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Indian Standard

CODE OF PRACTICE FOR DESIGN, FABRICATION AND ERECTION OF VERTICAL MILD STEEL CYLINDRICAL WELDED OIL STORAGE TANKS

(First Revision)

(Incorporating Amendment No. 1)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Price Group 14

Indian Standard

CODE OF PRACTICE FOR DESIGN, FABRICATION AND ERECTION OF VERTICAL MILD STEEL CYLINDRICAL WELDED OIL STORAGE TANKS

(First Revision)

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CONTENTS

Indian Standard

CODE OF PRACTICE FOR DESIGN, FABRICATION AND ERECTION OF VERTICAL MILD STEEL CYLINDRICAL WELDED OIL STORAGE TANKS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 27 September 1976, 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 This code has been prepared with a view to providing the petroleum industry with tanks of adequate safety and reasonable economy which can be built in any size required to meet the needs of the industry subject to limitations given in the code and also to establishing uniform practice for design, fabrication, erection, testing and inspection of oil storage tanks.

0.3 This code does not present nor it is contemplated to establish, a fixed series of allowable tank sizes; but it is intended to promote the selection by the purchaser, of the size of tank that may be required to meet his particular need.

0.4 This standard was first published in 1962. The following modifications have been made in this revision:

a) The use of steel conforming to IS : 226-1975*, IS : 2002-1962†, IS : 2041-1962‡ and IS : 961-1975§ has been permitted in addition to steel conforming to IS : 2062-1969||.

b) Provisions regarding design of various members of the tank have been elaborated, an appendix dealing with the alternate design for tank shell has been included.

c) Provisions regarding radiographic inspection of shell joints have been made.

d) An appendix dealing with the normal and emergency venting requirements of the tanks has been added.

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*Specification for structural steel (standard quality) (*fifth revision*).

†Specification for steel plates for boilers.

‡Specification for steel plates for pressure vessels.

§Specification for structural steel (high tensile) (*second revision*).

||Specification for structural steel (fusion welding quality) (*first revision*).

e) An appendix furnishing the design and construction requirements of pontoon type, double deck type floating roof tanks has also been included in this code.

0.5 This edition 2.1 incorporates Amendment No. 1 (November 1984). Side bar indicates modification of the text as the result of incorporation of the amendment.

0.6 For the purpose of deciding whether a particular requirement of this code is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this code.

1. SCOPE

1.1 This code covers materials, design, fabrication, erection and testing requirements for mild steel cylindrical welded oil storage tanks in various sizes and capacities, for erection above ground, of the following designs:

a) Fixed roof tanks (*see* Fig. 1) having no internal pressure or nominal internal pressure where the resultant upward force does not exceed the nominal weight of metal in tank shell, roof and any framing supported by the shell or roof; and

b) Open top tanks (*see* Fig. 2).

1.1.1 This code specifies the use of only butt welded shells and includes reference to appurtenances and mountings.

1.2 This code is complementary to IS : 800-1962† and IS : 816-1969‡. Provisions regarding permissible stresses, design, fabrication and erection as included in IS : 800-1962† shall apply unless specified otherwise in this code.

1.3 This code is intended to guide both purchasers and manufacturers of petroleum products storage tanks. Provisions of this code may also be applied to design and construct tanks for storage of water, acids and chemicals. In such cases, special considerations regarding lining, corrosion allowance and foundation shall be made while designing the tanks for the intended service.

2. DEFINITIONS AND SYMBOLS

2.1 For the purpose of this code, the definitions for welding terms employed in this standard shall be according to IS : 812-1957§.

2.2 Symbols for welding used on plans and drawings shall be according to IS : 813-1961||.

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*Rules for rounding off numerical values (*revised*).

†Code of practice for use of structural steel in general building construction (*revised*).

‡Code of practice for use of metal arc welding for general construction in mild steel (*first revision*).

§Glossary of terms relating to welding and cutting of metals.

||Scheme of symbols for welding (*amended*).

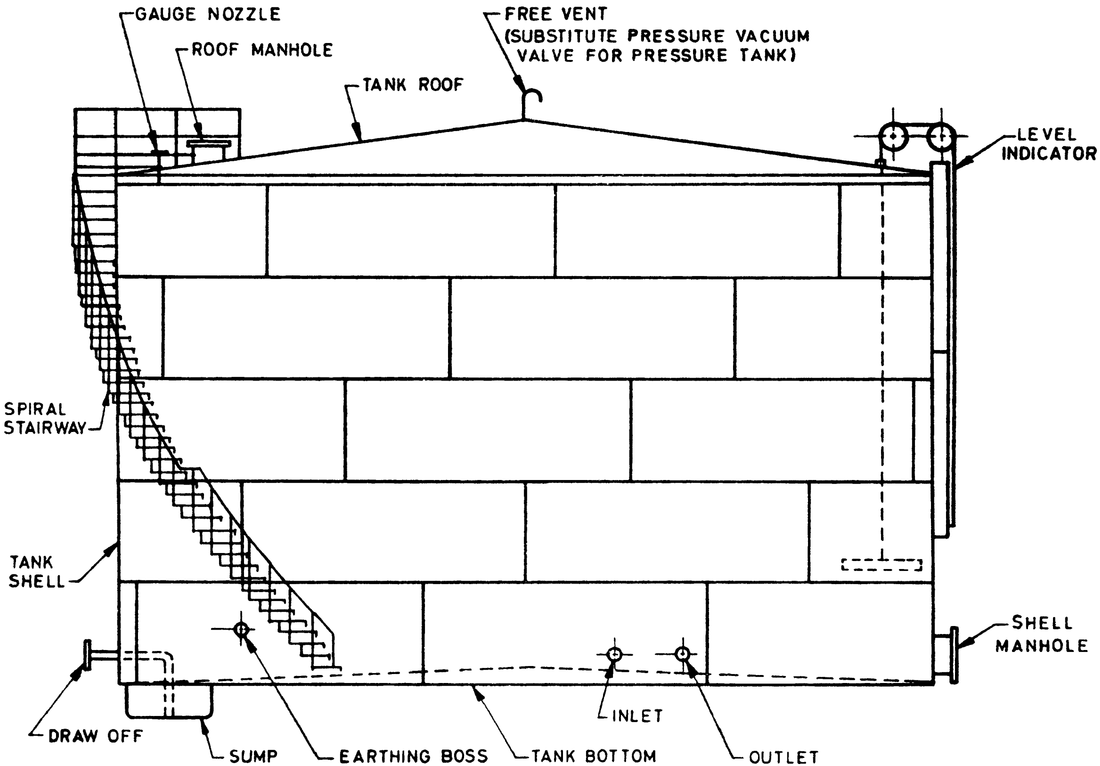

FIG. 1 TYPICAL FIXED ROOF TANK SHOWING STANDARD APPURTENANCES

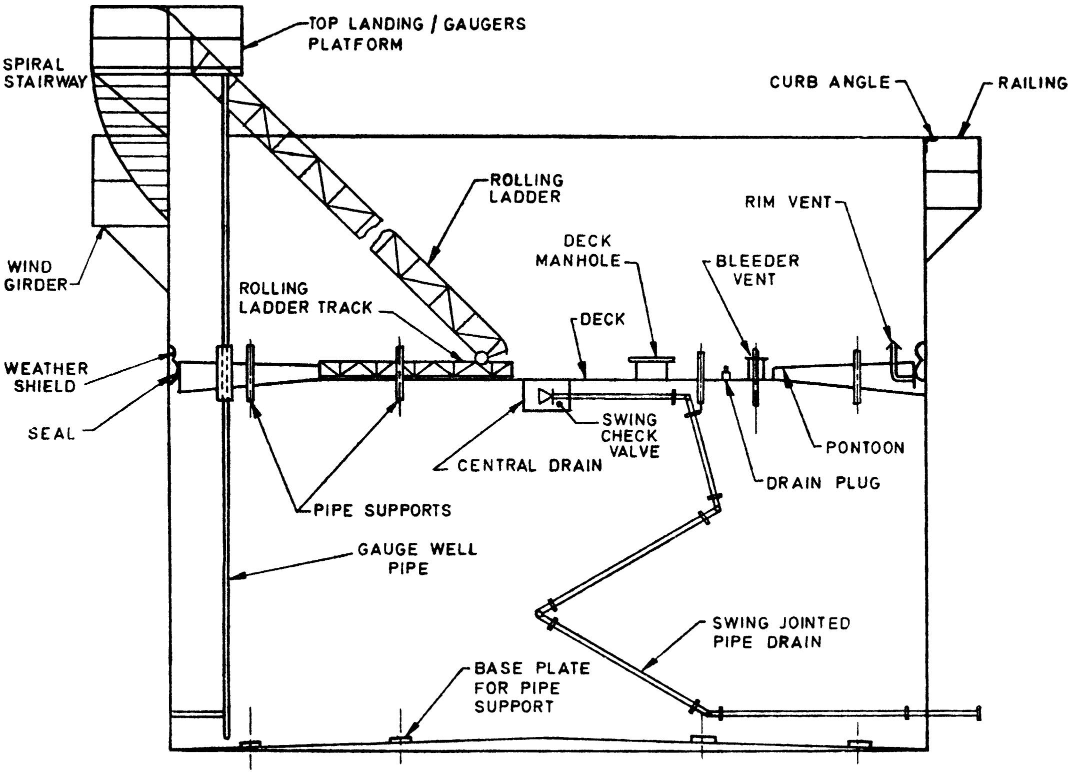

FIG. 2 TYPICAL OPEN TOP TANK WITH FLOATING ROOF — SECTIONAL VIEW

3. GENERAL

3.1 Tanks may be manufactured from suitable sizes of plates which have been covered in IS : 1730 (Part I)-1975*.

3.2 Tables 1 to 6 (*see* P 11 to 13) present for ready reference, typical data in regard to nominal sizes, nominal capacities and shell plate thicknesses for tanks which may be built in accordance with this code.

3.3 Enquiries or Order Form — With a view to facilitating the manufacture and supply of welded oil storage tanks, certain detailed information is to be supplied to the manufacturer. The information so required is listed in Appendix A.

4. MATERIALS

4.0 General — Unless mutually agreed otherwise, the material for the construction of oil storage tanks shall conform to Indian Standards where applicable.

4.1 Plates — Plates used in tank construction shall conform to any one of the following specifications:

IS : 226-1975 Structural steel (standard quality) (*fifth revision*)
(For up to 20 mm thickness. Thicker plates may be used provided the manufacturer establishes appropriate welding procedures recommended in IS : 823-1964† to the satisfaction of the purchaser)

IS : 961-1975 Structural steel (high tensile) (*second revision*)

IS : 2002-1962 Steel plates for boilers (Grade 2B)

IS : 2041-1962 Steel plates for pressure vessels

IS : 2062-1969 Structural steel (fusion welding quality) (*first revision*)

4.1.1 Plates for use in the manufacture of tanks shall be on thickness basis which are determined by design computations. Shell plates, for which minimum thicknesses are fixed in **6.3.3** for practical reasons and which will not underrun the theoretical required thickness by more than the minus tolerance specified in 1852-1973‡ and roof and bottom plates may be specified on weight basis. The plate thicknesses as stipulated in this standard are minimum; thicker or heavier material may be required depending on the nature of stored product, and the environment where the tank is located.

4.1.2 Steel conforming to IS : 1977-1975§ may also be used in tank construction subject to limitations under **0.3** of that specification.

*Dimensions for steel plate, sheet and strip for structural and general engineering purposes: Part I Plate (*first revision*).

†Code of procedure for manual metal arc welding of mild steel.

‡Specification for rolling and cutting tolerances for hot-rolled steel products (*second revision*).

§Specification for structural steel (ordinary quality) (*second revision*).

TABLE 1 NOMINAL CAPACITIES OF TYPICAL TANKS FOR PLATE WIDTH 1.5 m

(*Clause* 3.2)

TANK DIAMETER, m	3.0	4.5	5.0	6.0	7.5	9.0	10.0	12.0	14.0	16.0	18.0	20.0	22	24	26	28	30	32
TANK HEIGHT, m	NOMINAL CAPACITY, kl																	
1.5	10	23	29	42	66	95	117	169	230	301	381	471	569	678	795	923	1 059	1 205
3.0	21	47	58	84	132	190	235	339	461	602	763	942	1 139	1 356	1 591	1 846	2 119	2 411
4.5	31	71	88	127	198	286	353	508	692	904	1 144	1 413	1 709	2 034	2 387	2 769	3 179	3 617
6.0	42	95	117	169	264	381	471	678	923	1 205	1 526	1 884	2 279	2 712	3 183	3 692	4 239	4 823
7.5	52	119	147	211	331	476	588	847	1 153	1 507	1 907	2 355	2 849	3 391	3 979	4 615	5 298	6 028
9.0	63	143	176	254	397	572	706	1 017	1 384	1 808	2 289	2 826	3 419	4 069	4 775	5 538	6 358	7 234
10.5	74	166	206	296	463	667	824	1 186	1 615	2 110	2 670	3 297	3 989	4 747	5 571	6 462	7 418	8 440
12.0	84	190	235	339	529	763	942	1 356	1 846	2 411	3 052	3 768	4 559	5 425	6 367	7 385	8 478	9 646
13.5	95	214	264	381	596	858	1 059	1 526	2 077	2 712	3 433	4 239	5 129	6 104	7 163	8 308	9 537	10 851
15.0	105	238	294	423	662	953	1 177	1 695	2 307	3 014	3 815	4 710	5 699	6 782	7 959	9 231	10 597	12 057
16.5	116	262	323	466	728	1 049	1 295	1 865	2 538	3 315	4 196	5 181	6 269	7 460	8 755	10 154	11 657	13 263
18.0	127	286	353	508	7 948	1 144	1 413	2 034	2 769	3 617	4 578	5 652	6 838	8 138	9 551	11 077	12 717	14 469

(*Continued*)

TABLE 1 NOMINAL CAPACITIES OF TYPICAL TANKS FOR PLATE WIDTH 1.5 m — *Contd*

TANK DIAMETER, m	34	36	38	40	42	44	46	48	50	54	58	62	66	70	74	78	82
TANK HEIGHT, m	NOMINAL CAPACITY, kl																
1.5	1 361	1 526	1 700	1 884	2 077	2 279	2 491	2 712	2 943	3 433	3 961	4 526	5 129	5 769	6 447	7 163	7 917
3.0	2 722	3 052	3 400	3 768	4 154	4 559	4 983	5 425	5 887	6 867	7 922	9 052	10 258	11 539	12 895	14 327	15 835
4.5	4 083	4 578	5 100	5 652	6 231	6 838	7 474	8 138	8 831	10 300	11 883	13 578	15 387	17 309	19 343	21 491	23 752
6.0	5 444	6 104	6 801	7 536	8 308	9 118	9 966	10 851	11 775	13 734	15 844	18 105	20 516	23 079	25 791	28 655	31 670
7.5	6 805	7 630	8 501	9 420	10 385	11 398	12 457	13 564	14 718	17 167	19 805	22 631	25 645	28 848	32 239	35 819	39 587
9.0	8 167	9 156	10 201	11 304	12 462	13 677	14 949	16 277	17 662	20 601	23 766	27 157	30 775	34 618	38 687	42 983	47 505
10.5	9 528	10 682	11 902	13 188	14 539	15 957	17 441	18 990	20 606	24 035	27 727	31 684	35 904	40 388	45 135	50 147	55 422
12.0	10 889	12 208	13 602	15 072	16 616	18 237	19 932	21 703	23 550	27 468	31 688	36 210	41 033	46 158	51 583	57 311	63 340
13.5	12 250	13 734	15 302	16 956	18 693	20 516	22 424	24 416	26 493	30 902	35 649	40 736	46 162	51 927	58 031	64 475	71 257
15.0	13 611	15 260	17 003	18 840	20 771	22 796	24 915	27 129	29 437	34 335	39 611	45 263	51 291	57 697	64 479	71 639	79 175
16.5	14 973	16 786	18 703	20 724	22 848	25 076	27 407	29 842	32 381	37 769	43 572	49 789	56 421	63 467	70 927	78 803	87 092
18.0	16 334	18 312	20 403	22 608	24 925	27 355	29 899	32 555	35 325	41 203	47 533	54 315	61 550	69 237	77 375	85 966	95 010

