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Draft Indian Standard

Code of practice for treatment of water for marine boilers

(*First Revision* of IS 1813)

भारतीय मानक मसौदा

समुद्री बॉयलरों के लिए जल के उपचार के लिए अभ्यास संहिता

(*पहला पुनरीक्षण*)

(ICS No. 27.060)

Water Quality for Industrial Purposes Sectional Committee, CHD 13	**Last Date for Comments: 08.03.2024**

FOREWORD

In the case of land boilers it is practicable to treat the feed water in an external water softening plant but due to the limited space available on a ship, it is not possible to do so for marine boilers except on the largest of ships. Internal treatment has, therefore, to be used for marine boilers. The steam used for prime movers is condensed and recovered for use as a boiler feed; thus a comparatively small quantity of water is required as make-up. In many cases, evaporated, that is, distilled water is used as make-up so that the feed water is always of a uniformly good character, the only impurities being those derived from leakage of condensers and carryover from evaporators. These can be easily put right and the contamination avoided. However, many ships do not use evaporated or distilled water for make-up but use fresh water taken at ports, while some have to use, when in emergency, unevaporated sea water.

Also, mention has been made of the treatment necessary at the time of initial filling and for protection of standing boilers.

This Indian Standard was first published in 1961. In this first revision the following changes have been incorporated:

a) New category of chemicals such as oxygen scavengers, hydrazine hydrate and DEHA used in feed, boiler and condensate water have been incorporated;

b) Under clause 5 method of treatment, impurities in feed water, evaporators and boilers, oil contamination, gaseous impurities and feed system, and mechanical removal of oxygen have been incorporated;

c) Requirements for various parameters in boiler pressure range up to 130 bars have been incorporated; and

d) Effect of water on boiler quality has also been incorporated.

In preparing this code, assistance has been derived from BSI-BS 1170 Recommendations Treatment of Water for Marine Boilers, issued by the British Standards Institution.

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2: 2022 Rules for Rounding off Numerical Values (*second revision*).

1 SCOPE

1.1 This standard lays down the methods to be adopted for treatment of water for marine boilers.

2 REFERENCES

The Standards as given in Annex A 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 the standard are encouraged to investigate the possibility of applying the most recent editions of the standard as given in Annex-A.

3 OBJECTIVE OF TREATMENT

3.1 The type of treatment, and its various details, best suited to a particular case shall depend on the nature and extent of the impurities to be dealt with and on the use and efficiency of mechanical operations governing blow-down, de-aeration, oil filters, etc. but in all cases the aims are the same as with land boilers and may be summarized as following:

a) Complete removal of all scale-forming salts, metallic ions and oil from boiler water by precipitation in the form of non-adhering and smooth flowing sludge and maintenance of small but adequate reserve of precipitating agents;

b) Removal of dissolved gases such as dissolved oxygen is done by de-aerator and carbon dioxide by minimizing alkalinity in the boiler but yet good enough to maintain pH in boiler feed-water, boiler and steam condensate;

c) Prevention of priming and foaming under all operating conditions from Evaporators and as well as boiler; and

d) Reduction of corrosion to a minimum by maintaining sufficient alkalinity in the boiler water and reduction of dissolved oxygen to the minimum.

4 CHEMICALS USED IN TREATMENT OF FEED, BOILER AND CONDENSATE WATER

4.1 Sodium Phosphates (for Prevention of Scale)

4.1.1 Sodium phosphate is used for the precipitation of calcium salts. There are three phosphates that may be used for this purpose:

a) Tri-sodium phosphate, or
b) Disodium phosphate, or
c) Sodium meta-phosphate (sodium hexa-meta-phosphate).

4.1.2 In a boiler, sodium meta-phosphate and disodium phosphate are converted into tri-sodium phosphate which remains stable even under high boiler pressures and temperatures. The choice depends upon the alkalinity requirements of the feed water. All the three phosphates produce sodium carbonate in the boiler water when they react with the carbonate hardness of the feed water and ultimately converted to sodium hydroxide. Sodium meta-phosphate reduces a part of alkalinity and tri-sodium phosphate increase the alkalinity. When using a feed water with high alkaline hardness, sodium meta-phosphate that consume some amount of sodium carbonate is preferred and when feed water of low alkaline hardness is used, tri-sodium phosphate would be more suitable. Sometimes the sodium carbonate thus produced is insufficient and additional sodium carbonate has to be added to maintain the requisite alkalinity.

4.2 Oxygen Scavengers

It is expected and recommended that a de-aerator is used to remove the dissolved oxygen mechanically as efficiently as possible from the feed water and treated by an oxygen Scavenger to neutralize residual dissolved oxygen before the feed water reaches the boiler. Ideally, the dissolved oxygen content after de-aerator is uniformly maintained below 0.07 ppm (or 0.05 ml/l) for boilers with pressure up to 18 kg/cm^2 (or 250 psig)) and below 0.03 ppm (or 0.02 ml/l) in medium to high pressure boilers with pressure above 18 kg/cm^2 (or 250 psig) unless the dissolved oxygen content is uniformly maintained below 0.03 ppm (or 0.02 ml/l)sodium sulphite shall be added. It is a safe and good practice, especially with water tube boilers, to de-aerate the water and add sodium sulphite as a routine. A reserve of 20 to 30 ppm of sodium sulphite shall be maintained in the boiler water at all times.

4.3 Sodium sulphite (preferably with Catalyst)

4.3.1 It can be used to neutralize the residual oxygen coming after de-aerator. The requirement of oxygen Scavenger will be less if de-aerator is used and therefore TDS in boiler will accordingly be much lesser when sodium sulphite is used as oxygen scavenger. The reaction of sodium sulfite will be as below.

$$2SO_2^{2-} + O^2 \rightarrow 2SO_4^{2-}$$

4.3.2 The sodium sulfite is used up to 42 kg/cm^2 (600 psig) as at higher pressure it can product SO_2 and H_2S which can cause corrosion. This is considered safe to use when steam comes in contact with food items. However, sodium sulfite does not passivate to form magnetite film on boiler metal. About 8 ppm of sodium sulfite is required to neutralize each 1 ppm of dissolved oxygen.

4.4 Hydrazine hydrate (preferably catalyzed)

4.4.1 It is often used as it is a passivating agent as well as fact that it does not contribute to total dissolved solids (TDS) in the boiler. The reaction to neutralize dissolved oxygen is given below:

$$N_2H_2 + O_2 \rightarrow N_2 + H_2O$$

4.4.2 At above 250 °F, it converts iron from ferric into ferrous which helps form magnetite layer.

$$6Fe_2O_3 + N_2H_4 \rightarrow 4Fe_2O_4 + 2H_2O + N_2$$

4.4.3 Hydrazine starts decomposing to ammonia above 400 °F. The stoichiometric dosage is 1 ppm N_2H_4 per ppm O_2 but in practice 2 ppm to 3 ppm N_2H_4 is required per ppm O_2 depending upon conditions in the boiler.

