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RECOMMENDATIONS FOR MAINTENANCE AND OPERATION OF PETROLEUM STORAGE TANKS

PART II INSPECTION

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RECOMMENDATIONS FOR MAINTENANCE AND OPERATION OF PETROLEUM STOAGRE TANKS

PART II INSPECTION

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Indian Standard

RECOMMENDATIONS FOR MAINTENANCE AND OPERATION OF PETROLEUM STORAGE TANKS

PART II INSPECTION

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 11 February 1981, after the draft finalized by the Structural Engineering Sectional Committee had been approved by the Structural and Metals Division Council and Civil Engineering Division Council.

0.2 Storage tanks in marketing installations of refineries are used to store crude oil, intermediates and refined products, gas, chemicals and water. These tanks are of different types and sizes, depending on their intended use.

0.3 With the revision and subsequent publication of IS : 803-1976* the committee decided to formulate a comprehensive Indian Standard, stipulating recommendations in regard to the maintenance and operation of oil storage tanks.

0.4 In this standard, provisions regarding inspection and inspection procedures for the maintenance of petroleum storage tanks have been covered.

0.5 Provision regarding hazards which are encountered in the cleaning of petroleum tanks for the safe entry and methods and procedures for cleaning these tanks have been dealt with in Part I of this standard.

1. SCOPE

1.1 This standard (Part II) covers the inspection schedule and inspection procedures, including relevant test requirements, for the maintenance and operation of petroleum storage tanks.

*Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded oil storage tanks.

1.1.1 This standard covers only the atmospheric storage tanks.

2. STATUTORY REQUIREMENTS

2.1 Statutory requirements such as Factory Act 1948 and Petroleum Act and rules framed thereunder regarding inspection of petroleum storage tanks, relevant to the maintenance and operation of these tanks shall be complied with in addition to the provisions contained in this standard.

3. GENERAL

3.1 The reasons for inspecting the storage tanks are basically the same as for all other types of equipments, that is to determine:

a) Physical conditions of the tanks,

b) Rate of corrosion, and

c) The cause of deterioration.

With these factors known, proper measures may be taken to reduce the probability or fire, loss of storage capacity, keep working conditions safe, make repairs or determine when repair or replacement of a tank may be necessary and prevent or retard further deterioration.

SECTION I — SCHEDULE OF INSPECTION

4. FREQUENCY OF INSPECTION

4.1 The frequency of inspection of storage tanks is determined by the following factors:

a) Nature of the materials stored;

b) Results of visual maintenance checks;

c) Corrosion rates and corrosion allowance;

d) Conditions at previous inspections;

e) Methods and materials of construction and repair; and

f) Location of tanks such as in acidic atmosphere, isolated and high risk areas, etc.

4.2 The corrosion rate varies with the nature of the product stored and local atmospheric conditions. The corrosion rate is generally not high and, consequently, insufficient attention paid to corrosion sometimes causes unexpected, extensive and costly repairs. To avoid such repairs and the possibility of a sudden loss of tank storage capacity, a regular inspection programme is recommended which aims at achieving optimum saving in total inspection costs and unexpected breakdown costs. As far as possible, on-stream inspection shall be used as a guide for determining corrosion rates. Internal inspection shall take place either when indicated by the service history or when other indications point out that repairs are necessary.

4.3 The following frequencies are recommended as a guide:

PRODUCT AND TANK	ULTRASONIC WALL THICKNESS MEASUREMENTS (EXTERNAL INSPECTION)	INTERNAL INSPECTION OF EACH INDIVIDUAL TANK, IF NOT ALREADY OPENED FOR OTHER REASONS
Floating Roof Tanks		
Crude oil	Every 5 yrs	Every 5 yrs
Straight run/catalytic cracker gasoline	,,	,,
Cone Roof Tanks		
Acid	Ever 5 yrs	Every 5 yrs
Leaded gasoline	,,	,,
Fuel oil	,,	,,
Slops	,,	,,
Crude oil	,,	,,
Straight run/catalytic cracker gasoline	Every 5 yrs	Every 6 yrs
Fresh water	,,	,,
Salt water	,,	,,
Cycle oils	,,	,,
Gas oil	,,	,,
Caustic	Every 5 yrs	Every 7 yrs
Kerosene	,,	,,
Naphtha	Every 5 yrs	Every 8 yrs
Light diesel oil	,,	,,
High speed diesel	,,	,,
Waxy distillate	Every 5 yrs	Every 10 yrs
Bitumen	,,	,,
Jute batching oil	,,	,,
Lube oil	,,	,,

4.4 For new refineries, it is advisable to determine inspection intervals by establishing the corrosion rates of various product storage tanks. This may best be done by inspecting internally one or two tanks out of a group of identical tanks which store the same products during the first 5 years of refinery operation. Further, whenever ultrasonic wall thickness measurements indicate a high rate, an internal inspection shall be carried out.

4.5 Storage tanks painted internally with amine-cured epoxy resin paints shall be opened once in a year for cleaning and inspection of the painted surface.