TABLE 2 NOMINAL CAPACITIES OF TYPICAL TANKS FOR PLATE WIDTH 1.8 m

(*Clause* 3.2)

TANK DIAMETER, m	3.0	4.5	5.0	6.0	7.5	9.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0
TANK HEIGHT, m	NOMINAL CAPACITY, kl																	
1.8	12	28	35	50	79	114	141	203	276	361	457	565	683	813	955	1 107	1 271	1 446
3.6	25	57	70	101	158	228	282	406	553	723	915	1 130	1 367	1 627	1 900	2 215	2 543	2 893
5.4	38	85	105	152	238	343	423	610	830	1 085	1 375	1 695	2 051	2 441	2 865	3 323	3 815	4 340
7.2	50	114	141	203	317	457	565	813	1 107	1 446	1 831	2 260	2 735	3 255	3 820	4 431	5 086	5 787
9.0	63	143	176	254	397	572	706	1 017	1 384	1 808	2 289	2 826	3 419	4 069	4 775	5 538	6 358	7 234
10.8	76	171	211	305	476	686	847	1 220	1 661	2 170	2 746	3 391	4 103	4 883	5 731	6 646	7 630	8 681
12.6	89	200	247	356	556	801	989	1 424	1 938	2 532	3 204	3 956	4 787	5 697	6 686	7 754	8 901	10 128
14.4	101	228	282	406	635	915	1 130	1 627	2 215	2 893	3 662	4 521	5 471	6 511	7 641	8 862	10 173	11 575
16.2	114	257	317	457	715	1 030	1 271	1 831	2 492	3 255	4 120	5 086	6 155	7 324	8 596	9 970	11 445	13 022
18.0	127	286	353	508	794	1 444	1 413	2 034	2 769	3 617	4 578	5 652	6 838	8 138	9 551	11 077	12 717	14 469
19.8	139	314	388	559	874	1 258	1 554	2 238	3 046	3 979	5 035	6 217	7 522	8 952	10 507	12 185	13 988	15 916
21.6	152	345	423	610	953	1 373	1 695	2 441	3 323	4 340	5 493	6 782	8 206	9 766	11 462	13 293	15 260	17 362

(*Continued*)

TABLE 2 NOMINAL CAPACITIES OF TYPICAL TANKS FOR PLATE WIDTH 1.8 m — *Contd*

TANK DIAMETER, m	34.0	36.0	38.0	40.0	42.0	44.0	46.0	48.0	50.0	54.0	58.0	62.0	66.0	70.0	74.0	78.0	82.0
TANK HEIGHT, m	NOMINAL CAPACITY, kl																
1.8	1 633	1 831	2 040	2 260	2 492	2 735	2 989	3 255	3 532	4 120	4 753	5 431	6 155	6 923	7 737	8 596	9 501
3.6	3 266	3 662	4 080	4 521	4 985	5 471	5 979	6 511	7 065	8 240	9 506	10 863	12 310	13 847	15 475	17 193	19 002
5.4	4 900	5 493	6 121	6 782	7 477	8 206	8 969	9 766	10 597	12 360	14 259	16 294	18 465	20 771	23 212	25 790	28 503
7.2	6 533	7 324	8 161	9 043	9 970	10 942	11 959	13 022	14 130	16 481	19 013	21 726	24 620	27 694	30 950	34 386	38 004
9.0	8 167	9 156	10 201	11 304	12 462	13 677	14 949	16 277	17 662	20 601	23 766	27 157	30 775	34 618	38 687	42 983	47 505
10.8	9 800	10 987	12 242	13 564	14 955	16 413	17 939	19 533	21 195	24 721	28 519	32 589	36 930	41 542	46 425	51 580	57 006
12.6	11 433	12 818	14 282	15 825	17 447	19 148	20 929	22 788	24 727	28 842	33 273	38 021	43 085	48 465	54 163	60 176	66 507
14.4	13 067	14 649	16 322	18 086	19 940	21 884	23 919	26 044	28 260	32 962	38 026	43 452	49 240	55 389	61 900	68 773	76 008
16.2	14 700	16 481	18 363	20 347	22 432	24 620	26 909	29 299	31 792	37 082	42 779	48 884	55 395	62 313	69 638	77 370	85 509
18.0	16 334	18 312	20 403	22 608	24 925	27 355	29 899	32 555	35 325	41 203	47 533	54 315	61 550	69 273	77 375	85 966	95 010
19.8	17 967	20 143	22 444	24 868	27 417	30 091	32 888	35 811	38 857	45 323	52 286	59 747	67 705	76 160	85 113	94 563	104 511
21.6	19 601	21 974	24 484	27 129	29 910	32 826	35 897	39 066	42 390	49 443	57 039	65 178	73 860	83 084	92 851	103 160	114 012

TABLE 3 NOMINAL CAPACITIES OF TYPICAL TANKS FOR PLATE WIDTH 2.0 m

(*Clause* 3.2)

Tank Diameter, m	3.0	4.5	5.0	6.0	7.5	9.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0
Tank Height, m	Nominal Capacity, kl																	
2	14	31	39	56	88	127	157	226	307	402	508	628	760	904	1 089	1 231	1 413	1 608
4	28	63	78	113	176	254	314	452	615	804	1 017	1 256	1 520	1 059	2 123	2 463	2 827	3 217
6	42	95	117	169	265	381	471	678	923	1 206	1 526	1 884	2 280	2 714	3 185	3 694	4 241	4 825
8	56	127	157	226	353	508	628	904	1 231	1 608	2 035	2 513	3 041	3 619	4 247	4 956	5 654	6 434
10	70	159	196	282	441	636	785	1 130	1 539	2 010	2 544	3 141	3 801	4 523	5 309	6 157	7 068	8 042
12	84	190	235	339	530	763	942	1 357	1 847	2 412	3 053	3 769	4 561	5 428	6 371	7 389	8 482	9 650
14	98	222	274	395	618	890	1 099	1 583	2 155	2 814	3 562	4 398	5 321	6 333	7 433	8 620	9 896	11 259
16	113	254	314	452	706	1 017	1 256	1 809	2 463	3 216	4 071	5 026	6 082	7 238	8 494	9 852	11 309	12 867
18	127	286	353	508	795	1 145	1 413	2 035	2 770	3 619	4 580	5 654	6 842	8 143	9 556	11 083	12 723	14 476
20	141	318	392	565	883	1 272	1 570	2 261	3 078	4 021	5 089	6 283	7 602	9 047	10 618	12 315	14 137	16 084
22	155	349	431	622	971	1 399	1 727	2 488	3 386	4 423	5 598	6 911	8 362	9 952	11 680	13 546	15 550	17 693

(*Continued*)

TABLE 3 NOMINAL CAPACITIES OF TYPICAL TANKS FOR PLATE WIDTH 2.0 m — *Contd*

Tank Diameter, m	34.0	36.0	38.0	40.0	42.0	44.0	46.0	48.0	50.0	54.0	58.0	62.0	66.0	70.0	74.0	78.0	82.0
Tank Height, m	Nominal Capacity, kl																
2	1 815	2 035	2 268	2 513	2 770	3 041	3 323	3 619	3 927	4 580	5 284	6 038	6 842	7 696	8 601	9 556	10 562
4	3 631	4 071	4 536	5 026	5 541	6 082	6 647	7 238	7 854	9 160	10 568	12 076	13 684	15 393	17 203	19 113	21 124
6	5 447	6 107	6 804	7 539	8 312	9 123	9 971	10 857	11 781	13 741	15 852	18 114	20 572	23 090	25 805	28 670	31 686
8	7 263	8 143	9 072	11 053	11 083	12 164	13 295	14 476	15 707	18 321	21 136	24 152	27 369	30 787	34 406	38 226	42 248
10	9 079	10 178	11 341	12 566	13 854	15 205	16 619	18 095	19 634	22 902	26 420	30 190	34 211	38 484	43 008	47 783	52 810
12	10 895	12 214	13 609	15 079	16 625	18 246	19 842	21 714	23 561	27 482	31 704	36 228	41 054	46 181	51 610	57 340	63 372
14	12 710	14 250	15 877	17 592	19 396	21 287	23 266	25 333	27 488	32 063	36 989	42 267	47 896	53 878	60 211	66 897	73 934
16	14 526	16 286	18 145	20 106	22 167	24 328	26 590	28 952	31 415	36 643	42 273	48 305	54 739	61 575	68 813	76 453	84 496
18	16 342	18 321	20 414	22 619	24 937	27 369	29 914	32 572	35 342	41 224	47 575	54 343	61 581	69 272	77 415	86 010	95 058
20	18 158	20 357	22 682	25 132	27 708	30 410	33 239	36 191	39 269	45 804	52 841	60 381	68 423	76 969	86 016	95 520	105 620
22	19 974	22 393	24 950	27 646	30 479	33 451	36 561	39 810	43 196	50 384	58 125	66 419	75 266	84 665	94 618	105 124	116 182

TABLE 4 MINIMUM CALCULATED SHELL PLATE THICKNESS FOR TYPICAL TANKS FOR PLATE WIDTH 1.5 m

(Using plates conforming to IS : 226 or IS : 2062; E = 0.85 and sp gr = 1; excluding corrosion allowance)

(*Clause* 3.2)

TANK DIAMETER, m	3.0	4.5	5.0	6.0	7.5	9.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0
TANK HEIGHT, m	PLATE THICKNESS, mm																	
1.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
3.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
4.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
6.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.4
7.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.1	6.6	7.1	7.6	8.1
9.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.1	6.7	7.3	7.9	8.5	9.1	9.7
10.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.4	7.1	7.9	8.6	9.3	10.0	10.7	11.4
12.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.7	6.6	7.4	8.2	9.0	9.8	10.7	11.5	12.3	13.1
13.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.5	6.5	7.4	8.3	9.2	10.2	11.1	12.0	12.9	13.9	14.8
15.0	5.0	5.0	5.0	5.0	5.0	5.0	5.1	6.2	7.2	8.2	9.3	10.3	11.3	12.4	13.4	14.4	15.4	16.5
16.5	5.0	5.0	5.0	5.0	5.0	5.1	5.7	6.8	7.9	9.1	10.2	11.3	12.5	13.6	14.7	15.9	17.0	18.2
18.0	5.0	5.0	5.0	5.0	5.0	5.6	6.2	7.4	8.7	9.9	11.2	12.4	13.6	14.9	16.1	17.4	18.6	19.8

(*Continued*)

TABLE 4 MINIMUM CALCULATED SHELL PLATE THICKNESS FOR TYPICAL TANKS FOR PLATE WIDTH 1.5 m — *Contd*

(Using plates conforming to IS : 226 or IS : 2062; E = 0.85 and sp gr = 1; excluding corrosion allowance)

TANK DIAMETER, m	34.0	36.0	38.0	40.0	42.0	44.0	46.0	48.0	50.0	54.0	58.0	62.0	66.0	70.0	74.0	78.0	82.0
TANK HEIGHT, m	PLATE THICKNESS, mm																
1.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
3.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.2	6.6	7.0	7.4	7.8
4.5	6.0	6.0	6.0	6.0	6.2	6.5	6.8	7.1	7.4	7.9	8.5	9.1	9.7	10.3	10.9	11.5	12.1
6.0	6.8	7.2	7.6	8.0	8.4	8.8	9.2	9.6	10.0	10.8	11.6	12.4	13.2	14.0	14.8	15.6	16.4
7.5	8.6	9.1	9.6	10.1	10.6	11.1	11.6	12.1	12.6	13.6	14.6	15.6	16.6	17.6	18.7	19.7	20.7
9.0	10.4	11.0	11.6	12.2	12.8	13.4	14.0	14.6	15.2	16.4	17.7	18.9	20.1	21.3	22.5	23.8	25.0
10.5	12.1	12.9	13.6	14.3	15.0	15.7	16.4	17.1	17.9	19.8	20.7	22.1	23.6	25.0	26.4	27.9	29.3
12.0	13.9	14.7	15.6	16.4	17.2	18.0	18.8	19.7	20.5	22.1	23.8	25.4	27.0	28.7	30.3	32.0	33.6
13.5	15.7	16.6	17.6	18.5	19.4	20.3	21.3	22.2	23.1	25.0	26.8	28.7	30.5	32.4	34.2	36.1	37.9
15.0	17.5	18.5	19.6	20.6	21.6	22.6	23.7	24.7	25.7	27.8	29.9	31.9	34.0	36.0	38.1	—	—
16.5	18.3	20.4	21.6	22.7	23.8	25.0	26.1	27.2	28.4	30.6	32.9	35.2	37.4	39.7	—	—	—
18.0	21.1	22.3	23.6	24.8	26.0	27.3	28.5	29.7	31.0	33.5	35.8	38.4	—	—	—	—	—

TABLE 5 MINIMUM CALCULATED SHELL PLATE THICKNESS FOR TYPICAL TANKS FOR PLATE WIDTH 1.8 m

(Using plates conforming to IS : 226 or IS : 2062; *E* = 0.85 and sp gr = 1; excluding corrosion allowance)

(*Clause* 3.2)

TANK DIAMETER, m	3.0	4.5	5.0	6.0	7.5	9.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0
TANK HEIGHT, m	PLATE THICKNESS, mm																	
1.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
3.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
5.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
7.2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.3	6.8	7.2	7.7
9.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.1	6.7	7.3	7.9	8.5	9.1	9.7
10.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.1	6.0	6.6	7.4	8.1	8.8	9.6	10.3	11.0	11.8
12.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.2	6.0	6.9	7.8	8.6	9.5	10.3	11.2	12.1	12.9	13.8
14.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.9	6.9	7.9	8.9	9.9	10.9	11.8	12.8	13.8	14.8	15.8
16.2	5.0	5.0	5.0	5.0	5.0	5.0	5.6	6.7	7.8	8.9	10.0	11.1	12.2	13.4	14.5	15.6	16.7	17.8
18.0	5.0	5.0	5.0	5.0	5.0	5.6	6.2	7.4	8.7	9.9	11.1	12.4	13.6	14.9	16.1	17.4	18.6	19.8
19.8	5.0	5.0	5.0	5.0	5.1	6.1	6.8	8.2	9.6	10.9	12.3	13.7	15.0	16.4	17.8	19.1	20.5	21.8
21.6	5.0	5.0	5.0	5.0	5.6	6.7	7.5	8.9	10.4	11.9	13.4	14.9	16.4	17.9	19.4	20.9	22.4	23.7

(*Continued*)

TABLE 5 MINIMUM CALCULATED SHELL PLATE THICKNESS FOR TYPICAL TANKS FOR PLATE WIDTH 1.8 m — *Contd*

(Using plates conforming to IS : 226 or IS : 2062; *E* = 0.85 and sp gr = 1; excluding corrosion allowance)

TANK DIAMETER, m	34.0	36.0	38.0	40.0	42.0	44.0	46.0	48.0	50.0	54.0	58.0	62.0	66.0	70.0	74.0	78.0	82.0
TANK HEIGHT, m	PLATE THICKNESS, mm																
1.8	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
3.6	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.2	6.7	7.2	7.6	8.1	8.6	9.0	9.5
5.4	6.1	6.4	6.8	7.1	7.5	7.9	8.2	8.6	8.9	9.6	10.4	11.1	11.8	12.5	13.2	13.9	14.6
7.2	8.2	8.7	9.2	9.7	10.1	10.6	11.1	11.6	12.1	13.0	14.0	15.0	15.9	16.9	17.9	18.8	19.8
9.0	10.4	11.0	11.6	12.2	12.8	13.4	14.0	14.6	15.2	16.4	17.7	18.9	20.1	21.3	22.5	23.8	25.0
10.8	12.5	13.2	14.0	14.7	15.4	16.2	16.9	17.6	18.4	19.9	21.3	22.8	24.3	25.7	27.2	28.7	30.1
12.6	14.6	15.5	16.4	17.2	18.1	18.9	19.8	20.7	21.5	23.3	25.0	26.7	28.4	30.1	31.9	33.6	35.3
14.4	16.8	17.8	18.8	19.7	20.7	21.7	22.7	23.7	24.7	26.7	28.6	30.6	32.6	34.6	36.5	38.5	—
16.2	18.9	20.0	21.2	22.3	23.4	24.5	25.6	26.7	27.8	30.1	32.3	34.5	36.7	39.0	—	—	—
18.0	21.1	22.3	23.6	24.8	26.0	27.3	28.5	29.7	31.0	33.5	35.9	38.4	—	—	—	—	—
19.8	23.2	24.6	25.9	27.3	28.7	30.0	31.4	32.8	34.1	36.9	39.6	—	—	—	—	—	—
21.6	25.4	26.8	28.3	29.8	31.3	32.8	34.3	35.8	37.3	—	—	—	—	—	—	—	—

