0.0131	0.0131	0.0000
	IBUTENE		0.0137	0.0137	0.0000
	T2BUTENE		0.0615	0.0615	0.0000
	C2BUTENE		0.0432	0.0432	0.0000
	I3BD	ĺ	0.0000	0.0000	0.0000
	PENTENE	ĺ	0.2322	0.2322	0.0000
	ENTANE	1	0.1046	0.1046	0.0000
	M2BUTEN	}	0.0640	0.0640	0.0000
	HEXENE		0.2013	0.2013	
1	OCTENE		0.0314	0.0314	0.0000

15.2 Total Stream Properties

Stream Name Descripti Phase	on .	1001 FEED Mixed	1002 T-101 ovhd	100 To D10
Total Stream Propert	ies	Mixed	Vapor	Liqui
Rate	KG-MOL/HR	1000,000		
	KG/HR	1000.000	1460.222	1460.22
Std. Liquid Rate	M3/HR	49827.309	61447.797	61447.79
Temperature	C	88.790	117.832	117.83
Pressure	KG/CM2	74.000	43.742	42.984
Molecular Weight	Na/ CM2	18.780	18.560	18.350
Enthalpy	M*KCAL/HR	49.827	42.081	42.08 1
	KCAL/KG	3.348	6.046	1.654
Mole Fraction Liquid	riorib) Rd	67.184 0.6453	98.388	26.919
Reduced Temp.			0.0000	1.0000
Pres.		0.8791	0.8683	0.8662
Acentric Factor		0.4316	0.3939	0.3895
Watson K (UOPK)		0.1729	0.1435	0.1435
Standard Liquid Density	KG/M3	13.655	14.183	14.183
Specific Gra		561.180	521.486	521.486
API Gravity		0.5617	0.5220	0.5220
Vapor Phase Propertie		120.398	139.572	139.572
Rate				
	KG-MOL/HR KG/HR	354.718	1460.222	n/a
	M3/HR	16660.852	61447.797	n/a
Std. Vapor Rate	•	419.981	1568.601	n/a
Specific Gravity (Air=1.0	M3/HR	7950.638	32729.408	n/a
Molecular Weight	,	1.622	1.453	n/a
Enthalpy	VCAL IVO	46.969	42.081	n/a
CP	KCAL/KG	111.616	98.388	n/a
Density	KCAL/KG-C	0.512	0.489	n/a
Thermal Conductivity	KG/M3	39.670	39.174	n/a
iscosity/	KCAL/HR-M-C	n/a	n/a	n/a
	CP	n/a	n/a	n/a
<i>iquid Phase Properties</i> late				,
ale	KG-MOL/HR	645.283	n/a	1460.222
	KG/HR	33166.457	n/a	61447.797
td Liania n	M3/HR	69.308	n/a n/a	129.670
td. Liquid Rate	M3/HR	58.349	n/a	117.832
pecific Gravity (H2O @ 6	0 F)	0.5690	n/a	0.5220
lolecular Weight		51.398	n/a	42.081
nthalpy P	KCAL/KG	44.864	n/a	26.919
	KCAL/KG-C	0.750	n/a	0.775
ensity	KG/M3	478.540	n/a	473.880
urface Tension	DYNE/CM	n/a	n/a	
nermal Conductivity	KCAL/HR-M-C	n/a	n/a	n/a
scosity	CP	n/a	n/a n/a	n/a