5. VISUAL INSPECTION

5.1 In addition to the inspection schedule discussed in **4**, a visual external inspection of each tank shall be made once a year. During the visual inspection attention shall be given to the following points:

a) Condition of roof and shell plates with respect to deterioration of paint and presence of rusty spots;

b) Condition of handrailings and treads of the staircase with respect to weathering of paint, rusting and breakages;

c) Condition of the foundation pad with respect to any settlement of the tank and slope of the pad to see if there is possibility of ingress of water below the bottom plates and growth of shrubs on the pad;

d) Condition of foam chamber, frangible glass, foam lines drains, etc;

e) Any leakage from the circumferential joint of the tank bottom with shell plates;

f) General condition of fire fighting facilities provided on the tank with respect to clogging of spray nozzles, perforations of foam connections, etc;

g) Pressure and vacuum relief valves, free vents for fixed roof tanks and rim vents/bleeder vents for floating roof tanks shall be examined for proper working and shall be sent to the workshop for overhaul and resetting;

h) Proper functioning of relief valves on inlet/outlet lines, so that there shall not be any leakage during pumping-in operations;

i) Leakage from valve glands, expansion joints, etc;

k) Signs of external corrosion on inlet/outlet pipes at points where they pass through the bundwalls;

m) Condition of insulation of the insulated tanks to ensure that covering is complete and that no corrosion has taken place under the insulation; and

n) In floating roof tanks, the condition of the roof and the seal shall be noted, especially with respect to accumulation of scales on roof seal and patches of oil on deck plates.

5.2 The visual inspection of each tank has been asked for in the Factories Act 1948 (Section 31) wherein it has also been stipulated that a record be kept, indicating the extent of inspection, inspection findings and any recommendations arising out of the inspection findings. The inspection has to be carried out by a competent person and a certificate to this effect filed for verification in the form as shown in Appendix A may be used for this purpose.

SECTION II — INSPECTION PROCEDURES

6. INSPECTION RECORDS

6.1 For planning of inspection and keeping of records, the use of following type of documents is recommended:

a) Long term planning sheet for internal tank inspection (*see* Appendix B);

b) Yearly planning sheet for internal tank inspection (*see* Appendix C); and

c) Report of tank inspections and repairs (*see* Appendix D).

6.2 The above documents shall form part of the file and record card system, consisting of report and data of the tanks. It is obvious that the records shall start with the incorporation of data obtained from erection reports, as well as data of painting, type of product stored, etc.

7. INSPECTION OF THE TANK BOTTOM

7.1 After the tank has been cleaned of its sludge, but before the bottom has been freed from its protective coating (that may have been given earlier) or scale, it shall be visually inspected to obtain the first indication of the condition of the bottom.

7.2 When the general condition looks good and only slight pitting and a thin layer of scale is seen and, in case of riveted bottoms, the rivet heads are seen in good condition, a few measurements of the bottom thickness will be sufficient. These measurements shall preferably be carried out with an ultrasonic instrument. Ten checks, one in the bottom centre 5 towards the outer periphery and 4 in the middle areas of the bottom will give reliable information. The exact locations of these measurements shall be indicated in the tank inspection report for future reference.

7.3 When more serious pitting is detected, or when an appeciable layer of scale is present and, in the case of riveted bottoms, when the rivet heads seem to be in a state of deterioration, a detailed inspection of the bottom is necessary. In such a case, the bottom surface shall be completely cleaned of all scales/protective coating, etc, and ultrasonic measurement of thicknesses carried out on the pattern of a grid with measuring spots one metre apart all over the surface. Thinned out areas shall be closely surveyed further by additional thickness measurements.

7.4 Weld seams may be checked by running a thin scraper blade or a knife along both sides of the weld. Whenever seams are attacked by corrosion, the scraper or knife will normally go into the opening and indicate the fault.

7.4.1 If welds are found to be corroded on visual inspection, Spot Vacuum Box Test for the tank bottom plate welds and Dye Penetration Test for the shell to bottom plate weld shall be done.

7.5 Rivet heads shall be checked with regard to the thickness and diameter of the heads. Rivets shall be rejected when the dimensions of their heads are reduced to about 50 percent of the original.

8. LEAK TESTING OF TANK BOTTOM

8.1 After any rapairs to the bottom plates of a storage tank, all welds shall be tested to ensure that the tank bottom is free from leaks. The test shall preferably be made as soon as possible after welding is completed, but in any case before any surface coating is applied and water filled into the tank for hydrotesting. Leak testing may be done by using the vacuum box, which enables any leaks in the welds to be positively located by visual examination.

8.2 The vacuum box is fitted with a glass viewing panel on its top and has an open bottom, around which a continuous rubber seal and former is secured. The seal forms an air tight joint around the section of the weld to be tested when the box is pressed against the bottom plates. A partial vacuum may be created by means of a hand or motor driven vacuum pump. A vacuum gauge is incorporated in the box which has two connections, one for suction tube fitted with the non-return valve and the other for the vacuum release valve.

8.3 Alternatively, the tank bottom may be tested pneumatically with arrangements as shown in Appendix E. Air connections are installed at at least 5 points. An air pressure of 10 cm of water is maintained under the bottom by making a dam of clay or bitumen-sand mixture about 20 cm high around the tank as close as practicable to the shell wall and filling the space between the dam and the tank wall with fresh water to act as a seal. For the detection of leaks, soap suds are applied to all joints.

8.3.1 This system has the following advantage over the vacuum box method:

a) It is much faster,

b) The entire bottom gets tested, and

c) Possible small holes sealed by soil or rust get detected as a result of flexing of the bottom and partial lifting from its base.

