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DESIGN OF SHELL AND TUBE HEAT EXCHANGER USING HTRI SOFTWARE ACCORDING TO TEMA FOR BEVERAGE AND PROCESS INDUSTRY

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I.INTRODUCTION OF HEAT EXCHANGER

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperature sand in thermal contact, usually without external heat and Work interactions. The fluids may be single compounds or mixtures. Typical applications Involve heating or cooling of a fluid stream of concern, evaporation or condensation of a single or multi component fluid stream, and heat recovery or heat rejection from a system. In other applications, the objective may be to sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control process fluid. In some heat exchangers, the fluids exchanging heat are in direct contact. In other heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In most heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix. Such exchangers are referred to as the direct transfer type, or simply recuperators. In contrast, exchangers in which there is an intermittent heat exchange between the hot and cold fluid mesh via thermal energy storage and rejection through the exchanger surface or matrix--are referred to as the indirect transfer type or storage type, or simply regenerators. Such exchangers usually have leakage and fluid carryover from one stream to the other.

Heat Exchanger concept

II.INTRODUCTION OF HEAT EXCHANGER CODES

STANDARDS AND CODES

Standards and codes were established primarily to ensure safety against failure. The need for safety standards is obvious in a world growing increasingly aware of the hazards posed to people, property, and the environment by complex technology, which may have the potential for doing immense harm. The codes and standards give guidance and in some cases govern the design, manufacture, construction, operation, and maintenance of heat exchangers and pressure vessels. These codes and standards are themselves based upon research, develop- ment, and experience. The present-day codes have their origin in the rules laid down by the insurance companies in the past for the safe operation of boilers and pressure vessels against explosions or accidents and consequential damage to the human lives and property.

STANDARDS

A standard can be defined as a set of technical definitions and guidelines, or how-to instructions for designers and manufacturers. Standards are mostly voluntary in nature. They serve as guidelines but do not themselves have a force of law. Standards are universally adopted in manufacturing, procurement, and operation of thousands of devices and products, including raw materials, equipment, etc. Many standards have been adopted as a means of satisfying the regulatory or procurement requirements. Standards help to reduce the cost of products and processes in the following manner:

At the design level, rationalization of design procedure, drawings and specifications takes place. This avoids the repetition of detailed design analysis for either identical or similar jobs.

Standards help in complete interchangeability and uniformity of fundamental design, tools, gages, tool accessories, etc

The standards can be of the following major four types:

1. Company standards

2. Trade or manufacturers association standards

3. National standards

4. International standards

Company Standards

Company standards are followed by individual companies, subcontractors to the companies, and the license holders.

Trade or Manufacturers Association Standards

Trade or manufacturers association standards are the rules and the recommendations of various manufacturers of common interest, developed based on experience in design, manufacture, installation, and operation. While making the standards, feedback from users is normally included. Manufacturer's association standards that are most famous among heat exchanger manufacturers are TEMA , HE1 , and API Standards. There are also EJMA Standards for the design of membrane type expansion joints and ANSI (American National Standards Institute) standards for design of fittings, flanges, valves, piping and piping components.

National Standards

National Standards are followed in the country where the standard has been issued and by subcontractors or license holders in other countries or complied with when the purchasers have so specified. National standards like BSI (Britain) , JIS (Japan) , and DIN (Germany) .

British Standards (BSI), 1993.

BSI's major function is to help British industry compete effec- tively in world markets. Its work in standards, testing, quality assurance and export guidance is geared to enable British companies to meet the quality needs of buyers at home and abroad. BSI is independent, operating under a Royal Chatter. BSI was the first national standards body in the world. There are now more than 80 similar organizations that belong to the International Organization for Standardization (ISO) and the International Electro technical Commission (IEC). Over 1 1,000 British Standard publications are listed in British Standards, 1993. Orders for publications should be directed to BSI Publications at Linford Wood, Milton Keynes, United Kingdom MK14 6LE.

Japanese Industrial Standards (JIS).

JIS (Japanese Industrial Standards) are national voluntary standards for industrial and mineral products. Various industrial associations also establish voluntary standards for their specific needs. Many companies have a set of company standards like operation manuals some of them adopted from JIS and/or industrial association standards. DIN-German Standards. The creation of German standards is the task of DIN, Detaches Institute for Normung e.v, a self-governing institution of trade and industry. On the basis of its statutes and of DIN 820, the standard that specifies the principles directing its activities, and by virtue of an agreement concluded with the government in 1975, DIN is the institution that is competent for standardization in the Federal Republic of Germany. As the representative of Germany, it fulfills an equivalent function in the European (CENKENELEC) and international standards organizations (ISO), while in the field of electrical engineering such activities are coordinated through the Deutsche Elektro technischen Kommission von DIN and VDE (DKE).

International Standards

IS0 (International Organization for Standardization) is a worldwide federation of national standards bodies, at present comprising 92 members, one in each country. IS0 coordinates the exchange of information on international and national standards, technical regulations, and other standards type documents, through an information network called ISO-

NET, which links the IS0 Information Centre in Geneva with similar national centers in other countries. International Standards are followed all over the world. International Standards for quality, NDT, materials, heat exchangers, and others are framed by the ISO, Geneva. Relevant international standards for our studies include IS0 1993 and IS0 9000 Series on Quality. Information on IS0 1993 is given next, whereas the IS0 9000 Quality series is covered in Chapter14, Quality Control and Quality Assurance, Inspection, and NDT. IS0 1993. The scope of IS0 1993 covers standardization in all fields except electrical and electronic engineering standards, which are the responsibility of IEC, the International Electro technical Commission. Together, IS0 and IEC form the specialized system for world- wide standardization-the world's largest nongovernmental system for voluntary industrial and technical collaboration at the international level. The results of IS0 technical work are published in the form of International Standards. The 1993 IS0 Catalogue lists 8651 published international standards. They are available as single documents, in handbook compilations for specific fields, and, in many countries, on microfilms and microfiches as well as on CD-ROM (compact disk-read-only memory).

TEMA Standards

Founded in 1939, the Tubular Exchanger Manufacturers Association, Inc., or TEMA, is a group of leading manufacturers of shell and tube heat exchangers who have pioneered the research and development of heat exchangers for over 50 years. TEMA Standards are followed in most countries of the world for design of shell and tube heat exchangers. Standards such as BS 5500 and API 660 incorporate part or all part of the TEMA Standards by reference.

