INTRODUCTION

It is impossible to provide rules for manufacture and production which are sufficiently detailed to ensure satisfactory results. Successful manufacture basically depends on the know-how and means of each individual Manufacturer.

The rules given in SECTION V "FABRICATION" are the minimum requirements to be met: the Manufacturer shall make all additional provisions he may consider necessary to ensure the quality of his product.

In addition, the Manufacturer shall respect all tolerances and supplementary requirements specified in SECTION I or stipulated in the equipment specifications.
F 2000

MARKING PROCEDURE

F 2100 GENERAL REQUIREMENTS

a) The methods used for marking shall not result in contamination of the material, significant strain hardening, or sharp discontinuities.

b) Items shall be marked in areas which are subjected to minimum loading and shall not be marked in areas where there is stress concentration (particularly in areas where there are discontinuities in shape) or in weld heat affected zones. Marking must not adversely affect the interpretation of the results of non-destructive examination.

F 2200 METHODS

a) All methods which meet the requirements of F 2100 a) and the following requirements may be used for temporary and definitive marking.

b) The use of electric arc marking pencils is forbidden.

c) Stamping is permitted on materials more than 6 mm in thickness. Metal stamps shall be round nosed or ball type.

d) Electrolytic etching shall be permitted but shall preferably be used for parts of small dimensions and thickness. When this method is used, the concentration of S, Hg, Zn and Pb in the etching solution shall not exceed 250 ppm, and the halogen content shall not exceed 250 ppm. Etching shall immediately be followed by neutralizing, rinsing and drying.

The Manufacturer shall draw up an etching procedure prior to any marking operation.

e) A vibrating marking tool may be used for thickness less than 6 mm.

The tool shall be carbide tipped and the depth of the indentation shall be approximately 0.25 mm or less.

However, since this type of marking may be erased on ferritic non-stainless steels, a different method of marking should be used. For example, a temporary marking code may be painted onto individual components and the code markings tabulated for the finished item of equipment.
**F 2300  LETTERS OR SYMBOLS**

The recommended height for characters is 4 to 6 mm for pipes dia. \( \leq 350 \text{ mm} \) in diameter and from 8 to 12 mm for components and pipes dia. \( > 350 \text{ mm} \) in diameter.

For very small parts, the characters shall be as large as it is possible to make them.

**F 2400  TEMPORARY MARKING**

Ink stamps, indelible ink and paint may be used for temporary marking during manufacture in accordance with the following criteria for austenitic stainless steels and nickel base alloys.

a) Parts shall only be marked in this way provided that the marking may be removed afterwards.

b) The inks, paints, etc. used shall not contain any contaminants prohibited in F 6000.

c) These markings shall be eliminated prior to any heat treatment whenever there is a risk of their causing surface contamination.
F 3000

CUTTING
REPAIR WITHOUT WELDING

F 3100   GENERAL

All materials may be cut to shape and sized or prepared for welding by machining, grinding or thermal cutting.

Shearing of plates shall be permitted, subject to the provisions of F 3200.

F 3200   SHEARING

Plates less than 25 mm thick may be cut by shearing, provided that the strain hardened zone is subsequently eliminated by machining or grinding.

Weld edges may be prepared by shearing provided that the provision given above is respected. However, for plates less than 10 mm in thickness, it is sufficient that cross-sections of the welded procedure test joint demonstrate that the strain hardened zone has been eliminated.

F 3300   OXY-GAS CUTTING

a) Preheating shall be performed before oxy-gas cutting when preheating before welding is specified in S 1321, S 1322 or S 1323. However, for carbon steels listed in S 1321, the Manufacturer may dispense with preheating before oxy-gas cutting when he is satisfied that this will not result in cracking.

b) Oxidized surfaces shall be carefully deburred and all traces of oxide removed by brushing or grinding. When the surface remains as-cut, the use of oxy-gas cutting shall not adversely affect the mechanical properties of the material (hardness, for example).

c) Oxy-gas cut surfaces shall be carefully checked for cracks.

d) After all wrinkles resulting from oxy-gas cutting have been eliminated by grinding or machining, the weld edges prepared by oxy-gas cutting shall be examined in accordance with the requirements of chapters B, C and D 4000 (see S 7330 c). In addition, the Manufacturer shall use the test coupons for the welding procedure test to check that the maximum hardness value is satisfactory. If not, the affected zone is eliminated by mechanical means (grinding or machining).
F 3400  PLASMA ARC AND GAS TUNGSTEN ARC CUTTING

a) When plasma arc cutting is used to cut a part to its final shape and size, all residual traces such as metal roll-over and grooves etc. shall be removed from the faces of the cut. Approximately 1 mm of metal shall be removed from the face of the cut by grinding or machining. The same provisions shall be made when gas tungsten arc cutting is utilized for parts of small thickness.

For austenitic stainless steels, grinding or machining may be replaced by deburring followed by chemical pickling (see F 6000).

b) However, when a plasma arc is used to prepare weld edges on austenitic stainless steels, surface preparation after cutting may be limited to the requirements for examination of weld edges prescribed in SECTION I.

F 3500  CARBON ARC CUTTING AND GOUGING

(See S 7330).

F 3600  REPAIR WITHOUT WELDING

F 3610  GENERAL

This paragraph covers the repair of defects detected on parts which have already been accepted in accordance with the requirements of SECTION II "MATERIALS" and which are revealed or produced during a manufacturing or installation operation.

Defects of this type are usually surface defects.

These defects shall not be repaired by welding when they meet the criteria listed below.

F 3620  PROVISIONS FOR REPAIR WITHOUT WELDING

a) The defect shall be removed by grinding, chipping (followed by grinding), or machining. The use of thermal processes is prohibited.

b) The defect shall be removed or reduced to an acceptable size in accordance with the criteria given in SECTION II for parts and products in SECTION IV chapter S 7350 for weld edges and surfaces on which weld metal will be deposited.

c) After removal or reduction of the defect, the remaining thickness of the metal shall be sufficient to meet stress criteria in accordance with the applicable design methods given in SECTION I. In addition, the surface condition shall meet the requirements for assembly and non destructive examination.

d) Connection with the surrounding area shall be progressively and uniformly blended, taper being 0.25 at most.
F 4000

FORMING AND DIMENSIONAL TOLERANCES

F 4100  FORMING

F 4110  GENERAL

F 4111  SCOPE

a) The forming procedure comprises all the thermomechanical operations (thermal cycle, deformation and any heat treatment performed subsequent to forming) applied to a part or product to obtain a given component.

b) The use of any forming procedure whatsoever shall not cause a reduction in properties of the material of a component below minimum required values. Thus, heat treatment shall be performed subsequent to forming, if necessary, to restore the properties of the material so as to conform to the above-mentioned requirements.

c) For this purpose, the forming procedure qualification tests are designed to demonstrate that the required characteristics stipulated in the acceptance specification for the product prior to forming are complied with in the finished product.

d) Whatever the forming procedure used for welded plates, the welding procedure qualification shall take into account the heat treatments associated with forming.

F 4112  REQUIRED DOCUMENTS

a) All forming procedures shall be performed in accordance with the requirements defined in a set of duly identified documents comprising at least the following:

- the forming procedure specification used, and for manufacturing operations, the reference of the corresponding qualification report,

- the examinations to be performed during and after forming.

b) Content of the forming procedure specification

The forming procedure specification shall:

1) enumerate all of the variables defined in F 4120 as conditioning the range of approval when qualification of the forming procedure is required.
2) provide, for information purposes:
- either the technical parameters adopted for the forming operation,
- or reference to an internal procedure containing this information.

In the case of bending of tubes by induction, for example, the following in particular shall be specified:
- bending rate,
- electrical parameters (current, voltage, frequency, etc),
- cooling parameters,
- method used for measuring temperature,
- where applicable, the location prescribed for the welded zone undergoing the forming operation.

3) The reference to the qualification of the forming procedure shall appear in the forming procedure data sheet.

**F 4113 METHOD FOR EVALUATING ELONGATION**

a) The elongation of a formed part is calculated by means of the following formulas:

\[ A\% = \frac{50e}{Rf} \left(1 - \frac{Rf}{Ro}\right) \quad \text{for cylinders} \]

\[ A\% = \frac{65e}{Rf} \left(1 - \frac{Rf}{Ro}\right) \quad \text{for deformation < 1\%} \]

\[ A\% = \frac{75e}{Rf} \left(1 - \frac{Rf}{Ro}\right) \quad \text{for deformation \geq 1\%*} \]

\[ A\% = \left(\frac{n Df}{Dp}\right) \times 100 \quad \text{for vessel heads} \]

\[ A\% = \frac{100r}{R} \quad \text{for pipes} \]

where:
- \( e \) = nominal thickness of the product,
- \( Rf \) = final radius to the centreline of the part,
- \( Ro \) = original radius to the centreline of the part (equal to infinity for a plate),
- \( R \) = nominal bending radius to the centreline of the pipe,

* For spherical or dished surfaces.
r = nominal radius of the pipe,
Df = diameter of the blank,
Dp = diameter of the part.

b) When complex shapes are formed, the elongation shall be measured by means of grid lines on the test sample.

**F 4120  QUALIFICATION OF THE FORMING PROCEDURE**

This paragraph covers the qualification of forming procedures, with the exception of bending procedures for heat exchanger tubes.

**F 4121  PURPOSE OF QUALIFICATION AND CASES WHERE QUALIFICATION IS REQUIRED**

The purpose of the procedure qualification is to check, for the main variables adopted, on a test coupon, that the forming procedure allows the required quality criteria to be complied with.

Forming procedure qualification is required in the following cases:

a) For any operation or series of operations performed at temperatures above 150°C.

b) For an operation performed at a temperature less than or equal to 150°C when the maximum elongation (calculated on the basis of the formulas given in F 4113 for the various component shapes) is greater than 5% for carbon or alloy steels, and 10% or 15% with supporting file for austenitic stainless steels.

In the latter case, the required supporting file shall provide statistical proof (taking into account dispersion due to manufacturing) that:

- the guaranteed characteristics required by the acceptance specification of the filler material prior to forming are satisfied, with the exception of the minimum value required for elongation,
- the choice of the new criterion relative to the minimum elongation value is justified and is still compatible with the requirements of the design file.

Qualification of the forming procedure is not required for materials accepted subsequent to forming operations and associated heat treatments for mechanical properties.

**F 4122  REQUIRED DOCUMENTS**

All procedure qualifications shall be performed in accordance with the requirements defined in a set of duly identified documents, which shall conform to the requirements of the applicable paragraphs and comprise, at least:

- the forming procedure specification for the qualification test piece (see F 4112),
- the range of approval of the qualification,
- the examinations to be performed and associated criteria, according to the criterial level adopted for qualification,
- dimensional sketches showing positions of samples on specimens.

**F 4123  RANGE OF APPROVAL OF QUALIFICATION**

The main variables conditioning the range of approval of qualification are as follows.

**F 4123.1  Workshop**

- In the case of hot forming:
  Qualification tests shall be performed in the same workshop, with the same type of machine as the production parts.

- In the case of cold forming:
  Qualification tests performed in a workshop are valid for all the workshops of the Manufacturer whose production is assured by the same type of machine that is used for qualification.

**F 4123.2  Base metal grades**

Shall be considered equivalent, all carbon steels and alloy steels (except for austenitic stainless steels) of the same grade or standard grade. Non-stabilized austenitic stainless steels satisfying the intergranular corrosion test defined in MC 1310 shall be considered as equivalent.

Furthermore, forged, extruded and rolled products shall be considered as equivalent.

**F 4123.3  Welds**

Where welds are subjected to the forming operation, the following main variables shall be taken into account.

**Note:** In applying the range of approval of qualification, the Manufacturer shall take into account the provisions in table F 4123.3.

a) Deformation of the welded joint (see note)

  1) Pipes

    Only longitudinal welding is permissible and deformation is defined by the angle "\( \alpha \)" formed by the longitudinal weld with the neutral axis- Fig. F 4123.3.
<table>
<thead>
<tr>
<th>TYPE OF PRODUCTION PART</th>
<th>QUALIFICATION PART</th>
<th>NON-DESTRUCTIVE EXAMINATION ON QUALIFICATION</th>
<th>NON-DESTRUCTIVE EXAMINATION FOR PARTS REQUIRING QUALIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLATES WITHOUT WELDS OR WITH WELDS NOT TAKEN INTO CONSIDERATION IN ACCORDANCE WITH F 4123.3</td>
<td>Plates with welds not taken into consideration in accordance with F 4123.3</td>
<td>Before and after qualification test, weld and base metal included (1)</td>
<td>Before or after forming (1). For examination before forming: liquid penetrant examination of the formed zone and hardness testing of the stressed axis of the first 5 parts of each series of identical parts covered by the same qualification.</td>
</tr>
<tr>
<td>PLATES WITHOUT WELDS OR WITH WELDS NOT TAKEN INTO CONSIDERATION IN ACCORDANCE WITH F 4123.3</td>
<td>Plates without welds</td>
<td>Before and after qualification test (1)</td>
<td>Before or after forming (1). For examination before forming: liquid penetrant examination of the formed zone, hardness testing of the stressed axis and where a weld is present, radiographic examination after forming of the first 5 parts of each series of identical parts covered by the same qualification.</td>
</tr>
<tr>
<td>PLATES WITH WELDS TAKEN INTO CONSIDERATION IN ACCORDANCE WITH F 4123.3</td>
<td>Plates with welds taken into consideration in accordance with F 4123.3</td>
<td>Before and after qualification test, weld and base metal included (1)</td>
<td>After forming and associated heat treatment (1).</td>
</tr>
<tr>
<td>PIPE OR FITTING WITHOUT WELDS OR WITH WELDS TAKEN INTO CONSIDERATION IN ACCORDANCE WITH F 4123.3</td>
<td>Pipe or fitting with weld taken into consideration in accordance with F 4123.3</td>
<td>Before and after qualification test, weld and base metal included (1) (2)</td>
<td>Before or after forming (1): For examination before forming, liquid penetrant examination and hardness testing on the extrados of the first 5 parts of each series of identical parts covered by the same qualification.*</td>
</tr>
<tr>
<td>PIPE OR FITTING WITHOUT WELDS OR WITH WELDS TAKEN INTO CONSIDERATION IN ACCORDANCE WITH F 4123.3</td>
<td>Pipe or fitting without weld</td>
<td>Before and after qualification test (1) (2)</td>
<td>Before or after forming (1). For examination before forming: liquid penetrant and hardness testing on the extrados and where a weld is present, radiographic examination after forming of the first 5 parts of each series of identical parts covered by the same qualification.*</td>
</tr>
<tr>
<td>PIPE OR FITTING WITH WELDS TAKEN INTO CONSIDERATION IN ACCORDANCE WITH F 4123.3</td>
<td>Pipe or fitting with welds not taken into consideration in accordance with F 4123.3</td>
<td>Before and after qualification test, weld and base metal included (1) (2)</td>
<td>Before or after forming (1). For examination before forming: liquid penetrant examination and hardness testing on the extrados of the first 5 parts of each series of identical parts covered by the same qualification.*</td>
</tr>
</tbody>
</table>

(1) Non-destructive examination stipulated in S 7000 for welded joints and in the part procurement specification for the part to be formed. Hardness testing is not required for stainless steel.

(2) Ultrasonic examinations performed before forming shall not be repeated after forming.

* For the case of tubes a dimensional check shall be performed, if specified on the initial five bends of each series of identical bends subjected to the same qualification, in order to check that the criteria defined in F 4216 and in the procurement specification are satisfied.
The angle $\alpha_o$ corresponds to the generatrices of the pipe for which deformation during bending is 5% for alloy or carbon steels and 10% for austenitic stainless steels; it is defined by the following expressions:

$$|\alpha_o| \text{ (in°)} = 4.5 \frac{R}{r}$$

for carbon or alloy steels

$$|\alpha_o| \text{ (in°)} = 9 \frac{R}{r}$$

for austenitic stainless steels

where $R$ is the nominal bending radius to the centreline of the pipe and $r$ the nominal radius of the pipe.

If $|\alpha| \leq |\alpha_o|$, the weld is not taken into consideration and pipes with longitudinal welds and seamless pipes are considered to be equivalent, it being understood that provision shall be made for all of the thermal cycles undergone during bending and heat treatments subsequent to bending at the time of qualification of the welding procedure.

If $|\alpha| > |\alpha_o|$, the weld shall be qualified at the time of bending of the test piece on the extrados of the bend. In this case, high values for "$|\alpha|" qualify lower values for "$|\alpha|".  

2) Plates

In particular, bending and dishing of plates joined prior to forming.

As for pipes, the weld shall be qualified at the time of forming of the test piece if deformation exceeds a value of 5% for carbon steels or alloy steels, except in the case of austenitic stainless steels where this value is increased to 10%. In such cases, high deformation values qualify lower deformation values.

b) Welding processes

Welding processes as defined in S 3120 and qualified in accordance with the RCC-M, SECTION IV, constitute a main variable. In particular, heat treatment of the weld prior to forming, as defined in S 3X19, is a main variable (S 3219, S 3319, etc).

F 4123.4 Geometrical criteria

a) Plates and pipes

Deformation

High deformation values as defined by F 4113 qualify lower values.

Thicknesses

Qualification of a forming procedure is valid for thicknesses between 0.75 $e$ and 1.25 $e + 3$ mm (where $e$ is the thickness of the test piece).
b) Pipes

Diameter

In each of the areas defined below, the outside diameters of the pipes are considered as equivalent:

- \( \text{dia.} \leq 50 \text{ mm} \)
- \( 50 \text{ mm} < \text{dia.} \leq 150 \text{ mm} \)
- \( 150 \text{ mm} < \text{dia.} \)

Feasibility

This criterion only concerns pipes. Large \( r/e \) ratios qualify lower values.

Variable \( r \) is the nominal radius of the pipe and variable \( e \) is the nominal thickness of the pipe.

c) Additional restriction

These rules should not however allow use of a qualification obtained without impact testing for forming operations on a part which is of sufficient size for the performance of these tests.

F 4123.5 Forming technique

Qualification shall only be valid for one forming technique and one given type of machine (press, roller, induction bending machine, sand fill bending machine, etc).

F 4123.6 Forming thermal cycle

Any modification of the specified forming temperature ranges shall invalidate the forming procedure qualification.

Any modification of the specified conditions of the cooling method not followed by heat treatment for mechanical properties subsequent to forming shall invalidates the qualifications of the forming procedure.

It should be noted that the Surveillance Agent or Inspector may stipulate the values of these parameters for execution of the qualification test piece within the limits set forth in the documents describing the qualification test.

F 4123.7 Heat treatment after forming

If the heat treatment specified is stress relieving heat treatment, qualification shall be invalidated when one of the following modifications is made to the heat treatment after forming in production:

- modification of the range of specified temperature,
- modifications of the specified ranges of heat-up and cooling rates and holding time, taking into account the thickness equivalences defined in F 4123.4 and the recommendations defined in the RCC-M: S 1340 and S 7540.

If the heat treatment specified is heat treatment for mechanical properties (normalizing, normalizing plus tempering, quenching plus tempering, solution heat treatment, etc), the test piece shall be subjected to heat treatment of this type, similar to that planned for production parts (holding temperature, holding time, cooling rate, etc).

**F 4124 QUALIFICATION TESTS**

**F 4124.1 Number and nature of test pieces**

The number and nature of test pieces for the qualification of the forming procedure and the examinations to be performed depend on the forming operations to be carried out and are determined by:

- the main variables conditioning the range of approval of the qualifications,
- the quality level of the component which conditions the nature and criteria of the non-destructive examinations.

**F 4124.2 Dimensions**

The test piece shall be dimensioned according to:

- the forming process,
- the drawing of the removal of samples for tests and retests,
- the non-destructive examinations to be performed,
- qualification of the calibration or rebending procedure, where applicable.

In any event, for pipes, the angle of each bend shall be not less than 30°, and for plates, the width of the part shall be not less than the maximum value of (300 mm, 4e).

**F 4124.3 Fabrication of the test piece**

a) Base materials (base metal and weld metal)

The base metals and the filler materials, where applicable, shall either be those used in fabrication or else representative of those used in fabrication, taking into account the equivalences defined in F 4123. The base metal and filler materials used in the fabrication of the test piece shall be acceptance-tested and shall satisfy the criteria of SECTIONS II and IV with respect to chemical composition and mechanical properties.

b) Forming of the test piece and heat treatment

The test piece is formed with the same type of machine that is used for production. During the test, a continuous recording shall be made of the temperature of the part. If this is not possible, temperature readings shall be taken intermittently. After forming, the heat treatment, which shall be the same as that used for production, shall be recorded, if necessary.
F 4124.4 Examination of the qualification test piece

a) General

- All samples shall be removed after the test coupon has been subjected to all of the heat treatments and examinations stipulated in the documents describing qualification.

- Mechanical test specimens shall be taken from the zones shown by non-destructive examination to be the most sound.

Conversely, sections for macrographic and/or micrographic examinations shall be located in zones giving acceptable indications when subjected to non-destructive examination.

- Examinations and tests shall allow the properties of each of the zones subjected to forming to be defined:
  . Base metal: on the intrados and extrados or in a stressed and compressed zone.
  . Weld: (when taken into account in accordance with F 4123.3) deposited metal, heat affected zone of the base metal, cross-check testing of base metal and welded joint (if not performed elsewhere) not subjected to the forming thermomechanical cycle.

- In the case of pipe bending, the properties of the starting area of the bend, normal bend area and the restarting area shall also be determined.

b) Non-destructive examinations

The qualification test piece shall be subjected before and after forming, to all the non-destructive examinations required during fabrication for the parts which it qualifies, and satisfy the requirements for the highest class of these parts.

The test piece shall be subjected to a visual examination and liquid penetrant examination before and after forming at appropriate locations (particularly in stressed zones and in welded joints) in accordance with MC 4000. In the case of pipes, only the outside surface of the pipe shall be subjected to liquid penetrant examination.

The test piece shall be subjected to a dimensional check to make sure the criteria defined in F 4200 and in the equipment specification are satisfied.

The test piece shall be smooth and free from tears, overlaps, cracks or any other injurious defects.

Furthermore, when the other liquid penetrant criteria are not specified in the procurement specification, the criteria given in table F 4124.4 shall apply.

c) Destructive tests

1) Chemical analysis

For stainless steel parts which are hot formed or heat treated after forming, sulphur and carbon contents shall be measured after finishing, to a depth of 1 mm, only if there has been heating by combustion.
CRITERIA
Values defined in the procurement specification.

2) Mechanical tests

**BASE METAL:**
All of the tests stipulated for product acceptance (plate, pipe) shall be performed and the corresponding criteria complied with.

Test specimen sampling conditions shall be the same as those defined for product acceptance, unless this is physically impossible.

In the case of pipes, samples shall be taken from the intrados and extrados. Sampling conditions for the removal of test specifications in thickness shall be the same as those for product acceptance, unless this is physically impossible.

In the case of plates, skin samples shall be removed from the compressed zone and the stressed zone.

**Welded joint:**
The various tests stipulated for qualification of the welding procedure shall be performed and the corresponding criteria complied with.

In the case of welded pipes, tests shall be performed on the extrados side of the welded joint, the location of samples being the same as for qualification of the welding procedure.

In the case of welded plates, the location of samples in the thickness of the product shall be same as for qualification of the welding procedure, taking into account the following requirement:

- tests to be performed at a quarter or a third of the skin thickness of the product shall be performed on the extrados.

3) Intergranular corrosion test
The corrosion test is not required for all grades satisfying corrosion test MC 1310, treatment B.

4) Metallographic examination - Structural examination - Grain size measurement
When stipulated for procurement, an examination using a metallographic replica shall be performed before and after forming, in accordance with the conditions and criteria of the corresponding specification.

If this examination is not stipulated for procurement, it shall be performed for information purposes.
5) Hardness measurements

When stipulated for procurement, for carbon or alloy steels, with the exception of austenitic stainless steels, a hardness measurement shall be performed before and after forming, particularly along the stressed axis, in accordance with the conditions and criteria of the corresponding specification. If this measurement is not stipulated for procurement, it shall be performed for information purposes.

**TABLE F 4124.4**

<table>
<thead>
<tr>
<th>LIQUID PENETRANT CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forgings, rolled pipes, carbon steels and alloy steels of all classes</strong></td>
</tr>
<tr>
<td>- Any indications with one dimension exceeding 1 mm shall be considered a recordable condition.</td>
</tr>
<tr>
<td>- The following indications shall be unacceptable:</td>
</tr>
<tr>
<td>. linear indications,</td>
</tr>
<tr>
<td>. rounded indications with one dimension greater than 3 mm,</td>
</tr>
<tr>
<td>. 3 or more grouped indications in a line, separated by less than 3 mm (edge to edge),</td>
</tr>
<tr>
<td>. 5 or more grouped indications within a rectangular area of 100 cm², whose greatest dimensions shall not exceed 20 cm, taken in the most unfavourable location relative to the indications being evaluated.</td>
</tr>
<tr>
<td><strong>Plates, carbon steels and alloy steels</strong></td>
</tr>
<tr>
<td>On the faces and edges of plates, the same criteria as outlined above. However, on the edges of stainless steel plates, the following indications are permissible:</td>
</tr>
<tr>
<td>a) classes 1 and 2:</td>
</tr>
<tr>
<td>linear indications whose length does not exceed 8 mm for plates of thickness less than or equal to 40 mm and 10 mm for plates of thickness greater than 40 mm.</td>
</tr>
<tr>
<td>Two adjacent indications shall be considered as one if the distance separating them is less than twice the length of the smaller of the two indications. The cumulated length shall be equal to the sum of the lengths of the indications plus the distance separating them.</td>
</tr>
<tr>
<td>b) class 3:</td>
</tr>
<tr>
<td>linear indications whose length does not exceed 12 mm for plates of thickness less than or equal to 40 mm and 15 mm for plates of thickness greater than 40 mm.</td>
</tr>
</tbody>
</table>
F 4125  RETEST CONDITIONS

F 4125.1 Unsatisfactory non-destructive examinations
If the non-destructive examinations reveal unacceptable defects, qualification shall be resumed once the cause of the defects has been found.

If, during forming or examination of the test piece, unacceptable defects appear systematically, or are considered as characteristic of the forming procedure, qualification shall be refused.