9. INSPECTION OF TANK SHELL

9.1 Ultrasonic wall thickness measurements of each course of the tank shell shall be carried out over a width of 2 plates, on opposite sides of the shell. If the measurements indicate that the thickness is close to the minimum allowable as indicated in **10**, the entire course shall be checked. If the thicknesses measured are less than the allowable limit and spread over the entire surface of the course, all the shell plates of course shall stand rejected. However, if the thickness less than allowable limit is confined to one or more plates only, these plates shall be renewed. Consideration shall, however, be given to renew even these shell plates whose thickness may be marginally above the allowable limit, but may be expected to reach below this limit before the next scheduled inspection.

9.2 At locations where internal corrosion of the shell plates is observed, close inspection of welded seams may be necessary, especially for any evidence of cracking.

9.3 If the tank shell is repaired or partly renewed, the weld joints in case of partly renewed tank shall require radiographic inspection. The tank shell shall be tested by filling it with water up to the level of the top leg of the top curb angle and noting any leaks over a period of at least 24 hours. The filling shall be done slowly and a continuous inspection shall be maintained for the whole of the filling period. During filling, care shall be taken to notice any uneven settlement of the tank on its foundation.

9.4 Appendix F gives an example of the recording of tank shell inspection. This recording shall be kept together with the tank inspection report (Appendix D) for future reference.

10. REJECTION LIMITS FOR SHELL PLATES

10.1 Welded Tanks Designed with a Joint Efficiency Factor of 0·85

10.1.1 The general rule is that the maximum average decrease in the thickness of the shell plates due to corrosion over any considerable area shall never be allowed to exceed the corrosion allowance provided in the design calculation.

10.1.2 This simple rule, however, does not allow for the influence of differences in the specific gravity of the product stored and of the yield stress of the steel used.

10.1.3 As new tanks are designed for a liquid with a specific gravity of 1·00, all tanks storing liquids with the specific gravity of less than 1·00 shall reach the rejection limit laid down by the above mentioned rule at a stress lower than the one applying to a tank which is filled with water. This is economically undesirable. In such cases, it shall, therefore, be ascertained whether the following steps would make it possible to prolong the life of such tanks:

a) The rejection limit for all tank shell plates shall be based on a stress of 80 percent of the minimum guaranteed yield stress of the plates. (This, however, does not apply to areas close to joints, manholes and nozzles).

b) The stress shall be calculated with regard to the specific gravity of the liquid stored in the tank.

c) The average thickness over a considerable area of the corroded plate shall be taken as the 'measured plate thickness'.

d) The hoop stress equation given below, used in designing new tanks, shall be used for the calculation of the rejection limit of the shell plate thickness:

$$t_r = \frac{4{\cdot}9\,(H - 0{\cdot}3)\,DG}{SE} \text{ when } S \text{ is in N/mm}^2$$

$$t_r = \frac{50 \times G}{S \times D}\,(H - 0{\cdot}3)\,D \text{ when } S \text{ is in kgf/cm}^2$$

where

t_r = rejection limit of plate thickness in mm,

S = allowable stress in N/mm² or kgf/cm² (*see* IS : 803-1976*),

*Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded oil storage tanks.

E = joint efficiency factor according to tank shell design,

H = height from the bottom of the course under consideration to the top of the roof curb angle in metres,

D = nominal diameter of tank in metres, and

G = specific gravity of the liquid stored.

10.2 Welded Tanks Designed with a Joint Efficiency Factor of 1·00

10.2.1 For tanks storing liquids with a specific gravity higher than 0·90, the steps given in **10.1** for calculation of the rejection limit for shell plate thicknesses shall be used.

10.2.2 The steps given in **10.1** shall also be used in cases where it is desirable to prolong the life of the tank and the specific gravity of the product is less than 0·90.

10.3 Riveted Tanks

10.3.1 The same simple rule as stated in **10.1.1** applies in the case of riveted tanks. Where it is desirable to prolong the life of the tank, it shall be ascertained whether this may be achieved by using the steps given above for the calculation of the rejection limits for shell plate thickness, with the only exception that for the joint efficiency factor for the vertical seams the following values shall be used:

Single	16 mm	lap joint	= 59·3 percent
Double	16 mm	lap joint	= 73 percent
3-fold	20 mm	lap joint	= 73·3 percent
4-fold	20 mm	butt joint	= 87 percent
5-fold	22 mm	butt joint	= 91·25 percent
5-fold	25 mm	butt joint	= 91·25 percent
5-fold	28 mm	butt joint	= 90·12 percent

10.4 Arbitrary Limits for Top Shell Courses

10.4.1 The plate thicknesses of top shell courses are determined for practical reasons. For tanks having a diameter up to 31 metres inclusive it is normal practice to use top courses with a minimum thickness of 6 mm and for tanks with a diameter of 39 metre and over a minimum thickness of 8 mm. Under liquid load these top courses will never reach the allowable stress.

10.4.2 The rejection limit for shell plates, as specified above, shall also be applied for these top shell courses, but these courses shall in any case be rejected when, due to corrosion, the plate thicknesses have reached over a considerable area the following values:

a) When the original thickness of 6 mm has become 2·5 mm.

b) When the original thickness of 8 mm has become 3·2 mm.

10.4.3 It is pointed out that for many tanks, especially of medium and large size, the top shell courses may buckle before the limits mentioned under (a) and (b) have been reached. The rejection limit for top shell courses shall, therefore, not be determined before the stability of the shell has been checked according to the requirements described in **10.5**.