TABLE 6 MINIMUM CALCULATED SHELL PLATE THICKNESS FOR TYPICAL TANKS FOR PLATE WIDTH 2.0 m

(Using plates conforming to IS : 226 or IS : 2062; *E* = 0.85 and sp gr = 1; excluding corrosion allowance)

(*Clause* 3.2)

TANK DIAMETER, m	3.0	4.5	5.0	6.0	7.5	9.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0
TANK HEIGHT, m	PLATE THICKNESS, mm																	
2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.4
8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.5	7.0	7.5	8.1	8.6
10	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.1	6.8	7.5	8.2	8.8	9.5	10.2	10.9
12	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.7	6.6	7.4	8.2	9.0	9.8	10.7	11.5	12.3	13.1
14	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.8	6.7	7.7	8.6	9.6	10.0	11.5	12.5	13.4	14.4	15.6
16	5.0	5.0	5.0	5.0	5.0	5.0	5.5	6.6	7.7	8.8	9.9	11.0	12.1	13.2	14.3	15.4	16.5	17.6
18	5.0	5.0	5.0	5.0	5.0	5.6	6.2	7.4	8.7	9.9	11.2	12.4	13.6	14.9	16.1	17.4	18.6	19.8
20	5.0	5.0	5.0	5.0	5.2	6.2	6.9	8.3	9.7	11.0	12.4	13.8	15.2	16.6	17.9	19.0	20.7	22.1
22	5.0	5.0	5.0	5.0	5.7	6.8	7.6	9.1	10.6	12.2	13.7	15.2	16.7	18.2	19.8	21.3	22.8	24.3

(*Continued*)

TABLE 6 MINIMUM CALCULATED SHELL PLATE THICKNESS FOR TYPICAL TANKS FOR PLATE WIDTH 2.0 m — *Contd*

(Using plates conforming to IS : 226 or IS : 2062; *E* = 0.85 and sp gr = 1; excluding corrosion allowance)

(*Clause* 3.2)

TANK DIAMETER, m	34.0	36.0	38.0	40.0	42.0	44.0	46.0	48.0	50.0	54.0	58.0	62.0	66.0	70.0	74.0	78.0	82.0
TANK HEIGHT, m	PLATE THICKNESS, mm																
2	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
4	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.2	6.5	7.0	7.5	8.0	8.6	9.1	9.6	10.1	10.6
6	6.8	7.2	7.8	8.0	8.4	8.8	9.2	9.6	10.0	10.8	11.6	12.4	13.2	14.0	14.8	15.6	16.4
8	9.2	9.7	10.2	10.8	11.3	11.9	12.4	12.9	13.5	14.6	15.6	16.7	17.8	18.9	20.0	21.0	22.1
10	11.5	12.2	12.9	13.6	14.3	14.9	15.6	16.3	17.0	18.3	19.7	21.1	22.4	23.8	25.1	26.5	27.9
12	13.9	14.7	15.6	16.4	17.2	18.0	18.8	19.7	20.5	22.1	23.8	25.4	27.0	28.7	30.3	32.0	33.6
14	16.3	17.3	18.2	19.2	20.1	21.1	22.1	23.0	24.0	25.9	27.8	29.7	31.7	33.6	35.5	37.4	39.3
16	18.7	19.8	20.9	22.0	23.1	24.2	25.3	26.4	27.5	29.7	31.9	34.1	36.3	38.5	—	—	—
18	21.1	22.3	23.6	24.8	26.0	27.3	28.5	29.7	31.0	33.5	35.9	38.4	—	—	—	—	—
20	23.5	24.8	26.2	27.6	29.0	30.4	31.7	33.1	34.5	37.2	—	—	—	—	—	—	—
22	25.8	27.4	28.9	30.4	31.9	33.4	35.0	36.5	38.0	—	—	—	—	—	—	—	—

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4.1.3 Plate materials specified in **4.1** shall be used without impact testing on tank shells and its reinforcements for design metal temperatures greater than 10°C.

4.1.4 For temperature lower than 10°C and up to – 20°C, material listed in **4.1** with the exception of structural steel, conforming to IS : 226-1975*, shall be used, and shall demonstrate adequate notch toughness at the design metal temperature. Each plate as-rolled shall be impact-tested at the design metal temperature to show that the average of three charpy V-notch full size specimens is a minimum of 39 N.m (4 kgf.m) (longitudinal) or 25 N.m (2.5 kgf.m) (transverse).

4.2 Structural Sections — Dimensions of structural steel sections used in tank construction shall conform to IS : 808-1964† and IS : 808 (Part I)-1973‡.

4.3 Cast Steel Mountings — Cast steel mountings shall be suitable for welding and shall conform to Grade 3 of IS : 1030-1974§.

4.4 Electrodes — Electrodes for metal arc welding shall conform to IS : 814 (Part I)-1974|| and IS : 814 (Part II)-1974¶.

4.5 Piping — Unless specified otherwise, pipe and pipe couplings shall conform to IS : 1978-1971**. By agreement between the purchaser and the manufacturer, couplings for threaded connections may be supplied without recesses. When so supplied, the couplings in all other respects shall conform to IS : 1978-1971**. Pipe used for structural purposes shall conform to IS : 1978-1971** and IS : 1979-1971†† with respect to physical properties of the material. Pipes of heavy class conforming to IS : 1239 (Part II)-1969‡‡ may be used for nozzles on tank roofs and internal piping subject to agreement between the purchaser and the manufacturer.

4.6 Flanges — Plate ring flanges shall be made from any of the plate materials listed in **4.1**. Requirements of slip-on welding and welding neck flanges are covered in IS : 6392-1971§§.

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*Specification for structural steel (standard quality) (*fifth revision*).

†Specification for rolled steel beam, channel and angle sections (*revised*).

‡Dimensions for hot rolled steel beams: Part I MB series (*second revision*).

§Specification for steel castings for general engineering purposes (*second revision*).

||Specification for covered electrodes for metal arc welding of structural steels: Part I For welding products other than sheets (*fourth revision*).

¶Specification for covered electrodes for metal arc welding of structural steels: Part II For welding sheets (*fourth revision*).

**Specification for line pipe (*first revision*).

††Specification for high test line pipe (*first revision*).

‡‡Specification for mild steel tubes, tubulars and other wrought steel fittings: Part II Mild steel tubulars and other wrought steel pipe fittings (*second revision*).

§§Specification for steel pipe flanges.

4.7 Bolts and Nuts — Bolts shall conform to the requirements specified in IS : 1367-1967* for black grade bolts of class 4.6 or 4.8. Nuts shall be of black grade class 4. Screw threads shall conform to coarse series medium class referred in IS : 1367-1967*.

4.8 Other materials used in association with steelwork shall, where appropriate Indian Standard specifications for materials exist, conform to such specifications.

5. PERMISSIBLE STRESSES

5.1 Maximum allowable working stresses shall not exceed the following.

5.1.1 In the design of tank shells, the maximum tensile stress before applying the factor for joint efficiency shall be 165 N/mm^2 (1 680 kgf/cm^2) in case of steel conforming to IS : 2062-1969† and IS : 226-1975‡. For other grades of steels, maximum allowable stress shall be 0.7 of the minimum yield stress of each grade or 0.4 of the minimum ultimate tensile stress whichever is less.

5.1.2 Structural design stresses (not covered in **5.1.1**) shall conform to the allowable working stresses given in IS : 800-1962§. For this purpose steel conforming to IS : 2002-1962|| (Grade 2B) and IS : 2041-1962¶ (Type 1) should be treated as equivalent to IS : 226-1975‡ or IS : 2062-1969† whereas Type 2 steel conforming to IS : 2041-1962¶ shall be treated equivalent to IS : 961-1975**.

5.1.3 The above stresses are permissible for design temperatures of –10°C to +200°C, provided that below +10°C only semikilled or killed steels are used.

5.2 The permissible stresses for welds and welded connections shall conform to the values given in IS : 816-1969††.

6. DESIGN

6.0 General — Internal pressure of tanks designed in accordance with the rules and provisions made in this code shall not exceed the value given by:

$$P_{\max} = \frac{39W}{\pi D^2} + 77t, \text{ N/m}^2$$

or

$$= \frac{4W}{\pi D^2} + 7{\cdot}85t, \text{ kgf/m}^2$$

*Technical supply conditions for threaded fasteners (*first revision*).

†Specification for structural steel (fusion welding quality) (*first revision*).

‡Specification for structural steel (standard quality) (*fifth revision*).

§Code of practice for use of structural steel in general building construction (*revised*).

||Specification for steel plates for boilers.

¶Specification for steel plates for pressure vessels.

**Specification for structural steel (high tensile) (*second revision*).

††Code of practice for use of metal arc welding for general construction in mild steel (*first revision*).

where

P_{max} = internal pressure,

W = total weight of shell and structure supported by shell in N (kgf),

D = diameter of tank in m, and

t = thickness of roof in mm.

6.1 Foundation — Tanks shall be built on good foundations. Details of typical foundations normally adopted are shown in Fig. 3A and 3B respectively for earth foundation and concrete ringwall foundation. Where soil conditions are adverse, care should be taken to design the foundations properly such that no subsidence takes place.

6.2 Design of Bottom Plates

6.2.1 Bottom plate, uniformly resting on the ground or supporting substructure, shall conform to the following (*see* Fig. 4):

a) All bottom plates shall have a minimum nominal thickness of 6 mm.

b) All rectangular plates shall preferably have a minimum width of 1 500 mm. All sketch plates (bottom plates upon which the shell plate rests), which have one end rectangular shall also preferably have a minimum width of 1 500 mm for the rectangular end.

c) Bottom plates shall be of sufficient size so that when welded, at least a 25 mm width will project beyond the outside edge of the weld attaching the bottom to the shell plate.

NOTE — Bottom of excavation should be level. Remove muck, vegetation and unstable materials to whatever depth is necessary.

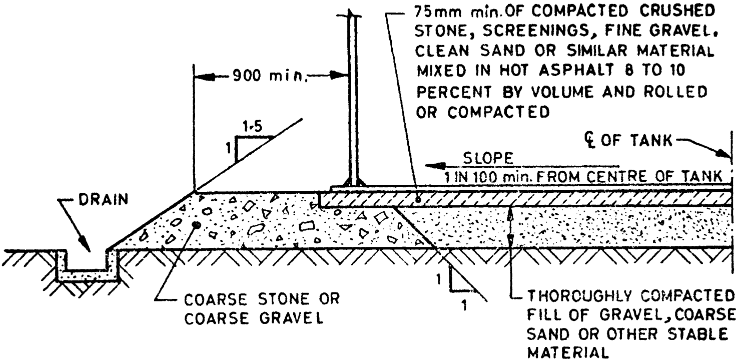
6.2.2 Bottoms shall be built according to either of the following two methods of construction:

a) Lap welded plates shall be reasonably rectangular and square edged. Three-plate laps shall not be closer than 300 mm from each other and also from the tank shell.

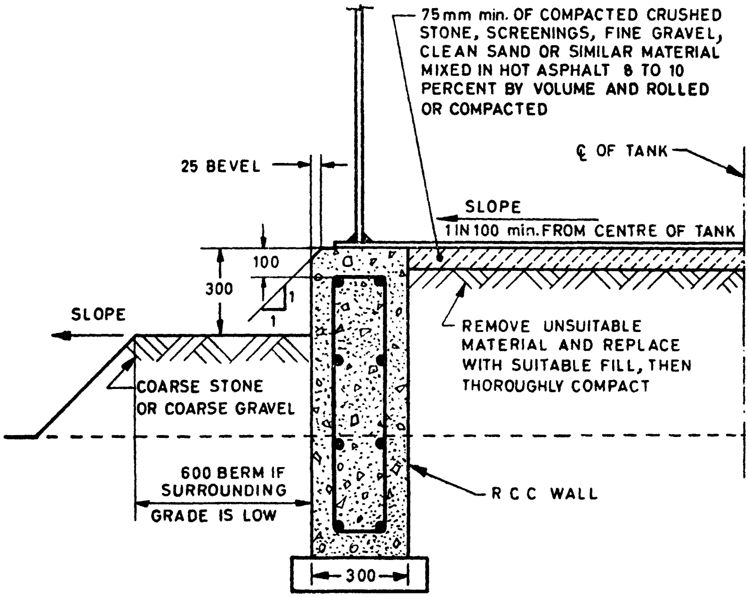
Plates shall be welded on top side only with a continuous fillet weld on all seams. Joints shall be lapped to 5 times the thickness of the thinner plate, but need not exceed 25 mm (*see* Fig. 4, Section BB).

Portion of the sketch plates coming under the bottom shell ring shall have the outer ends of the joints fitted and lap welded to form a smooth bearing for the shell plates, as shown in Fig. 5A.

Bottom plate attachment with the shell plate may be made by an annular ring of segmental plates as shown in Fig. 5B. Such annular rings, where used, shall have their radial seams butt welded with a backing strip as shown in the same figure. Bottom sketch and rectangular plates shall be lapped over the annular ring of segmental



3A Typical Earth Foundation

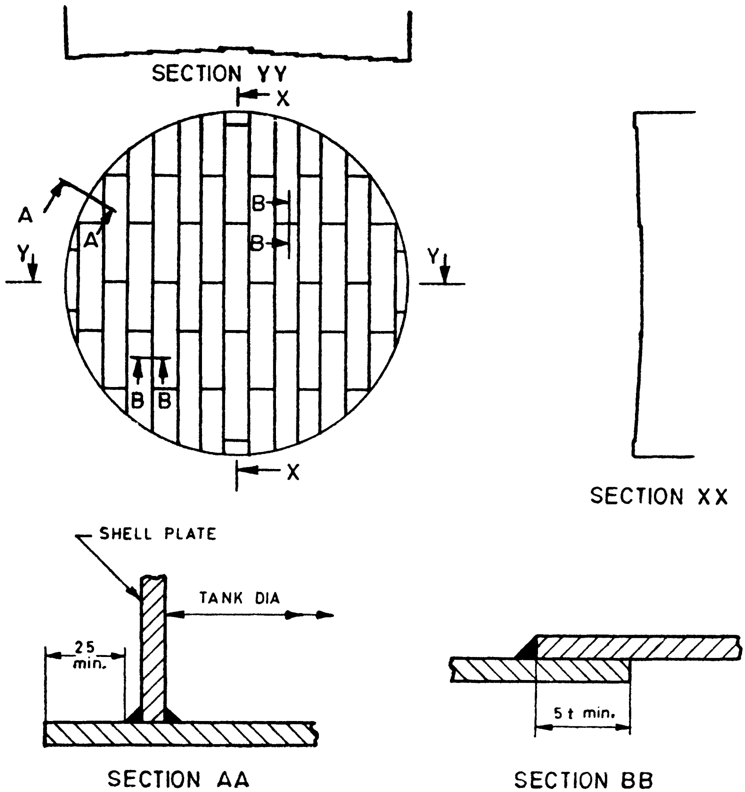


3B Typical Concrete Ringwall Foundation

All dimensions in millimetres.