Stream Name Description	on	1004	1005	100	
Phase	·••	TO P-101	REFLUX	SIDE DRAV	
Total Stream Propert	iac	Liquid	Mixed	Liquid	
Rate					
· ········	KG-MOL/HR	1460.222	970.097	479.45	
Std. Liquid Rate	KG/HR	61447.797	40822.801	27078.49	
Temperature	M3/HR	117.832	78.282	45.915	
Pressure	C	43.000	43.741	99.979	
Molecular Weight	KG/CM2	18.561	18.560	18.850	
Enthalpy	14417041	42.081	42.081	56.478	
Similarpy	M*KCAL/HR	1.654	1.142	1.692	
Mole Fraction Liquid	KCAL/KG	26.919	27.966	62.486	
Reduced Temp.		1.0000	0.9934	1.0000	
Pres.		0.8663	0.8683	0.8859	
Acentric Factor		0.3940	0.3939	0.4676	
Watson K (UOPK)		0.1435	0.1435	0.1984	
Standard Linuid D.		14.183	14.183	13.318	
Standard Liquid Density		521.486	521.486	589.751	
Specific Gra	vity	0.5220	0.5220	0.5903	
API Gravity		139.572	139.572	108.195	
Vapor Phase Properties				200.175	
Rate	KG-MOL/HR	n/a	6.437	2/2	
	KG/HR	n/a	270.859	n/a	
C. l	M3/HR	n/a	6.914	n/a	
Std. Vapor Rate	M3/HR	n/a	144.270	n/a	
Specific Gravity (Air=1.0)	n/a	1.453	n/a	
Molecular Weight		n/a	42.081	n/a	
Enthalpy CP	KCAL/KG	n/a	98.387	n/a	
	KCAL/KG-C	n/a	0.489	n/a	
Density	KG/M3	n/a	39.174	n/a	
Thermal Conductivity	KCAL/HR-M-C	n/a		n/a	
Viscosity	CP	n/a	n/a	n/a	
Liquid Phase Properties			n/a	n/a	
Rate	KG-MOL/HR	1460.222	062.664		
	KG/HR	61447.797	963.661	479.452	
	M3/HR	129.658	40551.941	27078.496	
td. Liquid Rate	M3/HR	117.832	85.844	58.111	
pecific Gravity (H2O @ 6	0 F)	0.5220	77.762	45.915	
lolecular Weight		42.081	0.5220	0.5903	
nthalpy	KCAL/KG	26.919	42.081 27.405	56.478	
P	KCAL/KG-C	0.774	27.495	62.486	
ensity	KG/M3	473.924	0.780	0.809	
urface Tension	DYNE/CM		472.392	465.982	
hermal Conductivity	KCAL/HR-M-C	n/a n/a	n/a	n/a	
iscosity	CP	· ·	n/a	n/a	
		n/a	n/a	n/a	

Stream Name Description	on	1007	1008	101
Phase	on .	FromE-103	C4 RECYCLE	BOTTOM
Total Stream Propert	inc	Liquid	Liquid	Liqui
Rate				
Trace	KG-MOL/HR	479.452	479.452	30.419
Std. Liquid Rate	KG/HR	27078.496	27078.496	2123.59
Temperature	M3/HR	45.915	45.915	3.324
Pressure	C	40.000	40.009	143.290
Molecular Weight	KG/CM2	19.141	18.441	18.920
Enthalpy	Marian de	56.478	56.478	69.81
Dittialpy	M*KCAL/HR	0.581	0.581	0.185
Mole Fraction Liquid	KCAL/KG	21.441	21.441	86.917
Reduced Temp.		1.0000	1.0000	1.0000
Pres.		0.7435	0.7435	0.8993
Acentric Factor		0.4749	0.4575	0.5241
Watson K (UOPK)		0.1984	0.1984	0.2426
Standard Liquid Density	. 1/0 (1/0	13.318	13.318	12.809
		589.751	589.751	638.835
Specific Gra		0.5903	0.5903	0.6395
API Gravity		108.195	108.195	89.779
Vapor Phase Propertie				
Rate	KG-MOL/HR	n/a	n/a	n/a
	KG/HR	n/a	n/a	•
0.17	M3/HR	n/a	n/a n/a	n/a
Std. Vapor Rate	M3/HR	n/a	n/a	n/a
Specific Gravity (Air=1.0)	n/a	n/a n/a	n/a
Molecular Weight		n/a	n/a n/a	n/a
Enthalpy CP	KCAL/KG	n/a	n/a n/a	n/a
Cr Density	KCAL/KG-C	n/a	n/a	n/a n/a
•	KG/M3	n/a	n/a	n/a
Thermal Conductivity	KCAL/HR-M-C	n/a	n/a	
Viscosity	CP	n/a	•	n/a
Liquid Phase Properties			n/a	n/a
Rate	KG-MOL/HR	479.452	470 480	
	KG/HR	27078.496	479.452	30.419
	M3/HR	48.218	27078.496	2123.590
Std. Liquid Rate	M3/HR	45.915	48.232	4.514
pecific Gravity (H2O @ 6	50 F)	0.5903	45.915	3.324
lolecular Weight		56.478	0.5903	0.6395
nthalpy	KCAL/KG	21.441	56.478	69.812
P	KCAL/KG-C	0.605	21.441	86.917
ensity	KG/M3	561.581	0.605	0.815
urface Tension	DYNE/CM	501.561 n/a	561.424	470.466
hermal Conductivity	KCAL/HR-M-C	n/a n/a	n/a /-	n/a
iscosity	CP	•	n/a	n/a
		n/a	n/a	n/a

FEED STOCKS:

Mixed C₃-C₄ Feed

Feed	Composition
Hydrocarbon Components,	mol %
Propylene	55.183
i-Butane	0.001
n-Butane	25.198
i-Butene	2.584
1-Butene	2.374
trans-2-Butene	5.976
cis-2-Butene	3.516
1,3-Butadiene	0.001
-Pentene	2.468
i-C5	0.971
M-2-Butene	0.504
-Hexene	1.061
-Octene	0.147
otal, mol%	100.00
otal, kgmol/hr	1000