4.4.4 The use of hydrazine should be discouraged as it is a SUSPECTED CARCINOGEN. Alternatively carbahydrazide can be used as carbahydrazide decomposes to hydrazine in the boiler. The hydrazine volatility in boiler is very low and it remains and decomposes in the boiler

4.4.5 Hydrazine should not be used where steam comes in contact with food items.

4.5 Di-ethyl hydroxylamine (DEHA) (preferably catalyzed)

4.5.1 DEHA is a volatile oxygen scavenger and neutralizes dissolved oxygen in the boiler, passivate the metallic surfaces and adds no TDS in the boiler.

$$4\,(CH_3CH_2)_2NOH + 9O_2 \rightarrow 8CH_3COOH + 2N_2 + 14H_20$$

4.5.2 In theory, 1.24 parts of DEHA react with 1 part of oxygen, but in application, a dosage of 3:1 DEHA to O_2 is recommended. As it is volatile it protects the steam condensate system also against if any part of dissolved oxygen (DO) remain present. It starts decomposes at 540 °F/300 psig in the boiler to ammonia and negligible amount of acetic acid. A residual of 0.4 ppm should be maintained in the boiler and 0.25 ppm in return condensate.

4.5.3 DEHA though having lower toxicity is not permitted where steam comes in contact with food items.

4.6 Erythrobrate

4.6.1 Erythorbic acid can be used to neutralize the dissolved oxygen up to 1 500 psig and is non-volatile. A dose of 11 ppm is required per ppm of dissolved oxygen stoichiometrically.

$$NaC_6H_6O_6 + \frac{1}{2}\, O_2 \rightarrow C_6H_5O_6 + NaOH + \text{Complex Organics}$$

4.6.2 Erythobrate is generally regarded as safe (GRAS) and can be used for food coming in contact with steam.

4.7 Return Line Condensate Treatment

4.7.1 The *p*H of steam condensate should be 8.5 to 9.0 to eliminate possibility of carbonic acid which can otherwise cause corrosion of condensate pipelines or system. Generally chemicals as specified in Table 1 are used depending upon their distribution coefficient. Lower the distribution coefficient will condense early while condensing from the steam.

Table 1 Amines used Depending upon Their Distribution Coefficients.
(*Clause* 4.7.1)

S No.	**Amines**	**Distribution Coefficient** (*see* Note)
(1)	(2)	(3)
i)	Morpholine	0.4 : 1.0
ii)	Cyclohexamine	2.6 : 1.0
iii)	Di-ethyl-amino-ethanol (DEAE)	1.1 :1.0
iv)	Ammonia	10.0 :1.0

NOTE — Distribution coefficient is ratio of ppm amine in vapor phase over vapor in liquid phase.

4.8 Antifoulant / Sludge Conditioners

In the internal process of water softening by addition of chemicals, the impurities are precipitated and the precipitate remains in a dispersed state in the boiler. It is of highest importance that the precipitate should be non-adherent in character. For this purpose, some organic substances, such as polymeric dispersants stable at operating pressure of boiler. Sometimes Sodium lignosulphonates tannin can be used for boilers below 18 kg/cm^2 (250 psig). All sludge conditioners are meant to convert the precipitate into a smooth, free flowing, non-adhering sludge which can be readily removed with blow-down water. The guidelines for use of active sludge conditioner depending on operating pressure are as specified in Table 2. The user should verify credentials of the supplier.

Table 2 Guidelines for Use of Active Sludge Conditioner Depending on Operating Pressure
(*Clause* 4.8)

S No.	**Operating Pressure (psig)**	**Active Sludge Conditioner in Boiler Water, ppm**
(1)	(2)	(3)
i)	Less than 24.13	20 - 25
ii)	24.13 to 44.82	10 - 15
iii)	44.82 to 65.50	5 - 10

iv)	65.50 to 86.18	2- 5
v)	86.18 to 106.87	2 - 3
vi)	106.87 to 124.11	1 - 2

4.9 Soda Ash (for maintaining alkalinity**)**
Soda ash is used when it is necessary to supplement the alkalinity / pH in the Boiler. Under boiler conditions, sodium carbonate gets partly converted into sodium hydroxide which precipitates non-carbonate hardness. The magnesium salts should precipitate as magnesium hydroxide is fluffy precipitate and is less adherent to the metallic surfaces. Instead of soda ash, caustic soda may also be used for maintaining the required alkalinity as sodium carbonate will produce CO_2 when converted to sodium hydroxide in the boiler. The user should divide above dose by cycles of Concentration to arrive at dosage in the feedwater.

4.10 De-Oiling Agents

Oil shall be removed by any of the usual mechanical methods used. The traces of oil remaining in the water are generally trapped by anionic dispersant such as Oil Dispersant during pretreatment itself.

4.11 Filming Amines

These amines are wax-like solids and protect the system by forming a barrier between the metal and the water. The amine is added continuously in water in order to maintain a suitable reserve in the condensate. It may be injected into the steam lines or into the feed system at a point where the feed water temperature is above 80 °C. Filming amines should under no circumstances be applied to water that is to be treated by ion exchange processes as the amines would permanently foul the resins. These should not be used above 1 500 psig boilers.

4.12 Sodium Sulphate or Sodium Nitrate (For Prevention of Caustic Embrittlement)

In the case of riveted drums and welded drums which have not been stress-relieved, sodium sulphate shall be added in sufficient amount to maintain the ratio of sodium sulphate/caustic alkalinity (as NaOH) above 2.5 at all times. If sodium nitrate is used, the ratio sodium nitrate/total alkalinity (as NaOH) shall be above 0.4. This is the best recommendation that can be made in the light of present knowledge on the subject which is still under investigation. But this treatment does not prevent the spread of any cracks existing prior to the use of the chemical.

5 METHODS OF TREATMENT

5.1 Impurities in Feed Water

5.1.1 The feed water that is used for boiler is main source of most of the impurities in the boiler water which give rise to scale formation or to corrosion. It is essential that any contamination of the feed water is traced to its source and stopped. The various contaminants in feed water result from the following causes:

a) Priming of evaporators and boilers, leakage of condensers and heat exchangers, and ingress of sea water into feed water tanks;
b) Oxygen dissolved in make-up water and from air leakage into condensers and other systems below atmospheric pressure;
c) Carbon dioxide which comes from residual alkalinity after pretreatment ,its decomposition from bicarbonates to carbonate and part of carbonates getting converted to Hydroxide in boiler and air leakage into condensers.
d) Oil from the lubrication of engines or fuel oil from faulty heating coils;
e) Scale-forming constituents arising from sea water contamination or from the use of un-softened shore water as make-up water;
f) Iron and copper oxides in condensate from deck steam lines and cargo heating coils; and
g) Impurities arising from the faulty operation of regeneration of demineralization plant, Evaporators and Boilers.

