

**TECHNICAL SPECIFICATION**

**SELECTED CONSTRUCTION MATERIALS  
FOR  
SHELL AND TUBE HEAT EXCHANGERS**

DEP 31.21.01.31-Gen.

November 1989  
(DEP Circulars 22/92 and 55/97 have been incorporated)

**DESIGN AND ENGINEERING PRACTICE**

USED BY  
COMPANIES OF THE ROYAL DUTCH/SHELL GROUP



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## APPENDICES

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## 1. INTRODUCTION

### 1.1 GENERAL

This publication contains a number of self-contained lists with detailed material specifications for non-fired shell-and-tube heat exchangers including coolers, condensers and reboilers used.

It is not intended as a materials selection guide. The overall selection of construction materials should be made after careful consideration of operating conditions, if necessary in consultation with the materials/corrosion engineering department. Once the selection has been determined, however, the lists in this specification will enable quick and effective specification of all heat exchanger parts. The lists as presented refer primarily to refinery and chemical plant service.

This edition constitutes a complete revision. The format of the lists has been changed to facilitate a unique numbering system for listing the components of the various heat exchanger types. As this DEP is intended to be an aid for completing heat exchanger requisition forms the nomenclature of these sheets has been adhered to. The component list matches the list format as presented on the data requisition sheet, according to DEP 31.21.00.93-Gen. Sheet 6, for heat exchangers.

All remarks added to material specifications are combined in one single short list of comprehensive notes, to which reference is made in the appropriate cases. More detail and some background information to this list is given separately in Section 3 in this document.

Compared to the 1974 issue a significant reduction of additional requirements has been achieved.

The designation of materials refers to the ASTM standards. For comparable material standards, refer to DEP 30.10.02.11-Gen. "Metallic materials". When specific corrosive circumstances have to be taken into account or materials do not comply with the standard, the materials engineering department must be consulted.

Unless otherwise authorized by SIPM, the distribution of this specification is confined to companies forming part of or managed by the Royal Dutch/Shell Group and to contractors nominated by them.

As a rule the requirements of this specification shall be adhered to. However, national and/or local regulations may exist in which some of the requirements are more stringent.

The contractor shall determine by careful scrutiny which of the requirements are 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 specification 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 specification as closely as possible.

Where cross references are made, the number of the section or sub-section referred to is shown in brackets.

## 1.2 DEFINITIONS

For the purpose of this specification, the following definitions shall hold :

**Shall** and **Should** - the word 'shall' is to be understood as mandatory and the word 'should' as strongly recommended to comply with the requirements of this specification.

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, authorized to act for the Principal.

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction and commissioning for the project.

The Principal may sometimes undertake all or part of the duties of the Contractor.

## 2. CLASSIFICATION OF MATERIAL SPECIFICATION LISTS

Six main groups of material specifications have been considered:

- List 1. Heat exchangers.
- List 2. Reboilers.
- List 3. Coolers and condensers with floating head.
- List 4. Coolers and condensers with fixed tube sheets.
- List 5. Heat exchangers made of stainless steel.
- List 6. Heat exchangers made of Monel 400, Alloy N04400.

The most common types of heat exchangers are considered in the lists mentioned above. Among these are: fixed tube sheet, floating head and hairpin bundle designs. It is not the intention to cover all possible heat exchanger designs. Specifications for variants are easy to derive in most cases as materials are virtually the same.

For instance "pull through bundle designs" are not considered in the specification lists since there are only minor dimensional differences from a standard floating head heat exchanger, a smaller floating tube sheet being used. The standard material list for floating head heat exchanger can be applied.

In list 1 both shell side and tube side are assumed to be non-corrosive products. In list 2 both product side and heating medium side are assumed to be non-corrosive. Lists 3 and 4 are intended for non-corrosive products on the shell side and cooling water on the tube side. The materials specified vary from carbon steel to copper alloy depending on the corrosivity of the cooling water.

Two heat exchanger groups with alloy materials are represented in list 5 and 6. List 5 covers heat exchangers of stainless steel grades AISI 304, 321, 316 and list 6 heat exchangers made of Alloy N04400 (Monel 400). In either group different specifications can be distinguished depending on where the alloy material is needed, shell side, tube side or both sides. Only the floating head type has been chosen, but these lists can easily be converted to other types. Three stainless steel grades are combined in list 5 because of similarity, hence in addition to the specification list number the stainless steel grade has to be mentioned, e.g. "List 5A-316L".

### 3. BACKGROUND INFORMATION TO ADDITIONAL REQUIREMENTS

#### 3.1 GENERAL

The material standards specified according to e.g. ASTM do not always completely cover the Shell specifications and engineering philosophy. Therefore additional requirements have to be attached in some cases. However, the aim is to restrict amendments to code specifications as far as possible and practical. In this issue the number of additional notes has again been reduced.

The additional requirements have been summarized in a comprehensive list to which reference is made, in the appropriate cases, in the material specification lists. This list of notes can be found on page 22. A brief explanation of the notes is given below.

##### Note 1.

Note 1 makes reference to the DEP 30.10.02.11-Gen. "Metallic Materials" and is applicable to all items. The latter is a guide to similar and acceptable substitute materials of other standards, such as British Standard, DIN, AFNOR and JIS.

##### Note 2.

Most steels according to ASTM specifications allow for carbon contents far above 0.23%. This increases the potential risk of weld cracking. Most steel manufacturers, however, can satisfy the required lower carbon content as specified in DEP 30.10.60.18-Gen. "Welding of Metals".

##### Note 3.

Some heat exchangers with fixed tube sheets require bellows in the shell to compensate for thermal expansion. The materials for this special construction shall be specified separately. The use of bellow constructions in pressure containing parts is not encouraged by SIPM.

##### Note 4.

It is difficult to clearly define what constitutes corrosive, non-corrosive or mildly-corrosive cooling water and it is advised to consult a materials engineer in case of doubt. Generally it will be necessary to have the cooling water source evaluated by experts in this field in case no "local" references are available with respect to material performance.

To give some guidance the following examples of each condition are given.

##### Example 1: Non-corrosive cooling water.

Cooling water from a closed or semi-closed treated water system can generally be regarded as non-corrosive. This means that the make-up water for treated water systems is of good quality, e.g. condensate or boiler feed water, that inhibitors are added, the oxygen has been removed and pH is continuously controlled.

##### Example 2: Mildly corrosive cooling water.

This condition is more difficult to specify. Local circumstances and experience determine if the material specifications for mildly corrosive cooling water can be followed. Sweet untreated aerated water, e.g. fresh water from a lake, can generally be regarded as mildly corrosive.

##### Example 3: Corrosive cooling water.

Seawater is considered to be corrosive.

Note 5.

Longitudinally welded tubes according to ASTM A214 are allowed. Additional non-destructive-testing (NDT) inspection of the weld seam is required to ensure integrity. For a good (roll-)expanded tube-tube sheet connection, redressing of the weld seam is required. In most cases the additional inspection costs will offset the financial benefit of ASTM A214 compared to ASTM A179 seamless tubes. Longitudinally welded tubes, however, usually have a smoother surface finish compared to the seamless grades although the intrusion of the weld will remain.

Note 6.

For welded tube-tube sheet connections a "cleaner" steel and a fine-grain structure of the steel tube sheet is required to optimize the quality of the weld, therefore ASTM A516 Gr70/65/60 has been specified. The carbon content shall not exceed 0.23% (See note 2). Tube sheets for (roll-)expanded connections shall be of a higher strength grade than the tubes so that the tubes will plastically deform before the tube sheet does, which helps to tighten the connection.

Note 7.

Instead of ASTM A105 forged tube sheet, applicable for fixed tube sheets where welds are an integral part of the pressurized construction, fine grain materials such as ASTM A516 of the appropriate grade with a carbon content not exceeding 0.23% may be used. To ensure sufficient resistance against lamellar tearing in the weld area of the plate, the material shall pass the 35% Z-value test according to ASTM A770. This means that the reduction of area in the tensile test shall exceed 35%.

**Amended per  
Circular 22/92**

Note 8.

Gaskets shall be selected according to DEP 31.21.01.30-Gen. For gaskets of shell and channel nozzles, the piping class of the connecting piping shall be followed.

Note 9.

Lists of approved manufacturers/suppliers were available as DEP documents in the past. These DEP's are obsolete, and have been superseded by a continuous manufacturing auditing/appraisal system managed by the SIPM materials procurement department. Information about suppliers and manufacturers can be obtained via SIPM-MA.

Note 10.

On some occasions, there is a potential risk of chloride stress corrosion cracking of stainless steel. In those cases, Alloy 825 or other resistant material is advised rather than stainless steel AISI 321/316L.

Note 11.

CuNi-alloy heat exchanger tubes of the composition 66%Cu, 30%Ni, 2%Fe and 2%Mn (ASTM B111-C71640 or BS 2871-CN108 in annealed condition), can be applied instead of aluminium-brass tubes when:

- water velocities exceed 1.5 m/s and erosion of aluminium brass is expected,
- corrosion conditions become more severe, e.g. seawater cooled condensers,
- design temperatures exceed 175°C so that mechanical properties of aluminium brass become impractically low.

The above-mentioned CuNi-alloy has proved to be superior as condenser tube material in seawater to the normal CuNi-alloy with 70%Cu and 30%Ni (ASTM B111-C71500). In addition to the standards an electrochemical test has to be specified to ensure that harmful oxide films which can be formed during fabrication are completely removed. These oxide films will cause severe pitting as they are more noble than the bare tube material. The electrochemical test procedure is given in Appendix III.

Note 12.

Magnesium or zinc anodes are used to protect carbon steel. Application according to standard drawings. Iron ions have a beneficial effect on the oxide layer of aluminium-brass tubes and therefore iron anodes are recommended for coolers in "corrosive service" which do not have an uncoated iron channel.

Note 13.

Aluminium bronze B169-C61400 can be applied either as overlay welding or as explosive

cladding. The cladding thickness for tube sheets shall be at least 10 mm to get a tight (roll) expanded joint connection. Refer to DEP 30.10.60.18-Gen. "Welding of metals" for further design details with respect to cladding of carbon steel.

Note 14.

Monel 400, alloy N04400, shall be ordered in the annealed condition. The annealed condition of Monel 400 is required to reduce the cracking susceptibility during welding.

