

ENGINEERING STANDARD

FOR

PROCESS DESIGN OF

DOUBLE PIPE HEAT EXCHANGERS

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0. INTRODUCTION

"Process Design of Non-Combustion Type Heat Exchanging Equipment", are broad and contain variable subjects of paramount importance. Therefore, a group of process engineering standard specifications are prepared to cover the subject.

This group includes the following Standards:

<u>STANDARD CODE</u>	<u>STANDARD TITLE</u>
IPS-E-PR-771	"Process Requirements of Heat Exchanging Equipment"
IPS-E-PR-775	"Process Design of Double Pipe Heat Exchangers"
IPS-E-PR-785	"Process Design of Air Cooled Heat Exchangers (Air Coolers)"
IPS-E-PR-790	"Process Design of Cooling Towers".

This Standard Specification covers:

"PROCESS DESIGN OF DOUBLE PIPE HEAT EXCHANGERS"

Double pipe heat exchanger is one of the many non-combustion types which finds the most application fields in OGP industries.

1. SCOPE

This Standard Specification covers the minimum process design requirements, field of application, selection of types, design consideration and thermal process design for double pipe heat exchangers.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor/ Consultant.

ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)

ASME CODE.

TEMA (TUBULAR EXCHANGERS MANUFACTURERS ASSOCIATION)

3. SYMBOLS & ABBREVIATIONS

A	= Total Exchanger area, (m ²)
ASME	= American Society of Mechanical Engineers
BWG	= Birmingham Wire Gage
DN	= Diameter Nominal, (mm)
K	= Temperature in Kelvin, (K)
OGP	= Oil, Gas and Petrochemical
TEMA	= Tubular Exchangers Manufacturers Association
U	= Overall duty heat transfer coefficient, W/m ² . °C (W/m ² .K).

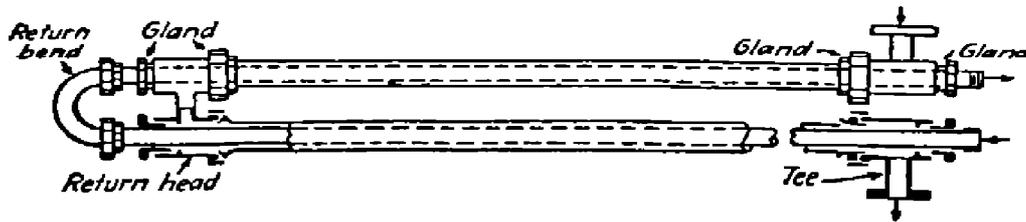
4. UNITS

This Standard is based on International System of Units (SI), except where otherwise is specified.

5. GENERAL

5.1 Double pipe heat exchangers are normally designed in a hairpin shape and are fabricated in accordance with ASME Code.

The principal parts are two sets of concentric pipes, two connecting tees, and a return head and a return bend as shown in Fig. 1



TYPICAL DOUBLE PIPE EXCHANGER

Fig. 1

Double pipe exchangers are divided into two major types:

Single-tube and Multi-tube. The Single-tube type consists of a single tube or pipe, either finned or bare, inside a shell. The Multi-tube type consists of several tubes, either finned or bare, inside a shell (see Fig. 2).

5.2 Double-pipe sections permit true counter-current or true co-current flow, which may be of particular advantage when very close temperature approaches or very long temperature ranges are required.

5.3 Double-pipe units are well suited for high pressure applications because of their relatively small diameters. This allows the use of small flanges and thin wall sections, as compared to conventional shell and tube equipment. Double-pipe sections have been designed for up to 165 bar (ga) (2,400 psig) on the shell side and up to 1033 bar (ga) (15,000 psig) on the tube side, Metal-to metal ground joints, ring joints or confined Orings are used in the front end closures at lower pressures.

5.4 Commercially available single tube double-pipe sections range from 50.8 through 101.6 mm (2 through 4-inch) pipe size shells with inner tubes varying from 19 to 63.5 mm ($\frac{3}{4}$ to $2\frac{1}{2}$ inch) pipe size. These can be justified economically if the equivalent shell and surface required is less than 27.8 m^2 (300 ft^2).

5.5 In some cases where the thermal resistances of the two fluid film are essentially the same, it will be found for small heat loads that the installation of double pipe finned tube units are more economical than shell and tube units.

5.6 The use of fin tubes in double pipe sections are normally economical if the annular heat transfer coefficient is less than 75% of the tube side coefficient.