F 4125.2 Unsatisfactory destructive tests
a) If an unsatisfactory result is obtained due to incorrect performance of the test or the presence of a defect in the test piece, the result in question shall not be taken into consideration and a retest shall be performed.

b) In the case of impact tests, retests may be performed in accordance with the conditions defined in the part or product procurement specification, or in the qualification of the welding procedure.

c) If a test piece doesn't have the required properties after the destructive tests and any retests, another test piece shall be produced after the cause of the deficiency has been determined. The test piece for the retest shall conform to requisite characteristics.

F 4126  TEST REPORTS
The results of the forming procedure qualification tests shall be kept at the disposal of the Surveillance Agent and supplied on request. These results shall be recorded in a test report describing:

- the principal conditions of execution (specified and executed) of the test piece,
- the non-destructive examinations performed, associated criteria and results,
- the destructive tests performed, together with required values and results obtained.

The test report shall give the conclusions of the Manufacturer's inspection service.

F 4130  PRODUCTION FORMING OPERATIONS

F 4131  OPERATING REQUIREMENTS

F 4131.1 Forming plates which include welds
a) The forming of welded parts is forbidden for ferritic steels below 150°C.

However, slight cold calibration, after forming of the component, is permissible on components (welded or otherwise), whether they have been hot or cold formed.
b) Any welded joint of a part formed after welding shall be ground flush before forming.

**F 4131.2 Forming cylindrical and conical shells**

a) Plates to be used for the fabrication of cylindrical and conical shells shall be roll or press formed.

b) When the plates are roll formed, the leading edge shall be pre-bent by means of a press or roll. The straight unformed edge sections shall then be eliminated prior to final bending in order to avoid a flat zone in the weld area. However, for thin-walled shells with a large diameter, this requirement shall not be obligatory, provided that the remaining flat areas meet the criteria for shape given in F 4213.

When necessary, the edges of plates shall be rounded off before forming.

c) Precautions shall be taken during the forming operation to prevent parts being marked, particularly when shims are used between the plates and the rollers or platens.

During hot bending, for example, the Manufacturer shall make all the necessary provisions to eliminate mill scale from the surface of the plates in order to prevent indentations.

d) When a press is used for pinching or bending, the platen of the press shall cover the entire width of the plate at each stroke.

**F 4131.3 Pipe bending**

a) The bending process used, which depends on the diameter and thickness of the pipe, shall respect the tolerances for ovality and reduction in thickness which the design permits.

b) It is important that the bending tools be suitable for the pipe (pipe diameter, thickness, mechanical properties, etc). When selecting his tools, the Manufacturer shall take into account the pipe bending tolerances specified in the pipe standard which he applies, since the tolerances given in different standards may vary.

c) When possible, the weld seam on welded pipes shall be located in the area subjected to the least deformation.

d) When the sand fill hot bending process is used, a packing material shall be used in such a way that it does not stick to the walls of the pipes, that it may be easily removed after the bending operation, and that it does not complicate the subsequent cleaning operation, as specified in F 6000.

**F 4131.4 Forming heads**

Whenever it is technically feasible, heads shall be formed as a single part. When the head is too large to be formed as a single part, the components of the head shall be dished and formed mechanically.

Spinning may be used for carbon or alloy steels, provided that the part is suitable heated over an area greatly exceeding the area actually being worked.
F 4131.5  **Supplementary precautions for the forming of austenitic stainless steels**

a) The preparation of tools used to form austenitic stainless steels shall preclude any risk of contamination (cleaning and degreasing of tools) or inclusion of ferritic steel.

b) When austenitic stainless steels are being hot formed, the parts shall be heated in an inert or oxidizing atmosphere in a furnace, fired by low sulphur oil, in an electric furnace or in a gas-fired furnace.

The use of a coal furnace or a furnace with carburizing flames for either local or global heating of parts shall not be permitted.

The part shall not come into contact with the flames, and all grease shall be removed before heating.

c) Contact between carbon steel parts and austenitic stainless steel pipes is to be avoided as far as possible.

When contact of this nature is unavoidable, ferritic contamination tests shall be performed in accordance with the requirements of F 6000.

d) When lubricants are used for cold forming austenitic stainless steels, they shall meet the requirements of F 6000 covering prohibited contaminants.

e) Before a hot bending operation or heat treatment subsequent to bending, all grease shall be removed from the parts in accordance with written instructions and using products which meet the requirements of F 6000.

F 4132  **PRODUCTION EXAMINATION OF FORMING OPERATIONS**

a) General case: except for tube mentioned in F 4132.b, on completion of forming operations having required qualification, all parts shall be subjected to:

- a visual examination (plus liquid penetrant examination, where doubt exists),

- a dimensional check in order to check that the criteria defined in F 4200 and in the equipment specification are satisfied,

- the examinations stipulated in table F 4123 with the criteria required for qualification.

b) Case of tubes (not intended for use in heat exchangers)

On completion of forming operations having required qualification, the following shall be performed:

- a visual examination of every tube (plus liquid penetrant examination, where doubt exists),

- a dimensional check, in order to check that:

  . the ovality satisfies the criteria defined in F 4216.a

  . the thickness of the extrados still satisfies the design criteria defined in SECTION I.
These checks shall be performed on:

- 100% of class 1 and 2 pipes
- 10% of class 3 pipes,

- the examinations stipulated in table F 4123 with the criteria required for qualification.
- In addition, for class 1 pipes with an outside diameter greater than or equal to 350 mm, the following shall be performed after the forming operation:
  - liquid penetrant examination of the bend area, on each pipe, with the criteria required for qualification of the forming procedure,
  - a metallographic replica (structural examination - measurement of grain size) on at least the three first initial bends per area of qualification and at least once per section.

Note: It should be recalled that, for the production weld test coupons required by paragraphs S 7821 and 7822 b, the Manufacturer shall in all cases take into account the heat treatments encountered by the types of joint he represents.

F 4140 CORRECTION OF PIPE ALIGNMENT BY THERMAL CONTRACTION

A - Definition

The operation of thermal contraction consists in the local heating of a part or a section of part to induce deformation during cooling without the use of mechanical means.

B - Requirements

Manufacture by peening shall not be authorized. Thermal contraction shall not be allowable on:
- RCC-M class 1 equipment,
- carbon steel of specified minimum tensile strength > 450 MPa,
- thicknesses > 10 mm

The practice may be tolerated for other materials, by way of exception, in accordance with a pre-defined procedure.

The following requirements shall be observed:
- all impurities (oxides, paint, grease, etc) shall be removed from the surface to be heated,
- in the event of heating by oxyacetylene torch, the flame shall be regulated as close as possible to neutral,
- heating in a flame shall not be allowable for stainless steels.
- the temperature shall be measured by infrared optical pyrometer (or a heat sensitive crayon for carbon steels) excluding contact thermocouples. The temperature shall not exceed 425°C for stainless steels and 700°C for carbon steels,

- the heated zone shall be cooled in still air,

- only one thermal contraction operation shall be authorized at the same location on the equipment,

In any event, the Manufacturer shall prepare a procedure for the thermal contraction operation prior to its performance. The identification marking and welding isometric shall provide clear indication of the thermal contraction and its location.

The quality plan shall include:

- a reference to the procedure for performance of the thermal contraction,
- temperature measurement,
- examination following performance.

C - Examinations

The surface of the heated zone and the area immediately surrounding it shall be subjected to the following examinations:

- a visual examination and in case of doubt following the latter, magnetic particle examination for class 3 equipment,

- a visual examination and magnetic particle examination for class 2 equipment.

If it is not possible to perform magnetic particle examination, the latter may be replaced by liquid penetrant examination.

If heating affects a weld, in addition, a radiographic examination of the weld is required.

D - Criteria

The visual inspection shall reveal a uniform surface, free from tears, blisters, weld craters, cracks, overlaps.

In all cases the acceptance criteria are those defined in S 7700, according to the equipment class.

The dimensional criteria to be observed during thermal contraction are those defined by the dimensional tolerances established by the pipe procurement standard.
F 4160 BENDING TUBES FOR CLASS 2 AND CLASS 3 HEAT EXCHANGERS

F 4161 GENERAL

a) This paragraph only deals with tubes for heat exchanger bundles for which qualification of the bending procedure is required, whatever the elongation values.

b) for the bending of these tubes, the requirements of the other chapters of F 4000 shall be supplemented by those of this paragraph, unless otherwise indicated.

F 4162 DIMENSIONAL TOLERANCES AFTER BENDING

a) After bending, the thickness of the tube on the bend shall satisfy the requirements of C and D 3320 as regards thickness and reduction of thickness.

b) The ovalization of the tube on the bend shall be at most equal to 7% calculated in accordance with the following formula:

\[ \frac{d_{\text{max}} - d_{\text{min}}}{d_N} \times 100 \]

\[ d_N = \text{nominal diameter of the tube}. \]

c) The deviation tolerances between the legs of a U-tube are specified by the heat exchanger Manufacturer. Depending on the design of the heat exchanger, these tolerances shall be such that the U-tubes may be inserted into the baffle and tube plates without being damaged and shall not exceed the values below, measured at the transition zone between straight and bend section as a function of the bending diameter D in mm.

- \( 55 < D \leq 150 \text{ mm} \) : \( \pm 1.5 \text{ mm} \)
- \( 150 < D \leq 500 \text{ mm} \) : \( \pm 2.5 \text{ mm} \)
- \( 500 < D \leq 1000 \text{ mm} \) : \( \pm 3.5 \text{ mm} \)
- \( 1000 < D \leq 1500 \text{ mm} \) : \( \pm 4.5 \text{ mm} \)
- \( 1500 < D \leq 2000 \text{ mm} \) : \( \pm 5.5 \text{ mm} \)

d) The tolerance for the overall length of the pins is \(-0, +4 \text{ mm}\).

F 4163 QUALIFICATION OF THE BENDING PROCEDURE

a) Before any manufacturing operation, the Manufacturer shall demonstrate by means of the tests performed on tubes of the prototype series stipulated in M 100 or on tubes forming part of the purchase order, that the adopted procedure allows the required dimensional tolerances to be satisfied, does not affect the material and that the level of stress in the bends does or does not require stress relieving treatment.

The qualification of a bending procedure shall only be valid for the machine used for qualification tests or for a machine of the same make and model in the same workshop.
b) The qualification procedure is as follows:

I. Verification of suitability to obtain dimensional tolerances: 5 bends shall be made to the minimum radius of curvature required by means of the bending machine used for production. The dimensions for the 5 bends are checked and the results must meet the tolerance requirements.

Measurements are made at the same points as in production (F 4164).

II. Resistance to stress corrosion and micrographic examination, for austenitic stainless steels:

II.1 The acceptable stress level is defined by the resistance or otherwise of the bends to a boiling magnesium chloride corrosion test in accordance with procedure MC 1362 (the absence of cracks determines the acceptable stress level).

If heat treatment is revealed necessary on completion of the primary tests required by a) above, the Manufacturer shall define the conditions.

II.2 The validity of the heat treatment is checked for the 5 bends below:

- 2 non heat-treated bends serving as specimen bends,
- 3 bends having undergone stress relieving heat treatment.

II.2.1 After heat treatment, the dimensional tolerances shall be re-checked on the 3 heat treated bends.

II.2.2 Tests shall be performed on each of the 2 untreated bends in accordance with MC 1362:

- one in the transition zone between straight and bent section,
- one in the middle of the bend section.

II.2.3 After heat treatment, the tubes shall be examined under a microscope to check (in accordance with MC 1330) that:

- the grain size is not significantly different from that of a specimen sample taken from the same zone not having undergone treatment (grain growth shall be accepted provided the number of grains is at least equal to the median value of the range corresponding to the grain size number one below that of the specimen sample),
- there is no generalized precipitation at the grain boundaries.

100 X magnification shall be used for micrographic examination.

II.2.4 If the 5 bends tested have a radius of curvature less than or equal to 10d*, two additional tubes shall be bent to the radius of curvature corresponding the closest to 10d.

These two tubes shall then be subjected to the same magnesium chloride tests and verification as defined in II.2.3 and II.2.2 above.

*d = outside diameter of tube.
If the level of stress prevents the tests from being performed, tests shall then be carried out on bends with the next radius of curvature greater than 10d to determine the minimum radius of curvature below which the stress relieving heat treatment is required.

If the level of stress allows the tests to be performed, heat treatment shall only be performed for bends up to a radius of curvature corresponding the closest to 10d.

II.2.5 If the radius of curvature of the 5 bends subjected to the tests specified in II.2.3 and II.2.2 is greater than 10d. and the magnesium chloride test does not give satisfactory results, the procedure given in the 2nd paragraph of II.2.4 above shall be followed.

III. Resistance to stress corrosion and micrographic examination for steels other than austenitic stainless steels (awaiting publication).

F 4164 DOCUMENTS REQUIRED ON COMPLETION OF QUALIFICATION

The Manufacturer shall draw up a bending procedure specifying:

- the tools used,
- the requirements for stress-relieving heat treatment (where applicable),
- the requirements for examinations and verifications,
- the range of approval of the qualification.

F 4165 EXAMINATION OF PRODUCTION BENDS

Fabrication shall be verified during bending operations per lot (defined in accordance with SECTION II) and per bundle. These operations comprise at least the following (prior to composition of bundles):

a) In each lot, the dimensional check is performed on 5 bends of the same radius (5 bends per radius if there are several radii in the same lot).

   The following examinations shall be performed:
   - the radius of curvature,
   - ovalization at three points (45, 90 and 135°).
   - thickness of the extrados (ultrasonic examination).

b) For each completely stress-relieved tube bundle, the following bending specimen samples shall be taken:
   - 1 bend at the minimum radius of curvature,
   - 1 bend of the maximum radius of curvature.
For each partially stress-relieved bundle, the following bending specimen samples shall be taken:

- 1 bend at the minimum stress-relieved radius,
- 1 bend at the maximum stress-relieved radius,
- 1 bend at the minimum non-stress-relieved radius.

The following tests shall be performed on bends:

- dimensional check at three points 45, 90 and 135°,
- verification of thickness by ultrasonic examination along the extrados,
- a magnesium chloride test in accordance with MC 1360 for austenitic stainless steels for non-stress-relieved bends:
  . 1 in the transition zone between straight and bend section,
  . 1 in the middle of the bend.
- a micrographic examination (on the smallest and largest stress-relieved bends on 2 samples, one taken from the transition zone between straight and bent section and the other taken from the middle of the bend) for examination of the grain size in accordance with F 4163b) II.2.3 for austenitic stainless steels on stress-relieved bends.

c) Surface examination of bends

- These should be free of scratches or signs of bumps or any defects capable of reducing the strength of the tube. In cases of doubt, liquid penetrant examination may be performed,
- the cleanliness of bends shall conform to the requirements of F 6000, particularly in the case of austenitic stainless steels as regards the existence of slight tinting after stress relieving heat treatment.

**F 4200 FORMING TOLERANCES**

**F 4210 TOLERANCES FOR A VESSEL UNDER INTERNAL PRESSURE**

**F 4211 GENERAL**

The cylindrical or conical shells and the heads of a vessel under internal pressure shall meet the requirements set forth below. These requirements represent minimum criteria which the Manufacturer may make more restrictive in order to meet the functional design criteria when he procures the component parts.

The equipment specification shall stipulate the permissible deviations from tolerances for stiffened areas, reinforcement of openings or any other structural discontinuity.
F 4212  THICKNESS

The wall thickness at all locations shall conform to the requirements established by analyses performed in accordance with the criteria given in chapters B, C and D 3000 of SECTION I.

F 4213  TOLERANCES FOR CYLINDRICAL AND CONICAL SHELLS
FOR A COMPLETED VESSEL

a) Out-of-roundness

The difference in mm between the maximum and minimum internal diameters at any cross section normal to the shell centreline shall be less than the smaller of:

\[
\frac{D + 1250}{200} \quad \text{or} \quad \frac{D}{100}
\]

where D is the nominal inside diameter in mm at the cross section under consideration.

The diameters may be measured on the inside or the outside of the shell. When measured on the outside, the diameters shall be corrected for the plate thickness at the cross section under consideration.

When the cross section passes through an opening, the permissible difference may be increased by 2% of the inside diameter of the opening.

b) Deviation from true form of cylinders

For vessels under internal pressure whose wall thickness is less than 10 mm, deviations from true theoretical form (measured by means of a segmental circular template of the designed form of the shell whose length is equal to the chord of an angle of 20° at the centreline of the cylinder) shall not exceed 5% of the minimum plate thickness plus 3 mm. This value may be increased by 25% when the length of the deviation does not exceed a quarter of the length of the cylindrical shell measured between two circumferential weld seams and does not exceed a maximum of 1 m.

c) Maximum deviation from straightness

( awaiting finalization).

d) Measurements required to verify the values specified in a) and c) above shall be made when the vessel is upright or horizontal. In order to compensate for deformation when the vessel is horizontal, after the first measurement has been made, the vessel shall be rotated 90°, the measurement shall be repeated and an average of the two measurements calculated.

F 4214  TOLERANCE DEVIATIONS FOR VESSEL PARTS
FABRICATED FROM PIPE

Vessel parts fabricated from pipe and subjected to internal pressure meet the tolerance requirements stipulated in the pipe specifications (procurement standards and fabrication requirements) and the design specifications.
**F 4215  TOLERANCES FOR FORMED VESSEL HEADS**

a) The difference in diameter, in mm, between the minimum and maximum internal diameters in any cross-section normal to the centreline of the cylindrical skirt for a head, when such a skirt is provided, shall not exceed the lesser of:

\[
\frac{D + 1250}{200} \quad \text{or} \quad \frac{D + 300}{100}
\]

where D is the nominal internal diameter in mm of the cylindrical shell under consideration.

b) The inner surface of a head shall not deviate from the specified shape by more than the percentage values specified below.

1) Ellipsoidal or torispherical heads

   The dished inner surface of an ellipsoidal or torispherical head shall not deviate from the specified inner shape at any given point by more than 1.25% of D towards the outside and 0.63% of D towards the inside (where D is the nominal diameter of the vessel). The deviation shall be measured normal to the wall of the head at the location under consideration.

   For this type of head, the knuckle radius shall not be less than the value specified in French standards.

2) Hemispherical heads

   The inner surface of a hemispherical head and any spherical portion of a formed head or tank shall meet the tolerance requirements specified in F 4127 for spheres subjected to external pressure.

c) All deviations from shape requirements shall be measured on base metal and not on welds.

**F 4216  TOLERANCES FOR PIPES AFTER FORMING**

a) Ovality

   The maximum ovality after forming shall be such that:

\[
\frac{D_{\text{max}} - D_{\text{min}}}{D_N} < 8\%
\]

   \(D_N\) = the nominal diameter of the pipe,

   \(D_{\text{max.}}\) = the maximum diameter after bending or forming,

   \(D_{\text{min.}}\) = the minimum diameter after bending or forming.
b) Thickness after bending

The wall thickness after bending shall always be sufficient to meet the design criteria given in SECTION I and in no case shall the reduction in pipe wall thickness exceed the following values:

- 10% for bending radii greater than or equal to 5 D,
- 50 D/R % for bending radii less than 5 D. D and R are pipe nominal diameter and bending radius with respect to the pipe axis respectively.

F 4217 VESSELS SUBJECTED TO EXTERNAL PRESSURE

1) The local plus or minus deviation $\delta$ from true circular form, measured radially in a cross-sectional plane normal to the centreline of the shell shall not exceed the value for deviation given in figure F 4217.1 where:

$$e = \text{nominal wall thickness (less corrosion allowance)}$$

(when the shell comprises elements of different thickness, e shall be the smallest wall thickness).

The deviation from true circular form $\delta$ shall be measured by means of a circular template whose radius is equal to the design inside or outside radius and a chord length equal to twice the arc length obtained from figure F 4217.2.

The value $L$ shall be obtained from the graphs in figure F 4217.1 and 4217.2 as follows:

- for cylinders, $L$ shall be either:
  . the length between head bend lines (tangent lines)
  or
  . the maximum distance between stiffener rings or between a head bend line and the first stiffener ring,

- for cones, $L$ is the axial length of the conical section or, if stiffener rings are used, the axial length from the large end of the cone to the first stiffener ring, with $D_e$ taken as the outside diameter of the larger section,
- for spheres, $L$ is half of the outside diameter $D_e$.

2) The deviation from specified shape of $L$ as defined above shall not be measured on welds.

3) Requirement F 4213 b) shall be mandatory for all thicknesses of vessels subject to external pressure.

F 4218 CYLINDRICAL OPENINGS AND NOZZLES

Cylindrical openings and nozzles shall meet the tolerance requirements specified in F 4212, F 4213, F 4214 and F 4217.
FIGURE F 4217.1

FIGURE F 4217.2
F 4300  ALIGNMENT OF PARTS JOINED BY WELDING

F 4310  GENERAL

a) Parts that are to be joined by welding may be aligned, fitted and retained in position during the welding operation by means of jacks, clamps, bridges, temporary attachments, tack welds, special devices, etc., in order to meet the tolerance requirements given in the following paragraphs.

b) The welding of temporary attachments, special devices and tack welds shall meet the requirements of S 7400 and the requirements for cleanliness given in F 6000.

c) The tolerances given in F 4300 represent maximum values which must not be exceeded. However, the component Manufacturer shall take into account the requirements for non-destructive examination specified in SECTION I. Consequently, surface alignment after welding shall be such that non-destructive examination may be properly performed.

d) The alignment of parts of different thickness or the fairing of offsets shall meet the requirements for design stipulated in chapters B, C and D 3000 of SECTION I.

F 4320  ALIGNMENT TOLERANCES FOR JOINTS WELDED FROM BOTH SIDES OR WELDED FROM ONE SIDE ONLY BUT ACCESSIBLE FROM THE ROOT SIDE

a) The tolerances for fabrication shall apply to the alignment of the centrelines of both parts to be joined by welding (unless otherwise justified by design).

b) The tolerances for aligning the inside surfaces of parts of equal thickness are given in table F 4320.b.

<table>
<thead>
<tr>
<th>SECTION THICKNESS</th>
<th>MAXIMUM PERMISSIBLE OFFSET</th>
</tr>
</thead>
<tbody>
<tr>
<td>e &lt; 12</td>
<td>$\frac{e}{4}$</td>
</tr>
<tr>
<td>e $\geq$ 12</td>
<td>$\frac{e}{10}$ + 2 (maximum 8 mm)*</td>
</tr>
</tbody>
</table>

e thickness in mm of joined parts
* for class 3 components, this value is increased to 10 mm

c) Alignment tolerances for parts of different thicknesses

1) The centrelines of two parts of different thicknesses may be offset so that the maximum misalignment of inside surfaces is less than the values given in table F 4320 b where e is taken to be the thickness of the thinnest part.
2) For longitudinal welds, the edge of the thinnest part shall be included in the section defined between the 2 faces of the thickest part (see figure F 4320.c).

![Figure F 4320 c](image)

**F 4330 JOINTS WELDED FROM THE OUTSIDE WHEN THE ROOT SIDE IS INACCESSIBLE**

a) Inside surfaces

The maximum offset of inside surfaces shall not exceed \(\frac{e}{20} + 1\) and a maximum of 3.00 mm for class 1 and 2 components, and 3.75 mm for class 3 components (\(e = \text{thickness in mm}\)).

b) Outside surfaces

The values specified in F 4320 b) and c) shall be applicable.

For parts of different thickness, \(e\) shall be the thickness of the thinner section.

**F 4340 DISHEd PARTS AND HEADS MADE OF WELDED PARTS**

The weld joints between the component parts of spherical vessels or the constituent elements of dished heads shall meet the alignment requirements for longitudinal joints accessible from the inside.

**F 4350 PIPES AND PIPING**

a) When the inside surfaces of butt welded counterbored pipe components are inaccessible, the inside diameters of the components shall be offset in accordance with the method given in F 4330. In these cases, the maximum misalignment at any point around the joint shall not exceed 1.5 mm.

b) In order to butt weld welded steel pipe and fittings whose thickness-to-diameter ratio is such that the pipe cannot be counterbored and may be subject to deformation, the Manufacturer shall calibrate the end sections of the joint, when necessary, to meet the tolerance requirements given in a) above.
c) For longitudinal joints of welded pipe, the internal offset shall not exceed:

\[
\begin{align*}
1 \text{ mm fore} & \quad e \leq 20 \text{ mm} \\
e/20 \text{ (in mm) for} & \quad 20 \text{ mm} < e \leq 40 \text{ mm} \\
2 \text{ mm for} & \quad e > 40 \text{ mm}.
\end{align*}
\]

For small schedule pipes welded longitudinally using the TIG process, it is recommended that these values be reduced.

d) For large pipes manufactured from rolled and longitudinally welded heavy steel plate, the tolerance requirements given in F 4320 and F 4330 shall apply.

F 4360  DEVIATIONS FROM TOLERANCES

a) The alignment tolerances specified in F 4300 may only be exceeded within the limits defined in SECTION I.

b) When either the inside or outside offset exceeds the values specified in F 4320 and F 4330, the offset shall be faired to a 4 to 1 taper (or 3 to 1 taper for circular joints) in accordance with the requirements of SECTION I chapters B, C and D 3353.

c) The offset may be faired to meet the requirements of b) above by either removing metal from the component with the thicker section or depositing additional weld metal on the component with the thinner section.

In this case, the examination procedures shall cover the area where metal is removed or where metal is deposited.

The removal of metal from the component with the thickest section shall only be permitted when this operation does not induce unacceptable stresses, in accordance with the criteria given in SECTION I for the class of component under consideration; when the stress level is unacceptable, only the deposition of weld metal shall be permitted.

F 4400  EXPANDING TUBES IN HEAT EXCHANGER TUBE PLATES

F 4410  GENERAL

F 4411  TERMINOLOGY

Expanding is the operation of increasing the diameter of the tube in the tube hole, to provide interfacial pressure between the surface of the tube and the tube hole, after springback of the plate.

The gap is the space remaining after expanding, between the external wall of the tube and the surface of the tube hole in the tube plate.

The crevasse comprises the tube/tube hole clearance in the non-expanded section of the tube.
The clearance is that between the tube and the tube hole before expanding.

Interfacial pressure is the average pressure between the tube and the tube hole after completion of the expanding cycle.

The transition zone is the geometric discontinuity between the expanded and non-expanded tube sections.

The primary side is by convention, that inside the tube.

**F 4412 EXPANDING PROCESSES**

Expanding tubes in heat exchanger tube plates may be performed using various processes:

1. - Mechanical expanding: by using rotating rolls.
2. - Hydraulic expanding: by pressurizing a fluid in the tube.
3. - Expanding by exploding an explosive charge located inside the tube.