10.5 Buckling of Upper Shell Courses when Tank is Empty

10.5.1 *General* — The rejection limits for the shell plates specified above are based on the condition that the tank is completely filled with liquid.

However, when the shell plates have corroded it may be possible that buckling of plates occurs before the above mentioned rejection limits are reached.

Buckling of shell plates will always occur in the upper half of the tank shell, as the upper courses are thinner than the lower courses.

10.5.2 *Loading Conditions* — Buckling of shell plates may occur when the stablilty of the tank shell is insufficient to withstand one or both of the two following loads:

a) Wind on the outside of the tank shell. (For open top tanks the wind load on the inside of the tank shall also be considered).

b) Internal vacuum inside the tank due to the setting of the vacuum valves.

10.5.3 *Appearance of Buckling* — Buckling due to wind load will show a local buckle on the windward side of the upper shell only. Buckling due to internal vacuum will show buckles over the entire circumference of the shell course.

10.5.4 *Flat Spots in Upper Courses* — Sometimes tank shells are constructed in such a way that the surface of the upper courses shows slight flat spots. This mostly occurs with tanks of 30 to 35 metres diameter where 6 mm thick plates are used for the upper courses. These flat spots have an unfavourable influence on the stability of the shell and may cause buckling at an earlier stage than theoretically expected.

10.5.5 *Points to be Noted in Calculations Against Buckling* — While carrying out calculations to check the stability of the corroded tank shell against buckling, the following points shall be noted:

a) Maximum wind gusts mostly result in a wind load which is approximately 20 percent higher than the wind loads specified in building regulations. Experience has shown that the gust value may be applied in the stability calculation for the shell.

b) Vacuum valves ordered with a vacuum setting of 5 cm water gauge often start to open at 5 cm water gauge, but are fully open at 7 to 8 cm water gauge. The higher value may be applied in the stability calculations for the shell.

10.5.6 The stability calculations may show that intermediate stiffening rings are required to prevent buckling of upper shell courses. If welding required for the application of shell rings is not immediately feasible, it is possible for tanks equipped with vacuum valves to lessen the loading condition for the tank shell by reducing the setting of the vacuum valves, say, from 5 cm water gauge to 2 to 3 cm water gauge. Since this will increase breathing losses slightly, it may be considered a temporary solution.

11. INSPECTION OF ROOF AND ROOF-SUPPORTING STRUCTURE

11.1 General

11.1.1 The roof-supporting structure and the inside of the roof plates may usually be inspected visually from the tank bottom with the aid of a pair of binoculars. A more detailed inspection of the inside of the roof plates and roof structure of cone roof tanks may be made by erecting scaffolding on the horizontal members of the roof-supporting structure after cutting a hole in the roof. When corrosion or distortion of the structure is observed, measurements shall be taken. The supporting members shall be rejected when the loss of material exceeds 25 percent. The welds and bolts of the structure shall also be examined for damage. Appendix G shows an example of the results of measurements on the supporting structure. These sheets shall be filed together with the tank inspection report for future reference.

11.1.2 If corrosion of roof plates is detected and a coating with paint does not give a fully reliable protection, the plate thickness shall be measured periodically in order to establish the corrosion rates. A minimum thickness of 3 mm may be allowed for tank roof plates.

11.1.3 If the roof is still sufficiently strong and reliable, that is when the average thickness of the plates is well above the minimum and only scattered holes are observed, then the roof may be patched. If roof plates are renewed, the renewed part shall be tested as stated in the subsequent clauses.

11.2 Fixed Roofs

11.2.1 When the tank is to be tested with water, the roof shall be tested by pumping air under the roof plates while the tank is still full of water.

11.2.2 Non-pressure tank roofs shall be tested to a pressure of 7·6 cm water gauge and pressure tank roofs to a pressure equal to maximum internal pressure rating. For the detection of leaks, soap suds shall be applied to all joints to be tested.

Alternatively, the roof may be tested using the vacuum box method as described in **8**.

11.2.3 While filling/removing water from the tank, openings on the tank roof shall be kept open.

11.3 Floating Roofs

11.3.1 *Centre Deck* — The weld joints of single centre deck plates shall be checked for liquid tightness by vacuum box method as described in **8**.

11.3.2 *Pontoon* — The pontoon compartments shall be inspected internally for corrosion and leakage. The suggested corrosion allowances for the bottoms of double decks, pontoon roofs and rim plates are 3 mm, 1·5 mm and 3 mm respectively.

If a compartment of the pontoon is repaired, its liquid tightness shall be checked by pumping air in the compartment and leaks detected by using soap solution.

11.3.3 *Roof Seals* — Roof seals shall be checked for any damage, distortion or improper functioning. Malfunctioning of seals may be caused by excessive uneven settlement of the tank. Checks shall be carried out periodically and particularly immediately after commissioning of the tank for any settlement.

The maximum uneven settlement allowance for a floating roof tank is given in **13.2** and its subclauses.

11.3.4 *Roof Drain* — Roof drain shall be hydrostatically tested at 3·5 kg/cm^2g pressure and carefully checked for leakage.

12. INSPECTION OF TANK FITTINGS

12.1 Nozzles Including Manholes — Details of the diameter of each nozzle and its purpose together with a note as to whether the nozzle is riveted or welded shall be included in the records.

