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TECHNICAL SPECIFICATION

FOULING RESISTANCES FOR HEAT TRANSFER EQUIPMENT

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DESIGN AND ENGINEERING PRACTICE

PREFACE

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for establishing fouling resistance values for new unfired heat transfer equipment. It may also be used as a common basis for comparison of measured fouling rates.

The fouling-resistance values given are based on average process conditions but shall be interpreted with judgement.

This DEP is a revision of the DEP of the same number dated April 1981; *a summary of the main changes is given in (1.5).*

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F" as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements are more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Fouling resistance — a measure of the ultimate additional resistance to heat transfer caused by deposits on and corrosion of the heat transfer material surface. The fouling resistance depends on the type of fluid, the heat-transfer surface material, the temperature conditions, the flow velocities and the operating period between two successive cleaning actions.

Fouling coefficient — the reciprocal of the fouling resistance.

NOTE: The use of the fouling coefficient has generally been abandoned, since it tends to be confusing that an increase in fouling results in a decrease in the fouling coefficient.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (5).

1.5 SUMMARY OF MAIN CHANGES

A summary of the main, non-editorial, changes since the last revision of this DEP are as follows:

Section	Description
2.3	Explains the types of heat exchangers for which the listed fouling resistances apply
3.	Recommended cooling water velocity now varies depending on tube material
5.	Values of fouling coefficient have been removed (explained in the definition in 1.3.2)
	Table 4 - amended for cracked residues
	Table 20 - more fluids included
	Table 21 - new table for LNG plants
Appendix 1	Frictional pressure drops included for cooling water

2. APPLICABILITY AND BASIS OF THE DATA

2.1 APPLICABILITY OF DATA

Fouling resistance values apply for shell and tube heat exchangers for both shell-side and tube-side fluids as well as for fluids flowing on tube side of air-cooled heat exchangers.

Other types of heat exchangers, non tubular, are not normally designed with these fouling resistance values.

2.2 BASIS OF DATA

The values given in (4) are the result of experience and common practice. Tables 1 to 21 are grouped by type of processing unit, since it is impossible to make a proper evaluation of all variables which affect fouling. Table 22 gives values for water and steam.

The values given are based on the assumption that flow velocities, temperature and fluid conditions are comparable in similar units.

The listed values generally do not take into account:

a) the effect of shell-side or tube-side flow;
b) the effect of flow velocities;
c) temperature limitations.

a) For products containing sediments, cracked products and other unstable materials containing for example polymers, tube-side flow is preferred. Fouling is more pronounced on the shell side of heat exchangers than on the tube-side flow because of dead corners and the effect of bundle bypassing. Therefore for these products the values given are for tube-side flows only, if not otherwise stated.

b) *Flow velocities of fluids should be chosen as high as compatible with process requirements and acceptable power consumption, having regard to the effect of erosion and corrosion caused by this velocity. This may be aggravated by the presence of sediments. For tube-side flow the velocity should be not less than 1.0 m/s; for shell-side flow the effective velocity (taking due account of bypass streams) should be not less than 0.5 m/s.
Shell-side velocities can often be improved by the installation of more shells in series.

For cooling water the preferred tube-side flow velocity depends on the tube material as shown in Appendix 1. The minimum allowed velocities are also given in Appendix 1.

c) *For cooling water, either from a cooling tower or a once-through system, the maximum water-side skin temperature in clean condition shall be not higher than 52 °C (in view of increased fouling tendency), unless otherwise specified.

* For those exchangers where definite restrictions are applicable with regard to maximum or minimum skin temperature and minimum or maximum flow velocity, this shall to be specified in the applicable process specification and data/requisition sheets.

3. APPLICATION OF LOWER FOULING RESISTANCES

Lower fouling resistances may be appropriate if one or more of the circumstances described below apply. However, such lower values may be applied only where specifically approved by the Principal.