5.2 Evaporators and Boilers

5.2.1 The salinity of the output from the evaporator should be monitored to ensure that distillate of a desired quality is maintained. If the distillate is to be used as make-up water for water-tube boilers, the output should be monitored continuously by means of a suitable conductivity meter and frequent testing of silica.

5.2.2 Maintain the water in the evaporator at the correct concentration and avoid unsteady conditions while operating the boiler and evaporator system. If exhaust steam is used, additional attention is required as unsteady evaporating conditions may result in adding impurities due to priming.

5.2.3 Ensuring that the designed output of the evaporator is not exceeded.

5.2.4 Maintaining the correct water level in the shell of submerged-coil type evaporators.

5.2.5 Keeping the heat exchanger tube expansions tight.

5.2.6 Ensuring that the baffles fitted in the shell of submerged-coil type evaporators are correctly assembled and free to operate, i.e. that drainage is correct.

NOTE— Chemical treatment of the sea water fed to evaporators to minimize scale formation and carry-over is usual but is outside the scope of this standard.

5.3 Oil Contamination

All possible steps should be taken to prevent any traces of oil entering the feed water system.

5.4 Condenser Operation

This applies to vessels not fitted with full feed flow de-aerators, the condenser serves as the sole means of effecting mechanical de-aeration of the feed water. The condenser should be operated with as high a condensate temperature as possible, consistent with the required vacuum, in order to minimize the extent to which the gases present dissolve in the condensate. The vacuum system should be maintained free from air leaks at all times. The conductivity of the condensate should be checked frequently when steaming to ensure that cooling water leaks have not developed. A suitable conductivity meter should be fitted for this purpose. If hydrazine or a neutralizing amine is used for feed water and condensate treatment. A condensation polishing unit (CPU) should be used and the condensate sample should be passed through a hydrogen ion exchange column in order to remove the ammonia (or amine) present before measuring the conductivity. It should be noted that some condensers may show traces of ammonia (or amine) in the residual condensate when these are standing idle. The steam should first be passed through CPU so as to remove contaminated water. Any presence of contaminants after steaming the CPU may be an indication of condenser leakage.

5.5 Gaseous Impurities in Condensate and Feed Systems

5.5.1 The steam condensate may be corrosive due to the solution of certain gaseous impurities originally present in the steam. These gaseous impurities include the following:

a) Dissolved oxygen entrained in feed water;
b) Carbon dioxide dissolved in feed water and also formed by decomposition of bicarbonates to carbonates and part decomposition of carbonates to hydroxides in boilers;
c) Ammonia present in the condensate of all boilers using hydrazine as an oxygen scavenger owing to the thermal decomposition of hydrazine in the boiler water; and
NOTE — Traces of ammonia may be present in all feed waters.
d) Sulphur dioxide from the decomposition of sodium sulphite at pressure above 600 psig.

5.5.2 Uncontrolled ingress of these impurities into feed and condensate water may lead to severe corrosion. The iron oxide or iron pick up from the condensate will enter the boiler but it will not get carried over along with steam. So it will keep on accumulating in the boiler leading to rust formation boiler which can lead to caustic gouging in the boiler tubes. This can be controlled by the following means:

a) Removing as much gaseous impurity from the feed water as possible by physical means;
b) Chemical dosing of the feed water to maintain a slight alkalinity (*p*H value not less than 8.5) to avoid presence of carbonic acid and to remove any remaining dissolved oxygen by adding oxygen scavenger.

5.6 Mechanical Removal of Oxygen

5.6.1 The dissolved oxygen after de-aerator may be little higher than 0.007 ppm (Say 0.03 ppm). While all efforts should be made to get lowest possible value of dissolved oxygen (DO) after de-aerator, the residual Oxygen should be treated with oxygen Scavenger and a residual of little excess amount of oxygen scavenger is kept in the boiler water to treat any excess of DO coming out from de-aerator due to some reason.

5.6.2 The amount of dissolved oxygen may be minimized by attending to all possible sources of air leaks on the vacuum side, by avoiding splash of water in hot wells, drain and filter tanks, by closing sniffling cocks on feed pumps, and by maintaining the optimum operating conditions in the condenser.

5.7 Three types of treatment which are intended for various types of makeup feed are prescribed in **5.7.1** to **5.7.3**.

5.7.1 *Make-Up Consisting of Evaporated Water or Unevaporated Soft Water*

5.7.1.1 *Treatment by standard mixture*

5.7.1.1.1 When the boilers are fed with condensate with make-up of evaporated water, the character of feed water remains very nearly the same all the time. The only impurities found are those obtained from leakage of condensers or carry-over from the evaporators. These impurities are very small in amount and of uniform character. The proportion of chemicals to be added thus remains the same and only the quantity has to be varied as required to obtain the necessary results. The condition remains almost the same if instead of using evaporated water as make-up, fresh water of low hardness is used direct. Under these conditions, adequate treatment can be effected by the addition of a standard mixture of the following composition:

a) Soda ash, 39 percent

b) Anhydrous disodium phosphate, 48 percent

c) Starch, 13 percent

5.7.1.1.2 In addition to this, sodium sulphite and sodium sulphate shall be added for prevention of corrosion and caustic embrittlement respectively. The boiler water shall be tested from time to time for hardness and alkalinity and the mixture or the other chemicals added to maintain the recommended conditions as specified in Table 3. This mixture gives quite satisfactory results and chemical boiler mixtures of approximately this composition are available at ports. This treatment will not only prevent formation of scale but will remove all previously formed scale. Care should, therefore, be taken when using this method in boilers with previous scale in existence.

5.7.1.1.3 *Adjustment of dose*

Test the boiler water sample for hardness and alkalinity to phenolphthalein. If the phenolphthalein alkalinity is lower than the lower limit as specified in Table 3 and residual hardness is present, increase the amount of mixture next time at the rate of 10 percent and continue adding such amount till the desired result is obtained. If the alkalinity is too high and hardness is zero, no mixture shall be added at all till the alkalinity drops down to the desired figure.