The fin efficiency increases with decreasing annular coefficient and increasing fin thermal conductivity. In addition, shorter fins have higher fin efficiencies.

5.7 Commercially available single tube double-pipe section range from 50.8 through 101.6 mm (2 through 4 inch) pipe size shells with inner tubes varying from 19 mm 63.5 mm ($\frac{3}{4}$ to $2\frac{1}{2}$ inch) pipe size. The inner pipe which may be bare or longitudinally finned.

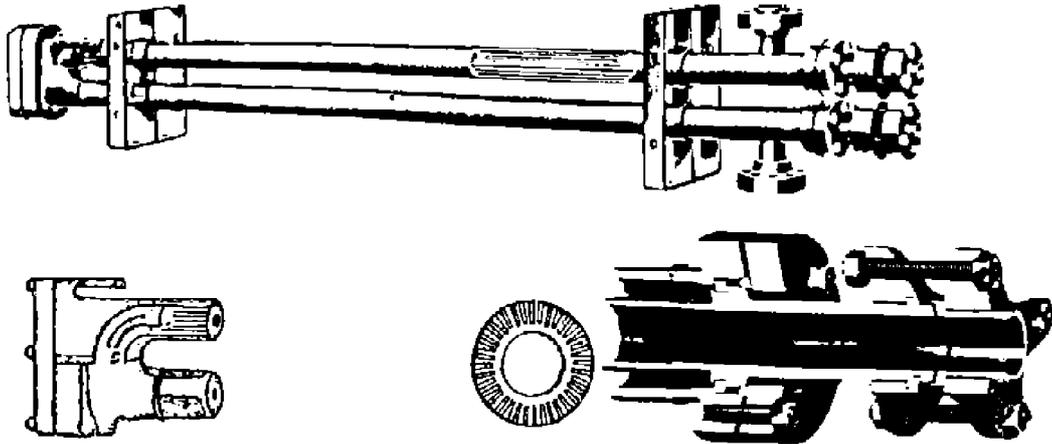
The fins 16 to 48 per tube are 12.7 to 25.4 mm ($\frac{1}{2}$ to 1 inch) high 0.9 to 1.3 mm (35 to 50 mils) thick.

5.8 Multiple tube double pipe sections contain from 7 to 64 tubes, bare or longitudinally finned, within the outer pipe shell. Normally, only bare tubes are used in sections containing more than 19 tubes. Section shells normally range from 101.6-406.4 mm (4 through 16 inch) pipe sizes. The inner tubes are available with outside diameters of 15.9-25.4 mm ($\frac{5}{8}$ inch to 1 inch). The fins, 12 to 20 per tube, are nominally 6.3 mm ($\frac{1}{4}$ inch) high and 0.9 mm (35 mils) thick.

5.9 Sections containing 7 tubes are the most common. However, the economics of these sections are difficult to define due to the high surface area per section. One or two sections are normally more economical than the equivalent surface area in single tube sections. But, if the particular service requires fractional portions or short tube lengths of a multitube section, single tube sections are more economical.

5.10 Section containing more than 7 tubes per section are rarely used since they have limited, if any, economic advantage for most services.

SINGLE TUBE DOUBLE PIPE SECTION

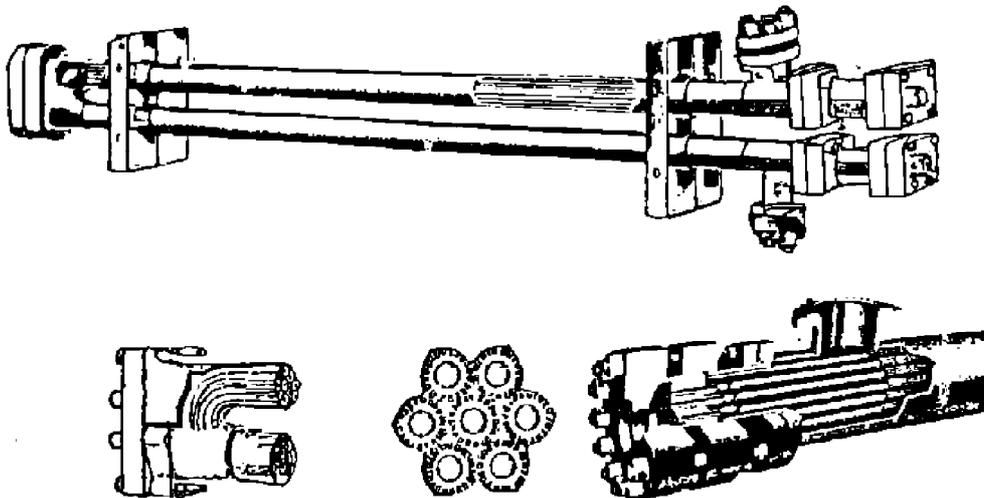


DETAIL A
Return bend housing and cover plate.