Note 15.

For large heat exchangers it is often much more economic to use clad steel. For tube sheets 10 mm clad thickness is required and for other items 3 mm unless otherwise specified. The specifications for the carbon steel base material are the same as for comparable items made of solid carbon steel, e.g. Note 2 is applicable.

Refer to DEP 31.22.10.32-Gen. and DEP 31.22.20.31-Gen. "Pressure vessels" and DEP 30.10.60.18-Gen. "Welding of metals" for further design details with respect to cladding of carbon steel.

Note 16.

Materials selection for flanges and nozzles of heat exchangers made in whole or in part from alloyed material, either stainless steel or Monel, depends on the type of flange construction. For all constructions the metal at sealing faces and at the internal surfaces shall be of similar chemical composition as the main alloy.

Some examples of flange constructions are:

- lap-joint-flange of carbon steel with a solid alloy stub end;
- slip-on-flange of carbon steel plus overlay welded facing;
- welding-neck-flange with overlay welded internal bore and facing.

Prior to manufacturing full agreement shall be obtained for the type of construction, as not all flange constructions are always acceptable.

**4. MATERIAL SPECIFICATION LISTS INCLUDING SKETCHES OF HEAT EXCHANGERS**

Sketches : Shell and tube heat exchangers  
List 1 : Shell and tube heat exchangers

Sketches : Reboilers  
List 2 : Reboilers

Sketches : Coolers and condensers (floating head)  
List 3 : Coolers and condensers (floating head)

Sketches : Coolers and condensers (fixed tube sheets)  
List 4 : Coolers and condensers (fixed tube sheets)

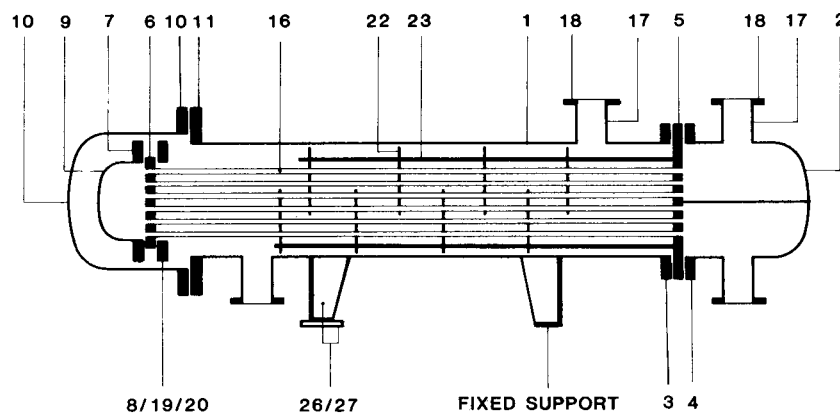
Sketches : Stainless steel heat exchangers  
List 5 : Stainless steel heat exchangers

Sketches : Alloy NO4400 (Monel 400) heat exchangers  
List 6 : Alloy NO4400 (Monel 400) heat exchangers

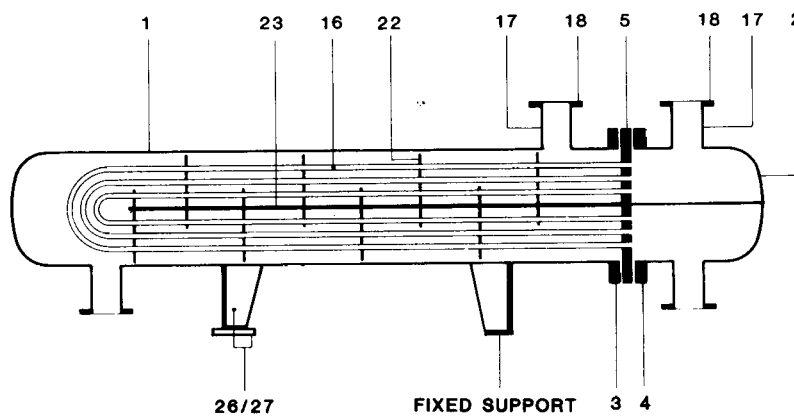
Item list and list of guiding notes (foldout page). Schematic drawings

## SCHEMATIC DRAWINGS

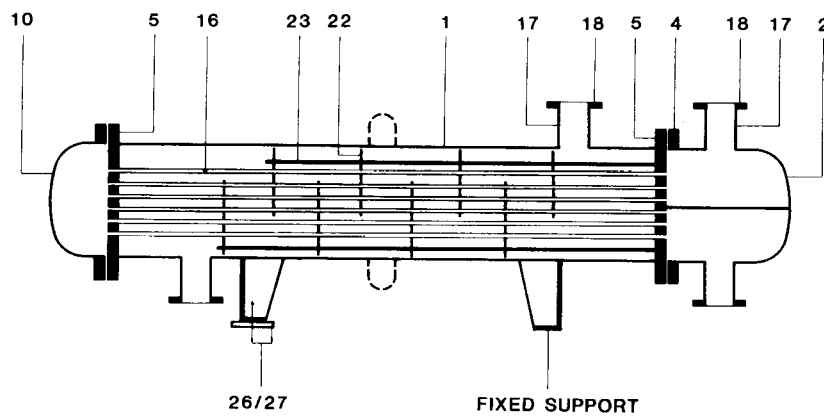
Type A:



Type B:



Type C:

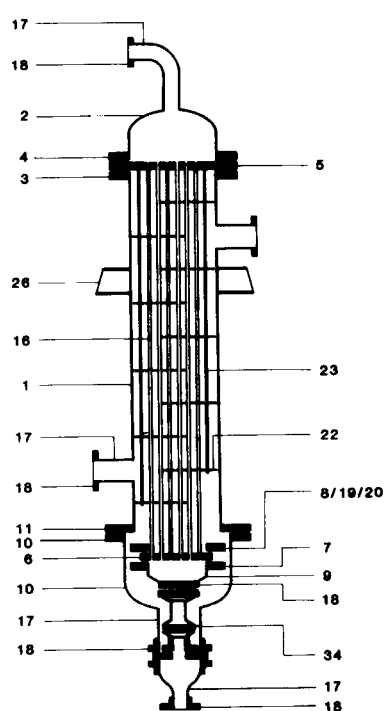


# **LIST 1 MATERIAL SPECIFICATION FOR SHELL AND TUBE HEAT EXCHANGERS**

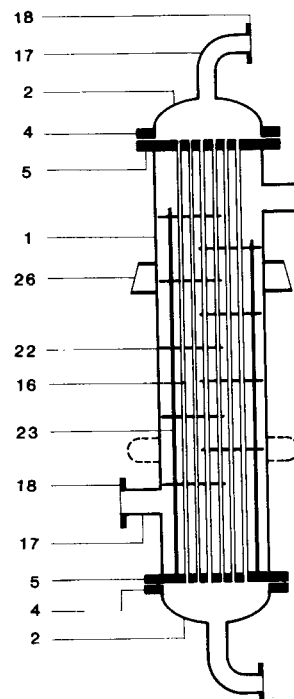
| Type A<br>with floating head |      | Type B<br>with hairpin bundle |      | Type C<br>with fixed tube sheets |      | Item<br>No. |
|------------------------------|------|-------------------------------|------|----------------------------------|------|-------------|
| Shell : Carbon Steel         | Note | Shell : Carbon Steel          | Note | Shell : Carbon Steel             | Note |             |
| Tubes : Carbon Steel         |      | Tubes : Carbon Steel          |      | Tubes : Carbon Steel             |      |             |
| Channel : Carbon Steel       | 1    | Channel : Carbon Steel        | 1    | Channel : Carbon Steel           | 1    |             |
| A515-Gr55/60 or A106-B       | 2    | A515-Gr55/60 or A106-B        | 2    | A515-Gr55/60 or A106-B           | 2,3  | 1           |
| A515-Gr55/60 or A106-B       | 2    | A515-Gr55/60 or A106-B        | 2    | A515-Gr55/60 or A106-B           | 2    | 2           |
| A515-Gr55/60                 | 2    | A515-Gr55/60                  | 2    | A515-Gr55/60                     | 2    | 3           |
| A105                         | 2    | A105                          | 2    | -                                |      | 4           |
| A105                         | 2    | A105                          | 2    | A105                             | 2    | 5           |
| A105                         | 2    | A105                          | 2    | A105                             | 2    | 6           |
| A515-Gr70 or A516-Gr70       | 6    | A515-Gr70 or A516-Gr70        | 6    | A105                             | 2,7  | 7           |
| A515-Gr70 or A516-Gr70       | 6    | -                             |      | -                                |      | 8           |
| A105                         | 2    | -                             |      | -                                |      | 9           |
| A515-Gr55/60 or A105         | 2    | -                             |      | -                                |      | 10          |
| A515-Gr55/60                 | 2    | -                             |      | -                                |      | 11          |
| A515-Gr55/60 or A106-B       | 2    | A515-Gr55/60 or A106-B        | 2    | A515-Gr55/60 or A106-B           | 2    | 12          |
| A515-Gr55/60                 | 2    | A515-Gr55/60                  | 2    | A515-Gr55/60                     | 2    | 13          |
| A105                         | 2    | A105                          | 2    | A105                             | 2    | 14          |
| A105                         | 2    | -                             |      | -                                |      | 15          |
| -                            |      | -                             |      | -                                |      | 16          |
| CAF                          | 8    | CAF                           | 8    | CAF                              | 8    | 17          |
| CAF                          | 8    | CAF                           | 8    | CAF                              | 8    | 18          |
| CAF                          | 8    | CAF                           | 8    | CAF                              | 8    | 19          |
| A193-B7 and A194-Gr2H        | 9    | A193-B7 and A194-Gr2H         | 9    | A193-B7 and A194-Gr2H            | 9    | 20          |
| A193-B7 and A194-Gr2H        | 9    | A193-B7 and A194-Gr2H         | 9    | A193-B7 and A194-Gr2H            | 9    | 21          |
| A179                         | 5    | A179                          | 5    | A179                             | 5    | 22          |
| A106-B                       | 2    | A106-B                        | 2    | A106-B                           | 2    | 23          |
| A106-B                       | 2    | A106-B                        | 2    | A106-B                           | 2    | 24          |
| A105                         | 2    | A105                          | 2    | A105                             | 2    | 25          |
| A105                         | 2    | A105                          | 2    | A105                             | 2    | 26          |
| A576-Gr1045                  |      | -                             |      | -                                |      | 27          |
| A105                         | 2    | -                             |      | -                                |      | 28          |
| -                            |      | -                             |      | -                                |      | 29          |
| -                            |      | -                             |      | -                                |      | 30          |
| A283-C                       | 2    | A283-C                        | 2    | A283-C                           | 2    | 31          |
| A283-C or A675-Gr50          | 2    | A283-C or A675-Gr50           | 2    | A283-C or A675-Gr50              | 2    | 32          |
| -                            |      | -                             |      | -                                |      | 33          |
| -                            |      | -                             |      | -                                |      | 34          |
| -                            |      | -                             |      | -                                |      | 35          |

