Material Selection Criteria

Scope:

This guide covers:

1. Materials and corrosion allowance (CA) for process equipment
2. Materials for low-temperature services
3. Materials for wear and abrasion resistance

Equipment Design Life

Material selection is based on the following approximate design lives:

1. Large vessels and columns	25 years
2. Small vessels (volume less than 2.2m^3)	10 years
3. Exchanger shell and channels	15years
4. Air coolers	15years
5. Furnace tubes and supports	10years
6. Piping, critical and 100mm or larger	15years
7. Pumps and valves	10years

Criteria for Material Selection

1. Material selection should be based on most severe operating conditions.
2. Process flow diagrams, stream analyses, contaminant level, upset conditions, safety, reliability, and environmental conditions during shut-downs and start-ups should be evaluated in selecting materials.

3.All materials for process equipment and piping should be identifiable and conform, where necessary, to the requirements of the ASTM or other national standard specifications. Table A-1 contains typical ASTM standard specifications for different product forms in frequent use.
4.When welding is involved, the low carbon grade SS (UNS S30403 and S31603) are preferred to the regular grades (UNS S30400 and S31600) except for use at operating temperatures higher than 425C and when intergranular stress corrosion or intergranular corrosion is not a problem during operation or downtime. Note: it is common practice for 300 series SS to be made so that it meets both the regular and low carbon grade requirement; thus, it will be stamped, e.g., 304/304L (UNS S30400/S30403).

Table A-1, typical ASTM specifications for materials

Material (UNS No. as applicable)	Plate	Pipe	Tubing	Forgings & Fittings	Bars	Castings
Cast Iron						A48, A126 A278
Carbon Steel	A285, A515 A516, A537 A737	A53, A106 A671, A672 A691	A214, A179 A192, A210	A105, A181 A266, A234	A29, A575 A576, A663 A675	A216
Carbon-1/2 Mo	A204	A335	A161, A209	A182, A234		A217
1 Cr-1/2 Mo, 1-1/4 Cr-1/2 Mo, & 2-1/4 Cr-1 Mo	A387	A335	A199 A200 A213	A182 A336 A234	A29 A739	A217
5Cr-1/2 Mo	A387	A335	A199, A200 A213	A182, A234		A217
12Cr, CA15	A240		A268	A182	A479	A217
Austenitic Stainless 304, 304L, 316, 316L, 321, 347, 310, CF3, CF3M, CF8, CF8C, CF8M	A240	A312 A358	A213 A249 A271	A182 A336 A403	A479	A351 A744
HK40(J94204) & HP modified						A297
Duplex 2205 SS (S32205)	A240	A790	A789	A182, A815	A276	
6 MoSS (N08367)	B688	B675	B676			
Alloy 800 (N08800)	B409	B407	B163, B407	B366, B564	B408	
Alloy 825 (N08825)	B424	B423	B163, B704	B366	B425	
904L (N08904)	B625	B673, B677	B674, B677		B649	
Alloy 20 (N08020)	B463	B464, B474	B468	B462	B472	A351
Copper (C10200)	B152	B42	B75, B111			
Admiralty Brass (C44300)			B111			
Naval Brass (C46500)	B171				B124	
70-30 Cu-Ni	B171	B467, B608	B111, B395			
Titanium Gr.2 (R50400)	B265	B337	B338	B381	B348	B367
Alloy 400 (N04400)	B127	B165	B163, B165	B564	B164	A494
Alloy 625 (N06625)	B443	B444	B444, B704	B446		
Alloy C276 (N010276)	B575	B622	B622, B626	B574		A494
Ni Resist TP2 (F41002)						A436
Aluminum	B209	B241	B234	B247	B211	

General Guidelines for Materials Selection and Corrosion Allowance

1. Materials typically used for the following environments are contained in Table A-2 through A-17. It is important to note that the materials listed are typical and that there can be exceptions.

    - General-hydrocarbon with low sulfur contents, non-corrosive steam and water.
    - Hydrocarbon plus sulfur greater than 1wt%
    - Hydrocarbon plus sulfur greater than 0.2wt% plus naphthenic acid
    - Hydrocarbon plus sulfur between 0.2wt% and 1.0wt%
    - Hydrocarbon plus hydrogens
    - Hydrocarbon plus hydrogen and hydrogen sulfide
    - Sour water and desalter water
    - Carbonate
    - Low pressure wet carbon dioxide
    - High pressure wet carbon dioxide
    - Amine
    - Acid gas
    - Liquid sulfur
    - Untreated, aerated water
    - Caustic
    - Valve trim

2. The following legend has been used for materials designations:

    1. CI = Cast Iron
    2. 12Cr = Types 405, 410, 410S, CA15 (UNS S40500, S41000, S41008, J9II59)
    3. CS = Carbon Steel
    4. 1-Cr = 1Cr-1/2 Mo
    5. 1-1/4Cr = 1-1/4 Cr-1/2Mo
    6. 18-8 = Types 304, 316, 321, 347, CF8, CF8M, CF8C (UNS S30400, S31600, S32100, S34700, J92600, J92900, J92710)
    7. 5Cr = 5Cr-1/2Mo
    8. 9Cr = 9Cr-1Mo
    9. SS = Stainless steel

3. The numerals after a material designation indicate the minimum nominal corrosion allowances in mm as follows:

- 1.3mm for SS furnace tubes unless otherwise specified
- 1.5mm for piping unless otherwise specified
- 2.5mm for 1Cr-5Cr furnace tubes and typical minimum thickness for clad.
- 3.0mm for carbon steel furnace tubes, for TEMA class R heat exchanger, and for sour water piping with hydrogen sulfide partial pressures less than 10psia
- 4.5 mm for sour water vessels and heat exchangers with hydrogen sulfide partial pressure less than 10 psia.
- 6mm for vessels and heat exchangers with hydrogen sulfide partial pressures greater than 10 psia or carbon dioxide partial pressures less than 4psia.

Table A-2

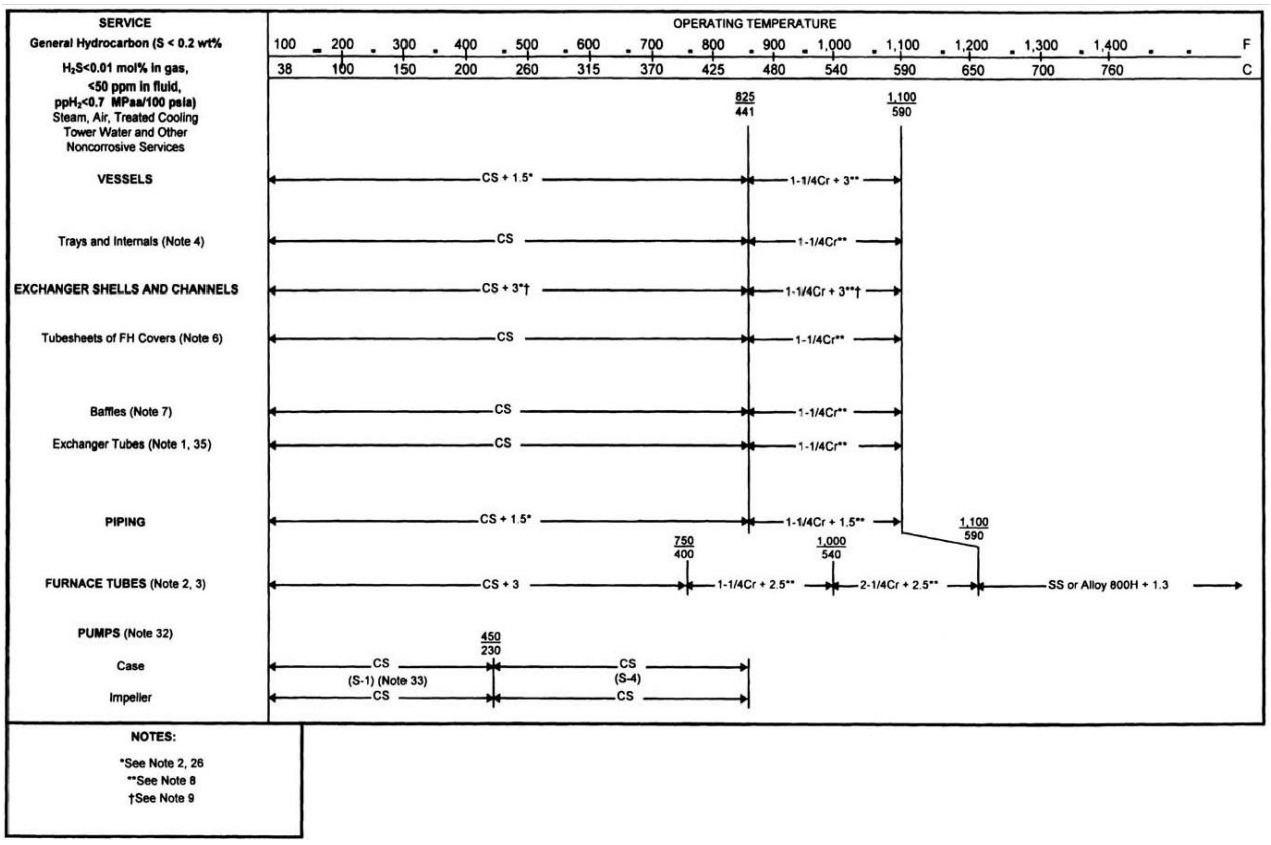
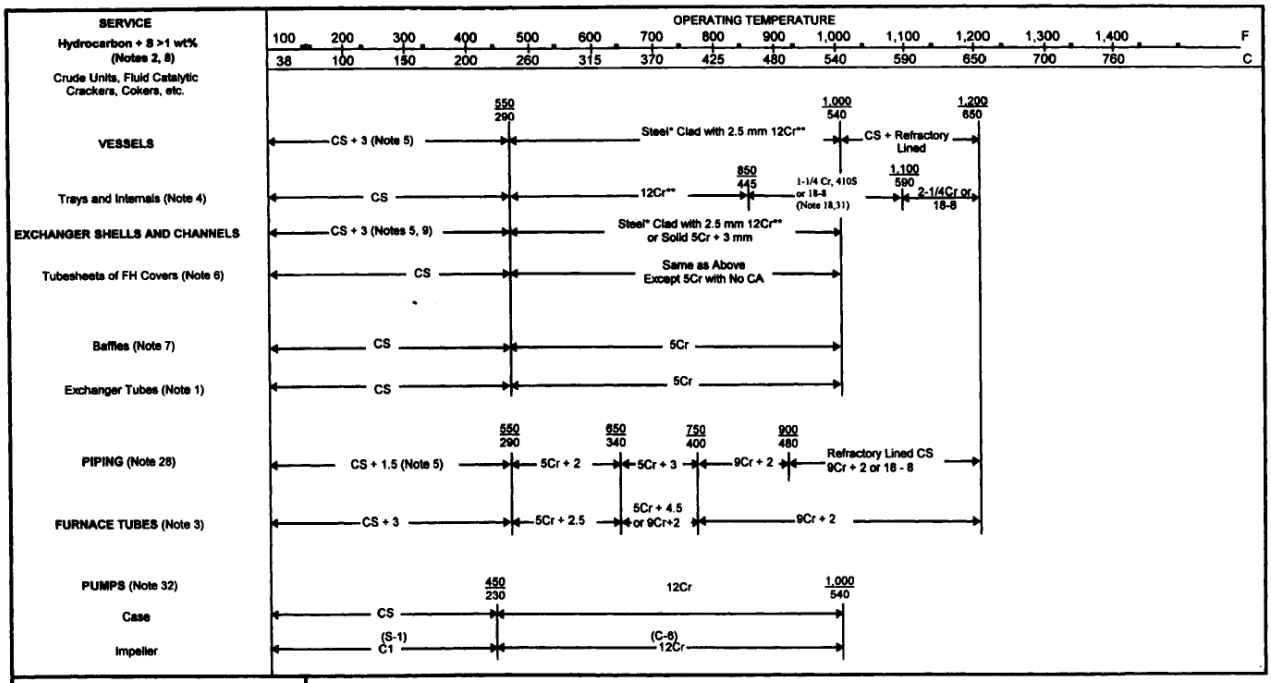