- In services where the surface requirements are significantly influenced by the degree of fouling, it may be advantageous to specify a lower resistance if a reduced period between two successive shutdowns is feasible. This can be achieved for instance by the installation of a spare exchanger in parallel with the one in operation, thus enabling cleaning at any time without plant shutdown. This is especially important where controllability/stability is influenced by fouling, e.g. in thermo-syphon reboilers.
- The maximum allowable pressure drop generally limits the fluid velocity. This means that for designs where low pressure drops have to be applied the fluid velocities will often become low. When the specified fouling resistance is high, resulting in the installation of considerable over-surface in clean condition, the maximum attainable velocity may reduce appreciably. This, in turn, will increase the tendency of fouling. By taking a lower fouling resistance, a smaller heat exchanger will be adequate, thus making it possible to apply a higher velocity and still stay within the limits of allowable pressure drop.

NOTE: The selection of lower fouling resistances should be done with due regard to the drive to longer periods between shutdowns.

4. FOULING RESISTANCE TABLES

Table	Title
1	Distillation units
2	Luboil plants
3	Hydroprocessing units
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6	Ethylene oxide plant
7	Cumene plant
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18	Wax cracking unit
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21	Liquefied natural gas plant
22	Values for water and steam

Table 1 DISTILLATION UNITS

Fluid	Fouling resistance $m^2.K/W$
Crude distilling unit	
Crude, waxy	0.57×10^{-3}
Crude, non-waxy	0.43×10^{-3}
Atmospheric Column overhead vapours	0.17×10^{-3}
Gasoline and lighter products	0.17×10^{-3}
Kerosine	0.21×10^{-3}
Light gas oil	0.25×10^{-3}
Heavy gas oil	0.25×10^{-3}
Long residue	0.57×10^{-3}
High vacuum unit	
Vacuum column overhead vapours	0.34×10^{-3}
Vacuum gas oil	0.25×10^{-3}
Spindle oil	0.25×10^{-3}
Light machine oil	0.25×10^{-3}
Medium machine oil	0.29×10^{-3}
Cylinder oil	0.34×10^{-3}
Dirty wash oil	0.86×10^{-3}
Short residue	0.86×10^{-3}

Table 2 LUBOIL PLANTS

Fluid	Fouling resistance $m^2.K/W$
Propane deasphalting unit	
Prediluted short residue	0.86×10^{-3}
De-asphalted oil	0.34×10^{-3}
De-asphalted oil/propane mixture	0.29×10^{-3}
Asphalt/propane mixture	0.86×10^{-3}
Asphalt	0.86×10^{-3}
Propane	0.17×10^{-3}
Furfural extraction unit	
Charge oil	0.34×10^{-3}
Furfural	0.34×10^{-3}
Pseudo-raffinate	0.51×10^{-3}
Extract/furfural mixture	0.86×10^{-3}
Wet furfural	0.86×10^{-3}
Extract	0.51×10^{-3}
Raffinate	0.25×10^{-3}
Raffinate/furfural mixture	0.34×10^{-3}
MEK de-waxing unit	
Solvent	0.17×10^{-3}
Propane or ammonia	0.17×10^{-3}
Waxy oil/solvent mixture	0.25×10^{-3}
De-waxed oil/solvent mixture	0.25×10^{-3}
Slack wax/solvent mixture	0.25×10^{-3}
De-waxed oil, above 110°C	0.17×10^{-3}
De-waxed oil, below 110°C	0.34×10^{-3}
Slack wax	0.25×10^{-3}
Common facilities	
Hot oil	0.34×10^{-3}

(MEK = methyl ethyl ketone)

Table 3 HYDRO-PROCESSING UNITS

Fluid	Fouling resistance $m^2.K/W$
Hydrodesulphurizer/Hydrotreater	
Reactor feed	0.25×10^{-3}
Reactor effluent	0.25×10^{-3}
Stripper feed	0.25×10^{-3}
Stripper overhead vapour	0.25×10^{-3}
Drier overhead vapour	0.25×10^{-3}
Platformer	
Reactor charge	0.29×10^{-3}
Reactor effluent	0.29×10^{-3}
Stabilized platformate	0.17×10^{-3}
Stabilizer feed	0.17×10^{-3}
Stabilizer overhead vapour	0.17×10^{-3}
Hydrogen-rich gas	0.17×10^{-3}

