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एल्यूमीनियम मिश्र धातुओं के ताप उपचार के लिए अभ्यास संहिता

(*आईएस 8860 का पहला पुनरीक्षण*)

Draft Indian Standard

CODE OF PRACTICE FOR HEAT TREATMENT OF ALUMINIUM ALLOYS

(*First Revision of IS 8860*)

ICS 77.080.20

Metallography and Heat-Treatment Sectional Committee, MTD 22	Last date for receipt of comments is XX/XX/2023

FOREWORD

(*Formal clause will be added later*)

In heat-treatable aluminium alloys, the alloying elements, singly or in various combinations, show increasing solid solubility in aluminium with increasing temperature making it possible to subject them to thermal treatments, which impart pronounced strengthening.

This standard is intended to assist manufacturers and fabricators of heat-treatable aluminium alloys in adopting suitable heat treatment techniques for attaining the optimum properties within the limitations of the respective alloys.

This standard was originally published in 1978. This revision has been brought out to bring the standard in accordance with the latest practices followed in the country for heat treatment of aluminium and aluminium alloys. In addition to this, references clause and clause on synthetic quenchants have been added.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2: 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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July 2023

Draft *Indian Standard*

CODE OF PRACTICE FOR HEAT TREATMENT OF ALUMINIUM ALLOYS

(*First Revision*)

1 SCOPE

This standard describes the heat-treating procedures, temperature schedules, equipment requirements and other details relating to the heat-treatment of aluminium alloys.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
IS 617 : 1994	Cast aluminium and its alloys ingots and castings for general engineering purposes — Specification (*third revision*)
IS 733 : 1983	Specification for wrought aluminium and aluminium alloy bars, rods and sections (for general engineering purposes) (*third revision*)
IS 734 : 1975	Specification for wrought aluminium and aluminium alloy forging stock and forgings (for general engineering purposes) (*second revision*)
IS 736 : 1986	Specification for wrought aluminium and aluminium alloy plate for general engineering purposes (*third revision*)
IS 737 : 2008	Wrought aluminium and aluminium alloy sheet and strip for general engineering purposes — Specification (*fourth revision*)
IS 1285 : 2023	Wrought aluminium and aluminium alloys — Extruded round tube and hollow sections for general engineering purposes — Specification (*fourth revision*)
IS 5047 (Part 1) : 1986	Glossary of terms relating to aluminium and aluminium alloys Part 1 Unwrought and wrought metals (*second revision*)
IS 6051 : 1970	Code for designation of aluminium and its alloys
IS 7428 : 1974	Specification for aluminium alloy extruded bars, rods and sections for aircraft purposes (Alloy No. 24345)
IS 7670 : 2002	Aluminium alloy forging stock and forgings (for parts operated at elevated temperatures) for aerospace applications (Alloy 22588) — Specification (*first revision*)
IS 7902 : 2001	Aluminium alloy forging stock and forgings (Alloy 24345) for aerospace applications — Specification (*first revision*)
IS 8561 : 1977	Specification for aluminium alloy clad sheet and strip for aircraft purposes (Alloy 76528)

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 5047 (Part 1) shall apply.

4 TYPES OF HEAT TREATMENT

4.1 The general types of production heat treatments applied to aluminium and its alloys are as follows:

a) *Annealing* — is carried out to soften work-hardened and heat-treated alloy structures and to relieve internal stresses. Aluminium alloy castings are also subjected to a 'stabilizing' anneal for stabilizing its properties and dimensions.

b) *Solution Heat-Treatment* — is carried out to effect solid solution of the alloying constituents and to improve the mechanical properties of the alloys.

c) *Precipitation Treatment* — is carried out to provide hardening by precipitation of constituents from solid solution.

5 EQUIPMENT FOR HEAT TREATMENT

5.1 Heating Media

Air, fluidized beds, burnt gases or protective atmosphere, and molten salt baths are suitable for heat-treating of, aluminium alloys, provided the material is not damaged thereby.

5.1.1 *Alternate Means for Precipitation Heat Treatment*

Superheated steam, not in contact with the material, or oil baths may also be used for precipitation treatment. Other means of ageing may be used, provided the material is not damaged thereby.