SERVICE
OPERATING TEMPERATURE
General Hydrocarbon (S < 0.2 wt%
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
H2S<0.01 mol% in gas,
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
<50 ppm in fluid,
ppH2<0.7 MPaa/100 psia)
Steam, Air, Treated Cooling
Tower Water and Other
Noncorrosive Services
825/441
1,100/590
VESSELS
CS + 1.5*
1-1/4Cr + 3**
Trays and Internals (Note 4)
CS
1-1/4Cr**
EXCHANGER SHELLS AND CHANNELS
CS + 3*†
1-1/4Cr + 3**†
Tubesheets of FH Covers (Note 6)
CS
1-1/4Cr**
Baffles (Note 7)
CS
1-1/4Cr**
Exchanger Tubes (Note 1, 35)
CS
1-1/4Cr**
PIPING
CS + 1.5*
1-1/4Cr + 1.5**
1,100/590
750/400
1,000/540
FURNACE TUBES (Note 2, 3)
CS + 3
1-1/4Cr + 2.5**
2-1/4Cr + 2.5**
SS or Alloy 800H + 1.3
PUMPS (Note 32)
450/230
Case
CS
(S-1) (Note 33)
CS
(S-4)
Impeller
CS
CS
NOTES:
*See Note 2, 26
**See Note 8
†See Note 9

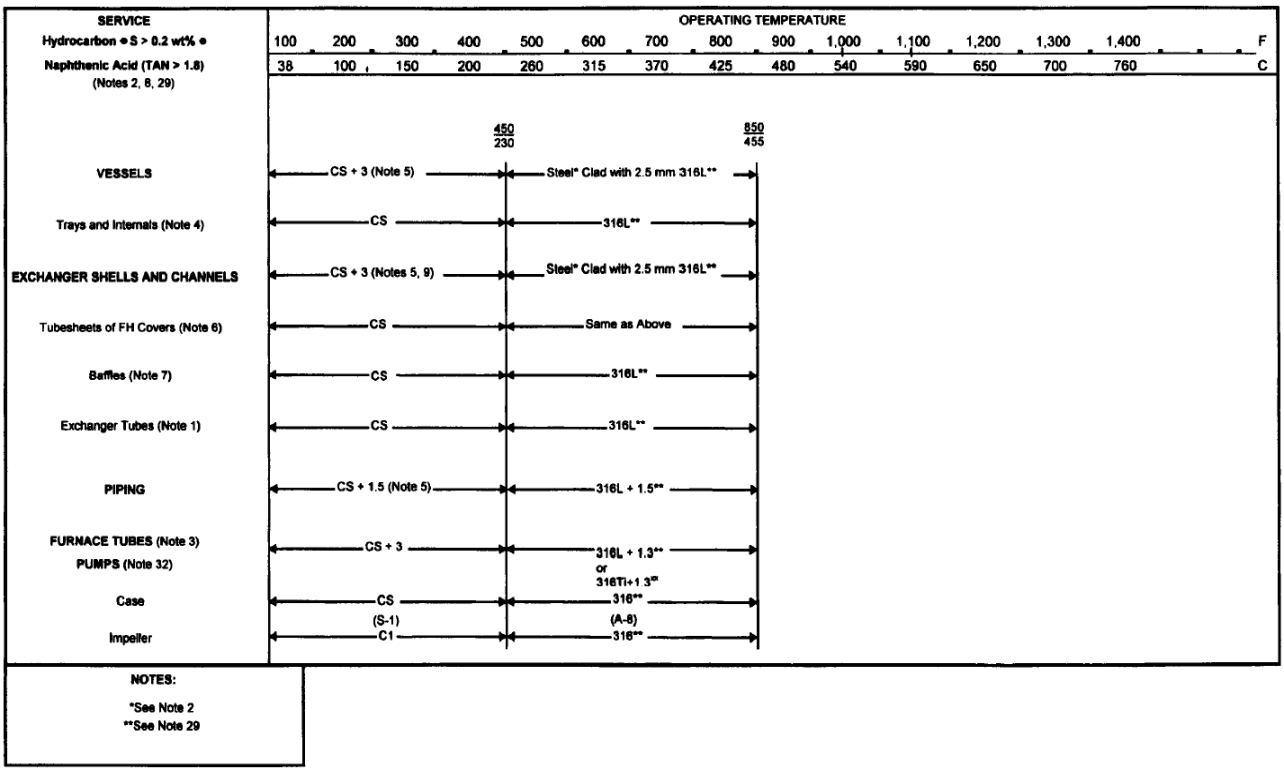
Table A-3



NOTES:

*See Note 2, 28
**See Note 18, 29
†See Note 8

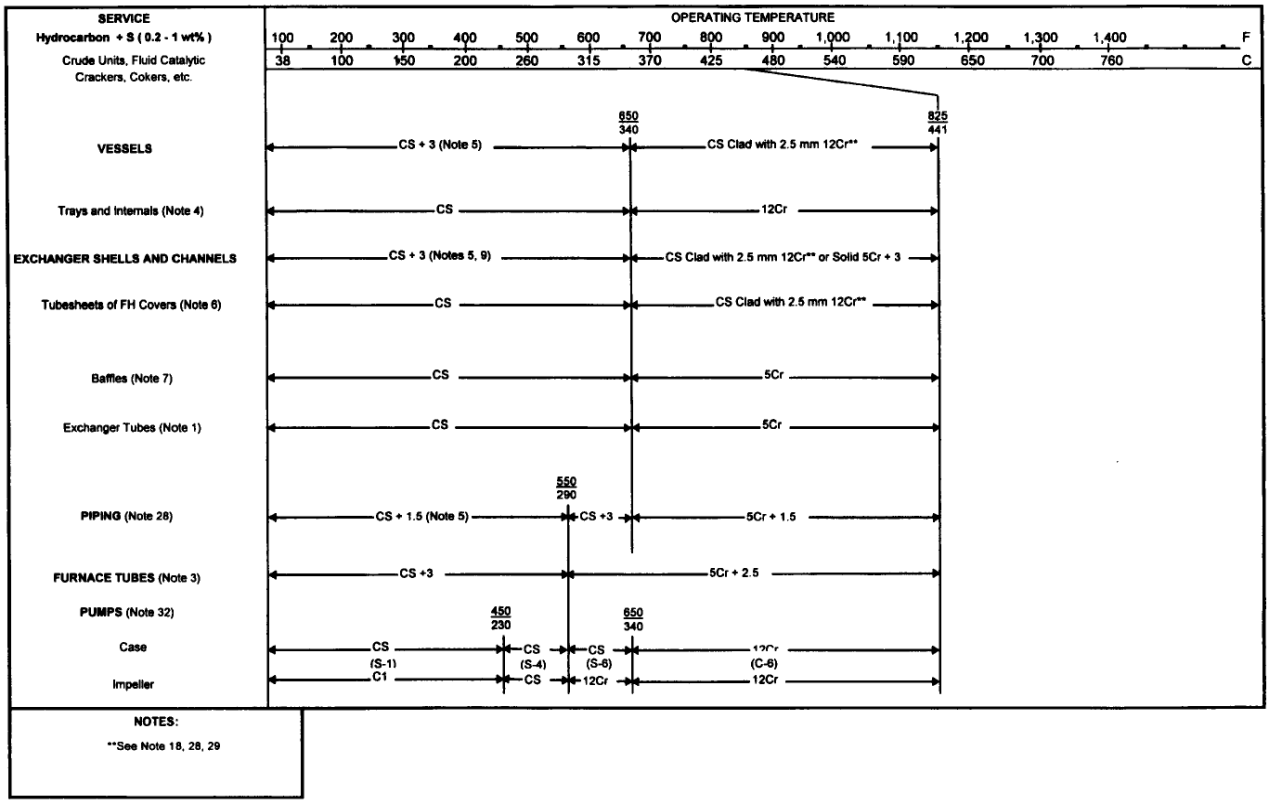
Table A-4



NOTES:

*See Note 2
**See Note 29

Table A-5



NOTES:

**See Note 18, 28, 29

Table A-6

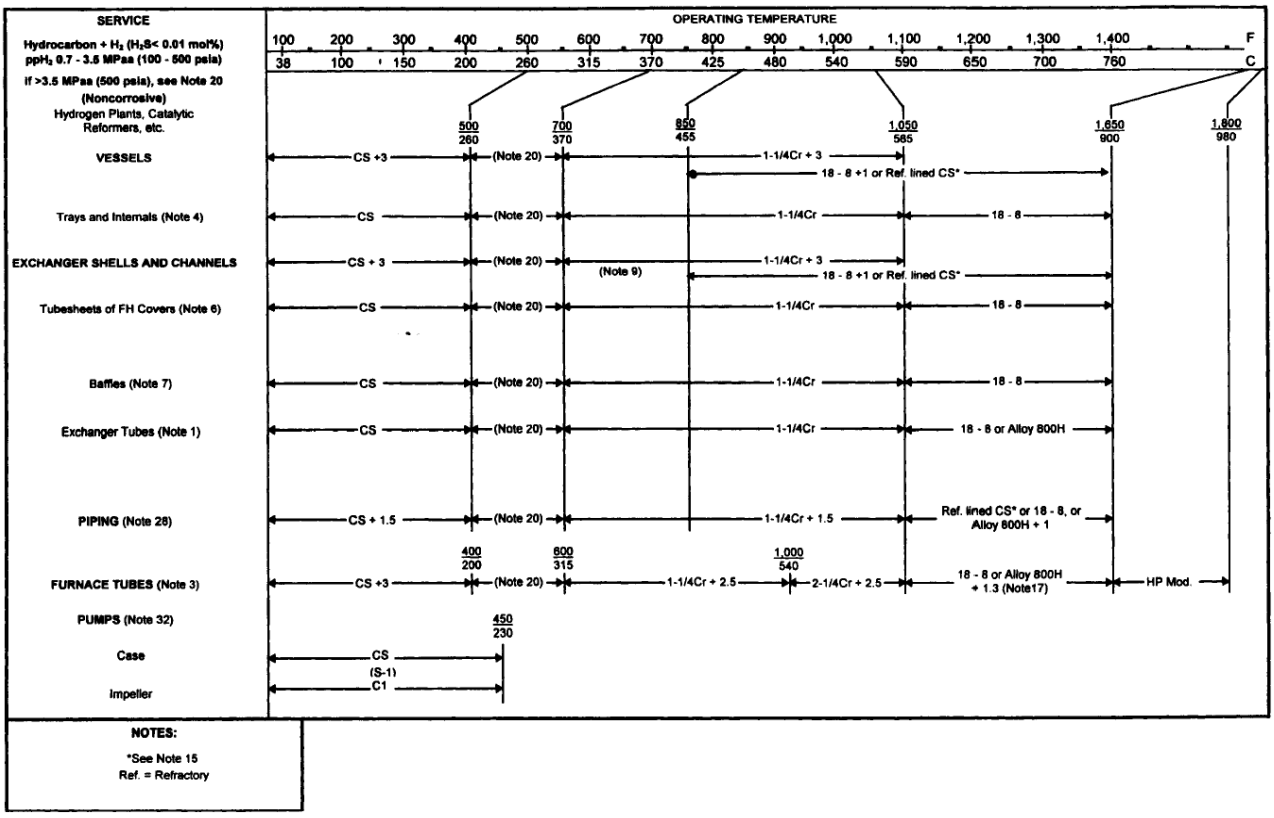

SERVICE
OPERATING TEMPERATURE
Hydrocarbon + H_2 (H_2S< 0.01 mol%)
$pp H_2$ 0.7 - 3.5 MPaa (100 - 500 psia)
If >3.5 MPaa (500 psia), see Note 20
(Noncorrosive)
Hydrogen Plants, Catalytic Reformers, etc.
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
500/260 700/370 850/455 1,050/565 1,650/900 1,800/980
VESSELS
CS +3 (Note 20) 1-1/4Cr + 3
18 - 8 +1 or Ref. lined CS*
Trays and Internals (Note 4)
CS (Note 20) 1-1/4Cr 18 - 8
EXCHANGER SHELLS AND CHANNELS
CS + 3 (Note 20) 1-1/4Cr + 3
(Note 9)
18 - 8 +1 or Ref. lined CS*
Tubesheets of FH Covers (Note 6)
CS (Note 20) 1-1/4Cr 18 - 8
Baffles (Note 7)
CS (Note 20) 1-1/4Cr 18 - 8
Exchanger Tubes (Note 1)
CS (Note 20) 1-1/4Cr 18 - 8 or Alloy 800H
PIPING (Note 28)
CS + 1.5 (Note 20) 1-1/4Cr + 1.5
Ref. lined CS* or 18 - 8, or Alloy 800H + 1
400/200 600/315 1,000/540
FURNACE TUBES (Note 3)
CS +3 (Note 20) 1-1/4Cr + 2.5 2-1/4Cr + 2.5
18 - 8 or Alloy 800H + 1.3 (Note17)
HP Mod.
PUMPS (Note 32)
450/230
Case
CS
(S-1)
Impeller
C1
NOTES:
*See Note 15
Ref. = Refractory