Table 4 CONVERSION UNITS

Fluid		Fouling resistance $m^2.K/W$
Thermal cracking unit		
Cracked gas oil		0.43×10^{-3}
Circulating reflux		0.57×10^{-3}
Cracked residues	≤ 320 °C	1.72×10^{-3}
Cracked residues	> 320 °C	
From short residue feed		2.15×10^{-3}
Special bitumen or cracked residues ex DTC		2.86×10^{-3}
Other cracked residue		1.72×10^{-3}
Catalytic cracking unit		
Light cycle oil		0.25×10^{-3}
Heavy cycle oil		0.29×10^{-3}
Slurry oil		0.57×10^{-3}
Gasoline		0.17×10^{-3}
HF alkylation unit		
Feed		0.17×10^{-3}
HF acid		0.17×10^{-3}
HF acid/Feed mixture		0.29×10^{-3}
Alkylate		0.17×10^{-3}
Depropanizer feed		0.17×10^{-3}
Bitumen blowing unit		
Short residue		0.86×10^{-3}
Bitumen		0.86×10^{-3}
Blown distillate		0.57×10^{-3}
Waste gas		0.57×10^{-3}

(DTC = Deep Thermal Conversion)

(HF = hydrofluoric acid)

Table 5 ETHYLENE PLANT

Fluid	Fouling resistance $m^2.K/W$
Feed section	
Gas oil feed	0.26×10^{-3}
Naphtha feed	0.26×10^{-3}
Quench oil	0.53×10^{-3}
Circulating quench media	
Water	0.44×10^{-3}
Light oil	0.35×10^{-3}
Heavy oil	0.18×10^{-3}
Regeneration section	
Regeneration gas (inlet)	0.18×10^{-3}
Regeneration gas (outlet)	0.26×10^{-3}
Cracked gas compressor section	
Compressed cracked gas	0.35×10^{-3}
Fourth stage condensate	0.53×10^{-3}
Primary fractionator	
Distillate stripper bottoms	0.53×10^{-3}
Fuel oil	0.53×10^{-3}
Utilities	
Hot oil	0.53×10^{-3}
Warm distillation section	
Gasoline rerun column bottoms	0.53×10^{-3}
Gasoline rerun column overheads	0.18×10^{-3}
Depropanizer stripper overheads	0.18×10^{-3}
Depropanizer rectifier bottoms	0.35×10^{-3}
Depropanizer rectifier overheads	0.18×10^{-3}
Debutanizer feed	0.26×10^{-3}
Debutanizer bottoms	0.53×10^{-3}
Debutanizer overheads	0.18×10^{-3}
Propane/propylene splitter bottoms	0.26×10^{-3}
Propane/propylene splitter overheads	0.18×10^{-3}

ETHYLENE PLANT (continued)

Fluid	**Fouling resistance $m^2.K/W$**
Refrigeration section	
Propylene (refrigerant)	0.09×10^{-3}
Ethylene (refrigerant)	0.09×10^{-3}
Cold distillation section	
Acetylene (reactor outlet)	0.26×10^{-3}
Demethanizer bottoms	0.26×10^{-3}
Demethanizer overheads	0.18×10^{-3}
Deethanizer bottoms	0.26×10^{-3}
Deethanizer overheads	0.18×10^{-3}
C_2 splitter bottoms	0.26×10^{-3}
C_2 splitter overheads	0.18×10^{-3}
Ethane product	0.26×10^{-3}
Ethylene product	0.18×10^{-3}