Codes

A code is a system of regulations or a systematic book of law often given statutory force by state or legislative bodies . A code becomes a legal document in a state, a province, or a country if the government concerned passes appropriate legislation making it a legal requirement. Among the codes, the ASME Code for construction of boilers and pressure vessels including heat exchangers is the most widely used and referred to code in the world today. Apart from ASME Code, many other codes are issued by various countries. These codes are shown in Table 2. Basically the codes differ in their legal status in their own countries. Range of applicability varies with regards to the scope of the codes, which includes basis of design and stress analysis, design pressure and temperature, diameter, volume, materials of constructions, fabrication, inspection, etc. There is no specific code available exclusively for construc- tion of heat exchangers in the world. Generally heat exchanger standards quote certain codes to be followed for construction of the heat exchangers. In the following paragraphs, codes like ASME Code , BS 500, CODAP , and A. D. Merkblatter are discussed. Addresses of important codes outside the United States and Canada are furnished by Yo-kell ..

Code name	Country
ASME Code, Section III [21], Section VIII, Divs. 1 & 2	United States
BS 5500	United Kingdom
CODAP, SNCT [22]	France
A. D. Merkblatter	Germany
ANNC [23]	Italy
Stoomwenzen [24]	Dutch
ISO/DIS-2694 [25]	International
IS:2825-1969 [26]	India
GOST	USSR
The Pressure Vessel Code [27][a]	Japan
Regels Voor Toesellen onder Druck [28]	Netherlands

International Design Code

ASME Codes

ASME Code establishes minimum rules of safety governing the design, fabrication, inspection, and testing of boilers, pressure vessels, and nuclear power plant components. It covers new construction and rerating the existing equipment. The existence of the code stamp on a pressure vessel, with the indicated pressure and temperature, establishes the design conditions, new and old. The service conditions such as corrosion, erosion, change in operating pressure, and/or temperature may be reasons to rerate the unit, but the original stamping remains valid. Supplemental stamping is a requirement to address rerating

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THERMAL DESIGN INPUTS:

This is a data sheet for thermal designing process. The data is collected from kerosene oil refinery plant.

1	Service of Unit : Kerosene Pre-heating	Item No.			
2	Size:	Type : BEM Horizontal			
3	**Performance of unit**				
4	Fluid Allocation	Shell Side (In/Out)		Tube Side (In/Out)	
5	Fluid Name	Steam		Heavy Coker Oil	
6	Fluid Quantity (Total) (kg/hr)	4736.88		52916.4	
7	Vapor (In/out)	-	-	0	0
8	Liquid	-	-	52919.261	52919.261
9	Non-condensable	-	-	0	0
10	Temperature (In/Out) °C	300.33	299.56	193.33	248.44
11	Density (Kg/m^3)	42.05	716.91	854.153	810.262
12	Viscosity (Ns/m^2)	0.000021	0.00095	0.000358	0.000226
13	Specific Heat (kJ/Kg K)	6.1025	4.89	2.177	2.3602
14	Thermal Conductivity (W/m K)	0.067	0.521	0.137	0.123
15	Pressure (bar)	87.2		3.082	

Input Data sheet

Thermal DESIGN CALCULATION

1 Mass flow rate of Steam:

As per TEMA, the following factors will determine the allocation of the fluid streams to the shell or tubes.Only the thermal design will be considered

- **Corrosion** : The more corrosive fluid should be allocated to the tube-side. This will reduce the cost of expensive alloy or clad components.
- **Fouling** : The fluid that has the greatest tendency to foul the heat-transfer surfaces should be placed in the tubes. This will give better control over the design fluid velocity, and the higher allowable velocity in the tubes will reduce fouling. Also, the tubes will be easier to clean.
- **Operating pressures** : The higher pressure stream should be allocated to the tube-side. High-pressure tubes will be cheaper than a high-pressure shell.
- **Pressure drop** : For the same pressure drop, higher heat-transfer coefficients will be obtained on the tube-side than the shell-side, and fluid with the lowest allowable pressure drop should be allocated to the tube-side.
- **Stream flow-rate**: Allocating the fluids with the lowest flow-rate to the shell-side will normally give the most economical design. By considering these factors, allocation of fluids will be :

Shell Side – Steam

Tube Side – Heavy coker oil

T_{h1} = Inlet Temp. of Steam = 573.33 K

T_{h2} = Outlet Temp. of Steam = 572.56 K

T_{c1} = Inlet Temp. of Oil = 466.33 K

T_{c2} = Outlet Temp. of Steam = 521.4 K

C_p = Specific Heat of Oil = 2.27 kJ/Kg K

m_o = Mass flow rate of Oil = 14.7 Kg/sec

h_{fg} = Latent heat of evaporation (at 87.2 bar) = 1398.02 KJ/kg

m_w = Mass flow rate of Steam.

Total Heat transfer required, $Q = m_o * C_p * (T_{c2} - T_{c1}) = m_w * h_{fg}$

$Q = 14.7 * 2270 * (521.4 – 466.33)$

$= 1838965.6$ W

therefore, Mass flow rate of Steam required $m_w = Q / h_{fg}$

= 1.32 Kg/sec = 4735.33 kg/hr.

2 Logarithmic Mean Temperature Difference (LMTD) :

It is defined as that temperature difference which, if constant, would provide same rate of heat transfer as actually occurs under variable conditions of temp. difference.

$LMTD = (\theta_1 – \theta_2) / \ln (\theta_1/ \theta_2)$

Where, θ_1 = Temperature diff. at Inlet of HE.

θ_2 = Temperature diff. at Outlet of HE.

For Counter Flow arrangement of Heat Exchanger,

$\theta_1 = T_{h1} - T_{c2} = 573.33 – 521.40 = 51.93$ K

$\theta_2 = T_{h2} - T_{c1} = 572.56 – 466.33 = 106.23$

$LMTD = (51.93 – 106.23) / \ln (51.93/ 106.23)$

$= 75.87$ K

The usual practice in the design of shell and tube exchangers is to estimate the “true temperature difference” from the logarithmic mean temperature by applying a correction factor to allow for the departure from true counter-current flow:

$T_m = F_t * LMTD$

where, Tm = true temp. difference, the mean temp. difference for design

Ft = temperature correction factor.