5.1.2 The furnaces and baths shall be of suitable type, design and construction for the intended purpose.

5.1.3 *Air-Chamber Furnaces*

Air-chamber furnaces in which the products of combustion come in contact with the material may be used for the heat treatment of those products which have been demonstrated by test to be substantially free from high-temperature oxidation after heat treatment in the furnace in question. Furnace components whose temperature differs from the material shall be suitably shielded in order that radiation to or from the charge will have no adverse effects. The shielding is not required in furnaces used for heat-treating heavy-sectioned material (over 6 mm thick), provided it has been demonstrated that the design of the furnace is such as to prevent localized overheating. Furnaces suitably designed and used only for precipitation treating need not have shielded components (*see* **A-l.2**).

5.1.4 *Salt Baths*

The salt used in salt baths shall be of a type and grade which will not react with the alloys being treated. Nitrate baths should not be used in the heat treatment of aluminium-magnesium alloys (*see* **A-l.1**).

5.1.5 *Lead Baths* (*Annealing Treatment Only*)

Molten lead or lead alloy baths may be used for annealing treatment of work-hardened wrought alloys. Lead baths shall be of such grade and purity as shall not react with the aluminium alloys being annealed.

5.1.6 *Temperature Uniformity*

The design and construction of batch furnaces and baths shall be such that, during the heating-up and soaking period, the air and metal temperature at any point in the working or soaking zone shall not exceed the maximum of the soaking temperature range indicated in Table 1 for the specific alloy being heat-treated or tested. After the metal reaches the minimum of the temperature range indicated in Table 1, furnaces or baths with their temperature-controlling equipment shall be such that the temperature of the heating media and metal at all points in the soaking zone are maintained within that range, and the maximum temperature variation of all points in the soaking zone shall be within ±5°C of the furnaces control set temperature. For continuous furnaces, the soaking zone is that part of the working zone in which the metal temperature is within the required soaking range. The design and construction of continuous furnaces shall be such that during the heating-up and soaking period, the metal temperature at any point in the working or soaking zone shall not exceed the maximum soaking temperature range in Table 1 for the specific alloy being heat-treated.

Table 1 Solution Heat Treatment and Precipitation Treatment Condition

(*Clauses* 5.1.6, 7.1 and 8.1)

ALLOY	PRODUCTS	HEAT-TREATMENT CONDITIONS			REMARKS
		Solution Heat-Treatment Temp (°C)	Precipitation Treatment		
			Temp (°C)	Time (h)	
(1)	(2)	(3)	(4)	(5)	(6)
24345	Forging stock and forgings extruded bars, rods, sections, sheets	495-505	160 175 190	12-20 9-12 3-6	Refer to IS 7428 IS 7902
22588	Forgings for high temperature use	520-530	200 ± 5	20	Refer to IS 7670
22500	Cold forged rivet stock	490-500	Room temp	96 *Min*	
24530	Cold forged rivet stock	490-500	Room temp	48 *Min*	
24435	Cold forged rivet stock	500-510	Room temp	48 *Min*	
24534	Wire, rod, bar, sheets	495-510	Room temp	96 *Min*	Refer to IS 733 IS 734
65400	Die forgings	510-525	Room temp 165-177	96 *Min* 10 *Min*	
65032	Sheet, plate wire, rod, bar extrusion, drawn tubes, forgings	515-552	Room temp 160 ± 5 177 ± 5	96 *Min* 6-20 6-10	Refer to IS 736 IS 737 IS 1285