Expanding shall be performed over the full height of the tube plate.

These different processes may be used singly or in combination. In the latter case, mechanical expanding may be partial when performed in conjunction with another process. When mechanical expanding only is performed, this is known as full-depth mechanical expanding.

Other uses of mechanical expanding are:

. Mechanically-improved expanding:

   Full-depth expanding followed by stress-relieving of the external wall of the tube in the transition zone, by controlled mechanical expanding.

. Initial expanding (tacking):

   Partial expanding aimed simply at reducing clearance during welding. This operation comprises part of the tube/plate welding qualification procedure (S3800).

**F 4413 FUNCTIONS OF TUBE EXPANDING**

Expanding can fulfill the following functions:

a) Protection of the weld joining the tube to the tube plate against bundles loadings during operation. In this case, the tube/plate expanding provides mechanical strength adequate to comply with the requirements for the mechanical strength of joints specified in B 3353.3.b.7 or C 3353.3.a.3 or D 3300.

b) Closing off the clearance between the tube and the tube hole on the secondary side to prevent secondary fluid penetrating the gap between the tube and the tube hole, and reducing the height of crevasses to a minimum.

c) Absorption of mechanical loading of the assembly.
d) Leaktightness of the two exchanger circuits.

Functions a and b are mandatory for welded tube to tube plate joints.

Functions c and d are mandatory for non-welded tube to tube plate joints.

**F 4414 PRELIMINARY TESTS**

To select the expanding process most likely to satisfy the operating requirements, the Contractor, in conjunction with the Manufacturer, shall, depending on his experience and technical capabilities, carry out a preliminary test programme to investigate the characteristics of the tube to tube plate joint obtained using the process selected. The test programme shall be performed on test coupons with a view to improving the definition of the expanding parameters and checking the assembly examination methods used during fabrication.

A file containing all the results of the preliminary tests shall be compiled and submitted by the Contractor. He shall indicate the range of parameters investigated and which will be used to define the range of approval of the procedure qualification.

The file may comprise work performed during other fabrications, possibly supplemented by tests specific to the exchanger concerned. The works and tests shall make possible investigation of the characteristics of the leaktightness and mechanical performance of the joint.

The equipment specification shall state whether the risk of stress corrosion should be taken into account. In this case, evaluation of the residual stress of the internal or external skin shall be performed.

The residual stress may be assessed in various ways: stress-corrosion cracking tests in boiling magnesium chloride (in accordance with MC 1360), X-ray diffraction meter, etc.

In the case where mechanically-improved expanding is to be used, the preliminary tests shall allow checking that the conditions adopted result in a reduction of residual stress on the external skin of the transition zone, within the range of values used for procedure qualification. These tests shall be performed in accordance with MC 1362.

**F 4420 PROCEDURE AND OPERATORS QUALIFICATION**

**F 4421 DOCUMENTS TO PREPARED**

Prior to any expanding operation, the Manufacturer shall prepare a procedure which shall comply with the requirements of the relevant paragraphs and shall include at least:

- all parameters defining the range of qualification in accordance with F 4422,
- all the examinations to be performed before and after expanding,
- the required results.
**F 4422** RANGE OF QUALIFICATION

**F 4422.1 Workshop**

Qualification tests shall be performed at the same shop or site as the production expanding. However, an expanding procedure qualification may be extended to another shop or site of the same Manufacturer, on condition that expanding is performed by personnel experienced in expanding operations.

**F 4422.2 Essential variables of the procedure**

Any change in one of the essential variables shall require renewal or extension of qualification.

The variables are defined for each type of process.

All quantifiable variables shall be tolerated to define the range of qualification.

**F 4423** PROCEDURE QUALIFICATION TESTS

This paragraph applies to all expanding processes except mechanically-improved expanding for which the tests are specified in F 4463.

**F 4423.1 Number and type of qualification test coupons**

The qualification tests shall require making at least 10 test coupons (1 test coupon = 1 tube). The test coupons shall be made in a multi-perforated block in which tube holes are drilled and cleaned using the same methods as for fabrication.

The thickness of the test coupon shall be representative of that of the exchanger tube plate.

The test coupon shall not be welded nor initially-expanded, even where these operations are scheduled during production, in order not to affect tests of the expanded joint characteristics.

**F 4423.2 Tests to be performed - Required results**

The following tests shall be performed on all test coupons.

**F 4423.2.1 Exchangers with welded tube to tube plate joints**

a) Visual examination

Visual examination of the inside of the tubes shall be performed to check if there is no deterioration.
b) Dimensional check

The profile of the inside of the tubes shall be recorded over the full height of the tube plate. In particular, the position of the beginning of the transition zone at the tube plate outlet shall be checked:

- in general, this should be recessed from the tube plate outlet, subject to this distance not exceeding 6 mm,
- in the particular case of full-depth expanding of a carbon steel tube, the transition zone may begin a maximum of + 2 mm beyond the tube plate outlet.

c) Gap leaktightness test

Leaktightness of the gap shall be checked by a hydraulic test with demineralized water to which 5% organol red has been added.

The minimum pressure applied to the gap on the secondary side of the tube plate shall be 1.5 times the maximum service pressure of the exchanger secondary circuit, with a ceiling of 50 bar.

It shall be checked using an indicator applied to the primary side of the test coupon, that the speed of penetration of the fluid is 40 mm/mn or less.

d) Mechanical strength check

Each test coupon shall be subjected to a tensile test intended to measure the force required to tear off the tube.

The force applied and the movement of the tensile test head shall be recorded.

The requirements are as follows:

- the force required to tear off the tube shall be twice the basic force determined as follows:

\[
F \geq \frac{1}{2} P \pi D^2
\]

\[
F = \text{force required to tear off the tube}
\]

\[
P = \text{the greatest pressure difference found in 2nd category situations}
\]

\[
D = \text{the inside diameter of the tube}
\]

- the stress, determined for the nominal cross-section, shall be greater than half the minimum yield strength specified for the tube at 20°C

\[
\frac{F}{S_0} > 0.5 \sigma_{p0.2}
\]

\[
S_0 = \text{the nominal cross-section of the tube}
\]

F 4423.2.2 Exchangers with non-welded tube to tube plate joints

a) Visual examination

The requirements of F 4423.2.1 a) apply.
b) Dimensional check

The requirements of F 4423.2.1 b) apply.

c) Joint leaktightness checks

Leaktightness of the gap shall be checked by a hydraulic test with demineralized water to which 5% of organol red has been added.

The minimum pressure at the gap on the secondary side of the plate shall be as follows:

- 2 MPa where the maximum service pressure is 1.0 MPa or less,
- Twice the maximum service pressure where the latter is greater than 1.0 MPa.

Leaktightness shall be checked using an indicator applied on the primary side of the test coupon.

d) Mechanical strength checks

Each test coupon shall be subjected to a tensile test intended to measure the force (F) required to tear off the tube; the force applied and the movement of the tensile test head shall be recorded.

The force required to tear off the tube shall be the smaller of the following two values:

- The value determined as a function of the maximum service pressure of the heat exchanger (P):

  \[
  \begin{align*}
  F &> 800 \text{ daN} \quad \text{for} \quad P \leq 0.5 \text{ MPa} \\
  F &> 1000 \text{ daN} \quad \text{for} \quad 0.5 < P \leq 1 \text{ MPa} \\
  F &> 1500 \text{ daN} \quad \text{for} \quad 1 < P \leq 2 \text{ MPa} \\
  F &> 2000 \text{ daN} \quad \text{for} \quad 2 < P \leq 3 \text{ MPa} \\
  F &> 2500 \text{ daN} \quad \text{for} \quad P > 3 \text{ MPa}
  \end{align*}
  \]

- the force corresponding to the minimum yield strength specified for the grade of tube at 20°C.

F 4424 PROCEDURE QUALIFICATION REPORT

Examinations and tests shall be covered by a qualification report.

F 4425 VALIDITY OF THE QUALIFICATION

The qualification of an expanding process is valid for 3 years from the date on which it was granted. Qualification may be extended for the same period, from the date of the last shop application of the process.

Beyond this date, the Manufacturer may ask the Contractor for an extension of the validity of the qualification. The request shall be supported by a file prepared on the basis of similar fabrication and which demonstrates the Manufacturer's capability to implement the procedure.
F 4426 QUALIFICATION OF PERMANENT ASSEMBLY OPERATORS

Operators who carry out mechanical, hydraulic or explosion expansion must be qualified prior to the manufacturing operations.

Operator qualification is based on a specification drawn up by the manufacturer. The specification can be based on the experience acquired by the operator within the expansion process, his ability to follow an expansion procedure, his follow-up by a tutor considered as skilled in this field, suitable training, etc.

Qualification is awarded by the manufacturer.

The manufacturer keeps an up-to-date list of qualified operators.

F 4430 FABRICATION
F 4431 GENERAL

The expanding sequence shall be included in the manufacturing programme, in order to take into account the effect of the variation in the length of tubes and operations performed after fabrication of the exchanger, e.g. welding heat treatment, stress-relieving and the deformation of parts.

F 4432 DOCUMENTS TO BE PREPARED

Prior to fabrication, a specification shall be drawn up to indicate:

- the type and nature of the equipment used,
- the process and its parameters,
- the examinations to be performed before, during and after expanding.

F 4433 CLEANLINESS PRIOR TO EXPANDING

The tube holes in the tube plate shall be cleaned before tubing using suitable methods to remove all traces of grease, oxides, adherent deposits or dust.

Suitable protection shall be provided to preserve cleanliness between cleaning and tubing operations.

F 4434 CLEANLINESS AFTER EXPANDING

Cleanliness inside the tube shall be restored after expanding.

F 4440 EXAMINATIONS
F 4441 EQUIPMENT CHECKS

The settings, condition and correct functioning of equipment shall be checked at the start of fabrication, at the beginning of each shift and at suitable intervals based on operating experience, and any deviations which may be noticed.
**F 4442 CHECKS DURING IMPLEMENTATION OF THE PROCEDURE**

A suitable system (marking, marking on a drawing, use of plugs, stoppers, positioning tooling etc) shall be used to ensure all the tubes are expanded in accordance with the applicable procedure.

Special checks are indicated for each process.

In the event of an incident, an endoscopic examination of all tubes which may have been damaged shall be performed.

**F 4443 PRODUCTION TEST COUPONS**

Production test coupons are only required for non-welded tube/tube plate joints.

- Number of production test coupons:
  
  15 or 0.5/1000 of the expanding operations performed on the heat exchanger, whichever is the greater.

  **Note:** In the case of identical heat exchangers comprising less than 1000 tube holes and where expanding operations are performed during the same month, only one test coupon is required per 3 heat exchangers.

- The requirements of F 4423.1 shall be respected to ensure that the test coupon is representative of production conditions.

Test coupon expanding shall be performed in parallel with production expanding operations. Expanding of test coupons shall be identified in relation to the corresponding expanded zone on the heat exchanger. This identification making shall also indicate the reference numbers of the expanding equipment used in each zone.

- Examination and tests

Examination and tests on the test coupons shall be performed as soon as possible, results shall be recorded in a test report.

- Required results

The tests to be performed and the required results are the same as for the procedure qualification tests.

**F 4444 FINAL EXAMINATIONS**

The examination of the position of the beginning of the expanding transition zone on the secondary side shall be performed for all the tubes in the heat exchanger. The criteria to apply are those stated in F 4423.2.1b). The leaktightness of non-welded tube/tube plate joints shall be checked on the heat exchanger.

**F 4445 REWORKING**

After the expanding operations have been checked, reworking may be performed after technical analysis, provided a justification file has been prepared for the operations concerned.
F 4450 FULL-DEPTH MECHANICAL EXPANDING

F 4451 ESSENTIAL VARIABLES OF QUALIFICATION

- Equipment
  . grade of roll material,
  . geometry of the roll
  . angle of the rolls cage slots
  . slope of mandrel taper
  . rotating speed of mandrel

- With or without of lubrication

- Grade of the tubes

- Grade of the tube plate
  Another grade may be used provided that the stated chemical composition is comparable, and the yield strength at room temperature does not deviate by more than 20% from the value stated for the grade used during procedure qualification.

- Dimensional characteristics:
  . nominal outside diameter of the tube,
  . nominal diameter of the tube plate hole,
  . nominal thickness of the tube,
  . expanded length L, where L is the expanded length of the qualification test coupon:
    for \(L < 150\) mm, the qualification remains valid between \(L\) and \(1.5L\)
    for \(L \geq 150\) mm, the qualification is valid for all lengths \(\geq 150\) mm.

- Ratio of step/diameter of perforated area

- Technique for drilling the tube plate hole

- Expanding torque

- Specified clearance, determined during preliminary tests.

F 4452 FABRICATION

In the case of tubes previously welded to the tube plate, expanding shall begin on the welded side of the plate.

The rolling step shall be such as to ensure adequate overlay of steps (3 mm minimum).

The system for identification marking of holes shall allow identification of tubes which will be subject to a special expanding operation linked to a drilling defect or expanding reworking.

F 4453 EXAMINATIONS

F4453.1 Examination during fabrication

The torque shall be checked at least once at the beginning of the shift.
**F 4453.2  Final examinations**

During final examination, ensure no steps have been omitted.

**F 4460  MECHANICALLY-IMPROVED EXPANDING**

Reduction of the residual stress in the external wall of the tubes in the expanding transition zone.

**F 4461  GENERAL**

On completion of expanding, if the risk of stress corrosion must be taken into account on the external skin (refer to F 4414), mechanically-improved expanding of the expanding transition zone may be performed.

**F 4462  DESCRIPTION OF THE PROCESS**

The process comprises the creation of a slight diametrical deformation in the transition zone and adjacent section of non-expanded tube. The operation is performed with a mechanical expander.

For stress-relieving to be effective, the amount of deformation must be sufficient but must not be such as to bring the tube into contact with the tube hole: this may be expressed as follows:

\[
\text{minimum } \Delta \text{ dia. } < \Delta \text{ dia. } < J
\]

\[
\Delta \text{ dia. } = \text{dia.}_1 - \text{dia.}_0
\]

\[
J = \text{minimum tube hole clearance}
\]

\[
\text{Dia.}_0 = \text{inside diameter of the tube before stress-relieving.}
\]

\[
\text{Dia.}_1 = \text{the inside diameter of the tube after stress-relieving, measured in the middle of the stress-relieved zone.}
\]

The zone deformed during the stress-relieving expanding shall extend at least 10 mm.
F 4463 PROCEDURE QUALIFICATION

F 4463.1 Essential variables
- Initial expanding process (with all its essential variables)
- Stress-relieving process
- Equipment
  . dimensions and geometry of the roll
  . number of rolls
  . grade of roll material
  . angle of the rolls cage slots
  . slope of mandrel taper
- with or without lubrication
- Grade of tubes
- Nominal outside diameter of the tubes
- Nominal thickness of the tubes
- change in Δ dia.

F 4463.2 Qualification tests
The tests are performed on test coupons the dimensions of which will allow at least two expanding steps.

At least 20 test coupons shall be made using the qualified full-depth expanding process. They shall undergo stress-relieving under conditions identical to those used during fabrication. The Δ diameter of the tube shall be measured using suitable equipment. In particular, the height at which expanding is measured shall be established with care.

If the permitted range can be covered by several values which differ from the parameter displayed (number of revolutions of the mandrel, value of mandrel movement, etc.) execute at least 10 test coupons per value determined by the parameter.

F 4463.3 Required results
No diametrical expansion value shall fall outside the range permitted within the range of approval.

The absence of damage to the tubes shall be verified.

The report prepared shall state the initial dimensions of test coupons and the individual Δ diameters recorded, and the results of the visual examination.
F 4464  EXAMINATIONS

F 4464.1 Examinations during fabrication

Checking of $\Delta$ dia. value shall be performed at least once per shift and each time the tool is changed, either directly on the heat exchanger or on a test coupon made using the production tool.

The change in $\Delta$ dia. shall be checked to ensure it falls within the range specified in the range of approval of the process qualification, and that there are no scratches in the transition zone.

F 4464.2 Final examination

The final identification marking method shall prove that stress-relieving of all the tubes has been performed.

F 4470  HYDRAULIC EXPANDING

F 4471  ESSENTIAL VARIABLES OF THE PROCEDURE

- Equipment
  - commercial designation of the expanding probe, defining the technology

- Nature of the expanding fluid

- Lubrication of the probe joints

- Process
  - expanding pressure
  - hold time
  - number of successive sequences per cycle

- Grade of the tube plate
  
  Another grade may be used provided that the stated chemical composition is comparable, and the yield strength at room temperature does not deviate by more than 20\% from the value stated for the grade used during procedure qualification.

- Grade of the tube

- Dimensional characteristics
  - nominal outside diameter of the tube
  - nominal thickness of the tube
  - nominal diameter of the tube plate hole
  - length of expanding between 0.75 L and 1.25 L, L being the expanded length of the qualification test coupon
  - ratio step/diameter of the perforated area
  - technique for drilling the tube plate hole
  - specified clearance determined during preliminary tests
**F 4472  EXAMINATIONS**

The expanding pressure shall be checked at least once at the beginning of the shift.

---

**F 4480  MIXED HYDROMECHANICAL EXPANDING**

In general, mixed expanding is a combination of 2 or more expanding processes as described in F 4412.

Mixed hydromechanical expanding consists of first carrying out hydraulic expanding of the tube, followed by partial expanding on the secondary side, slightly behind the end of the hydraulic expanding.

Where the basic hydraulic expanding process has already been qualified (in accordance with F 4420 and F 4470), the Manufacturer may submit to the Contractor a supplementary file relating specifically to the qualification of the mixed process.

---

**F 4481  ESSENTIAL VARIABLES OF THE PROCEDURE**

- Hydraulic expanding equipment
  - commercial designation of the expanding probe, defining the technology

- Nature of the expanding fluid

- Lubrication of the probe joints

- Process
  - expanding pressure
  - hold time
  - number of successive sequences per cycle

- Grade of the tube plate

  Another grade may be used provided that the stated chemical composition is comparable, and the yield strength at room temperature does not deviate by more than 20% from the value stated for the grade used during procedure qualification.

- Grade of the tube

- Dimensional characteristics
  - nominal outside diameter of the tube
  - nominal thickness of the tube
  - nominal diameter of the tube plate hole
  - length of expanding between 0.75 L and 1.25 L, L being the expanded length of the qualification test coupon
  - ratio step/diameter of the perforated area
  - technique for drilling the tube plate hole
  - specified clearance determined during preliminary tests
- Expanding equipment
  - grade of roll material
  - geometry of the roll
  - angle of the rolls cage slots
  - slope of mandrel taper
  - speed of rotation of the mandrel

- Addition or deletion of lubrication

- Length expanded: where \( L_1 \) is the expanded length of the qualification test coupon, the qualification is valid between \( L_1 \) and \( 1.5 L_1 \)

- Expanding torque

**F 4482 FABRICATION**
Partial expanding is performed by a minimum of two steps moving away from the tube/tube plate weld. The expanding steps shall be adjusted to ensure sufficient overlap of steps (3 mm minimum).

**F 4483 EXAMINATIONS**

**F 4483.1 Basic hydraulic expanding**
See F 4472.

**F 4483.2 Partial expanding**
The requirements of F 4453.1 are applicable. In addition, the position on completion of partial expanding shall be checked by sampling at least 1% of the tubes.

**F 4490 EXPANDING BY EXPLOSION**
Expanding by explosion consists of detonating a cord coated with a damping device inside the tube.

The explosion of the cord generates sufficient pressure to deform the tube and the tube sheet bore in such a way that interfacial pressure is subsequently retained between the walls of the tube and the tube hole after springback of the tube plate.

**F 4491 ESSENTIAL VARIABLES OF THE PROCEDURE**
- Equipment
  - nature and designation of the explosive
  - explosive charge per unit length
  - type of damping device used
- Grade of the tube

- Grade of the tube plate

Another grade may be used provided that the stated chemical composition is comparable, and the yield strength at room temperature does not deviate by more than 20% from the value stated for the grade used during procedure qualification.

- Dimensional characteristics

  - nominal diameter of the tube plate hole
  - nominal outside diameter of the tube
  - nominal thickness of the tube
  - ratio step/diameter of the perforated area
  - specified clearance determined during preliminary tests
  - length of expanding, where L is the expanding length of the qualification test coupon

    for \( L < 150 \text{ mm} \), the qualification remains valid between 0.75 \( L \) and 1.25 \( L \)
    for \( L \geq 150 \text{ mm} \), the qualification remains valid for all values of \( L \geq 150 \text{ mm} \)

- Position of the cord in relation to the secondary side of the tube plate

- Firing sequence

- Drilling technique

F 4492  FABRICATION

Under no circumstances shall both ends of the same tube be expanded simultaneously.

In all cases where the cord fails to explode, a fresh expanding by explosion is not permitted.
F 5000
SURFACE TREATMENT

F 5000  CHROMIUM PLATING

F 5110  GENERAL
In order to increase hardness and reduce friction, certain items of nuclear island mechanical equipment may be chromium plated. Chromium plating shall be performed in accordance with the following requirements.

F 5120  BASE METAL
All austenitic stainless steels, chromium steels, carbon or low alloy steels and nickel base alloys may be chromium plated.

F 5130  PROCEDURE
Prior to any plating operation, the Supplier shall draw up a chromium plating procedure which shall specify:

1) the nature of the basis material (hardness),

2) the requirements for surface preparation of the part (roughness),

3) the type of the bath and the electrolysis parameters:
   - composition of bath,
   - current density,
   - temperature,

4) the design of supports for parts to be plated (including a description of contacts between parts and conductors) and the grade of steel used to manufacture these supports. These materials shall not be contaminants, i.e. they shall be insoluble in the electrolyte.

5) the agitator apparatus,

6) when necessary: the use, design and location of thieves at points of high current density on the workpiece,

7) the anode material,
8) the use of non-conducting plugs (resists) for cavities,
9) the arrangement of parts on their supports to facilitate the evacuation of gas bubbles,
10) examinations and acceptance criteria for the deposited metal (in accordance with F 5170).

**F 5140 QUALIFICATION**

Prior to any plating operation, the Supplier responsible for chromium plating shall qualify his process in accordance with the procedure specified in F 5130 and using:
- an actual part, each time it is possible to do so,
- representative samples when it is not possible to use actual parts.

Qualification shall be granted when the requirements for coating quality given in F 5170 have been met.

**F 5150 PREPARATION OF PARTS**

**F 5151 PRELIMINARY CONDITION OF PARTS**

The following examinations shall be performed prior to electrolysis:

a) non-destructive examination (liquid penetrant, magnetic particle, etc.) to ensure that there are no cracks,

b) a check of the surface roughness of the basis metal to be plated to ensure that it conforms to the qualification parameters and that the surface condition of the finished product will be satisfactory,

c) Rockwell hardness test of basis metal.

**F 5152 CLEANING**

a) Degreasing

In accordance with the requirements of F 6000, all grease shall be removed by vapour degreasing or by washing using an organic solvent.

b) Blasting

Surfaces to be chromium plated shall be cleaned to the level shown in plate Ds3* (portions which are not cleaned shall be suitably protected).

The thickness of metal removed shall not exceed 2.5 µm. The abrasive used shall be either silica, alumina or silicon carbide. This operation shall be performed under a bright light to ensure that all superficial oxide has been removed. The abrasive shall then be removed by a soft brush (other than a wire brush) and/or dry oil-free compressed air (see F 6000).

* Defined in the "Spécifications techniques de décapage par projection d’abrasifs” edited by ONHGPI “Office National d’Homologation des Garanties de la Peinture Industrielle”, 29 rue François 1er - 75008 PARIS.
c) Anodic pickling

Subsequent to operations a) and b) above and prior to chromium plating, parts made from carbon steel or low alloy steel shall be subjected either to anodic pickling by direct immersion in the chromium plating bath at its operating temperature, or by immersion in a suitable sulphuric acid bath provided that this pickling operation immediately precedes chromium plating. Parts made from nitrided steel or nickel base alloy may be prepared by anodic pickling provided that this treatment is followed by cathodic etching.

F 5160 CHROMIUM PLATING

F 5161 CHROMIUM PLATING IN ACID BATH

a) The chromium plating operation shall be the same whether the part has been cleaned by anodic pickling or not. Under no circumstances shall the current be interrupted. When, for any reason, the current is interrupted or cut off, the deposit of chromium shall be removed and chromium plating started afresh (parts cleaned by anodic pickling shall be cleaned again prior to the second chromium plating operation).

b) The electrolyte used shall contain:

- 150 to 400 grams/litre of chromic trioxide CrO$_3$,
- a sufficient quantity of sulphate ions so that

\[
\frac{\text{CrO}_3}{\text{SO}_4} \quad \text{the weight ratio is as favourable as possible. The sulphate shall be in the form of sulphuric acid}
\]

The operating temperature shall be between 40°C and 60°C and the current density shall not exceed a value which may produce excessive hydrogenation of the substrate.

c) Rinsing

After chromium plating has been completed, the parts shall be rinsed in water either by dipping in a bath or spraying.

F 5162 DEHYDROGENATION

Directly after the chromium plating and rinsing operations, all parts (with the exception of austenitic stainless steel, nickel-base alloy and carbon steel parts) shall be heat treated in a furnace at between 230°C and 260°C for at least 3 hours in order to eliminate occluded hydrogen.

F 5170 EXAMINATION

F 5171 VISUAL EXAMINATION

a) The final surface of the coating shall be free from bare spots, blisters, scratches, pits, porosity and burnt or milky areas. A 10 X magnifying lens shall be used for visual examination of samples and all areas of doubtful quality.
b) The roughness of the final surface shall meet the requirements specified in the drawings or in the equipment specification.

**F 5172  THICKNESS VERIFICATION**

The thickness shall be verified either by:

- differential measurement using a micrometer performed after abrasive blasting before the coating operation, and after coating, on parts or representative samples (where measurement of parts is not possible),

- or magnetic measurement of parts (or samples) when the substrate and geometry of the part make use of this method possible. The measurement apparatus shall be calibrated prior to each examination operation in accordance with the requirements of AFNOR standard NF A 91-101 paragraph 4.1.6,

- or by means of micrographic examination of a test sample.

The micrographic section shall be taken from a test specimen representing the surface configuration which presents the greatest difficulties for coating and shall be of the same material as the parts to be chromium plated.