PRODUCTS:

A) Polymer Grade Propylene Product (High Purity)

Component	<u>Units</u>	Specifications
Propylene	wt%	99.9+ min
Ethylene	ppm wt	10 max
Ethane	ppm wt	200 max
Total C ₄ 's	ppm wt	10 max

B) C₄ Product

Estimated composition:

Components	Mol %	
Isobutene	6.41	
1-Butene	5.79	
cis-2-Butene	7.95	
trans-2-Butene	13.95	
Isobutane	0.01	
n-Butane	58.4	
C5 Hydrocarbons	5.9	
C6 Hydrocarbons	1.1	
Water	0.0	
Total	100	

UTILITIES:

A) Steam

Battery limits specification for equipment using steam directly from the site steam headers:

	Pressure, MPaG				Temperature, °C		
Min	Norm	Max	Design	Min	Norm	Max	Design
Ор.	Op.	Op.		Op.	Op.	Op.	- 33.8
4.00	4.20	4.40	5.00	350	380		435
0.8	1.5	2.6	3	165			255
0.36	0.40	0.44	0.60	130			165
	4.00	Min Norm Op. Op. 4.00 4.20 0.8 1.5	Min Norm Max Op. Op. Op. 4.00 4.20 4.40 0.8 1.5 2.6	Min Norm Max Design Op. Op. Op. 4.00 4.20 4.40 5.00 0.8 1.5 2.6 3	Min Norm Max Design Min Op. Op. Op. Op. 4.00 4.20 4.40 5.00 350 0.8 1.5 2.6 3 165	Min Norm Max Design Min Norm Op. Op. Op. Op. Op. Op. 4.00 4.20 4.40 5.00 350 380 0.8 1.5 2.6 3 165 195	Min Norm Max Design Min Norm Max Op. Op. Op. Op. Op. Op. Op. 4.00 4.20 4.40 5.00 350 380 410 0.8 1.5 2.6 3 165 195 225 0.36 0.40 0.44 0.60 0.60 0.60 0.60

B) Cooling Water

Cooling water shall be supplied and returned to the battery limits at the following conditions:

Pressure, MPaG				Tempera	ture °C	
	Min Op	Norm Op	Max Op	Design	Operating	Design
Supply	0.48	0.50	0.58	1.00	33	65
Return	0.25	0.30	0.35	1.00	43 max	65

BATTERY LIMIT CONDITIONS

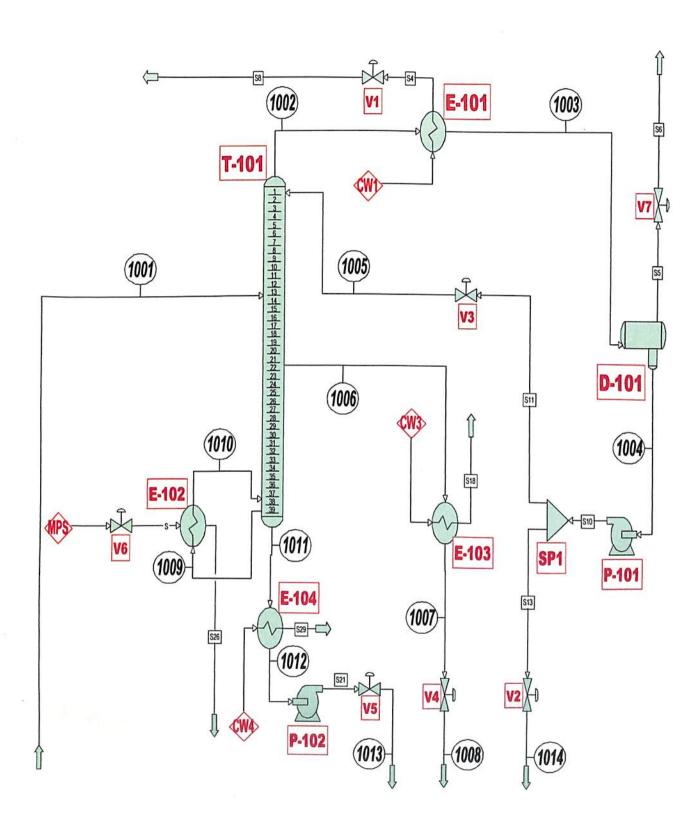
A. Feed stocks

		Operating C	onditions
	State	Pressure, MPaG	Temp, °C
Depropylenizer feed	Liquid	1.876	74