64423	Die forgings	515-543	Room temp 171-182	96 *Min* 8 *Min*	Refer to IS 734
63400	Extruded rod, bar shapes and tubes	500-540	160-175	8-20	Refer to IS 733 IS 1285
64430	Plate, sheet, extrusions, and forgings	515-550	165-185	8-12	Refer to IS 736 IS 737 IS 1285
62400	Drawn tube	500-540	160-175	8-20	
74530	Sheet and plate	400-470	Room temp	72 *Min*	Refer to IS 736
	Extrusions (rod, bar, shapes and tubes)	430-470	85-95	8 *Min*	IS 737 IS 733 IS 1285
	Forgings	450-470	145-155	16 *Min*	IS 734
76528	Clad sheets	450-470	130-140	12 *Min*	IS 8561
2550	Castings	500-515	193-204 165-177	10-12 7-9	Sand castings Die castings
2285	Castings	510-527	160-177 205-232	22-26 1-3	Sand castings Die castings
2280	Castings	505-521	149-160	12-20 1-8	Sand castings Die castings
5500	Castings	427-438	Room temp	96 *Min*	
4223	Castings	493-510	149-166	1-6	
4225	Castings	515-532	221-232 149-160	7-9 1-6	Sand castings Die castings

(*Continued*)

Table 1 Solution Heat Treatment and Precipitation Treatment Condition — *Contd*

ALLOY	PRODUCTS	HEAT-TREATMENT CONDITIONS			REMARKS
		Solution Heat-Treatment Temp (°C)	Precipitation Treatment		
			Temp (°C)	Time (h)	
(1)	(2)	(3)	(4)	(5)	(6)
4450	Castings	527-543	149-160	1-6	
4685	Castings	505-521	149-177	14-16	

NOTE — Digital alloy designations, given in this table, are in accordance with IS 6051. For detailed chemical composition of the casting alloys reference may be made to IS 617.

5.2 Pyrometric Equipment

A sufficient number of suitable temperature control devices, properly arranged, should be provided on all heat-treating equipment to assure adequate control of temperature in all working and soaking zones. The devices shall be so located as to avoid exposure to excessive dust, vibration, and temperature outside the range of 0 to 60°C.

5.2.1 *Temperature Measuring and Recording Equipment*

Automatic controlling and recording instruments should be used. Instruments should be of the potentiometer type. Temperature-sensing elements should be located in, or as close as possible to, the working zone. The exact location of the temperature-sensing elements shall be dependent upon the furnace design. However, they shall be in such a location as to give accurate measurement of the working or soaking, or both, zone temperature.

5.2.2 *Accuracy*

Temperature readings should be adjusted to within ±1°C of true temperature by applying corrections established by calibrating equipment. If corrections greater than ±3°C are indicated, the source of error should be determined and adjustments to the measuring equipment shall be made so that the readings represent a true temperature within ±3°C, or less.

5.3 Quenching Equipment

Suitable equipment for water, glycol water solution, liquefied gas, or oil quenching shall be provided.

5.3.1 *Synthetic Quenchant*

Although hard quenching with water/aqueous brine solutions is required for achieving desire mechanical properties, it may lead to quench distortions in Al alloys used in the aerospace industry. In such cases, synthetic quenchants (also called polymer quenchant) based on the aqueous solution of poly-alkaline glycol copolymer and corrosion inhibitor additives could be used.

5.3.2 *Quenching Baths*

Means shall be provided for circulation of the quenching media and for heating or cooling, as necessary. Tanks shall be of adequate size for the workload involved in order to ensure that satisfactory quenching rates are attainable.

5.3.2.1 All water-baths employed in quenching parts which have been heated in salt-bath furnaces shall be provided with a drain and an inflow of fresh water to prevent a concentration of dissolved salts in the tanks.

5.3.3 *Location of Quenching Equipment*

Quenching equipment should be located in such manner, and handling-facilities should be so arranged and equipped, as to permit rapid transfer of the load from the heating medium to the quenching medium.

5.4 Rinsing Equipment

Rinse tanks or sprays, or any other suitable processing should be employed for removing salt residues or film from the surfaces of materials which have been immersed in molten salt baths or quenched in a glycol water solution. Separate rinse tanks or sprays may not be necessary if it may be demonstrated that the quench bath, under maximum load conditions, is capable of removing salt residues without becoming so contaminated that its efficiency is impaired.

6 RECOMMENDED PROCEDURE AND OPERATIONS

6.1 Heat-Treating Operations

Heat-treating operations shall be performed on the whole of a part or piece of material never on a portion only and shall be applied in a manner that will produce the utmost uniformity.