5.7.1.1.4 *Limits of treatment*

Normally this treatment shall be followed and the condition of boiler water maintained within limits as specified in Table 1. However, when there is gross contamination due to heavy leakage of condensers of serious carry-over from evaporators, a very large quantity of the mixture would be required to maintain these limits. This will also produce an excessive amount of precipitate as well as dissolved solids both of which are undesirable and harmful. Under these circumstances, the treatment shall be stopped.

5.7.1.2 *Treatment by separate chemicals*

If it is desired to use separate chemicals instead of the standard mixture mentioned in **5.7.1.1.1**, the boiler water shall be tested for phosphate and alkalinity.

5.7.1.2.1 If phosphate is less than 30 ppm (as PO_4) in the boiler water, sodium meta-phosphate shall be added. If phosphate is more than 70 ppm in the boiler water, no phosphate shall be added till the concentration drops down to below 70 ppm. When phosphate is to be added, sodium meta-phosphate at the rate of 14 g/metric tonne (or 0.5 oz/ton) for every 10 ppm phosphate deficiency in the boiler water shall be added. In the absence of sodium meta-phosphate, equivalent amounts of other sodium phosphates shall be added.

5.7.1.2.2 If the phenolphthalein alkalinity is lower than what is desired, increase soda ash by 55 g/metric tonne (or 2 oz/ton) of boiler water for every 50 ppm of alkalinity deficiency. If phenolphthalein alkalinity is too high, stop adding soda ash till the condition falls down to the desired point.

5.7.1.2.3 Limits of treatment

5.7.1.2.3.1 Boiler water shall be maintained within limits as specified in Table 3.

Table 1 Water Chemistry Limits for Scotch, Vertical Water Tube and Water Tube Boilers (up to 18 kg/cm^2 or 250 psig)

(*Clause* 5.7.1.1.2, 5.7.1.1.3, 5.7.2.2, 6.2)

S No.	**Parameters**	**Scotch Boilers**	**Vertical Boilers**	**Water Tube Boilers**	**Package Boilers**	**Method of Test ref to**	
						Annex	IS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i.	Total Hardness (as $CaCO_3$), ppm, *Max*	Nil	Nil	Nil	Nil	-	3025 (Part 21)
ii.	Alkalinity to Phenolphthalein (as $CaCO_3$), ppm	300 - 700	300 - 500	150 - 300	150 - 300	-	3025 (Part 23)
iii.	Caustic Alkalinity (as $CaCO_3$), ppm	150 - 500	150 - 400	75 - 200	75 - 250	-	3025 (Part 23)
iv.	Chlorides (as NaCl)$^{2)}$, ppm, *Max*	3 000	1 200	350	350	-	3025 (Part 32)
v.	Conductivity @ 25 °C, mS/cm^2	10 000	4 500	2 250	3 000	-	3025 (Part 14)

vi.	Sodium Sulfite (as Na_2CO_3), ppm	50 - 100	50 - 100	50 - 100	50 - 100	B-1	-

NOTES

1 For sodium level to prevent caustic cracking, sodium sulphate (as $NaSO_4$) is 2.0 times of caustic alkalinity (as $CaCO_3$) or $NaNO_3$ as 50 percent of caustic alkalinity as $CaCO_3$.

2 To convert from sodium chloride in mg/l as NaCl to mg/l in terms of $CaCO_3$ multiply by 0.85, and to convert to mg/l as Cl multiply by 0.61.

3 If a filming amine is used for the treatment of condensate systems, a reserve of 1 mg/l as amine should be maintained in the condensate from the condensers.

5.7.1.2.3.2 *Feed water limits*

The feed water limits shall be as specified in Table 4.

Table 4 Feed water Requirements

(*Clause* 5.7.1.2.3.2)

S. No	**Characteristics**	**Requirements, ppm**	**Method of Test refer to IS**
(1)	(2)	(3)	(4)
i.	Chlorides (as NaCl), ppm, *Max*	10	3025 (Part 32)
ii.	Return Condensate (as NaCl), ppm, *Max*	10	3025 (Part 32)

5.7.1.2.3.2 The feed water, condensate, and boiler water shall be maintained within the limits as specified in Table 5.

Table 5 Water Chemistry Limits for Industrial Water Tube Drum type Boilers (Includes Super-heaters, Turbine Operation and Process Steam Restrictions

(*Clause* 5.7.1.2.3.3, 5.7.2.2)

S No.	**Characteristics**	**Requirements Boiler Drum Operating Pressure (Kg/cm^2)**					**Method of Test Ref to**
		18 - 30	**31 - 42**	**42 - 60**	**60 - 80**	**80 - 130**	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Feed Water at Economizer Inlet							
i.	pH at 25 °C	8.5 – 9.5	8.5 – 9.5	8.5 – 9.5	8.5 – 9.5	*see* Note 1	IS 3025 (Part 11)

ii.	Dissolved Oxygen (as O_2), ppm, Max	0.06	0.03	0.015	0.01	0.005	IS 3025 (Part 38)
iii.	Chloride (as NaCl), ppm, *Max*	5	1	1	1	-	IS 3025 (Part 32)
iv.	Iron (as Fe), ppm, *Max*	-	-	0.01	0.01	0.01	IS 3025 (Part 53)
v.	Copper (as Cu), ppm, *Max*	-	-	0.01	0.005	0.005	IS 3025 (Part 42)
vi.	Sodium (as Na), ppm, *Max*	-	-	-	-	0.005	IS 3025 (Part 45)
Condensate							
vii.	pH at 25 °C	8.5 – 9.5	*see* Note 2	*see* Note 2	*see* Note 2	9.0-9.5	IS 3025 (Part 11)
viii.	Dissolved Oxygen (as O_2), ppm, Max	-	-	-	-	-	IS 3025 (Part 38)
ix.	Chloride (as NaCl), ppm, *Max*	5.0	1.0	1.0	1.0	-	IS 3025 (Part 32)
x.	Iron (as Fe), ppm, *Max*	-	-	-	-	-	IS 3025 (Part 53)
xi.	Copper (as Cu), ppm, *Max*	-	-	-	-	-	IS 3025 (Part 42)
xii.	Sodium (as Na), ppm, *Max*	-	-	-	-	0.05	IS 3025 (Part 45)
Boiler Water Limits							
xiii.	Conductivity at 25 °C, µS/cm, *Max*	1500	750	600	450	*see* Note 4	IS 3025 (Part 14)
xiv.	Alkalinity to phenolphthalein (as $CaCO_3$), ppm	150 - 300	100 - 150	50 - 100	50 - 80	*see* Note 4	IS 3025 (Part 23)
xv.	Caustic (OH) Alkalinity, ppm	100 - 250	50 - 100	40 -60	40 - 60	*see* Note 4	IS 3025 (Part 23)
xvi.	Silica (as SiO_2), ppm, *Max*	-	-	-	3.0	As per Fig 1.	IS 3025 (Part 35)
xvii.	Phosphate (as PO_4), ppm, *Max*	30 - 70	30 - 50	30 - 50	20 - 30	*see* Note 4	IS 3025 (Part 31/Sec1)

xviii.	Chloride (as NaCl), ppm, Max	150	100	50	30	*see* Note 4	IS 3025 (Part 32)
xix.	Sulfite residual (as Na_2SO_3),	50 - 100	20 - 50	-	-	*see* Note 4	Annex B-1
xx.	Hydrazine as N2H4 mg/L	0.1- 0.5	0.1 - 1.0	0.1 - 1.0	0.1	*see* Note 3	Annex B-2