Table 6 ETHYLENE OXIDE PLANT

Fluid	Fouling resistance $m^2.K/W$
Reactor fluid	
Feed gas to reactor	0.17×10^{-3}
Reactor product	0.34×10^{-3}
Coolant separator overheads	0.17×10^{-3}
Ethylene oxide recovery section	
CO_2 absorber overheads	0.17×10^{-3}
CO_2 absorber feed gas	0.17×10^{-3}
CO_2 stripper tops	0.17×10^{-3}
Ethylene oxide absorber feed	0.34×10^{-3}
Lean absorbent	0.17×10^{-3}
Ethylene oxide stripper feed	0.17×10^{-3}
Ethylene oxide stripper bottoms	0.26×10^{-3}
Quench bleed stripper bottoms	0.69×10^{-3}
Glycol bleed reboiler	0.52×10^{-3}
Ethylene oxide purification section	
Ethylene oxide stripper tops	0.26×10^{-3}
Light ends column bottoms	0.17×10^{-3}
Ethylene oxide dehydration column bottoms	0.17×10^{-3}
Acetaldehyde column bottoms	0.17×10^{-3}
Ethylene oxide (product)	0.26×10^{-3}
Ethylene oxide purification column tops	0.34×10^{-3}
Residual gas	0.17×10^{-3}
Glycol reaction and recovery section	
Reactor feed	0.17×10^{-3}
Reactor product	0.17×10^{-3}
Concentrator column bottoms	0.17×10^{-3}
Dehydrator column bottoms	0.17×10^{-3}
Dehydrator column tops	0.085×10^{-3}

ETHYLENE OXIDE PLANT (continued)

Fluid	Fouling resistance $m^2.K/W$
Glycol purification section	
Glycol column tops	0.17×10^{-3}
Glycol recycle column bottoms	0.52×10^{-3}
Glycol recycle column tops	0.17×10^{-3}
DEG column bottoms	0.52×10^{-3}
DEG column tops	0.17×10^{-3}
DEG recycle column bottoms	0.52×10^{-3}
DEG recycle column tops	0.17×10^{-3}
TEG column bottoms	0.52×10^{-3}
TEG column tops	0.52×10^{-3}
Glycol bleed recovery section	
Glycol bleed flasher reboiler	0.52×10^{-3}
Glycol bleed dehydration column bottoms	0.17×10^{-3}
Glycol bleed dehydration column tops	0.17×10^{-3}
Standard glycol purification column bottoms	0.52×10^{-3}
Standard glycol purification column tops	0.34×10^{-3}

DEG = diethylene glycol

TEG = triethylene glycol

Table 7 CUMENE PLANT

Fluid	Fouling resistance $m^2.K/W$
Feed (73% benzene + 8.8% C_3 + 3.4% cumene + 5% propylene + 6% cyclohexane)	0.26×10^{-3}
Mixture of recycle benzene and fresh PP (80% benzene + 8% cyclohexane + 8% PP + 4% cumene)	0.26×10^{-3}
Rectifier overheads (61% benzene + 12% iC_4 + 5% cyclohexane)	0.26×10^{-3}
Depropanizer bottoms	0.26×10^{-3}
Depropanizer tops	0.17×10^{-3}
Recycle column bottoms	0.26×10^{-3}
Recycle column tops	0.17×10^{-3}
Cumene column bottoms (reboiler)	0.34×10^{-3}
Cumene column bottoms (cooler)	0.17×10^{-3}
Cumene column tops	0.17×10^{-3}

(PP = propane/propylene)

Table 8 PHENOL PLANT

Fluid	Fouling resistance $m^2.K/W$
Reactor section	
Air (compressor intercooler)	0.17×10^{-3}
Chillers refrigerant (propylene)	0.17×10^{-3}
Cleavage product coolers (30% DMK + 46% phenol + by-products)	0.34×10^{-3}
Concentrator of peroxides up to 55% (evaporators)	0.34×10^{-3}
Concentrator of peroxides above 55% (evaporators)	0.86×10^{-3}
Concentrator (condensers and chillers)	0.17×10^{-3}
Cumene (99%)	0.17×10^{-3}
Dimethyl ketone	0.17×10^{-3}
Off gas	0.34×10^{-3}
Oxidate	0.34×10^{-3}
Phenol distillation unit	
Cleavage product preheaters	0.86×10^{-3}
Crude acetone column bottoms	0.54×10^{-3}
Crude phenol column bottoms	0.86×10^{-3}
Pure phenol column bottoms	0.34×10^{-3}
Pure phenol column tops	0.17×10^{-3}
Cracker feed	0.86×10^{-3}
Dimethyl ketone distillation unit	
DMK mixture (50% DMK + 25% cumene + 21% H_2O)	0.34×10^{-3}
Top product (72% DMK + 13% acetaldehyde)	0.17×10^{-3}
Pure DMK column bottoms (48% cumene + 41% H_2O)	0.34×10^{-3}
Pure DMK column tops (99% DMK)	0.17×10^{-3}
Cumene distillation unit	
Any concentration of cumene and alpha methyl styrene	0.17×10^{-3}