Table A-7

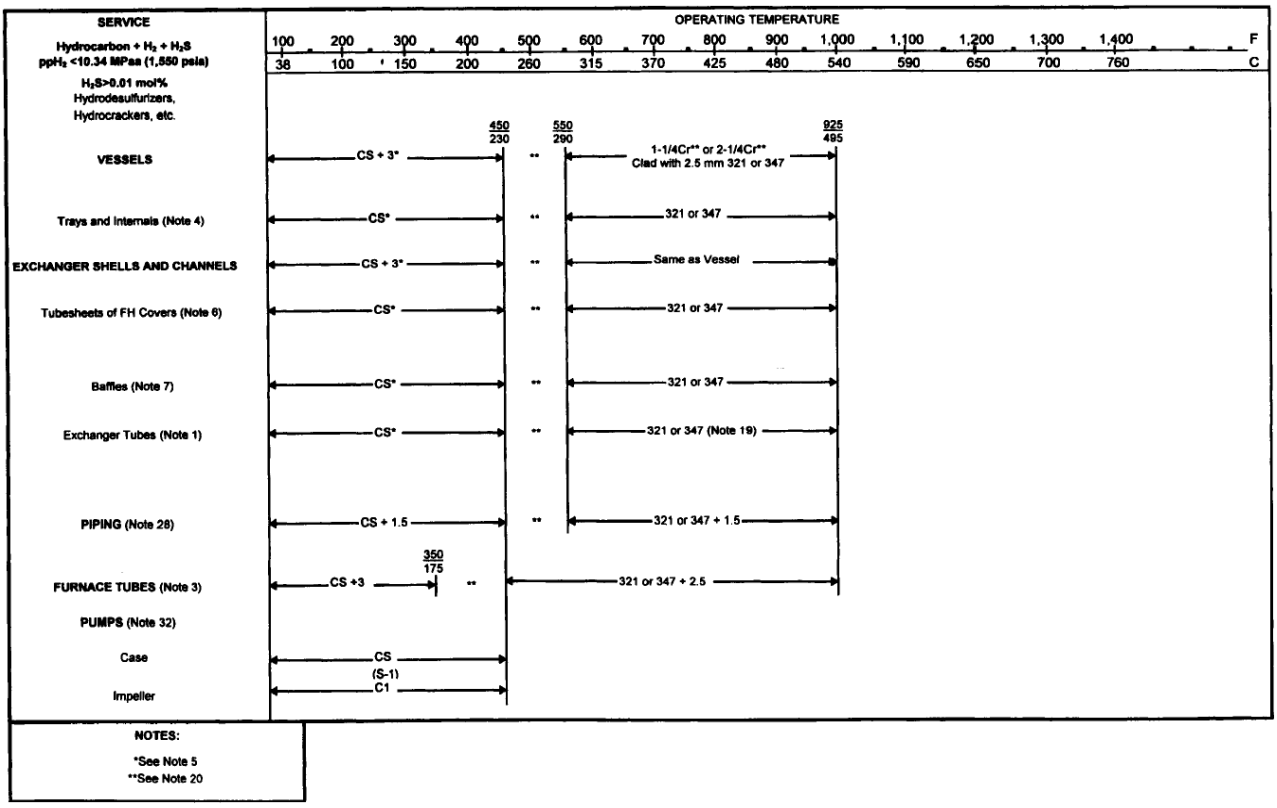

SERVICE
OPERATING TEMPERATURE
Hydrocarbon + H2 + H2S
ppH2 <10.34 MPaa (1,550 psia)
H2S>0.01 mol%
Hydrodesulfurizers,
Hydrocrackers, etc.
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
450/230
550/290
925/495
VESSELS
CS + 3*
**
1-1/4Cr** or 2-1/4Cr**
Clad with 2.5 mm 321 or 347
Trays and Internals (Note 4)
CS*
321 or 347
EXCHANGER SHELLS AND CHANNELS
CS + 3*
Same as Vessel
Tubesheets of FH Covers (Note 6)
Baffles (Note 7)
Exchanger Tubes (Note 1)
PIPING (Note 28)
CS + 1.5
321 or 347 + 1.5
350/175
FURNACE TUBES (Note 3)
CS +3
321 or 347 + 2.5
PUMPS (Note 32)
Case
CS
(S-1)
Impeller
C1
NOTES:
*See Note 5
**See Note 20

Table A-8

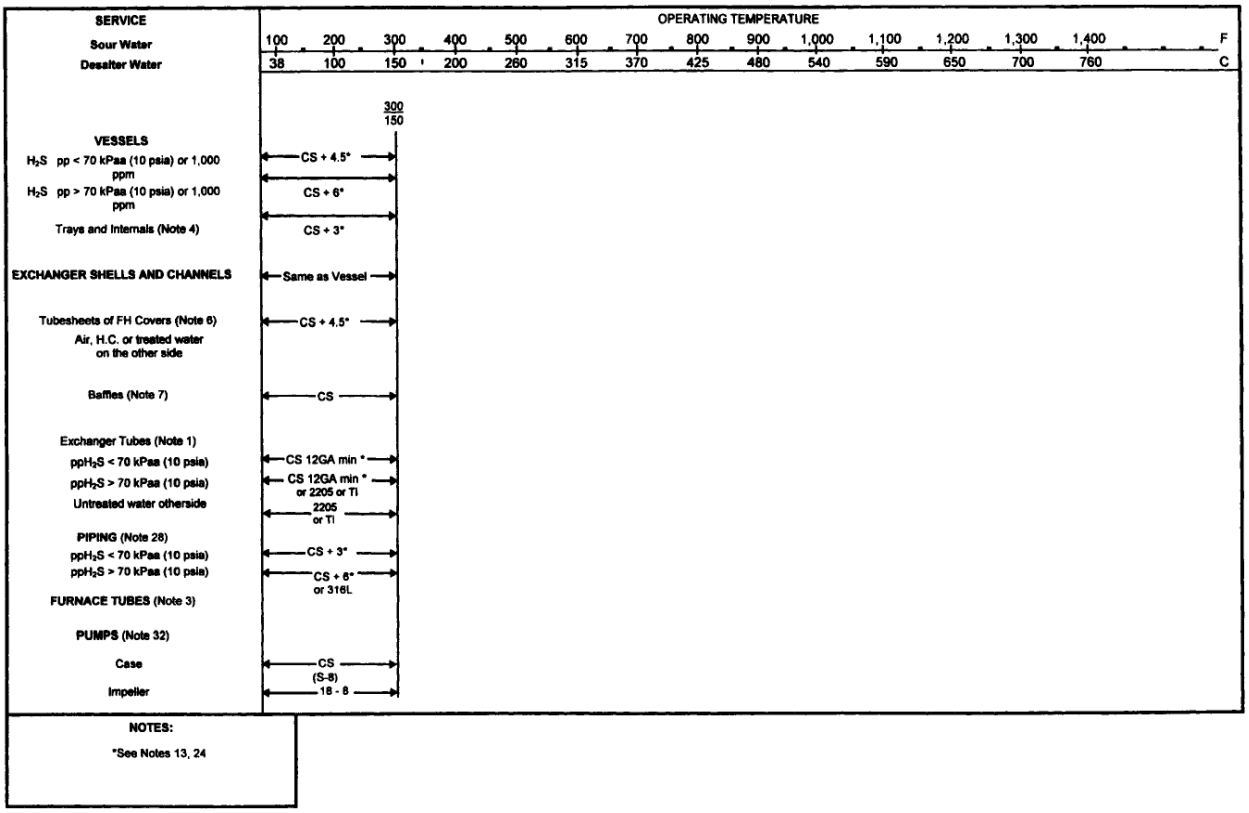

SERVICE
Sour Water
Desalter Water
OPERATING TEMPERATURE
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
300
150
VESSELS
H2S pp < 70 kPaa (10 psia) or 1,000 ppm
CS + 4.5*
H2S pp > 70 kPaa (10 psia) or 1,000 ppm
CS + 6*
Trays and Internals (Note 4)
CS + 3*
EXCHANGER SHELLS AND CHANNELS
Same as Vessel
Tubesheets of FH Covers (Note 6)
Air, H.C. or treated water on the other side
CS + 4.5*
Baffles (Note 7)
CS
Exchanger Tubes (Note 1)
ppH2S < 70 kPaa (10 psia)
CS 12GA min *
ppH2S > 70 kPaa (10 psia)
CS 12GA min * or 2205 or Ti
Untreated water otherside
2205 or Ti
PIPING (Note 28)
ppH2S < 70 kPaa (10 psia)
CS + 3*
ppH2S > 70 kPaa (10 psia)
CS + 6* or 316L
FURNACE TUBES (Note 3)
PUMPS (Note 32)
Case
CS (S-8)
Impeller
18 - 8
NOTES:
*See Notes 13, 24

Table A-9

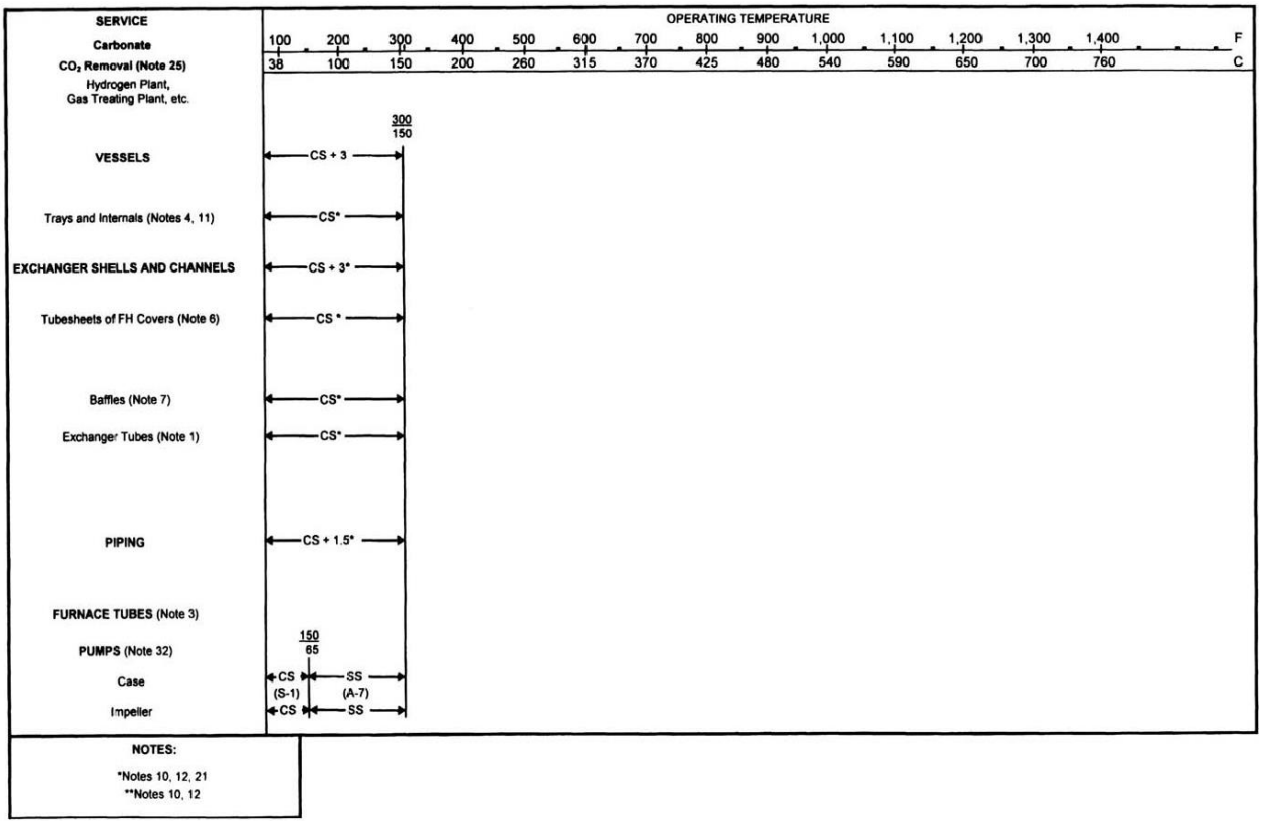

SERVICE
OPERATING TEMPERATURE
Carbonate
CO2 Removal (Note 25)
Hydrogen Plant,
Gas Treating Plant, etc.
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
300
150
VESSELS
CS + 3
Trays and Internals (Notes 4, 11)
CS*
EXCHANGER SHELLS AND CHANNELS
CS + 3*
Tubesheets of FH Covers (Note 6)
CS *
Baffles (Note 7)
CS*
Exchanger Tubes (Note 1)
CS*
PIPING
CS + 1.5*
FURNACE TUBES (Note 3)
PUMPS (Note 32)
150
65
Case
CS
(S-1)
SS
(A-7)
Impeller
CS
SS
NOTES:
*Notes 10, 12, 21
**Notes 10, 12