The wall thickness of nozzles shall be measured using the ultrasonic instrument. The minimum allowable wall thickness of nozzles shall be the same as applicable for process piping.

12.2 Dip Hatches and Roof Manholes — Gasketing and the hinge (when employed) on dip hatches and roof manholes shall be tested so that spark-free operation is ensured. All similar fittings intended to be gas-tight shall be inspected for leaks after assembly.

12.3 Open Vents and Pressure-Relieving Devices — All open vents and breather valves shall be examined to see that the protective gauzes are neither torn nor clogged by foreign matter or insects. The pressure relieving devices shall be checked to ensure that they are functioning properly while the tank is in commission.

12.4 Heating Coils — Heating coils shall be thoroughly hammer-tested, particularly at the underside of the coils and the bends. Experience has shown that hammer-testing alone does not always give feel-proof results. In case of doubt, ultrasonic testing shall be employed, which will also give an indication of internal corrosion.

The coils shall be hydraulically tested at 3·5 kg/cm^2 above their working pressure and welds shall again be hammer-tested at this pressure.

12.5 Structural Parts — All structural parts, such as ladders, stairways, walkways, handrails, etc, shall be carefully inspected for corrosion/broken parts. In particular, it shall be determined whether these parts shall be safe for use at least until the next inspection.

Ladder and stair treads should be checked for wear and corrosion. In addition to loss of strength caused by loss of metal, treads becomes slippery when the surface is worn; such treads shall be replaced.

13. INSPECTION OF TANK FOUNDATION

13.1 Erosion — The raised foundations of vertical tanks shall be protected from the effects of erosion. The part of the foundation which projects beyond the base of the tank shall be inspected at regular intervals to ensure that the sealing coat of sand-bitumen mix is offering satisfactory resistance to the weather and to normal wear and tear. Any damage to the surface of the sealing coat or any breakdown of the sand-bitumen mix should be remedied before damage to the underlying foundation may occur.

13.2 Settlement — The main source of trouble with tank foundations is usually settlement, which may be major or minor, and even or uneven in nature. All tanks shall be inspected at intervals for signs of settlement and, if necessary, remedial action shall be taken as described in this section. Major settlement usually occurs when the tank is first placed in service, after which the rate of settlement usually decreases and eventually becomes imperceptible. Special attention shall be paid to settlement which continues at a steady or increasing rate, as this is usually a sign of serious weakness in the foundation or sub-soil.

13.2.1 *Total Settlement* — The tolerance on settlement is dependent to a great extent on the manufacturer's specification for continued satisfactory performance of the tank. When in use, however, considerable settlements may be tolerated depending on circumstances, and it is not unknown for tanks to have experienced total settlements of up to 600 mm without being seriously impaired.

13.2.2 *Minor Settlement* — Even with relatively minor settlement, a vertical tank will sink until the outer edges of the bottom plates reach a level below the surface of the projecting part of the foundation. This forms a channel around the periphery of the tank, in which rainwater collects on the projecting part of the tank bottom. When this occurs, small outlet channels shall be cut in the seal coat of sand-bitumen mix at the lowest point and at intervals of about 6 m around the periphery to provide drainage. If settlement exceeds 25 mm, this method may destroy the effectiveness of the sand-bitumen sealing coat. In such instances, the surface of the projecting part of the foundation shall be trimmed and a new sealing coat of sand-bitumen mix 50 mm thick shall be laid to provide a proper drainage surface away from the toe of the tank bottom.

13.2.3 *Major Even Settlement* — A major settlement may lower the level of the tank bottom until access to connections in the bottom course of shell plates becomes difficult and proper drainage becomes impossible. If such settlement occurs, it may be necessary to restore the level of the tank bottom by lifting the tank bodily and building a new foundation on top of the old one.

13.2.4 *Uneven Settlement* — An uneven settlement may cause the following difficulties in addition to those already listed:

a) The formation of pockets or hollows in the tank bottom. Such pockets may not be drained, so that water accumulates in them and they tend to become focal points for corrosion. They shall be checked whenever a tank is opened for cleaning or repairs.

b) Distortion of the tank bottom, shell and roof imposes structural stresses which may eventually result in leaks at the seams. It may also cause inaccuracy in the calibration of the tank. With floating roof tanks, distortion may lead to jamming of the roof.

The following tolerances on uneven settlement are recommended:

a) 10 mm maximum in 10 m of perimeter length as a combine result of pad construction, tank erection, water testing and ultimate likely soil settlement.

b) 25 mm maximum across the tank diameter.

c) *Sagging of the Battom of the Tank* — The maximum sag in tank bottoms (*see* Fig. 1), resulting from settlement in poor soils, shall not exceed the value derived from the following equation:

$$f = \frac{D}{100}\sqrt{\frac{(100 f_0)^2 + 3{\cdot}75}{D}}$$

where

f = maximum allowable sag in the tank bottom in cm;

D = diameter of tank in cm; and

f_0 = deflection of bottom centre in cm, in relation to bottom curb when the tank is erected (positive, zero or negative).