NOTES

1 Check with Specifications from Boiler manufacturer

2 For using hydrazine pH to be maintained at 8.5 to 9.0, for neutralizing amine pH to be maintained at 9.0 to 9.5, and for using both pH to be maintained at 9.0 to 9.5.

3 At pressure above 100 bar it may not be possible to maintain hydrazine reserves in the boiler. The daily additions of hydrazine should be calculated for oxygen content of the feed water after the de-aerator. Use twice the theoretical quantity of hydrazine required to react with the oxygen, bearing in mind that hydrazine is normally supplied as a 15 percent to 35 percent solution in water.

4 The boiler water characteristics for boiler pressure 80 bar to 120 bar are as specified in Table 6.

Table 6 Boiler water characteristics for boiler pressure 80 bar to 120 bar

(*Clause* note 4 of Table 5)

S No.	**Characteristics**	**Requirements for Boiler water characteristics for boiler pressure 80 bar to 120 bar**				**Method of test ref to IS**
		With Congruent / pH control		**No Solid Treatment**		
		80 - 100	**100 -130**	**80 - 100**	**100 - 130**	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i.	Alkalinity to Phenolphthalein	-	-	5 -10	2 -5	IS 3025 (Part 23)
ii.	Conductivity at 25 °C, µS/cm, *Max*	150	100	50	25	IS 3025 (Part 14)
iii.	Chloride (as NaCl), ppm, Max	10	05	10	05	IS 3025 (Part 32)
iv.	Sodium Phosphate (as PO_4), ppm	10 - 20	5 - 15	-	-	IS 3025 (Part 31/Sec1)
v.	pH	9.6 – 10.0	9.3 – 9.9	-	-	IS 3025 (Part 11)
vi.	Hydrazine (as N_2H_4), ppm,	0.05 – 0.1	*see* Note 3	0.05 – 0.1	*see* Note 3	Annex B-2

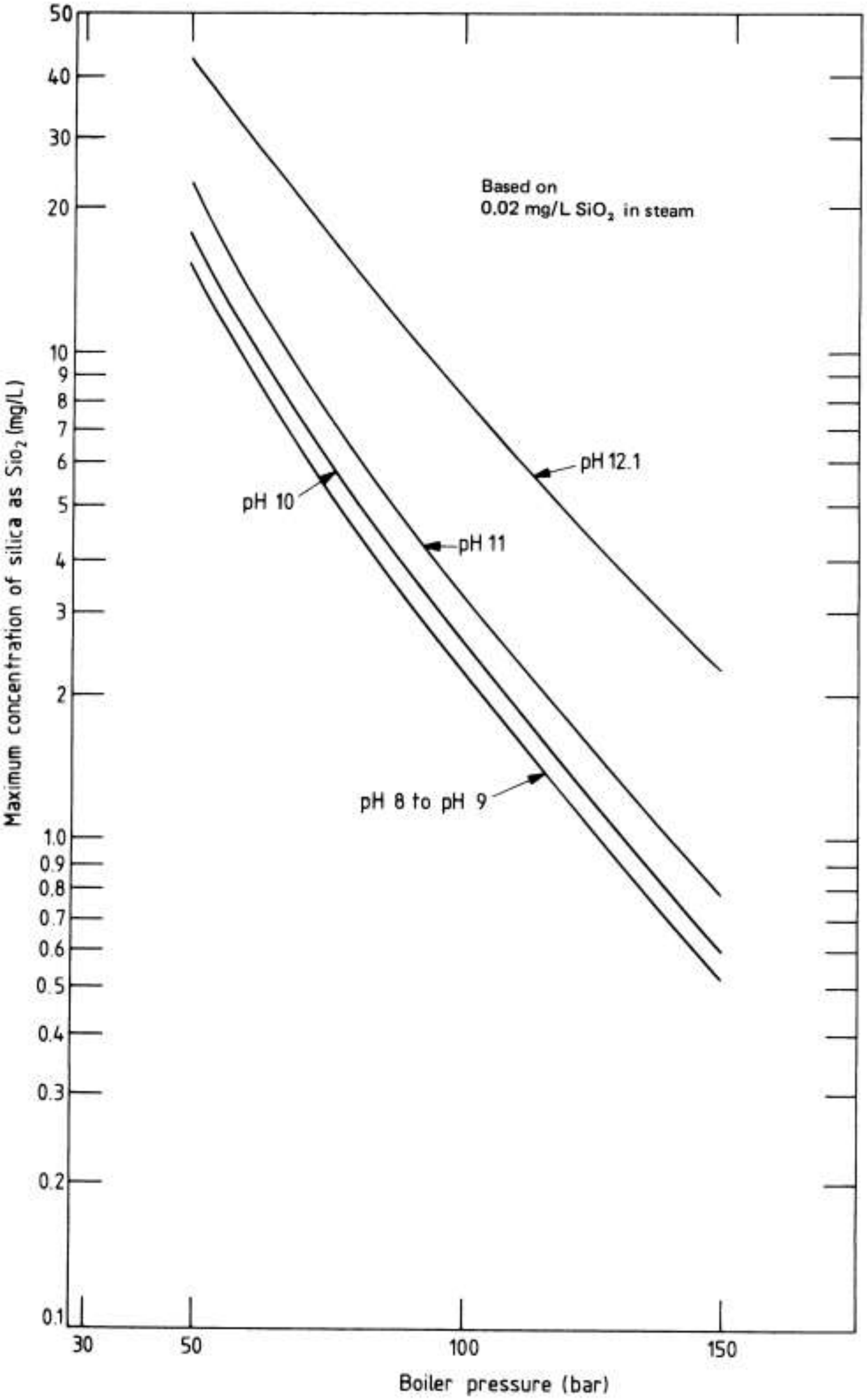

FIG 1 SILICA IN BOILER WATER WITH RESPECT TO BOILER PRESSURE AND pH

5.7.1.2.3.3 If the **phenolphthalein alkalinity** is lower than what is desired, increase soda ash by 55 g/MT (or 2 oz/MT) of boiler water for every 50 ppm of alkalinity deficiency. If phenolphthalein alkalinity is too high, stop adding soda ash till the condition falls down to the desired point.