The correction factor is a function of the shell and tube fluid temperatures, and the number of tube and shell passes. It is normally correlated as a function of two dimensionless temperature ratios

R = Capacity ratio = $(T_{h1} - T_{h2}) / (T_{c2} - T_{c1}) = 0$

P = Temperature ratio = $(T_{c2} - T_{c1}) / (T_{h1} - T_{c1}) = 0.52$

The correction factor is given b

$F_t = 0.986$

Therefore, $T_m = 0.986 * 75.87 = 74.81$ K.

3 Numbers of Tubes:

The general equation for heat transfer across a surface is:

Q = U * A * Tm

Where, Q = Heat transfer rate.

U = Overall heat transfer coefficient.

A = Heat-transfer area.

Tm = the mean temperature difference.

Now, total heat transfer area A = Perimeter area * No. of tubes

$= \pi * d_o * l * N$

As per TEMA section 9, table D-7M, for copper material tube of 14 gage :

d_o = Outside dia. = 25.4 mm

d_i = Inside dia. = 21.2 mm

t = Thickness = 2.1 mm

l = Recommended length = 2.438 m

For Steam-Coker oil, estimated heat transfer co-efficient U = 1250 W/ m^2 K

therefore, Q = 1838965.6 = 74.81 * 1250 * π * 0.0251 * N

N = 103 tube

4 Shell Diameters (D):

To find shell diameter (D),

Bundle dia. $D_b = d_o * (N / k)^{(1/n)}$ (k = 0.175 & n = 2.235)

= 25.4 * (103 / 0.175) ^ (1/2.235)

= 414 mm

For semi-elliptical head, side clearance = 56 mm

Shell Diameter $D = D_b$ + side clearance

= 414 + 56 = 470 mm

5 Tube side Heat Transfer Co-efficient (h_t):

Cross section area = $\pi * d_i^2 / 4$

= 353 mm^2

Tube per pass = N / no of pass

= 104 / 4 = 26

Total flow area = Tube per pass * cross section area

= 26 * 353 = 9178 mm^2

Reynolds Number Re = $\rho * v * d_i / \mu$

= (854.153 * 1.9812 * 0.0212) / 0.000358 = 100211.33

Prandtl Number Pr = $C_p * \mu / K_f$

= 2200 * .000358 / 0.137 = 5.75

Now, $(h_t * d_i) / K_f = 0.004 * Re^{0.8} * Pr^{0.33}$

We'll find h_t =9393.8 W/m

6 Shell side Heat Transfer Co-efficient (h_s):

Baffle spacing (B) = D / 5

= 93.8 mm

Pitch (p) = $1.25d_o$ = 31.75 mm

Now, Cross flow area = $A_s = (p - d_o) * D * B / p$

= 0.009 m^2

G = Mass velocity = m_w / A_s = 146.2 kg/s m^2

Equivalent diameter de = $1.1 * (p^2 – 0.917d_o^2) / d_o$

= 18.04 mm

Reynolds Number Re = $G * d_e / \mu$

= (146.2 * 0.01804) / 0.000021

= 125559.8321

Prandtl Number Pr = $C_p * \mu / K_f$ = 6120 * 0.000021 / 0.067 = 1.92

Now, $(h_s * d_e) / K_f = 0.0039 * Re^{0.8} * Pr^{0.33}$

We'll find h_s = 2154.7 W/m

7 <u>Overall Heat Transfer Co-efficient (U):</u>

Overall heat transfer co-efficient (on outside area based) is give by,

$(1 / U) = (1 / h_t) + d_o * \ln(d_o/d_i) / 2* K_w + d_o/ d_i * (1 / h_s)$

We'll find U = 1213.5 W/m K

8 <u>fouling:</u>

Rd = fouling factor - or unit thermal resistance of the deposit (m2K/W)

Thermal conductance of heat exchanger after fouling: Ud = 1213.5 (W/m2K)

Thermal conductance of clean heat exchanger: U =1678(W/m2C)

$R_d = 1 / U_d - 1 / U$

= (1/1213.5) - (1/1678)

=0.00019

Mass flow rate of Steam (kg/hr)	Fouling (m^2 K/W)
1036	0.00057
1536	0.00042
2036	0.00033
2536	0.00029
3036	0.00025
3536	0.00023
4036	0.00021
4536	0.0002
4736	0.00019

Mass Flow v/s Fouling Factor

Generation of HTRI sheet:

In the generation of HTRI software data input sheet, Firstly we select the case mode like Rating, simulation, Design. Here we are select the Rating mode because we know the duty and geometry and put the values in the sheet and software will tell if the specified geometry is enough or not for the specific duty (exchanger is under designed or overdesigned) . In this sheet input data is related to fluid parameters.

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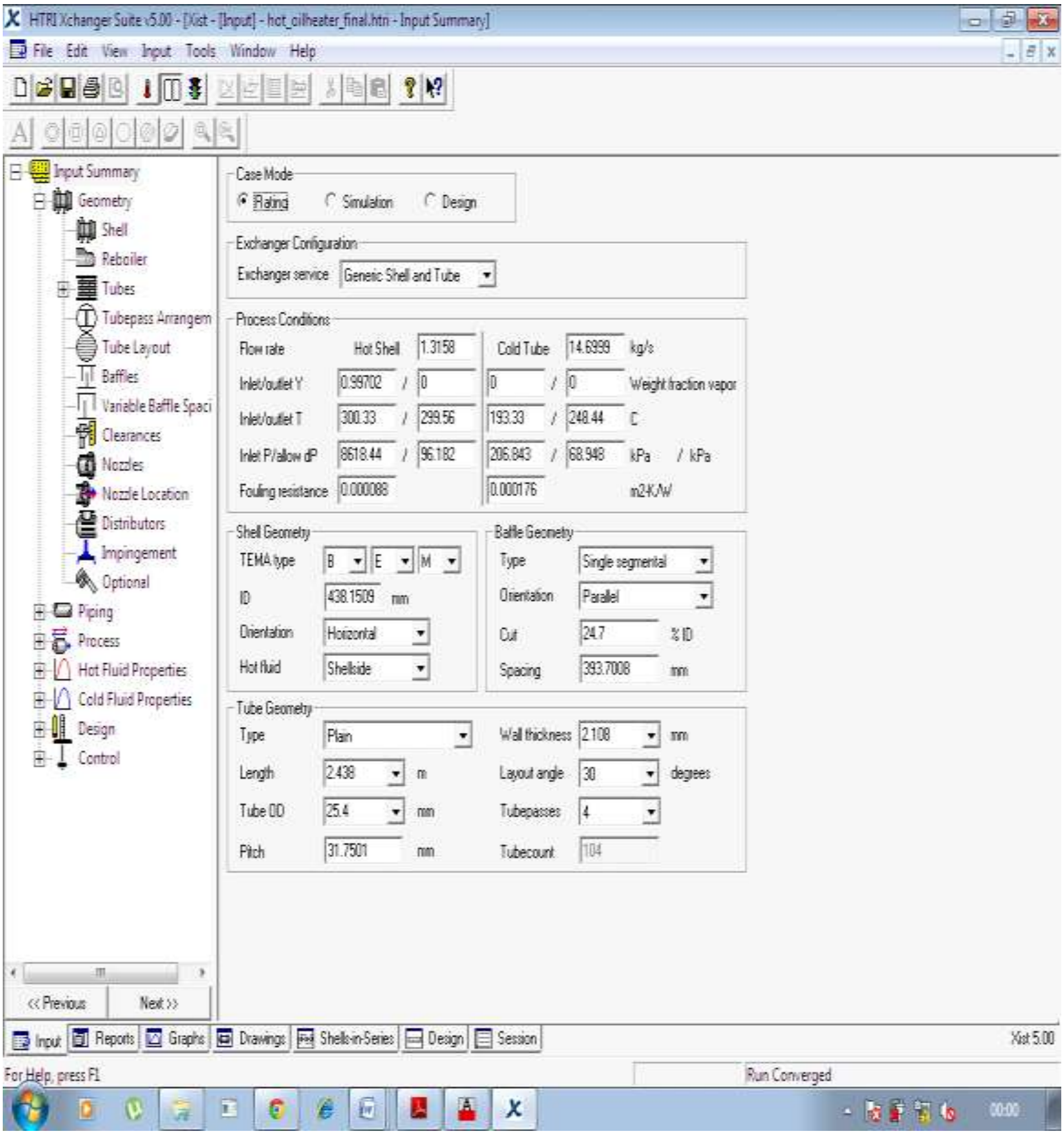