(DMK = dimethyl ketone)

Table 9 DI-PHENYLOL PROPANE PLANT

Fluid	Fouling resistance $m^2.K/W$
Reactor feed (96% phenol + 4% DMK)	0.34×10^{-3}
Reactor product	0.34×10^{-3}
Dehydration column bottoms (96% phenol + 4% DPP + traces of HCl)	0.43×10^{-3}
1st and 2nd stage flasher bottoms	0.86×10^{-3}
1st and 2nd stage phenol flasher tops	0.86×10^{-3}
Brine (10% NaCl + 5% phenol + 85% H_2O)	0.34×10^{-3}
DIPE column bottoms	0.34×10^{-3}
DIPE column tops (85% DIPE + 15% CH_3SH)	0.17×10^{-3}
Pure phenol flash column tops	0.17×10^{-3}
Flashed phenol evaporators	0.22×10^{-3}
Pure DIPE	0.17×10^{-3}
HCl stripper bottoms (22% HCl + 78% H_2O)	0.17×10^{-3}
HCl stripper tops (60% HCl + 40% H_2O)	0.17×10^{-3}

(DMK = dimethyl ketone)

(DPP = diphenylol propane)

(DIPE = di-isopropyl ether)

Table 10 EPIKOTE PLANT

Fluid	Fouling resistance $m^2.K/W$
LIQUID EPIKOTE	
Reactor section	
Reactor overheads	0.86×10^{-3}
Epichlorohydrin	0.25×10^{-3}
Solvent removal section	
Resins solution	0.17×10^{-3}
MIBK condenser	0.86×10^{-3}
MIBK aftercondenser	0.25×10^{-3}
SOLID EPIKOTE	
Washing section	
Clarified solution	0.86×10^{-3}
Evaporator feed (preheater)	0.86×10^{-3}
Evaporator overhead condenser	0.25×10^{-3}
MIBK (preheater)	0.25×10^{-3}
Reactor vent condenser	0.25×10^{-3}
MIBK stripper condenser	0.25×10^{-3}

(MIBK = methyl isobutyl ketone)

Table 11 C_3= SOLVENT PLANT

Fluid	Fouling resistance $m^2.K/W$
Crude/PA unit	
Reactor feed (81% C_3= +12% H_2O + 7% IPA)	0.21×10^{-3}
Reactor product (77% C3 + 10% H_2O + 13% IPA)	0.29×10^{-3}
IPA recovery unit	
Pure IPA	0.17×10^{-3}
Mixture (20% IPA + 10% H_2O + 70% benzene)	0.17×10^{-3}
Mixtures of water and IPA at any %	0.17×10^{-3}
Water (recirculation)	0.17×10^{-3}
DMK conversion unit	
Feed (87.5% IPA + 12.5% H_2O) preheaters	0.17×10^{-3}
Product (47% DMK + 21% IPA + H_2O) coolers	0.17×10^{-3}
DMK recovery unit	
Pure DMK	0.17×10^{-3}

(IPA = isopropyl alcohol)

(DMK = dimethyl ketone)

Table 12 C_4= SOLVENT PLANT

Fluid	Fouling resistance $m^2.K/W$
Crude SBA unit	
Mixture butane/butylene (80% C_{4-0} + 20% C_4=$_{-2}$)	0.25×10^{-3}
Bottom product (38% C_{4-0} + 50% SBE + 12% H_2SO_4)	0.57×10^{-3}
Reactor coolers (66% $C_{4(total)}$ + 34% H_2SO_4)	0.43×10^{-3}
Debutanizer tops (59% C_4= + 41% C_{4-0} + traces of H_2SO_4 and polymers)	0.17×10^{-3}
Debutanizer bottoms (55% SBA + 37% H_2O + 8% SBE)	0.17×10^{-3}
Caustic evaporator (58% H_2O + 42% caustic)	0.17×10^{-3}
H_2SO_4 concentration unit	
Acid coolers (72% H_2SO_4 + 28% H_2O)	0.43×10^{-3}
SBA recovery unit	
Any mixture of SBA and water	0.17×10^{-3}
Mixture (60% SBA + 40% polymers)	0.43×10^{-3}
MEK conversion unit	
Feed (pure SBA)	0.17×10^{-3}
Product (71% MEK + 26% SBA)	0.25×10^{-3}
MEK recovery unit	
Light ends column tops (42% IPE + 55% MEK)	0.17×10^{-3}
Finishing column bottoms (93% SBA + 5% polymers)	0.25×10^{-3}
Finishing column tops (pure MEK)	0.25×10^{-3}