FIG. 3 TYPICAL FOUNDATIONS

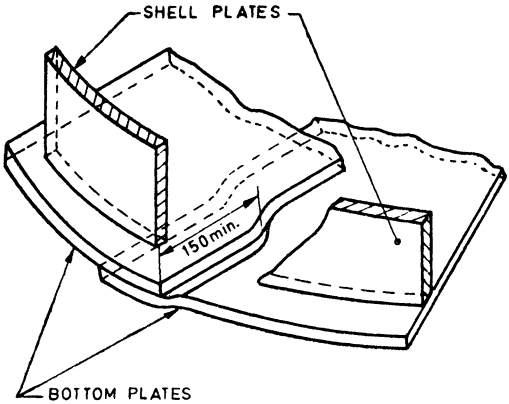
plates with the lap not less than five times the nominal thickness the thinner plates joined.



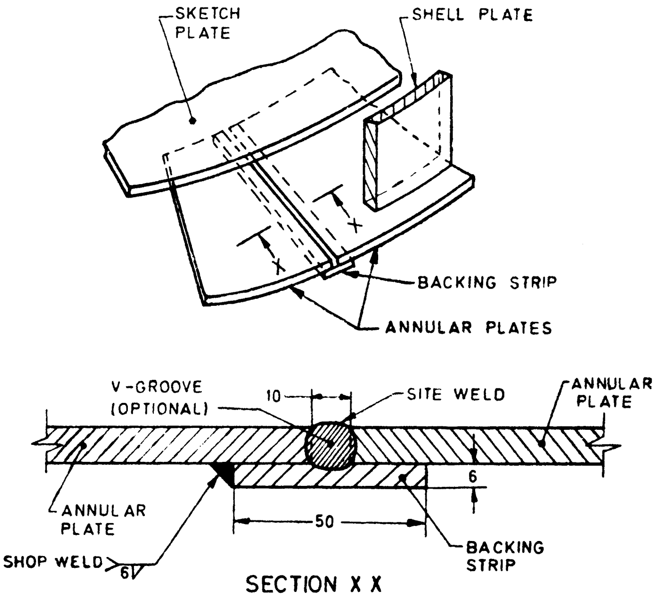
All dimensions in millimetres.

FIG. 4 TYPICAL LAYOUT OF TANK BOTTOM

b) Bottoms may be of butt welded construction. Plates shall have the parallel edges prepared for butt welding with either square or V-grooves. If square grooves are employed, the root opening shall be not less than 6 mm. The butt welds shall be made by applying a backing strip 3 mm thick or heavier by tack welding to the underside of the plate (*see* Fig. 5B, Section XX). A metal spacer shall be used, if necessary, to maintain the root opening between the adjacent plates. The manufacturer may submit the other methods of butt welding the bottom for the purchaser's approval. Three-plate joints shall not be closer than 300 mm from each other and also from the tank shell.



5A Preparation of Bottom Plates Under Tank Shell



5B Joint in Annular Plates Under Tank Shell

All dimensions in millimetres.

FIG. 5 BOTTOM PLATE ARRANGEMENT UNDER TANK SHELL

6.2.3 *Bottom Plate Resting on Piers*

6.2.3.1 For tanks erected on an elevated foundation, and the bottom plate supported on piers or beams, minimum thickness of bottom plate t_b in mm shall be obtained by the equation:

$$t_b = \sqrt{\frac{3\,G \times H_p \times l^2}{4\,S_b}}$$

where

G = specific gravity of stored product but not less than 1,

H_p = uniform loading on the bottom plate in N/mm^2 (kgf/cm^2) due to maximum head of water in the tank,

l = length of bottom plate in mm freely supported between the successive piers/beams, and

S_b = maximum allowable bending stress in plate in N/mm^2 (kgf/cm^2).

6.2.3.2 The thickness determined by **6.2.3.1** shall be checked by shear stresses due to the total load $H_p \times l$ acting at the supports and shall be increased if required, to keep these stresses within limits specified in IS : 800-1962*.

6.2.3.3 Special consideration shall be given for any other concentrated loads acting on the bottom plate.

6.2.3.4 Generally bottom plate built under this rule is a butt welded construction so that the plate rests uniformly on the supporting structure.

6.2.3.5 Rules for fabrication given in **6.2.1** (b), **6.2.1** (c) and **6.2.2** (b) above shall also govern fabrication of the bottom plate resting on piers/beams.

6.2.4 The joint between the bottom edge of the lowest course of shell plate and bottom plate or annular segmental plate shall be by a continuous fillet weld laid on each side of the shell plate. The size of each weld shall be not greater than 12 mm and not less than the nominal thickness of the thinner of the two plates joined, nor less than the following values:

Maximum Thickness of Shell Plate, mm	*Minimum Size of Fillet Weld*, mm
5	5
6 to 20	6
21 to 30	8
Over 32	10

*Code of practice for use of structural steel in general building construction (*revised*).

6.3 Design of Shell Plates

6.3.1 *Loads*

6.3.1.1 Stresses in the tank shell shall be computed on the assumption that the tank is filled with water of specific gravity 1.00 or the liquid to be stored, if heavier than water. The tension in each course shall be computed at 30 cm above the centre line of the lower horizontal joint of the course in question.

6.3.1.2 Isolated radial loads on tank shells, such as caused by heavy loads from platforms and elevated walkways between tanks, shall be distributed appropriately, preferably in a horizontal position.

6.3.1.3 Wind and internal vacuum loads shall be considered together to check the stability of tank shells. Wind loads shall be as specified in Fig. 1A of IS : 875-1964*. Internal vacuum in the tank shall be specified by the purchaser; however, a minimum of 500 N/m^2 (50 kg/m^2) vacuum shall be considered.

6.3.2 *Joint Efficiency Factor* — This shall be taken as 0.85 for double welded butt joints, to determine the minimum thickness of shell plates computed from the stress on the vertical joints, subject to all vertical and horizontal butt welds being spot radiographed as recommended by this code. Where welds are not to be so examined by radiography, the joint efficiency factor considered for design shall be 0.70.

6.3.3 *Plate Thicknesses*

6.3.3.1 The minimum thickness of shell plates shall not be less than that calculated from the following formula or as specified in **6.3.3.2** whichever is greater:

$$t = \frac{4.9(H-0.3)DG}{SE} \quad \text{if } S \text{ is in N/mm}^2$$

or

$$= \frac{50(H-0.3)DG}{SE} \quad \text{if } S \text{ is in kgf/cm}^2$$

where

- t = minimum thickness in mm;
- D = nominal diameter of tank in m;
- H = height from the bottom of the course under consideration to top of top curb angle or to bottom of any overflow which limits tank filling height in m;
- G = specific gravity of liquid to be stored, but in no case less than 1.0;
- S = allowable stress; and
- E = joint efficiency factor.

*Code of practice for structural safety of buildings: Loading standards (*revised*).

6.3.3.2 In no case shall the nominal thickness of shell plates (including shell extensions for floating roof) be less than the following:

Nominal Tank Diameter	*Minimum Nominal Thickness*
m	mm
Less than 15	5.0
Over 15 up to and including 36	6.0
Over 36 up to and including 60	8.0
Over 60	10.0

6.3.3.3 The nominal thickness of shell plates refers to the tank shell as constructed and is based on stability rather than stress. Any required corrosion allowance for the shell plates shall be added to the calculated thickness of **6.3.3.1**, unless otherwise specified by the purchaser.

6.3.3.4 The maximum nominal thickness of tank shell plates shall be 40 mm, except that insert plates up to 75 mm thickness inclusive shall be permitted for material conforming to IS : 2002-1962* Grade 2B and IS : 2041-1962† steels.

6.3.3.5 The width of the shell plate shall be as agreed to between the purchaser and the manufacturer, but preferably should not be less than 1 500 mm.

6.3.3.6 Stability of tank shells against external loads shall be checked by determining the maximum height of the shell from the tap curb angle or wind girder that does not buckle under this loading and providing stiffening to the shell if required.

The maximum height of unstiffened shell, in metres, shall not exceed H_1 as determined by the following equation:

$$H_1 = \frac{14\,700\,t}{p}\sqrt{\left(\frac{t}{D}\right)^3}, \text{ if } p \text{ is in N/m}^2$$

or

$$= \frac{1\,500\,t}{p}\sqrt{\left(\frac{t}{D}\right)^3}, \text{ if } p \text{ is in kgf/m}^2$$

where

H_1 = vertical distance between the intermediate wind girder and top angle of the shell or the top wind girder of an open top tank in m;

t = average shell thickness in height H_1 in mm determined from the actual thicknesses of plates used unless the purchaser specifies that the net thickness (actual thickness used minus corrosion allowance specified) shall be considered;

*Specification for steel plates for boilers.

†Specification for steel plates for pressure vessels.

D = nominal tank diameter in m; and
p = sum of all external pressures acting on the tank shell, that is, wind pressure and internal vacuum.

An initial calculation shall be made using the thickness of the top shell course. Further calculations shall be made by considering the weighted average thickness of the top course and part or all of the next lower course, or courses, till the value H_1 equals or is less than the height of shell used in determining the average thickness.

When such a value of H_1 is obtained, an intermediate wind girder shall be provided on the shell at a distance below the top wind girder of curb angle, equal to or less than the height of shell used in determining the average thickness.

Minimum distance from this girder to the nearest horizontal joint in the shell shall be 150 mm. The required minimum section modulus in cubic centimetres of this girder shall be determined by the equation:

$$Z = 0.059\ D^2 H_1$$

This formula is applicable for total external pressures up to 1 470 N/m² (150 kgf/m²). For greater external pressures P, required minimum section modulus of this girder is computed by multiplying above equation by

$$\frac{P}{1\ 470} \text{ or } \frac{P}{150} \text{ where } P \text{ is in N/m}^2 \text{ or kgf/m}^2 \text{ respectively.}$$

Thereafter, the rest of the shell below this intermediate girder shall be checked in the same manner considering this girder as the top of the tank.

If value of H_1 continues to be greater than the height of shell used in determining the average thickness, the shell is considered stable against the external loads that are considered and no intermediate girder is required.

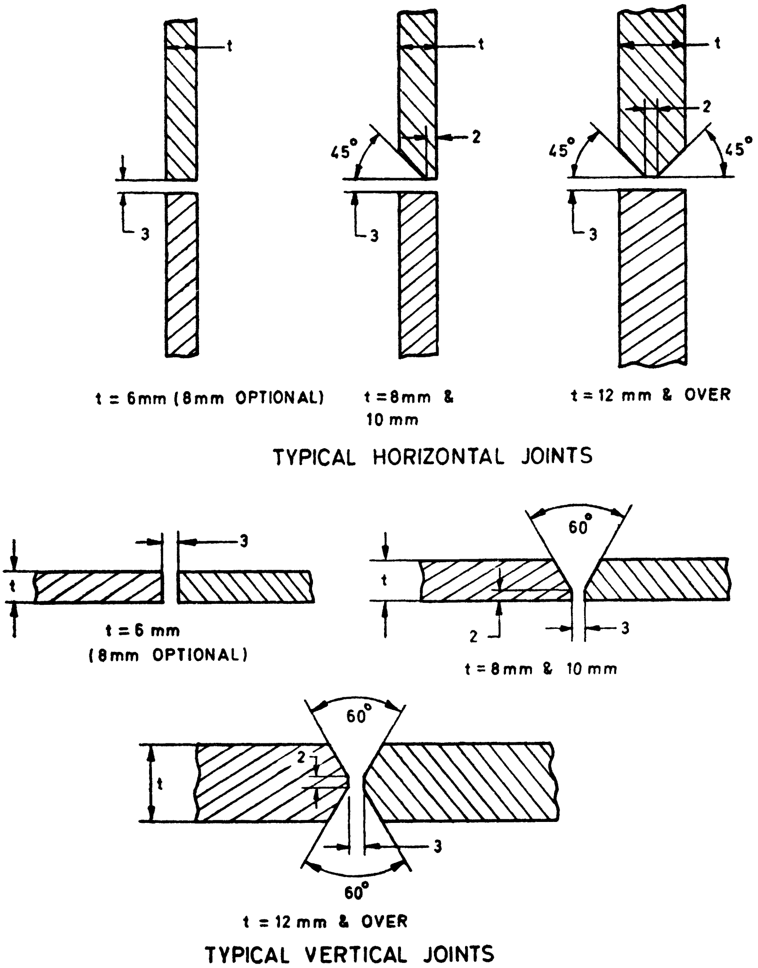
6.3.4 *Shell Plate Arrangement*

6.3.4.1 The shell shall be designed to have all courses truly vertical. The centre-line of each course shall be on top of the centre-line of the course immediately below or alternatively the inside surfaces of offset horizontal butt joints shall be kept flush, as desired by the purchaser. The system of construction to be followed should be specified in the order.

6.3.4.2 Vertical joints in adjacent shell courses shall not be in alignment but shall be offset from each other as large a distance as possible but in no case less than a distance of $5t$, t being the plate thickness of the thicker course at the point of offset.

6.3.5 *Shell Joints*

6.3.5.1 *Vertical and horizontal joints* — All vertical and horizontal joints shall be of double-welded butt construction with complete penetration and fusion through the full thickness of the parent plate. Suggested forms of joints are shown in Fig. 6.



All dimensions in millimetres.

FIG. 6 TYPICAL HORIZONTAL AND VERTICAL JOINTS

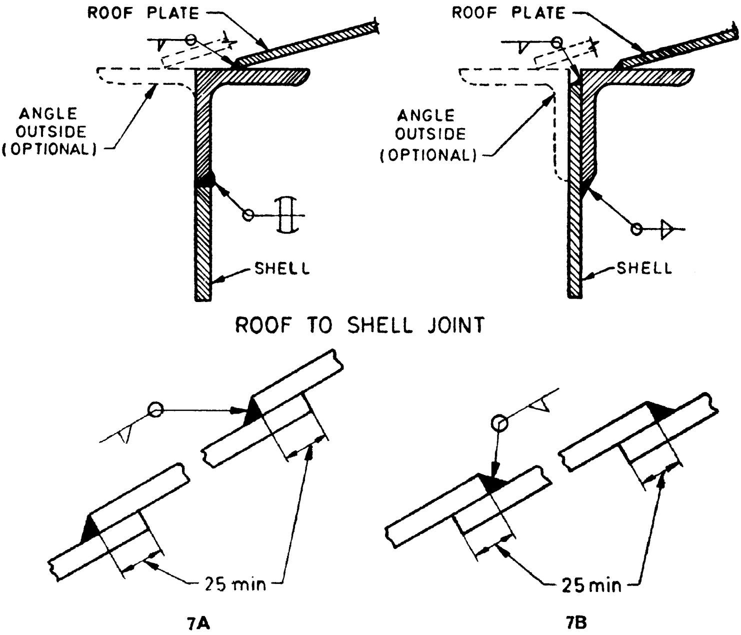
6.3.5.2 The suitability of plate preparation and welding procedure shall be the manufacturer's choice subject to welding procedure qualification as specified in IS : 823-1964*.

*Code of procedure for manual metal arc welding of mild steel.

6.3.5.3 The wide face of unsymmetrical V or U butt joints may be on the outside or on the inside of the tank shell.

6.3.6 *Roof-Curb Angle*

6.3.6.1 Except as specified for open top tanks in **6.3.8.6**, tank shells shall be provided with top-curb angles of sizes not less than specified in **6.3.6.2** and as may be required by **6.3.6.3**. This will be attached to the upper edge of the shell plate by a double-welded butt or lap joint. The horizontal leg of the top angle may extend inside or outside the tank shell at the purchaser's option. Typical roof to shell joints and roof plate joints are given in Fig. 7.



All dimensions in millimetres.

FIG. 7 TYPICAL ROOF JOINTS

6.3.6.2 Minimum sizes of top curb angle shall be:

a) Tanks up to and including 10 m diameter	65 × 65 × 6.0 mm
b) Tanks over 10 m and up to and including 18 m diameter	65 × 65 × 8.0 mm
c) Tanks over 18 m and up to and including 36 m diameter	75 × 75 × 10.0 mm
d) Tanks over 36 m diameter	100 × 100 × 10.0 mm

NOTE — Thickness specified above includes corrosion allowance required for petroleum service. Special consideration should be given for severe service.

6.3.6.3 For tanks having internal pressure, cross-sectional area of curb angle provided shall not be less than the area required to resist the compressive force at the roof shell junction minus the participating shell and roof area shown in Fig. 8.