# SCHEMATIC DRAWINGS

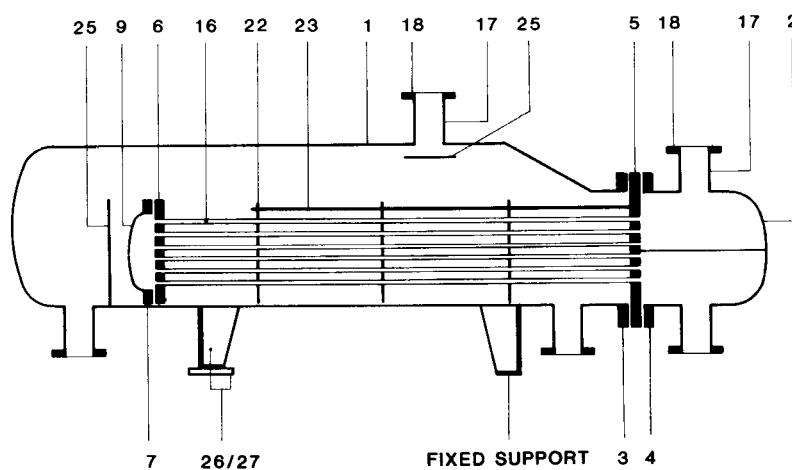
Type A:



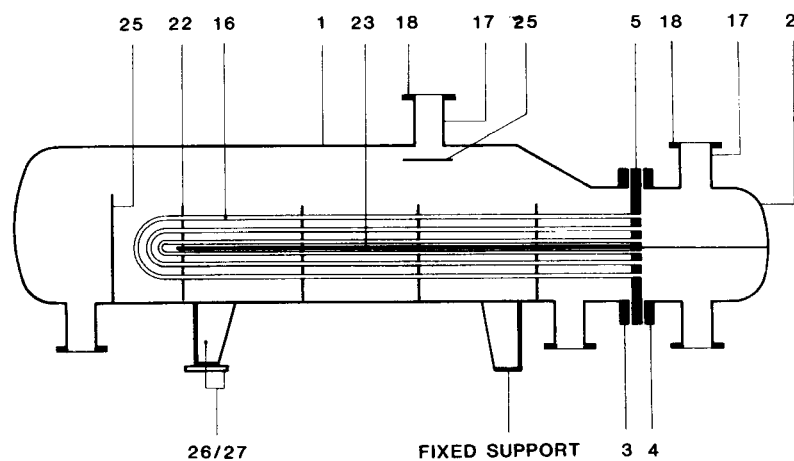
Type B:



Type C:



Type D:

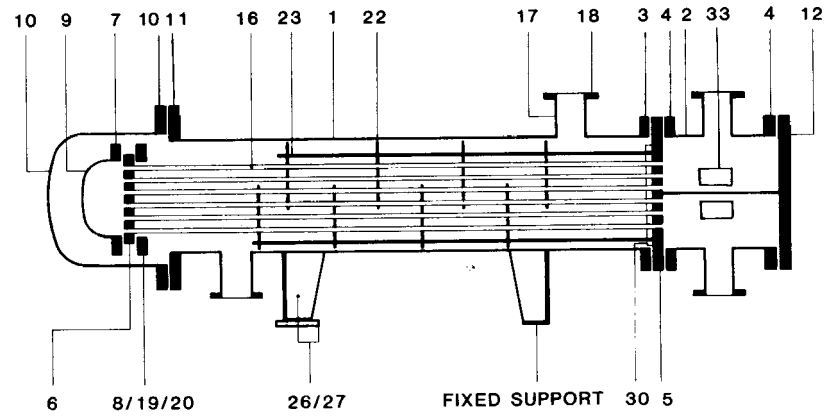


## LIST 2 MATERIAL SPECIFICATION FOR REBOILERS

| Type A<br>Vertical, floating head |      | Type B<br>Vertical, fixed tubesheets |      | Type C<br>Kettle-type, floating head |      | Type D<br>Kettle-type, hairpin |      | Item<br>No. |
|-----------------------------------|------|--------------------------------------|------|--------------------------------------|------|--------------------------------|------|-------------|
| Shell : Carbon Steel              | Note | Shell : Carbon Steel                 | Note | Shell : Carbon Steel                 | Note | Shell : Carbon Steel           | Note |             |
| Tubes : Carbon Steel              |      | Tubes : Carbon Steel                 |      | Tubes : Carbon Steel                 |      | Tubes : Carbon Steel           |      |             |
| Channel : Carbon Steel            | 1    | Channel : Carbon Steel               | 1    | Channel : Carbon Steel               | 1    | Channel : Carbon Steel         | 1    |             |
| A515-Gr55/60 or A106-B            | 2    | A515-Gr55/60 or A106-B               | 2,3  | A515-Gr55/60 or A106-B               | 2    | A515-Gr55/60 or A106-B         | 2    | 1           |
| A515-Gr55/60 or A106-B            | 2    | A515-Gr55/60 or A106-B               | 2    | A515-Gr55/60 or A106-B               | 2    | A515-Gr55/60 or A106-B         | 2    | 2           |
| A515-Gr55/60                      | 2    | A515-Gr55/60                         | 2    | A515-Gr55/60                         | 2    | A515-Gr55/60                   | 2    | 3           |
| A105                              | 2    | A105                                 | 2    | A105                                 | 2    | A105                           | 2    | 4           |
| A105                              | 2    | A105                                 | 2    | A105                                 | 2    | A105                           | 2    | 5           |
| A515-Gr70 or A516-Gr70            | 6    | A105                                 | 2,7  | A515-Gr70 or A516-Gr70               | 6    | A515-Gr70 or A516-Gr70         | 6    | 6           |
| A515-Gr70 or A516-Gr70            | 6    | -                                    |      | A515-Gr70 or A516-Gr70               | 6    | -                              |      | 7           |
| A105                              | 2    | -                                    |      | A105                                 | 2    | -                              |      | 8           |
| A515-Gr55/60 or A105              | 2    | -                                    |      | A515-Gr55/60 or A105                 | 2    | -                              |      | 9           |
| A515-Gr55/60                      | 2    | -                                    |      | A515-Gr55/60                         | 2    | -                              |      | 10          |
| A515-Gr55/60 or A106-B            | 2    | A515-Gr55/60 or A106-B               | 2    | -                                    |      | -                              |      | 11          |
| A515-Gr55/60                      | 2    | A515-Gr55/60                         | 2    | -                                    |      | -                              |      | 12          |
| A105                              | 2    | A105                                 | 2    | -                                    |      | -                              |      | 13          |
| A105                              | 2    | -                                    |      | -                                    |      | -                              |      | 14          |
| -                                 | 8    | -                                    | 8    | -                                    | 8    | -                              | 8    | 15          |
| -                                 | 8    | -                                    | 8    | -                                    | 8    | -                              | 8    | 16          |
| -                                 | 8    | -                                    | 8    | -                                    | 8    | -                              | 8    | 17          |
| A193-B7 and A194-Gr2H             | 9    | A193-B7 and A194-Gr2H                | 9    | A193-B7 and A194-Gr2H                | 9    | A193-B7 and A194-Gr2H          | 9    | 18          |
| A193-B7 and A194-Gr2H             | 9    | A193-B7 and A194-Gr2H                | 9    | A193-B7 and A194-Gr2H                | 9    | A193-B7 and A194-Gr2H          | 9    | 19          |
| A179                              | 5    | A179                                 | 5    | A179                                 | 5    | A179                           | 5    | 20          |
| A106-B                            | 2    | A106-B                               | 2    | A106-B                               | 2    | A106-B                         | 2    | 21          |
| A106-B                            | 2    | A106-B                               | 2    | A106-B                               | 2    | A106-B                         | 2    |             |
| A105                              | 2    | A105                                 | 2    | A105                                 | 2    | A105                           | 2    |             |
| A105                              | 2    | A105                                 | 2    | A105                                 | 2    | A105                           | 2    |             |
| A576-Gr1045                       |      | -                                    |      | A576-Gr1045                          |      | -                              |      |             |
| A105                              | 2    | -                                    |      | A105                                 | 2    | -                              |      |             |
| -                                 |      | -                                    |      | -                                    |      | -                              |      |             |
| A283-C                            | 2    | A283-C                               | 2    | A283-C                               | 2    | A283-C                         | 2    | 22          |
| A283-C or A675-Gr50               | 2    | A283-C or A675-Gr50                  | 2    | A283-C or A675-Gr50                  | 2    | A283-C or A675-Gr50            | 2    | 23          |
| -                                 |      | -                                    |      | -                                    |      | -                              |      | 24          |
| -                                 |      | -                                    |      | A283-C                               | 2    | A283-C                         | 2    | 25          |
| A283-C                            | 2    | A283-C                               | 2    | A283-C                               | 2    | A283-C                         | 2    | 26          |
| A283-C                            | 2    | A283-C                               | 2    | A283-C                               | 2    | A283-C                         | 2    | 27          |
| -                                 |      | -                                    |      | -                                    |      | -                              |      | 28          |
| A240 type 321/316L                | 10   | -                                    |      | -                                    |      | -                              |      | 29          |
| -                                 |      | -                                    |      | -                                    |      | -                              |      | 30          |
| -                                 |      | -                                    |      | -                                    |      | -                              |      | 31          |
| A283-C or A675-Gr50               | 2    | -                                    | 2    | A283-C or A675-Gr50                  | 2    | A283-C or A675-Gr50            | 2    | 32          |
| -                                 |      | -                                    |      | -                                    |      | -                              |      | 33          |
| A105/A106B                        | 2    | -                                    |      | -                                    |      | -                              |      | 34          |
| -                                 |      | -                                    |      | -                                    |      | -                              |      | 35          |