DETAIL B
Cross-section view of fin-tube inside shell.

DETAIL C
Shell-to-tube closure and tubeside joint.

MULTIPLE TUBE DOUBLE PIPE SECTION



DETAIL D
Return bend housing and cover plate.

DETAIL E
Cross-section of fin-tubes inside shell, with baffles.

DETAIL F
Shell-to-tube closure and tubeside joint.

TYPICAL DOUBLE PIPE COMPONENTS
SINGLE TUBE DOUBLE PIPE SECTION & MULTIPLE TUBE DOUBLE PIPE SECTION

Fig. 2

6. ADVANTAGES & DISADVANTAGES

6.1 Advantages

- 6.1.1 The use of longitudinal finned tubes will result in a compact heat exchanger for shell side fluids having a low heat transfer coefficient.
- 6.1.2 Counter current flow will result in lower surface area requirements for services having a temperature cross.
- 6.1.3 Potential need for expansion joint is eliminated due to U-tube construction.
- 6.1.4 Shortened delivery times can result from the use of stock components that can be assembled into standard sections.
- 6.1.5 Modular design allows for the addition of sections at a later time or the rearrangement of sections for new services.
- 6.1.6 Simple construction leads to ease of cleaning inspection and tube element replacement.

6.2 Disadvantages

- 6.2.1 Hairpin sections are specially designed units which are normally not built to any industry standard other than ASME Code. However, TEMA tolerances are normally incorporated wherever applicable.
- 6.2.2 Multiple hairpin sections are not always economically competitive with a single shell and tube heat exchanger.
- 6.2.3 Proprietary closure design requires special gaskets.

7. DESIGN CONSIDERATIONS

- 7.1 The heat transfer area and heat transfer coefficients shall be based on the total effective outside tube and fin surface. The effective tube wall and fin metal resistance shall be considered in calculating the heat transfer coefficient.
- 7.2 The more viscous fluid is usually passed through the annulus. Cooling water is normally passed through the tube side.
- 7.3 Fouling factors for circulating cooling water may be taken $0.35 \text{ m}^2 \cdot ^\circ\text{C}/\text{kW}$ or $0.00035 \text{ m}^2 \cdot ^\circ\text{C}/\text{W}$ ($0.002 \text{ ft}^2 \cdot \text{h} \cdot ^\circ\text{F}/\text{Btu}$) when the water velocity is maintained at 1 meter per second or greater. No water velocity less than 1 meter per second shall be allowed without approval of the Company. Other fouling factors shall be as shown on the individual specification sheet.
- 7.4 Tube elements shall be removable without cutting the shell or connecting piping and without disconnecting the shell piping.
- 7.5 One end of the tube element shall be free-floating for thermal expansion.
- 7.6 No internal screwed connections shall be allowed.
- 7.7 Fins shall be longitudinal and may be attached to the outside of the inner tube or pipe either by welding or by mechanical bonding. Minimum thickness of the fins shall be 0.8 mm.

7.8 Over-all length shall be approximately 10 meters. Minimum outside tube diameter of the tube element shall be 25.4 mm (1 inch) and minimum thickness shall be equivalent to 12 BWG tubing or Schedule 40 pipe.

7.9 Minimum corrosion allowance on pressurized steel pressure parts shall be 3 mm except for tubes.

7.10 All pipe and tubing used in construction of the exchangers shall be seamless.

7.11 Heat exchangers shall be designed to conform to specified shell side or tube side design pressure. Designs based on differential pressure of shell side and tube side will not be permitted.

7.12 Minimum design temperature shall be 10% above maximum operating temperature, or maximum operating temperature plus 28°C whichever is greater.

7.13 Minimum design pressure shall be 10% above the maximum operating pressure or maximum operating pressure plus 2 bar (200 kPa), whichever is greater.