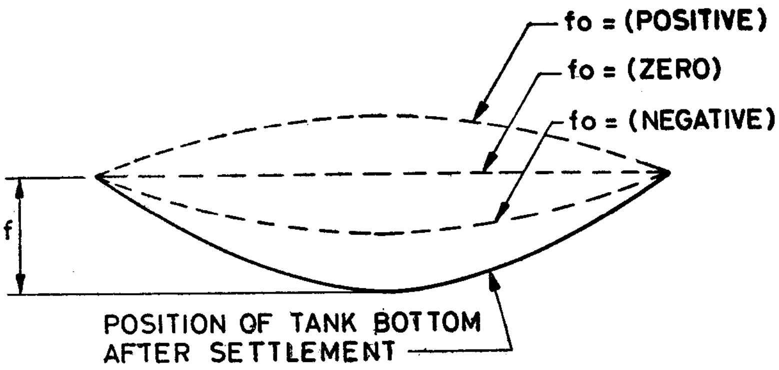


FIG. 1 SAGGING OF THE BOTTOM OF THE TANK

If the sag exceeds this limit, the stresses in the bottom of shell joint may become excessive. It such a case, it is advisable to lift the tank and re-pack the foundation before this occurs. If soil conditions are bad, it may be necessary to re-pack the foundation several times during the life time of the tank.

d) *Tilting of the Tank* — If tilting continues unchecked, there is a danger that the foundation or sub-soil may eventually fail and the tank overturn or collapse. Any departure from the vertical is a source of danger, as it may lessen the stability of the tank in high wind.

If serious uneven settlement occurs, it may be necessary to jack up the low part of the tank perimeter and re-pack under the bottom with clean river sand and/or other suitable material, or even to lift the tank bodily and level the foundation.

e) *Maximum Allowable Tilting* is shown in Fig. 2. This will cause an increase in the hoop stress of the shell plates equal to 2 percent of the hoop stress calculated for tanks without settlement. This increase shall be deducted from the allowable stress when calculating the rejection limit of shell plates of tanks which have tilted.

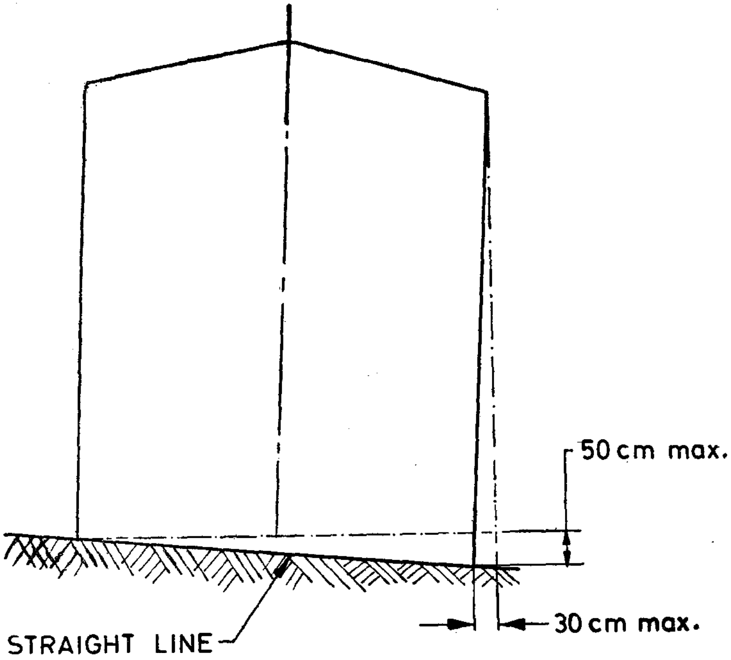


FIG. 2 MAXIMUM ALLOWABLE TILTING

It may, however, be noted that in case of floating roof tanks, floating roof may become inoperable even before the above limit is reached.

The tank shall be lifted and the fundation repacked in correct shape, in case of tilting when either horizontal or the vertical limit for tilting given above is reached.

14. INSPECTION OF TANK INSULATION

14.1 The waterproof sealing of the tank insulation shall be inspected every year and specially after the rainy season. This is important since the entry of moisture will gradually reduce the insulation properties and may also result in serious undetected corrosion of the tank plates underneath the insulation. If it is suspected that moisture has penetrated through, a small area of the plate should be uncovered and examined for signs of corrosion.

APPENDIX A

(*Clause* 5.2)

ATMOSPHERIC TANK INSPECTION REPORT

(External)

TANK NO. ....TYPE : CONE/FLOATING/WELDED/INSULATED

DATE INSPECTED:.....................SERVICE:....................................

LOCATION :............................LAST INSPECTION ;....................

SIZE : DIAMETER...............HEIGHT..............CAPACITY..............

TANK PART	CONDITION	RECOMMENDATIONS
ROOF		
SHELL		
BOTTOM		
FOUNDATION		
NOZZLES & PIPE CONNS	SERVICE SIZE	
FITTINGS, ETC	P & V VALVE	
	BREATHER VENT	
	SALT WATER SPRAY	
	PIPE	
	STEAM COIL	
	SAMPLE NOZZLE	
	MANWAY	
	LEVEL INDICATOR	
	STAIRCASE	
	RAILING	
	ROOF LADDER	
	ROOF WATER PIPE	

REMARKS:

INSPECTOR

APPENDIX B

(*Clause* 6.1)

TYPICAL EXAMPLE OF A LONG-TERM PLANNING SHEET FOR INTERNAL TANK INSPECTIONS

Tank No.	Type	Dimensions $D \times H$	Previous Inspection Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Remarks
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												
		×												

APPENDIX C

(*Clause* 6.1)

TYPICAL EXAMPLE OF A YEARLY PLANNING SHEET

Tank No.	Type	Dimensions $D \times H$	Product	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Remarks
		×														
		×														
		×														
		×														
		×														
		×														
		×														
		×														
		×														
		×														
		×														
		×														
		×														
		×														

APPENDIX D

(*Clause* 6.1)

TYPICAL EXAMPLE

REPORT ON TANK INSPECTION AND REPAIRS

Inspected on: 19 Tank No.