## SCHEMATIC DRAWINGS

Type A/B/C:



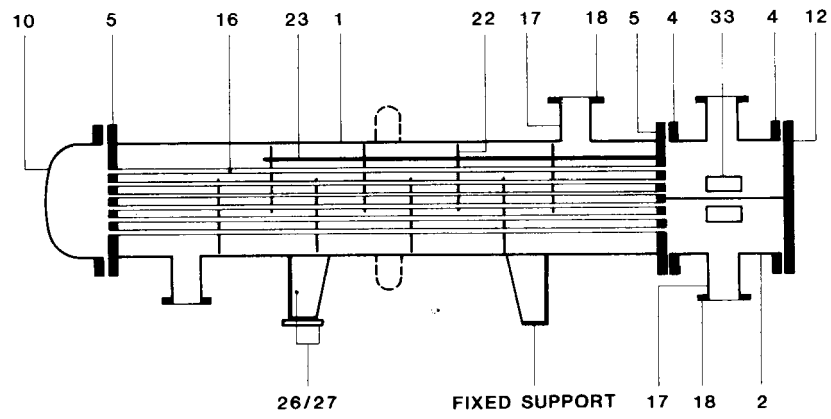
### LIST 3 MATERIAL SPECIFICATION FOR COOLERS AND CONDENSERS WITH FLOATING HEAD

Amended per  
Circular 55/97

| Type A<br>non-corrosive cooling water<br>Shell : Carbon Steel<br>Tubes : Carbon Steel<br>Channel : Carbon Steel | 4<br><br><br>Note<br>1 | Type B<br>mildly-corrosive cooling water<br>Shell : Carbon Steel<br>Tubes : Copper Alloy<br>Channel : Carbon Steel | 4<br><br><br>Note<br>1 | Type C<br>corrosive cooling water<br>Shell : Carbon Steel<br>Tubes : Copper Alloy<br>Channel : Copper Alloy | 4<br><br><br>Note<br>1 | Item<br>No. |
|-----------------------------------------------------------------------------------------------------------------|------------------------|--------------------------------------------------------------------------------------------------------------------|------------------------|-------------------------------------------------------------------------------------------------------------|------------------------|-------------|
| A515-Gr55/60 or A106-B                                                                                          | 2                      | A515-Gr55/60 or A106-B                                                                                             | 2                      | A515-Gr55/60 or A106-B                                                                                      | 2,3                    | 1           |
| A515-Gr55/60 or A106-B                                                                                          | 2                      | A515-Gr55/60 or A106-B                                                                                             | 2                      | B148 C95800, Ni-AL Bronze                                                                                   | 9                      | 2           |
| -                                                                                                               |                        | -                                                                                                                  |                        | -                                                                                                           |                        |             |
| A105                                                                                                            | 2                      | A105                                                                                                               | 2                      | A105                                                                                                        | 2                      | 3           |
| A105                                                                                                            | 2                      | A105                                                                                                               | 2                      | Integral part of item 2                                                                                     |                        | 4           |
| A105                                                                                                            | 2                      | A105                                                                                                               | 2                      | Integral part of item 2                                                                                     |                        |             |
| A515-Gr70 or A516-Gr70                                                                                          | 6                      | B171 C63000, AL-Ni Bronze                                                                                          |                        | B171 C63000, AL-Ni Bronze                                                                                   |                        | 5           |
| A515-Gr70 or A516-Gr70                                                                                          | 6                      | B171 C63000, AL-Ni Bronze                                                                                          |                        | B171 C63000, AL-Ni Bronze                                                                                   |                        | 6           |
| A105                                                                                                            | 2                      | Integral part of item 9                                                                                            |                        | Integral part of item 9                                                                                     |                        | 7           |
| A515-Gr55/60 or A105                                                                                            | 2                      | A515-Gr55/60 or A105                                                                                               | 2                      | A515-Gr55/60 or A105                                                                                        | 2                      | 8           |
| A515-Gr55/60 or A106-B                                                                                          | 2                      | B148 C95800, Ni-AL Bronze                                                                                          |                        | B148 C95800, Ni-AL Bronze                                                                                   |                        | 9           |
| A515-Gr55/60                                                                                                    | 2                      | A515-Gr55/60                                                                                                       | 2                      | A515-Gr55/60                                                                                                | 2                      | 10          |
| A515-Gr55/60 or A106-B                                                                                          | 2                      | A515-Gr55/60 or A106-B                                                                                             | 2                      | A515-Gr55/60 or A106-B                                                                                      | 2                      |             |
| A105                                                                                                            | 2                      | A105                                                                                                               | 2                      | A105                                                                                                        | 2                      |             |
| A105                                                                                                            | 2                      | A105                                                                                                               | 2                      | A105                                                                                                        | 2                      | 11          |
| A515-Gr55/60                                                                                                    | 2                      | A515-Gr55/60                                                                                                       | 2                      | B171 C63000, AL-Ni Bronze                                                                                   |                        | 12          |
| CAF                                                                                                             | 8                      | CAF                                                                                                                | 8                      | CAF                                                                                                         | 8                      | 13          |
| CAF                                                                                                             | 8                      | CAF                                                                                                                | 8                      | CAF                                                                                                         | 8                      |             |
| CAF                                                                                                             | 8                      | CAF                                                                                                                | 8                      | CAF                                                                                                         | 8                      |             |
| A193-B7 and A194-Gr2H                                                                                           | 9                      | A193-B7 and A194-Gr2H                                                                                              | 9                      | A193-B7 and A194-Gr2H                                                                                       | 9                      | 14          |
| A193-B7 and A194-Gr2H                                                                                           | 9                      | A193-B7 and A194-Gr2H                                                                                              | 9                      | A193-B7 and A194-Gr2H                                                                                       | 9                      | 15          |
| A179                                                                                                            | 5                      | B111 C68700, Al-Brass                                                                                              | 11                     | B111 C68700, Al-Brass                                                                                       | 11                     | 16          |
| A106-B                                                                                                          | 2                      | A106-B                                                                                                             | 2                      | A106-B                                                                                                      | 2                      | 17          |
| A106-B                                                                                                          | 2                      | A106-B                                                                                                             | 2                      | Integral part of item 2                                                                                     |                        |             |
| A105                                                                                                            | 2                      | A105                                                                                                               | 2                      | A105                                                                                                        | 2                      | 18          |
| A105                                                                                                            | 2                      | A105                                                                                                               | 2                      | Integral part of item 2                                                                                     |                        |             |
| A576-Gr1045                                                                                                     |                        | A576-Gr1045                                                                                                        |                        | A576-Gr1045                                                                                                 |                        | 19          |
| A105                                                                                                            | 2                      | A105                                                                                                               | 2                      | A105                                                                                                        | 2                      | 20          |
| -                                                                                                               |                        | -                                                                                                                  |                        | -                                                                                                           |                        | 21          |
| -                                                                                                               |                        | B169 C61400, AL Bronze                                                                                             | 15                     | B169 C61400, AL Bronze                                                                                      | 15                     |             |
| -                                                                                                               |                        | B169 C61400, AL Bronze                                                                                             | 15                     | B169 C61400, AL Bronze                                                                                      | 15                     |             |
| -                                                                                                               |                        | B169 C61400, AL Bronze                                                                                             | 15                     | B169 C61400, AL Bronze                                                                                      | 15                     |             |
| A283-C                                                                                                          | 2                      | B171 C46400, Naval Brass                                                                                           | 2                      | B171 C46400, Naval Brass                                                                                    | 2                      | 22          |
| A283-C or A675-Gr50                                                                                             | 2                      | A283-C or A675-Gr50                                                                                                | 2                      | A283-C or A675-Gr50                                                                                         | 2                      | 23          |
| -                                                                                                               |                        | -                                                                                                                  |                        | -                                                                                                           |                        | 24          |
| -                                                                                                               |                        | -                                                                                                                  |                        | -                                                                                                           |                        | 25          |
| A283-C                                                                                                          | 2                      | A283-C                                                                                                             | 2                      | A283-C                                                                                                      | 2                      | 26          |
| A283-C                                                                                                          | 2                      | A283-C                                                                                                             | 2                      | A283-C                                                                                                      | 2                      | 27          |
| -                                                                                                               |                        | -                                                                                                                  |                        | -                                                                                                           |                        | 28          |
| -                                                                                                               |                        | -                                                                                                                  |                        | -                                                                                                           |                        | 29          |
| -                                                                                                               |                        | A283-C or A675-Gr50                                                                                                |                        | A283-C or A675-Gr50                                                                                         |                        | 30          |
| -                                                                                                               |                        | A193-B7 and A194-Gr2H                                                                                              | 9                      | A193-B7 and A194-Gr2H                                                                                       | 9                      | 31          |
| A283-C or A675-Gr50                                                                                             | 2                      | A283-C or A675-Gr50                                                                                                | 2                      | A283-C or A675-Gr50                                                                                         | 2                      | 32          |
| -                                                                                                               |                        | Magnesium or Zinc                                                                                                  | 12                     | Steel                                                                                                       | 12                     | 33          |
| -                                                                                                               |                        | -                                                                                                                  |                        | -                                                                                                           |                        | 34          |
| -                                                                                                               |                        | -                                                                                                                  |                        | -                                                                                                           |                        | 35          |

## SCHEMATIC DRAWINGS

Type A/B/C:

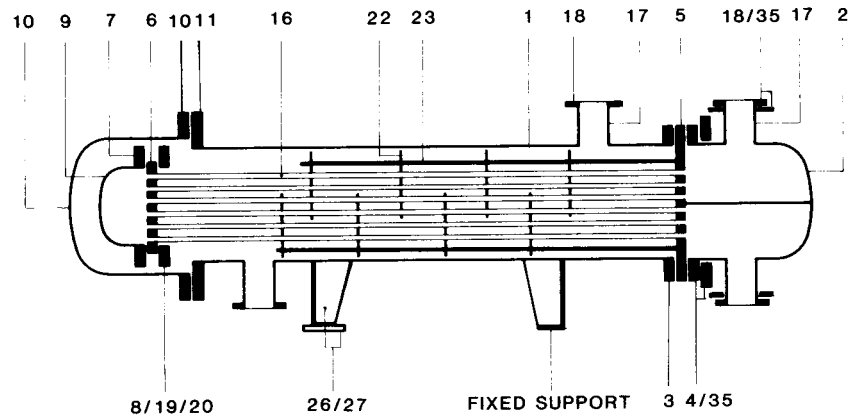


#### LIST 4 MATERIAL SPECIFICATION FOR COOLERS AND CONDENSERS WITH FIXED TUBE SHEETS

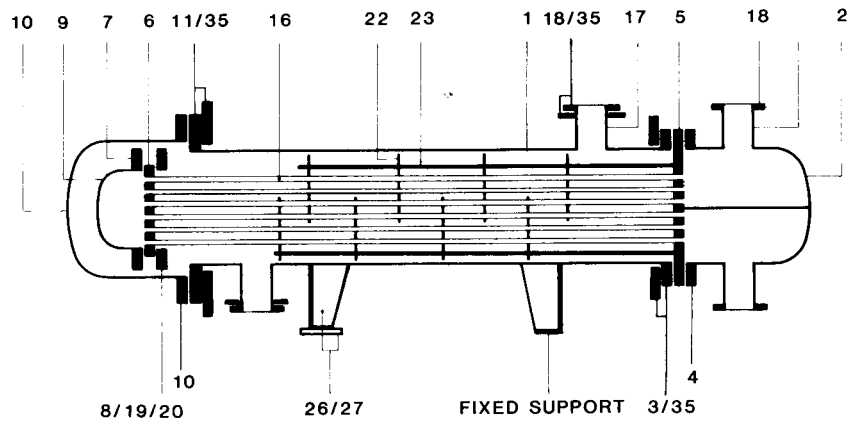
| Type A<br>non-corrosive cooling water | 4    | Type B<br>midly-corrosive cooling water | 4    | Type C<br>corrosive cooling water | 4    |      |
|---------------------------------------|------|-----------------------------------------|------|-----------------------------------|------|------|
| Shell : Carbon Steel                  |      | Shell : Carbon Steel                    |      | Shell : Carbon Steel              |      |      |
| Tubes : Carbon Steel                  | Note | Tubes : Copper Alloy                    | Note | Tubes : Copper Alloy              | Note | Item |
| Channel : Carbon Steel                | 1    | Channel : Carbon Steel                  | 1    | Channel : Copper Alloy            | 1    | No.  |
| A515-Gr55/60 or A106-B                | 2    | A515-Gr55/60 or A106-B                  | 2    | A515-Gr55/60 or A106-B            | 2,3  | 1    |
| A515-Gr55/60 or A106-B                | 2    | A515-Gr55/60 or A106-B                  | 2    | B148 C95800, Ni-AL Bronze         | 9    | 2    |
| -                                     |      | -                                       |      | -                                 |      |      |
| A105                                  | 2    | A105                                    | 2    | A105                              | 2    | 3    |
| A105                                  | 2    | A105                                    | 2    | Integral part of item 2           |      | 4    |
| A105                                  | 2    | A105                                    | 2    | Integral part of item 2           |      |      |
| A105                                  | 2,7  | A105/B169 C61400 AL Bronze              | 2/13 | A105/B169 C61400 AL Bronze        | 2/13 | 5    |
| -                                     |      | -                                       |      | -                                 |      | 6    |
| -                                     |      | -                                       |      | -                                 |      | 7    |
| -                                     |      | -                                       |      | -                                 |      | 8    |
| -                                     |      | -                                       |      | -                                 |      | 9    |
| A515-Gr55/60 or A106-B                | 2    | A515-Gr55/60 or A106-B                  | 2    | B148 C95800, Ni-AL Bronze         | 9    | 10   |
| A515-Gr55/60                          | 2    | A515-Gr55/60                            | 2    | Integral part of item 10          |      |      |
| A105                                  | 2    | A105                                    | 2    | Integral part of item 10          |      |      |
| A105                                  | 2    | A105                                    | 2    | A105                              | 2    | 11   |
| A515-Gr55/60                          | 2    | A515-Gr55/60                            | 2    | B171 C63000, AL-Ni Bronze         |      | 12   |
| CAF                                   | 8    | CAF                                     | 8    | CAF                               | 8    | 13   |
| CAF                                   | 8    | CAF                                     | 8    | CAF                               | 8    |      |
| CAF                                   | 8    | CAF                                     | 8    | CAF                               | 8    |      |
| A193-B7 and A194-Gr2H                 | 9    | A193-B7 and A194-Gr2H                   | 9    | A193-B7 and A194-Gr2H             | 9    | 14   |
| A193-B7 and A194-Gr2H                 | 9    | A193-B7 and A194-Gr2H                   | 9    | A193-B7 and A194-Gr2H             | 9    | 15   |
| A179                                  | 5    | B111 C68700, Al-Brass                   | 11   | B111 C68700, Al-Brass             | 11   | 16   |
| A106-B                                | 2    | A106-B                                  | 2    | A106-B                            | 2    | 17   |
| A106-B                                | 2    | A106-B                                  | 2    | Integral part of item 2           |      |      |
| A105                                  | 2    | A105                                    | 2    | A105                              | 2    | 18   |
| A105                                  | 2    | A105                                    | 2    | Integral part of item 2           |      |      |
| -                                     |      | -                                       |      | -                                 |      | 19   |
| -                                     |      | -                                       |      | -                                 |      | 20   |
| -                                     |      | -                                       |      | -                                 |      | 21   |
| -                                     |      | B169 C61400, AL Bronze                  | 15   | B169 C61400, AL Bronze            | 15   |      |
| -                                     |      | B169_C61400,_AL_Bronze                  | 15   | B169_C61400,_AL_Bronze            | 15   |      |
| A283-C                                | 2    | B171 C46400, Naval Brass                | 2    | B171 C46400, Naval Brass          | 2    | 22   |
| A283-C or A675-Gr50                   | 2    | A283-C or A675-Gr50                     | 2    | A283-C or A675-Gr50               | 2    | 23   |
| -                                     |      | -                                       |      | -                                 |      | 24   |
| -                                     |      | -                                       |      | -                                 |      | 25   |
| A283-C                                | 2    | A283-C                                  | 2    | A283-C                            | 2    | 26   |
| A283-C                                | 2    | A283-C                                  | 2    | A283-C                            | 2    | 27   |
| -                                     |      | -                                       |      | -                                 |      | 28   |
| -                                     |      | -                                       |      | -                                 |      | 29   |
| -                                     |      | -                                       |      | -                                 |      | 30   |
| -                                     |      | -                                       |      | -                                 |      | 31   |
| A283-C or A675-Gr50                   | 2    | A283-C or A675-Gr50                     | 2    | A283-C or A675-Gr50               | 2    | 32   |
| -                                     |      | Magnesium_or_Zinc                       | 12   | Steel                             | 12   | 33   |
| -                                     |      | -                                       |      | -                                 |      | 34   |
| -                                     |      | -                                       |      | -                                 |      | 35   |

# SCHEMATIC DRAWINGS

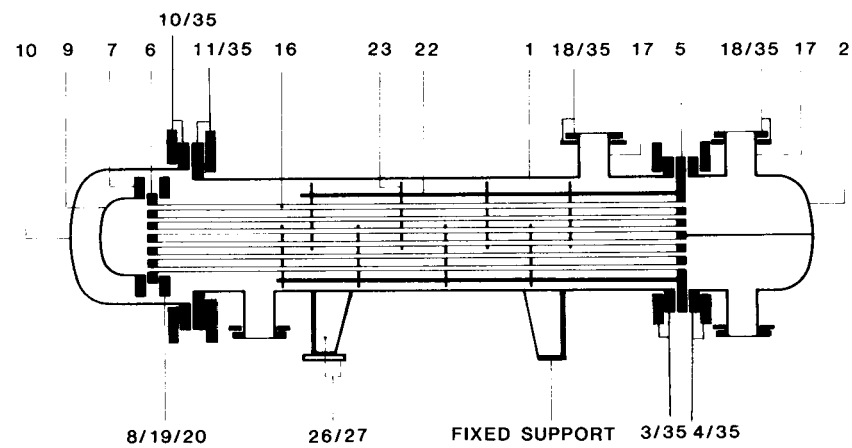
Type A:



Type B:



Type C:

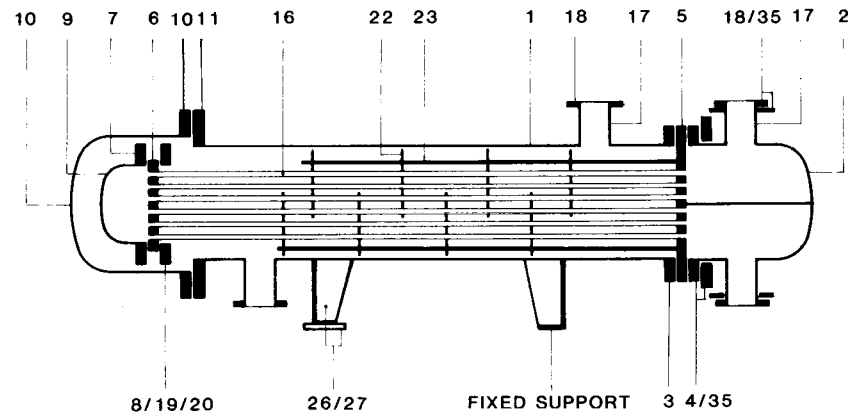


**LIST 5 MATERIAL SPECIFICATION FOR STAINLESS STEEL HEAT EXCHANGERS WITH A FLOATING HEAD**

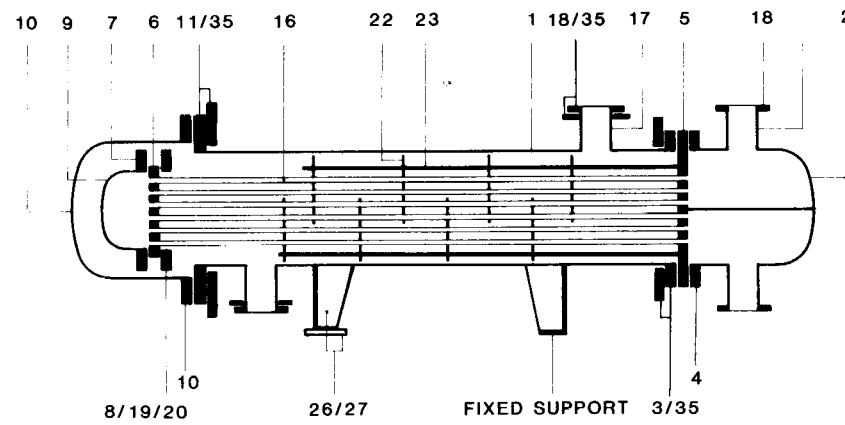
| Type A                        |                   |      | Type B                        |                   |      | Type C                        |                   |      | Item No. |
|-------------------------------|-------------------|------|-------------------------------|-------------------|------|-------------------------------|-------------------|------|----------|
| Shell : Carbon Steel          | Tubes : Stainless | Note | Shell : Stainless             | Tubes : Stainless | Note | Shell : Stainless             | Tubes : Stainless | Note |          |
| Channel : Stainless           |                   |      | Channel : Carbon Steel        |                   |      | Channel : Stainless           |                   |      |          |
| A515-Gr55/60 or A106-B        |                   | 2    | A240 or A312 TP-304L/316L/321 |                   |      | A240 or A312 TP-304L/316L/321 |                   |      | 1        |
| A240 or A312 TP-304L/316L/321 |                   |      | A515-Gr55/60 or A106-B        |                   | 2    | A240 or A312 TP-304L/316L/321 |                   |      | 2        |
| A240 or A312 TP-304L/316L/321 |                   |      | A515-Gr55/60 or A106-B        |                   | 2    | A240 or A312 TP-304L/316L/321 |                   |      |          |
| A105                          |                   | 2    | A182 F-304L/316L/321          |                   | 16   | A182 F-304L/316L/321          |                   | 16   | 3        |
| A182 F-304L/316L/321          |                   | 16   | A105                          |                   | 2    | A182 F-304L/316L/321          |                   | 16   | 4        |
| -                             |                   |      | -                             |                   |      | -                             |                   |      |          |
| A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | 5        |
| A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | 6        |
| A182 F-304L/316L/321          |                   | 16   | A182 F-304L/316L/321          |                   | 16   | A182 F-304L/316L/321          |                   | 16   | 7        |
| A240 or A312 TP-304L/316L/321 |                   |      | A515-Gr55/60 or A106-B        |                   | 2    | A240 or A312 TP-304L/316L/321 |                   |      | 8        |
| A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | 9        |
| A515-Gr55/60 or A106-B        |                   | 2    | A240 or A312 TP-304L/316L/321 |                   |      | A240 or A312 TP-304L/316L/321 |                   |      | 10       |
| A515-Gr55/60                  |                   | 2    | A240 or A312 TP-304L/316L/321 |                   |      | A240 or A312 TP-304L/316L/321 |                   |      |          |
| A105                          |                   | 2    | A182 F-304L/316L/321          |                   | 16   | A182 F-304L/316L/321          |                   | 16   |          |
| A105                          |                   | 2    | A182 F-304L/316L/321          |                   | 16   | A182 F-304L/316L/321          |                   | 16   | 11       |
| -                             |                   |      | -                             |                   |      | -                             |                   |      | 12       |
| -                             |                   | 8    | -                             |                   | 8    | -                             |                   | 8    | 13       |
| -                             |                   | 8    | -                             |                   | 8    | -                             |                   | 8    |          |
| -                             |                   | 8    | -                             |                   | 8    | -                             |                   | 8    |          |
| A193-B7 and A194-2H           |                   | 9    | A193-B7 and A194-2H           |                   | 9    | A193-B7 and A194-2H           |                   | 9    | 14       |
| A193 and A194-B8/B8M/B8T      |                   |      | A193 and A194-B8/B8M/B8T      |                   |      | A193 and A194-B8/B8M/B8T      |                   |      | 15       |
| A213 TP-304L/316L/321         |                   | 9    | A213 TP-304L/316L/321         |                   | 9    | A213 TP-304L/316L/321         |                   | 9    | 16       |
| A106-B                        |                   | 2    | A312 TP-304L/316L/321         |                   | 16   | A312 TP-304L/316L/321         |                   | 16   | 17       |
| A312 TP-304L/316L/321         |                   | 16   | A106-B                        |                   | 2    | A312 TP-304L/316L/321         |                   | 16   |          |
| A105                          |                   | 2    | A182 F-304L/316L/321          |                   | 16   | A182 F-304L/316L/321          |                   | 16   | 18       |
| A182 F-304L/316L/321          |                   | 16   | A105                          |                   | 2    | A182 F-304L/316L/321          |                   | 16   |          |
| A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | 19       |
| A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | 20       |
| -                             |                   |      | A240 TP-304L/316L/321         |                   | 15   | A240 TP-304L/316L/321         |                   | 15   | 21       |
| A240 TP-304L/316L/321         |                   | 15   | -                             |                   |      | A240 TP-304L/316L/321         |                   | 15   |          |
| A240 TP-304L/316L/321         |                   | 15   | A240 TP-304L/316L/321         |                   | 15   | A240 TP-304L/316L/321         |                   | 15   |          |
| A240 TP-304L/316L/321         |                   | 15   | A240 TP-304L/316L/321         |                   | 15   | A240 TP-304L/316L/321         |                   | 15   |          |
| A283-C                        |                   | 2    | A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | 22       |
| A283-C or A675-Gr50           |                   | 2    | A240 or A276 TP-304L/316L/321 |                   |      | A240 or A276 TP-304L/316L/321 |                   |      | 23       |
| A276 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | A240 TP-304L/316L/321         |                   |      | 24       |
| -                             |                   |      | -                             |                   |      | -                             |                   |      | 25       |
| A283-C                        |                   | 2    | A240 TP-304L / (A283-C)       |                   | -/2  | A240 TP-304L / (A283-C)       |                   | -/2  | 26       |
| A283-C                        |                   | 2    | A240 TP-304L / (A283-C)       |                   | -/2  | A240 TP-304L / (A283-C)       |                   | -/2  | 27       |
| -                             |                   |      | -                             |                   |      | -                             |                   |      | 28       |
| -                             |                   |      | -                             |                   |      | -                             |                   |      | 29       |
| A240 TP-304L/316L/321         |                   |      | -                             |                   |      | -                             |                   |      | 30       |
| A193 B7/B8/B8M/B8T            |                   |      | -                             |                   |      | -                             |                   |      | 31       |
| A283-C or A675-Gr50           |                   | 2    | A283-C or A675-Gr50           |                   | 2    | A283-C or A675-Gr50           |                   | 2    | 32       |
| -                             |                   |      | -                             |                   |      | -                             |                   |      | 33       |
| -                             |                   |      | -                             |                   |      | -                             |                   |      | 34       |
| A240 or A213 TP-304L/316L/321 |                   | 19   | A240 or A213 TP-304L/316L/321 |                   | 19   | A240 or A213 TP-304L/316L/321 |                   | 19   | 35       |

## SCHEMATIC DRAWINGS

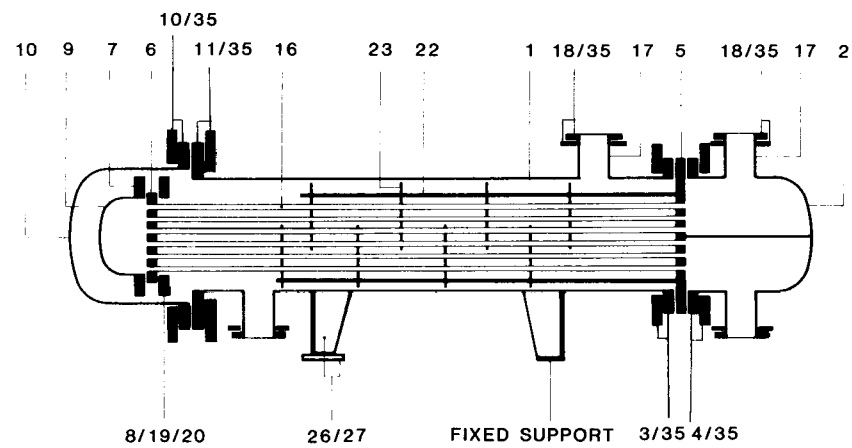
Type A:



Type B:



Type C:



**LIST 6 MATERIAL SPECIFICATION FOR ALLOY N04400 (MONEL 400) HEAT EXCHANGERS WITH A FLOATING HEAD**

| Type A                           |      | Type B                           |      | Type C                           |      |      |
|----------------------------------|------|----------------------------------|------|----------------------------------|------|------|
| Shell : Carbon Steel             |      | Shell : Monel                    |      | Shell : Monel                    |      |      |
| Tubes : Monel                    | Note | Tubes : Monel                    | Note | Tubes : Monel                    | Note | Item |
| Channel : Monel                  | 1,14 | Channel : Carbon Steel           | 1,14 | Channel : Monel                  | 1,14 | No.  |
| A515-Gr55/60 or A106-B           | 2    | B165 or B127 N04400, Ni-Cu alloy |      | B165 or B127 N04400, Ni-Cu alloy |      | 1    |
| B165 or B127 N04400, Ni-Cu alloy |      | A515-Gr55/60 or A106-B           | 2    | B165 or B127 N04400, Ni-Cu alloy |      | 2    |
| B127 N04400, Ni-Cu alloy         |      | A515-Gr55/60                     | 2    | B127 N04400, Ni-Cu alloy         |      |      |
| A105                             | 2    | B127 N04400, Ni-Cu alloy         | 16   | B127 N04400, Ni-Cu alloy         | 16   | 3    |
| B127 N04400, Ni-Cu alloy         |      | A105                             | 2    | B127 N04400, Ni-Cu alloy         | 16   | 4    |
| -                                |      | -                                |      | -                                |      |      |
| B127 N04400, Ni-Cu alloy         |      | B127 N04400, Ni-Cu alloy         |      | B127 N04400, Ni-Cu alloy         |      | 5    |
| B127 N04400, Ni-Cu alloy         |      | B127 N04400, Ni-Cu alloy         |      | B127 N04400, Ni-Cu alloy         |      | 6    |
| B127 N04400, Ni-Cu alloy         | 16   | B127 N04400, Ni-Cu alloy         | 16   | B127 N04400, Ni-Cu alloy         | 16   | 7    |
| A105                             | 2    | B164 N04400, Ni-Cu alloy         |      | B164 N04400, Ni-Cu alloy         |      | 8    |
| B127 N04400, Ni-Cu alloy         |      | B127 N04400, Ni-Cu alloy         |      | B127 N04400, Ni-Cu alloy         |      | 9    |
| A515-Gr55/60 or A106-B           | 2    | B165 or B127 N04400, Ni-Cu alloy |      | B165 or B127 N04400, Ni-Cu alloy |      | 10   |
| A515-Gr55/60                     | 2    | B127 N04400, Ni-Cu alloy         |      | B127 N04400, Ni-Cu alloy         |      |      |
| A105                             | 2    | B127 N04400, Ni-Cu alloy         | 16   | B127 N04400, Ni-Cu alloy         | 16   |      |
| A105                             | 2    | B127 N04400, Ni-Cu alloy         | 16   | B127 N04400, Ni-Cu alloy         | 16   | 11   |
| -                                |      | -                                |      | -                                |      | 12   |
| -                                | 8    | -                                | 8    | -                                | 8    | 13   |
| -                                | 8    | -                                | 8    | -                                | 8    |      |
| -                                | 8    | -                                | 8    | -                                | 8    |      |
| A193-B7 and A194-2H              | 9    | A193-B7 and A194-2H              | 9    | A193-B7 and A194-2H              | 9    | 14   |
| A193-B7 and A194-2H              | 9    | F468/467 N05500                  |      | F468/467 N05500                  | 9    | 15   |
| B163 N04400, Ni-Cu alloy         |      | B163 N04400, Ni-Cu alloy         | 17   | B163 N04400, Ni-Cu alloy         | 17   | 16   |
| A106-B                           | 2    | B165 N04400, Ni-Cu alloy         | 16   | B165 N04400, Ni-Cu alloy         | 16   | 17   |
| B165 N04400, Ni-Cu alloy         | 16   | A106-B                           | 2    | B165 N04400, Ni-Cu alloy         | 16   |      |
| A105                             | 2    | B127 N04400, Ni-Cu alloy         | 16   | B127 N04400, Ni-Cu alloy         | 16   | 18   |
| B127 N04400, Ni-Cu alloy         | 16   | A105                             | 2    | B127 N04400, Ni-Cu alloy         | 16   |      |
| A576-Gr1045                      |      | B164 N04400, Ni-Cu alloy         |      | B164 N04400, Ni-Cu alloy         |      | 19   |
| A105                             | 2    | B164 N04400, Ni-Cu alloy         |      | B164 N04400, Ni-Cu alloy         |      | 20   |
| -                                |      | B127 N04400, Ni-Cu alloy         | 15   | B127 N04400, Ni-Cu alloy         | 15   | 21   |
| B127 N04400, Ni-Cu alloy         | 15   | -                                |      | B127 N04400, Ni-Cu alloy         | 15   |      |
| B127 N04400, Ni-Cu alloy         | 15   | B127 N04400, Ni-Cu alloy         | 15   | B127 N04400, Ni-Cu alloy         | 15   |      |
| B127 N04400, Ni-Cu alloy         | 15   | B127 N04400, Ni-Cu alloy         | 15   | B127 N04400, Ni-Cu alloy         | 15   |      |
| B171 C71500, 70/30 Cu-Ni         |      | B127 N04400, Ni-Cu alloy         |      | B127 N04400, Ni-Cu alloy         |      | 22   |
| A283-C or A675-Gr50              | 2    | B127 or B164 N04400, Ni-Cu alloy |      | B127 or B164 N04400, Ni-Cu alloy |      | 23   |
| B164 N04400, Ni-Cu alloy         |      | B164 N04400, Ni-Cu alloy         |      | B164 N04400, Ni-Cu alloy         |      | 24   |
| -                                |      | -                                |      | -                                |      | 25   |
| A283-C                           | 2    | B127 N04400 / A283-C             | -/2  | B127 N04400 / A283-C             | -/2  | 26   |
| A283-C                           | 2    | B127 N04400 / A283-C             | -/2  | B127 N04400 / A283-C             | -/2  | 27   |
| -                                |      | -                                |      | -                                |      | 28   |
| -                                |      | -                                |      | -                                |      | 29   |
| A283-C                           | 2    | -                                |      | -                                |      | 30   |
| A193- B7and A194-2H              | 9    | -                                |      | -                                |      | 31   |
| A283-C or A675-Gr50              | 2    | A283-C or A675-Gr50              | 2    | A283-C or A675-Gr50              | 2    | 32   |
| -                                |      | -                                |      | -                                |      | 33   |
| -                                |      | -                                |      | -                                |      | 34   |
| B127 N04400, Ni-Cu alloy         |      | B127 N04400, Ni-Cu alloy         |      | B127 N04400, Ni-Cu alloy         |      | 35   |

| Item list<br>(According to data requisition sheet<br>DEP 31.21.00.93-Gen. sheet 6,3/78.) |                                       |                           | List of Guiding Notes |                                                                     |  |
|------------------------------------------------------------------------------------------|---------------------------------------|---------------------------|-----------------------|---------------------------------------------------------------------|--|
| Item<br>No.                                                                              | Pressure parts                        | Note<br>1                 | No.                   |                                                                     |  |
| 1                                                                                        | Shell                                 |                           | 1                     | General note. Equivalent materials, as e.g. specified in            |  |
| 2                                                                                        | Channel                               | - shell                   |                       | DEP 30.10.02.11-Gen., may be specified as well.                     |  |
|                                                                                          |                                       | - head                    | 2                     | C-content max. 0.23% for carbon steel.                              |  |
| 3                                                                                        | Shell flange                          | - channel side            | 3                     | Bellows in shell to be specified separately if applicable.          |  |
| 4                                                                                        | Channel flange                        | - shell side              | 4                     | For description of non-, mildly corrosive- and corrosive water, see |  |
|                                                                                          |                                       | - cover side              |                       | Par.3.2 note 4.                                                     |  |
| 5                                                                                        | Fixed or stationary tube sheet        |                           | 5                     | Optional are longitudinally welded tubes as per ASTM-A214 with      |  |
| 6                                                                                        | Floating tube sheet                   |                           |                       | additional NDT, according to ASTM A450. Redressing of weld seam     |  |
| 7                                                                                        | Floating head flange                  |                           |                       | required for expanded tube sheet connections.                       |  |
| 8                                                                                        | Clamp ring                            |                           | 6                     | For welded tube-tube sheet connects. use A516-Gr70/65/60; C-content |  |
| 9                                                                                        | Floating head                         |                           |                       | max.0.23%.                                                          |  |
| 10                                                                                       | Cover                                 | - shell                   | 7                     | ASTM A516-Gr70/65 is allowed when in addition a Z-value of 35% acc. |  |
|                                                                                          |                                       | - head                    |                       | to ASTM A770+S3 or SEL 096 Cl.3, is specified and C-content         |  |
|                                                                                          |                                       | - flange                  |                       | max.0.23%.                                                          |  |
| 11                                                                                       | Shell flange                          | - cover side              | 8                     | For select. of gaskets see Ch. R-6 of DEP 31.21.01.30-Gen. and      |  |
| 12                                                                                       | Channel cover                         |                           |                       | DEP 30.10.40.11-Gen.                                                |  |
| 13                                                                                       | Gasket                                | - shell side/shell cover  | 9                     | Accepted suppliers only. Contact SIPM-MA "sourcing" department for  |  |
|                                                                                          |                                       | - floating head           |                       | current supplier list.                                              |  |
|                                                                                          |                                       | - tube side/channel cover | 10                    | Optional ASTM B424-N08825 (Alloy 825) may be used.                  |  |
| 14                                                                                       | Stud bolt and nuts                    |                           | 11                    | Preference for CuNi-alloy ASTM B111-C71640, under certain           |  |
| 15                                                                                       | Stud bolt and nuts for floating head  |                           |                       | (corrosive) conditions. Annealed condition. See Par. 3.2 Note 11.   |  |
| 16                                                                                       | Tubes                                 |                           | 12                    | Composition of sacrificial anodes:                                  |  |
| 17                                                                                       | Nozzles                               | - shell side              |                       |                                                                     |  |
|                                                                                          |                                       | - tube side               |                       |                                                                     |  |
| 18                                                                                       | Nozzle flange                         | - shell side              |                       |                                                                     |  |
|                                                                                          |                                       | - tube side               |                       |                                                                     |  |
| 19                                                                                       | Split key ring (chem. service)        |                           |                       |                                                                     |  |
| 20                                                                                       | Key ring flange (chem. service)       |                           |                       |                                                                     |  |
| 21                                                                                       | Cladding/ lining                      | - shell side              |                       |                                                                     |  |
|                                                                                          |                                       | - tube side               |                       |                                                                     |  |
|                                                                                          |                                       | - tube sheets             |                       |                                                                     |  |
|                                                                                          |                                       | - floating head           |                       |                                                                     |  |
| Non-Pressure Parts                                                                       |                                       |                           |                       |                                                                     |  |
| 22                                                                                       | Baffles and support plates            |                           |                       |                                                                     |  |
| 23                                                                                       | Seal. strips,bars/rods,spacers,strips |                           |                       |                                                                     |  |
| 24                                                                                       | Eye bolts/loosening bolts             |                           |                       |                                                                     |  |
| 25                                                                                       | Weir plates                           |                           |                       |                                                                     |  |
| 26                                                                                       | Saddle/brackets                       |                           |                       |                                                                     |  |
| 27                                                                                       | Sliding plate                         |                           |                       |                                                                     |  |
| 28                                                                                       | Reinforcing ring for floating head    |                           |                       |                                                                     |  |
| 29                                                                                       | Expansion bellows (internal)          |                           |                       |                                                                     |  |
| 30                                                                                       | Bearing ring                          |                           |                       |                                                                     |  |
| 31                                                                                       | Internal set screws of bearing ring   |                           |                       |                                                                     |  |
| 32                                                                                       | Test ring/flange                      |                           |                       |                                                                     |  |
| 33                                                                                       | Sacrificial plates/anodes             |                           |                       |                                                                     |  |
| Additional Items                                                                         |                                       |                           |                       |                                                                     |  |
| 34                                                                                       | Reducer construction                  |                           |                       |                                                                     |  |
| 35                                                                                       | Stub ring                             |                           |                       |                                                                     |  |

| Magnesium anode         | Zinc anode                      | Iron anodes |
|-------------------------|---------------------------------|-------------|
| Al 5.3-6.7%wt           | Pb 0.006%wt max                 | ASTM A285-C |
| Zn 2.5-3.5%wt           | Fe 0.005%wt max                 |             |
| Si 0.10%wt max.         | Cd 0.025-0.15%wt                |             |
| Cu 0.02%wt max.         | Cu 0.005%wt max                 |             |
| Ni 0.002% wt max.       | Al 0.10-0.50%wt                 |             |
| Fe 0.003%wt.max.        | Si 0.125%wt max                 |             |
| impurities 0.03%wt.max. | Zn balance                      |             |
| Mg balance              | (Composition in accordance with |             |
|                         | US military specification       |             |
|                         | MIL-A-18001 H)                  |             |

Note: For correct mounting of Mg and Zn anodes see drawing S  
21.072, Fe anodes according drawing S21.073.