Fluid Parameters

The next sheet is related to the shell and tube exchanger geometry . Sheet has three part of input that are shell geometry, befell geometry and tube geometry. According to heat exchanger type, geometry parameter can be select.

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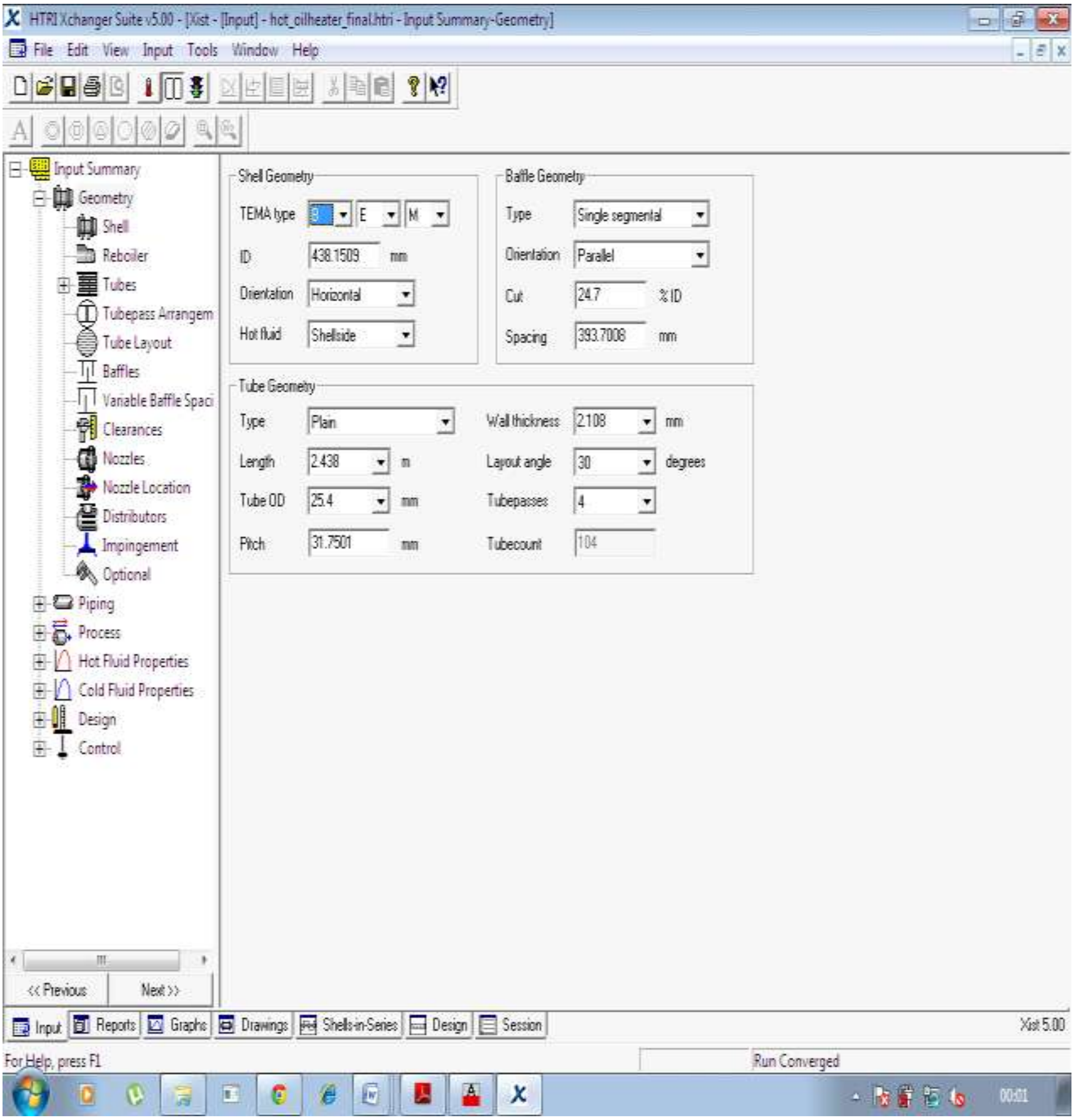

Shell & Tube Geometry

Next sheet is for Fluid flow arrangement. This sheet show how much tube passes in the heat exchanger for the fluid flow and systematic layout of tube passage. In Our case there are four tube passage.