Area of curb angle required is given by:

$$A_c = \frac{PD^2}{117\,500 \tan\theta} - 0{\cdot}1\ W_s.t_s - 0{\cdot}1\ W_R\ .\ t_R \text{ where } P \text{ is in N/m}^2$$

or

$$= \frac{PD^2}{12\,000 \tan\theta} - 0{\cdot}1\ W_S.t_S - 0{\cdot}1\ W_R.t_R \text{ where } P \text{ is in kgf/m}^2$$

where

A_c = area of curb angle in cm^2;
D = tank diameter in m;
P = upward force due to internal tank's pressure minus weight of roof plates;
θ = angle between the roof and a horizontal plane at the roof shell junction in degrees;
W_s = width of the shell in the compression region in cm;
= $0.19\sqrt{R_S\, t_S}$ where R_S = radius of tank shell in cm;
t_S = nominal shell thickness in mm;
W_R = width of the roof in the compression region in cm;
= $0.095\sqrt{R_R\, t_R}$;
R_R = radius of roof at roof shell junction in cm; and
t_R = nominal roof thickness in cm.

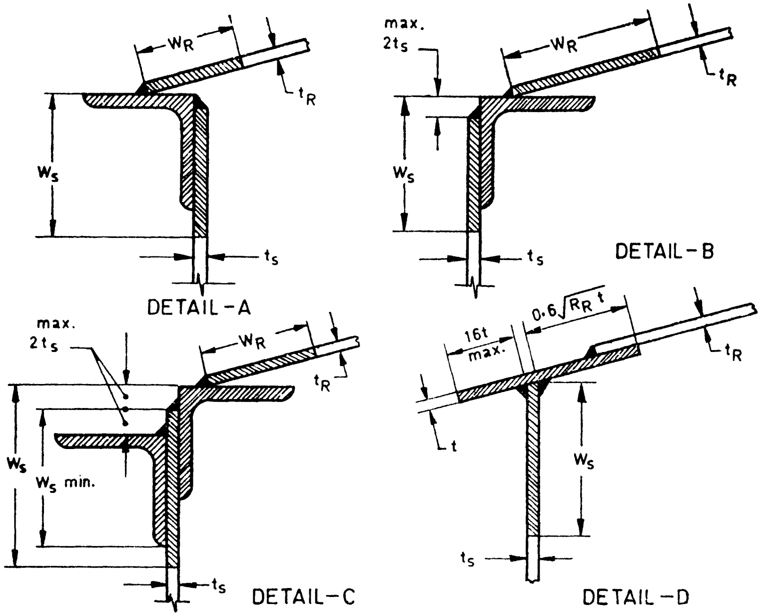
This area may be provided by using rolled angle or other section or plate girder as shown in Fig. 8.

When plate girder as shown in Fig. 8, Detail—D is used, required area of this girder is given by:

$$A_c = \frac{PD^2}{117\,500 \tan\theta} - 0{\cdot}1\ W_s.t_s \text{ where } P \text{ is in N/m}^2$$

or

$$= \frac{PD^2}{12\,000 \tan\theta} - 0{\cdot}1\ W_s.t_s \text{ where } P \text{ is in kgf/m}^2$$



All dimensions in millimetres.

NOTE — Shaded portion indicates the area resisting the compression force.

FIG. 8 SOME PERMISSIBLE DETAILS OF COMPRESSION RINGS

6.3.7 *Circular Shell Openings*

6.3.7.1 Opening in tank shells larger than 64 mm in diameter shall be reinforced. The minimum cross-sectional area of the reinforcement shall be not less than the product of the vertical diameter of the hole cut in the tank shell and the shell plate thickness required under **6.3.3.1**. The cross-sectional area of the reinforcement shall be measured along the vertical axis passing through the centre.

6.3.7.2 If a thicker shell plate is used than is required for the hydrostatic loading and corrosion allowance (*see* **6.3.3.3**), the excess shell plate thickness, within a vertical distance, both above and below the centre-line of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate, may be considered as reinforcement, and the thickness *T* of the opening reinforcement plate may be decreased accordingly.

6.3.7.3 All effective reinforcements shall be made within a distance, above or below the centre-line of the shell opening, equal to the vertical dimensions of the hole in the tank shell plate. The reinforcement may be provided within a vertical distance, both above and below the centre-line of the hole in the shell, equal to the vertical dimension of the hole in the tank shell plate by any one, or by any combination, of the following:

a) The reinforcing plate;

b) The portion of the neck of the fitting which may be considered as reinforcement according to **6.3.7.4**; and

c) Any excess shell plate thickness, beyond that required under **6.3.3.1**, and corrosion allowance.

6.3.7.4 The following portions of the neck of a fitting may be considered as part of the area of reinforcement:

a) The portion extending outwardly from the outside surface of the tank shell plate for a distance equal to four times the neck wall thickness or, if the neck wall thickness is reduced within this distance, to the point of transition;

b) The portion lying within the shell plate thickness; and

c) The portion extending inwardly from the inside surface of the tank shell plate for a distance as specified under **6.3.7.4**(a).

6.3.7.5 The aggregate strength of the weld attaching a fitting to the shell plate, or to an intervening reinforcing plate, or to both, shall equal at least the proportion of the forces passing through the entire reinforcement which is computed to pass through the fitting considered.

6.3.7.6 The aggregate strength of the weld attaching any intervening reinforcing plate to the shell plate shall at least equal to proportion of the forces passing through the entire reinforcement which is computed to pass through the reinforcing plate considered.

6.3.7.7 The attachment welding to the shell, along the outer periphery of the reinforcing plate, shall be considered effective only for the parts lying outside the area bounded by vertical lines drawn tangent to the shell opening. The outer peripheral welding, however, shall be applied completely around the reinforcement. All the inner peripheral welding shall be considered effective.

The strength of the effective attachment welding shall be considered as its shear resistance at the stress values given for fillet welds under **5.2**.

The outer peripheral weld shall be of a size not less than 0.5 t_{min} where t_{min} is the smaller of 20 mm or the thickness less corrosion allowance of either of the parts joined by a fillet weld or groove weld; except that when low type nozzles are used with the reinforcing plate extending to the tank bottom, the size of that portion of the peripheral weld which attaches the reinforcing plate to the bottom plate shall conform to **6.2.4**. The inner peripheral welding shall be large enough to sustain the remainder of the loading.

Figures 11 and 12 show acceptable methods of attachment. For convenience fillet sizes for one type of attachment are given in Table 9, and Table 10 respectively for manholes and nozzles. For other types of attachments, fillet sizes shall be determined according to **6.3.7.5**, **6.3.7.6** and **6.3.7.7**.

6.3.7.8 When two or more openings are located so close that their normal reinforcing plate edges are closer than ten times the thickness of the thicker reinforcing plate with a minimum of 150 mm, they shall be treated and reinforced as follows:

a) All such openings shall be included in a single reinforcing plate, which shall be proportioned for the largest opening in the group;

b) If the normal reinforcing plates for the smaller openings in the group, considered separately, would fall within the area limits of the solid portion of normal plate for the largest opening, the smaller openings may be included in a normal plate for the largest openings without increase in size of that plate; provided, however, that if any opening intersects the vertical centre-line of another, the total width of the final reinforcing plate along the vertical centre-line of either opening shall be not less than the sum of the widths of the normal plates for the openings involved; and

c) If the normal reinforcing plates for the smaller openings, considered separately, would not fall within the area limits of the solid portion of a normal plate for the largest opening, the group reinforcing plate size and shape shall be such as to include the outer limits of the normal reinforcing plates for all of the openings in the group. Change of size from the outer limits of the normal plate for the largest opening to the outer limits of that for the smaller opening farthest therefrom shall be by uniform straight taper unless the normal plate for any intermediate opening would extend beyond the limits so fixed, in which case uniform straight tapers shall join the outer limits of the several normal plates. Provisions under **6.3.7.8** (b) with respect to openings on the same or adjacent vertical centre-lines shall also apply in this case.

6.3.7.9 Reinforcement for non-circular openings shall be given special consideration.

6.3.8 *Design of Wind Girders for Open-Top Tanks*

6.3.8.1 Open top tanks shall be provided with stiffening rings to maintain roundness when the tank is subjected to wind loads. Stiffening rings shall be located at or near the top course, and preferably on the outside of the tank shell.

6.3.8.2 The required minimum section modulus of the wind girder shall be determined by the following formula:

$$Z = 0.059\, D^2 H$$

where

Z = section modulus in cm^3,

D = normal diameter of tank in m, and

H = height of tank shell in m including any 'free board' provided above the maximum filling height as guide for the floating roof.

Stiffening ring having a section modulus given by the above formula is adequate for external pressures (wind + vacuum) up to 1 470 N/m^2 (150 kgf/mm^2). For greater external pressure P, required section modulus of the stiffening ring shall be computed by multiplying above equation by $\frac{P}{1\,470}$ (or $\frac{P}{150}$ where P is in kgf/m^2).

6.3.8.3 The section modulus of the stiffening ring shall be based upon the properties of the applied members and may include a portion of the tank shell for a distance of 16 plate thicknesses below and, if applicable, above the ring shell attachment. When curb angles are attached to the top edge of the shell ring by butt welding, this distance shall be reduced by the width of the vertical leg of the angle. Section modulii values for typical ring members are given in Table 7.

6.3.8.4 Stiffening rings may be made of either structural section, formed plate section, or sections built-up by welding, or of combinations of such types of sections assembled by welding. The outer periphery of stiffening rings may be circular or polygonal. Built-up stiffening rings using flats and bars are permitted subject to purchaser's approval.

6.3.8.5 The minimum size of angle for use along, or as component in a built-up stiffening ring, shall be 60 × 60 × 6 mm. The minimum nominal thickness of plate for use in formed or built-up stiffening rings shall be 6 mm.

6.3.8.6 When stiffening rings are located more than 0.6 m below the top of the shell, the tank shall be provided with a 60 × 60 × 5 mm top curb angle for 5 mm shells, and with a 75 × 75 × 6 mm angle for shell greater than 5 mm. Other rolled sections of equivalent section modulus may also be used.

6.3.8.7 Rings of such design that liquid may be trapped thereon shall be provided with adequate drain holes.

6.3.8.8 Stiffening rings or portions thereof, which are regularly used as a walkway, shall have a width not less than 0.6 m clear of the projecting curb angle on the top of the tank-shell, shall be located preferably 1 m below the top of the curb angle, and shall be provided with a standard railing on the unprotected side and at the ends of the section so used.

6.3.8.9 When a stair opening is installed through a stiffening ring, the section modulus of that portion of the ring outside the opening, and including the transition section, shall conform to the requirements of **6.3.8.2**. The shell adjacent to such opening shall be stiffened with an angle, or bar, placed horizontally. The other sides of the opening shall be stiffened with an angle, or bar, placed vertically. The cross-sectional area of these rim stiffeners shall be at least equivalent to the cross-sectional area of that portion of shell included in the section modulus calculations of the stiffening ring (*see* **6.3.8.8**). These stiffeners, or additional members, shall furnish a suitable tee board around the opening. The stiffening members shall extend beyond the end of the opening for a distance equal to or greater than the minimum depth of the regular ring section. The end stiffening members shall frame into the side stiffening members and shall be connected to them in such a manner as to develop their full strength.

6.3.8.10 Supports shall be provided for all stiffening rings when the dimension of the horizontal leg or web exceeds 16 times the leg or web thickness. Such supports shall be spaced at intervals as required for the dead load and vertical live load that may be placed upon the ring. However, the spacing shall not exceed 24 times the width of the outside compression flange.

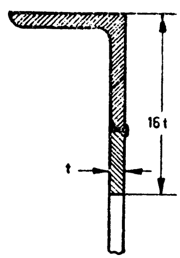
6.3.8.11 Continuous seal welds of about 3 mm shall be used for all joints which, because of their location, may be subjected to corrosion from entrapped moisture or cause rust markings on the tank shell. Full penetration butt welds shall be used for jointing ring sections.

6.3.9 An alternate method for design of tank shells is dealt with in Appendix B.

TABLE 7 SECTION MODULUS OF WIND GIRDERS

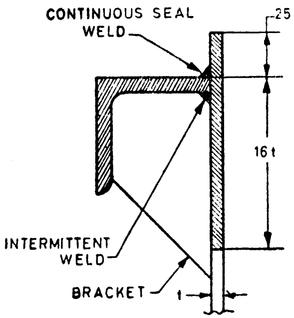
(*Clause* 6.3.8.3)

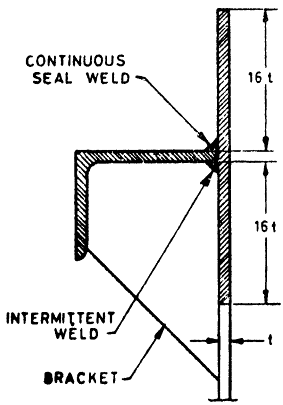
All dimensions in millimetres.

SECTION THROUGH WIND GIRDER	MEMBER SIZE IN mm × mm × mm	SECTION MODULUS IN cm^3 FOR SHELL THICKNESS 5 mm	SECTION MODULUS IN cm^3 FOR SHELL THICKNESS 6 mm
 Detail A — Top Angle	ISA 65 × 65 × 6	6.4	6.5
	ISA 65 × 65 × 8	8.3	8.5
	ISA 75 × 75 × 10	13.6	13.0

(*Continued*)

TABLE 7 SECTION MODULUS OF WIND GIRDERS — *Contd*

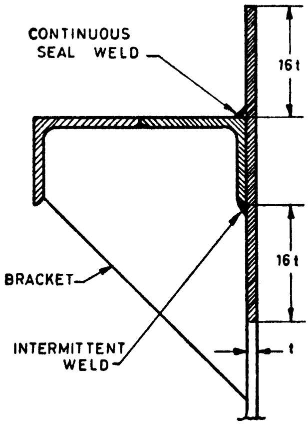
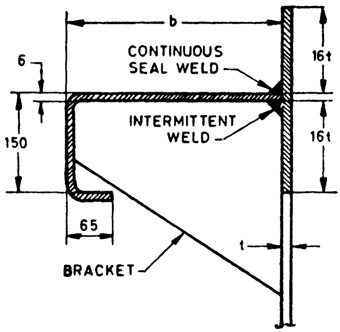
<table>
<tr><th rowspan="2">SECTION THROUGH WIND GIRDER</th><th>MEMBER SIZE IN</th><th colspan="2">SECTION MODULUS IN cm^3 FOR SHELL THICKNESS</th></tr>
<tr><th>mm × mm × mm</th><th>5 mm</th><th>6 mm</th></tr>
<tr><td rowspan="6">

Detail B — Curb Angle</td><td>ISA 65 × 65 × 6</td><td>27.2</td><td>28.4</td></tr>
<tr><td>ISA 65 × 65 × 8</td><td>33.2</td><td>34.9</td></tr>
<tr><td>ISA 75 × 75 × 6</td><td>36.3</td><td>37.8</td></tr>
<tr><td>ISA 75 × 75 × 10</td><td>50.0</td><td>54.1</td></tr>
<tr><td>ISA 100 × 100 × 6</td><td>63.8</td><td>66.8</td></tr>
<tr><td>ISA 100 × 100 × 10</td><td>73.7</td><td>92.2</td></tr>
<tr><td rowspan="5">

Detail C — Single Angle</td><td>ISA 65 × 65 × 6</td><td>28.3</td><td>29.4</td></tr>
<tr><td>ISA 65 × 65 × 8</td><td>34.8</td><td>36.4</td></tr>
<tr><td>ISA 100 × 75 × 8</td><td>67.5</td><td>70.6</td></tr>
<tr><td>ISA 125 × 75 × 8</td><td>90.1</td><td>94.5</td></tr>
<tr><td>ISA 150 × 115 × 10</td><td>157.5</td><td>190.1</td></tr>
</table>

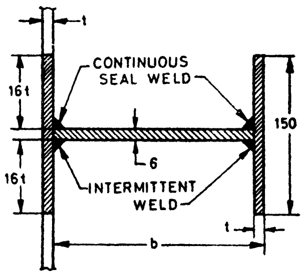
(*Continued*)

TABLE 7 SECTION MODULUS OF WIND GIRDERS — *Contd*

SECTION THROUGH WIND GIRDER	MEMBER SIZE IN	SECTION MODULUS IN cm^3 FOR SHELL THICKNESS	
	mm × mm × mm	5 mm	6 mm
 Detail D — Two Angles	ISA 100 × 75 × 8	182.2	187.5
	ISA 100 × 75 × 10	217.6	224.1
	ISA 125 × 75 × 8	250.7	258.4
	ISA 125 × 75 × 10	300.2	309.5
	ISA 125 × 95 × 8	288.5	296.0
	ISA 125 × 95 × 10	346.9	356.2
	ISA 150 × 115 × 10	506.7	518.9
 Detail E — Formed Plate	*b* = 250	—	341.0
	b = 300	—	427.2
	b = 350	—	518.7
	b = 400	—	615.5
	b = 450	—	717.4
	b = 500	—	824.4
	b = 550	—	936.6
	b = 600	—	1 053.8
	b = 650	—	1 176.1
	b = 700	—	1 303.5
	b = 750	—	1 435.9
	b = 800	—	1 573.4
	b = 850	—	1 716.0
	b = 900	—	1 863.5
	b = 950	—	2 016.1
	b = 1 000	—	2 166.7

(*Continued*)

TABLE 7 SECTION MODULUS OF WIND GIRDERS — *Contd*

SECTION THROUGH WIND GIRDER	MEMBER SIZE IN mm	SECTION MODULUS IN cm^3 FOR SHELL THICKNESS, 6 mm
 Detail F — Formed Plate	*b* = 250	335.2
	b = 300	417.6
	b = 350	504.6
	b = 400	596.5
	b = 450	693.2
	b = 500	794.8
	b = 550	901.3
	b = 600	1 012.8
	b = 650	1 129.2
	b = 700	1 250.6
	b = 750	1 376.6
	b = 800	1 508.2
	b = 850	1 644.4
	b = 900	1 785.6
	b = 950	1 931.8
	b = 1 000	2 082.9
	b = 1 050	2 239.1
	b = 1 100	2 400.2
	b = 1 150	2 566.3
	b = 1 200	2 737.4

6.4 Designs of Roof

6.4.1 *Definitions* — The following definitions shall apply to designs of roofs.