When the parts are of small dimensions, one part from the lot shall be used as the test specimen.

a) The thickness tolerances shall be those given on the drawings. In all cases, the tolerances shall be ± 10% of the specified thickness (for normal surfaces).

b) When the thickness measured by this means of examination does not meet the tolerance requirements specified in (a) above, the requirements of F 5180 shall be applicable.

**F 5173  VERIFICATION OF ADHESION**

a) Bend test

One representative test specimen shall be taken for each lot of parts plated. This test specimen shall either be machined from the specimen described in F 5172 or shall be specially prepared and plated at the same time as the lot. The specimen shall be bent repeatedly through an angle of 180° around a mandrel having a diameter 4 times the thickness of the specimen until fracture occurs.

When peeling between the coating and the basis metal is detected by means of visual examination under 4 X magnifying glass, the lot shall be rejected.

b) Replacement test

When special provision is made in the equipment specification, the following test shall be performed in place of the test specified in a) above:

- a test specimen which is representative of the lot of parts shall be placed on an anvil,

- the peen of a hammer shall be placed in contact with the chromium plated surface of the specimen (the hammer shall have a 10 mm hemispherical peen).

This hammer is then struck a sharp blow with another hammer weighing approximately 500 grams to obtain an indentation with a nominal depth of 0.2 mm (which corresponds to a circular indentation 3 mm in diameter).
A satisfactory coating will tear at the edge of the indentation and there will be no peeling of the
deposited metal from the surface of the crater depression.

**F 5180  REPAIR OF DEFECTIVE COATINGS**

When the results of the examinations specified in F 5170 do not satisfactorily meet all the requisite
criteria, the lot of parts shall be completely stripped of its chromium plating and shall then be
replated.

The new chromium plating shall then be subjected to the examinations specified in F 5170.

**F 5200  MANGANESE PHOSPHATE COATING**

**F 5210  GENERAL**

The purpose of manganese phosphate coating is to improve the coefficient of friction and to avoid
galling. It is used for treating bolting materials for light water nuclear islands and also for certain
mechanical components which cannot be protected by paint due to their function.

The anti-corrosive properties resulting from this type of treatment permit the storage of oiled
parts.

Only manganese phosphating shall be permitted.

**F 5220  BASE METAL**

The substrates shall consist of carbon or low alloy steels.

**F 5230  PROCEDURE**

Prior to any operation, the Supplier shall draw up a manganese phosphating procedure specifying:
- grade and mechanical properties of steels to be coated,
- the nature of the products used at the stages defined in F 5250 and F 5260 (the technical data
  sheets* shall be appended to the procedure),
- process requirements (temperature, time, etc.),
- coating examinations and acceptance criteria,
- type of finish and operating conditions.

* The technical data sheet provided by the product Supplier shall specify the nature of the product and the
  requirements for use.
**F 5250 PREPARATION OF PARTS**

Cleaning

The following operations shall be performed directly before phosphate coating in the order given below:

1) Degreasing

   Grease shall be removed from machined parts by dipping in an alkaline bath or by vapour degreasing with perchloroethylene at 120°C or trichloroethylene at 90°C (see F 6000).

2) Oxide removal

   Oxides on the surfaces of non-machined parts shall be removed by blasting (using zirconia or alumina) or by pickling.

3) Rinsing

   Parts to be coated shall be thoroughly rinsed in running water.

**F 5260 PHOSPHATING**

**F 5261 SURFACE ACTIVATION**

Prior to the phosphating treatment, the surface of the part shall be pre-treated to form a homogeneous layer of line phosphate crystals.

**F 5262 PHOSPHATING METHODS**

Manganese phosphate coating shall be conducted in accordance with the requirements of the procedure described in F 5230. The coating shall be from 5 to 10 µm thick.

**F 5263 RINSING - PASSIVATION - DRYING**

Directly after phosphating, the parts shall be:

- rinsed in running cold water,
- passivated by dipping in a chromic-phosphoric acid bath at 50°C to 70°C for 1 to 2 min, or passivated in accordance with standard NF ISO 9717,
- dried in hot air or in a drying oven between 80°C and 110°C for 5 minutes minimum.
F 5270  EXAMINATION

F 5271  VISUAL EXAMINATION

Directly after drying, parts shall be 100% visually examined under a light equal to at least 500 lux (the equivalent of the light directly beneath a 100 watt bulb held at 30 cm from the surface of the part) to verify the homogeneity of the phosphate coating. If any bare spots are detected, the entire coating shall be stripped in accordance with the procedure given in F 5280 and the phosphating procedure started from the beginning.

F 5272  THICKNESS VERIFICATION

The thickness shall be verified by micrographic examination of one or more section samples. All other processes shall be subject to the Contractor's approval, based on an equivalence file.

F 5273  DEHYDROGENATION OF STEELS WITH UTS GREATER THAN 1450 MPa

Subsequent to satisfactory visual examination in accordance with F 5271, these steels shall be subjected to gas removing at 100°C ± 5°C for 8 hours.

F 5274  FINISH

After examination, phosphated parts shall be coated with a molybdenum* disulphide or graphite solid film lubricant or any other lubricant qualified to remain stable in the ambient medium, depending upon the requirements of the equipment specification.

* The Manufacturer should be aware that the use of this product may be forbidden in accordance with the requirements of F 6000.

F 5280  ELIMINATION OF PHOSPHATE COATING

When the visual examination specified in F 5271 detects unacceptable bare spots, or if the coating thickness does not meet requirements, the phosphate coating shall be entirely stripped from the part in accordance with the following procedure:

- stripping of phosphate coating by alkaline treatment,
- rinsing in running water,
- stripping the basis metal bare in a bath of cold sulphuric acid containing an inhibitor,
- rinsing in running water.

After this preparation, the parts shall be phosphated in accordance with the procedure given in F 5260.
F 5300   PAINT COATING SYSTEM

F 5310   GENERAL

a) The requirements of this paragraph are only applicable to metal surfaces and do not include stainless steel basis metals.

b) For protection by paint, a distinction is made between two types of equipment depending upon the area in which they are located:
   - equipment located inside the reactor containment,
   - equipment located in nuclear buildings outside the reactor containment.

c) Paints for mechanical components associated with the nuclear steam supply system shall, with the exception of PIT series paints, be qualified in accordance with the requirements of F 5330.

F 5320   CLASSIFICATION AND CHARACTERISTICS OF PAINT COATING SYSTEMS

F 5321   CLASSIFICATION

Paint coating systems are classified into three series which are defined in table F 5321. Classification takes into account:

- the location of equipment,
- operating conditions (service temperature and insulation).

The term operating conditions is taken to mean normal operating conditions and not faulted conditions.

**TABLE F 5321**

<table>
<thead>
<tr>
<th>COMPONENTS LOCATED INSIDE THE REACTOR CONTAINMENT</th>
<th>COMPONENTS LOCATED OUTSIDE THE REACTOR CONTAINMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulated components operating at a temperature ≥ 120°C</td>
<td>Insulated components operating at a temperature &lt; 120°C and non-insulated components operating at any temperature</td>
</tr>
</tbody>
</table>

| PIT* SERIES COATING SYSTEM | PIC* SERIES COATING SYSTEM | PIT* SERIES COATING SYSTEM | PID* SERIES COATING SYSTEM |

* PIC  Coating system inside the reactor containment  
* PID  Coating system which may be decontaminated  
* PIT  Temporary coating system
**F 5322 CHARACTERISTICS**

The main requirements for paint coating systems are listed in table F 5322.

<table>
<thead>
<tr>
<th>PIC SERIES</th>
<th>PID SERIES</th>
<th>PIT SERIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provides protection against corrosion (see F 5340)</td>
<td>Provides protection against corrosion (see F 5340)</td>
<td>Provides protection against corrosion (see F 5340)</td>
</tr>
<tr>
<td>Able to withstand the service conditions specified (1)</td>
<td>Able to withstand the service conditions specified (1)</td>
<td>Able to withstand the service conditions specified (2)</td>
</tr>
<tr>
<td>Able to withstand design basis accident conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth and easily washed</td>
<td>Smooth and easily washed</td>
<td>May be repaired</td>
</tr>
<tr>
<td>May be decontaminated</td>
<td>May be decontaminated</td>
<td></td>
</tr>
<tr>
<td>May be repaired</td>
<td>May be repaired</td>
<td></td>
</tr>
<tr>
<td>Able to withstand the irradiation specified</td>
<td></td>
<td>May be repaired</td>
</tr>
<tr>
<td>Free from pigments based on metallic Al</td>
<td></td>
<td>See (3)</td>
</tr>
<tr>
<td>Film thickness of at least:</td>
<td>Film thickness of at least:</td>
<td>Film thickness in accordance with the type of product, the requisite service life and degree of protection</td>
</tr>
<tr>
<td>- 120 µm for components whose service temperature is &lt; 60°C</td>
<td>- 120 µm for components whose service temperature is &lt; 60°C</td>
<td></td>
</tr>
<tr>
<td>- 100 µm for components whose service temperature is between 60°C and 120°C</td>
<td>- 100 µm for components whose service temperature is between 60°C and 120°C</td>
<td></td>
</tr>
<tr>
<td>- 80 µm for components whose service temperature is &gt; 120°C</td>
<td>- 80 µm for components whose service temperature is &gt; 120°C</td>
<td></td>
</tr>
</tbody>
</table>

1. The service conditions specified in the equipment specification shall be as follows:
   - temperature during operation and shutdown of the component (taking the insulation into account)
   - relative humidity of the surrounding medium
   - pressure in the building in which the component is located (when necessary)

2. The service conditions required for PIT coating systems shall be as follows:
   - temperature during operation and shutdown of the component (taking the insulation into account)
   - protection of components during transportation, storage and installation of the component prior to installation of the insulation

3. PIT coating systems for components located inside the reactor containment shall be free from pigments based on metallic Al.
F 5330 MAIN CHARACTERISTICS SUBJECT TO QUALIFICATION TESTS

F 5331 RESISTANCE TO "DESIGN BASIS ACCIDENT" (DBA) CONDITIONS

a) Tests

PIC series paint coating systems are qualified to resist "Loss Of Coolant Accident" conditions. The qualification shall be conducted in accordance with the requirements of AFNOR standard NF T 30-900. It shall be performed on test specimens which have been subjected to ionizing irradiation, in conformance with AFNOR Standard NF T 30-903. This shall include exposure to radiation corresponding to both normal operating and LOCA conditions.

Any previous qualification obtained with tests performed on non-irradiated test specimens or with a technical specification recognized as equivalent shall remain valid.

All new qualifications shall be conducted in accordance with the edition of the standard listed in A 1300.

b) The test specimens shall meet the following criteria subsequent to testing:

1) no flaking.

Flaking is a form of deterioration characterized by the detachment of flakes of variable dimensions and distribution.

2) slight blistering is acceptable provided that the maximum diameter of the blisters is 2 mm and that there is a maximum of 50 blisters per m².

Blistering is a form of deterioration characterized by convex deformation of coating forming blisters related to the detachment of one or more layers of the coating.

3) no peeling.

Peeling is a form of deterioration characterized by the partial or total detachment of one or more layers of the coating.

4) no chalking.

Chalking is a form of deterioration involving the release of one or more ingredients of the coating in the form of non-adherent fine dust.

5) cracks extending from the substrate to the surface of a maximum length of 1 cm shall be acceptable provided that there is only one crack per test specimen face. Slight discoloration shall be acceptable.

Cracking is a form of deterioration appearing as continuous solutions on the external surface of the layer or throughout its thickness.

6) no alligatoring.

Alligatoring is a form of deterioration appearing as surface cracking.

c) The equipment specification shall stipulate either the test conditions or the qualified paint coating systems that the Manufacturer may use.
F 5332  DECONTAMINATION
PIC and PID coating systems shall meet the requirements of the decontamination test defined in AFNOR Standard NF T 30-901. The decontamination treatment shall eliminate at least 85% of the activity.

F 5340  MAINTENANCE OF ANTI-CORROSION PROPERTIES
The permissible surface degradation of paint coating systems for mechanical equipment in the nuclear steam supply system shall meet the criteria given in table F 5340. Verification shall consist of comparison with a reference plate from ISO standard 4628/3

TABLE F 5340

<table>
<thead>
<tr>
<th>SERIES</th>
<th>DURATION</th>
<th>EFFICIENCY OF ANTI-RUST PROTECTIVE COATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIT series system</td>
<td>2 years</td>
<td>plate Ri3</td>
</tr>
<tr>
<td>PIC series system</td>
<td>8 years</td>
<td>plate Ri2</td>
</tr>
<tr>
<td>PID series system</td>
<td>8 years</td>
<td>plate Ri2</td>
</tr>
</tbody>
</table>

F 5350  PREPARATION OF SUBSTRATES
F 5351  DEGREASING
The chemical or mechanical preparation of substrate surfaces contaminated by grease or oil shall be preceded by degreasing using solvents, emulsions or alkaline cleaning products. The use of detergents or alkaline cleaning products shall be followed by rinsing with hot water.

The use of chlorinated organic solvents shall be discouraged or prohibited when there is a risk of contaminating stainless steels. Benzine, acetone or alcohol shall preferably be used. These products are mandatory for parts with cavities.

F 5352  BLASTING
a) For blasting conditions see F 6522 b)

b) It is recommended that dry abrasive be used for blasting, and that blasting operations shall be performed at a temperature above 5°C and at less than 80% relative humidity*. Upon completion of these operations, all residual particles resulting from the work shall be carefully eliminated by cleaning with oil-free compressed air (see F 6000) or by means of a brush.

* In tropical climates, relative humidity is increased to 85%, provided paint is applied less than 4 hours after surface preparation.
c) Permissible abrasives are as follows:
- sand from slag (containing less than 3% silicon),
- steel shot,
- glass beads,
- crushed corundum.

The grain size for these abrasives shall be chosen in accordance with the required surface finish.

d) The required surface finish * for substrates shall be equivalent to plate Ds3 for PIC coatings and to plate Ds2 1/2 for PID coatings, and to plate Ds2 for PIT coatings.

* Defined by the "Spécifications techniques de décapage par projection d'abrasifs "edited by ONHGPI "Office National d'Homologation des garanties de Peinture industrielle", 29 rue François 1er, 75008 PARIS.

**F 5353** OTHER METHODS OF SURFACE PREPARATION

a) The methods referred to in this paragraph may be used when they enable a surface finish equivalent to that specified in F 5352 to be obtained.

b) Preparation by mechanical means

Preparation by mechanical means is only permissible when blasting in accordance with F 5352 is difficult, and shall be subject to the following reservations:
- chipping must only produce slight work hardening of the metal substrate,
- hard brushes (wire or bristle) shall be used for brushing and soft brushes (fibre or horsehair) may be used for finishing,
- subsequent to descaling, chipping, brushing or grinding, all residual particles shall be removed by cleaning with oil-free compressed air (F 6000).
- scraping shall be followed by brushing and rinsing with fresh water under pressure or cleaning with dry oil-free air (F 6000).

c) Chemical cleaning

1) Acid cleaning

A solution of sulphuric acid containing an inhibitor shall be used in accordance with the requirements of paragraph F 6530, followed by neutralizing (e.g., using hot sodium carbonate diluted to 5 grams per litre) and rinsing with hot water. The use of hydrochloric acid is prohibited.

2) Phosphating

Components shall be phosphated either by immersion or by spraying. Phosphating shall be preceded by degreasing and rinsing. Surface scale or rust shall be removed before phosphating by pickling (see acid cleaning F 5353 c.1). When phosphating is used, tests shall be performed to demonstrate that the protective coating applied complies with the requirements given in table F 5322.
F 5360  REQUIREMENTS FOR THE APPLICATION OF PROTECTIVE COATINGS

a) Paints shall be applied less than 8 hours after the surface has been cleaned.

This time period may be extended, provided that a visual examination is immediately performed before applying the paint, to ensure that the surface finish meets the requirements given in F 5352.

b) Products shall always be applied in accordance with the Supplier's instructions, particularly with respect to the method of application, drying time, pot life time interval between the application of successive layers of paint, final drying time, etc.

c) Unless otherwise specified, paint shall only be applied when the room temperature is between + 5°C and 30°C and when the relative humidity is less than 75%. A higher relative humidity is allowable if the following conditions are complied with:

1) relative humidity \( \leq 85\% \),

2) the temperature of the equipment to be painted shall be at least 3°C, above the dew point,

3) application conditions shall comply with the requirements of the Supplier's product to be applied.

d) Spray guns shall preferably be used for the application of primers. The layers shall be thicker at points where there is significant risk of corrosion (rivet lines, ribs, welds etc.)

e) Spray guns or brushes may be used for the application of intermediate strengthening or finish coats.

F 5370  PROCEDURE

The Manufacturer shall draw up a paint coating procedure specifying:

- coating system series,
- details of basis metal surface preparation,
- the nature of each layer,
- detailed instructions for the application of each layer in accordance with the requirements given in F 5360,
- inspections and acceptance criteria.
F 5400 NITRIDING

F 5410 GENERAL
The requirements given in this paragraph apply to the nitriding of parts for static assemblies such as pins for reactor internals.

F 5420 BASE METAL
Solution annealed austenitic stainless steels:
- the corrosion resistance of this base metals being reduced, nitriding shall be avoided, unless technical justification is provided.

F 5430 PROCEDURE
Before performing any treatment, the Supplier shall draw up a nitriding procedure specifying:
- the treatment process including details of:
  . the type of bath or furnace gases,
  . temperature,
  . time,
  . the method of cooling after treatment,
- the protection of surfaces which are not to be treated. The methods of protection and the products used shall meet the requirements of F 6000,
- examinations and acceptance criteria.

F 5440 PREPARATION OF PARTS
F 5441 CONDITION OF PARTS
- The surface roughness of parts prior to nitriding shall correspond to $R_a < 1.6 \mu m$ (63 RMS), (LCA rugotest No.15).
  - Materials of parts previously cut or machined to their final dimensions shall be solution annealed before nitriding.

F 5442 CLEANING
a) Before nitriding, all parts shall be cleaned and all grease carefully removed. The Supplier shall make adequate provisions to ensure that the cleanliness of the part is maintained until treatment.

b) Products used for cleaning and degreasing shall meet the requirements of F 6000.
F 5450  NITRIDING

Nitriding shall be performed in accordance with the requirements of F 5430.

The surface hardness of nitrided parts shall be at least equal to a Vickers hardness number of 693 (Rockwell N 90). This hardness value shall be measured to a depth of between 0.1 and 0.2 mm.

F 5460  EXAMINATION

F 5461  VISUAL EXAMINATION

No peeling or grooves shall be acceptable.

F 5462  HARDNESS

a) The hardness and depth of nitrided area shall be checked as follows:

1) Parts weighing $\geq 2$ kg

   One sample shall be included in each furnace batch (a bar 15 mm in diameter and 40 mm long).

2) Parts weighing $< 2$ kg

   1% of parts shall be examined. This shall mean a minimum of 1 and a maximum of 5 parts per lot of parts in the same furnace batch.

   Samples of parts shall be cut at the widest cross section and at a sufficient distance from the ends. Micrographic examination of these cross sections shall be used to check the hardness and depth of nitriding.

b) When the results of samples examination do not meet the requirements specified in F 5450, the following procedure shall be followed:

1) Parts weighing $\geq 2$ kg

   One part chosen at random from the furnace batch shall be used to provide a cross section for verification. If this part also proves to be defective, the entire furnace batch shall be rejected. If this is not the case, the batch shall be accepted.

2) Parts weighing $< 2$ kg

   When one or more sample parts do not meet the acceptance criteria, 10% of the batch from which they are taken shall be sampled (a minimum of 2 parts shall be sampled). If one of these parts does not meet the criteria, all parts from that batch shall be rejected. If all the sample parts are satisfactory, the entire batch shall be accepted.

F 5470  STORAGE

When it is not possible to perform a pre-oxidation treatment after nitriding, special precautions shall be taken, in accordance with the requirements of F 6000, to avoid any risk or corrosion of parts during storage.
F 5500  ELECTROLYTIC TIN-PLATING
AND DIFFUSION TREATMENT

F 5510  GENERAL
The requirements of this paragraph concern electrolytic tin-plating immediately followed by
diffusion treatment at a temperature of 380°C to 400°C depending on the deviation of the furnace
for static assembly parts (stainless steel screws) which do not come into direct contact with the
reactor coolant.

This treatment is designed to improve the friction properties of stainless steels. The following
provisions apply particularly to zones where there is a high risk of sticking.

F 5520  BASE METAL
Austenitic stainless steels.
Martensitic stainless steels.
Ferritic stainless steels.

F 5530  TEST PROCEDURE AND TEST PART
Prior to any treatment, the Supplier shall draw up a procedure describing all of the requirements
applied, and shall keep these at the disposal of the Manufacturer and the Contractor.

Prior to any surface treatment operation, and for each grade of steel, the Supplier shall perform a
test on:

- an actual part wherever possible,
- representative samples, where this not possible,

This test shall satisfy the requirements of F 5550.

F 5540  PREPARATION OF PARTS

F 5541  CONDITION OF PARTS
The surface roughness of the parts to be treated shall be less than or equal to 1.6 μm (Rₐ). In the
case of tapping, this value may be up to 3.2 μm.

F 5542  CLEANING
a) Before surface treatment, parts shall be thoroughly cleaned and degreased.

b) Cleaning and degreasing products shall comply with the requirements of F 6000.
F 5550    TESTING

F 5551    TEST SAMPLE

For each batch of parts subjected to diffusion treatment in the same furnace charge, a part or test sample shall be removed to check the quality of the treatment.

If the furnace charge includes parts of different grades, one part or test sample shall be taken for each of the following steel types:

- austenitic steels,
- martensitic steels,
- ferritic steels.

The part or test sample shall be polished along a section such that micrographic examination will allow the thickness of the diffused layer and the adherence of the surface coating to the base metal to be assessed. In the case of screws, this section shall be axial, and for other parts it may be axial or radial. A series of Vickers hardness indents shall also be made under a load of 5 or 15 g on the various layers of the surface coating. The last layer shall have a hardness value greater than or equal to 400 HV.

F 5552    VISUAL EXAMINATION

All of the parts shall be visually examined.

The surface of the coating obtained shall show no signs of incomplete coverage and shall be free of scaling, scratches and droplets.

F 5553    DIMENSIONAL CHECK

A dimensional check shall be made by representative sampling.

Parts shall comply with the drawing.

F 5600    CADMIUM-COATING

F 5610    GENERAL

The requirements of this paragraph concern the electrode position of cadmium on static assembly parts (screws, bolts) or parts of valves which are not in direct contact with reactor coolant fluid.

F 5620    BASE METAL

This treatment is only applied to carbon steel, alloy steel or low alloy steel parts so as to avoid jamming of screws and bolts and/or to increase resistance to corrosion.
F 5630  PROCEDURE
The Supplier shall draw up a cadmium-coating procedure covering all of the points mentioned in F 5130.

F 5640  TEST PART
Prior to any cadmium coating operation, and for each grade in the case of low alloy or alloy steels, the Supplier shall perform a test in accordance with the procedure stipulated in F 5630 on:
- an actual part wherever possible,
- representative samples, if not.

This test shall comply with the requirements of F 5670.

F 5650  PREPARATION OF PARTS
CLEANING
The operations below shall be performed immediately before cadmium-coating and in the order indicated.
1) Degreasing
   Machined parts are degreased or quenched in an alcaline bath or in trichlorethylene vapour.
2) Pickling
   Oxides on unmachined parts shall be removed by blasting or pickling.
3) Anodic etching
   When applied to parts, anodic etching shall take place immediately before cadmium-coating.

F 5660  DEPOSITION
a) Cadmium deposition shall be performed in accordance with the requirements of the procedure specified in F 5630.

b) After cadmium-coating, parts are rinsed with water either by immersion or spraying. All appropriate measures shall be taken to ensure that all of the electrolyte has been removed.

c) Dehydrogenation treatment: steels treated at $R_m \geq 1100$ MPa and parts which have received surface hardening treatment, shall be subjected to dehydrogenation treatment as defined in standard NF EN 12330 paragraph 6.
F 5670  EXAMINATION

F 5671  EXAMINATION OF THE TEST PART (F 5640)

1) Visual examination

The surface of the coating shall show no signs of incomplete coverage and shall be free of blisters, surface pores, roughness, cracks and peeling.

2) Thickness check

The thickness shall be measured on a micrographic section which includes the most prejudicial zones. Measured thickness shall be at least equal to the minimum required thickness.

3) Adhesion check

Adhesion shall be checked by means of a burnishing test (as per paragraph 7.4.1 of standard NF EN 12330).

F 5672  EXAMINATION OF MANUFACTURED PARTS

1) Visual examination

All parts shall be visually examined in accordance with F 5671.

2) Dimensional check

A dimensional check shall be made by representative sampling. Parts shall conform to the drawing.

3) Thickness and adhesion checks

These checks shall be performed on one production run sample or preferably one part per batch.

Test conditions and criteria shall be those stipulated in F 5671.

F 5680  RECOATING

When the examinations stipulated in F 5670 have not met all of the criteria, the cadmium coating shall be completely removed from part lots and the parts recoated.

The new coating shall in turn be subjected to the examinations of F 5670.

F 5690  FINISHING TREATMENT

After cadmium-coating, finished treatment by chromating shall be authorized to increase the cadmium coating’s resistance to corrosion, in accordance with F 5630.
F 5700 OTHER METALLIC COATINGS OR SURFACE TREATMENTS

F 5710 GENERAL
Other surface treatments may be proposed by the Manufacturer for Contractor approval in order to improve corrosion and wear resistance or to avoid seizing. This application shall be accompanied with a technical file demonstrating the suitability of the process, as well as the utilisation and inspection conditions and the industrial references.

F 5720 PROCEDURE
For each process used, the Supplier shall draw up a procedure describing all steps involved in the process.

It shall specify:

1) the nature of the materials involved,
2) the conditions under which the parts are prepared and any precautions and protection required,
3) the nature of the deposit products and the acceptance conditions,
4) the deposit or treatment conditions,
5) the inspection methods, giving the scope of the inspection and the acceptance criteria for each method.

F 5730 QUALIFICATION
The means used in the Supplier's shops shall be adapted to the requirements of the procedure used in each particular case.

Prior to any deposit or treatment, the Supplier shall qualify its process in accordance with the procedure defined in F 5720 on:
- an actual part whenever possible,
- representative samples if not.

This qualification shall be accorded when the quality requirements of F 5760.b) are satisfied.

