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RESTRICTED

DP/ID/SER.A/1225
7 July 1989
ORIGINAL: ENGLISH

17639

SHORT-TERM CONSULTANCIES TO STATE ENGINEERING CORPORATION

DP/PAK/84/026/11-54

PAKISTAN

Technical report: The training of H.M.C. Taxila designers in the designing of heat exchangers*

Prepared for the Government of Pakistan
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Popa Stelian, expert in heat exchanger design

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Industrial Operations Technology Division

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Vienna

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* This document has not been edited.

V.89 57570

INTRODUCTION:

The purpose of the project was the training of the Heavy Mechanical Complex (HMC), Taxila designers in the designing of heat exchangers. The job was initially programmed for a period of 4 months and subsequently extended to 6 months. It took place in the period 02.10.1988 to 05.04.1989 as follows.

On 02.10.1988 I left Bucharest, arriving in Islamabad on 03.10.1988. Next day, on 04.10.1988 I went to UNIDO Islamabad where I met Mr. J.Holten, Mr. M.Ogbewe and others. Here, all necessary arrangement for the shifting to Taxila were done, and the shifting took place on 05.10.1988.

In HMC, Taxila I discussed with:

- Mr. Zahoor Ahmed, General Manager (Engineering)
- Mr. Hussnain Siddiqui, General Manager (CMD)
- Mr. S. Ali Enser, Deputy General Manager (PPC)
- Mr. M.A. Fidai, Manager (Boiler Design)

Following those discussions and based on the job description received from UNIDO Vienna, a programme of the activity was established. That initial programme was subsequently improved, based on the requirements of the daily design activity of HMC, Taxila. The final form of this programme is as follows:

1) The drawing up of the manual entitled "Design criteria and selection of heat exchangers"

2) The compilation of the various methodologies for the thermodynamic calculation of heat exchangers.

3) The perform of the illustrative calculations for the methodologies of calculation from the point 2.

4) The training of the HMC Taxila designers in the thermodynamic design of heat exchangers, based on the works from the points 1 - 3.

5) The development of computer programmes, based on the methodologies and examples of calculation, alongwith Mr. Naseer Ahmad Salmaan from the Computer Center.

6) From time to time, help in existing jobs under execution in the design department of HMC, Taxila.

The way in which every point of this programme was realized is described below.

1) <u>**THE DRAWING UP OF THE MANUAL "DESIGN CRITERIA AND SELECTION OF HEAT EXCHANGERS**</u> (55 pages in typed form).
The manual was prepared in October, 1988 and handed over to HMC design department on 31.10.1988. It contains detailed technical data for the heat exchangers, namely:

a) the classification of the heat exchangers according to different criteria, which includes: utilization, construction, action, surface for heat transfer, fluids flow, etc.;

b) the processes which can occur in a heat exchanger: fluid cooling/heating without phase change, condensation, boiling, evaporation;

c) the stages of the designing and the analysis of the selected heat exchangers, which are suitable from the thermodynamic and mechanical point of view, in order to establish the optimum variant;

d) the analysis of the main parameters involved in the thermodynamic calculation of the heat exchangers: the mean temperature difference, the overall heat transfer coefficient, the pressure drops;

e) the analysis of the geometrical characteristics of the heat exchangers: tubes, shells, baffles, nozzles. At this point as well as at the point (d) the recommended ranges and the constructive restrictions in TEMA and ASME standards were mentioned;

f) the placing of the fluids involved in the heat transfer, based on their characteristics and the economicity of the heat exchanger construction;

g) the thermal insulation required to minimize the heat losses;

h) the analysis of the main thermal agents used in these heat exchangers;

i) the comparision of different types of heat exchangers of tube bundle in a shell, involved in TEMA standards (advantages and disadvantages).

Because the most used heat exchangers in the chemical, petrochemical, etc. plants and processes are of tube bundle in a shell type, the technical data from the points (a) - (e) above refer mainly to them.

The manual contains also two sections relating to:

- heat exchangers with finned tubes (low, high, transversal and longitudinal fins);
- other types of heat exchangers (with plates, with coils, with sprinkle, scrubbers).