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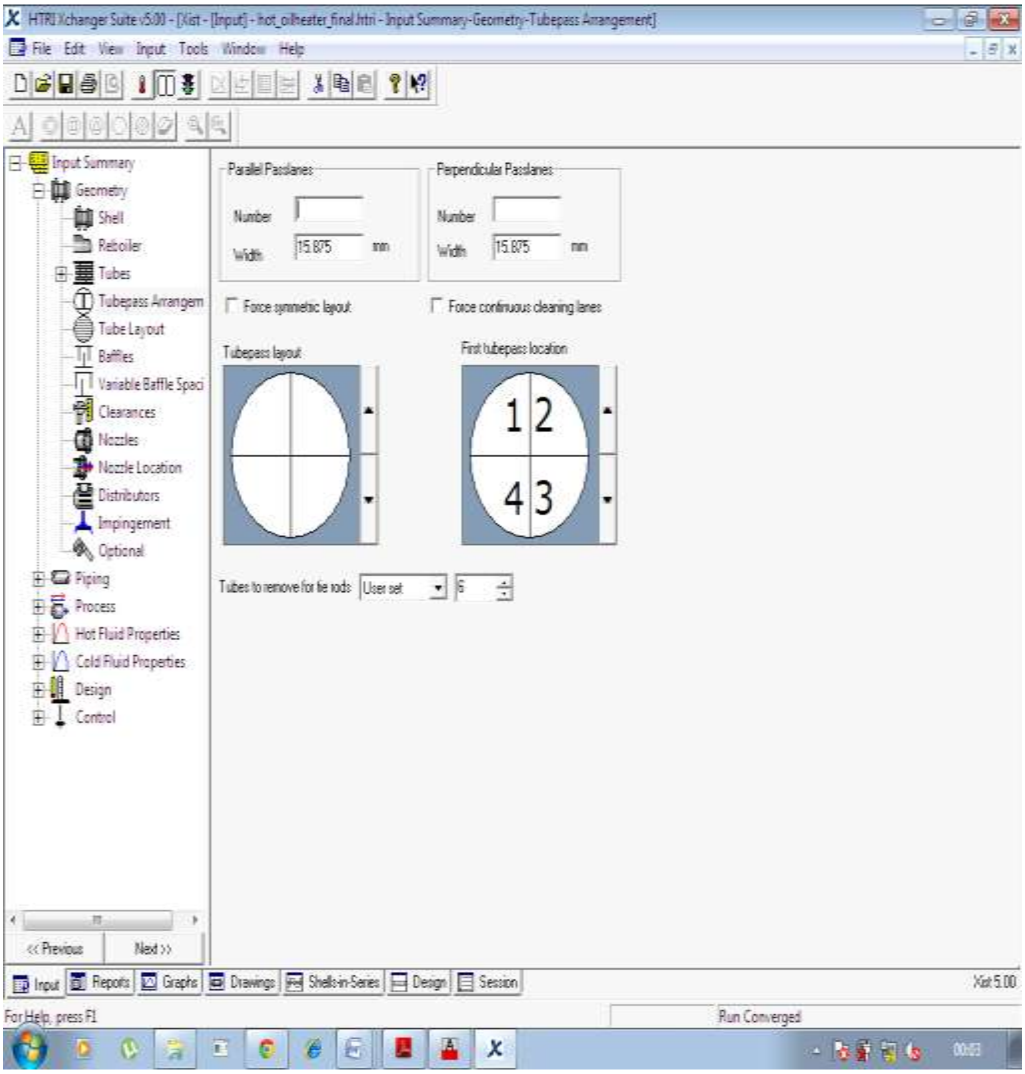
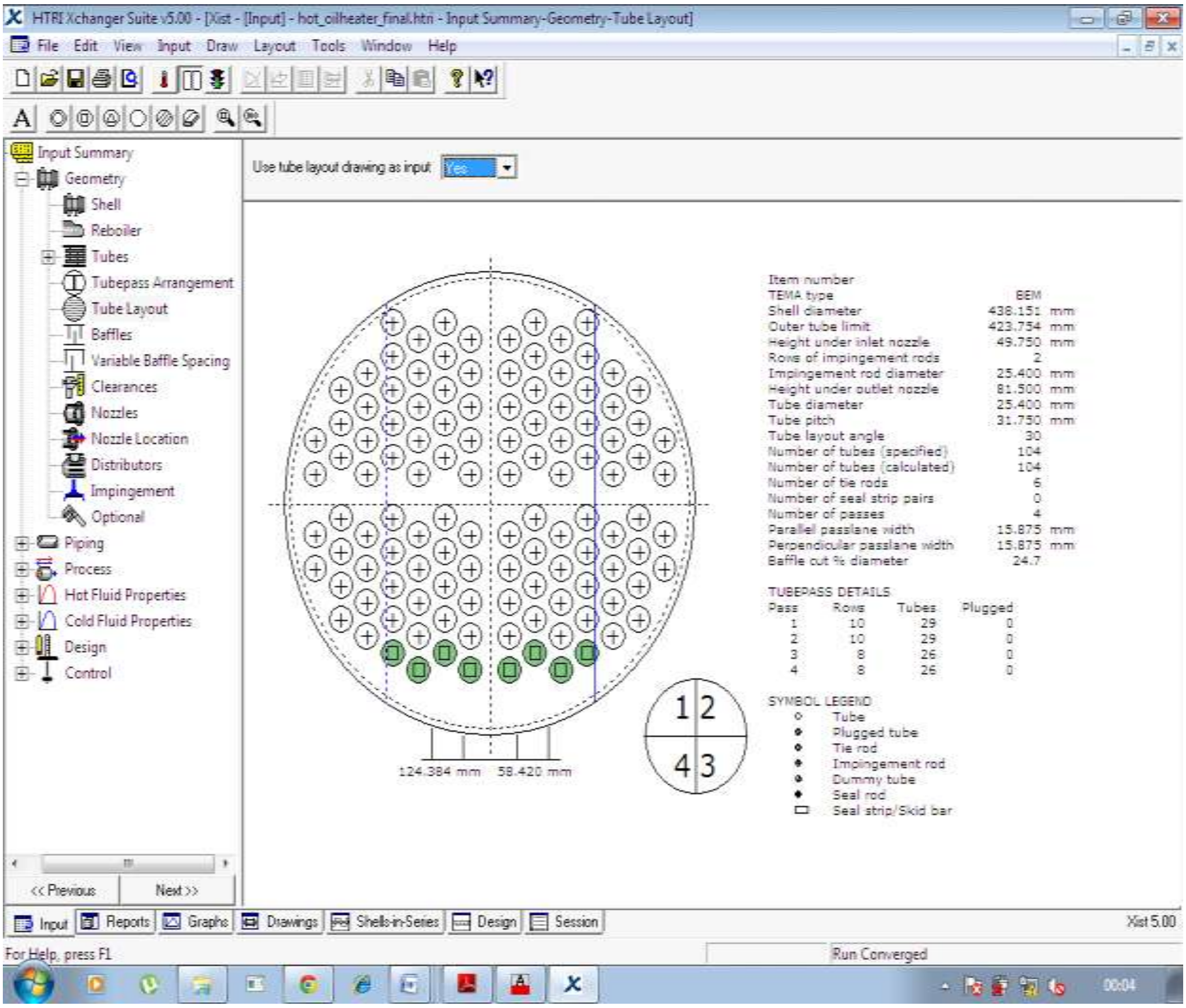


Fluid Flow Arrangement.