(SBA = secondary butyl alcohol)

(SBE = secondary butyl ether)

(IPE = isopropyl ether)

(MEK = methyl ethyl ketone)

Table 13 BUTADIENE PLANT

Fluid	Fouling resistance $m^2.K/W$
Pure butadiene	0.34×10^{-3}
Butane/butylene	0.34×10^{-3}
Mixture of butane/butylene/ butadiene (condensing)	0.34×10^{-3}
Mixture of butane/butylene/ butadiene (boiling)	0.86×10^{-3}
Mixture of butadiene and solvent (ACN)	0.86×10^{-3}
Mixture of ACN and water	0.68×10^{-3}
Heavy ends (12% butadiene + 30% VAC + 17% $C_4^=$ + 15% $iC_4^=$)	0.34×10^{-3}
Fractionation bottom product	0.86×10^{-3}

(ACN = acetonitrile)

(VAC = vinyl acetylene)

Table 14 SULFOLANE PLANT

Fluid	Fouling resistance $m^2.K/W$
Stripper bottoms	0.17×10^{-3}
Stripper tops	0.17×10^{-3}
Recovery column bottoms	0.17×10^{-3}
Recovery column tops	0.17×10^{-3}
Raffinate	0.17×10^{-3}
Lean solvent (Sulfolane)	0.25×10^{-3}
Fat solvent (Sulfolane + hydrocarbons)	0.25×10^{-3}
Extract (aromatics)	0.17×10^{-3}
Mixture of Sulfolane and water (water evaporator)	0.25×10^{-3}
Sulfolane regenerator reboiler*	2.46×10^{-3}
Water stripper reboiler	0.43×10^{-3}

NOTE*: Steam injection into the regenerator can reduce fouling resistance.

Table 15 AROMATICS PLANT

Fluid	Fouling resistance $m^2.K/W$
Benzene	0.17×10^{-3}
Toluene	0.17×10^{-3}
Xylenes	0.17×10^{-3}
Heavier aromatics	0.17×10^{-3}
Any mixture of benzene/toluene/ xylenes/heavier aromatics	0.29×10^{-3}

Table 16 XYLENES PLANT

Fluid	Fouling resistance $m^2.K/W$
Orthoxylene distillation unit	
Feed (20% EB + 16% PX + 32% MX + 11% OX + C_9)	0.25×10^{-3}
Xylenes splitter bottoms (13% PX + 66% OX + C_9 aromatics)	0.25×10^{-3}
Xylenes splitter tops (20% EB + 24% PX + 53% MX + 1.4% OX)	0.17×10^{-3}
OX recovery column bottoms (6% OX + C_9)	0.25×10^{-3}
OX recovery column tops (97% OX)	0.17×10^{-3}
Crystallization unit	
Paraxylene	0.17×10^{-3}
Any mixture of MX, PX and EB	0.17×10^{-3}
Reboilers of strippers	0.25×10^{-3}
Isomerization unit	
Any mixture of OX, MX, PX and EB	0.17×10^{-3}
Reboilers of strippers	0.25×10^{-3}

(EB = ethyl benzene)

(PX = paraxylene)

(MX = metaxylene)

(OX = orthoxylene)