Location:

Dimensions:

Type of tank: Product:

Year of construction: 19

Previous internal inspection: 19

Previous external inspection: 19

Type of inspection : internal/external

Summary:

	Inspection observations	Repairs executed
Foundation:		
Bottom:		
Shell:		
Roof Structure:		

	Inspection observations	Repairs executed
Roof : Fixed/Floating Pontoon Ladder hinges		
Miscellaneous Suction and inlet devices Free vents Breather valve Splash plate Spray water riser Foamite spray riser Foam connections Dip hatches Wind shield of dip batch Roof manhole Shell manhole Liquid level indicator Hand railing Stairways Product drain Water draw-off Measuring point Nozzles Mixing coils Heating coils Shunts Hinge bolts and roller		
Insulation painting		

	Inspection observation	Repairs executed
Bazooka (anti-rotation device)		
Emergency drain		
Foam drain		
Rubber fabric seal		
Pantograph hangers		
Steel sealing ring		
Bonding wire		
Insulation		
Painting		

Recommended date for next inspection:
Repairs expected during next inspection:

Remarks:

Inspected by (Name) Date

(Signature)

APPENDIX E

(*Clause* 8.3)

APPLICATION OF PNEUMATIC TEST

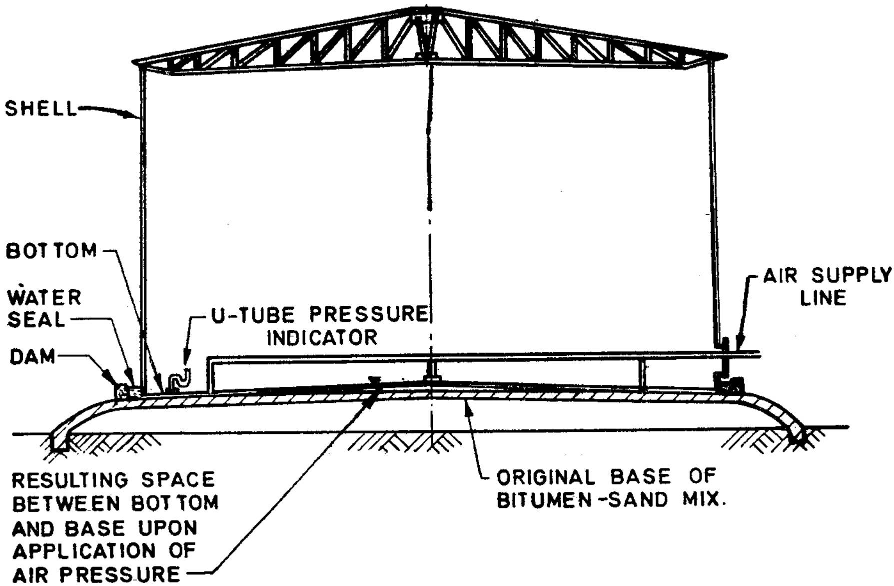
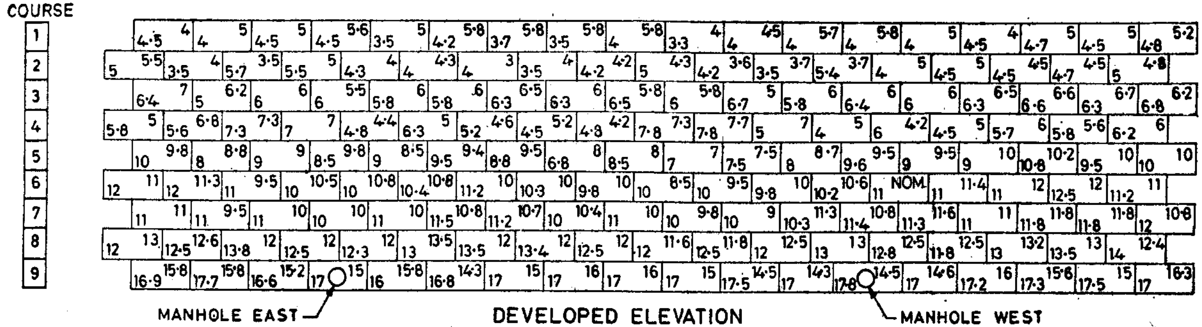