6.2 Charging of Furnaces and Baths

Material being heat-treated shall be supported in such manner as to permit free access of the heating or quenching media in order to facilitate heating and cooling the material to a uniform temperature in a minimum time interval. Furnaces shall not be charged prior to elapse of the initially unstable temperature condition following an upward or downward furnace setting. The time required for attaining stability following such a change depends upon furnace construction and condition as well as degree of change of furnace setting encountered during heat treating operations.

6.3 Heat Treatment of Alclad Sheet

When heat-treating alclad sheet, the size and spacing of the load should be such as to permit the entire load to come quickly to the specified temperature range.

6.3.1 The grouping of alclad alloys of widely different thicknesses into the same charge should be avoided, whenever practicable to prevent the holding of thin sections at temperature for an excessive period of time.

6.4 Cleaning of Material

Surfaces of material should be substantially free from lubricants and other foreign matter which could harm material being heat-treated.

7 SOLUTION HEAT-TREATMENT

7.1 Temperature

Aluminium alloy products, including alclad material shall be solution heat-treated within the temperature range, as given in Table 1, unless otherwise specified in the relevant material specification (*see* **A-2.2**).

7.2 Soaking Time

After reaching the solution temperature range, the charge should be held within that temperature range for sufficient time for the necessary solution to take place and to insure that the specified properties will be developed. Recommended soaking times for batch furnaces are given in Tables 3 and 4 (*see* **A-2.1**).

7.2.1 When a charge includes sections of various thicknesses whether in an assembly, in separate pieces, or as overlapping members, the soaking time should be determined by the thickness of the maximum section.

7.3 Reheat-Treatment

The heat treatment of a material which has previously been heat-treated shall be considered a reheat-treatment. Accordingly, the first heat treatment of a material purchased in the heat-treated condition shall be considered a reheat-treatment.

7.3.1 *Limitations Applicable to Alclad Alloys*

Alclad products shall not be solution heat-treated more than the number of times specified in Table 2.

Table 2 Reheat-Treatment of Alclad Alloys

(*Clauses* 7.3.1 and 10.4.2)

THICKNESS mm	MAXIMUM NUMBER OF REHEAT-TREATMENTS PERMISSIBLE
Under 0.5	0
0.5 up to and including 3	1
Over 3	2

Table 3 Soaking Time for Solution Heat-Treatment of Wrought Products

(*Clauses* 7.2 and A-2.1)

TYPE OF ARTICLE	THICKNESS OF MATERIAL	SOAKING PERIOD	
		In Air-Furnaces	In Salt-Baths
	mm	mm	mm
Annealed clad sheets	Up to 1.4	10-12	5
	Over 1.4 up to 2.0	15-20	7
	Over 2.0 up to 4.0	20-25	10
	Over 4.0 up to 10	35-40	20
Annealed non-clad sheets	Up to 1.2	10-20	5
	Over 1.2 up to 3	15-30	10

Annealed cold formed parts, hot-rolled plates, hot-pressed sections, rods, strips and bushes	Over 3 up to 5	20-45	15
	Over 5 up to 10	30-60	20
	Over 10 up to 20	35-75	25
	Over 20 up to 30	45-90	30
	Over 30 up to 50	60-120	40
	Over 50 up to 75	100-150	50
	Over 75 up to 100	120-180	70
	Over 100 up to 150	150-210	80
Stampings and forgings	Up to 2.5	15-30	10
	Over 2.5 up to 5.0	20-45	15
	Over 5.0 up to 15	30-50	25
	Over 15 up to 30	40-60	40
	Over 30 up to 50	60-150	50
	Over 50 up to 75	150-210	60
	Over 75 up to 100	180-240	90-180
	Over 100 up to 150	210-360	120-140

Table 4 Soaking Time for Solution Treatment of Cast Alloys

(*Clauses* 7.2 and A-2.1)

ALLOY	TIME, HOURS
Sand Cast Alloys	
2350	6 to 18
2285	2 to 10
2280	6 to 18
5500	12 to 24
4223	6 to 18
4225	6 to 18
4450	6 to 18
Permanent Mould Cast Alloys	
2250	6 to 18
4685	6 to 18
2285	2 to 10
4225	4 to 12
4450	6 to 18

7.4 Quenching

7.4.1 *Wrought Alloys*

Wrought alloy products (except forgings) should be quenched by total immersion in water of sufficient volume or circulation, or both, so that the water temperature at the completion of the quenching operation and removal of the load will be not more than 40°C. Maximum quench delay for immersion quenching is shown in Table 5. When a glycol water solution is used for quenching, the bath temperature may be allowed to reach 55°C if it may be shown that adequate quenching is obtained from the particular concentration utilized so that acceptable properties and corrosion resistance is achieved.