All technical data in this manual are useful in the selection of different geometries of the heat transfer surface, to be used subsequently in the thermodynamic calculations, using the methodologies of calculation.

2) **THE METHODOLOGIES OF CALCULATION** (107 pages in handwritten form).

For the practical design of the heat exchangers of tube bundle in a shell type, eleven methodologies of calculation were prepared, taking into account the most common combinations of the thermal processes. They are:

I)	shellside:	fluid heating/cooling without phase change (forced convection)
	tube side:	fluid cooling/heating without phase change (forced convection)
II)	shellside:	cooling of vapors, isothermal condensation, subcooling of condensate (forced convection)
	tube side:	fluid heating without phase change (forced convection)
III)	tube side:	vapors cooling, isothermal condensation, condensate subcooling (forced convection)
	shellside:	fluid heating without phase change (forced convection)
IV)	tube side:	liquid heating, isothermal boiling, vapors superheating (forced convection)
	shellside:	isothermal condensation (forced or natural convection)
V)	tube side:	liquid heating, isothermal boiling, vapors superheating (forced convection)
	shellside:	fluid cooling, without phase change (forced convection)

VI) shellside: liquid heating, isothermal boiling, vapors superheating (forced convection)
tube side: isothermal condensation (forced or natural convection)

VII) shellside: liquid heating, isothermal boiling, vapors superheating (forced convection)
tube side: fluid cooling without phase change (forced convection)

VIII) shellside: liquid heating, isothermal boiling (kettle boilers)
tube side: isothermal condensation (forced or natural convection)

IX) shellside: liquid heating, isothermal boiling (kettle boilers)
tube side: fluid cooling without phase change (forced convection)

X) tube side: evaporation in thin film of liquid (natural convection)
shellside: isothermal condensation (forced or natural convection)

XI) tube side: evaporation in thin film of liquid (natural convection)
shellside: fluid cooling without phase change (forced convection)

In all these methodologies are presented in detail:

a) the stages of the thermodynamic calculation;

b) the specific formula for every type of fluid, flow regime, set of geometrical characteristics, arrangement of fluxes, etc. The number of the formula for each methodology mentioned above is between 55 and 104;

c) the possible and recommended modification of the selected geometrical characteristics if the heat transfer surface is not sufficient for the required duty and/or the calculated pressure drops exceed the maximum allowable ones.

For each methodology of calculation was drawn up a data sheet mentioning the necessary data (numerical and qualitative) their symbols and measure units, as well as the indication for the filling of the data sheet.

3) **THE ILLUSTRATIVE EXAMPLES OF CALCULATION**

(75 pages in handwritten form)

For a better understanding of the methodologies of calculation, of the use of the set of formula and analyses in each one were prepared illustrative examples of calculation. Every methodology is accompanied by an example of calculation properly selected to meet the restrictions and recommendations in the manual "Design criteria and selection of heat exchangers".

The data for every example are mentioned in a copy of the data sheet and in the proper calculation are:

a) mentioned the stages and the specific formula for that particular example, selected from the entire set of formula of the methodology;

b) described the stages of geometrical characteristics establishment (several different sets);

c) pointed out the zones of the trial-and-error calculations, giving the results of the initial and final iteration;

d) done again the calculations, if at least one of the restrictions imposed by the technological plants or process requirements is not met;

e) mentioned the requirements of the mechanical calculation (which is the second major step of the designing of heat exchangers).

The methodologies of calculation, accompanied by the data sheet and the example of calculation were handed over, one by one, along the period November, 1988 - March, 1989.

4. **THE TRAINING OF H.M.C. TAXILA DESIGNERS.**

HMC, Taxila has appointed the following engineers, for the training, based on the works from the points 1 - 3 above:

- Mr. M.A. Fidai
- Mr. Imdad Hussain Shah
- Mr. Javed Khattak
- Mr. Naseer Ahmad Salmaan
- Mr. Nadeem Mehdi
- Mr. Shafiq Ahmad Viqar

To be mentioned that the last one engineer couldn't participate at the whole programme for the training because he was transferred to another city.