A) Products

		Operating Conditions		
		Pressure, MPaG	Temp, °C	
Propylene product	Liquid	3.3	47	
C ₄ Side draw	Liquid	0.3	40	

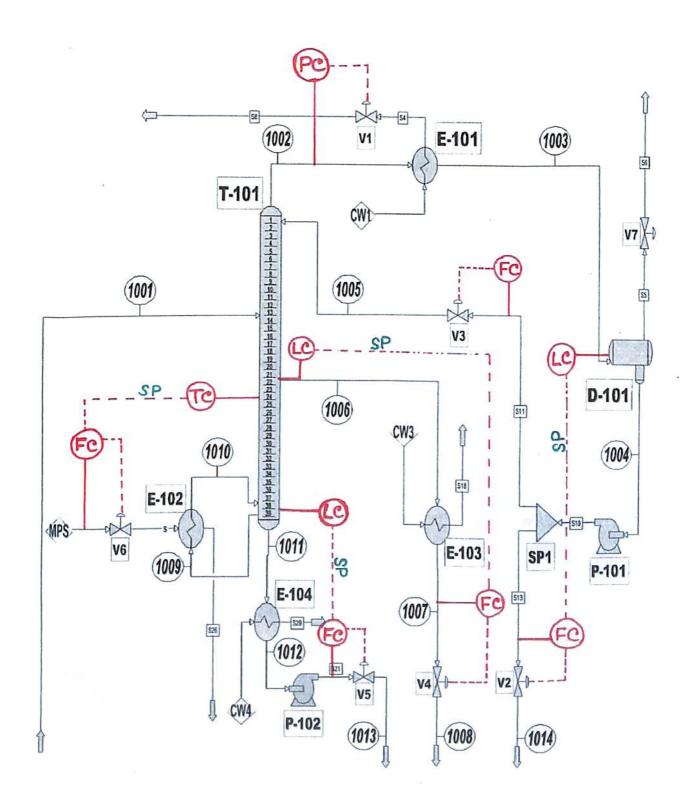
PROCESS FLOW DIAGRAM



EQUIPMENTS LIST

Service	No
Depropylenizer Reflux Drum	1
Depropylenizer Reboiler Condensate Bot	
	1
Depropylenizer Condenser	
	1
Depronylenizer Rehoiler	
Zopropylemzer Reboller	1
C4 Recycle Cooler	
	1
C4+ Product Cooler	
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	1
Depropylenizer Reflux/Propylene Product Pump	
The state of the s	2
C4+ Product Pump	
	2
Depropylenizer	
	1
	Depropylenizer Reflux Drum Depropylenizer Reboiler Condensate Pot ers Depropylenizer Condenser Depropylenizer Reboiler C4 Recycle Cooler C4+ Product Cooler Depropylenizer Reflux/Propylene Product Pump C4+ Product Pump Depropylenizer

PROCESS FLOW DIAGRAM WITH CONTROL SCHEME



23. REFERENCES

 \Box

- ANDREW W.SLOLEY, Effectively Control Column Pressure, The Distillation Group, Chemical Engg. Progress, PP 39-48, Jan 2001.
- BORA AYDIN AND MARZOUK BENALI, Simulation and Optimization of Depropanizer / Depropylenizer, C3-splitter and Debutanizer, Natural Resources Canada, Canment Energy, 2007.
- 3. L. URLIC, S. BOTTINI, E.A. BRIGNOLE AND J.A. ROMAGNOLI, Thermodynamic Tuning in Separation Process Simulation and Design, Computers Chem. Engg. Vol.15, No.-7, PP 471-479, 1991.
- 4. RAJIV MUKHERJEE, Engineers India LTD, Effectively Design Shell and Tube Heat Exchangers, Chemical Engg. Progress, Feb 1998.
- 5. H.SILLA- Chemical Process Engineering Design and Economics, Taylor & Francis Group LLC, New York, 2003.
- 6. KISTER, H.Z., Distillation Design, McGraw-Hill, New York, 1992.
- 7. PERRY R.H AND DON W.GREEN, Chemical Engineers Handbook 6th edition, McGraw-Hill publishers, 1999.
- 8. TREYBAL R, Mass Transfer Operations, 3rd edition, McGraw-Hill, 1980.
- 9. S.B THAKORE, B.I. BHATT, Introduction to Process Engineering and Design 2th edition, Tata McGraw-Hill publishers, 2009.
- 10. ERNEST E LUDWIG, Applied Process Design for Chemical and Petrochemical Plants 3rd edition, volume 1, 2, 3, Gulf Publishing Company, Houston, 1997.
- 11. HENLEY, E.J., AND J.D. SEADER, Equilibrium-Stage Separation Operations in Chemical Engineering, Wiley, New York, 1980.