Table 5 Maximum Quench Delay, Wrought Alloys

(For Immersion Quenching)

NOMINAL THICKNESS mm	MAXIMUM TIME seconds
Up to and including 0.4	5
Over 0.4 up to and including 0.8	7
Over 0.8 up to and including 2.4	10
Over 2.4	15

7.4.1.1 Quench delay time should begin when the furnace door begins to open or when the first corner of a load emerges from a salt bath, and end when the last corner of the load is immersed in the water, glycol water solution; liquefied gas, or oil quench tank. The maximum quench delay times may be exceeded (for example, with extremely large loads or long lengths) if performance tests prove that all parts will be above 415°C when quenched.

7.4.1.2 Total immersion in a glycol water solution, liquefied gas or the use of high-velocity, high-volume jets of water in which the material is thoroughly and effectively flushed in a specially constructed chamber is satisfactory, for quenching wrought alloys, provided samples from the material so quenched conform to the mechanical property requirements of the applicable material specification.

7.4.2 *Castings and Forgings*

Castings should be quenched by total immersion in water at 65 to 100°C. Forgings should be quenched by total immersion in water at 60 to 70°C.

7.4.2.1 Where considerations warrant, the castings or forgings may be quenched in cold water or other suitable quenching media.

7.4.3 Rivets, fasteners, fastener components, washers, spacers, and other small parts should be quenched by dumping into cold water.

7.5 Control Stretching

To relieve the residual stresses induced during solution heat-treatment, extrusions, rolled products and complex forgings should be subjected to a controlled stretching operation to the extent of 1.5-2.5 percent.

7.6 Retardation of Age-Hardening

Any necessary cold-working fabrication operation on the solution-treated alloys-should be performed while it is still in soft condition, and should be completed within two hours or so, before age-hardening reaches any significant proportion. If this is not possible, solution-treated material should be stored at sub-zero temperature in the range of 6 to -10°C, so that they are still in the soft condition during subsequent fabrication.

8 PRECIPITATION HEAT TREATMENTS

8.1 Recommended Precipitation Treatment

The recommended time-temperature cycles shown in Table 1 are typical for various forms, sizes and methods of manufacture, and may not exactly describe the optimum treatment for specific product. However, in general, for products of large cross-sectional area or mass (such as plate), the longer time — lower temperature precipitation treatments are to be preferred to ensure maximum uniformity of properties.

8.1.1 The time at temperature depends on time required for load to reach temperature. The times shown are based on rapid heating with soaking time measured from time the load reaches the minimum temperature shown.

9 ANNEALING

9.1 Annealing of Work-Hardened Wrought Alloys

In alloys, annealing should be accomplished by heating to 325°C or above, holding at temperature until uniform temperature has been established throughout the furnace load, and cooling in air or in the furnace. The maximum permissible annealing temperature is not critical, but should not exceed 415°C to avoid excessive oxidation and grain growth. In all cases, a relatively rapid heating rate and the minimum soaking period required to attain temperature uniformity should be used.

9.2 Annealing of Heat-Treated Wrought Alloys

Annealing of heat-treated alloys may be accomplished by heating to 415°C and holding at temperature for not less than 1 hour. Material should be cooled at a rate not greater than 30°C per hour until the temperature is below 260°C. The rate of cooling from 260°C is not important.

9.3 Annealing (Stress-Relieving) of Cast Alloys

Castings should be annealed by heating within the temperature range 345 to 400°C holding for approximately 2 hours, and cooling to room temperature. The purposes of such annealing are the relief of stresses and the attainment of dimensional stability.