The proper training of the above mentioned engineers took place in group (more often) or individually (from case to case), in the form of periodically lectures and daily discussions. In these meetings every section of the manual "Design criteria and selection of heat exchanger" as well as the methodologies and examples of calculation were analysed. The technical details of these works were clarified and amplified. The examples of calculation were performed step-by-step. For some of the eleven methodologies of calculation, supplementary examples of calculation were performed and analysed.

I also gave to the above mentioned engineers:

a) indications for the analysis of the correctness of the data received from the beneficiary of calculation;

b) the usual ranges of the properties of the fluids;

c) solutions to interpolate and extrapolate the properties of the fluids together with a list of references for these data;

d) examples for some possible cases at the points (a) - (e) above, etc.

I consider that the engineers who participated at the training programme, have assimilated the technical data included in the works from the points 1 - 3 above and will be able to use them in the future design activity.

5. THE DEVELOPMENT OF COMPUTER PROGRAMMES.

In order to facilitate the heat exchanger design, the implementation of the methodologies of calculation from the point 2 above was also started.

It were prepared the flowcharts and programmes for the computer, for the first and second methodology of calculation, following that the rest to be implemented further.

It were established the results of the calculation to be printed as well as the comments accompanying these results, if one (or more) of the restrictions is not met. Evidently, based on these comments, the selected constructive solutions will be modified and the calculations performed again till the taking part in the imposed conditions. The programmes for the computer are especially useful in this respect as well as in the avoiding of the mistakes in the selecting of the proper formula for each particular case and in the calculation using pocket calculators.

The initial forms of the two programmes for the computer were continuously improved till my mission end.

The results of the illustrative examples for the methodologies No. I and II, obtained using the computer programmes are presented in the appendix 1.

6. THE HELP IN THE EXISTING JOBS.

In the period of mission, HMC, Taxila design department had to calculate several heat exchangers for National Fibre Limited, Pakistan State Oil, Dawood Hercules Chemicals Limited, etc. (economizers, condensers, heaters, etc.).

In these jobs I have helped the designers in the establishing of the geometrical characteristics, the calculation and analysis of those heat exchangers as well as in the formulation of the observations to be handed over to the beneficiaries, in the cases when the received data and restrictions were not suitable or incomplete. For the calculation of the heat exchangers for Dawood Hercules Chemicals Limited were used the two computer programmes mentioned at the point 5.

HMC, Taxila prepared a report concerning the development of chemical, petrochemical, power, fertilizers, etc. plants, for the next five years. It were estimated the possible number of such plants to be built, the necessary equipment, the weights and costs, etc. In this case I participated in the establishing of the necessary number of heat exchangers and of the equipment to produce these heat exchangers (some of them being necessary to be imported).

Also I have helped in the calculation of the necessary quantity of air for cooling a mixture of hot flue gases (by mixing).

I consider that the works prepared by me and analysed and clarified in the period of these 6 months are good basis for the future design activity of HMC, Taxila. It follows that these basis should be further developed both by the studying of the reference list which I prepared (21 titles of books and 101 titles of articles from the specialized magazines, selected from a larger set of works in this field) and by eventual future meetings.

APPENDIX NO. 1

I) INPUT DATA

```
H, S, 1.000E+05, 4, 1.500E+01, 2.500E+01, 9.990E-01, 5.060E-01, 5.210E-01
1.155E-03, 9.025E-04, 9.990E+02, 9.960E+02, 5.000E-01, 1, 5.000E+01
3.000E+01, 5.380E-01, 1.000E-01, 1.100E-01, 3.740E-04, 7.740E-04, 7.940E+02
8.720E+02, 5.000E-01, 2.100E-02, 2.500E-02, 3.000E-01, 3.000E-01
R, 3.700E+01, 4.000E-04, 2, T, L, L, 1, 0
4.0,   362, 3.20E-02,  14, 2.40E-01, 1.75E-01, 7.000E-01
```