Table A-10

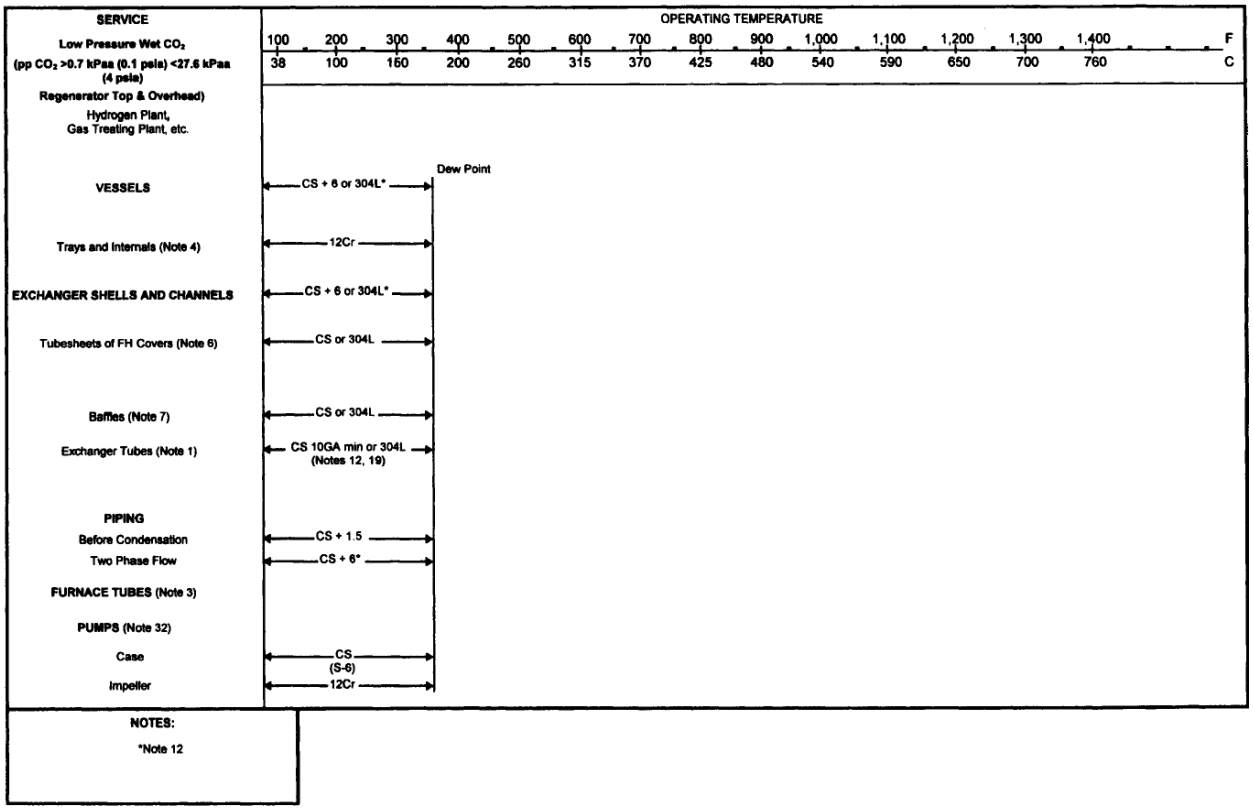

SERVICE
OPERATING TEMPERATURE
Low Pressure Wet CO_2
(pp CO_2 >0.7 kPaa (0.1 psia) <27.6 kPaa (4 psia)
Regenerator Top & Overhead)
Hydrogen Plant, Gas Treating Plant, etc.
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
Dew Point
VESSELS
CS + 6 or 304L*
Trays and Internals (Note 4)
12Cr
EXCHANGER SHELLS AND CHANNELS
CS + 6 or 304L*
Tubesheets of FH Covers (Note 6)
CS or 304L
Baffles (Note 7)
CS or 304L
Exchanger Tubes (Note 1)
CS 10GA min or 304L (Notes 12, 19)
PIPING
Before Condensation
CS + 1.5
Two Phase Flow
CS + 6*
FURNACE TUBES (Note 3)
PUMPS (Note 32)
Case
CS (S-6)
Impeller
12Cr
NOTES:
*Note 12

Table A11

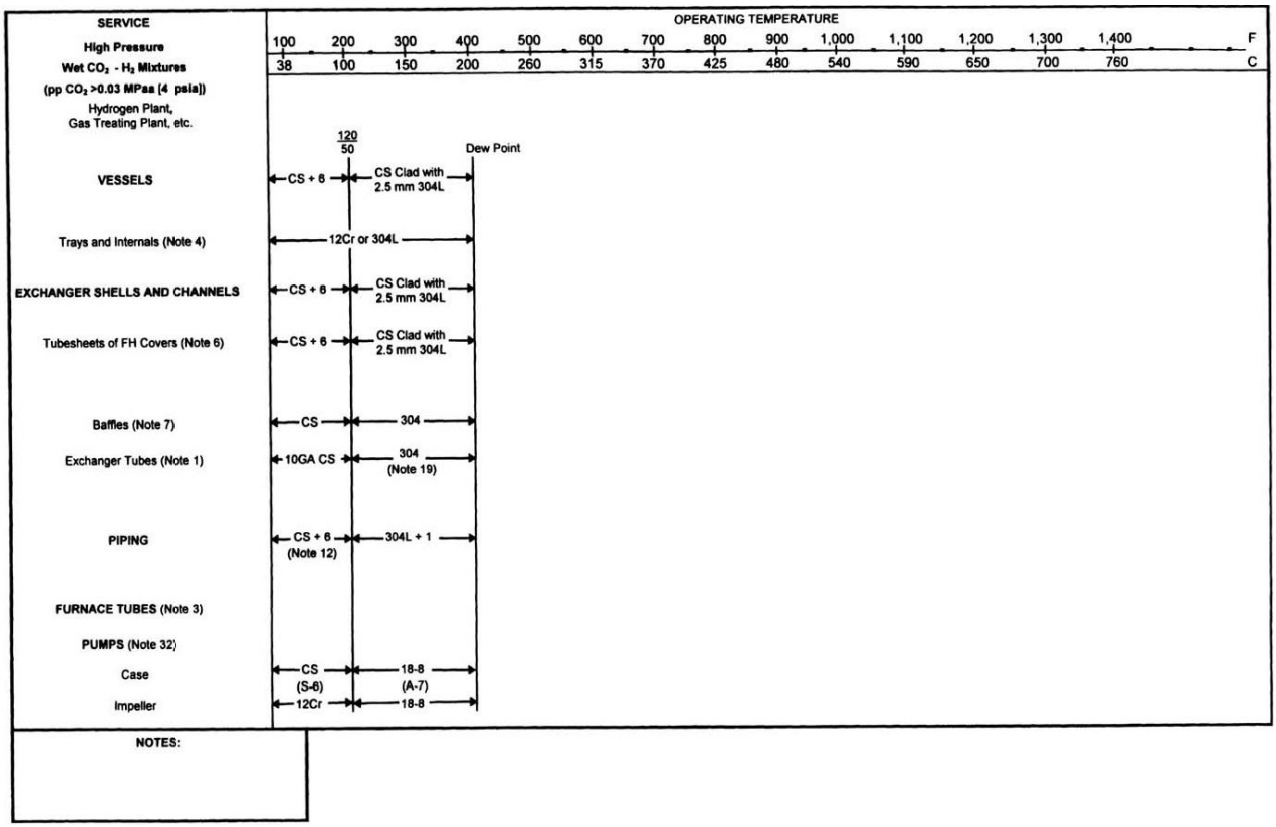

SERVICE
High Pressure
Wet CO_2 - H_2 Mixtures
(pp CO_2 >0.03 MPaa [4 psia])
Hydrogen Plant,
Gas Treating Plant, etc.
OPERATING TEMPERATURE
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
120
50
Dew Point
VESSELS
CS + 6
CS Clad with 2.5 mm 304L
Trays and Internals (Note 4)
12Cr or 304L
EXCHANGER SHELLS AND CHANNELS
CS + 6
CS Clad with 2.5 mm 304L
Tubesheets of FH Covers (Note 6)
CS + 6
CS Clad with 2.5 mm 304L
Baffles (Note 7)
CS
304
Exchanger Tubes (Note 1)
10GA CS
304 (Note 19)
PIPING
CS + 6 (Note 12)
304L + 1
FURNACE TUBES (Note 3)
PUMPS (Note 32)
Case
CS (S-6)
18-8 (A-7)
Impeller
12Cr
18-8
NOTES:

Table A-12

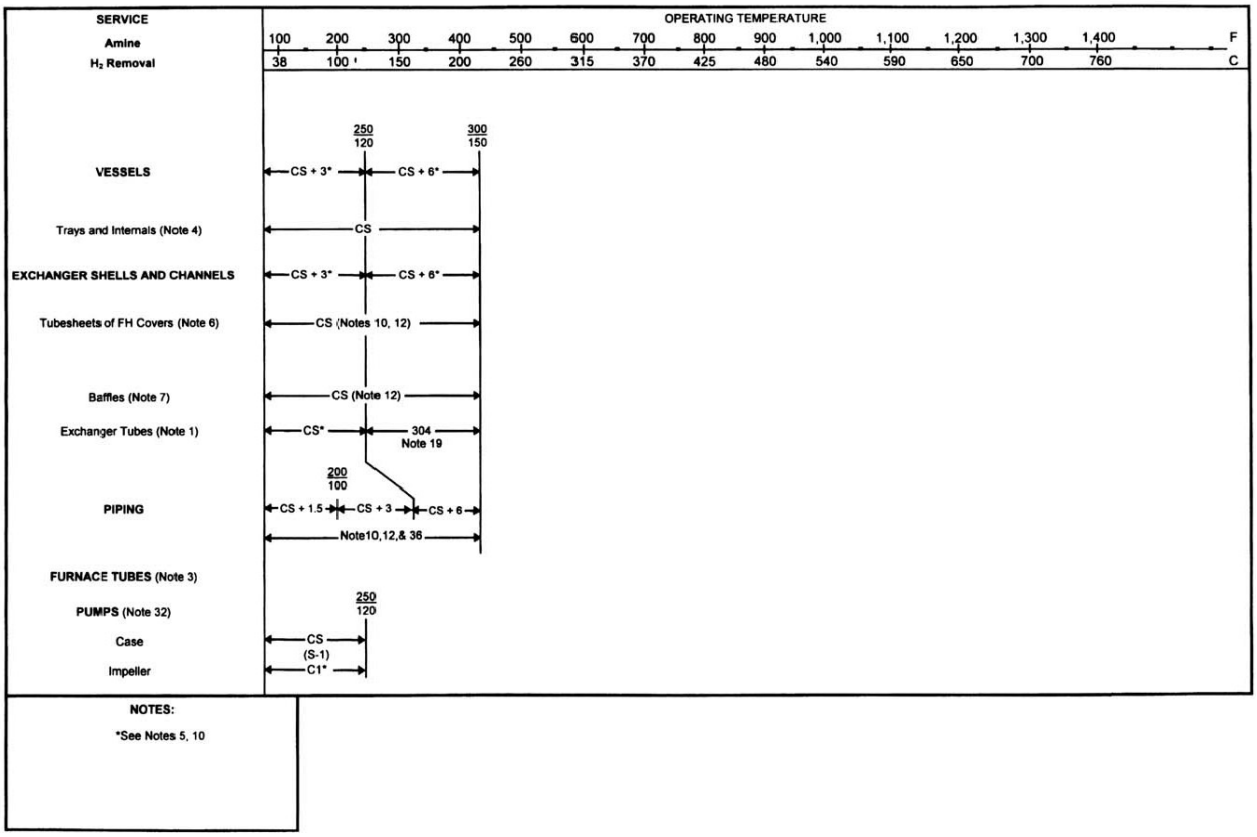

SERVICE
OPERATING TEMPERATURE
Amine
H2 Removal
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
250 120
300 150
VESSELS
CS + 3*
CS + 6*
Trays and Internals (Note 4)
CS
EXCHANGER SHELLS AND CHANNELS
CS + 3*
CS + 6*
Tubesheets of FH Covers (Note 6)
CS (Notes 10, 12)
Baffles (Note 7)
CS (Note 12)
Exchanger Tubes (Note 1)
CS*
304
Note 19
200 100
PIPING
CS + 1.5
CS + 3
CS + 6
Note10,12,& 36
FURNACE TUBES (Note 3)
PUMPS (Note 32)
250 120
Case
CS
(S-1)
Impeller
C1*
NOTES:
*See Notes 5, 10