5.7.2 Make-Up Consisting of Unevaporated Hard Water

5.7.2.1 The chemicals to be used are the same as those used in the treatment of water described in **5.7.1**, namely sodium phosphate, soda ash, some coagulant, sodium sulphite and sodium sulphate. As the character of water taken at different ports may be different, it would not be practicable to prepare stock mixtures for treatment of such water. But if the water taken from ports happens to be very similar, mixtures to suit them could be prepared by specialists who supply them. The usual course is to test the boiler water for phosphate and alkalinity and add sodium meta-phosphate and soda ash as explained in **5.7.1.2**. It is preferable to use sodium meta-phosphate as in case disodium or tri-sodium phosphate were used a large amount of alkali would be produced. In some cases, these latter phosphates also may be used satisfactorily.

5.7.2.2 Limits of treatment

Boiler water should be maintained within limits as specified in Table 3 and Table 5.

5.7.3 Make-Up Consisting of Unevaporated Sea Water or Water Heavily Contaminated with Sea Water

In this case, it is not practicable to precipitate all the hardness with phosphates as it would be too expensive and the concentration of dissolved solids and suspended solids in the boiler water would also be excessive and give rise to priming and foaming. The only treatment to be applied in this case would be to prevent corrosion and prevent priming and foaming. The water should be maintained alkaline to phenolphthalein. No definite limits of alkalinity can be recommended. The boiler water should show a pink colour when a few drops of phenolphthalein solution are added to it. The above treatment will afford a certain amount of protection .against corrosion while addition of suitable antifoams will minimize foaming and priming

6 EFFECT OF BOILER TYPE ON REQUIRED WATER QUALITY

6.1 General

The recommendations for feed water quality and boiler water conditions given under the various boiler groups are for boiler of traditional design. There are many boiler designs for which the water treatment requires special consideration.

6.2 Water Tube boilers

Distilled water is only water suitable for water-tube boilers. This water should be obtained by distilling either fresh or sea water. For water tube boilers from 17.5 bars to 60 bars, the distillate from evaporator should not contain more than 4 mg/l of dissolved solids. For boilers from 60 bars to 80 bars, the distillate from the evaporator should contain not more than 2 mg/l of dissolved solids. The dissolved oxygen to be in limit as specified in Table 3.

6.3 Scotch Boilers, Vertical Boilers and Steam/Steam Generators

6.3.1 The following waters are suitable for these types of boilers:

a) Evaporated water; and
b) Fresh water with the lowest calcium plus magnesium content available but in general not more than 300 mg/l of total hardness as calcium carbonate and treated thereafter

6.3.2 A condenser leak giving rise to about 30 mg/l of dissolved solids in the feed water can be treated for a limited time but should be rectified as soon as possible.

6.4 Scotch Boilers with Impure Feed

As with all boilers the purer the feed the better, it is good for boilers. but it is recognized that in certain ships, e.g. trawlers, a supply of good quality water cannot be provided. Waters for which only very limited treatment can be carried out are as following:

a) Shore water contaminated with sea water; and
b) Sea water.

6.5 Exhaust Gas boilers

As the name suggests Exhaust gas boilers are designed to produce low-pressure steam by utilizing the heat contained in the exhaust gases from main propulsion (or large generating set) diesel engines and gas turbines. The boilers mostly have forced circulation, but may also have natural circulation, usually in a parallel water circuit with a conventionally fired auxiliary boiler. The most of problems are associated with actual operating issues. These type of boilers are required to be in use when less as steam is generated as a reduction in steam demand should be achieved by bypassing gas and not by reducing the feed rate nor by isolation of sections on the water-side. These actions can result in drying out and formation of deposition of solids within the boiler.

6.6 Dual pressure boilers

6.6.1 Dual pressure boilers have, as the name suggests, two water circuits. The primary circuit produces high-pressure steam which in turn passes through a secondary steam generator producing low-pressure steam. The primary circuit is basically a closed cycle requiring only minimal make-up water to replace the incidental losses.

6.6.2 Sodium sulphite should be used for oxygen scavenging in the primary circuit to avoid the build-up of high levels of ammonia that would occur if hydrazine were used as Hydrazine decomposes to ammonia in medium to high pressure boilers. If feed water to the secondary circuit contains a high level of dissolved oxygen, hydrazine is recommended as the oxygen scavenger so as to avoid the high level of solids that would otherwise result from the use of sodium sulphite.

6.7 Coil Boilers

The Coil type boilers have a single-pass forced circulation generating section from which a mixture of steam and boiler water is delivered to a separator or accumulator vessel. The steam is separated from the water in this section by a mechanical separator or by flashing, and the residual boiler water is recirculated to the feed tank or to the inlet of the coil. These boilers are more tolerant to a poor quality of feed water provided the hardness is low and within limits.

6.8 Packaged boilers

The modern packaged Fire tube boiler is a highly rated shell and tube boiler, the heat flux density in the fire tube often being as high, or higher than in a water-tube boiler and balance water is recirculated to the feed tank or to the inlet of the coil. These boilers can tolerate a poorer quality of feedwater than tabulated.

6.9 Reheat boilers

Boiler/turbine systems using a reheat cycle are becoming more and more common. The use of reheat does not affect the need for same type of boiler water conditioning. Mostly the feed water quality remains consistent when the boilers are fed with feed water consisting of condensate with make-up of evaporated water. The only impurities found are those obtained from leakage of condensers or carry-over from the evaporators. These impurities are very small in amount and of uniform character. The proportion of chemicals to be added thus remains the same and only the quantity has to be varied as required to obtain the necessary to maintain desired parameters.

7.0 CARE OF BOILERS

7.1 Initial Filling

Boilers shall be initially filled with evaporated water and various chemicals should be added according to impurities in water and to maintain desired residuals. Sodium Sulphate or Sodium Nitrate shall be added to maintain the desired ratio in the case of riveted boilers and non-stress relieved drums are incorporated in the boiler.

7.2 Chemical cleaning

7.2.1 The surfaces of modern day Marine boilers have to be clean due to need of operating a high heat flux. And to maintain high heat flux the schedule of cleaning has to be maintained and the cleaning should be done by a company or people very carefully. the operation be efficiently supervised, with chemical testing to ensure that the main acid stage is efficient and carried out without damage to the plant and that subsequent rinsing, flushing, neutralizing and passivation are satisfactory. It is essential that the following safety precautions are observed.