F 5740 DEFINITION OF LOTS
A lot is defined as being a number of parts having been subjected to the same coating process, the same procedure and, where applicable, the same heat treatment.
F 5750  PART PREPARATION

a) Condition of the parts

Before deposit or treatment, the parts shall be examined to ensure the absence of all defects likely to impair the quality of the deposit in the application area.

The roughness of the surface to be treated shall comply with the parameters given in procedure F 5720.

b) Cleaning

The parts may be prepared mechanically and/or chemically, as stated in the requirements of chapters F 6520 and 6530.

F 5760  APPLICATION OF THE DEPOSIT OR TREATMENT AND INSPECTIONS

a) Application

The composition of the baths and the deposit or treatment conditions shall be periodically inspected and shall comply with the procedure given in F 5720. If necessary, precautions should be taken to avoid distorting the parts. As a general rule, the deposit or treatment operations should be performed after the various heat treatment cycles scheduled for the base material.

b) Inspection

The inspections shall be performed in accordance with the requirements of procedure F 5720. Additional examinations should in general be performed on the test part.

F 5770  REPAIRS

When the examinations specified in F 5760.b) fail to satisfy all criteria, the deposits on the part or the lot of parts are generally totally removed.

Local repairs shall only be authorized if they have been simulated during the qualification defined in F 5730.

F 5780  MARKING AND SHIPMENT

When specified, the marking on the parts shall remain visible after deposit or treatment.

For all unmarked parts, the Supplier shall take the necessary steps to avoid all identification error.

The Supplier shall take all necessary precautions during packing to prevent damage during transportation, handling and any storage.
F 5790 DOCUMENTS

During performance, the Supplier shall draw up documents allowing the conformity with procedure F 5720 to be checked and shall be kept at the disposal of the Contractor and the Manufacturer. These documents shall in particular comprise:

- the qualification file,
- the procurement documents for the deposit materials (powder, fuse wire, etc.),
- the examination results.
F 6000

CLEANLINESS

F 6100 GENERAL

F 6110 PURPOSE OF CLEANLINESS - DEGREE OF CLEANLINESS

The purpose of the requirements given in this chapter is to limit the risk of damage caused by impurities in fluid systems:

- activation of deposits in the reactor core,
- adverse effect of deposits on the operation of moving parts,
- local (or generalized) corrosion of stainless steel alloys,
- reduction in heat exchange due to the effect of deposits.

The degree of cleanliness is the required cleanliness of a given surface prior to testing and start-up of the facility. There are several degrees of cleanliness.

Verification tests and different levels of criteria, as defined in F 6300, are associated with each degree of cleanliness.

F 6120 APPLICABILITY

The requirements of this chapter are applicable to mechanical components subject to the RCC-M which convey or are in contact with one of the fluids listed in F 6220 (primary fluids, secondary fluids, component cooling fluids and effluent).

For these components, the majority of the requirements given in this chapter are applicable to all surfaces in contact with process fluids.

Only the requirements given in paragraphs F 6300, F 6400 and F 6640 are also applicable to the outer surfaces of these components.

F 6130 TIME OF APPLICATION

At the very latest, the required degree of cleanliness shall be achieved during the last phase of fabrication in which the verification of the applicable criteria is possible, and shall be maintained up to initial filling of the system with the process fluid. Cleaning shall be performed in the workshop unless otherwise stipulated in the equipment specification. Further fabrication, conditioning, transportation, site installation, etc., processes shall also include dispositions to preserve and (or) restitute the required degree of cleanliness.
Slight degradation in cleanliness between the time the component is cleaned and the time when the system to which the component pertains is filled, shall be acceptable provided that:

- there is no adverse effect on the conservation of the component, i.e. there is no corrosion of the materials,

- the required degree of cleanliness may be obtained by the normal cleaning operation scheduled for a later phase.

The respect of the requirements given in this chapter limits remedial cleaning operations.

The Manufacturer shall specify at which phase in fabrication he considers that the requirements of this chapter should be applied. This phase shall be, at the very latest, the phase at which the required degree of cleanliness is achieved.

**F 6140 STRUCTURE OF THIS CHAPTER**

F 6200 specifies the rules for assigning components to one of three cleanliness classes. The requirements of this chapter are based on this classification.

F 6200 also specifies the required ambient conditions for cleaning and subsequent work operations (work areas). The concept of work zones on the construction site, with specific zone designation and conditions applicable to the various construction phases are similarly explained in this paragraph.

F 6300 specifies the tests to be performed after cleaning and the associated criteria.

F 6400 specifies rules for the prevention of contamination.

F 6500 specifies requirements for main methods of cleaning.

F 6600 specifies the requirements for the preservation of cleanliness and for the final cleaning operations during on-site construction prior to startup.

**F 6150 REQUIRED DOCUMENTS**

Operations relating to cleaning, inspection, protection, preservation, packaging, storage and transportation covered by this chapter shall be performed in accordance with the requirements specified in properly identified documents (procedures, work sheet, instruction sheets, etc.) which must conform to the applicable paragraphs of this chapter.

As the case may be, these documents relate specifically to a given component or are applicable to a workshop or construction site.

They are drawn up by the Manufacturer responsible for the operation.
F 6200   CLASSIFICATION

F 6210   CLEANLINESS CLASSES

There are three cleanliness classes, A, B and C (in decreasing order of severity), which are assigned in accordance with the types of system and process fluid contained inside the nuclear island.

Cleanliness classification is applicable to the surfaces of components in contact with process fluids*.

Class A is divided into subclasses according to the accessibility of surfaces:

- Subclass A1 covers component surfaces which in the final stages of construction, are directly accessible for cleaning and examination.
- Subclass A2 covers component surfaces which are not assigned to subclass A1.
- Subclass A2 is itself divided into further subdivisions.
  - Subclass A21 cleanliness applies to the surfaces of components which are sensitive or of complex shape, which require special conditions for cleaning.
  - Subclass A22 cleanliness applies to the surfaces of all other subclass A2 components, with the exception of piping and fittings which are covered by subclass A23.

F 6220   ASSIGNMENT OF COMPONENTS TO CLEANLINESS CLASSES

The equipment specification, in accordance with the requirements given below, shall specify to which cleanliness class or subclass a component or component part shall be assigned.

Class A cleanliness shall apply to all components whose process fluid is the primary fluid or fluid injected into the primary fluid *.

Class B cleanliness shall apply to all components whose process fluid is:

- water or steam for the secondary side of the nuclear boiler (except for recirculation) (1),
- water from the component cooling systems,
- letdown of primary fluid (without re-injection) and liquid (stainless steel surfaces) or non-aerated gaseous effluents.

Class C cleanliness shall apply to all components whose process fluid is liquid effluent (surfaces other than stainless steel) or aerated gaseous effluent.

* See definition given in Annex F I.

(1) The external surface of steam generator tubes in assigned to subclass A22 until fabrication of the steam generator has been completed.
F 6230 WORK AREAS REQUIRED

Throughout this chapter a work area shall be taken to mean the surrounding environment in the immediate vicinity of a component or component part (for example, internal or external surfaces).

Paragraph F 6240 defines three levels of work area. They are designated I, II and III according to decreasing order of severity of requirements.

Level I work areas are required for surfaces in contact with the process fluids for subclass A21 components.

Level II work areas are required for surfaces in contact with the process fluids for components covered by subclasses A1, A22 and A23.

Level III work areas are required for surfaces in contact with process fluids for components covered by cleanliness classes B and C.

However, for the outer part of steam generators tube bundles, level II work areas are required.

The concept of work areas shall only be applicable subsequent to initial component (or component part) cleaning operations and to later operations which may adversely affect component cleanliness. Work areas may be permanent or temporary and shall be applicable to fabrication shops and construction sites.

The surrounding environment in the immediate vicinity of a component which is designated as a work area may, as the case may be, consist of an entire building or workshop, a delimited area inside a shop or on a construction site, or the wall of a component with respect to internal surfaces when adequate means of blanking off this wall are provided.

F 6240 CHARACTERIZATION OF WORK AREAS

F 6241 LEVEL I WORK AREA

The following conditions are required for level I work areas.

a) Enclosure

A closed or pressurized enclosure shall be permanently or temporarily installed around components.

Enclosures shall provide adequate protection against external contamination and an adequate degree of cleanliness.

b) Special clothing

Personnel shall wear white overalls with no outside buttons (zip fasteners shall be used where possible). Pockets shall be capable of being fastened 100% closed. Personnel shall wear a head covering, lint-free white gloves and clean shoes or overshoes.

Visitors may be admitted to the work area provided that they wear white overalls or smocks and overshoes (and white gloves where there is manual contact with components).
c) Air filtering

The make-up air for pressurized enclosures shall be clean, dry and filtered. The air shall be blown through a filter with a nominal mesh size less than 20 - 30 µm.

d) Access for personnel and visitors

Personnel shall have access to the work area through an air-lock or adjacent room equipped with changing facilities. Personnel shall change clothing on entering or leaving the work area.

e) Smoking, eating or urinating shall not be allowed.

f) Floors, walls and ceilings

Floors shall be covered with a smooth coating (permanent and removable). If the enclosure is permanent all walls and ceilings shall not produce dust.

g) Creation of dust

Machining and all activities leading to the creation of dust inside the enclosure shall be limited to the strict minimum. Where such activity is unavoidable, a system shall be installed to collect and evacuate dust.

h) Cleaning of floors

Floors shall be kept clean at all times: when a specific activity produces unwanted material, such material shall be removed immediately.

i) Mechanical protection

Adequate mechanical protection shall be provided to protect components against heavy falling bodies. Such protection is mandatory on the plant for reactor internals.

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**F 6242 LEVEL II WORK AREA**

The following conditions are required for level II work areas.

a) Special clothing

Personnel shall wear clean clothes and clean shoes or overshoes.

b) Pollution

Every precaution shall be taken to limit the risk of pollution by the personnel (food - drinks - cigarettes, etc.)

c) Floors, walls and ceilings

Floors shall be covered with a smooth coating (permanent and removable). If the enclosure is permanent all walls and ceilings shall not produce dust.
d) Creation of dust

Inside the work area measures shall be taken to prevent dust penetrating into components already cleaned or in the process of being cleaned. Accordingly, work on the concrete shall be avoided on the construction site.

e) Cleaning of floors

Floors shall be cleaned daily. This interval may be reduced or increased according to the type of work performed.

f) Identification of work areas

The boundaries of work areas shall be marked off physically.

F 6243 LEVEL III WORK AREA

The following conditions are required for level III work areas.

a) Pollution

Every precaution shall be taken to limit the risk of pollution by the personnel (food - drink - cigarettes, etc.)

b) Creation of dust

When fabrication, installation and work on the Civil Works are performed at the same time such work activity shall be subject to regulations.

c) Cleaning of floors

Floors shall be cleaned weekly. This interval may be reduced or increased according to the type of work performed

d) Identification of work areas

The boundaries of work areas shall be marked off physically on the plant (this requirement is optional in the workshop).

F 6250 WORK ZONES ON THE PLANT

On the plant, in addition to the work areas defined in F 6230, shall also be work zones.

Work zones consist of various rooms (on the same level, for example) inside nuclear island buildings.

As work progresses on the plant, the degree of cleanliness in such rooms is improved.

These rooms represent work zones which are progressively reclassified.
On each plant, the Prime Contractor shall prepare a flow chart indicating how zone N buildings are redesignated as zone N-1 and shall forward this chart to the Manufacturers concerned. An example is given in table F 6250.

There are four levels of work zone. They are designated I, II, III and IV according to decreasing order of severity of requirements as described below.

F 6251 LEVEL I WORK ZONE

a) Enclosure
   Closed enclosure

b) Special clothing
   Personnel shall wear white overalls with no outside buttons (zip fasteners shall be used where possible). Pockets shall be capable of being fastened 100% closed. Personnel shall wear a head covering, lint-free white gloves and clean shoes or overshoes.

c) Access for personnel and equipment
   A zone guard shall keep a list of tools taken into the zone and personnel working inside the zone.
   Tools and equipment must be cleaned before being taken into the zone.

d) Smoking, eating or urinating shall not be allowed

e) Cleaning of floors
   Floors shall be kept clean at all times; when a dirt generating activity is working, the resulting dirt shall be immediately removed.

f) Identification of work zones
   The boundaries of level 1 work zones shall be marked off physically.

F 6252 LEVEL II WORK ZONE

a) Special clothing
   Personnel shall wear clean clothes and clean shoes or overshoes. This requirement shall be met progressively.

b) Access for personnel and equipment
   A zone guard shall keep a list of personnel working inside the zone.
   Only essential tools and equipment may be taken into the zone.
c) Pollution

Every precaution shall be taken to limit the risk of pollution by the personnel (food - drinks - cigarettes, etc.)

d) Cleaning of floors

Floors shall be cleaned daily. This interval may be reduced or increased according to the type of work performed.

e) Identification of work zones

The boundaries of level II work zones shall be marked off physically.

F 6253 LEVEL III WORK ZONE

a) Access for personnel and equipment

Access for personnel and equipment shall be subjected to regulations but shall not be systematically controlled.

b) Cleaning of floors

Floors shall be cleaned weekly. This interval may be reduced or increased according to the type of work performed.

c) Identification of work zones

The boundaries of level III work zones shall be marked off physically. There shall be limited access.

F 6254 LEVEL IV WORK ZONE

a) Access for personnel and equipment

Access for personnel and equipment shall be subject to regulations but shall not be systematically controlled.

b) Cleaning of floors

Floors shall be periodically cleaned and all rubbish shall be removed.
TABLE F 6250

TYPICAL FLOWCHART FOR REDESIGNATION OF ZONE N AREAS AS ZONE N-1 AREAS

Installation of stainless steel plates of storages pools start
Installation of stainless steel piping starts
End of installation of carbon steels components
Reactor internals storage pool made available
Delivery of reactor closure head assembly
End of construction of civil works in reactor building
End of piping work
Delivery of components
OPEN VESSEL FUNCTIONAL TESTS
COLD FUNCTIONAL TESTS
Fuel delivered
HOT FUNCTIONAL TESTS
CORE LOADING
F 6260    RELATIONSHIP BETWEEN WORK AREAS
           AND WORK ZONES ON THE PLANT

Temporary work areas shall be set up around work stations where the installation operations affect
surfaces for which the requirements for environment are not met.

- When a level I work area is required inside a level I work zone on the plant, it is not necessary
to set up a temporary work area provided that the following requirements specified in F 6241
have been met:

  c) air filtering for pressurized enclosures,
  f) floor, walls and ceiling,
  g) creation of dust,
  i) mechanical protection.

- When a level II work area is required inside a level II work zone on the plant, it is not
necessary to set up a temporary work area provided that the following requirements specified in
F 6242 have been met:

  a) special clothing (this requirement may not yet be applied in the work zone),
  c) floor, walls and ceiling,
  d) creation of dust.

- When a level III work area is required inside a level III work zone on the plant, it is not
necessary to set up a temporary work area provided that the points a and b of F 6243 are met.

F 6300    CLEANLINESS CHECKING

F 6310    GENERAL

F 6311    Immediately after cleaning, a check shall be made to verify that the required degree
of cleanliness of surfaces has been obtained.

F 6312    The check shall consist of performing the tests and applying the associated criteria
specified in tables F 6310.1 and F 6310.2 for the various cleanliness classes and subclasses.
Moreover, a distinction shall be made between corrosion-resistant surfaces* and non-corrosion-
resistant surfaces *, and between critical surfaces * and non-critical surfaces.

* See definition in annex F I.
If any degradation is subsequently detected (particularly during and after installation) and if this degradation is sufficient to adversely affect the degree of cleanliness obtained, checks shall be made by performing the tests specified in F 6320 and if necessary, cleaning operations shall be repeated.

### TABLE F 6310.1

**SUBCLASS A1, A21, A22, A23**
**TESTS AND ASSOCIATED CRITERIA**

<table>
<thead>
<tr>
<th>CLEANLINESS SUBCLASS</th>
<th>CORROSION RESISTANT SURFACES*</th>
<th>NON-CRITICAL SURFACES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CRITICAL SURFACES*</td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>Test A criterion 2</td>
<td>Test A criterion 3</td>
</tr>
<tr>
<td></td>
<td>Test B criterion 6</td>
<td>Test B criterion 6</td>
</tr>
<tr>
<td></td>
<td>Test D (or Da) criterion 8</td>
<td>Test D criterion 9</td>
</tr>
<tr>
<td>A21</td>
<td>Test Ab (or Aa) criterion 1</td>
<td>Test A criterion 1</td>
</tr>
<tr>
<td></td>
<td>Test B criterion 6</td>
<td>Test B criterion 6</td>
</tr>
<tr>
<td></td>
<td>Test D (or Da) criterion 8</td>
<td>Test D criterion 8</td>
</tr>
<tr>
<td>A22</td>
<td>Test A criterion 2</td>
<td>Test A criterion 3</td>
</tr>
<tr>
<td></td>
<td>Test B criterion 6</td>
<td>Test B criterion 6</td>
</tr>
<tr>
<td></td>
<td>Test D (or Da) criterion 8</td>
<td>Test D criterion 9</td>
</tr>
<tr>
<td></td>
<td>Non-visible surfaces*:</td>
<td>Non-visible surfaces*:</td>
</tr>
<tr>
<td></td>
<td>test F** criterion 10</td>
<td>test F** criterion 10</td>
</tr>
<tr>
<td></td>
<td>Internal surface of heat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>exchanger tubes: test E (or Ea)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>criterion 6</td>
<td></td>
</tr>
<tr>
<td>A23</td>
<td>Test A criterion 2</td>
<td>Test A criterion 3</td>
</tr>
<tr>
<td></td>
<td>Test B criterion 6</td>
<td>Test B criterion 6</td>
</tr>
<tr>
<td></td>
<td>Test D (or Da) criterion 8</td>
<td>Test D criterion 9</td>
</tr>
<tr>
<td></td>
<td>During or after installation on</td>
<td>During or after install</td>
</tr>
<tr>
<td></td>
<td>the construction site:</td>
<td>ation on the construc</td>
</tr>
<tr>
<td></td>
<td>test F criterion 10</td>
<td>tion site: test F crit</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>erion 10</td>
</tr>
</tbody>
</table>

* See definition in Annex F I.

** This test shall be performed when verification of the degree of cleanliness is necessary, after accidental deterioration of this condition, for surfaces which are no longer accessible provided that disassembly is not required to reach the required degree of cleanliness.

*** For piping designated non-visible* (diameter ≤ 6") these tests shall only be performed on the ends of the pipes.
TABLE F 6310.2
CLASSES B AND C:
TESTS AND ASSOCIATED CRITERIA

<table>
<thead>
<tr>
<th>CLEANLINESS CLASS</th>
<th>CORROSION-RESISTANT SURFACES*</th>
<th>NON-CORROSION-RESISTANT SURFACES*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CRITICAL SURFACES</td>
<td>NON-CRITICAL SURFACES</td>
</tr>
<tr>
<td>B</td>
<td>Test A criterion 2</td>
<td>Test A criterion 4</td>
</tr>
<tr>
<td></td>
<td>Test B criterion 6</td>
<td>Test B criterion 6**</td>
</tr>
<tr>
<td></td>
<td>Test F criterion 10</td>
<td>Test F criterion 11 (+ criterion 12 for effluent systems)</td>
</tr>
<tr>
<td></td>
<td>Internal surface of heat exchange tubes</td>
<td>Internal surface of heat exchange tubes</td>
</tr>
<tr>
<td></td>
<td>Test E criterion 6</td>
<td>Test E criterion 6</td>
</tr>
<tr>
<td>C</td>
<td>Test A criterion 2</td>
<td>Test A criterion 4 or 5</td>
</tr>
<tr>
<td></td>
<td>Test F criterion 10</td>
<td>Test F criterion 12</td>
</tr>
</tbody>
</table>

Note: Test F mentioned above, shall be performed on:

- piping: during or after installation on the construction site.
- for other parts: this test shall be performed when verification of the degree of cleanliness is necessary, after accidental deterioration of this condition, for surfaces which are no longer accessible provided that disassembly is not required to reach the required degree of cleanliness.

For piping designated non-visible* (diameter ≤ 6"), tests A and B above shall be performed on the ends of the pipes.

* See definition in Annex F I.
** Test A shall be supplemented by test B only if doubtful zones are detected.

F 6320 CLEANLINESS CHECK OF SURFACES IN CONTACT WITH A PROCESS FLUID

F 6321 Tests, criteria and methods are specified in annex F II.

F 6322 For any given component, the cleanliness tests A, B and D shall be performed on a sample selection of surfaces in accordance with procedures which the Manufacturer shall specify. The sample selection shall be sufficiently wide to enable the Manufacturer to ensure that, taking into consideration the environment, the component has the required degree of cleanliness.

In all cases, these tests shall be performed on areas considered doubtful.

F 6323 Tests for the same cleanliness class complement each other and shall be performed in the order specified in tables F 6310.1 and F 6310.2.

F 6324 Measures shall be taken between each test to maintain the degree of cleanliness established by the previous test. No fabrication operations shall be performed between tests.
F 6330 OTHER EXAMINATIONS

F 6331 CORROSION-RESISTANT SURFACES NOT IN CONTACT WITH A PROCESS FLUID

These austenitic stainless steel surfaces (generally external surfaces of components) shall be visually examined:

- for cleanliness class A components: test A, criterion 3,

This examination shall be performed in the workshop prior to shipment, and shall be repeated on the construction site before the surfaces examined are made inaccessible, particularly prior to installing insulation.

Moreover, prior to installing the insulation a check shall be made to ensure that all adhesive tape, adhesive residue or peel-off varnish has been removed.

F 6332 CHECKING OF PROTECTIONS AND PACKAGING

Means of protection (packing, blanks) shall be regularly checked, particularly after loading and unloading during transportation. There is no need for systematic control.

For preservation systems, a check shall be made as often as necessary on the humidity indicator cards or the relative humidity, gas blanket pressure and desiccant condition.

If degradation is detected by these checks and if the degradation is sufficient to adversely affect the degree of cleanliness obtained (particularly when there is a risk of corrosion), the subsequent checks and any cleaning operations as specified in F 6313 shall be followed by restoration of the protection or packaging.

F 6340 CLEANLINESS EXAMINATION REPORT

A report shall be drawn up for each component or system cleaned. The report shall specify the cleanliness tests performed and the results obtained.

F 6400 REQUIREMENTS RELATIVE TO CONTAMINANTS

The requirements of paragraph F 6400 cover the control of contamination of materials in order to prevent corrosion.

Except for special requirements specified elsewhere in the Code, they are applicable from the time a component is cleaned and during subsequent stages (further fabrication, protection, transportation, installation on the construction site, etc.).
In certain cases, the Manufacturer shall take measures to avoid contamination during fabrication phases prior to cleaning when any such contamination may not be eliminated by later operations preceding cleaning. The need for such provisions is particularly applicable to corrosion-resistant surfaces.

The term "contamination" shall be taken to mean contact with one of the elements listed in F 6420.

**F 6410 REQUIREMENTS FOR MATERIALS**

Refer to SECTION II (M 100).

**F 6420 REQUIREMENTS RELATIVE TO CONTAMINATION**

**F 6421 COMPONENTS IN CONTACT WITH THE PRIMARY FLUID OR FLUIDS INJECTED INTO THE PRIMARY FLUID***

The requirements of this paragraph are applicable to corrosion-resistant surfaces whether they are in contact with these fluids or not.

Contamination by ferritic steel and by the following elements or products is prohibited:

- products which may release chlorides or fluorides,
- materials with a chlorine content greater than 0.25%. This requirement is particularly applicable to the following plastics:
  - chloroprene,
  - chlorinated polyethylene,
  - chlorinated butyl rubber,
  - polyvinyl chloride (PVC) and associated copolymers,
  - asbestos bonded with rubber,
- water with a halogen content greater than 25 ppm (unless a more restrictive requirement is specified in chapter F 6000),
- sulphur and sulphur compounds,
- products which may release the following chemical elements (especially elements with a low melting point and associated compounds):
  - Pb, Hg, P, Zn, Cd, Sn, Sb, Bi, As, Cu, rare earth elements (cerium, lanthanum, etc.),
- insoluble marking products,
- products which may form alloys or deposits on materials particularly during welding or heat treatment.

* See definition in Annex F I.
F 6422  CLEANLINESS CLASS B COMPOUNDS WHOSE PROCESS FLUID IS STEAM OR WATER FROM THE SECONDARY SYSTEM (EXCEPT FOR RECIRCULATION)

After these components have been cleaned to their final degree of cleanliness in the work-shop, the following elements and chemical compounds:

- Cl, F, Pb, Hg, S, As,
- nitrites,
- chromates and phosphates (only for the secondary parts of the steam generators),

shall be prohibited for use as the basis for products and tools which may be placed in contact with cleaned surfaces. The use of the above-mentioned chemical elements is also prohibited in products used for preservation which may be used after final cleaning.

F 6423  REQUIREMENTS FOR THE USE OF PRODUCTS CONTAINING NOXIOUS CHEMICAL ELEMENTS*

1) Chlorinated and Fluorinated solvents

Degreasing in the vapour phase by means of chlorinated and/or fluorinated solvents, is authorized on non-austenitic materials, subject to the following:

- the materials contain no inaccessible cavities,
- the solvents are stabilized to avoid acidification of the condensed vapour.

2) Adhesive tapes and peel-off preservative varnishes

Adhesive tapes and peel-off preservative varnishes used for austenitic stainless steels and nickel-base alloys shall meet the following requirements:

- the halogen or sulphur content shall be less than 0.10% in weight,
- less than 15 ppm chloride and 10 ppm of fluoride shall be released through lixiviation.

This requirement specifically applies to adhesive tapes used for identification and various attachments (packing, blanks, insulation, radiographic films, etc.).

Adhesive tapes, tape residue and peel-off varnishes shall be completely removed from the material surfaces prior to any fabrication, inspection or work operation which would make them inaccessible, and before any operation which would increase the temperature of the component.

3) Products used for liquid penetrant examination (penetrants and developers)

The maximum allowable content of products applied to austenitic stainless steels and nickel-base alloy surfaces shall be:

. 200 ppm for chloride plus fluoride
. 200 ppm for sulphur

* Chemical method of analysis described in Annex FV.
4) Packing materials

These materials (plastic wraps, blanks, etc.) used for austenitic stainless steels and nickel-base alloys shall meet one or other of the following requirements:

- the halogen or sulphur content shall be less than 0.10% in weight,
- less than 50 ppm of chloride or 50 ppm of fluoride shall be given off through lixiviation.