7.14 Double pipe sections can be combined in a variety of series/ parallel arrangements to provide the required surface area while maintaining pressure drop limitations. Sections installed in series are normally mounted one on top of the other. Sections connected in parallel are normally side by side series/parallel arrangements which are obtained using a combination of side by side and one over the other mountings.

7.15 The following restrictions shall apply to double-pipe heat exchangers:

-Finned tubes should not be used where fouling is expected on the shell side; finned tubes shall not be used where the fins are likely to be exposed to a corrosive medium; a hairpin exchanger is not permitted if fouling is expected on the tube side.

7.16 The suitability of using hairpin exchanger in a given application may be evaluated by computing the product of heat transfer coefficient and area (U.A).

For preliminary evaluation a U.A of 80 kW/K may be considered to be the upper economical limit for applying hairpin type units.

Above this value the unit may be uneconomical for a hairpin type design. If a hairpin is applied, it may require multiple DN 400 (16") multitube sections.

In the range of 53 to 80 kW/K one or more DN 300 (12") to DN 400 (16") multitube sections will normally be required.

In the range of 26 to 53 kW/K one or more DN 100 (4") to DN 300 (12") multitube sections will normally be required. Below 26 kW/K both double pipe and multitube sections should be evaluated. Table 1 lists typical sizes for hairpin type exchangers.

TABLE 1 - TYPICAL HAIRPIN TYPE EXCHANGER SIZES

	DOUBLE PIPE	MULTITUBE
SHELL DIA DN in mm, (inch)	50-150 (2-6")	80-400 (3"-16")
TUBE DIA, DN in mm, (inch)	20-100 (¾"-4")	20-25 (¾"-1")
No. OF LONGITUDINAL FINS	0-72	0-24
FIN HEIGHT, mm, (inch)	0-19 (0-¾")	0-12.7 (0-½")
SURFACE m ² /6m (ft ² /20 ft)	3-12.2 (10-40 ft)	23-60 (75-1500)

7.17 The specification sheet for double pipe heat exchangers shall be as per Appendix A.

APPENDICES

APPENDIX A
NIOC/NIGC/NPC
SPECIFICATION SHEET DOUBLE PIPE HEAT EXCHANGER

REV	DATE
Δ	-----

MINISTRY OF PETROLEUM
NATIONAL IRANIAN OIL COMPANY
NATIONAL IRANIAN GAS COMPANY
NATIONAL PETROCHEMICAL COMPANY

N.I.O.C N.I.G.C N.P.C

SPECIFICATION SHEET
DOUBLE PIPE HEAT EXCHANGER

N.I.O.C / -----
N.I.G.C / -----
N.P.C REF -----
JOB No. -----
ITEM No. -----
SHELT -----OF-----
DATE -----BY-----
ENQUIRY No. -----
P.O. No. -----

FOR _____	b MULTI-TUBE		b SINGLE TUBE		b FINNED TUBE	
VENDOR _____						
DUTY kg/s	SHELL SIDE				TUBE SIDE	
FLUID						
TOTAL FLOW kg/s						
	INLET		OUTLET		INLET	
LIQUID. kg/s						
RELATIVE DENSITY (SP-GR)	•	°C	•	°C	•	°C
THERMAL COND W/m.°C	•	°C	•	°C	•	°C
SPECIFIC HEAT kJ/kg.°C	•	°C	•	°C	•	°C
VISCOSITY Pa.s	•	°C	•	°C	•	°C
VAPOR kg/s						
MOLECULAR MASS (WEIGHT)						
THERMAL COND. W/m °C	•	°C	•	°C	•	°C
SPECIFIC HEAT KJ/kg °C	•	°C	•	°C	•	°C
VISCOSITY Pa.s	•	°C	•	°C	•	°C
ADDITIONAL DATA ON SHEET NO						
OPERATING TEMPERATURES °C						
PRESSURES bar(ga)						
VELOCITIES m/s						
PRESSURE DROP (NOTE A) ORE	ALLOW		CALC		ALLOW	CALC
DESIGN TEMPERATURE °C						
PRESSURE bar(ga)	MIN.	ACTUAL	TEST		MIN.	ACTUAL
MIN. CORROSION ALLOWANCE mm	MIN.		CALC		MIN.	CALC
FOUL RESIST m ² h °C/kg	SHELL FOUL. () + TUB FOUL. () ×		TOT. OUT SURF. () = TOT. FOUL. ()			
			TOT. IN SURF. ()			

(to be continued)

APPENDIX A (to be continued)