6.4.1.1 *Supported cone roof* — A roof formed to approximately the surface of a right cone, with its principal support provided by either rafters on girders and columns or rafters on trusses with or without columns.

6.4.1.2 *Self-supporting cone roof* — A roof formed to approximately the surface of a right cone, supported only at its periphery.

6.4.1.3 *Self-supporting dome roof* — A roof formed to approximately a spherical surface, supported only at its periphery.

6.4.1.4 *Self-supporting umbrella roof* — A modified dome roof so formed that any horizontal section is a regular polygon with as many sides as there are roof plates, supported only at its periphery.

6.4.2 *General*

6.4.2.1 All roofs and supporting structures shall be designed to support dead load, plus a uniform live load of not less than 1 225 N/m^2 (125 kgf/m^2) of projected area.

6.4.2.2 Roof plates shall have a minimum nominal thickness of 5 mm. A greater thickness may be required for self-supporting roofs (*see* **6.4.5** and **6.4.6**).

6.4.2.3 Roof plates of supported cone roofs shall not be attached to the supporting members.

6.4.2.4 All internal and external structural members of the roof shall have a minimum nominal thickness, in any component, of 4.5 mm.

6.4.2.5 Roof plates shall be attached to the top angle of the tank with a continuous fillet weld on the top side only.

If the continuous fillet weld between the roof plates and the top angle does not exceed 5 mm and the slope of the roof at the top angle attachment does not exceed 1 in 6, the joint may be considered to be frangible and, in case of excessive internal pressure, will fail before failure occurs in the tank shell joints or the shell-to-bottom joint. Failure of the roof-to-shell joint may be accompanied by buckling of the top angle.

Where the weld size exceeds 5 mm or where the slope of the roof at the top-angle attachment is greater than 1 in 6, emergency venting devices in accordance with Appendix C shall be provided by the purchaser. The manufacturer shall provide a suitable tank connection for the device.

6.4.2.6 Roof plate shall be lapped with a minimum overlap of 25 mm and shall be welded with a continuous fillet weld on the top side only. Laps shall be arranged as shown in Fig. (A) or (B) of Fig. 7 for roof plate joint depending on the local conditions by agreement between the purchaser and the manufacturer.

6.4.2.7 For all types of roofs, the plates may be stiffened by sections welded to the plates but not to the supporting rafters and/or girders.

6.4.3 *Permissible Stresses* — All parts of the structure shall be so proportioned that the sum of the maximum static stresses shall not exceed the permissible stresses given in IS : 800-1962*.

6.4.4 *Supported Cone Roofs* — The design of supported cone roof shall conform to the following:

a) Roof plates shall be welded on the top side with continuous full-fillet welds on all seams. The size of the roof-to-top angle weld shall be 5 mm or smaller if so specified by the purchaser.

b) The slope of the roof shall be 1 in 16 or greater as specified by the purchaser. If the rafters are set directly on chord girders producing slightly varying rafter slopes, the slope of the flattest rafter shall conform to the specified or ordered roof slope.

c) Main supporting members, including those supporting the rafters, may be rolled or fabricated section or trusses, with or without supporting columns. Although these members may be in contact with the roof plates, the compression flange of a member or the top chord of a truss shall be considered to receive no lateral support from the roof plates and shall be laterally braced, if necessary, by other acceptable methods.

d) Structural members, serving as rafters, may be rolled or fabricated sections. Rafters in direct contact with the roof plates applying the loading to the rafters may be considered to receive adequate lateral support from the friction between the roof plates and the compression flanges of the rafters, with the following exceptions:

   (1) Trusses and open-web joists used as rafters,

   (2) Rafters having a nominal depth greater than 375 mm, and

   (3) Rafters having a slope greater than 1 in 6.

e) Rafters shall be spaced so that, in the outer ring, their centres shall not be more than 2 m measured along the circumference of the tank. Spacing on inner rings shall not be greater than 1.75 m. When specified by the purchaser for tanks located in areas subject to earthquake, 20 mm diameter tie rods (or equivalent) shall be placed between the rafters in the outer rings. These tie rods may be omitted if I or H sections are used as rafters.

f) Roof columns shall be made from structural shapes or pipes or built-up sections. Suitable base frames or reinforcing pads shall be provided at the column base to distribute loads coming on the tank bottom.

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*Code of practice for use of structural steel in general building construction (*revised*).

g) Rafters clips for the outer row of rafters shall be welded to the tank shell. Columns shall not be rigidly attached to the bottom plate. Guide clips shall be welded to the tank bottom to prevent lateral movement of columns. All other structural attachments shall be either bolted, riveted, or welded.

6.4.5 *Self-Supporting Cone Roofs* — Self-supporting cone roofs shall conform to the following requirements:

Maximum θ = 37°

Minimum sin θ = 0.165 (slope 1 in 6)

Minimum t = $\frac{D}{5 \sin \theta}$ but not less than 5 mm

Maximum t = 12 mm

NOTE — Self-supporting roofs having the roof plates stiffened by sections welded to the plates need not conform to the above minimum thickness requirements, but should be not less than 5 mm when so designed by the manufacturer, subject to the approval of the purchaser.

6.4.5.1 The cross-sectional area of the top angle in cm^2 plus the cross-sectional areas of the shell and roof plates within a distance of 16 times their thicknesses measured from their most remote point of attachment to the top angle, shall not be less than:

$$\frac{D^2}{40 \sin \theta}$$

where

D = nominal diameter of tank shell in m,

θ = angle of cone elements with the horizontal in degrees, and

t = nominal thickness of roof plates in mm.

6.4.6 *Self-Supporting Dome and Umbrella Roofs* — Self-supporting dome and umbrella roofs shall conform to the following requirements:

Minimum R = 0.8 D

Maximum R = 1.2 D where R = radius of the dome in m,

Minimum t in mm = R/2.5 but not less than 5 mm

Maximum t = 12 mm

These formulae for self-supporting roofs assume a uniform live load of 1 225 N/m^2 (125 kgf/m^2).

NOTE — Self supporting roofs having the roof plates stiffened by sections welded to the plates need not conform to the minimum thickness requirements, but should not be less than 5 mm when so designed by the manufacturer, subject to the approval of the purchaser.

6.4.6.1 The cross-sectional area of the top angle in cm^2 plus the cross-sectional areas of the shell and roof plates within a distance of 16 times their thicknesses, measured from their most remote point of attachment to the top angle, shall equal or exceed:

$$\frac{DR}{20}$$

where

D = nominal diameter of tank shell in m,

R = radius of curvature of roof in m, and

t = nominal thickness of roof plates in mm.

6.4.7 *Top-Angle Attachment for Self-Supporting Roofs*

6.4.7.1 The top-angle sections for self-supporting roofs shall be joined by butt welds having complete penetration and fusion. Joint efficiency factors need not be applied if it conforms to the requirements of **6.4.5** and **6.4.6**.

6.4.7.2 For self-supporting roofs whether of the cone, dome or umbrella type, the edges of the roof plates, at the option of the manufacturer, may be flanged horizontally to rest flat against the top angle to improve welding conditions.

6.4.8 Recommended column layout for tanks and column and girder attachment details are shown in Fig. 9 and 10.

6.5 Floating Roof — Reference may be made to Appendix D for the design and construction of floating roofs.

7. APPURTENANCES AND MOUNTINGS

7.1 General

7.1.1 Appurtenances or mountings installed on tanks should conform to this code. Alternative designs of appurtenances which provide equivalent strength, tightness and utility are permissible, if so agreed by the purchaser.

7.1.2 Manhole necks, nozzle necks, reinforcing plates, and shell-plate openings, which have either sheared or oxygen-cut surfaces, shall have such surfaces made uniform and smooth, with the corners rounded, except where such surfaces are fully covered by attachment welds.

7.2 Shell Manholes

7.2.1 Shell manholes shall conform to Fig. 11 and Tables 8 and 9.

7.2.2 Manhole frames may be press-formed or of built-up welded construction.

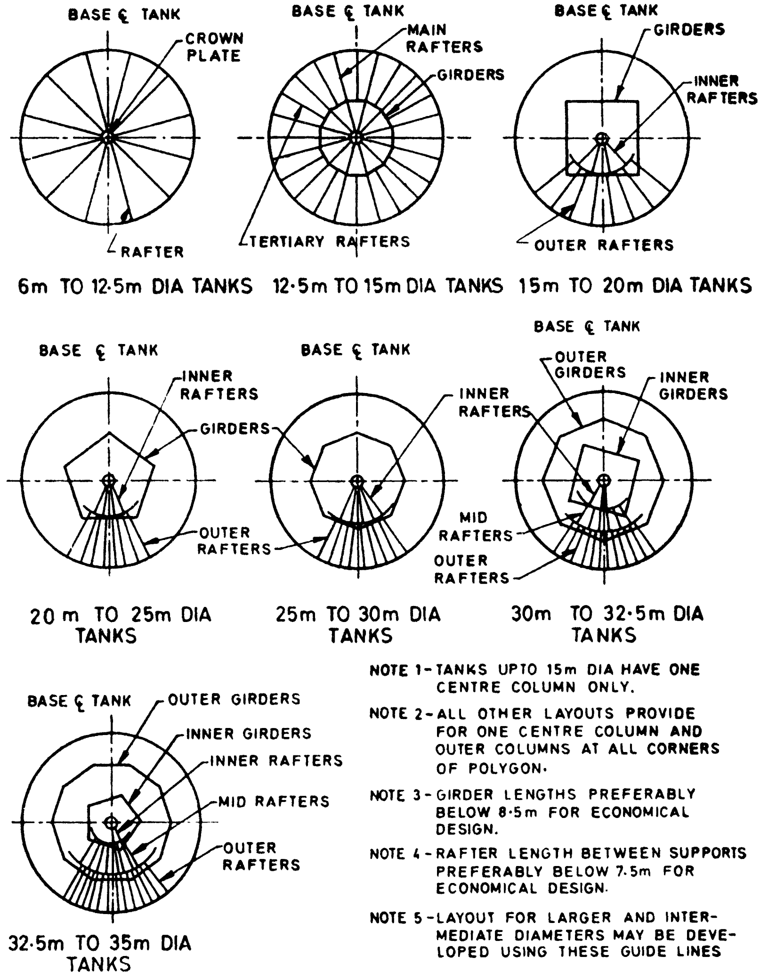
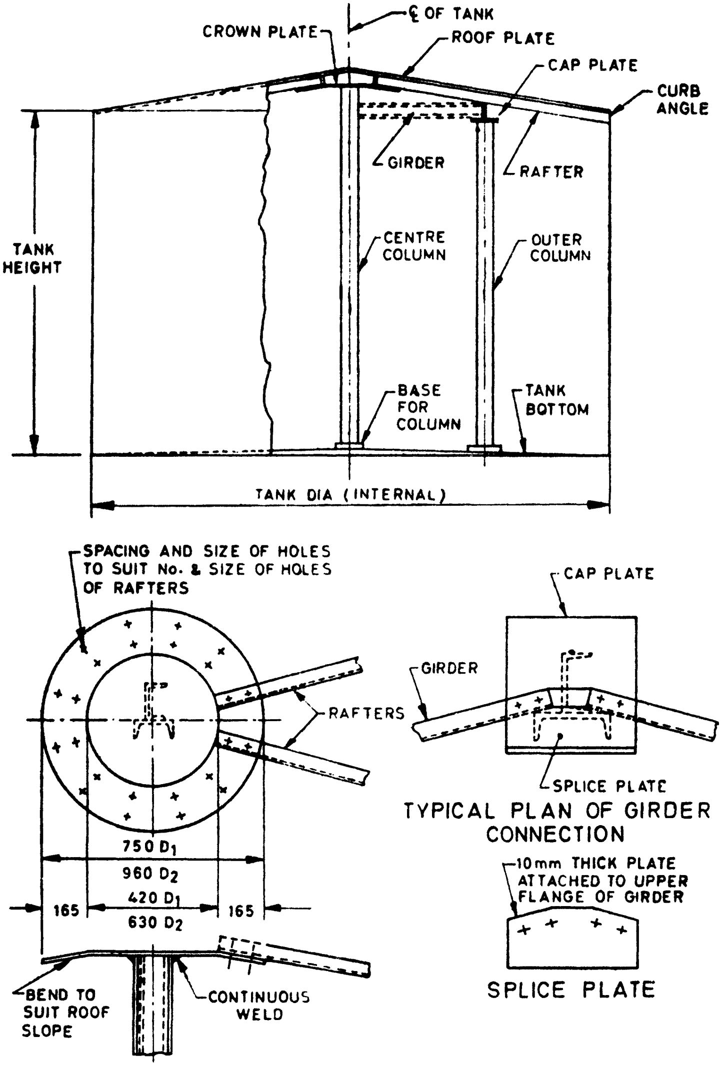


FIG. 9 RECOMMENDED LAYOUT OF COLUMNS FOR NORMAL SIZE TANKS



NOTE 1 — D_1 crown plate 10 mm thick; 6 to 9 m dia tanks.
NOTE 2 — D_2 crown plate 20 mm thick; for greater dia tanks.

All dimensions in millimetres.

FIG. 10 TYPICAL COLUMN AND GIRDER ATTACHMENT DETAILS

7.3 Shell Nozzles

7.3.1 Shell nozzles shall conform to Fig. 12 and 13 and Table 10.

7.3.2 Details and dimensions specified herein are for nozzles installed with their axes perpendicular to the shell plate. Nozzles may be installed at an angle of other than 90° to the shell plate in a horizontal plane, provided that the width of the reinforcing plate is increased by the amount that the horizontal chord of the opening cut in the shell plate increases as the opening changes from circular to elliptical in making the angular installation. In addition, nozzles not larger than 75 mm nominal pipe size, for insertion of thermometer wells, sampling connections, or other purposes not involving the attachment of extended piping, may be installed at an angle of 15° or less off perpendicular in a vertical plane, without modification of the nozzle reinforcing plate.