5) Non-metallic insulation

Materials shall meet the requirements given in the annex "insulation" (Annex F IV).

6) Machining lubricants

The maximum allowable content of products applied to austenitic stainless steels and nickel-base alloy surfaces shall be:

. 200 ppm for chloride plus fluoride
. 200 ppm for sulphur

7) Soluble paper plugs for protection of weld backs

The soluble paper shall contain less than 0.10% by weight of halogen or sulphur.

8) Provisional blanking plugs for protection of weld backs

If used on stainless steel or nickel-based alloy, the blanking plugs shall meet one of the following requirements:

- contain less than 0.10% by weight of halogens or sulphur,
- release less than 50 ppm of chlorides and 50 ppm of fluorides by lixiviation (see Annex FV).

F 6430 REQUIREMENTS APPLICABLE TO FABRICATION AND PLANT INSTALLATION

F 6431 GENERAL

In order to prevent contamination by the products listed in F 6420 during fabrication and installation including the storage, transportation and handling phases, the following precautions shall be taken.

F 6432 PRECAUTIONS TO BE TAKEN WITH AUSTENITIC STAINLESS STEELS AND NICKEL BASE ALLOYS

a) Precautions for tools

Cutting tools: when possible tungsten carbide tools shall be used.

Tools for manual assembly: when possible stainless steel or chrome vanadium tools shall be used.
Brushes: brushes shall be made from stainless steel or nylon and used only for brushing austenitic stainless steels and nickel-base alloys.

Grinding wheels: grinding wheels shall be aluminium based, free from iron and used only for grinding austenitic stainless steels and nickel-base alloys.

Bending and dishing: see F 4000.

b) Precautions during handling and installation operations

Contact with lifting and handling devices made from ferritic steel is prohibited.

c) Precautions for pickling with abrasive blasting

- When silica sand is used for sand blasting, the operation shall be followed by nitric hydrofluoric acid pickling.
  
  The use of zirconia or alumina sand is preferable.

- The sand shall be free from iron. It must not have been used previously for treating cast iron, carbon steel or low-alloy steel surfaces.

- High-alloy steel shot only shall be used for shot blasting.

- All dust shall be removed from blasted surfaces.

d) Precautions for machining lubricants

For cleanliness class A and B components, all lubricants shall meet the requirements of this chapter. Lubricants shall be completely removed from surfaces before these surfaces become inaccessible.

F 6440 WATER QUALITY

The requirements for the quality of water whose use is specified in this chapter are tabulated in annex F III.

F 6450 DRY, OIL-FREE AIR

For operations requiring the use of dry and oil-free air, the compressed air supply system shall include:

- the drying equipment necessary (e.g. a cooling unit downstream of the compressor, separators at low points in the installation with, when possible, automatic removal of condensed water, etc.),

- the oil-removing equipment (filters, requisite separators, etc.).

The humidity level at 20°C must be less than 50%.
F 6500 REQUIREMENTS FOR CLEANING METHODS

F 6510 DEFINITIONS
See annex F I.

F 6520 MECHANICAL CLEANING PROCESSES

F 6521 MECHANICAL DESCALING
The advantage of mechanical descaling is that it does not produce the physical conditions which could lead to pitting, intergranular corrosion or hydrogen embrittlement. Accordingly, it is the only method which may be used for sensitized* austenitic stainless steels and quenched and tempered martensitic stainless steels.

Mechanical descaling may be performed by grinding, blasting or vigorous brushing, etc.

F 6522 MECHANICAL CLEANING METHODS

a) Grinding, brushing

Grinding and brushing of austenitic stainless steels and nickel-base alloys: see F 6432.

Local heating of parts by grinding operations must be avoided.

b) Abrasive blasting

Surface preparation prior to painting: the requirements given in F 5352 shall be met.

Cleaning of austenitic stainless steels and nickel-base alloys: see F 6432.

Abrasive with particle size less than 0.32 mm shall be used for pickling plates less than 3 mm thick. For plates whose thickness is $3 \leq e < 5$ mm (where $e$ = thickness), abrasive blasting may be used provided that the longest free edge of the plate does not exceed 100 times the thickness.

c) Ultrasonic cleaning

Ultrasonic cleaning is used for small parts and may be supplemented by the use of solvents and detergents.

* See definition in Annex F I.
F 6530  CHEMICAL CLEANING PROCESSES

F 6531  DEFINITION

Chemical cleaning refers to the following operations:
- degreasing,
- descaling,
- decontamination,
- pickling,
- rinsing.

F 6532  GENERAL REQUIREMENTS

a) The following parts shall not be subject to acid cleaning:
   - parts made from hardened steel or nitrided austenitic stainless steel or quenched-tempered martensitic steel, unless otherwise specified in F 6534 b),
   - parts hardfaced by the deposition of weld metal,
   - parts made from austenitic stainless steel which do not meet the requirements of the intergranular corrosion test specified in MC 1000,
   - parts with cavities or inaccessible areas (when such parts must mandatorily be acid cleaned, they shall be dipped in water after degreasing and prior to cleaning to prevent retention of these products in concentrated form).

b) Surfaces requiring protection (e.g. polished or lapped surfaces) shall be protected against attack.

c) Solutions in baths shall be mixed by an agitator. Supplementary provisions shall be made to ensure that solutions circulate to areas which are not easily accessible.

d) The directions for use specified by the Supplier of the product shall be followed (pH, time, temperature, etc.).

e) All chemical cleaning operations shall be followed by rinsing with water. The pH of the water shall be measured after rinsing to check that all acid cleaning products have been completely eliminated. Carbon steels cleaned by means of products based on phosphoric acid shall be mandatorily rinsed after cleaning.

F 6533  SPECIAL REQUIREMENTS FOR DEGREASING

a) The use of sodium hydroxide or potassium hydroxide based products for degreasing is prohibited. However, on surfaces where there is no risk of the solution being retained and provided the operation is immediately followed by acid cleaning and rinsing, degreasing with sodium or potassium based products shall be permissible.
b) Products containing halogens (including the vapour phase) shall not be used on corrosion-resistant surfaces or on the surfaces of cleanliness class A or B components. For vapour degreasing using chlorinated solvents, see F 6423.1.

c) The use of sodium or potassium carbonate is prohibited on surfaces where there is a risk of the solution being retained (especially on partially assembled components) or when the degreasing operations are not followed by acid cleaning.

d) Surfaces of parts which include cavities shall only be degreased with isopropyl alcohol, clean redistilled ethyl alcohol, acetone or other products which are proved to be harmless for the surfaces in question.

e) Degreasing operations with alkaline reagents or detergents shall be followed by rinsing (with hot water at minimum temperature 60° in the case of trisodium phosphate) and drying. However, for surfaces non-resistant to corrosion, degreasing not followed by rinsing in workshop shall be acceptable when degreasing is performed with a product ensuring temporary protection.

f) Residual films resulting from the use of organic solvents such as aliphatic hydrocarbons shall be removed by means of isopropyl alcohol, ethyl alcohol or acetone.

F 6534  SPECIAL REQUIREMENTS FOR DESCALING, PICKLING, DECONTAMINATION AND PASSIVATION

a) General

1) All chemical cleaning shall be followed by rinsing with water (in accordance with the requirements specified in F 6540), particularly carbon steels cleaned by means of products based on phosphoric acid which shall at all times be rinsed after cleaning.

2) Hydrofluoric acid is the only product containing halogens whose use shall be acceptable.

3) Acid cleaning installations shall be located in a clean area isolated from the fabrication stations.

4) The use of pastes for pickling and passivation shall be acceptable when, for technical reasons, spraying or immersion is impractical.

Component surfaces must be carefully rinsed after utilization of such pastes.

Elimination of the paste shall be verified by checking the pH of the rinsed surface.

b) Requirements for stainless steels

1) Descaling of austenitic steels

The use of sulphuric or nitric hydrofluoric acid solutions is acceptable.

When the layer of scale is watertight, descaling may be divided into two phases: attack by sulphuric acid followed by rinsing and then attack by nitric hydrofluoric acid followed by rinsing.
2) Pickling of austenitic steels

Austenitic steels shall be pickled by means of nitric hydrofluoric or dilute nitric acid solutions (these treatments may only be used for solutions annealed products which have not been sensitized by subsequent heat treatment not taking welding into consideration).

In the case of pickling stations with continuous potential checks, hydrofluoric and/or sulphuric acid solutions with oxygenated water are allowed.

Pickling by means of dilute nitric acid (which is less efficient than nitric hydrofluoric acid) shall be used to eliminate soluble salts, corrosion products and superficial metallic contamination.

3) Pickling of martensitic steels

Pickling may be performed by means of phosphoric or nitric solutions. No fluorinitric solutions shall be used.

4) Decontamination, passivation

A chemical treatment may be used to decontaminate and passivate the surfaces.

This is done by means of a nitric (or equivalent) solution or passivating paste.

For example:

- Nitric acid solution for austenitic steels and steels with a Cr content greater than 17%:
  - nitric acid (HNO₃ 70%) : 10 to 20% of the volume
  - water : the remainder
  - temperature : 20 to 50°C
  - immersion time : 10 to 30 min.

- Nitric acid solution for polished surfaces and chromium steel with less than 17% Cr:
  - nitric acid (HNO₃ 70%) : 20 to 30% of the volume
  - sodium bichromate (Na₂Cr₂O₇ - 2H₂O) : 2% in weight
  - water : the remainder
  - temperature : 20 to 50°C
  - immersion time : 10 to 30 min.

c) Requirements for carbon steel

1) Descaling - Pickling

Inhibited organic (chelating or not) or mineral acids may be used for descaling or pickling.

2) Protection

The cleaned surface shall be preserved by:

- either dry or wet preservation (see F 6600).
- or by surface treatment or the use of a coating system (products which are not compatible with the process fluid shall be eliminated by rinsing with treated water prior to filling with the process fluid).
F 6540  RINSING AND DRYING REQUIREMENTS

F 6541  RINSING

1) Rinsing after chemical cleaning in the workshop

Parts shall preferably be rinsed in running water. Neutralizing solutions may be added to the water for intermediate rinsing to accelerate the rinsing operation.

Grade A or B water shall be used for the final rinsing operation of stainless steels and grade A, B or C water shall be used for steels not resisting corrosion. Rinsing is completed when the pH of the water has stabilized and is within the limits of acceptability for the quality of water under consideration.

Final rinsing might be carried out on the plant when provided for in the equipment specification.

2) Rinsing during and after installation on the plant

a) Rinsing water

For cleanliness classes A and B, rinsing is carried out with water meeting the requirements of the following table. In case of difficulties to obtain water conforming to grade A requirements, rinsing with normal water may be tolerated provided that a final rinsing with grade A demineralized water is done.

If such intermediate rinsing is used, drying shall be performed with special care so that no harmful material can be kept back in zones of complex geometry.

<table>
<thead>
<tr>
<th>CORROSION-RESISTANT SURFACES</th>
<th>NON-CORROSION-RESISTANT SURFACES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade A demineralized water</td>
<td>Type 1</td>
</tr>
<tr>
<td></td>
<td>Grade A demineralized water treated with 200 mg/l of hydrazine whose pH is maintained at 10.5 by the addition of ammonia (approximately 100 ppm).</td>
</tr>
<tr>
<td></td>
<td>Type 2</td>
</tr>
<tr>
<td></td>
<td>Grade A demineralized water whose pH is maintained at 9 by the addition of ammonia or morpholine.</td>
</tr>
<tr>
<td></td>
<td>Type 3</td>
</tr>
<tr>
<td></td>
<td>Grade A demineralized water whose pH is maintained at 10.5 by the addition of trisodium phosphate (not applicable to the secondary side of steam generators).</td>
</tr>
</tbody>
</table>

Designation of water for rinsing non-corrosion-resistant surfaces:

- type 1 water : shall be used for rinsing for wet conservation provided there are no copper-base alloys.
- type 2 water : rinsing only (for wet lay-up refer to type 1).
- type 3 water : when the water is drained after rinsing and the component conservation is not immediate (the trisodium phosphate provides temporary protection).
b) Operating procedure

Rinsing may be performed as follows:

- "once-through" flushes,
- "recirculating" flush with a filter installed on the system (mesh size 30 to 50).

The pH and conductivity of the water used for the last rinse shall be checked immediately after the last rinsing operation to ensure that they conform to the requirements for rinse water.

A sample of 1000 cm$^3$ of the water used for the last flush of cleanliness class A components, prior to filling the system with the process fluid, shall be taken and placed in a polyethylene flask containing 10 cm$^3$ of HNO$_3$ (70%, d = 1.42 for analysis) which shall be hermetically sealed and appropriately identified. This sample shall be stored for possible analysis until commissioning is completed.

**F 6542 DRYING**

Drying may be performed as follows:

- by means of a clean cloth,
- by evaporation,
- by means of forced hot air, the air shall be dry and oil-free (in accordance with F 6450) and at 60°C to 80°C.

*Note*: Nitrogen, carbon dioxide, argon or helium may be used in place of air.

- by placing under vacuum and heating:
  - this method is only applicable to components which are capable of withstanding external pressure,
  - drying shall be considered to be completed when the vacuum ($\approx$ 1 mm of Hg) is maintained for 30 minutes without pumping.
- in a furnace or oven:
  - the furnace atmosphere shall consist of an inert gas.
  - drying shall be considered to be completed when the gas dewpoint is $<$ - 40°C after the furnace has been stopped.

**F 6600 PRESERVATION OF CLEANLINESS**

This chapter provides rules for hydraulic tests, packing, storage, transportation and final on-site installation of components, in order to maintain the degree of cleanliness achieved in the shops and to protect components against corrosion and external contamination from the environment (salt spray, dust, dirt, etc.).
F 6610  CHARACTERISTICS OF WATER USED FOR TESTS

Characteristics of water used for component testing (acceptance or functional testing, hydraulic and hydrostatic tests...) or in some cases for wet lay-up (F 6623 b) and F 6660 a) 2), when components have been cleaned, shall comply with requirements of table F 6610.

When the required degree of cleanliness is to be restored, during a later phase, workshop tests may be performed using water of grade immediately below the required grade (for example grade B instead of grade A, running water instead of grade C).

In this case, at the end of tests, drying shall be performed with special care in order to preclude any water retention, more particularly in zones showing cavities.

F 6620  PROTECTION AND PRESERVATION

F 6621  GENERAL REQUIREMENTS

When fabrication has been completed, cleaned components shall be protected in accordance with the requirements of F 6622 and the cleanliness preserved by a method which meets the following criteria.

a) The cleanliness of surfaces of vessels (tanks, heat exchangers, etc.) in contact with process fluids but which are not corrosion-resistant shall be preserved in accordance with the requirements of F 6623.

Preservation techniques shall be permanently applied from the time class A components, class B vessels and feedwater/steam piping are cleaned until such time as these components are first fitted with a process fluid.

If a work operation on a component results in the preservative barrier being broken, the preservative barrier shall be restored upon completion of the work.

b) All packing and preservation operations shall meet the requirements relative to contaminants specified in F 6420.

c) The equipment specification shall stipulate the type of packing and special requirements, in accordance with the type of material and the intended use of the component.

F 6622  PROTECTION

Cleaned components shall be protected either by being completely packed or by blanking all openings:

- requirements for work areas (see F 6230) shall be applicable to packing operations,
- plastic sheets used for wraps shall be:
  - steamproof and waterproof,
  - heat sealable,
### TABLE F 6610
**CHARACTERISTICS APPLICABLE TO WATER USED FOR TESTING AND WET LAY-UP**

<table>
<thead>
<tr>
<th>STEEL SURFACES</th>
<th>WATER FOR TEST (1)</th>
<th>USE</th>
<th>SUPPLEMENTARY REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion-resistant</td>
<td>Grade A, B, C</td>
<td>Components which do not have parts made from sensitized austenitic stainless steel (2)</td>
<td>- analysis of water (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- the use of grade A water is mandatory for:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- components containing cavities,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- components tested at a temperature &gt; 60°C (in this case, add 200 ppm of hydrazine except if the component comprises aluminium or copper-base alloys),</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- when grade C water is used, use grade B min. (preferably grade A) water for final rinsing</td>
</tr>
<tr>
<td>Corrosion-resistant</td>
<td>Grade A + ammonia (to maintain the pH from 10.00 to 10.50)</td>
<td>Components with parts made from sensitized austenitic stainless steel (2)</td>
<td>- analysis of water (3),</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- when the water temperature is &gt; 60°C add 200 ppm of hydrazine except if the component comprises aluminium or copper-base alloys</td>
</tr>
<tr>
<td>Non-corrosion-resistant</td>
<td>Grade A, B or C in workshop Grade A or B on site + hydrazine (200 ppm) + ammonia (when there are no copper-base alloys)</td>
<td>All components</td>
<td>- pH ≈ 10.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- operation followed by drying</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- preservation in accordance with the requirements of F 6620</td>
</tr>
<tr>
<td>Non-corrosion-resistant</td>
<td>Grade A or B + trisodium phosphate</td>
<td>Components whose process fluid is normally treated with trisodium phosphate</td>
<td>- pH ≈ 10.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- operation followed by drying</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- preservation in accordance with the requirements of F 6620</td>
</tr>
</tbody>
</table>

(1) Grades A, B, C water characteristics are defined in Annex F III.
(2) See definition in Annex F I.
(3) The verification shall take place less than 24 hours before tests. However, this verification may be done more than 24 hours, but not more than a week, before on condition that the following additional requirements are met:
- the water production device must be fitted with a resistivity meter,
- the resistivity of the water drawn off for the test must be shown by measurement to be in conformance with the water grade selected for the test.
resistant to tearing and perforation,
- in conformance with the requirements of F 6420 when used for the protection of corrosion-resistant steel surfaces,
- cleanliness class A 21 and A 22 components shall be packed in waterproof, dustproof wraps and placed in containers or boxes. If there is a risk of condensation inside the wrap which could damage the component, dessicants shall be used within the wrap barrier in accordance with the requirements of F 6624,
- openings on cleanliness class A and B components shall be hermetically sealed by means of caps or plugs, etc. These shall not be attached by brazing. Welding shall be allowed provided that the requirements in S 7420 are met or the weld and the entire heat affected zone are eliminated when these devices are removed.
- plugs or caps may be either metallic and compatible with the materials to be protected or non-metallic and conforming to the requirements of F 6420.

F 6623 PRESERVATION

a) Dry conservation
Dry conservation shall be used for vessels, tanks and heat exchangers and shall be implemented subsequent to drying by means of:
- filling the component with a dry, clean, non-halogenated inert gas whose dewpoint is < -40°C and which is at a pressure > atmospheric pressure,
- filling the component with dry and oil-free air (see F 6450),
- dessicants and humidity indicator cards (see F 6624) for sealed vessels of small volume to maintain a relative humidity level < 50%.

The type of preservation (gas used) pressure of the gas blanket and the requisite relative humidity shall be marked on clearly visible labels attached to the component.

b) Wet preservation
Wet preservation is used when:
- a component or system is not made operational immediately after it is initially filled with the process fluid (for example, after functional testing or prior to a regulatory hydrostatic test),
- after cleaning on the construction site, the component(s) is not subjected to cold functional or operating tests.
One of the following fluids shall be used for wet lay-up:
- the process fluid for the system,
- water whose purity is equivalent to that of the system makeup water,
- water treated chemically using a method approved by the Contractor.

c) Temporary preservation by preservative covers and surface treatment (passivating agents, peel-off preservative varnishes, etc.)

The products used shall:
- meet the requirements of F 6400 and be submitted to the Contractor for approval,
- be completely removed before the system is made operational.

Furthermore, the name of each product used and the instructions for removal shall be marked on component packing and, as the case may be, on documents relating to transportation.

F 6624 REQUIREMENTS FOR DESSICANTS AND HUMIDITY INDICATOR CARDS

a) Dessicants

Dessicants shall consist of non-deliquescent, non-dusting, non-halogenated, chemically inert agents. They shall be packed in bags which meet the requirements of F 6420.

Dessicants shall not be placed in contact with surface to be protected.

There shall be a sufficient quantity of dessicants for the volume of the component including packing and dunnage material.

b) Humidity indicator cards

Humidity indicator cards shall not be placed next to dessicants.

Closures before indicator cards shall be transparent to enable the cards to be read.

F 6630 STORAGE REQUIREMENTS

F 6631 GENERAL

These requirements shall be applicable to components cleaned, protected or packaged in accordance with F 6620.
F 6632 STORAGE IN THE SHOPS OR ON THE PLANT

Components

Precautions shall be taken when storing stainless steel components to ensure that they do not come into contact with carbon steel or contaminants (in accordance with the requirements of F 6420).

Protection

Except for inspections, protected or preserved components shall remain in this condition until the end of the storage period (in particular, all caps and plugs shall remain in place).

After inspection, the packaging or preservation system shall be replaced.

F 6633 STORAGE AREAS – GENERAL

A storage area is taken to mean the area surrounding a component.

The concept of a storage area does not imply the designation for each individual component of a specific area in its vicinity. This area may consist of the component itself when the surfaces concerned are considered to be easily isolated from the environment.

There are three levels of storage area, I, II and III, according to the decreasing order of severity of requirements.

F 6634 REQUIREMENTS FOR STORAGE AREAS

F 6634.1 Level I storage area

A level I storage area consists of an enclosure protected against the weather with a floor which shall be slabbed or made from compact material which does not create dust.

The enclosure may or may not be heated. The temperature shall be maintained above 16°C in order to reduce condensation of moisture in the atmosphere inside the enclosure.

Components shall be stored on supports (pallets or shoring).

The enclosure shall be periodically cleaned and dust removed.

F 6634.2 Level II storage area

A level II storage area consists of an enclosure protected against the weather with a floor which shall be slabbed or made from compacted material which does not create dust.

Components shall be stored on supports (pallets or shoring).

The enclosure shall be periodically cleaned and dust removed.

F 6634.3 Level III storage area

Storage shall be outdoors.

The storage area shall be well drained, gravel-covered or concrete slabbed.
Components shall be stored on pallets or shoring.

The storage area shall be periodically cleaned of rubbish.

**F 6635 REQUIRED STORAGE AREAS ACCORDING TO CLEANLINESS CLASS OR SUBCLASS**

A level I storage area shall be required for cleanliness subclass A 21 components.

A level II storage area shall be required for components assigned to subclasses A 1, A 22 and A 23, class B, and valves and pumps assigned to class C. However, the following exceptions shall be applicable.

1) When local conditions so permit (i.e. no corrosive atmosphere such as salt spray), pipes more than 1” in diameter may be stored in a level III storage area provided that they are sealed.

2) Components laid-up in accordance with the requirements of F 6623 may be stored in a level III storage area, provided their external surfaces are suitably protected.

A level III storage area is required for other class C items.

**F 6636 STORAGE OF COMPONENTS IN WORK ZONES**

Provided that components are stored on supports or shoring:

- a work zone I may be used as a level I storage area if the temperature is maintained above 16°C,
- a work zone II or III may be used as a level II storage area,
- a work zone III may be used as a level III storage area.

**F 6640 TRANSPORTATION**

**F 6641 MEANS OF TRANSPORTATION**

Open carriers may be used for the transportation of components provided that they may safely be exposed to environmental conditions without sustaining damage.

**F 6642 REQUIREMENTS FOR TRANSPORTATION AND ASSOCIATED HANDLING**

1) The requirements for the prevention of contamination specified in F 6420 shall be met.

2) Components transported in an open carrier shall be suitably protected from environmental conditions by means of waterproof tarpaulins installed in such a manner as to ensure air circulation to prevent condensation.

This requirement shall only be applicable to painted vessels and tanks when it is possible that the protection afforded by the paint may be degraded through contact with the ambient medium.
F 6643 COMPONENTS TRANSPORTED BY SEA

a) Transportation of components on the deck of the ship should be avoided, unless necessitated by the size of the component or if the component is placed inside a sealed container.

b) The external surfaces of equipment whose packing does not provide waterproof protection against salt atmosphere during transportation, shall be subjected as soon as arrived to an inspection of their degree of cleanliness. If necessary, the component shall be carefully rinsed with running water before erection, in order to remove, in particular all residual chlorides. The rinsing shall only be performed after ensuring that the water can not penetrate into the component.

When the equipment has to be stored after transportation, before entering the work area, the requirements for storage areas defined in F 6635 shall be applied according to their classes and subclasses. If the equipment is scheduled to remain outside for a long period, particularly at seaside plants, without a water-tight protection, the degree of cleanliness achieved in the workshop shall be, if necessary, restored as soon as the equipment is under cover or about to be sheltered.

F 6650 FINAL INSTALLATION ON THE PLANT

F 6651 GENERAL

The purpose of the requirements given in this paragraph is to reduce the number of cleaning operations on the plant, due to problems associated with such operations, and to facilitate the restoration of the degree of cleanliness obtained in the shops, when there is subsequent degradation taking into consideration the fact that the requirements for work areas, cleanliness control, prohibited contaminants, cleaning methods and the protection and lay-up of cleaned components are applicable.

F 6652 SPECIAL REQUIREMENTS FOR ERECTION

1) As far as possible, components shall be transported to the place of final installation, protected and laid-up in accordance with the requirements of F 6620.

2) Common openings shall remain blanked off except during work operations.

3) In accordance with the requirements of F 6621, the preservation system shall be restored after the work of inspection operations have been completed.

4) When parts are not to be welded straightaway, edge preparations shall be protected until they are welded, by means of a non-halogenated plastic film (see F 6420) to prevent accumulation of dust inside the component.

5) When work operations may result in the contamination of cleanliness class A or B components by solid or air-borne particles, precautions shall be taken to limit the risk of contamination (plugs, vacuum devices, etc.). In particular, solid particles resulting from welding operations inside the component shall be removed when the welding is finished.
6) Before and after operation, an inventory shall be kept of tools taken inside components or systems (when visual examination alone is not sufficient to check that no tools have been left inside).

F 6653 SPECIAL REQUIREMENTS FOR CLEANING ON THE PLANT

1) Rinsing of piping and components subjected to a water quality test in accordance with the requirements of F 6310 shall be continued until the pertinent criteria for water quality have been met.

2) Class A and B components may only be cleaned by one of the following methods:
   - mechanical means (grinding and brushing),
   - clean, non-halogenated, volatile solvents (ethyl or isopropylic alcohol, acetone, methylethylacetone),
   - grade A water or water treated in accordance with the requirements of F 6541.2.