Table 17 UREA WAX PLANT

Fluid	Fouling resistance $m^2.K/W$
Reactor vapour (98.5% DCM + 1.5% H_2O)	0.17×10^{-3}
Stripper overheads (72% DCM + 28% H_2O)	0.17×10^{-3}
Drier overheads	0.17×10^{-3}
Decomposer vapour	0.17×10^{-3}
Concentrator vapour (90% H_2O + 9% DCM + traces of NH_3 + CO_2 + air)	0.34×10^{-3}
Vent gas (96% DCM + CO_2 + NH_3 + air + H_2O)	0.17×10^{-3}
Decomposer circulation (91% wax + 3% oil + 6% DCM)	0.34×10^{-3}
Paraffin stripper feed (91% wax + 3% oil + 6% DMK)	0.43×10^{-3}
Drier column feed (25% DCM + 75% oil)	0.34×10^{-3}
High pressure column preheaters	0.34×10^{-3}
Low, medium and high pressure columns evaporators	0.34×10^{-3}
Oil stripper feed (10% DCM + 90% oil)	0.34×10^{-3}

(DCM = dichloromethane)

(DMK = dimethyl ketone)

Table 18 WAX CRACKING UNIT

Fluid	Fouling resistance $m^2.K/W$
Wax cracker residue	0.43 x 10^{-3}
Fractionator overhead vapour	0.43 x 10^{-3}
Stabilizer feed	0.25 x 10^{-3}
Stabilizer bottom product	0.25 x 10^{-3}
Stabilizer top product	0.17 x 10^{-3}
C_6/C_8 column bottoms	0.25 x 10^{-3}
C_6/C_8 column tops	0.17 x 10^{-3}
C_8/C_{10} column bottoms	0.25 x 10^{-3}
C_8/C_{10} column tops	0.17 x 10^{-3}
C_{10} column bottoms	0.25 x 10^{-3}
C_{10} column tops	0.17 x 10^{-3}
C_{11}/C_{12} column bottoms	0.25 x 10^{-3}
C_{11}/C_{12} column tops	0.17 x 10^{-3}
C_{13}/C_{14} column bottoms	0.25 x 10^{-3}
C_{13}/C_{14} column tops	0.17 x 10^{-3}
C_{15}/C_{18} bottoms (reboiler)	0.34 x 10^{-3}
C_{15}/C_{18} product (cooler)	0.25 x 10^{-3}
Slops C_6/C_{18}	0.25 x 10^{-3}

Table 19 LUBOIL HYDROCRACKING UNIT

Fluid	Fouling resistance $m^2.K/W$
Shell side	
Charge/effluent heat exchangers and combined effluent air cooler. Feedstock:	
WD-60	0.25×10^{-3}
WD-90	0.21×10^{-3}
WD-95	0.25×10^{-3}
WD-130	0.29×10^{-3}
WD-160	0.29×10^{-3}
DAO	0.34×10^{-3}
Tube side	
Charge/effluent heat exchangers and combined effluent air cooler. Feedstock:	
WD-60	0.21×10^{-3}
WD-90	0.21×10^{-3}
WD-95	0.21×10^{-3}
WD-130	0.25×10^{-3}
WD-160	0.25×10^{-3}
DAO	0.29×10^{-3}
Heat exchanger equipment for fresh gas and/or recycle gas	0.19×10^{-3}
Hot recycle gas air cooler	0.29×10^{-3}

(WD = waxy distillate)

(DAO = de-asphalted oil)

Table 20 TREATING UNITS

Fluid	Fouling resistance $m^2.K/W$
GAS	
SULFINOL process	
Fat sulfinol : tube side	0.26×10^{-3}
Lean sulfinol : shell or tube side	0.26×10^{-3}
Overhead vapours (mainly steam condensation) shell or tube side	0.17×10^{-3}
Reclaimer vapours (steam + sulfinol):	
shell or tube side	0.26×10^{-3}
Solvent in PFHE	0.09×10^{-3}
ADIP/SCOT process	
Fat ADIP : tube side	0.36×10^{-3}
Lean ADIP : shell or tube side	0.36×10^{-3}
Overhead vapour (mainly steam condensation)	0.17×10^{-3}
Process gas cooler (tube side)	0.34×10^{-3}
CLAUS process	
Process gas (WHB, tube side)	0.52×10^{-3}
Process gas (S-cond., tube side)	0.52×10^{-3}
Acid gas feed (preheater, tube side)	0.34×10^{-3}
Sour Water Stripper offgas (preheater, tube side)	0.34×10^{-3}
Liquid sulphur (steam coils)	0.52×10^{-3}
LIQUID	
Sour water stripper	
Sour water	0.34×10^{-3}
Stripped water	0.34×10^{-3}
Desalter	
Stripped sour water	0.34×10^{-3}