7.2.2 Some gases are liberated during chemical cleaning and those are toxic or flammable or sometimes form an explosive mixture with air. The area of work should be well ventilated and all means of ignition, including smoking, should be avoided.

7.2.3 A proper Inhibitor is used to reduce corrosion while cleaning by withholding the attack by acid on boiler metal. Entry to a boiler or similar confined space after the use of inhibited acid should be made with care; the space should be vented thoroughly before entry and protective clothing should be used with a face respirator having pressurized fresh air supply.

7.3 Blow down

7.3.1 In order to maintain parameters within limits, the Cycles of Concentration are to be maintained by giving desired blowdown. Traditionally, blowdown is maintained to keep Suspended Solids limits. These suspended solids are due to precipitation of Hardness salts such as Calcium Phosphate, Magnesium hydroxides etc. The Suitable means for blowing down are a large valve opened intermittently or a small valve and/or orifice passing blowdown continuously. The blowdown is calculated in % as 100/coc

7.3.2 This has been so successfully accomplished that the need for blowdown for concentration control has been greatly reduced. Furthermore, there is no need of using shore water as evaporator feed for modern high-pressure boilers, as voluminous quantities of sludge resulting from the calcium and magnesium hardness are not encountered. The result of this development has been the decreasing use of the boiler blowdown valve. More recently, this may have been due to the tendency observed in recent years for deposits of iron oxide and copper/copper oxide to form on boiler tubes. Some of the iron oxide arises due to the slow conversion of the tube metal to iron oxide, but a higher quantity originates from the products of corrosion of the condensate/feed system. Thus, notwithstanding that visual examination of boilers may indicate much less quantities of deposit by the standard of previous years, the blowdown facility should not be regarded as being only for the purpose of concentration control but should also be used to remove corrosion products from the boiler, the valve should nonetheless be operated at least daily and, for best results, after each load change.

7.4 Corrosion

The corrosion is largely defined as the interaction of a metal with its environment in which the metal is dissolved or forms an insoluble reaction product such as oxide. The reactions in boiler plant are generally between steel and an aqueous solution resulting in pitting, general corrosion, caustic gouging, hydrogen embrittlement or corrosion fatigue. Corrosion reactions are complex ones but may be summarized by saying that they are directly or indirectly associated with dissolved gases, oxygen, carbon dioxide, and dissolved salts either in the bulk solution or locally concentrated at the metal/water interface. The presence of carbon dioxide and sulphur dioxide carried over in the steam may result in an acidic condensate causing corrosion in steam recovery pipelines / systems. The another type of corrosion is under deposit corrosion which may result in undetected under a layer of deposit until the metal is perforated or at least so weakened that it fails to withstand the pressure of the steam in the boiler. Corrosion fatigue occurs when the metal is subjected to repeated or fluctuating stresses while in contact with a corrosive medium. Historically, caustic cracking was a major concern in riveted drum boilers. But The use of welded stress-relieved drums has alleviated the situation with few exceptions.

7.5 Phosphate Hideout

7.5.1 The operators sometime experience sudden reduction in Phosphate in spite of increased level of dosage. This has been seen in boilers having a high rate of heat input per unit area of heating surface. Phosphate Hideout may be expected when the heat transfer rate (Heat Flux) exceeds about 300 kW/m^2. One possible cause is inadequate circulation due either to poor design or faulty operation, such as boiler overloading resulting in steam blanketing, producing restricted circulation. Sometimes it has been observed that the deposit in a particular area forms slowly over a large period of Boiler life. These deposits normally have a high iron content, are very hard, and are invariably porous. Seepage occurs through the porous medium until the true metal surface is found. The concentration of the dissolved substances in the film of boiler water adjacent to these highly rated heating surfaces increases.

7.5.2 The film of concentrated boiler salts thus formed remain fairly stationary close to the metal, its high concentration of salts resulting in a high boiling point and little disturbance from bubble formation. Boiling thus takes place mainly outside the film and the consequent evaporation helps to maintain an increase in the concentrated film. Eventually, some of the least soluble materials and especially those such as trisodium phosphate for which the solubility decreases drastically with increasing temperature, are actually deposited on the metal surfaces. The same phenomenon happens with Sodium Hydroxide when it form a high concentrated solution below a deposit resulting in caustic corrosion or to say caustic gauging. There is also a risk of tube failure from hydrogen embrittlement, the hydrogen being generated as a result of the reaction between sodium hydroxide and the metal surface. Hideout takes place when firing rate is high.

7.5.3 Under low steaming conditions the concentrated film and deposited solids mix with the boiler water and returns back in mainstream of boiler.

7.6 Steam purity

Provided that carry-over does not occur, the main impurities in the steam are likely to be carbon dioxide, oxygen and possibly silica and ammonia. Since silica has a limited solubility in steam it volatilities with steam depending upon pH and boiler water pressure. Higher the pH higher silica becomes less volatile. The boilers in which Sodium Hydroxide is allowed, the maintenance of 2.4 ppm OH Alkalinity per ppm SiO_2 the volatility of Silica is drastically reduces.

8. Pre-commission cleaning of boilers and feed systems

Wherever possible, boilers and their associated feed systems should be chemically cleaned before they are put into service. The process is designed to remove any oil, grease and surface rust that forms during erection, mill scale remaining from manufacturing processes and siliceous material that enters the plant during erection. These deposits, if not removed chemically, can cause boiler tube failures or lead to carry-over of silica and oxide particles which may deposit on turbine blading with consequent loss in efficiency. Separate cleaning processes should preferably be used for the feed system and for the boiler or, alternatively, they can be combined. The following is an example of a commonly used sequence.

a) *Initial degreasing*

The oil, grease and dirt is removed by boiler boil out. This is often carried out by boiling an alkaline solution in the boiler along with some surfactant. Usually, this is done before Acid cleaning.

b) *Ammoniated citric acid clean*

This process is carried out at the appropriate temperature to remove surface rust and traces of mill scale.

c) *Flushing*
This is carried out several times to remove traces of acid and undissolved deposits.

d) *Passivation*
This is often followed by boiling hydrazine solution to produce a magnetite layer on the boiler tubes.

9 PROTECTION OF IDLE BOILERS

9.1 Short Periods

When boilers are to be kept at idle for short periods the excess residuals Sulfite/ Hydrazine /DEHA as the case may be shall be maintained and pH of boiler water should be maintained slightly in excess of 10.0 If Boilers are riveted the desired ratio of Sodium Sulphate (preferred) or Sodium Nitrate should be maintained.