Identification Number is TEST1
Heat Exchanger is HORIZONTAL

Total Heat Transfered	1076000.000	KCal/Hr.
Overall Heat Transfer Coefficient	534.324	KCal/Hr.m2 C
Heat Transfer Surface	113.726	m2
L.M.T.D.	17.707	C
Tube Wall Temperature	24.306	C
Total Fouling Resistance	0.00040	m2 Hr. C/KCal

SHELLSIDE PARAMETERS

Inlet Temperature	50.000	C
Exit Temperature	30.000	C
Flow Rate	100000.000	Kg/Hr.
Reynolds No.	33392.887	
Velocity	0.810	m/s
Pressure Drop	0.472	at

TUBESIDE PARAMETERS

Inlet Temperature	15.000	C
Exit Temperature	25.000	C
Flow rate	107707.708	Kg/Hr.
Reynolds No.	19784.857	
Velocity	0.957	m/s
Pressure Drop	0.179	at

HEAT EXCHANGER GEOMETRY -All data are in meters-

Tube length	4.0	No. of tubes	362
Tube pitch	0.032	Tube inner dia.	0.021
Tube outer dia.	0.025	Shell inner dia.	0.70
Shellside No. of pass(es)	1	Tubeside No. of pass(es)	4
Nozzle inner dia.	0.300	Nozzle exit dia.	0.300
No. of baffles	14	Baffle spacing	0.240
Bafffle cut	0.175	X	2.90

C O M M E N T S

11) INPUT DATA

```
H, V, 1.900E+03  1, 7.000E+01, 5.700E+01, 4.000E+01, 4.525E-01, 1.800E-02
1.700E-02, 1.610E-05, 1.520E-05, 1.500E+00, 1.400E+00, 5.380E-01, 9.300E-02
1.050E-01, 2.340E-04, 5.740E-04, 7.670E+02, 8.330E+02, 4.710E+02, 1.000E+00
5.000E-02, 4, 2.800E+01, 3.800E+01, 9.981E-01, 5.244E-01, 5.566E-01
8.320E-04, 6.780E-04, 9.960E+02, 9.930E+02, 3.000E-01, 2.100E-02, 2.500E-02
1.500E-01, 5.000E-02, R, 3.700E+01, 3.000E-04, 2, 1, L, 1
4.0,   252, 3.20E-02,   8, 5.05E-01, 3.00E-02, 6.000E-01
```

Identification Number is TEST2
Heat Exchanger is HORIZONTAL

Total Heat Transfered	923454.150	KCal/Hr.
Overall Heat Transfer Coefficient	667.605	KCal/Hr.m2 C
Heat Transfer Surface	79.168	m2
L.M.T.D.	17.472	C
Tube Wall Temperature	34.850	C
Total Fouling Resistance	0.00030	m2 Hr. C/KCal

SHELLSIDE PARAMETERS

Inlet Temperature	70.000	C
Exit Temperature	40.000	C
Vapour Flow Rate	1900.000	Kg/Hr.
Condensate Flow Rate	1900.000	Kg/Hr.
Reynolds No. for Vapours	11637.187	
Reynolds No. for Condensate	547.339	
Velocity of Vapour	5.026	m/s
Velocity of Condensate	0.009	m/s
Pressure Drop	0.003	at

TUBESIDE PARAMETERS

Inlet Temperature	28.000	C
Exit Temperature	38.000	C
Flow rate	92521.205	Kg/Hr.
Reynolds No.	33104.173	
Velocity of Fluid	1.184	m/s
Pressure Drop	0.258	at

HEAT EXCHANGER GEOMETRY -All data are in meters-

Tube length	4.0	No. of tubes	252
Tube pitch	0.032	Tube inner dia.	0.021
Tube outer dia.	0.025	Shell inner dia.	0.60
Shellside No. of pass(es)	1	Tubeside No. of pass(es)	4
Nozzle inner dia.	0.150	Nozzle exit dia.	0.050
No. of baffles	8	Baffle spacing	0.505
Bafffle cut	0.030	X	4.31

C O M M E N T S