7.4 Roof Manholes

7.4.1 Manholes in the roof shall conform to Fig. 14 and Table 11. They shall be suitable for attachment by welding to the tank roof sheets and shall be positioned close to roof sheet supporting members.

7.4.2 The manhole cover may be hinged with single or multiple bolt fixing as required by the purchaser.

7.4.3 Openings made for fixing manholes on self supporting roofs and roofs subjected to internal pressure shall be reinforced by a plate ring having the same thickness of roof plate and outer diameter equal to twice the diameter of the opening.

7.5 Roof Nozzles

7.5.1 Flanged roof nozzles shall conform to Fig. 15 and Table 12, installation of threaded nozzles shall be as shown in Fig. 15.

7.5.2 All nozzle openings greater than 150 mm diameter, shall be reinforced by a plate ring having the same thickness as roof plate and outer-diameter equal to twice the diameter of the opening.

7.6 Water Draw-Offs and Drain Pad

7.6.1 Water draw-off sumps shall conform to Fig. 16.

7.6.2 Drain pad for elevated tanks shall be in accordance with Fig. 17 and Table 13.

7.7 Platforms, Gangways and Stairways

7.7.1 Platforms and gangways shall conform to the following:

a) Platforms and gangways shall be capable of supporting a moving concentrated load of 4 412 N (450 kgf) and the handrailing structure shall be capable of withstanding a load of 882 N (90 kgf) applied in any direction at any point on the top rails.

b) All parts shall be made of metal.

c) Flooring shall be of grating or of non-slip material.

d) A standard width of such gangways on a tank is 600 mm. Wider gangways may be used if required by the purchaser.

e) Handrailing of 1 m height shall be provided on all open sides and shall have a toe board not less than 75 mm besides top and mid-rails.

f) At handrail openings, any space between the tank and the platform wider than 150 mm shall be floored.

7.7.2 Stairways shall conform to the following:

a) Stairways shall be capable of supporting a moving concentrated load of 4 412 N (450 kgf) and the handrailing structure shall be capable of withstanding a load of 882 N (90 kgf) applied in any direction at any point on the top rail.

b) Handrails shall be on both sides of straight stairs, as well as on spiral stairs when the clearance between the tank shell and stair stringer exceeds 200 mm.

c) Spiral stairways should be completely supported on the shell of the tank and ends of the stringers should be clear of the ground.

d) All parts to be made of metal.

e) Standard width of stairs is 800 mm. Wider stairs may be used if required by purchaser.

f) Standard width of stair treads is 250 mm, and shall be of a grating or non-slip material.

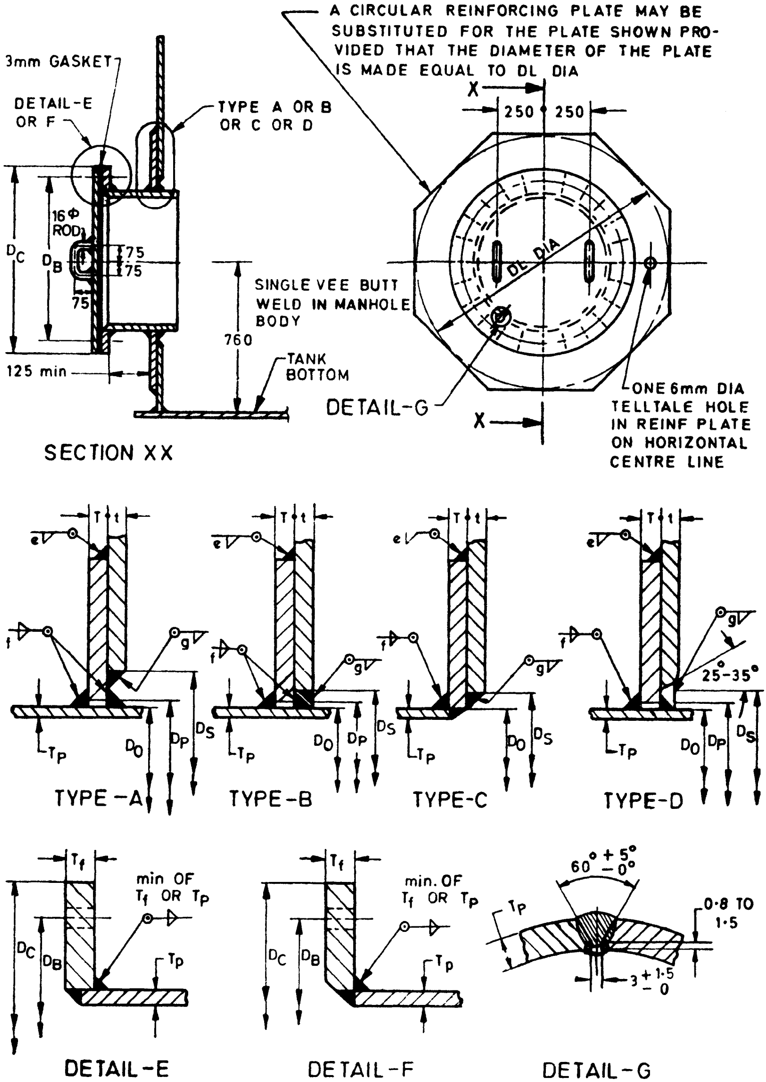
g) Maximum angle of stairway with a horizontal line shall be 50°.

h) Stair tread rises shall be uniform throughout the height of the stairway and preferably be 200 mm.

j) Top railing shall join the platform handrail without offset, and the height measured vertically from tread level at nose of tread shall be 750 to 850 mm.

k) Maximum distance between railing posts measured along the slope of the railing shall be 2.4 m.

7.8 Flush Type Cleanout Fitting — Figure 18 shows an acceptable type of flush type cleanout fitting that may be incorporated in a tank if



All dimensions in millimetres.

FIG. 11 TYPICAL SHELL MANHOLES (*see* Tables 8 and 9) specified by the purchaser. Tables 14, 15 and 16 give additional data and dimensions of this fitting. Special consideration shall be made by the purchaser in design of foundation to provide an adequate support to this fitting.

7.9 Gauge Wells — Typical sketches of gauge wells showing two different methods of installing gauges without welding them to the existing roof nozzles are given in Fig. 19.

7.10 Tank Accessories — Other tank accessories like level indicator, foam chamber, gauge hatch, free vents and earthing boss be provided conforming to Indian Standard specifications wherever available and in agreement with the purchaser.

TABLE 8 SHELL MANHOLE COVER PLATE AND BOLTING FLANGE THICKNESS (*see* Fig. 11)

(*Clause* 7.2.1)

Maximum Tank Height m	Equivalent *Pressure in N/mm² (kgf/cm²)	Minimum Cover Plate Thickness in mm				Minimum Bolting Flange Thickness After Finishing in mm			
		500-mm Manhole	600-mm Manhole	750-mm Manhole	900-mm Manhole	500-mm Manhole	600-mm Manhole	750-mm Manhole	900-mm Manhole
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
6.5	0.065 (0.65)	8	10	12	12	6	6	8	10
8.0	0.08 (0.80)	10	12	12	14	6	8	10	12
10.0	0.10 (1.00)	10	12	14	16	6	8	10	12
12.0	0.12 (1.20)	12	12	16	18	8	10	12	14
14.0	0.14 (1.40)	12	14	16	20	10	12	12	16
16.5	0.165 (1.65)	12	14	18	20	10	12	14	18
20.0	0.20 (2.0)	14	16	20	22	11	12	16	20
23.0	0.23 (2.3)	16	18	20	25	12	14	18	20

*Equivalent pressure is based on water loading.

TABLE 9 SHELL MANHOLE DIMENSIONAL DATA (*see* Fig. 11)

(*Clause* 7.2.1)

All dimensions in millimetres.

a) Nominal size, D	500	600	750	900
O.D. of cover plate, D_C	725	825	975	1 125
Bolt circle dia, D_B	650	750	900	1 050

b) The minimum neck thickness T_p shall be the thickness of the shell plate, or the allowable finished thickness of the bolting flange (*see* Table 8) whichever is thinner, but in no case shall it be thinner than the following:

Shell Thickness mm	*Thickness of Neck,* T_p mm
5-20	8
21-25	11
26-30	12
31-36	18
37-40	20

NOTE — If neck thickness on a built-up manhole is greater than the required minimum, the manhole reinforcing plate may be decreased accordingly within the limits specified in **6.3**.

c) Opening in the shell D_S shall be equal to D_o + 100 mm for Type A attachments. For other type of attachments D_S shall be established by manufacturer as required.

d) Opening in the reinforcing plate D_p shall be equal to O.D. of neck D_o + 3 mm.

e) Sizes of fillet welds (leg length) for attachment Type A shall be as follows:

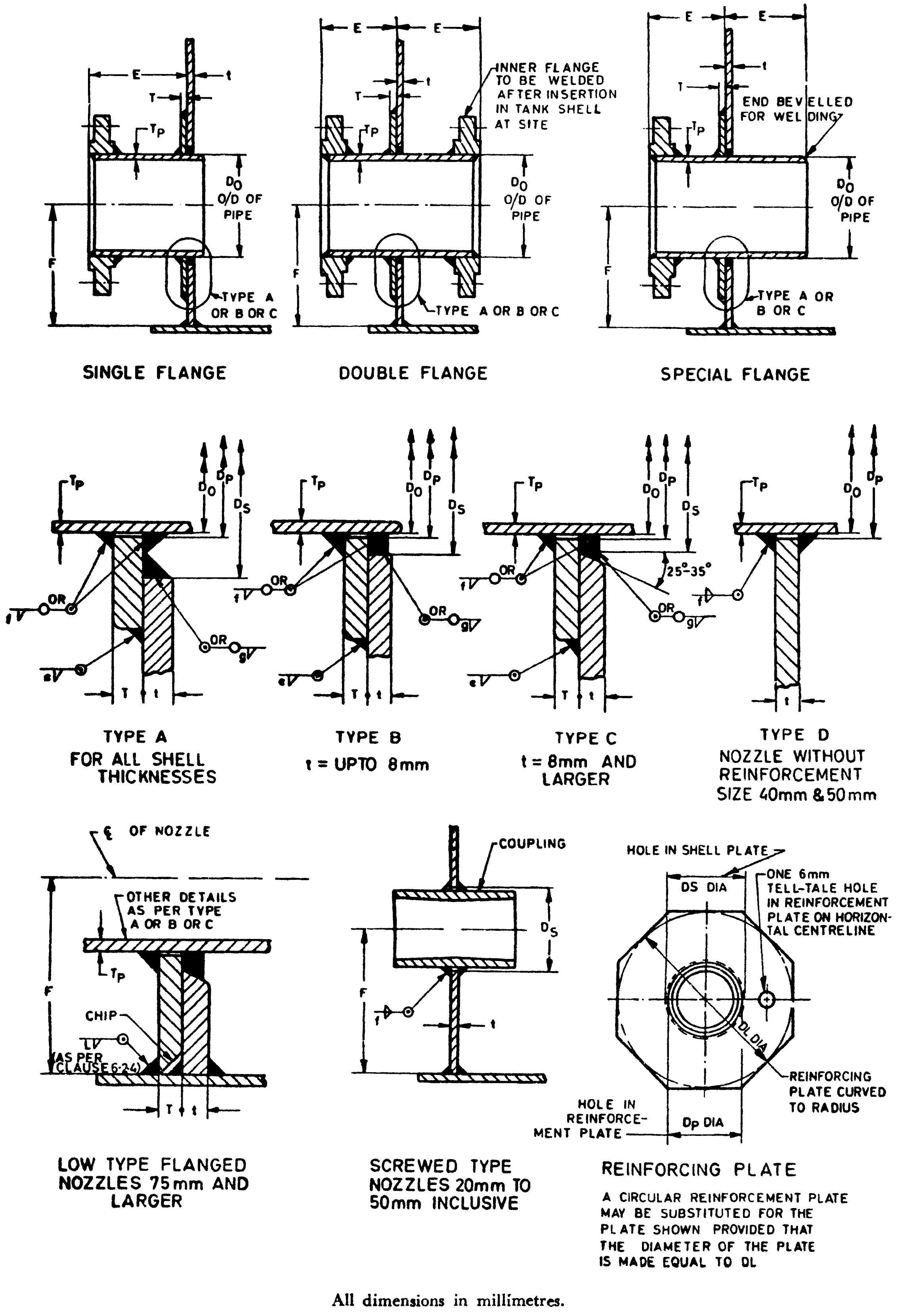
e =≥ 3T/4, but not less than 6 mm.

f = T/2, but not more than 12 mm and not less than 8 mm.

g = t, where t is 10 mm or less, or

t/2 with a minimum of 10 mm where t exceeds 10 mm.

f) For attachment Types B, C and D, sizes of fillet welds shall be fixed in accordance with **6.3.7.5**, **6.3.7.6** and **6.3.7.7**.



All dimensions in millimetres.

FIG. 12 TYPICAL SHELL NOZZLES (*see* Table 10)

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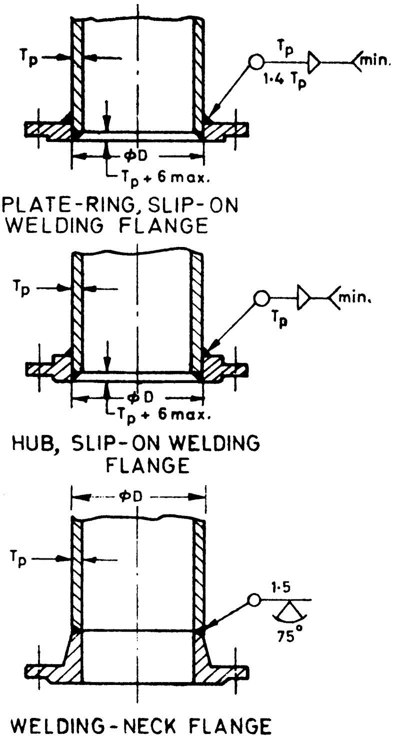


All dimensions in millimetres.

FIG. 13 SHELL NOZZLE FLANGES (*see* Table 10)

8. SHOP FABRICATION AND INSPECTION

8.1 Workmanship

8.1.1 All work of fabrication shall be done in accordance with this code. The workmanship and finish shall be first class in every respect subject to the closest inspection by the manufacturer's inspector, whether or not the purchaser waives any part of the inspection.

TABLE 10 SHELL NOZZLES DIMENSIONAL DATA (*see* Fig. 12 and 13)

(*Clause* 7.3.1)

All dimensions in millimetres.

A. FLANGED FITTINGS

Nominal Size of Nozzle, D	Minimum Wall Thickness, T_p*	Distance from Shell to Flange, E	Distance from Tank Bottom to Nozzle Centre	
			Regular Type	Low Type
(1)	(2)	(3)	(4)	(5)
900	12	350	1 000	920
850	12	330	950	870
800	12	330	900	820
750	12	300	850	770
700	12	300	800	720
650	12	300	750	670
600	12	300	700	620
550	12	280	650	570
500	12	280	600	520
450	12	250	550	470
400	12	250	500	420
350	12	250	450	370
300	12	220	430	350
250	12	220	380	300
200	12	200	330	250
150	11	200	280	200
100	8.5	175	230	150
75	7.5	175	200	120
50	5.5	150	175	100
40	5	150	150	75

B. SCREWED FITTINGS

Nominal Size of Nozzle	Wall Thickness	Distance from Tank Bottom to Nozzle Centre	
		Regular Type	Low Type
(1)	(2)	(3)	(4)
75	Coupling	230	140
50	,,	175	75
40	,,	150	75
25	,,	125	75
20	,,	100	75

*Includes corrosion allowance required for petroleum service. Special consideration should be given for severe service.

(*Continued*)

TABLE 10 SHELL NOZZLES DIMENSIONAL DATA — *Contd*

NOTE 1 — If neck thickness on a built-up nozzle is greater than the required minimum, the nozzle reinforcing plate may be decreased accordingly within the limits specified in **6.3.7**.