No. OF SECTIONS _____ AREA PER SECT. (NOTE B) _____ TOT. AREA (NOTE B) _____ LMTD _____ CORRECTED MTD _____ TRANSFER COEF. CLEAN _____ KW/m °C SERVICE _____ CODE REQUIREMENTS _____ CODE STAMP _____ REMOVABLE TUBES _____ MATERIALS (MARK STRESS RELIEVED, S.R., RADIOGRAPHED, X.R.) _____	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="height: 15px;"></td></tr> <tr><td style="text-align: right;">.m²</td></tr> <tr><td style="text-align: right;">.m²</td></tr> <tr><td style="height: 15px;"></td></tr> <tr><td style="text-align: center;">ASME (YES) (NO)</td></tr> <tr><td style="text-align: center;">(YES) (NO)</td></tr> <tr><td style="text-align: center;">(YES) (NO)</td></tr> </table>		.m ²	.m ²		ASME (YES) (NO)	(YES) (NO)	(YES) (NO)	SHELL DIA. × LENGTH _____ SCHEDULE _____ No. TUBES PER SHELL _____ TUBE DIA.×. LENGTH _____ SCHED. OR GAUGE. BWG _____ FINN PER TUBE _____ FIN MT.×. THICKNESS _____ FIN CUTS PER SECT _____ MASS PER SECT _____ MASS PER ELEMENT _____	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="text-align: center;">mm.NOM.x</td><td style="text-align: center;">m.</td></tr> <tr><td style="height: 15px;"></td><td></td></tr> <tr><td style="text-align: center;">INX</td><td style="text-align: center;">m.</td></tr> <tr><td style="height: 15px;"></td><td></td></tr> <tr><td style="text-align: center;">mm×</td><td style="text-align: center;">mm.</td></tr> <tr><td style="height: 15px;"></td><td></td></tr> <tr><td style="text-align: center;">kg</td></tr> <tr><td style="height: 15px;"></td><td></td></tr> <tr><td style="text-align: center;">kg</td></tr> </table>	mm.NOM.x	m.			INX	m.			mm×	mm.			kg			kg	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="text-align: center;">NOZZLES (ANSI)</td><td colspan="2" style="text-align: center;">TUBE SIDE</td></tr> <tr><td style="text-align: center;">INLET _____</td><td style="text-align: center;">SIZE</td><td style="text-align: center;">RATING</td></tr> <tr><td style="text-align: center;">OUTLET _____</td><td style="text-align: center;"> </td><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td><td colspan="2" style="text-align: center;">SHELL SIDE</td></tr> <tr><td style="text-align: center;">INLET _____</td><td style="text-align: center;">SIZE</td><td style="text-align: center;">RATING</td></tr> <tr><td style="text-align: center;">OULET _____</td><td style="text-align: center;"> </td><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td><td colspan="2" style="text-align: center;"> </td></tr> <tr><td style="text-align: center;">TOTAL MASS THIS ITEM _____</td><td colspan="2"></td></tr> <tr><td style="text-align: center;">BMPTY _____</td><td colspan="2" style="text-align: right;">kg</td></tr> <tr><td style="text-align: center;">FLOODED _____</td><td colspan="2" style="text-align: right;">kg</td></tr> </table>	NOZZLES (ANSI)	TUBE SIDE		INLET _____	SIZE	RATING	OUTLET _____				SHELL SIDE		INLET _____	SIZE	RATING	OULET _____						TOTAL MASS THIS ITEM _____			BMPTY _____	kg		FLOODED _____	kg	
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SKETCH SHOWING ARRANGEMENT OF SECTIONS

TUBES _____		
FINS _____		
SHELL _____		
SHELL COVER _____		
TUBE CONNECTORS _____		
SHELL CONNECTORS _____		
GASKETS _____	NOTE A: FOR CONDENSERS AND THERMOSYPHON REBOILERS PRESSURE DROP STATED SHALL INCLUDE STATIC HEAD BETWEEN CENTERLINES OF INLET AND OUTLET FLANGES.	
SHELL NOZZ FLGS _____	NOTE B: OUTSIDE TUBE AND FIN AREA	
HO ONE UP SHELL SICE _____	PARALLEL BANKS OF _____	SECTIONS IN SERIES _____
TUBE SICE _____	PARALLEL BANKS OF _____	SECTIONS IN SERIES _____
STACKING ARRANGEMENT _____	WIDE _____	HIGH _____
REMARKS: _____		