Table A-13

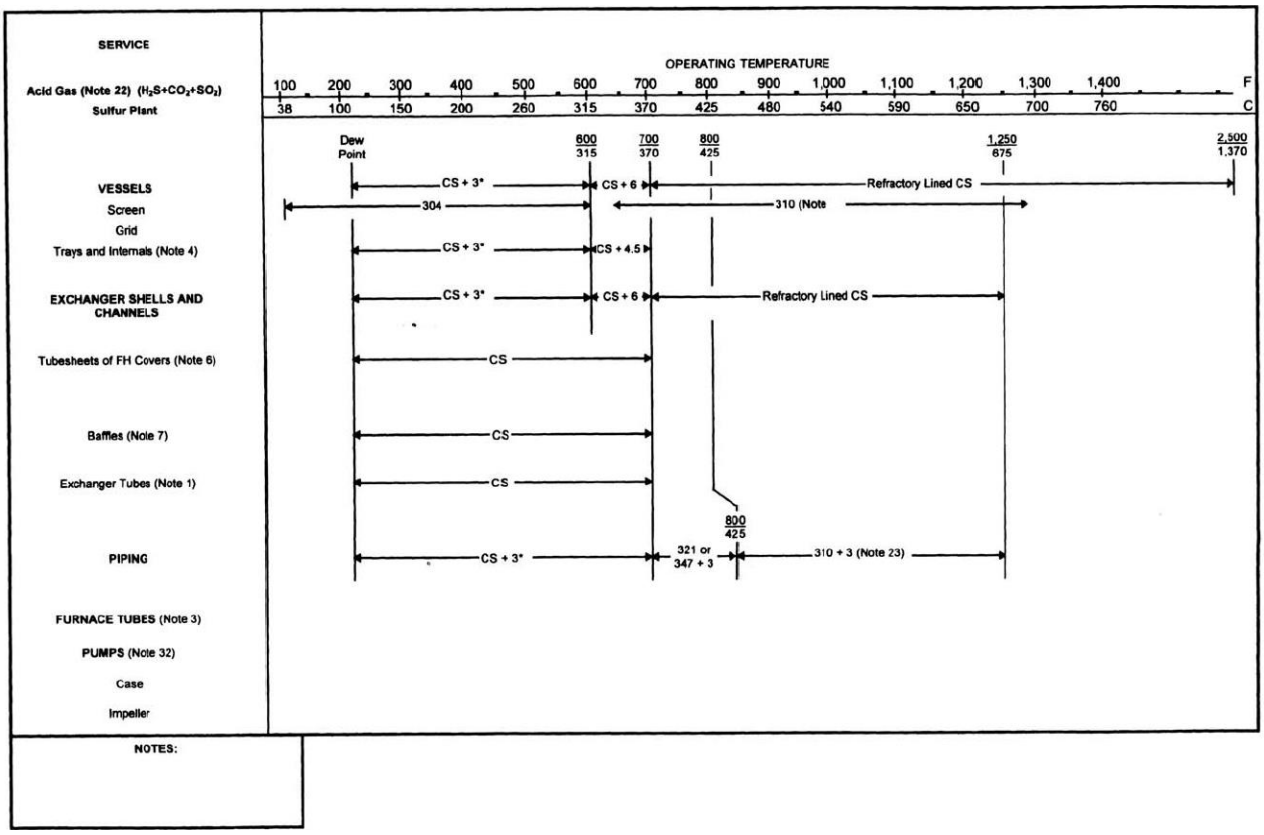

SERVICE
Acid Gas (Note 22) ($H_2S+CO_2+SO_2$)
Sulfur Plant
OPERATING TEMPERATURE
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
Dew Point
600 315
700 370
800 425
1,250 675
2,500 1,370
VESSELS
Screen
Grid
Trays and Internals (Note 4)
EXCHANGER SHELLS AND CHANNELS
Tubesheets of FH Covers (Note 6)
Baffles (Note 7)
Exchanger Tubes (Note 1)
PIPING
FURNACE TUBES (Note 3)
PUMPS (Note 32)
Case
Impeller
CS + 3*
CS + 6
Refractory Lined CS
304
310 (Note
CS + 4.5
CS
800 425
321 or 347 + 3
310 + 3 (Note 23)
NOTES:

Table-A14

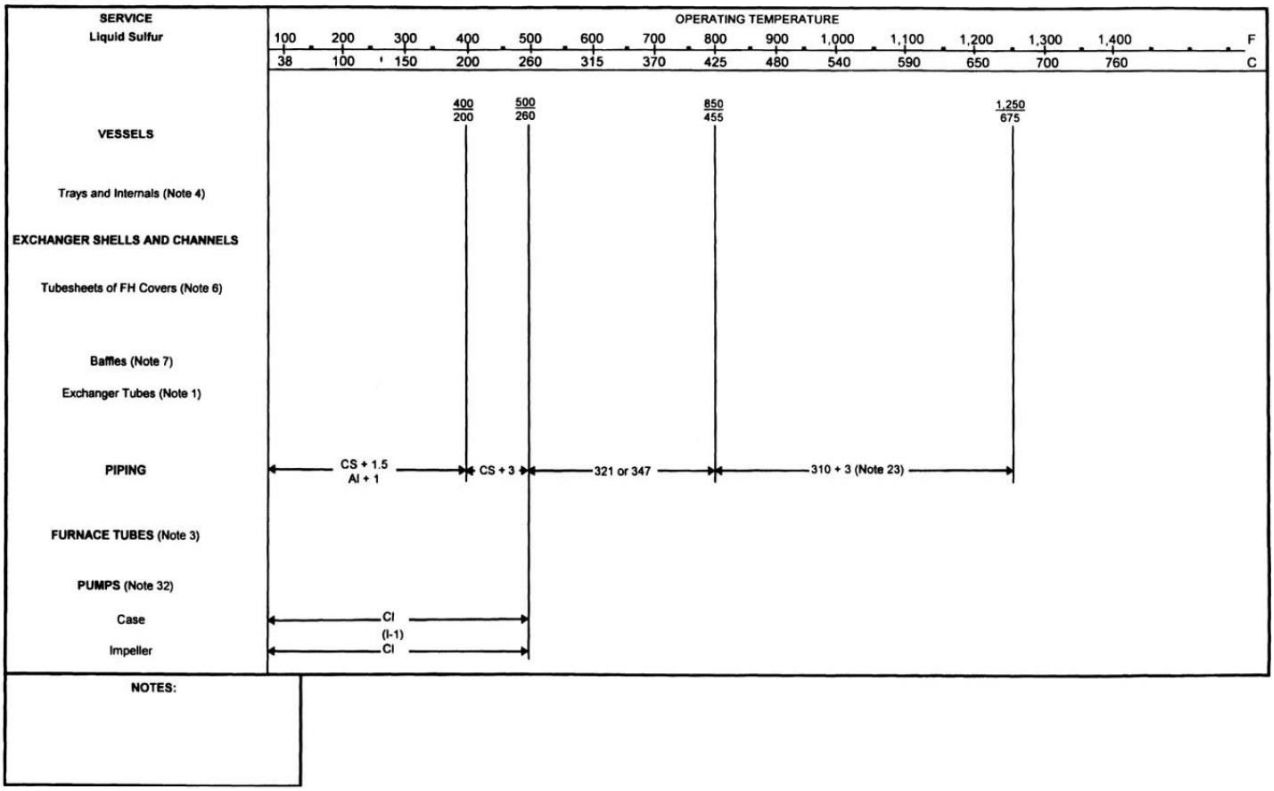

SERVICE
Liquid Sulfur
OPERATING TEMPERATURE
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
400/200
500/260
850/455
1,250/675
VESSELS
Trays and Internals (Note 4)
EXCHANGER SHELLS AND CHANNELS
Tubesheets of FH Covers (Note 6)
Baffles (Note 7)
Exchanger Tubes (Note 1)
PIPING
CS + 1.5 Al + 1
CS + 3
321 or 347
310 + 3 (Note 23)
FURNACE TUBES (Note 3)
PUMPS (Note 32)
Case
CI
Impeller
(I-1) CI
NOTES:

Table A-15

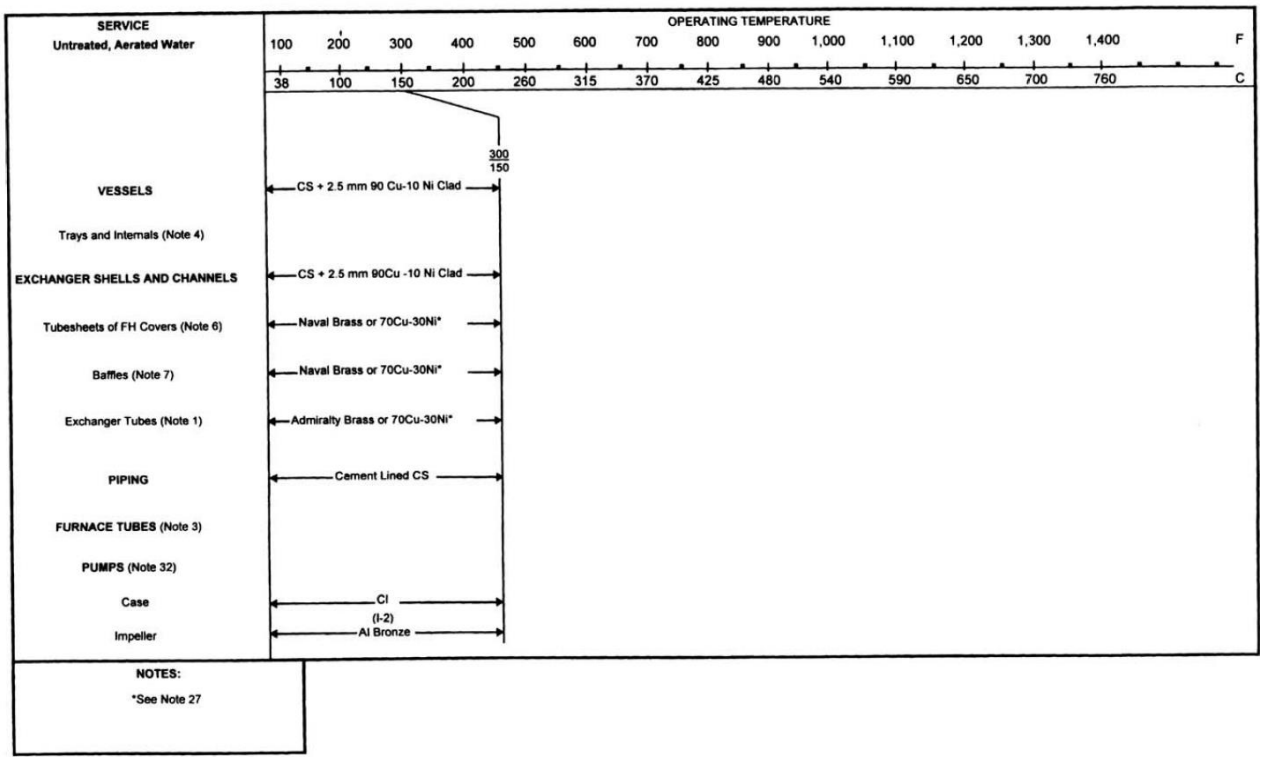
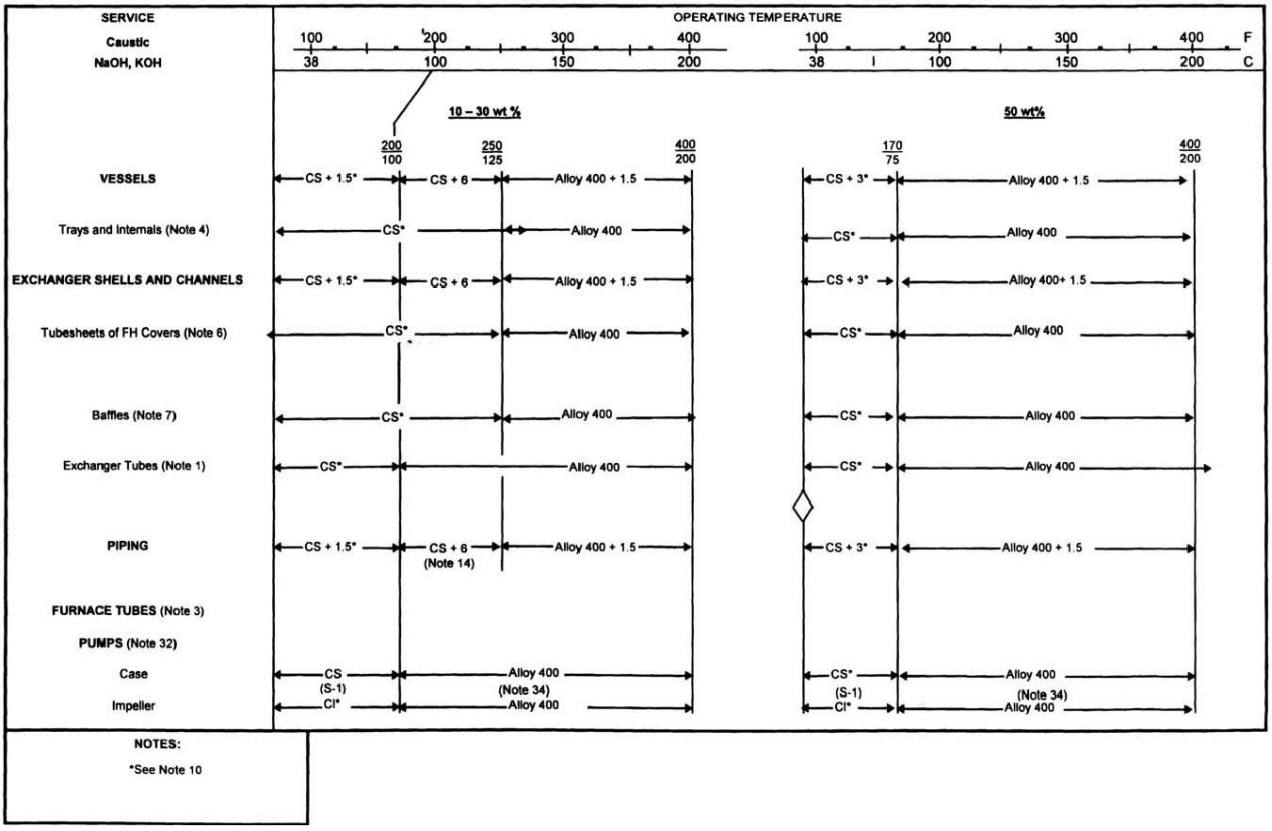

SERVICE
Untreated, Aerated Water
OPERATING TEMPERATURE
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 F
38 100 150 200 260 315 370 425 480 540 590 650 700 760 C
300
150
VESSELS
CS + 2.5 mm 90 Cu-10 Ni Clad
Trays and Internals (Note 4)
EXCHANGER SHELLS AND CHANNELS
CS + 2.5 mm 90Cu -10 Ni Clad
Tubesheets of FH Covers (Note 6)
Naval Brass or 70Cu-30Ni*
Baffles (Note 7)
Naval Brass or 70Cu-30Ni*
Exchanger Tubes (Note 1)
Admiralty Brass or 70Cu-30Ni*
PIPING
Cement Lined CS
FURNACE TUBES (Note 3)
PUMPS (Note 32)
Case
CI
(I-2)
Impeller
Al Bronze
NOTES:
*See Note 27

Table A-16


SERVICE
Caustic
NaOH, KOH
OPERATING TEMPERATURE
100 200 300 400 F
38 100 150 200 C
10 – 30 wt %
50 wt%
200/100
250/125
400/200
170/75
400/200
VESSELS
CS + 1.5* CS + 6 Alloy 400 + 1.5
CS + 3* Alloy 400 + 1.5
Trays and Internals (Note 4)
CS* Alloy 400
EXCHANGER SHELLS AND CHANNELS
CS + 1.5* CS + 6 Alloy 400 + 1.5
CS + 3* Alloy 400+ 1.5
Tubesheets of FH Covers (Note 6)
CS* Alloy 400
Baffles (Note 7)
CS* Alloy 400
Exchanger Tubes (Note 1)
CS* Alloy 400
PIPING
CS + 1.5* CS + 6 (Note 14) Alloy 400 + 1.5
CS + 3* Alloy 400 + 1.5
FURNACE TUBES (Note 3)
PUMPS (Note 32)
Case
CS (S-1) CS* Alloy 400 (Note 34) Alloy 400
Impeller
Cl* Alloy 400
NOTES:
*See Note 10

Environment

1.General Service

a. Treated Water

b. Steam ΔP< 150psig in multi-phase flow

< 500psig in single phase flow

ΔP>150psig in multi-phase flow

>500psig in single phase flow

2.Hydrocarbon, Carbonate, Wet CO_2, Acid Gas, Liquid Sulfur

a. Carbon and low alloy steel piping

b. 321 or 347 (UNS S32100 or S34700) piping

3.Sour Water, Desalter Water

4.Amine

a. T<100C

b. T>100C

5. Untreated Water<100C

6.Caustic

a.10-30wt%, T<100C

b.10-30wt%, T>100C, 50wt% all temperatures

General Guideline for Valves and PSVs Body

1. Cast Carbon Steel, A216 Gr WCB/WCC or forged carbon steel, A105 is used in non-corrosive service from -28C to 427C. Low temperature carbon steel, A352 Gr LCB/LCC can be used down to -46C (stainless steel may be considered as an alternative)
2. Alloy Steel, A217 Gr WC1, WC6, WC9 is used for temperatures above 427C. WC9 may also be used for flashing services.
3. Stainless Steel, A351 CF8 is used in flashing services, corrosive service and for temperatures below -28C.
4. Monel is used in pure oxygen services.

Valve Trim

1. As standard the material shall be AISI 316, unless otherwise specified.
2. Erosion-resistant trim with hardened or hard-faced surfaces are required when the pressure drop across the valve exceeds 10 bar, the temperature is above 315C, the pressure drop across the valve exceeds 5 bar in steam service, or when there is a risk of flashing /incipient cavitation.
3. Cobalt-based alloys must not be used for hard-facing in boiler feed water and amine service.
4. Anti-cavitation trim is selected for high-pressure drop applications to prevent the onset of cavitation.
5. Anti-noise trim is selected for reducing the noise generated by the fluid.
6. Trim material for butterfly and gate valves may be the same as the body material.

Packing

1. The packing design for linear motion valves shall include a packing flange.
2. PTFE shall be used as standard packing material for bonnet temperature below 230C and graphite for higher temperatures. Higher temperatures can be accepted for PTFE if the bonnet is extended. Packing design and material shall be selected carefully for minimum stem friction and live-loading packing boxes shall be considered for PTFE packing.
3. Vacuum service and special services like oxygen, require special packing materials and should be given special consideration.

Notes for Tables A-2 through A-17

1.The thickness of exchanger tubes should be that specified in the Exchanger Design Criteria. Where a gauge is specified, the thickness must be checked for adequacy with regard to pressure. Alternatively, a corrosion allowance of 0.25mm to 1.5 mm can be specified.

2.Above 400C, use silicon-killed (not aluminum-killed) carbon steel. Above 440C, use 1 Cr-1/2Mo or 1-1/4 Cr-1/2 Mo.

3.Material selection for furnace tubes in non-hydrogen containing hydrocarbons plus sulfur services is based on the assumption that the metal temperature is 50C higher than the internal fluid temperature. To avoid excessive oxidation the outside skin temperatures should not exceed 530C for carbon steel, 650C for 1-1/4Cr to 9 Cr and 930C for 18-8 SS. When austenitic SS is specified for temperatures above 530C, H grade should be used, and cold forming should be prohibited where creep strength governs the allowable stress unless it is followed by solution annealing. Cold forming of carbon steel furnace and boiler tubes, e.g., cold bends, should be prohibited unless followed b stress relief.

4.Corrosion allowance (CA) for trays and internals:

	Removable	Welded In
Carbon steel	1mm	Vessel CA × 1.5
Corrosion-resistant alloys in carbon steel vessel	none	1.5mm
Corrosion-resistant alloys in alloy vessel	none	Vessel CA

5.Use only silicon-killed steels for temperatures above 232C.For areas where sour water collects, see Table A-8.

6.Where not covered by TEMA and the material specified for both sides is the same, corrosion allowance should be 0.75 × the sum of the corrosion allowances for each side up to 6mm maximum. Where not covered by TEMA and alloy requirements for two sides are different and solid alloy tube sheet is used, use corrosion allowance for higher alloy side as the total corrosion allowance. Where cladding is required on the tube side, the minimum thickness of cladding should be 10mm so that at least one of the grooves for rolling will be in the cladding.

7.Baffles should be 6mm minimum thickness; no other corrosion allowance need be used.

8.Where 1-1/4Cr-1/2Mo is specified, 1Cr-1/2Mo also may be used. Do not use 1 Cr-1/2Mo in hydrogen service if hydrogen partial pressure is greater than 100 psia above 480C.Do not use 1 Cr-1/2Mo in general services above 530C.

9.A corrosion allowance of 3mm should be used on carbon steel and low alloy steel exchangers since it is standard for TEMA Class R.

10.Stress relieve carbon and chrome steel welds and cold bends in amine service regardless of service temperature. For all concentrations of carbonate solutions and in concentrations of caustic up to 30%, stress relieve for service temperatures above 60C. For 30% to 50% caustic, the service

temperature where stress relief is required decreases from 60C to 48C. Welded tubing does not require heat treatment in addition to that required by the ASTM specifications. Rolled tube to tube sheet joints do not require stress relief.

11.Use 12Cr for valve trays and valves. Sieve trays and stationary bubble cap trays must be made of carbon steel.

12.For control valves and other areas of high turbulence (Velocity > 2.5 m/s e.g., downstream of control valves, the rich carbonate inlet of a carbonate regenerator, reboiler tube-sheets, baffles., use 304SS (UNS S30400) plus 1mm corrosion allowance. Do not use miters; long-radius elbows are preferred. Piping specifications usually contain other limitations on miters.

13.Hardness of completed carbon and low-alloy steel welds should not exceed 200 Brinell. Valve trim should be 18Cr-8Ni SS and meet NACE standard MR0175. For piping, if the ammonium bisulfide concentration exceeds 4% or the product of the mol% H_2S and the mol%NH_3 exceeds 0.05, use materials recommended for ppH_2S > 10psia.

14.Use alloy 400 valve trim for caustic service above 93C.

15.The metal temperature should not exceed that where carbon steel starts to lose its resistance to hydrogen attack.

16.If the service temperature will exceed 480C, check with a metal engineer.

17.Stress corrosion cracking of 300 series SS may result if solids carry-over exceeds 1 ppm.