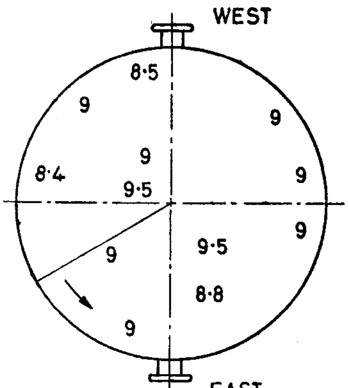
FIG. 3 APPLICATION OF PNEUMATIC TEST

APPENDIX F

TYPICAL EXAMPLE REPORT ON ULTRASONIC MEASUREMENTS



DEVELOPED ELEVATION
OF SHELL VIEWED EXTERNALLY



PLAN VIEW

WELDED JOINT EFFICIENCY, E = 0·95

BUTT WELDED: YES

LAP WELDED : —

RIVETED : —

COURSE	SHELL THICKNESS, mm							
	ORIGINAL NOMINAL	Min. ALLOWABLE FOR S=200MPa AND G=1	MEASURED					
			INSPECTION DATE 1968		PREVIOUS INSPECTION DATE (AVERAGE)			
			MIN	AVG	1955	1963		
1	6·5	4	3·3	4·5	5·2	4·8		
2	6·5	4	3	4·4	5·1	4·6		
3	8·1	5·5	5	6·1	7	6·8		
4	10	7	4	5·8	7·5	6·5		
5	12	9	7	9	10·5	10		
6	14	11	8·5	10·6	13	11·5		
7	15	11·5	9·3	10·8	13·1	11·7		
8	16·5	12·5	11·6	12·6	15·2	14		
9	18·5	14	14·3	16·1	17·2	16·7		

NOTE — Tanks to be ultrasonically measured from outside. However, externally insulated tanks to be measured from inside.

APPENDIX G

(*Clause* 11.1.1)

TYPICAL EXAMPLE OF ROOF STRUCTURE MEASUREMENTS

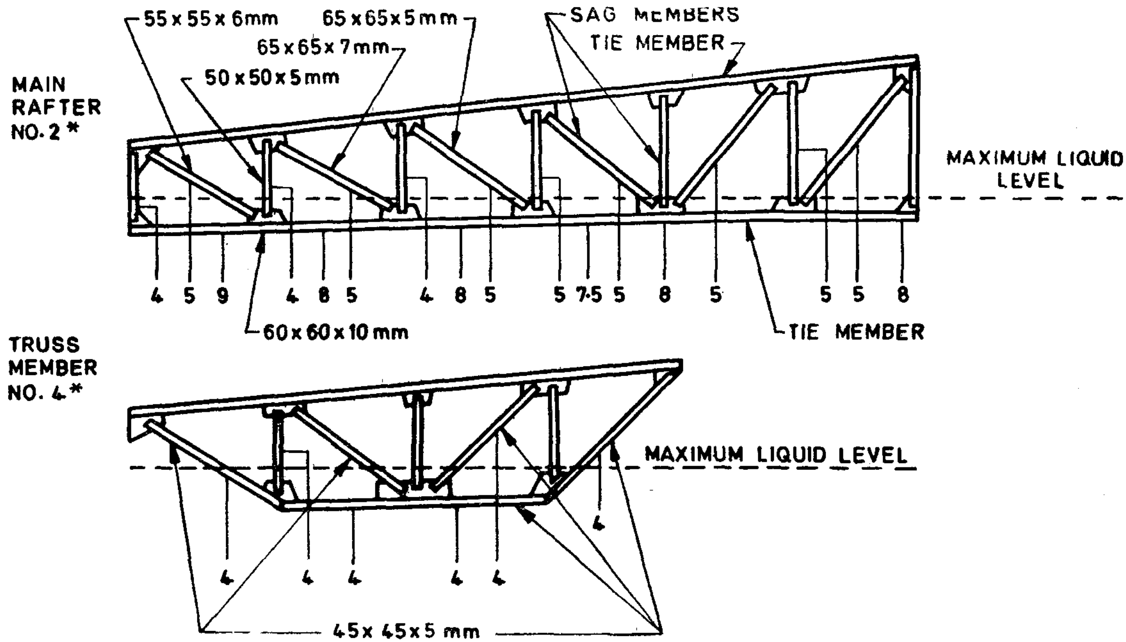


FIG. 4 TYPICAL EXAMPLE OF ROOF STRUCTURE MEASUREMENTS

Subcommittee for Use of Steel in Oil and Gas Storage Tanks, SMBDC 7 : 3

Convener	*Representing*
SHRI P. C. SILAICHIA	Bharat Petroleum Corporation Ltd, Bombay
Members	
SHRI C. S. R. ULLAL (*Alternate* to Shri P. C. Silaichia)	
SHRI HARCHARAN SINGH	The Fertilizer Corporation of India Ltd, Sindri
SHRI S. K. HAZRA	Engineers India Ltd, New Delhi
SHRI A. S. MANGET (*Alternate*)	
SHRI C. D. KESWANI	Hindustan Petroleum Corporation Ltd, Bombay
SHRI I. N. MURTHY	Department of Explosives, Nagpur
SHRI CHARANJIT LAL (*Alternate*)	
SHRI M. D. PHANSE	Indian Oil Corporation Ltd, Refinery Division, New Delhi
SHRI P. C. JOHRI (*Alternate*)	
SHRI R. V. RAGHAVAN	Vijay Tanks and Vessels Pvt Ltd, Bombay
SHRI A. THIRUNARAYANAN (*Alternate*)	
SHRI T. K. RAMANATHAN	Triveni Structurals Ltd, Allahabad
SHRI V. R. K. MURTHY (*Alternate*)	
SHRI A. P. RAO	Bharat Heavy Plate and Vessels Ltd, Visakhapatnam
SHRI V. S. PRASADARAO (*Alternate*)	