9.2 Long Periods

When boilers are to be kept idle for longer periods, they shall be emptied, thoroughly dried, and deposits removed. Trays of quick lime shall be placed in the drums and the boilers sealed. If using a wet storage a proper method should be opted.

ANNEX A

(*Clause* 2)

LIST OF REFERRED STANDARDS

IS No.	*Title*
265: 2021	Hydrochloric acid specification (*fifth revision*)
1070: 2023	Reagent Grade Water Specification (*fourth revision*)
3025	Methods of sampling and test (Physical and Chemical) for water and waste water
(Part 11): 2022	Part 11 *p*H value (*second revision*)
(Part 14): 2013	Part 14 Specific conductance (wheatstone bridge, conductance cell) (*second revision*)
(Part 21) : 2009	Part 21 hardness (*second revision*)
(Part 23) : 2023	Part 23 Alkalinity (*second revision*)

(Part 31/Sec 1) : 2022	Part 31 PHOSPHORUS; Section 1 Determination by Vanadomolybdo-phosphoric acid Stannous chloride Ascorbic acid and Persulphate method (*second revision*).
(Part 32) : 1988	Part 32 chloride (*first revision*)
(Part 35): 1988	Part 35 Silica *(first revision*)
(Part 38) : 1989	Part 38 dissolved oxygen (*first revision*)
(Part 42) : 1992	Part 42 copper (*first revision*)
(Part 45) : 1993	Part 45 sodium and potassium (*first revision*)
(Part 53) : 2003	Part 53 iron (*first revision*)

ANNEX-B

(*sl. no. vi. of Table 1, sl. no. xix. , xx. of Table 5, sl no. vi of Table 6*)

CONTROL TESTS FOR WATER FOR MARINE BOILERS

B.0. GENERAL

B-0.1 Only such methods as are required for routine tests for controlling the quality of boiler water for marine boilers have been described in this appendix.

B-0.2 Quality of Reagents

Unless specified otherwise, pure chemicals and distilled water (IS 1070) shall be employed in tests.

NOTE - ‘Pure chemicals’ shall mean chemicals which do not contain impurities that effect the results of analysis.

B-1 SODIUM SULPHITE

B-1.1 Reagents

B-1.1.1 *Dilute Hydrochloric Acid*

Add 200 ml of concentrated hydrochloric acid (conforming to IS 265) to 100 ml of water.

B-1.1.2 *Standard Iodate-Iodide Solution*

Dissolve 0.710 g of potassium iodate in about 160 ml of water. Add 7 g of potassium iodide and 0.5 g of sodium bicarbonate. Dilute the solution to exactly one litre.

B-1.1.3 *Starch Indicator*

Titrate 5 g of pure starch and 0.01 g of mercuric iodide with 30 ml of cold water and slowly pour it with stirring into 1litreof boiling water. Boil for 3 minutes. Allow the solution to cool and decant off the supernatant clear liquid.

B-1.2 Procedure

Take by means of a pipette 2 ml of dilute hydrochloric acid in a porcelain dish. Discharge the sample cooled below 27°C through a cooling coil into a bottle of capacity approximately 250 ml, the end of the tube being placed near the bottom. Allow a quantity of the sample approximately ten times the volume of the bottle to overflow the bottle to ensure a representative specimen of the sample to be obtained. Pour contents of the completely filled bottle into the porcelain basin. Add 1 ml of starch indicator and titrate with constant stirring with standard iodate-iodide solution until a faint blue colour persists in the solution. Measure accurately the capacity of the bottle used.

B-1.3 Calculation

$$Sodium\ sulphite\ (\ as\ Na_2SO_3), parts\ per\ million = \frac{1260\ V_1}{v}$$

where,

V_1 = volume of standard iodate-iodide solution used, in ml; and
v = volume of the sample contained in the bottle, in ml.

B-2 HYDRAZINE

B-2.1 Reagents

B-2.1.1 *p-Dimethylaminobenzaldehyde Reagent*

Take 800 ml of Oxygen free water prepared as per **B-2.1.1.1** in a 1 l volumetric flask. Add 40 ml of concentrated sulphuric acid slowly through a glass rod with stirring. Dissolve 27.5 g of p-Dimethylaminobenzaldehyde completely and cool to room temperature. Make the final volume to 1 liter and store it in polyvinylchloride bottle.

B-2.1.1.1 *Preparation of Oxygen free water*

Take 1.5 l of MB water in a 2 l reagent bottle. Pass nitrogen gas for 5 min into the water. Add 2 ml of concentrated sulphuric acid slowly using glass stirrer. Then add 3 g of Sodium carbonate and adjust the pH to 7 using 5 percent sodium hydroxide solution.

B-2.1.2 *Standard Hydrazine solution*

1. Weigh accurately 1 gm of hydrazine hydrate (99%) in a 100 ml volumetric flask. Make up to the mark using oxygen free water.
2. Pipette out 10 ml of this solution in a 100 ml volumetric flask and make it up (Concentration is 1 000 ppm).
3. Dilute 1 ml of this solution to 100ml in a volumetric flask (Concentration is 10ppm).
4. Pipette out 10 ml and make up to 100ml in volumetric flask (Solution Concentration is 1000 ppb).

5. Pipette out 2ml, 4ml, 6ml, 8ml, 10ml and 15 ml separately in 100ml volumetric flasks and make up to the mark to get 20 ppb, 40 ppb, 60 ppb, 80 ppb, 100 ppb and 150 ppb solutions respectively.

Note : Use only Oxygen free water for Make up.

B-2.2 Procedure

Collect 100ml of test sample in a narrow mouth glass or plastic bottle. Fill the bottle without any air gap to avoid Hydrazine oxidization. If the sample is turbid, filter it. Take 5 ml p-Dimethylaminobenzaldehyde reagent in a 25 ml conical flask. Add 5 ml of sample to it using pipette and stir to mix. Allow the colour to develop for 5 minutes and then measure the absorbance at 455 nm in spectrophotometer. Find out concentration from standard graph, **B-2.2.1**. Run blank using distilled water in place of sample.

B-2.2.1 *Standard Calibration Procedure*

Take 5 ml reagent in a 25 ml conical flask. Add 5 ml standard hydrazine solution and stir to mix. Allow the colour to develop for 5 min. Measure the optical absorbance at 455nm in spectrophotometer. In a similar way, read the absorbance value for reagent blank using oxygen free water in place of standard. Generate the standard graph for all the above concentration after deducting blank absorbance value. Establish a linear graph by plotting the Concentration (X-axis) versus the absorbance value (Y-axis).

B-1.3 Calculation

$$Hydrazine\ (as\ N2H4), parts\ per\ billion\ =\ a - b$$

where,

a = Sample concentration

b = Blank concentration