This sheet show the systematic layout of tube passage arrangement in one tube pass . This layout shows the four tube passage with no of tubes arrangement in one pass shell.



Tubes Arrangement.

This sheet shows the fluid property according to flow of fluid conditions in heat exchanger. It gives information about the which type of fluid flow in the shell side or tube side, fouling resistance etc.

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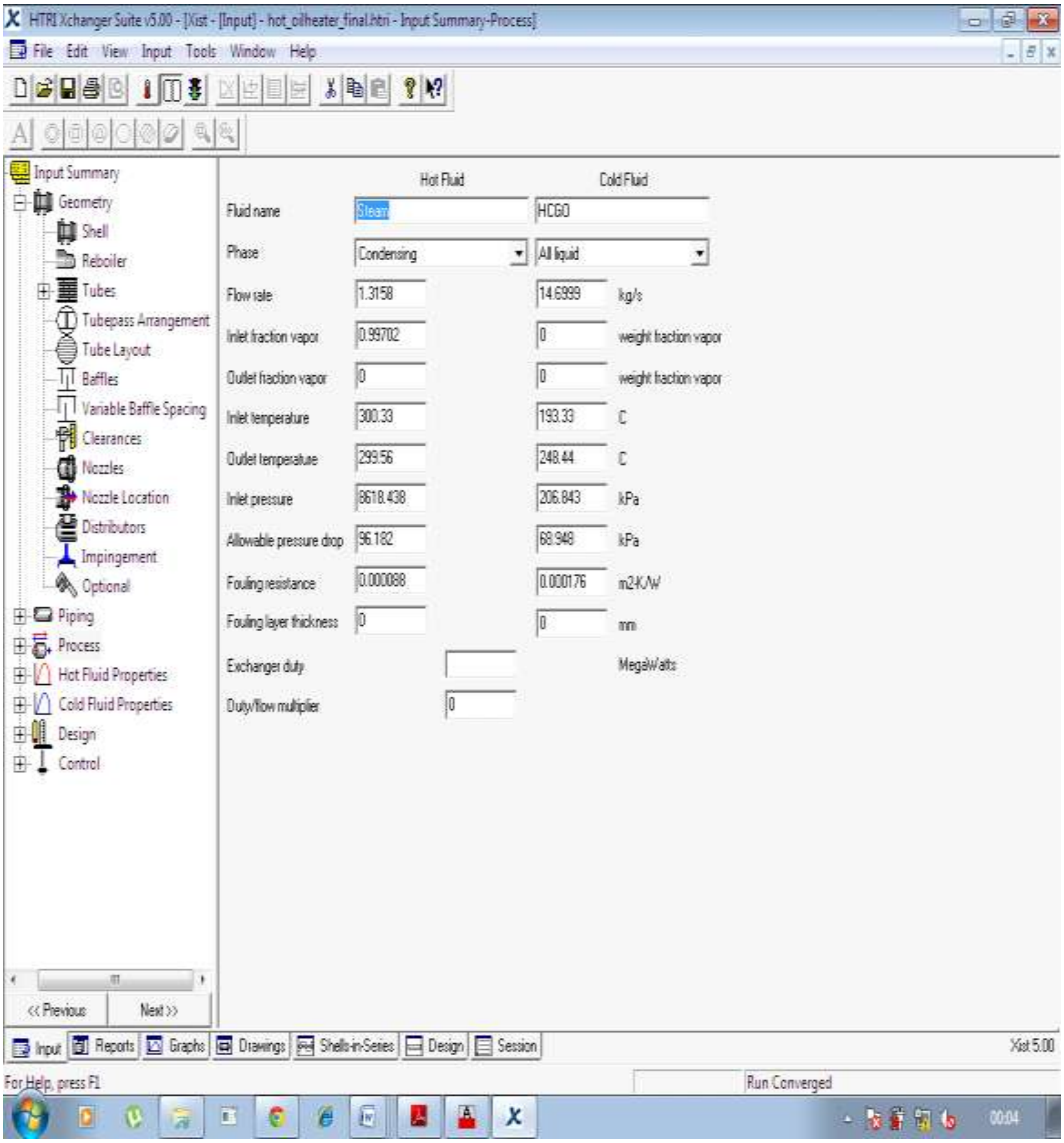
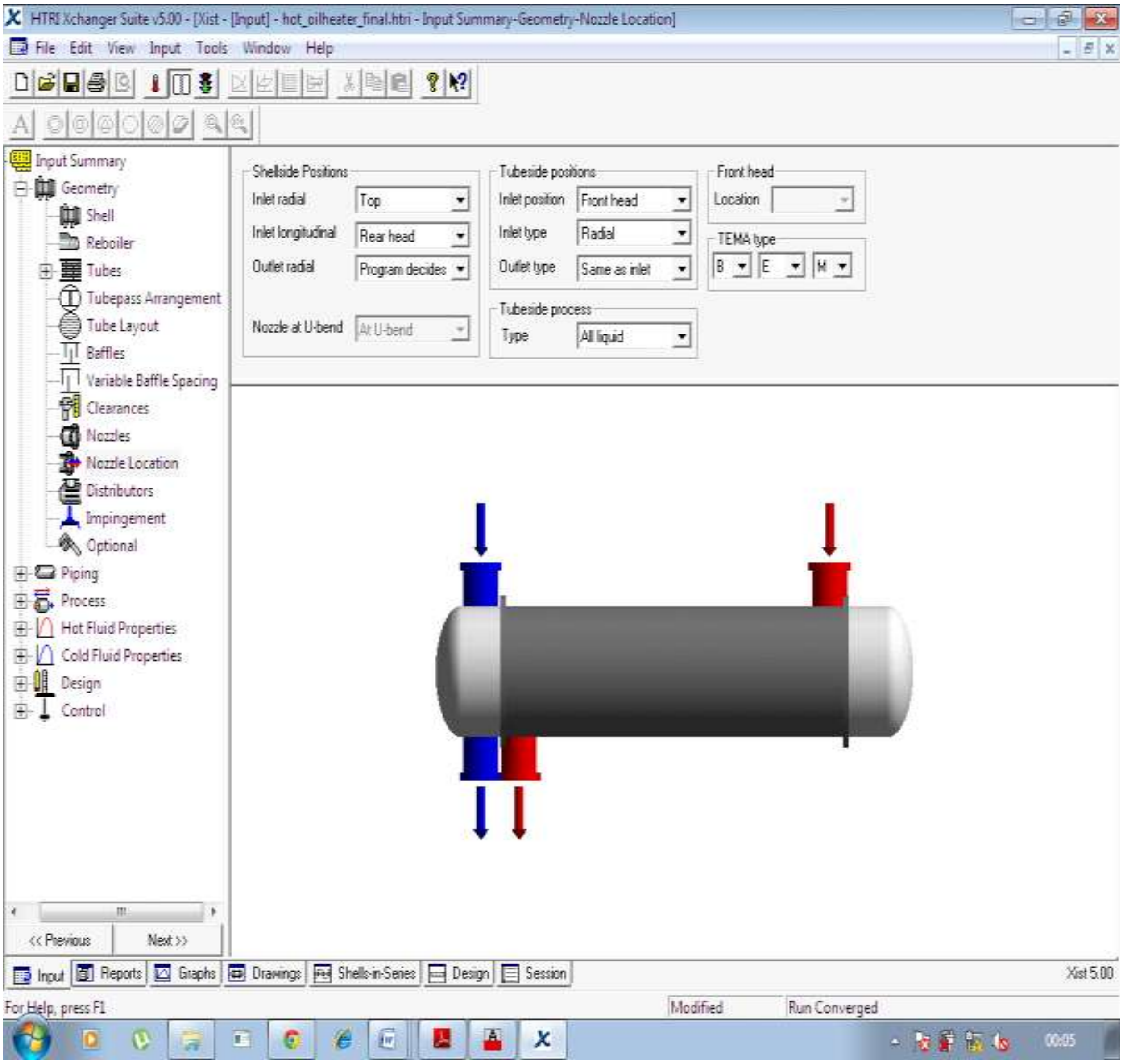