(ADIP = aqueous solution of DIPA)

(DIPA = di-isopropanol amine)

Table 21 LIQUIFIED NATURAL GAS PLANT

Fluid	Fouling resistance $m^2.K/W$
Natural Gas Circuit	
Wet Natural Gas	0.17×10^{-3}
Dehydrated Natural Gas	0.09×10^{-3}
Mixed Refrigerant Circuit	
Mixed Refrigerant	0.09×10^{-3}
Propane Circuit	
Propane	0.09×10^{-3}
Fractionation unit	
Hydrocarbon liquids	0.17×10^{-3}
Heat Transfer Fluid	0.17×10^{-3}
Hot water	0.25×10^{-3}
Fuel gas	0.17×10^{-3}
Sulfinol process	
Fat sulfinol : tube side	0.26×10^{-3}
Lean sulfinol : shell or tube side	0.26×10^{-3}
Overhead vapours (mainly steam): shell or tube side	0.17×10^{-3}
Reclaimer vapours (steam + sulfinol): shell or tube side	0.26×10^{-3}
Solvent in PFHE	0.09×10^{-3}

Table 22 VALUES FOR WATER AND STEAM

Fluid	Fouling resistance $m^2.K/W$
Clear sea water	0.25×10^{-3}
Dirty sea water	0.34×10^{-3}
Brackish water	0.34×10^{-3}
Dirty brackish water	0.52×10^{-3}
Fresh treated water	0.25×10^{-3}
Non-treated fresh water	0.34×10^{-3}
Stripped water	0.34×10^{-3}
Sour water	0.34×10^{-3}
Closed recirculating cooling water system	0.25×10^{-3}
Open recirculating cooling water system	0.29×10^{-3}
Steam + (sour) condensate	0.17×10^{-3}
Steam	0.085×10^{-3}

5. REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments, supplements or revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Shell and tube heat exchangers (amendments/supplements to TEMA standards)	DEP 31.21.01.30-Gen.

APPENDIX 1 COOLING WATER DATA

Table 1-1 COOLING WATER VELOCITIES (TUBE SIDE)

	Tube material*	Preferred velocity for design m/s	Velocity m/s	
			Minimum	Maximum
1.	Aluminium brass, B111-C68700	1.5	1.0	2.2
2.	Copper nickel (90 Cu-10 Ni), B111-C70600	1.8	1.0	2.5
3.	Copper nickel (70 Cu-30Ni), B111-C71640	2.1	1.0	3.0
4.	Carbon steel	1.5	1.0	2.2
5.	Stainless steel	2.5	2.0	4.5
6.	Titanium	3.5	2.5	5.0

NOTE*: Materials selection shall be done in consultation with the materials and corrosion engineer

Table 1-2 COOLING WATER FRICTIONAL PRESSURE DROP (TUBE SIDE)

		FRICTIONAL PRESSURE DROP (Pa/m)		
	Tube material	For preferred velocity	For minimum velocity	For maximum velocity
1.	Aluminium brass, B111-C68700	1 800	900	3 600
2.	Copper nickel (90 Cu-10 Ni), B111-C70600	2 500	900	4 500
3.	Copper nickel (70 Cu-30Ni), B111-C71640	3 300	900	6 100
4.	Carbon steel	1 940	960	3 800
5.	Stainless steel	4 430	3 000	12 400
6.	Titanium	7 200	4 000	13 400

Pressure drop is calculated for a tube OD of 19.05 mm with wall thickness in accordance with DEP 31.21.01.30-Gen. Wall thickness of titanium tubes = 0.914 mm (SWG 20).

The frictional pressure drop on tube side can be estimated by using the above table. This pressure drop still needs correcting for inlet, contraction, turnaround, expansion and outlet losses.