- 13 B169 C61400 cladding, minimum layer thickness of 10mm.
- 14 All Ni-Cu alloy N04400 in annealed condition.
- 15 Instead of solid alloy material, A515-Gr55/60 (incl. note 2) plus cladding is allowed. Minimum cladding thickness of 10mm for tube sheets, other items minimum 3mm.
- 16 Material selection depends on type of flange construction.  
Common options are:
- carbon steel "slip-on-flange" plus overlay welded facing.
  - carbon steel "lapped-joint-flange" (stub end construction).
  - carbon steel "welding-neck-flange" plus cladding/overlay welding of facing and internal bore.
  - solid alloy material, "welding-neck-flange".

## 5. REFERENCES

In this specification/manual reference is made to the following publications.

NOTE: The latest issue of each publication shall be used together with any amendments/supplements/revisions to such publications.

It is particularly important that the effect of revisions to international, national or other standards shall be considered when they are used in conjunction with DEP's unless the standard referred to has been prescribed by date.

|                                                                              |                      |
|------------------------------------------------------------------------------|----------------------|
| Metallic materials - Selected standards                                      | DEP 30.10.02.11-Gen. |
| <b>Amended per<br/>Circular 22/92</b>                                        |                      |
| Shell-and-tube heat exchangers -<br>Amendments/supplement to TEMA standards) | DEP 31.21.01.30-Gen. |
| Welding of metals                                                            | DEP 30.10.60.18-Gen. |
| Pressure vessels (Amendments/supplements to<br>BS 5500)                      | DEP 31.22.10.32-Gen. |
| Pressure vessels (Amendments/supplements to<br>ASME VIII)                    | DEP 31.22.20.31-Gen. |

### AMERICAN STANDARD

|                                                                                                                                    |               |
|------------------------------------------------------------------------------------------------------------------------------------|---------------|
| US Military Specification Obtainable from:<br>Superintendent of Documents, Government Printing<br>Office, Washington DC 20402, USA | MIL-A-18001 H |
|------------------------------------------------------------------------------------------------------------------------------------|---------------|

### STANDARD DRAWINGS

In this specification reference is made to the following standard drawings, the latest issue of which shall be used.

|                                                    |          |
|----------------------------------------------------|----------|
| Magnesium and zinc sacrificial anodes for tubulars | S 21.072 |
| Steel sacrificial plates for tubulars              | S 21.073 |

**6. APPENDICES**

|                                                                          | <b>Appendix</b> |
|--------------------------------------------------------------------------|-----------------|
| Lists of material specifications for shell-and tube heat exchangers      | 1               |
| Method of detection of harmful oxide films on copper-nickel alloy tubes. | 2               |

**APPENDIX 1      LISTS OF MATERIAL SPECIFICATIONS FOR SHELL-AND-TUBE HEAT EXCHANGERS**

| List |                                                             |                 |                 | MESC          |
|------|-------------------------------------------------------------|-----------------|-----------------|---------------|
| 1.   | Heat exchangers                                             |                 |                 | 43.53.10./16. |
| A.   | With floating head                                          |                 |                 |               |
| B.   | With hairpin tube bundle                                    |                 |                 |               |
| C.   | With fixed tube sheets                                      |                 |                 |               |
| 2.   | Reboilers                                                   |                 |                 | 43.72.10./16. |
| A.   | Vertical, with floating head                                |                 |                 |               |
| B.   | Vertical, with fixed tube sheets                            |                 |                 |               |
| C.   | Kettle type, with floating head                             |                 |                 |               |
| D.   | Kettle type, with hairpin tube bundle                       |                 |                 |               |
| 3.   | Coolers/Condensers with floating head                       |                 |                 | 43.28.20./29. |
| A.   | For non-corrosive water                                     |                 |                 |               |
| B.   | For mildly corrosive water                                  |                 |                 |               |
| C.   | For corrosive water                                         |                 |                 |               |
| 4.   | Coolers/Condensers with fixed tube sheet                    |                 |                 | 43.28.20./29. |
| A.   | For non-corrosive water                                     |                 |                 |               |
| B.   | For mildly corrosive water                                  |                 |                 |               |
| C.   | For corrosive water                                         |                 |                 |               |
| List | Shell                                                       | Channel         | Tubes           | MESC          |
| 5.   | Stainless steel heat exchangers with floating head          |                 |                 | 43.53.10./16. |
| A.   | Mild steel                                                  | Stainless steel | Stainless steel |               |
| B.   | Stainless steel                                             | Mild steel      | Stainless steel |               |
| C.   | Stainless steel                                             | Stainless steel | Stainless steel |               |
| 6.   | Monel 400, alloy NO4400, heat exchangers with floating head |                 |                 | 43.53.10./16. |
| A.   | Mild steel                                                  | Monel           | Monel           |               |
| B.   | Monel                                                       | Mild steel      | Monel           |               |
| C.   | Monel                                                       | Monel           | Monel           |               |

## APPENDIX 2      METHOD OF DETECTION OF HARMFUL OXIDE FILMS ON COPPER-NICKEL ALLOY TUBES

(ASTM B111-C71640 or BS 2871-CN 108, tubes)

### 1.0      GENERAL

The principle of the method is to compare the corrosion (rest) potential  $E_{\text{corr}}^a$  of freshly abraded tube alloy with the rest potential  $E_{\text{corr}}^t$  of the tube bore in the as-received condition. The difference,  $\Delta E$ ,  $E_{\text{corr}}^t - E_{\text{corr}}^a$ , is a measure of the "nobility" of films on the tube bore surface. The larger the difference, the more cathodic is the tube. A clean, acceptable tube left in the atmosphere will develop an oxide film which can be up to +0.070 volts cathodic compared to the bare material. Therefore, the criterion for acceptance has been taken as  $\Delta E < +0.070$  volts.

### 2.0      PROCEDURE

#### 2.1      Cleaning

Prior to testing, the tube should be degreased thoroughly by pulling a soft cloth, soaked in a petroleum spirit, through the tube and repeating this

until the cloth is clean. Allow the solvent to evaporate. The potential  $E_{\text{corr}}^a$  is noted 10 minutes after inserting the reference electrode.

#### 2.2      Filling with KCl

One end of the tube is plugged with a rubber stopper and, with the tube either vertical or inclined, it is filled with the potassium chloride (0.02 M) solution. To enable the steady-state potential to be reached quickly a dilute solution of potassium chloride (0.02 M or approximately 1.5 g/l) shall be used to fill the tube. Potentials shall be measured against silver/silver chloride reference electrode, also in 0.02 M KCl, so avoiding liquid junction potentials.

#### 2.3      Measuring potential of "as delivered condition"

Without undue delay the reference electrode, removed from its storage capsule, is carefully lowered into the tube to dip into the solution, so completing the circuit via high impedance millivolt meter, such as Fluke Model 8000 A. (The connections to the meter are: reference electrode to the ground (or black) terminal tube/crocodile clip (**kept dry**) to the positive (red) terminal.).

Note :      It is important to prevent the solution wetting either the tube exterior/crocodile clip junction or a freshly cut end of the tube since either possibility will result in false readings.

#### 2.4      Measuring potential of "bare material"

To obtain the value for the freshly abraded tube alloy a piece of tube is stoppered as before with a rubber bung and the outer surface of the tube is abraded with silicon carbide paper under clean water to obtain a bright surface. This is rinsed first with clean water and then with the potassium chloride (KCl) solution (0.02 M) before being immersed in fresh KCl solution into which the reference electrode is placed. A crocodile clip is attached to a dry portion of the tube and the potential  $E_{\text{corr}}^a$  noted after 10 minutes.

### 3.0 INTERPRETATION OF RESULTS

For ASTM B111-C71640 or BS 2871-CN 108 alloy repeated measurements of many tubes have shown that  $E_{\text{corr}}^a$  determined by this method is  $-0.230 \pm 0.010$  volts.

An acceptable tube has the difference,  $\Delta E$ , below  $+0.070$  Volts

where  $\Delta E = E_{\text{corr}}^t - (-0.230)$  volts,

e.g. for an acceptable tube  $E_{\text{corr}}^t$  may be found to be  $-0.180$  Volts

so that  $\Delta E = -0.180 - (-0.230)$   
 $= +0.050$  volts

whereas for an unacceptable tube  $E_{\text{corr}}^t$  would be more positive than  $-0.160$  volts.

### 4.0 REMOVAL OF AN UNACCEPTABLE CATHODIC OXIDE FILM

Removal of an unacceptable cathodic film ( $\Delta E > +0.07$  Volts) may be done by either blast cleaning or acid cleaning. After cleaning the test shall be repeated on representative samples.

### 5.0 CERTIFICATION

Manufacturers shall issue certificates showing that **each batch** of tubes supplied is free of harmful films.