Fluid Properties.

We are designing one pass shell –tube heat exchanger. In this type of heat exchanger one nozzle is present for incoming and another nozzle is for outgoing of fluid flow in shell side as well as tube side. So with help of HTRI software we can design the effective location of the nozzles.



Nozzles Locations.

HTRI OUT PUT Sheet:

This is the output sheet of the HTRI software input data. It gives final calculated fluid parameters , Geometry and layout of the heat exchanger.

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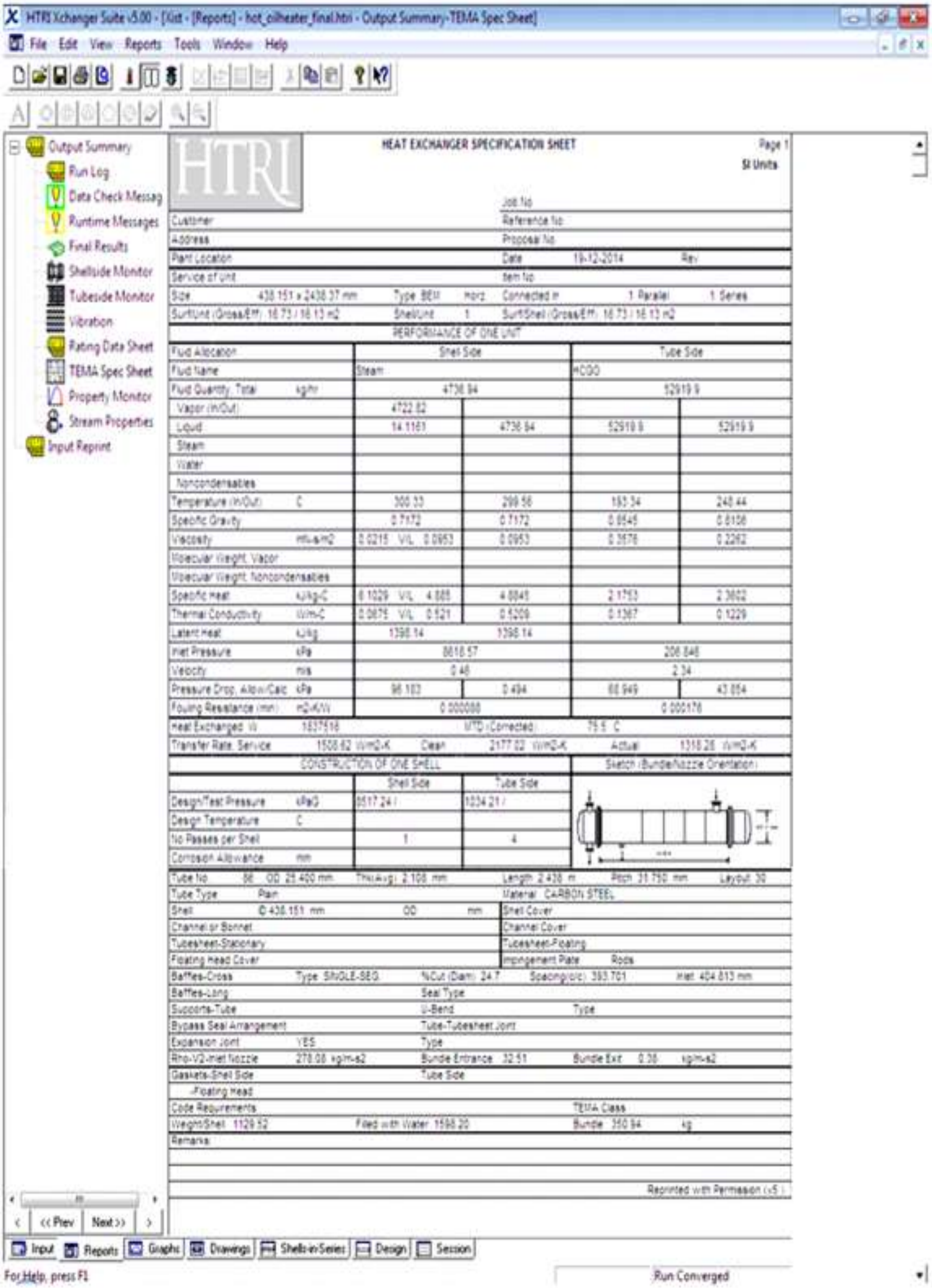