18.Do not use type 405 SS above 343C. When welding is anticipated, use 410S SS rather than 410 SS.

19.For U-bends, heat treat the entire 18Cr-8Ni SS tube at 1000C minimum after bending. Where a 1000C minimum heat-treating temperature is not practical, 900C may be used. Use 321 or 347 SS if only the U-bends can be heat treated.

20. To choose between carbon and alloy steels in hydrogen service, see API-941. The corrosion allowance given in the table must be applied.

21. See Table A-10 for recommended materials for the top of the regenerator column and overhead system.

22.Severe corrosion may occur if lines are not kept above the dew point.

23.Welded assemblies must be heat treated at 900C for four hours after completion to prevent polythionic acid cracking during downtime.

24.Unless more restrictive velocities are specified, the maximum velocity should not exceed 6m/s in mixed phase flow piping where the ammonium bisulfide concentration exceeds 4% or the product of mol% H_2S and the mol% NH_3 exceeds 0.05. Use 2205 for tubes and 309L clad headers

in mixed phase flow where the ammonium bisulfide concentration exceeds 4% and 2205 piping where the ammonium bisulfide concentration exceeds 8%. For control valves where high turbulence occurs due to a pressure drop of greater than 2000psig, use Stellite 6 valve trim and 304L piping for 10 diameters downstream of the control valve.

25.Do not use nickel or cobalt base alloys, e.g., alloy 600, alloy 400, Colmonoy, etc. Stellite may be used.

26.The 1.5mm corrosion allowance should be used where the vessel is externally coated and either internally lined or where experience has shown that the corrosion rate is essentially nil e.g. pure hydrocarbons, dry steam, ertc.

27.The choice between brass and copper nickel alloys is contingent upon ammonia content and temperature of process side. Brass should not be used when the PH due to ammonia exceeds 7.2. Copper nickel alloys should not be used if the sulfides in the water exceed 0.007 mg/l. Admiralty is usually limited to a process limited inlet temperature of 177C for cooling services. Aluminum bronze or copper nickel alloys often are used when the process inlet temperature is 177C to 232C. Aluminum bronze has a somewhat higher tolerance for hydrogen sulfide than copper nickel alloys.

28. For lines and equipment handling catalyst, use refractory-lined steel or hard facing on the indicated alloy. Hard facing is not required for vertical pipe runs.

29. Use solid 5 Cr or 12 Cr clad for hydrocarbons containing over 1 wt% sulfur above 290C and for crude oils containing 0.1 wt% to 1.0 wt% sulfur above 340C unless there is operating experience or hydrogen sulfide evolution data to indicate where the break between carbon steel and alloy should be.
Regardless of the sulfur content, when hydrocarbons have a TAN above 1.5 mg of KOH /gm and the temperature is above 230C, use 316L- except use 317L for California crude oils. For casting, use CF8M, or CG8M provided the ferrite content is 8% minimum.

30. When 18Cr-8 Ni SS is specified, any grade may be used. However, un-stabilized regular carbon (0.08% carbon maximum) grades usually are not used for operating temperatures above 425C. For temperatures above 425C, stabilized grades should be used if there is a possibility of intergranular attack during down-time. For 321 or 347 SS in thickness in excess of 13 mm, restricted chemistry should be used. In addition, 347 should be limited to 19mm maximum to avoid problems associated with welding. Types 309, 310, 316, 321, 347 should be used with caution for operating temperatures above 600C because of the possibility of sigma phase embrittlement.

31.When experience shows that coking will occur above 455C, 1-1/4Cr-1/2Mo can be used up to 590C and 2-1/4Cr-1Mo can be used up to 650C. Conversely, if coking does not occur or if high velocities occur that will prevent coke lay-down, SS is required. The choice between 410S and 18-8 depends on the anticipated loading. This is because 410S will lose some room temperature ductility due to 475C embrittlement. Thus, 410S should be limited to parts with relatively low stress levels.

32.Designations in parenthesis are API-610 materials classes.

33. For water services from 120C to 175C use class S-5. For water service over 175C or boiler feed water over 100C, use class C-6.

34.See note 9 in Table G-1 of API 610.

35.Experience has shown that carbon steel tubes will only give economical life if water treating and corrosion inhibitors additions are carefully controlled on a continual basis.

36.When ammonia is present in the stripper overhead system, ammonium bisulfide forms. This requires 316L for reflux piping.

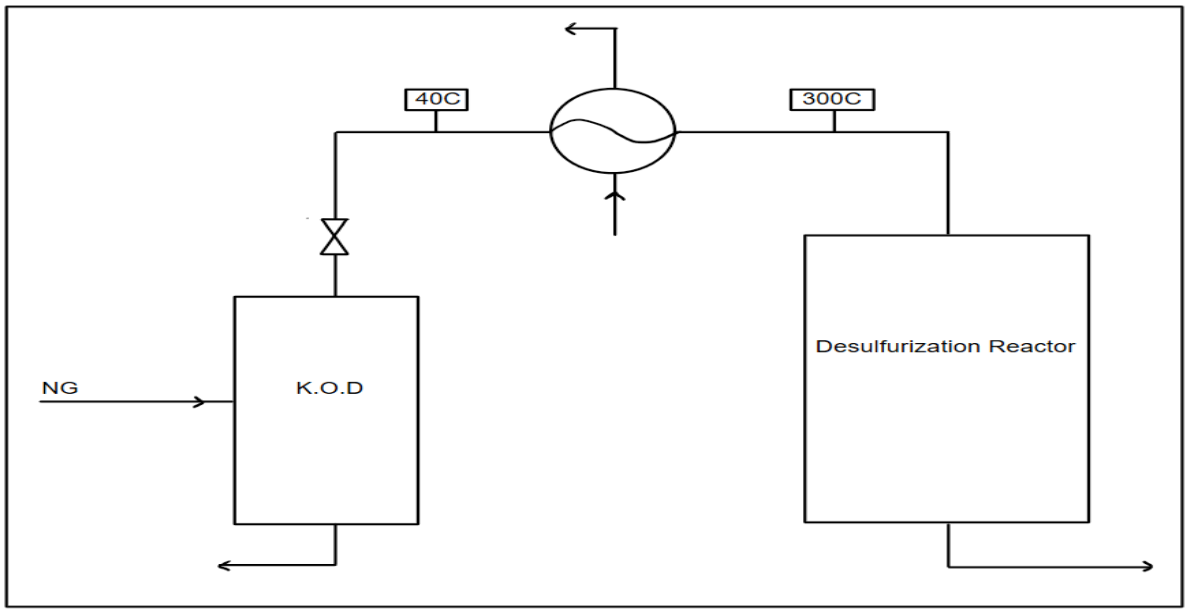
Example 1:

Imagine we are during basic design of a petrochemical plant in Oman and we work as process material specialist in the project.

Process Description:

After passing through gas station to be filtered, measured, and regulated, NG goes to a Knock-out drum, which is typical in most petrochemicals. Since the NG contains some amount of sulfur and the sulfur is poisonous for downstream reactor catalysts, it shall pass through a desulfurization reactor. So far, everything is obvious, right? The desulfurization reactor operates at above 300C, which means that the NG should be preheated from atmospheric temperature like 40C to above 300C.

Sketch:
Here is the sketch:



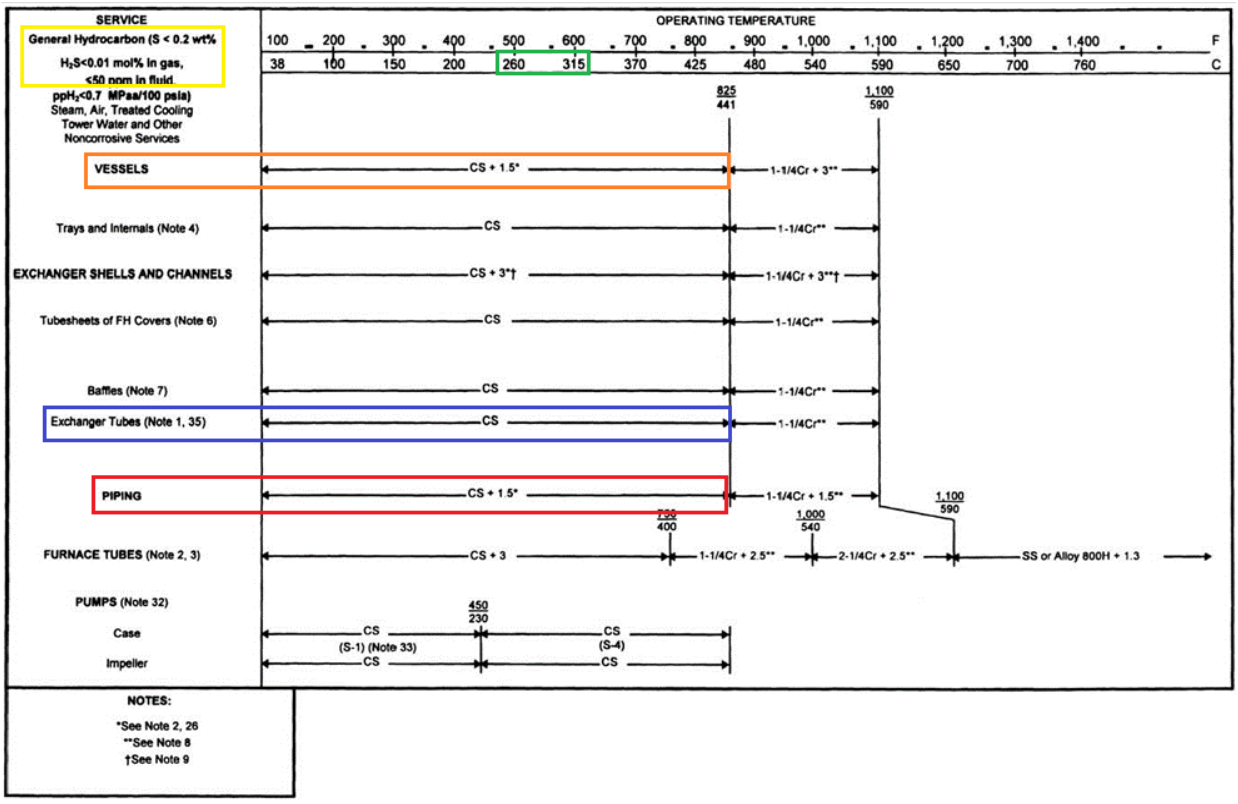
Based on the above tables, specify the material vessels, piping, control valve.

Solution: How to approach as process-material specialist

1. Table Selection: Select one of A-2 to A-16 Tables based on the service mentioned. For this problem, since we have NG as our fluid with low amount of sulfur within the range of Table A-2, then we select Table A-2.