3) The following cleaning means:
   - abrasive blasting,
   - chemical pickling,
   may only be used on the plant under exceptional circumstances and provided that technical justification is given.

4) Implementation of high-pressure flushing
   - Pipes with a diameter of 3” or less shall not be cleaned by this process.
   - The equipment used for high-pressure flushing shall not contaminate the parts to be cleaned.

5) Cleaning by "recirculating" flushes
   Cleaning by recirculating flushes shall be performed in two phases.
   - during installation, by means of water or clean, dry and oil-free compressed air,
   - after installation has been completed, by water circulation. Filter cartridges shall be installed in system filters and protective screens installed at pump suction.

6) When high-pressure flushing or "sieves" flushing is performed, the following shall be specified for each cleaning operation:
   - the portion of the system to be cleaned,
   - system devices which must not be actuated,
   - components which must be removed or isolated,
   - temporary protective screens or filters to be installed.
F 6660  PRESERVATION OF CLEANLINESS AFTER ERECTION

These requirements are applicable to components awaiting testing or startup.

a) Components cleaned on the plant:

1) Non-corrosion-resistant surfaces in contact with the process fluid shall be preserved until startup or testing by means of one of the methods specified in F 6623.

2) Corrosion-resistant surfaces shall be:

- either suitable protected and isolated from external ambient conditions in order to preserve their cleanliness until startup,
- or preserved in wet condition in accordance with the requirements of F 6623.b).

In the latter case, the fluid used for wet preservation may be:

. the process fluid,
. water meeting the requirements for quality given in F 6610,
. water whose purity is equivalent to that of the system makeup water.

3) Prior to the operations relating to cold test or starting functional tests, residual solutions for cleaning or conservation shall be removed from the system by rinsing until the effluent water from the system meets the cold functional test water quality requirements.

b) Other components

Components which are not subjected to any cleaning operation on the plant may be maintained in the state of cleanliness obtained in the shops by meeting the requirements given in F 6400 and F 6652.
ANNEX F I

DEFINITIONS

A  FLUIDS

1) Process fluid

   A liquid or gas which fills a system or component during normal plant operation

2) Primary fluid and injected fluids

   Process fluid which ensures core cooling and which includes fluids from the make-up, instrumentation and safeguard system.

B  SURFACES

1) Corrosion-resistant surfaces

   Stainless steels and nickel-base alloys.

2) Non-corrosion-resistant surfaces

   Carbon and low-alloy steels and certain chromium-base stainless steels.

3) Critical surfaces

   - Surfaces of heat exchanger tubes.
   - Surfaces subjected to friction such as: bearings, spindles, bearing surfaces, joint contact faces, etc.

4) Visible surfaces

   Surfaces visible to the naked eye or by means of a borescope.

5) Non-visible surfaces

   Surfaces which do not meet the definition given in 4) above. In addition, internal surfaces of all piping whose diameter \( \leq 6^\circ \) shall be considered to be non-visible.

C  CLEANING OPERATIONS

1) Descaling

   The elimination of the thick layers of adherent oxides (and other contaminants) formed by the heat treatment of products during manufacture or fabrication operations at high temperature.
2) Pickling

   Removal of metallic contaminants or light films of oxide from surfaces by means of acid solutions to which detergent or emulsifying agents may be added.

3) Passivation

   Process by which an insulating layer of adherent oxide is formed on the surface of a metal. Passivation is also used to decontaminate stainless steels.

4) Decontamination

   The removal of superficial particulate matter which may initiate or increase generally localized corrosion. During pickling or passivation, contamination is automatically removed by the acid.

5) Sensitized, austenitic or austenitic-ferritic stainless steel

   Throughout this chapter, an austenitic or austenitic-ferritic stainless steel shall be considered to be sensitized if it does not meet the requirements of the intergranular corrosion test specified in MC 1310.

6) Lixiviation

   Physical phenomenon resulting in the extraction of chemicals by dissolution in water, saturating vapour or other solvents.
ANNEX F II

CLEANLINESS CONTROL

CLEANLINESS TESTS AND ACCEPTANCE CRITERIA

Note: cleanliness tests A, B, and D, specified in tables F 6310.1 and F 6310.2 shall be performed on the basis of random sampling. Tests shall preferably be performed on doubtful areas.

a) VISIBLE SURFACES (see definition given in annex F I)

Test A, Aa, Ab - Visual examination - Criteria 1, 2, 3, 4 and 5:

- Test A

Surfaces shall be visually examined under a lighting equal to at least 500 lux (equivalent to the luminance directly beneath a 100 watt light bulb held 30 cm from the surface) provided that this does not dazzle the operator.

- Test Aa

Visual examination under ultraviolet light (radiation wavelength between 3500 and 4000 Å) to show up traces of oil (detection level $4 \times 10^{-6}$ g of oil/cm$^2$).

- Test Ab

Visual examination using a 5 X magnifying lens.

. Criterion 1

No corrosion products or foreign matter of any kind.

. Criterion 2

The metal shall be "metal clean". Very thin oxide films (detected by irridescence) resulting from welding, heat treatment, etc., shall be acceptable.

Scattered areas of oxidation, including surface rust stains of either the base metal or caused by contamination, shall be acceptable provided that the aggregate area of oxides does not exceed 0.1% of the total surface area to be taken into consideration.

. Criterion 3

As criterion 2 except that aggregate area of rust shall not exceed 1% of the total surface area.

. Criterion 4

The metal shall be free from foreign materials. An adherent, superficial film of continuous oxide caused by short-time exposure to the atmosphere shall be acceptable.
STAINLESS STEEL SURFACES

Scattered superficial rust stains shall be acceptable provided that the aggregate area of rust does not exceed 1% on the total surface area.

CARBON STEEL SURFACES

Thin uniform films of local or generalized initial rust formation shall be acceptable.

. Criterion 5

Tightly adherent mill scale on carbon steel surfaces shall be acceptable, as shall paint marks which do not flake or peel when flushed with cold water.

Rust films on carbon steels and stainless steels which are able to withstand brushing with a bristle brush shall be acceptable.

Note: Criteria 2 to 4

Performance of this test does not entail determination of the exact percentage of rust stains. Only conformance to test criteria shall be recorded in the test report (F 6340).

Test B - White cloth test - Criteria 6 and 7

Procedure

Doubtful areas shall be rubbed with a clean lint-free white cloth made from a non-synthetic material:

- if this operation is repeated 24 hours later, the same results must be obtained,
- when stipulated in the equipment specification, the test shall be performed with a cloth wetted in acetone.

. Criterion 6

The cloth must remain clean. No stains shall be acceptable.

. Criterion 7

Stains from superficial rust shall be acceptable. Stains caused by oil or foreign materials shall not be acceptable.

Test D, Da - Surface passivity - Criteria 8 and 9

This test is used to detect iron or iron oxides on the surfaces of stainless steels or high nickel content alloys.

Ferritic contamination may be either superficial or in the form of inclusions.

- Test D
Procedure:

- the surface to be tested shall be placed in contact with demineralized water (or water with a low mineral content) continuously oxygenated by bubbling with clean, oil-free, compressed air, by either immersion or filling with water, for a period of 12 hours.

  **Note:** When immersion or filling is not practicable, component parts shall be sprayed every hour for 12 hours with cold water and without any intermediate drying (the spraying period may be reduced to 6 hours if the droplets are sufficiently fine to adhere without running).

- parts shall be visually examined (or examined using a 5 X magnifying lens in case of doubt) after they have been exposed to the air for at least 24 hours.

- **Test Da**

  Test Da is used when there is doubt about the interpretation of the results of test D or when ferritic contamination is particularly dangerous ("critical surfaces"), it may only be used for local checking.

  **Procedure:**

  - test solution (applied by means of a glass or plastic spatula):
    - distilled water : 1000 ml
    - HNO₃ (65%) : 20 ml
    - potassium ferricyanide : 30 g

  - ferritic contamination is indicated by the appearance of blue stain during the 15 seconds subsequent to application,

  - the surface shall be thoroughly rinsed immediately after the treatment using a 20% acetic acid solution, and then rinsed several times in distilled water.

- **Criteria for test D and Da**

  - **Criterion 8**
    
    No superficial ferritic contamination (1) or ferritic incrustations (2) shall be present on the surface examined.

  - **Criterion 9**
    
    Superficial contamination (1) shall be acceptable. Parts shall only be accepted when there is no incrustation.

  (1) Contamination shall be considered to be superficial when there is no penetration of the metal substrate.

  (2) Ferritic incrustation shall be indicated by one or more of the following:

    - the presence of pit-like indications in which the voids are visible,
    - the build-up of corrosion products in a circular manner surrounding the pits (the voids may not be visible).
    The thickness of such corrosion deposits is generally significantly greater than that of surrounding oxides,
    - the presence of annular rings of discolouration surrounding the core of the pits.
b) NON-VISIBLE SURFACES (see definition given in annex F I)

Test E - Ea: Plug test - Criteria 6 and 7

This method is used to evaluate the cleanliness of heat exchanger tubes.

- Test E
  
  Test E is identical to test B, the white cloth is replaced by a cotton plug which is blown through the tube by clean, dry, oil-free air.

- Test Ea
  
  Test Ea is identical to test E but the plug is wetted with acetone (performance of this test shall be stipulated in the equipment specification).

- Criteria
  
  Acceptance criteria are identical to test B criteria 6 and 7.

Test F - Control of rinsing water - Criteria 10, 11 and 12

Procedure: See F 6541.2

The water is circulated at a velocity greater than or equal to that of the process fluid during normal operation.

The water sample (at least 40 l) from the last flush shall be filtered through a clean white cloth approximately 90 gr/m$^2$ with a mesh size of 3 to 4 threads/mm in both directions. The surface area of the cloth shall be 10 dm$^2$.

- Acceptance criteria for test F
  
  . Criterion 10
    
    The general appearance of the cloth shall be that of a clean, white, wet cloth showing no more than slight stains (rust or dirt).

    There shall be no particles on the cloth larger than 1.0 mm in any dimension except for very fine or hair-like slivers which may be up to 1.5 mm in length.

    There shall be no readily apparent quantities of organic impurities or unusual foreign materials (oil, abrasives, etc.).

  . Criterion 11
    
    The same requirements as for criterion 10 shall be applicable except that a copious deposit of rust on the filter shall be acceptable.

  . Criterion 12
    
    The same requirements as for criterion 11 shall be applicable except that there shall be no particles greater than 1.5 mm in any dimension apart for very fine or hair-like slivers which may be up to 3 mm in length.
### ANNEX F III

#### WATER QUALITY

<table>
<thead>
<tr>
<th>GRADES</th>
<th>Fresh water</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Chloride ion (maxi. ppm)</td>
<td>0.15</td>
</tr>
<tr>
<td>Fluoride ion (maxi. ppm)</td>
<td>0.15</td>
</tr>
<tr>
<td>Conductivity (µS/cm) (microSiemens/cm)</td>
<td>2.0</td>
</tr>
<tr>
<td>Resistivity (Ω.cm)</td>
<td>500 000</td>
</tr>
<tr>
<td>Total solids (maximum ppm)</td>
<td>-</td>
</tr>
<tr>
<td>Solids in suspension (maximum ppm)</td>
<td>0.1</td>
</tr>
<tr>
<td>SiO₂ (maximum ppm)</td>
<td>0.1</td>
</tr>
<tr>
<td>pH</td>
<td>6.0-8.0</td>
</tr>
</tbody>
</table>

(1) : A drop in the minimum pH level to 5.5 is permissible on the condition that it can be shown that the drop in pH is effectively due to the carbonation of the water.

**Note:** Water supplied by the reactor coolant makeup water production station shall meet the requirements applicable to grade A water.
ANNEX F IV

SPECIAL REQUIREMENTS FOR THE SELECTION AND INSTALLATION OF INSULATION (QUALIFICATION AND ACCEPTANCE TESTS FOR THE PREVENTION OF CORROSION)

A GENERAL

Insulation shall be made from either:

- metallic materials (stainless steel strip or wire gauze), in which case there are no requirements for acceptance of qualification,
- or glass fibre or rock wool manufactured, in which case the insulation shall meet the requirements given below.

B REQUIREMENTS FOR NON-METALLIC INSULATION

Insulation shall be:

- unvariable to ageing, steam, fungi,
- fire-resistant (or classified as M0 or M1 fire-resistant material)*.

The insulation for austenitic stainless steel components must not contain leachable chloride or fluoride ions in excess of the acceptable limits stipulated in C and D (particularly local concentrations).

By extension, the insulation for carbon steel components shall meet the same requirements where the arrangement of components is such that austenitic stainless steel components may be contaminated by runoff.

* Classification in accordance with the "Arrêté” of 4th June 1973 (Journal Officiel of 26/7/73)

C QUALIFICATION TESTING OF NON-METALLIC INSULATION

1 - CHEMICAL ANALYSIS

An aqueous solution shall be used for analysis. The purpose of the analysis is to determine the concentration of Cl\(^-\), F\(^-\), SiO\(_3\)\(^{2-}\) and Na\(^+\) ions.

Acceptable ion concentrations are listed in figure C 1.

Method of analysis: undergoing validation.

2 - TESTING THE CORROSION OF STAINLESS STEEL INDUCED BY INSULATION MATERIALS

The test is awaiting validation.
D  NON-METALLIC INSULATION ACCEPTANCE TEST

Any lot of insulation material qualified in accordance with the requirements of C above shall be acceptance tested. Acceptance is based on the chemical analysis specified in C1, whereby the concentration of corrosive ions (Cl\(^-\) and F\(^-\)) and inhibitors (Na\(^+\) + SiO\(_3^{2-}\)) must not deviate by more than 50% from the values determined in the qualification test.

E  REQUIREMENTS FOR THE INSTALLATION OF INSULATION

The metal shells of insulation installed on components located inside the reactor containment shall be made from stainless (austenitic or ferritic) steel. The use of aluminium or aluminium alloys is prohibited.

Insulation shells for other components shall be made from:

- stainless steel,
- aluminium or aluminium alloy,
- or galvanized steel plate.

For the removable sections of insulation installed on components made from austenitic stainless steel, all plates which are in contact with the component must be made from stainless steel.

Non-metallic materials used to maintain the insulation in position must meet the requirements of the chemical analysis specified in C1.

The metallic insulation shells must be made water-tight to prevent water from seeping in. Accordingly, joints between shells shall be crimped so as to inhibit penetration by runoff fluids.
FIGURE C.1

ACCEPTABILITY OF INSULATION ON THE BASIS OF CHEMICAL ANALYSIS

\[(\text{Cl + F}) \text{ ppm}\]

\[(\text{Na} + \text{SiO}_3) \text{ ppm}\]

RESULTS OF ANALYSIS NOT ACCEPTABLE

RESULTS OF ANALYSIS ACCEPTABLE
ANNEX F V

CHEMICAL METHOD OF ANALYSIS FOR DETERMINING CHLORINE, FLUORINE AND SULPHUR CONTENTS

A GENERAL

1. SCOPE

This annex concerns the chemical analysis methods to be used to determine the chlorine, fluorine and sulphur content of products for which the contents of these elements are limited.

The limit values are specified:
- in chapter F 6000 of the RCC-M,
- in the procedures involving use of the product.

Chapter B describes the treatment methods for the product to be analysed:
- mineralization with a calorimetric bomb for high and low-combustibility products,
- alkaline mineralization for incombustible products,
- lixiviation.

Chapter C specifies the chemical analysis methods:
- chlorine analysis by spectrocolorimetry,
- chlorine, fluorine and sulphur analysis by ion cromatography,
- chlorine analysis by mercuric nitrate titration,
- fluorine analysis by ionometric measurement,
- sulphur analysis by plasma emission spectrometry.

Only those product treatment methods and chemical analysis methods specified in this annex are allowable for determining the chlorine, fluorine and sulphur contents.

2. GENERAL PRECAUTIONS

Any material or chemical product (including water and solvents) likely to come into contact with or pollute the solutions to be analyzed, shall be free of chloride and sulphur.

Glassware in particular should be cleaned with concentrated nitric acid and then rinsed in demineralized water free of chlorine or sulphur.

3. ANALYSIS REPORT

This document shall state:
- the product identification (where applicable the manufacturing lot number, the packaging lot number),
- presentation and packaging of the product (aerosol can, drum, etc.),
- analysis laboratory's name,
- product treatment method and analysis method for the chemical element looked for.

**B PRODUCT TREATMENT METHOD**

- Treatment by lixiviation is described in paragraph 3.
- When the product is not treated by lixiviation, the recommendations are as follows:
  - totally combustible products are treated by calorimetric bomb mineralization (B1),
  - incombustible aqueous liquids are treated by alkaline mineralization (B 2.2.1),
  - incombustible solids or pastes are treated by alkaline mineralization (B.2.2.3),
  - partially combustible products are treated by calorimetric bomb mineralization and then by alkaline mineralization (B 2.2.2).

1. TREATMENT OF THE PRODUCT TO BE ANALYZED BY CALORIMETRIC BOMB MINERALIZATION

1.1 Apparatus

- A calorimetric bomb preferably coated internally with 10% iridium platinum, or failing that, stainless steel.
- Platinum crucible made of 10% rhodium platinum.
- Platinum wire preferably, for connecting the electrodes.

1.2 Treatment (to be carried out in the following order)

- Dry the cover of the bomb.
- Connect the electrodes with the metal wire and attach a chlorine, fluorine and sulphur free cotton wick.
- Introduce less than 5 ml of demineralized water into the calorimetric bomb.
- Quickly and accurately weigh out between 0.5 and 1 g of substance into the platinum dish depending on the chlorine and sulphur contents (the sampling techniques for products in aerosol cans is described in para. 1.3).
- In the case of inflammable substances (aqueous solutions, liquid detergents, etc.), introduce 1 ml of alcohol for a test sample of 0.2 to 0.5 g (alcohol can be replaced by acetone provided that all necessary safety precautions are taken).
- Place the dish in the bomb and screw on the cover (it is preferable to screw on the body of the bomb while holding the cover stationary in order to avoid splashing any product from the dish).

- Three-quarters submerge the bomb in a cooling bath of water and ice.

- Gently raise the oxygen pressure to 25 bar (checking with the pressure gauge).

- Degas with oxygen, except in the case of a volatile product (limitation of nitrate interference).

- Ignite.

- After cooling, remove the bomb from the cooling bath and let the oxygen escape very gently (regulate the rate of escape of gas by bubbling through a beaker of demineralized water, such that a minimum of 20 minutes are taken to empty the bomb).

- Open the bomb, rinse the walls and the electrodes several times using small quantities of demineralized water (the part of the cover protected by the O-ring should not be rinsed).

- Collect the solution containing the condensates in a 50 ml volumetric flask and top up with demineralized water.

- Blank test.

  Carry out a blank test in the same conditions as the cotton wick sample (plus alcohol when necessary).

1.3 Technique for sampling products contained in an aerosol can

The content of the can comprises the following components:

- the propellant gas (generally butane),

- the actual active product.

Shake the aerosol can and bleed for 5 seconds before taking the sample.

At the moment of weighing, the content of the aerosol can is sprayed into a 100 ml beaker and then immediately transferred to the platinum dish.

This operation is carried out quickly in order to minimise the loss of volatile solvents. The time between the beginning of sampling and closure of the bomb should not exceed 2 mn 30.

2. TREATMENT OF THE PRODUCT TO BE ANALYZED BY ALKALINE MINERALIZATION

2.1 Apparatus and reagent

- Pure platinum crucibles.

- Exchanger of $\text{H}^+$ cations.

- Temperature controlled furnace.
- Sodium peroxide (analysis quality).
- Nitric acid N prepared from concentrated HNO₃ (analysis quality).

2.2 Treatment (to be carried out in the order given below)

2.2.1 Treatment of incombustible aqueous liquids

PRELIMINARY TREATMENT

Accurately weigh out a sample of between 0.5 and 1 g into a platinum crucible. Add 50 mg of sodium peroxide and with a pH paper check that the solution is indeed alkaline. Place the crucible in an oven at a temperature of 80°C. Bring the solution to dry content and leave to cool.

SECONDARY TREATMENT

Add 1.45 g of sodium peroxide to the crucible and place in a furnace at ambient temperature. Gradually raise the furnace temperature to 500°C at a rate of 25°C/mn, and hold it there for 20 mn. Remove the crucible from the furnace, leave to cool and resume sintering by adding 25 ml of demineralized water.

After the effervescent phase, top up the solution with demineralized water in a 50 ml volumetric flask and centrifuge the solution to separate out any hydroxide precipitates if necessary.

TREATMENT OF THE SUPERNATANT SOLUTION

Treat a maximum volume of supernatant solution or, if there is no precipitate, all of it on the H⁺ ion exchanger resin regenerated beforehand with HNO₃. Collect the solution in a 100 ml volumetric flask. Rinse the resin with demineralized water and top up the eluant to 100 ml with this rinsing water in the volumetric flask.

BLANK TEST

Carry out a blank test in the same conditions as for the sample, starting from the secondary treatment, using 1.5 g of sodium peroxide (instead of 1.45 g).

2.2.2 Treatment of partially combustible products

PRELIMINARY TREATMENT

Mineralize the sample in a calorimetric bomb as shown in chapter 1, and recover any unburned substances from the platinum dish.

Finely crush the combustion residues in the calorimetric bomb. then introduce either a fraction or all of the deposit into a platinum crucible.

SECONDARY TREATMENT

Gradually raise the furnace temperature to 500°C, at a rate of 25°C/mn, and hold it there for 20 mn. Remove the crucible from the furnace, leave to cool and resume sintering by adding 25 ml of demineralized water.
After the effervescent phase, top up the solution in a 50 ml volumetric flask with demineralized water and centrifuge the solution to separate out any hydroxide precipitates if necessary.

TREATMENT OF THE SUPERNATANT SOLUTION

The treatment of the supernatant solution is identical to that in B 2.2.1.

BLANK TEST

Carry out a blank test in the same conditions as for the sample.

2.2.3 Treatment of combustible solids or pastes

PRELIMINARY TREATMENT

Crush small fractions of the sample and then accurately weigh out between 0.3 and 0.5 g of the product into a platinum crucible. Add 1 g of sodium peroxide and mix. Then cover the mixture with 0.5 g of sodium peroxide.

SECONDARY TREATMENT

Gradually raise the furnace temperature to 500°C, at a rate of 25°C/mn, and hold it there for 20 mn. Remove the crucible from the furnace, leave to cool and resume sintering by adding 25 ml of demineralized water.

After the effervescent phase, top up the solution in a 50 ml volumetric flask with demineralized water and centrifuge the solution to separate out any hydroxide precipitates if necessary.

TREATMENT OF THE SUPERNATANT SOLUTION

The treatment of the supernatant solution is identical to that in B 2.2.1.

BLANK TEST

Carry out a blank test in the same conditions as for the sample.

3. TREATMENT OF THE PRODUCT BY LIXIATION

Wearing gloves, sample a surface area of between 300 and 1000 cm², which is cut into fractions of a few cm². They are placed in a 800 ml beaker containing 200 ml of deionized water, which is weighed before the sample is added. Then weigh again.

Note: When adhesive tapes are usually wound around the supports, the first 3 layers shall be eliminated.

Cover the beaker with a watch glass and heat to near boiling (95-100°C) for 30 mn.

Cool and filter the solution through a mesh size 5 µm. Rinse the beaker several times and transfer the contents into a 500 ml volumetric flask. Dilute to 500 ml with deionized water.
C  CHEMICAL ANALYSIS METHODS

1. ANALYSIS OF CHLORINE BY SPECTROCOLORIMETRY

The presence of halogenated elements such as bromine and iodine interfere with dosing.

1.1 Principle

The chlorides in solution together with the mercuric thiocyanate form a mercuric chloride releasing thiocyanate ions according to the following reaction:

$$2 \text{Cl}^- + \text{Hg} (\text{SCN})_2 \rightarrow \text{HgCl}_2 + 2 \text{SCN}^-$$

The thiocyanate ions then react with $\text{Fe}^{3+}$ to give a red complex whose colour intensity is proportional to the concentration of SCN$^-$ ions and thus of Cl$^-$.

$$\text{SCN}^- + \text{Fe}^{3+} \rightarrow \text{Fe} (\text{SCN})^{2+}$$

1.2 Scope

This method is used to determine chlorine contents upwards of 10 mg.kg$^{-1}$ in the product or the material, and 25 mg.kg$^{-1}$ in the solution to be dosed.

1.3 Apparatus

UV-VIS spectrocolorimetry.
40 mm vessels.
100, 200, 1000 and 5000 µl micro-pipettes.

1.4 Reagents

1 - Ferric nitrate solution

Weigh out 15.1 g of Fe(NO$_3$)$_3$, 9 H$_2$O, add 45 ml of 70% perchloric acid, dissolve and top up to 100 ml in a volumetric flask with demineralized water.

2 - Saturated solution of mercuric thiocyanate prepared in alcohol using pure ethanol.

3 - Cl$^-$ ion reference solution at 50 mg.kg$^{-1}$

Accurately dissolve 1.648 g of NaCl in one litre of demineralized water. 1 ml of this solution corresponds to 1 mg of Cl$^-$.

Then dilute 20 times this solution to obtain a solution at 50 mg.kg$^{-1}$. 
1.5 Procedure
In a 50 ml volumetric flask introduce an aliquot of the mineralized sample. Top up the volumetric flask to 50 ml with demineralized water.

Pour the solution into a 100 ml beaker and add:
- 4 ml of ferric nitrate (1.4.1),
- 4 ml of mercuric thiocyanate (1.4.2) and homogenize with a magnetic agitator.

Wait 5 mn and measure the optical density of the solution at a wavelength of 460 nm, as compared with a blank test with "demineralized water + reagents".

Determine the chlorine content of the sample as compared to the calibration range (1.6).
Deduct from the value obtained that from the blank test.

1.6 Preparation of the calibration range
In five 50 ml volumetric flasks identified a, b, c, d, e, introduce the following respectively, using micro-pipettes:

- 0 µl of the solution (1.4.3), i.e. 0 µg of Cl
- 100 µl of the solution (1.4.3), i.e. 5 µg of Cl
- 200 µl of the solution (1.4.3), i.e. 10 µg of Cl
- 300 µl of the solution (1.4.3), i.e. 15 µg of Cl
- 400 µl of the solution (1.4.3), i.e. 20 µg of Cl

Then top up each 50 ml volumetric flask with demineralized water corresponding to the respective concentrations of 0 - 0.1 - 0.2 - 0.3 - 0.4 mg.kg-1 [Cl].