HEAT EXCHANGER SPECIFICATION SHEET

Page 1
SI Units

Job No
Customer | Reference No
Address | Proposal No
Plant Location | Date 19-12-2014 | Rev
Service of Unit | Item No
Size 438.151 x 2438.37 mm | Type BEM | Horz | Connected in 1 Parallel 1 Series
Surf/Unit (Gross/Eff) 16.73 / 16.13 m2 | Shell/Unit 1 | Surf/Shell (Gross/Eff) 16.73 / 16.13 m2

PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side		Tube Side	
Fluid Name		Steam		HCGO	
Fluid Quantity, Total	kg/hr	4736.94		52919.9	
Vapor (In/Out)		4722.82			
Liquid		14.1161	4736.94	52919.9	52919.9
Steam					
Water					
Noncondensables					
Temperature (In/Out)	C	300.33	299.56	183.34	240.44
Specific Gravity		0.7172	0.7172	0.8545	0.8108
Viscosity	mN-s/m2	0.0215 V/L 0.0953	0.0953	0.3576	0.2262
Molecular Weight, Vapor					
Molecular Weight, Noncondensables					
Specific Heat	kJ/kg-C	0.1029 V/L 4.885	4.8845	2.1753	2.3602
Thermal Conductivity	W/m-C	0.0875 V/L 0.521	0.5209	0.1367	0.1229
Latent Heat	kJ/kg	1398.14	1398.14		
Inlet Pressure	kPa	8618.57		206.846	
Velocity	m/s	0.46		2.34	
Pressure Drop, Allow/Calc	kPa	96.103	0.494	68.949	43.054
Fouling Resistance (min)	m2-K/W	0.000088		0.000176	

Heat Exchanged W 1637518 | MTD (Corrected) 79.5 C
Transfer Rate, Service 1508.62 W/m2-K | Clean 2177.02 W/m2-K | Actual 1318.26 W/m2-K

CONSTRUCTION OF ONE SHELL | Sketch (Bundle/Nozzle Orientation)

		Shell Side	Tube Side
Design/Test Pressure	kPaG	8517.24 /	1034.21 /
Design Temperature	C		
No Passes per Shell		1	4
Corrosion Allowance	mm		

Tube No 98 | OD 25.400 mm | Thk(Avg) 2.108 mm | Length 2.438 m | Pitch 31.750 mm | Layout 30
Tube Type Plain | Material CARBON STEEL
Shell ID 438.151 mm | OD mm | Shell Cover
Channel or Bonnet | Channel Cover
Tubesheet-Stationary | Tubesheet-Floating
Floating Head Cover | Impingement Plate Rods
Baffles-Cross Type SINGLE-SEG | %Cut (Diam) 24.7 | Spacing(c/c) 393.701 | Inlet 404.813 mm
Baffles-Long | Seal Type
Supports-Tube | U-Bend | Type
Bypass Seal Arrangement | Tube-Tubesheet Joint
Expansion Joint YES | Type
Rho-V2-Inlet Nozzle 278.08 kg/m-s2 | Bundle Entrance 32.51 | Bundle Exit 0.38 kg/m-s2
Gaskets-Shell Side | Tube Side
-Floating Head
Code Requirements | TEMA Class
Weight/Shell 1129.52 | Filled with Water 1598.20 | Bundle 350.94 kg
Remarks

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HTRI Output Sheet

Results:

These are the final results of manually design calculation and by HTRI. The table shows the comparatively study of final result. With the help of results we can make a decision on design of heat exchanger.

Parameter	**As per Design Calculations**	**As per HTRI**
Mass flow rate of Steam m_o	4735.33 kg/hr	4736.91 kg/hr
Total Heat Transferred Q	1911.97 KW	1836.84 KW
LMTD (corrected)	74.81 C	75.80 C
No. of Tubes N	95	104
Tube side velocity	1.95 m/sec	2.34 m/sec
Overall Heat transfer co-efficient	1888W/m^2 c	1292.85 W/m^2 c

Comparison of Final Results

The new design solved the fouling problem of the customer by comparing fouling resistance at different calculation like as per design standard, as per HTRI, and by manual design calculation according to plant running conditions. As a result of reduced fouling, the overall heat transfer coefficient also increased.HTRI report determined the safety and performance of the designed heat exchanger.

	As per Design Calculation	As per HTRI	At Plant

Fouling Resistance m^2 K/W	0.00016	0.00018	0.00019

Comparison of Final Results of fouling resistance

Flow rate Vs fouling resistance (m2k/w)

III.CONCLUSION

In this thesis , I have calculated the diffrent parameter by manual design calculation on the basis of working condition of oil refinery per - heater exchanger and that results compair with HTRI software . Errors are eliminating by comparision of result for further design of heat exchanger . We can do optimal design of heat exchanger of any industry on the basis of wotking requirements .vSo it is a better way to design of heat exchangerand chance of errors are less in this type of designing method . Calculated parameters are:

1. Amount of total heat transfered by heat exchanger is calculated through manual design calculations and by HTRI software. THE value of heat transfer is different for both the methods. So errors are eleiminating by comparision and improve the efficiency of heat exchanger.

2. Fouling factor is also calculated and got the improve results in tempraturedrop of heat exchanger . It makes preventive for hazard due to temprature drop in heat exchanger

3. We can do suitable calculations for thermal design to meet the operating condition of plant.

FUTURE SCOPE

- Vibration analysis can be carried out according to TEMA for safety against flow induced vibrations.
- Construction of testing rig to measure the efficiency of the manufactured prototype.
- The prototype is operational and can be readily used for small scale applications.
- The prototype can also be used for academic purpose to illustrate the principle and different techniques of heat transfer between fluid streams.
- WRC or Nozzle Load Analysis in ANSYS for ensuring safety of nozzles during operation.
- Wind and Seismic analysis on the tank design for safety against environmental calamities like cyclones and earthquakes.
- Thermal and mechanical design was carried out to obtain major dimensions of heat exchanger by manual calculation as per TEMA, according to which we will be able to generate assembly drawing.

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