2. Table Output: Based on the Table, since the operating temperature is around 300-400 C, CS is selected as base material for K.O.D, heat exchanger shell, piping and desulfurization reactor, as shown in the following picture:

Table A-2



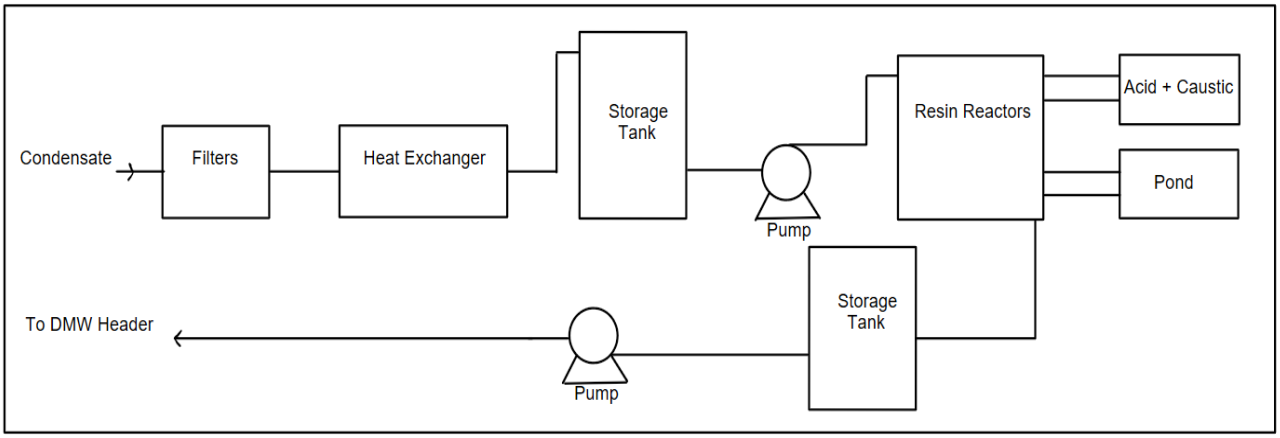
3. Detailed Design: Now use Table A-1 in next page to detail out our material specification:

Equipment	Base Material	Material Grade
K.O. D	CS	A-516
Piping	CS	A-106
Heat Exchanger Tube	CS	A-179
Desulfurization Reactor	CS	A-516

Table A-1

Material (UNS No. as applicable)	Plate	Pipe	Tubing	Forgings & Fittings	Bars	Castings
Cast Iron						A48, A126 A278
Carbon Steel	A285, A515 A516, A537 A737	A53, A106 A671, A672 A691	A214, A179 A192, A210	A105, A181 A266, A234	A29, A575 A576, A663 A675	A216
Carbon-1/2 Mo	A204	A335	A161, A209	A182, A234		A217
1 Cr-1/2 Mo, 1-1/4 Cr-1/2 Mo, & 2-1/4 Cr-1 Mo	A387	A335	A199 A200 A213	A182 A336 A234	A29 A739	A217
5Cr-1/2 Mo	A387	A335	A199, A200 A213	A182, A234		A217
12Cr, CA15	A240		A268	A182	A479	A217
Austenitic Stainless 304, 304L, 316, 316L, 321, 347, 310, CF3, CF3M, CF8, CF8C, CF8M	A240	A312 A358	A213 A249 A271	A182 A336 A403	A479	A351 A744
HK40(J94204) & HP modified						A297
Duplex 2205 SS (S32205)	A240	A790	A789	A182, A815	A276	
6 MoSS (N08367)	B688	B675	B676			
Alloy 800 (N08800)	B409	B407	B163, B407	B366, B564	B408	
Alloy 825 (N08825)	B424	B423	B163, B704	B366	B425	
904L (N08904)	B625	B673, B677	B674, B677		B649	
Alloy 20 (N08020)	B463	B464, B474	B468	B462	B472	A351
Copper (C10200)	B152	B42	B75, B111			
Admiralty Brass (C44300)			B111			
Naval Brass (C46500)	B171				B124	
70-30 Cu-Ni	B171	B467, B608	B111, B395			
Titanium Gr.2 (R50400)	B265	B337	B338	B381	B348	B367
Alloy 400 (N04400)	B127	B165	B163, B165	B564	B164	A494
Alloy 625 (N06625)	B443	B444	B444, B704	B446		
Alloy C276 (N010276)	B575	B622	B622, B626	B574		A494
Ni Resist TP2 (F41002)						A436
Aluminum	B209	B241	B234	B247	B211	

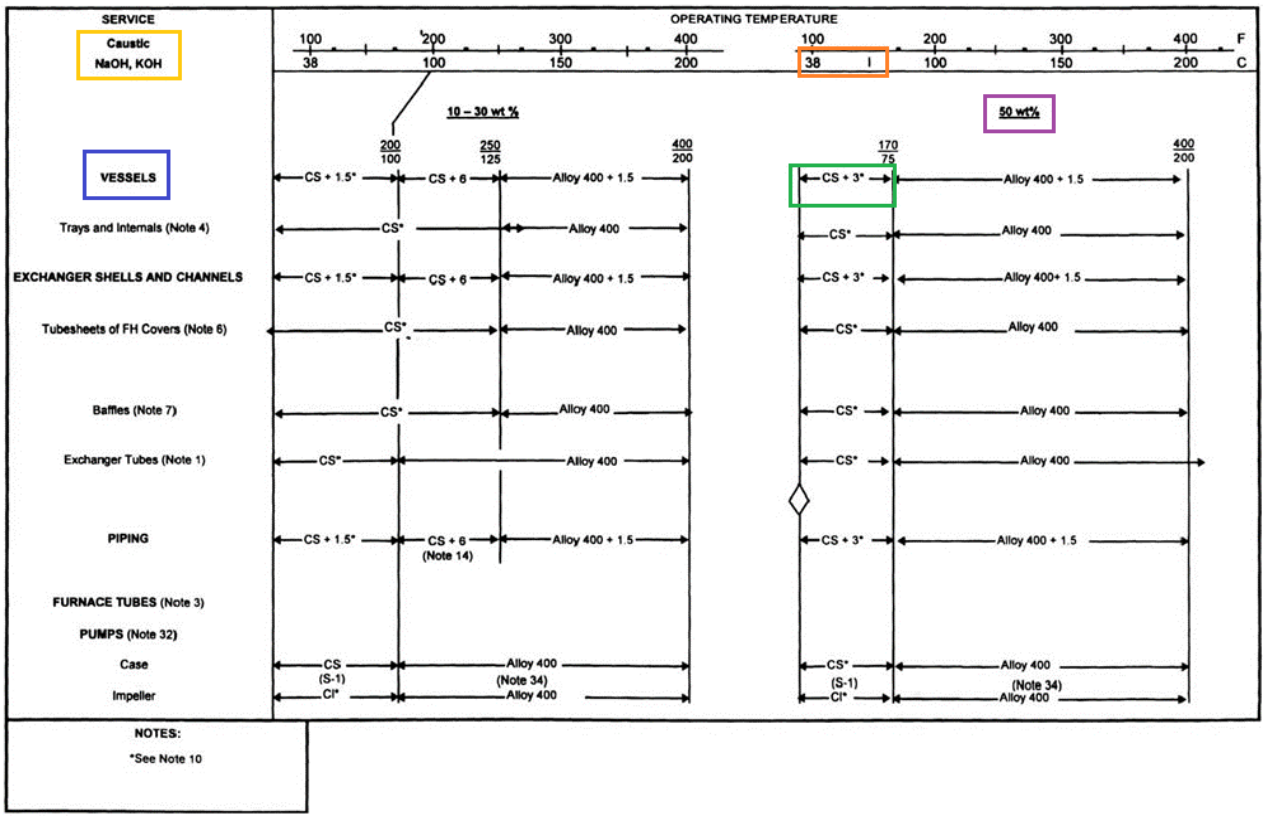
Example 2:In polishing unit whose function is to convert untreated water to high quality DMW, there are acid sulfuric acid and caustic package to provide resin mixed ion exchanger with low concentrated acid and caustic during regeneration process.



Solution:

1.Table Selection: Among tables, Table A-16 is selected, which is developed for caustic services.

2.Table Output: Based on the table, since the operating temperature is atmospheric and the concentration of storage is around 50%, CS is selected.



Example 3: Select body material for control valves for the following applications:

1. Natural Gas
2. Nitrogen
3. Low pressure steam
4. Process water with dissolved CO_2
5. Boiler feed water or BFW
6. Demineralized water or DMW
7. Pure methanol
8. Partially Flashed methanol
9. Condensate which has a pressure drop of 40barg.
10. HHPS with operating temperature of 490C

Solution:

Based on material selection criteria for valve bodies, we can categorize the fluids into three groups:

A. Simple and non-corrosive fluids: Natural Gas, Nitrogen, Low pressure steam, Boiler feed water, pure methanol.
B. High temperature or flashed fluids:
   B.1. HHPS with operating temperature of 490C. It is considered high temperature because it is more than 427C.
   B.2. Partially flashed methanol. Since it is in a state of flash.
   B.3. Condensate which has a pressure drop of 40barg. Such high pressure drop means being in a state of flashed.

C. Corrosive fluids:
   C.1. Process water with dissolved CO_2.
   C.2. Demineralized water or DMW

For group A, based on valve material selection criteria, we select A216 WCB/WCC.

For group B, based on valve material selection criteria, we select A217 WC6/WC9.

For group C, based on valve material selection criteria, we select A351 CF8.

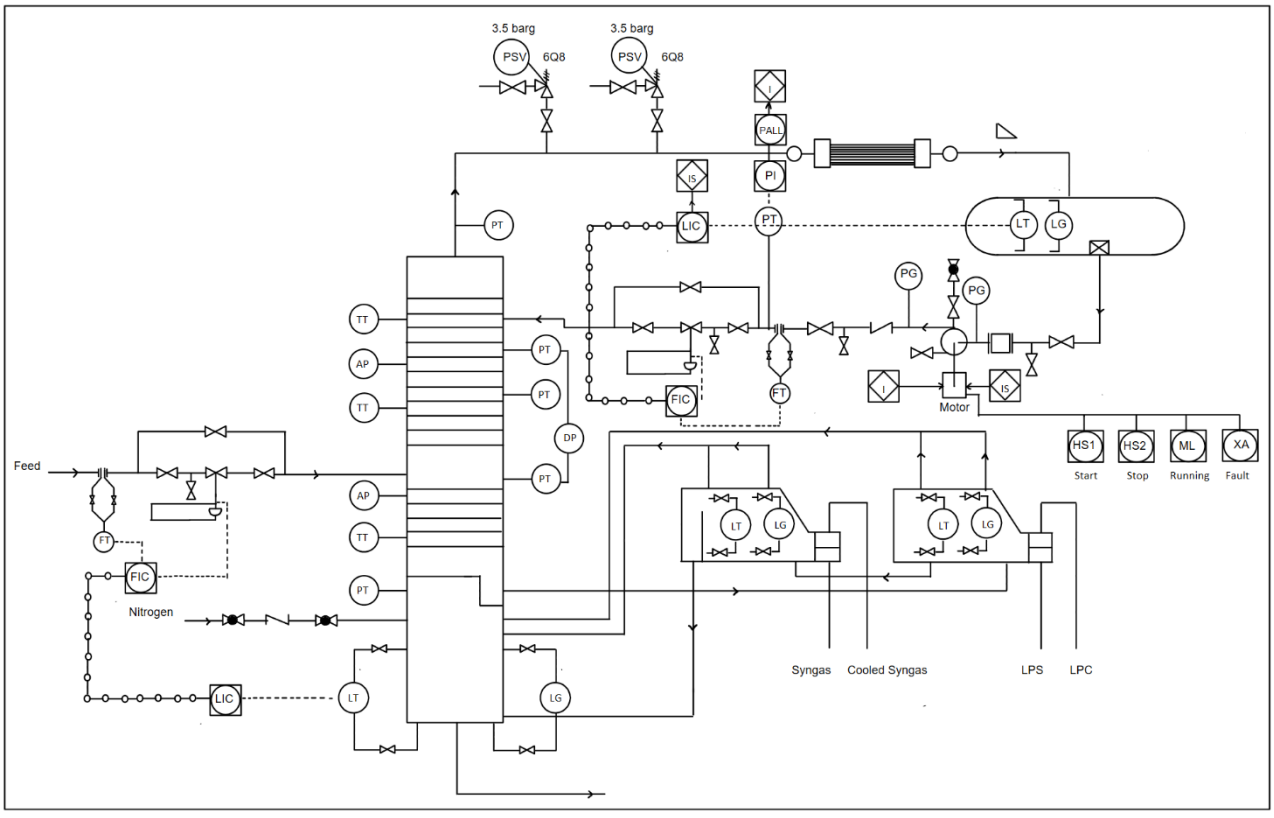
Practice 1:

Here, we have a mixture which is categorized as noncorrosive. The mixture passes through a control valve and its flow is controlled. Then, goes into a distillation column. The mixture then goes into the reboiler, gets heated, and becomes vaporized. The vapor passes through trays and goes up and finally exits the column. The overhead vapor passes through air cooler and becomes condensed. Afterwards, it is held-up in reflux drum and via pump as the reflux is sent to the tower.

Select materials for control valve assembly, reflux drum, pump, distillation column, and reboilers.

Note:

1. By reboilers, it is meant that tube, shell, and baffle materials should be specified.
2. By distillation column, you are supposed to specify valve tray and vessel material.
3. By pumps, you are ought to stipulate the casing and impeller materials.
4. By control valve assembly it is meant to select material for body and trim.



Practice 2:

Select the body material and proper packing for the following applications:

1.CW applications

2.Water coming to the deaerator with 13% flashing

3.Level control valve which is at outlet of pump for a separator which separates process water from a mixture of H_2 + CO + CO_2