9.4 Annealing of Alclad Articles

When annealing clad articles, soaking period should be reduced to bare minimum so that diffusion of copper into the clad layer is limited.

10 TESTS ON HEAT-TREATED MATERIAL

10.1 Mechanical Properties

The test samples, selected from heat-treated/reheat-treated materials, shall exhibit tensile strength, proof stress and elongation properties not less than those specified in applicable material specifications.

10.2 Eutectic Melting and High-Temperature Oxidation

There shall be no eutectic melting and no evidence of excessive high-temperature oxidation, when tested in accordance with the method given in **10.2.1**.

10.2.1 *Eutectic Melting and High-Temperature Oxidation*

High temperature oxidation and eutectic melting specimens from the heat-treated samples shall be sectioned, the sections polished to appropriate fineness, and the unetched surface examined at 500 diameters magnification with a metallurgical microscope to detect evidence of high temperature - oxidation. The sections may then be mildly etched (approximately 2 seconds) in an etchant, such as Keller's Etch, to reveal evidence of eutectic melting.

10.3 Intergranular Corrosion and Alclad Diffusion

There shall be no evidence of excessive intergranular corrosion or alclad diffusion. Consideration shall be given to size and thickness of the material in deciding whether the intergranular corrosion is excessive. Alclad sheet in all alloys and thicknesses less than 0.5 mm generally contain areas of diffusion to the surface of the cladding, even though heat-treated in accordance with the relevant requirements of this standard. Degree of susceptibility to intergranular corrosion and degree of alclad diffusion when determined with method given in Appendix B should be not greater than that mutually agreed between the supplier and the purchaser.

10.4 Improper Heat Treatment

The failure of the test specimen is evidence that heat treatment or materials, or both, are unsatisfactory.

10.4.1 *Status of Equipment and Process*

In case the tests indicate improper heat treatment, the equipment, and process should not be used for heat treatment of aluminium alloys until it is demonstrated to the satisfaction of the purchaser that all requirements of this standard have been met.

10.4.2 *Status of Material*

Materials heat-treated in the furnace since the time of the previous satisfactory tests and found unsatisfactory shall be rejected or reheat-treated (beginning with the solution heat-treatment) in an acceptable furnace, depending on the character of the failed tests. Materials in which eutectic melting, high-temperature oxidation, or substantial diffusion of alloying elements from the core material through the cladding is found, shall be rejected and no reheat-treatment permitted. Materials which fail for reasons other than those enumerated above may be reheat-treated up to the limit of the permissible number of times specified in Table 2.

10.5 Test Report

If required by the purchaser, the supplier shall supply a test certificate, incorporating the results of all tests carried out on materials heat-treated in accordance with this standard.

APPENDIX A

(*Clauses* 5.1.3, 5.1.4, 7.1 and 7.2)

GENERAL INFORMATION RELATING TO HEAT-TREATMENT FURNACES AND SOLUTION HEAT-TREATMENT

A-1 FURNACES

A-1.1 Advantages of Salt-Bath Furnaces

The time required to bring the load to temperature is shorter in molten salt baths than in air-chamber furnaces; also, uniform temperature is more easily maintained.

There is no danger of high-temperature oxidation when heat treating in molten salt. After prolonged use, there is some decomposition of the sodium nitrate to form compounds which, when dissolved in the quenching water, attack the aluminium alloys. The addition to the salt bath of about 3 g of sodium or potassium dichromate per 10 kg of nitrate tends to inhibit this attack.

A-1.2 Advantages of Air-Chamber Furnaces

Air-chamber furnaces are more flexible and more economical for handling large volumes of work. When heat-treating certain of the aluminium alloys, it is necessary to control the atmosphere in order to avoid high-temperature oxidation. High-temperature oxidation lowers the mechanical properties of aluminium alloys and commonly causes large numbers minute blisters over the surface of the alloy. In severe cases, the metal may even crack when it is quenched. Products of combustion contain water vapour and may contain gaseous compounds of sulphur, both of which tend to promote high-temperature oxidation. For this reason, furnaces which permit the products of combustion to come in contact with the load are not recommended for the heat treatment of alloys which are susceptible to high-temperature oxidation. Either anodic oxide films or the metal coating of the clad materials protect the underlying alloy from this effect. Certain fluoborates will protect against or minimize high-temperature oxidation.