Then treat each flask using procedure (1.5) and measure the optical densities of these solutions as compared with a blank test using "demineralized water + reagents".

1.7 Expression of results

\[
\text{Cl}^- \text{ in mg.kg}^{-1} \text{ in the sample} = \frac{\text{Concentration read on curve} \times \text{Dilution factor}}{1000} \times \frac{\text{Sample weight in mg}}{1000} \times 10^6
\]

Note: For the blank test measurement, dilute the solution to be analyzed as little as possible.

1.8 Example of dilution factor (F) calculation method

\[
F = \frac{50 \times (\text{solution volume in ml specified in the procedure})}{V \times (\text{test sample volume in ml taken from the eluate})} \times 100 \times (\text{total eluate volume in ml})
\]
2. CHLORINE, FLUORINE AND SULPHUR ANALYSIS USING ION CHROMATOGRAPHY

This is the only completely chlorine selective method. Dosing can be hampered by a high level of nitrates.

2.1 Principle

The unknown solution is injected using a low-volume loop into an ion exchange chromatography system comprising conductimetric detection.

2.2 Scope

This method can be used to determine the chlorine, fluorine and sulphur contents above 10 mg.kg\(^{-1}\) in the product or the material, and 5 µg.kg\(^{-1}\) in the solution to be dosed.

2.3 Apparatus

1 - Chromatograph

2 - Liquid phase ion chromatography system with conductimetric detection, comprising:
   - a potentiometric recorder or peak integrator,
   - an ion exchange pre-column. HPIC - AG2 P/N 031 022 (DIONEX),
   - an anion exchange separation column,
   - a background noise cancellation column,
   - an injection loop of volume between 100 and 350 µl.

3 - Micro-pipettes of 100 - 200 - 1000 - 5000 µl.

2.4 Reagents

2.4.1 Separation column eluants

Prepared according to the configuration of the apparatus used and compatible with the separation columns and the elements to be dosed.

2.4.2 Mother solutions

- 1 g.kg\(^{-1}\) [Cl\(^-\)] solution, prepared from NaCl
- 1 g.kg\(^{-1}\) [F\(^-\)] solution, prepared from NaF
- 1 g.kg\(^{-1}\) [S] solution, prepared from H\(_2\)SO\(_4\)

2.5 Preparation of calibration ranges

From the mother solutions (2.4.2) prepare the following reference solutions by dilution:

Solution of 0.050 mg.kg\(^{-1}\) Cl\(^-\) + 0.050 mg.kg\(^{-1}\) SO\(_4\)\(^{2-}\) + 0.050 mg.kg\(^{-1}\) F\(^-\).
Solution of 0.100 mg.kg\(^{-1}\) Cl\(^-\) + 0.100 mg.kg\(^{-1}\) SO\(_4^{2-}\) + 0.100 mg.kg\(^{-1}\) F\(^-\).
Solution of 0.150 mg.kg\(^{-1}\) Cl\(^-\) + 0.150 mg.kg\(^{-1}\) SO\(_4^{2-}\) + 0.150 mg.kg\(^{-1}\) F\(^-\).
Solution of 0.200 mg.kg\(^{-1}\) Cl\(^-\) + 0.200 mg.kg\(^{-1}\) SO\(_4^{2-}\) + 0.200 mg.kg\(^{-1}\) F\(^-\).

### 2.6 Procedure

Balance the chromatographic system in an eluant medium until a stable baseline is obtained. Rinse the sampling loop with the sample to be analyzed and inject this sample (diluted between 25 and 50 times). The peaks corresponding to the chlorine, fluorine, sulphur in Cl\(^-\), F\(^-\), SO\(_4^{2-}\) ion state are identified on the respective chromatograms of the separation columns according to the retention times determined beforehand using the standard solutions (2.5). The chlorine, fluorine and sulphur contents of the sample are determined by measuring the height of the conductivity peaks obtained for each of these elements as compared with those of the standard solutions.

Deduct from the values obtained those from the blank test.

### 2.7 Expression of results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Blank test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration read on curve × Dilution factor</td>
<td>Concentration read on curve × Dilution factor</td>
</tr>
</tbody>
</table>
| \[
\text{Cl, F, S in mg.kg}^{-1}\text{ in the sample} = \left(\frac{1000}{\text{Sample weight in mg}}\right) \times 10^6
\] | |

### 3. CHLORINE ANALYSIS BY MERCURIC NITRATE TITRATION

This method can be used above 0.2 mg/kg of chloride in the solution to be dosed for a 100 ml test sample. The presence of halogenated elements such as bromine and iodine interferes with the dosing. This method is chiefly suited to dosing of chlorides released by lixiviation (paragraph B.3).

#### 3.1 Principle

Mercuric salts form the soluble complex HgCl\(_2\) when Cl\(^-\) ions are added. A mixed indicator of diphenylcarbazone and bromophenol blue is used to detect excess Hg\(^{2+}\). The end point of titration is the formation of the blue-violet mercury diphenylcarbazone complex.

#### 3.2 Apparatus

- Standard laboratory glassware specifically reserved for this kind of titration: 800 ml beakers, watch glasses, 500 ml volumetric flasks.
- Hot plate.
- microburet 5 ml, with 0.01 ml precision.
- 5 µm filter.
- Cotton gloves.

### 3.3 Reagents

#### 3.3.1 Nitric acid

Suprapur d = approximately 1.40.

#### 3.3.2 Mercuric nitrate standard 0.014 N

Dissolve approximately 2.4 g of mercuric nitrate $\text{Hg(NO}_3\text{)}_2$, $\text{H}_2\text{O}$ in 50 ml of deionized water acidified by the addition of 0.5 ml of concentrated nitric acid (3.3.1). Dilute to 1000 ml with deionized water. Filter if necessary and calibrate using a sodium chloride standard (3.3.3).

#### 3.3.3 Sodium chloride standard

Weigh out exactly 0.1649 g of NaCl of guaranteed purity which has previously been dried at 105°C. Dissolve in deionized water and dilute to 1000 ml.

This solution contains 100 mg/l of chloride.

#### 3.3.4 Mixed indicator

Dissolve 0.5 g of crystalline diphenylcarbazone and 0.05 g of bromophenol blue powder in 75 ml of ethyl alcohol (95%). Dilute to 100 ml with alcohol. Store in a brown bottle and discard after 6 months.

#### 3.3.5 HNO$_3$ approximately 0.04 N

Place 3 ml of concentrated nitric acid (3.3.1) in a 1000 ml volumetric flask. Dilute to one litre using deionized water.

#### 3.3.6 NaOH at 10 g/l

Dissolve 10 g of sodium hydroxide in 100 ml of deionized water and dilute to one litre.

### 3.4 Procedure

#### 3.4.1 Determination of titer of the mercuric nitrate solution

Place 10 ml of the sodium chloride standard (3.3.3) in a 100 ml beaker. Add 5 drops of the mixed indicator (3.3.4). Add the solution (3.3.5) drop by drop until the colour turns yellow, and then an additional 0.1 ml.

Titrate the solution with mercuric nitrate (3.3.2) until a blue-violet colour persists. Use a white background under the beaker to aid in colour change appreciation.

Make a blank test using deionized water.
Calculation of the mercuric nitrate solution.

\[
N = \frac{C \times S}{(V_1 - V_2) \times 35.5 \times 10^3}
\]

(1)

\(C\) = Concentration of the standard chloride solution (100 mg/l) (2.3.3)

\(S\) = volume of test sample (10 ml)

\(V_1\) = Volume of titer used for the sample

\(V_2\) = Volume of titer used for blank (in ml)

\(N\) should be close to 0.014.

3.4.2 Determination of chloride ions

Sample 100 ml of the solution to be analyzed (chapter B) and proceed as for titration of the mercuric nitrate solution.

Expression of results:

Chloride concentration of the solution:

\[
\text{Cl}^{-} \text{ in ppm:}
\]

\[
\frac{(V'_1 - V'_2) \times N \times 35.5 \times 10^3}{S'}
\]

(2)

\(V'_1\) = volume of titer poured for the test sample in ml

\(V'_2\) = volume of titer for the blank in ml

\(N\) = normality of the mercuric nitrate solution

\(S'\) = volume of sample analyzed in ml (100 ml)

Deduct the concentration obtained with the blank from this value.

By comparing formulae (1) and (2) it may be observed that the chloride content is obtained using the following equation:

\[
\text{Cl}^{-} = \frac{V'_1 - V'_2}{V_1 - V_2} \times \frac{S}{S'}
\]

Concentration of leached by lixiviation chloride per gram of sample:

\[
\frac{\text{ppm Cl}^{-} \times \text{final filtering (500 ml)}}{\text{weight of the sample (in g)}}
\]

3.5 Alternative method

Titration may be performed by colorimetric titrimetry (at 520 nm) by recording the curve of variations in absorption. This method eliminates the human error factor in the evaluation of the indicator end point.

APPARATUS

Identical to the previous method plus spectrophotometry and potentiograph.
5 ml buret coupled to the potentiograph.

Titration cells.

50 ml of the leaching solution prepared in accordance with the previous procedure are placed in the cell. The titration cell is placed in its compartment.

The agitator device is started up, the wavelength is adjusted to 520 nm and the potentiograph operation switch is set to 100 mV. Proceed with titration. The potentiograph ensures that the recorder and the buret piston are driven at the same time. The equivalent point is determined from the recording.

4. FLUORIDE ANALYSIS BY IONOMETRIC MEASUREMENT

4.1 Principle
A potential difference is established between a specific F⁻ ion electrode and a reference electrode, as a linear function of the F⁻ ion concentration logarithm.

4.2 Scope
This method is used to determine the fluorine contents above 10 mg·kg⁻¹ in the product or material, and 2 µg·kg⁻¹ in the solution to be dosed.

Note:
The curve is linear up to 10⁻⁶ mole/l (20 ppb).
Measurement is possible for 10⁻⁷ < F < 10⁻⁶ mole/l (2 ppb < F < 20 ppb)
Detection is possible from 5.10⁻⁸ mole/l (1 ppb).

4.3 Apparatus
- Precision ion meter (minimum resolution 0.1 mV).
- F⁻ ion specific measurement electrode.
- Calomel reference electrode (filled with saturated KCl).
- 100, 200, 1000, 5000 µl micro-pipettes.

4.4 Reagents
1 - "TISAB III" ion buffer solution (composition: mixture of ammonium acetate - CDTA ammonium chloride "cyclohexane dinitrotetra-acetic acid").
2 - pH 6 buffer solution (composition: mixture of sodium citrate and potassium nitrate).
3 - Molar solution of F⁻ ions prepared by dissolving 41.99 g of sodium fluoride in demineralized water.
4 - 0.01 molar solution of F⁻ ions prepared by diluting the solution (4.4.3) 100 times.
5 - 0.001 molar solution of F⁻ ions prepared by diluting the solution (4.4.4) 10 times.
4.5 **Procedure**

Introduce an aliquot (V) of the mineralized sample into a 50 ml volumetric flask, plus 2 ml of TISAB III ion buffer solution (4.4.1) and 3 ml of pH 6 buffer solution (4.4.2). Top up the flask to 50 ml with demineralized water and pour the solution into a 100 ml beaker.

Keep the solution constantly agitated using the magnetic agitation device, immerse the electrodes 5 cm into the solution and record the potential difference reading on the ion meter after stabilization. This can last a few minutes for low concentrations.

Then determine the fluorine concentration of the sample by comparing with the calibration range (4.6). Deduct from the value obtained that from the blank test.

4.6 **Preparation of the calibration range**

In four 100 ml volumetric flasks a, b, c, d, insert 4 ml of ion buffer solution (4.4.1), 6 ml of pH 6 buffer solution (4.4.2) then add as follows:

a - 0.1 ml of 0.001 M solution (4.4.5),
b - 0.5 ml of 0.001 M solution (4.4.5),
c - 1 ml of 0.001 M solution (4.4.5),
d - 10 ml of 0.001 M solution (4.4.5),

and top up each flask to 100 ml with demineralized water, which corresponds to concentrations of: 0.019 - 0.095 - 0.19 - 1.9 mg.kg$^{-1}$ of [F] respectively.

For each solution, record the potential difference given on the ion meter and plot the calibration line on semi-log paper.

4.7 **Expression of results**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Blank test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration read on curve × Dilution factor</td>
<td>Concentration read on curve × Dilution factor</td>
</tr>
<tr>
<td>$\frac{F}{\text{mg.kg}^{-1}}$ in the sample</td>
<td>$\frac{\text{Sample weight in mg}}{1000}$</td>
</tr>
</tbody>
</table>

Note: To get round the problem of possible interference, the results can be checked using the method of dosed additions (method only usable within the range in which the electrode response is linear).

In this case, the fluorine content of the sample can be calculated as follows:

$$\text{mg of F in the sample (V)} = \frac{\Delta CX}{10^{\Delta E / \nu} - 1}$$

$\Delta CX$ = Weight of F corresponding to the addition.
$\Delta E$ = potential difference recorded between the dosed additions.
$\nu$ = Potential difference recorded for a decade (slope coefficient).
5. ANALYSIS OF SULPHUR BY PLASMA EMISSION SPECTROMETRY

5.1 Principle
The sulphur in the solution in the form of $SO_4^{--}$ ions is introduced into the "ARGON-$Ar^+$" plasma (partially ionized gas giving a temperature of about 6000°C) in order to be excited. De-excitation of the sulphur atoms leads to the emission of light whose intensity is proportional to the concentration of the element excited and can be measured by a spectrophotometer.

5.2 Scope
This method can be used to determine sulphur contents above 10 mg.kg$^{-1}$ in the product or material, and 25 µg.kg$^{-1}$ in the solution to be analysed.

5.3 Apparatus
- Emission spectrophotometer (plasma torch) equipped with:
  - a high frequency generator supplying an induction coil,
  - a network monochromatic illuminator able to operate in a vacuum,
  - a pneumatic or ultrasonic nebulizer,
  - a computerized signal processing system or potentiometric recorder.
- Argon cylinder.
- Nitrogen cylinder.
- 100, 200, 1000, 5000 µl micro-pipettes.

5.4 Reagent
Sulphuric acid at 1 g.kg$^{-1}$ $SO_4^{--}$.

5.5 Procedure
- Start up the apparatus.
- Create a vacuum in the network monochromatic illuminator(s) using the pump.
- Ignite the torch.
  Nebulize the demineralized water in the plasma for a few minutes in order to rinse the nebulizer, then ignite the torch.
- Measurements (sample)
  Nebulize the mineralized sample in the plasma and measure the intensity of the emission signal against a "demineralized water" blank.
  Then determine the sulphur concentration of the sample against the calibration range (5.6). Deduct from the value obtained that from the blank test.
5.6 Preparation of the calibration range

Using sulphuric acid (5.4), prepare the 5 - 10 - 15 - 20 mg.kg\(^{-1}\) [S] standards by dilution and measure the intensity of the emissions signal from each of these solutions as compared with a demineralized water blank.

Any analysis of less than 5 mg.kg\(^{-1}\) must be backed up by an additional standard solution.

5.7 Expression of results

\[
S \text{ in mg.kg}^{-1} \text{ in the sample} = \frac{\text{Concentration read on curve} \times \text{Dilution factor}}{1000} - \frac{\text{Concentration read on curve}}{1000} \times 10^6
\]
F 7000

SCREWED JOINTS

F 7100  GENERAL

a) Screwed joints consist of bolted flanges* for piping, vessel nozzles and closure assemblies for vessel openings.

b) The design and choice of bolted flange joints shall meet the requirements of annex Z V 110 of SECTION I.

F 7200  PROCEDURE

A procedure shall be established for all screwed joint operations. This procedure shall specify the following:
- checks to be performed prior to assembly (type of joint, condition of joint contact faces, thread condition, etc.),
- type of lubricants used,
- tightening torque (additional initial torque when relevant) or the elongation required,
- the sequential order of bolt tightening and the type of tools required.

F 7300  INSTALLATION REQUIREMENTS **

1) The personnel installing screwed joints shall be provided with:
- written instructions specifying the same requirements as the installation procedure,
- the tools specified in the installation procedure.

* Bolting material is a general term which also covers threaded rods.

** These requirements are not applicable to:
- vessel head closure assemblies,
- closure assemblies which also act as guides (shaft guide, valve stem), for which the Manufacturer shall draw up a specific procedure for each item or type of item.
2) Prior to installation a check must be made to verify that:
   - the condition of the threads or bores and bolting material is satisfactory (no degradation of foreign materials),
   - no radial scratches or damage are apparent on the flange contact faces in accordance with the requirements of the Manufacturer of the gasket,
   - the condition and the dimensions of the gasket prior to installation are satisfactory.

3) For pipes, after installing the gaskets, the joint contact faces shall be placed in contact, checked to be parallel and secured in position.

4) In accordance with the pertinent procedure, the threads of nuts and bolts shall be lubricated prior to installation.

5) Nuts shall be screwed by hand until they are in contact with the contact faces.

6) Nuts shall then be screwed in the sequential order specified in the procedure (it is recommended that all nuts be screwed initially to 20% of the specified torque, subsequent to which screwing should be continued in accordance with the specified sequential order).

7) When all nuts have been screwed to the specified torque, a final torque shall be successively applied to all nuts in order to detect and rectify the torque of bolts which may have worked loose due to interaction with other bolts.

F 7400  LUBRICANT REQUIREMENTS

Bolts and nuts shall be lubricated.

The lubricants used shall be:
   - stable at service temperature,
   - compatible with the materials with which they are in contact (special attention must be paid to stress corrosion),
   - in accordance with the requirements of F 6300 with respect to chemical elements prohibited for austenitic stainless steels.

F 7500  THREAD REQUIREMENTS

a) Bolts and rods shall preferably be thread rolled using roller type dies.

   Thread cutting of bolts and rods shall be acceptable provided that they meet the requirements of SECTION I, annex Z V 110. Threads cut with flat dies shall not be acceptable.

b) Internal threads shall be protected by plugs whenever there is any danger of contamination by foreign materials during painting or fabrication operations.
F 7600    FLANGE REQUIREMENTS

Grooves machined into joint contact faces (RF flanges for example) shall be concentric. Helix grooves shall not be acceptable.

F 7700    TOOL REQUIREMENTS

Fluids used for the hydraulic systems of tightening tools (jacks), when such tools are used, shall meet the requirements of F 6420 with respect to prohibited products whenever a mechanical failure may result in contamination of reactor coolant system fluids as defined in annex FI, chapter F 6000.

F 7800    SURFACE TREATMENT OF BOLTING MATERIALS

There are no particular restrictions concerning the use of manganese phosphate coating in accordance with the requirements of F 5200.

For bolting materials which are not in direct contact with the reactor coolant fluid, the following may be permissible:

- either surface treatment consisting of electrolytic tinning and diffusion in accordance with the requirements of F 5500,

- or electrolytic treatment consisting of cadmium-coating followed or not by chromatizing finishing treatment in accordance with the requirements of F 5600.

Note: Other surface treatments may be proposed by the Manufacturer with the Contractor’s agreement. This request must be accompanied by a technical file justifying the suitability of the proposed technique and setting forth the conditions of application and examination as well as references of industrial application.

F 7900    STANDARDS RELATING TO BOLTING MATERIAL FOR BOLTED FLANGE JOINTS

- Threads: standard NF ISO 262.
- Dimensional tolerances: standard NF ISO 4759-1.
- NF EN 12330: Electrodeposited coatings of cadmium.
F 8000

HEAT TREATMENT
(PARTS AND COMPONENTS)

F 8100 HEAT TREATMENT PROCEDURES

F 8110 GENERAL
a) Heat treatments performed during the manufacture of parts or products or as part of fabrication operations subsequent to acceptance of materials shall meet the requirements of this chapter.

b) Vocabulary and parameters relating to heat treatment are defined in AFNOR standard NF EN 10052. The expression "heat treatment for mechanical properties" is defined as being the heat treatment(s) which enable materials to meet the requirements of the procurement specifications contained in SECTION II "MATERIALS".

F 8120 HEAT TREATMENT PARAMETERS
a) A heat treatment is defined according to:
   - process (tempering, quenching, annealing, thermochemical surface treatment, other processes),
   - thermal cycle as represented by time-temperature-transformation curves (heating rate, holding temperature and time, cooling rate),
   - method of cooling.

b) These parameters are determined on the basis of:
   - grades of materials concerned,
   - desired mechanical or physical and chemical effect (stress relieving heat treatment, heat treatment for mechanical properties, etc.),
   - shape and size of the part to be treated (particularly in relation to heating and cooling rates),
   - preceding heat treatments and forming operations.
**F 8130 PERFORMING REQUIREMENTS**

a) Requirements for personnel

Personnel performing the heat treatment shall be clearly informed of the heat treatment conditions by means of a written procedure.

b) Requirements for heat treatment equipment

1) Any method of heating may be used, on condition that temperature and atmosphere requirements, if any can be met.

2) The design of the furnace (or other equipment) shall be suitable for the required treatment (dimensions, useful volume, capacity, heating rate, control system, etc.).

3) The control system shall be such that the specified maximum temperature difference can be maintained between any two points in the useful volume.

4) Temperature measurement and recording channels shall be in good working order and shall undergo quarterly inspections. Thermocouples shall be calibrated at least once a year and replaced, if necessary.

5) Where the type of atmosphere is specified, it shall be possible to check for correct composition throughout the duration of the treatment.

6) Inspection of heating and control systems shall occur at not more than 6-monthly intervals.

**F 8140 HEAT TREATMENT TEMPERATURE MEASUREMENT AND RECORDING**

a) Temperature shall be measured by means of thermocouples placed on the load itself, on the component or part thereof, or fixed to blocks in close contact with the part. Thermocouples shall be shielded from radiation from the furnace and the atmosphere by a protective shield, and shall be sufficient in number:

- to ensure that the load, the entire component or the section being treated is within the required temperature range. In the case of heat treatment of a component or section thereof, at least one thermocouple shall be placed on one of the thickest parts of the component and at least one other on one of the thinnest parts. In the case of a load comprising several parts, at least one thermocouple shall be placed on one of the parts at the centre of the load,

- to verify the absence of harmful temperature gradients.

However, the Manufacturer or Supplier need not comply with the above requirements if the furnace is provided with special measuring devices not in contact with the load, component or part. In such a case, the Manufacturer or Supplier shall provide justification by demonstrating that the latter method is equivalent to the thermocouple method of measuring the temperature.
Such justification shall be kept available for the Surveillance Agent. Temperature measuring devices not in contact with the load, component, or part shall be tested under operating conditions at less than 6-monthly intervals and whenever the heat conditions change (e.g. after furnace overhaul). This requirement shall not apply to heat treatment of component parts as defined in paragraph S 7542 b 2.

b) The main parameters concerning heat treatment, time and temperature shall be continuously and automatically recorded. This applies also to the throughput rate in the particular instance of a continuous feed furnace. Continuous readings are not required for cooling outside the furnace, forming operations and heat treatments before and after welding. It shall be verified throughout the duration of the treatment that the requirements of a) above are met.

c) The design of the furnace and its loading characteristics shall be such that the maximum permissible deviation of the "obtained temperatures" at each point of the load, with respect to the holding temperature specified by the Manufacturer, shall be ± 15°C for the entire load, except where the procurement specification stipulates a different permissible deviation.

d) Each recording chart and channel shall be coded so as to permit identification of the relevant load, component, section of component or weld. A sketch showing location of the thermocouples shall be attached to the recording chart so that each channel can be related to the location.

e) All time, temperature and throughput recordings shall be retained and kept available. The heat treatment report shall refer to these recordings and shall give the characteristics of the thermal cycles obtained to enable comparison with the cycle stipulated in the manufacturing programme.

F 8200 PROCEDURES FOR HEAT TREATMENT AFTER FORMING

a) In all cases, the requirements of F 8100 shall be met.

b) For stress relieving heat treatments, the recommended temperatures are given in paragraph S 1340; the relevant thickness is the maximum finished thickness of those areas of the part which undergo deformation.

c) In the case of heat treatments for mechanical properties, reference shall be made to the procurement specification for the part or product concerned (SECTION II: MATERIALS); these specifications indicate the required thermal cycles, cooling methods and other special precautions relating to heat treatment.
F 8300 POSTWELD HEAT TREATMENTS

The requirements of paragraphs S 1340 and S 7540 shall apply, in addition to the general requirements of F 8100.

F 8400 VARIOUS HEAT TREATMENTS DURING FABRICATION

F 8410 DIMENSIONAL STABILIZING TREATMENTS PERFORMED ON UNSTABILIZED AUSTENITIC STAINLESS STEEL COMPONENTS

F 8411 GENERAL

Where subsequent machining operations require that the dimensional stability of a part is ensured, dimensional stabilizing treatments may be performed on unstabilized austenitic stainless steel components.

F 8412 PROCEDURE

1) Prior to heat treatment, parts shall be thoroughly degreased and all products liable to reduce the corrosion resistance of the component (halogenated products, carbides) shall be carefully removed.

2) The atmosphere inside the furnace shall be slightly oxidizing.

3) The initial furnace temperature shall in no case exceed 120°C and shall be determined as a function of the complexity of the component so as to avoid the risk of deformation.

4) The holding temperature shall in no case exceed 425°C.

5) Heating and cooling rates shall be determined as a function of the complexity of the component.

   During heating and cooling, the temperature difference between two points not more than 4.5 m apart shall in no case exceed 55°C.

F 8413 VERIFICATION AND MEASUREMENT

The temperature curve for the treatment shall be recorded.

Temperatures shall be measured by means of thermocouples placed on the part.

At least two thermocouples shall be used: one to be placed on one of the thinnest zones and the other on one of the thickest zones.
F 8420  BRIGHT ANNEALING OF AUSTENITIC STAINLESS STEELS

Bright annealing may be performed on moderately thick austenitic stainless steel parts, for maximum softening on condition that:

- the atmosphere inside the furnace is neutral or slightly reducing (inert gas, vacuum or hydrogen),

- parts are thoroughly cleaned prior to treatment and there are no surface traces of products liable to reduce the corrosion resistance of the product (halogenated of carburized products),

- cooling is performed as rapidly as possible in a neutral (or slightly oxidizing) atmosphere to 120°C,

- after treatment, parts have a bright appearance with no trace of oxides.