A-2 SOLUTION HEAT-TREATMENT

A-2.1 Heating Time

The heating time required to bring about the required degree of solid solution increases with increasing thickness of the section. The minimum soaking period is determined by testing samples of the material to make certain that the required mechanical properties have been developed. The soaking periods specified in Tables 3 and 4 have been found to be sufficient in commercial practice.

A-2.1.1 When heating the wrought alloys in air-chamber furnaces, excessive soaking periods increase the danger of high-temperature oxidation. However, with proper atmosphere control, soaking periods several times those shown may be used safely.

A-2.1.2 The soaking period for clad products should be the minimum which is required to develop the required mechanical properties. Longer soaking causes the alloying constituents of the base metal to diffuse into the clad coating. When this occurs, corrosion resistance is adversely affected. Consequently, every effort should be made to avoid diffusion by using the minimum possible soaking periods for clad sheet.

A-2.2 Heat-Treating Temperature

If the specified maximum temperature is exceeded, there is danger of eutectic melting, with consequent lowering of the mechanical properties of the alloy. Excessive overheating will cause severe blistering of the metal. If the temperature is below the minimum specified, complete solution is not effected and the maximum mechanical properties are not developed.

APPENDIX B

(*Clause* 10.3)

TESTS FOR HEAT-TREATED MATERIAL

B-l INTERGRANULAR CORROSION TEST

B-1.1 Corrosion tests shall be conducted in accordance with the procedure outlined below. In the case of alclad alloys the alclad shall be removed from both sides of the samples by filing or by other suitable means. Prior to the corrosion test, each sample shall be immersed for 1 minute in an etching solution at 93°C to produce a uniform surface condition. The solution shall have the following composition:

a) Nitric acid, concentrated (70 percent) — 50 ml
b) Hydrofluoric acid (48 percent) — 5 ml
c) Distilled or deionized water — 945 ml

After this etching treatment, the sample shall be rinsed in distilled or deionized water, immersed for 1 minute in concentrated nitric acid (70 percent) at room temperature to remove any metallic copper that may have been plated out on the specimen, rinsed in distilled or deionized water, and allowed to dry. The sample shall be corroded by immersion in a minimum of 5 ml/cm^2 of surface area of a solution of the following composition, which shall be prepared immediately before use (the temperature during the immersion period shall be 30±5°C):

a) Sadism chloride — 57 g
b) Hydrogen peroxide (30 percent) — 10 ml

c) Dilute to 1 litre with distilled or deionized water.

The immersion period shall be 6 hours. All chemicals shall be reagent grade.

B-1.2 More than one sample of the same alloy may be corroded in a container, provided that at least 5 ml of solution are used for square centimetre of specimen surface and provided that the specimens are electrically insulated from each other.

B-2 MICROSCOPIC EXAMINATION

B-2.1 At the end of the immersion period, the sample shall be removed from the solution, washed, and dried. A representative specimen, through the most corroded area shall be cut from the sample and mounted for microscopic examination. Microscopic examination shall be made of the specimen both before and after etching, at 100 to 500 diameters magnification, with a metallurgical microscope. The etching shall be done by immersion for 6 to 20 seconds in a solution of the following composition:

a) Nitric acid, concentrated (70 percent) — 2.5 ml
b) Hydrochloric acid, concentrated — 1.5 ml
c) Hydrofluoric acid (48 percent) — 1.0 ml
d) Distilled or deionized water — 95.0 ml

All chemicals shall be reagent grade.

B-3 TEST FOR DIFFUSION IN ALCLAD ALLOYS

B-3.1 A microscopic examination of sections through specimens cut from parts or sheets representative of a lot or furnace charge shall be made to determine the extent of diffusion of the alloying constituents through the cladding, except for gauges under 0.5 mm for which this test shall not apply. Examination shall be made with a metallurgical microscope at 100 to 1000 diameters magnification, after etching as specified in **B-2.**