NOTE 2 — Opening in the shell D_S shall be equal to D_0 + 65 mm for Type A attachments. For other type of attachments, D_S shall be established by manufacturer as required.

NOTE 3 — Opening in the reinforcing plate D_p shall be equal to O.D. for neck D_0 + 3 mm.

NOTE 4 — Standard size of reinforcing plate $D_L = 2\ D_S$.

NOTE 5 — Fillet weld sizes for Type A attachment shall be as follows:

$e = t$ (shell plate thickness).

f = thickness for pipe wall T_p or reinforcing plate T whichever is lesser.

$g = r$ for shell thicknesses up to 10 mm

or

$t/2$ for shell thicknesses greater than 10 mm.

NOTE 6 — For attachment Types B, C and D, fillet weld sizes shall be in accordance with **6.3.7.5**, **6.3.7.6** and **6.3.7.7**.

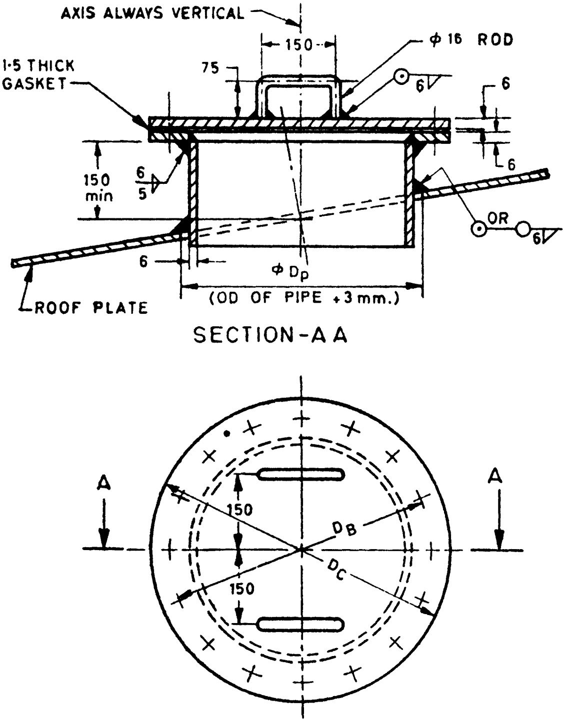
NOTE 7 — Nozzle pipe wall thicknesses listed above for 650, 700, 750, 800, 850 and 900 mm dia nozzles are applicable for use on tank shells up to 25 mm thickness. When these nozzles are installed on thicker shell plate, their wall thickness shall be as follows:

t	T_p
28	14
32	17.5
36	19.0
40	19.0

TABLE 11 ROOF MANHOLES (*see* Fig. 14)

(*Clause* 7.4.1)

SIZE OF MANHOLE	COVER PLATE DIAMETER D_C	BOLT CIRCLE DIAMETER D_B	NO. OF BOLTS	BOLT HOLE DIAMETER
(1)	(2)	(3)	(4)	(5)
mm	mm	mm		mm
500	650	590	16	18
600	750	690	20	18



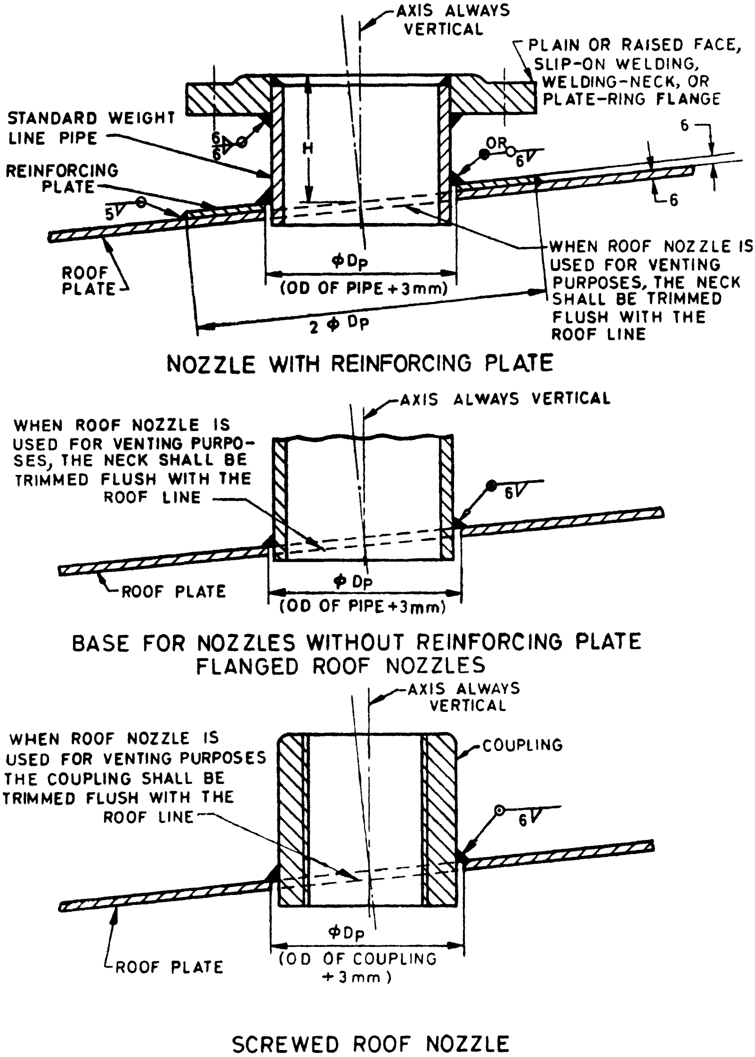
All dimensions in millimetres.

FIG. 14 TYPICAL ROOF MANHOLE (*see* Table 11)

TABLE 12 ROOF NOZZLES (*see* Fig. 15)

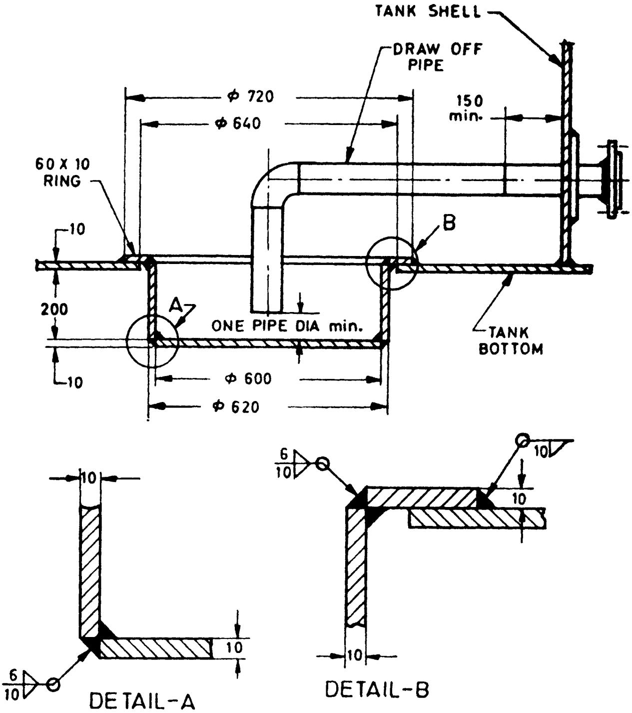
(*Clause* 7.5.1)

NOMINAL SIZE OF NOZZLE	PROJECTION OF NOZZLE *H*
(1)	(2)
mm	mm
40	150
50	150
75	150
100	150
150	150
200	150
250	200
300	200



All dimensions in millimetres.

FIG. 15 TYPICAL ROOF NOZZLES (*see* Table 12)



All dimensions in millimetres.

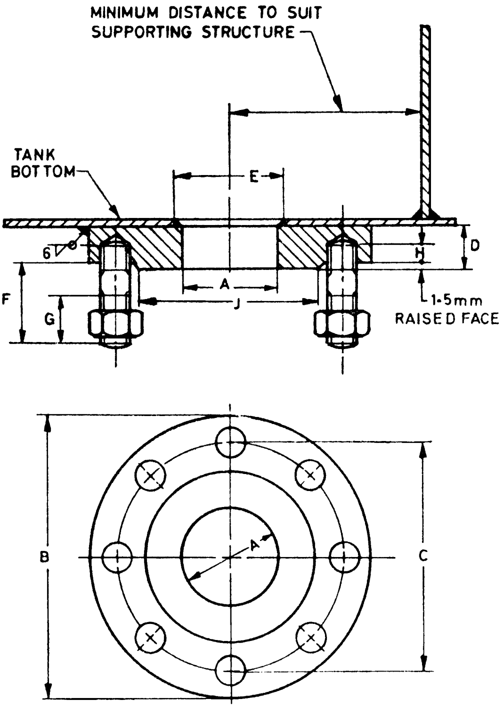
FIG. 16 TYPICAL WATER DRAW-OFF SUMP

TABLE 13 DETAIL OF DRAIN PAD FOR ELEVATED TANKS (*see* Fig. 17)

(*Clause* 7.6.2)

All dimensions in millimetres.

NOMINAL SIZE	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*	NO. AND DIA OF STUDS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
50	50	150	120	22	65	42	25	15	90	4 of 16 mm
75	90	190	150	25	105	45	25	19	120	4 of 16 mm
100	120	230	190	28	135	45	25	22	150	8 of 16 mm
150	170	280	240	32	185	50	32	24	200	8 of 20 mm



All dimensions in millimetres.

FIG. 17 TYPICAL DRAIN PAD FOR ELEVATED TANKS (*see* Table 13)

TABLE 14 FLUSH TYPE CLEANOUT FITTINGS (*see* Fig. 18)

(*Clause* 7.8)

All dimensions in millimetres.

SIZE OF OPENING HEIGHT (h) × WIDTH (b)	ARC WIDTH OF SHELL REINFORCING PLATE	UPPER CORNER RADIUS OF OPENING	UPPER CORNER RADIUS OF SHELL REINFORCING PLATE	BOTTOM FLANGE WIDTH	SPECIAL BOLT SPACING	NO. OF BOLTS	DIAMETER OF BOLTS
	W	r_1	r_2	f	g		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
600 × 600	1 800	200	725	85	80	36	20
900 × 1 200	2 650	375	1 025	120	105	46	25
1 200 × 1 200	3 125	400	1 280	125	110	52	25

TABLE 15 THICKNESS OF COVER PLATE, BOLTING FLANGE AND REINFORCING PLATE FOR FLUSH TYPE CLEANOUT FITTINGS (*see* Fig. 18)

(*Clause* 7.8)

All dimensions in millimetres unless otherwise specified.

MAXIMUM TANK HEIGHT	MINIMUM THICKNESS OF BOLTING FLANGE AND COVER PLATE, t_c FOR OPENING SIZE			MINIMUM THICKNESS OF BOTTOM REINFORCING PLATE, t_b FOR OPENING SIZE		
	600 × 600	900 × 1 200	1 200 × 1 200	600 × 600	900 × 1 200	1 200 × 1 200
(1) m	(2)	(3)	(4)	(5)	(6)	(7)
6.0	10	16	16	12	22	22
10.25	12	19	22	12	25	28
12.5	12	22	22	14	28	32
16.0	14	25	25	16	32	36
18.25	16	25	28	28	38	36

TABLE 16 THICKNESS AND HEIGHT OF SHELL REINFORCING PLATE FOR CLEANOUT FITTINGS (*see* Fig. 18)

(*Clause* 7.8)

All dimensions in millimetres unless otherwise specified.

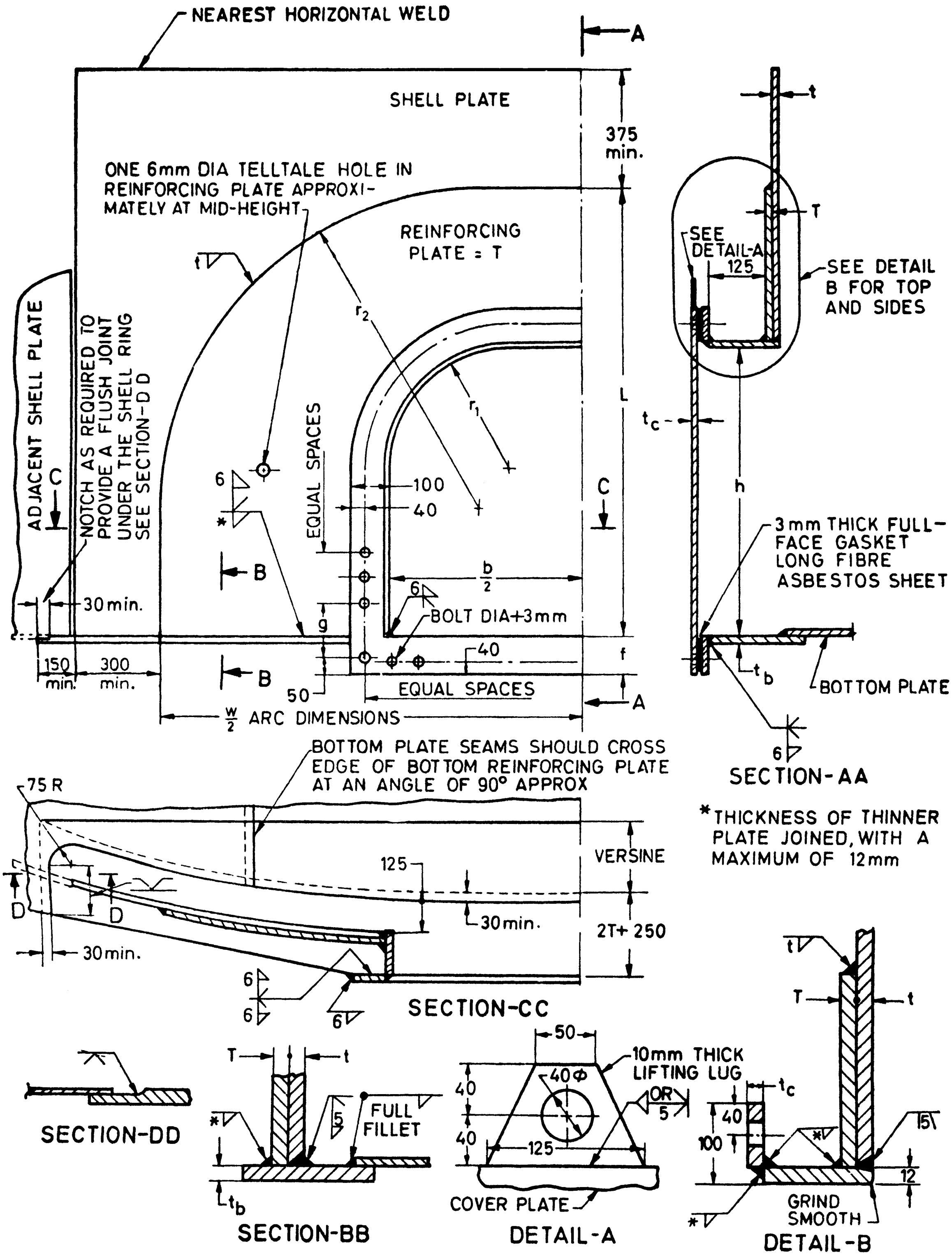
MAXIMUM TANK HEIGHT	THICKNESS OF SHELL REINFORCING PLATE, T FOR OPENING SIZE			HEIGHT OF REINFORCING PLATE, L FOR OPENING SIZE		
	600 × 600	900 × 1 200	1 200 × 1 200	600 × 600	900 × 1 200	1 200 × 1 200
(1) m	(2)	(3)	(4)	(5)	(6)	(7)
6.00	t+3	t+2	t+3	850	1 400	1 700
10.25	t+5	t+3	t+6	850	1 400	1 700
12.50	t+6	t+5	t+6	850	1 400	1 700
16.00	t+10	t+8	t+10	850	1 400	1 700
18.25	t+12	t+6	t+12	850	1 400	1 700

t = thickness of first shell course.

NOTE 1 — Opening for a cleanout fitting shall be rectangular, except that the upper corners of the opening shell have a radius at least equal to one-third the greatest height of the clear opening. The width or height of the clear opening shall not exceed 1 200 mm.

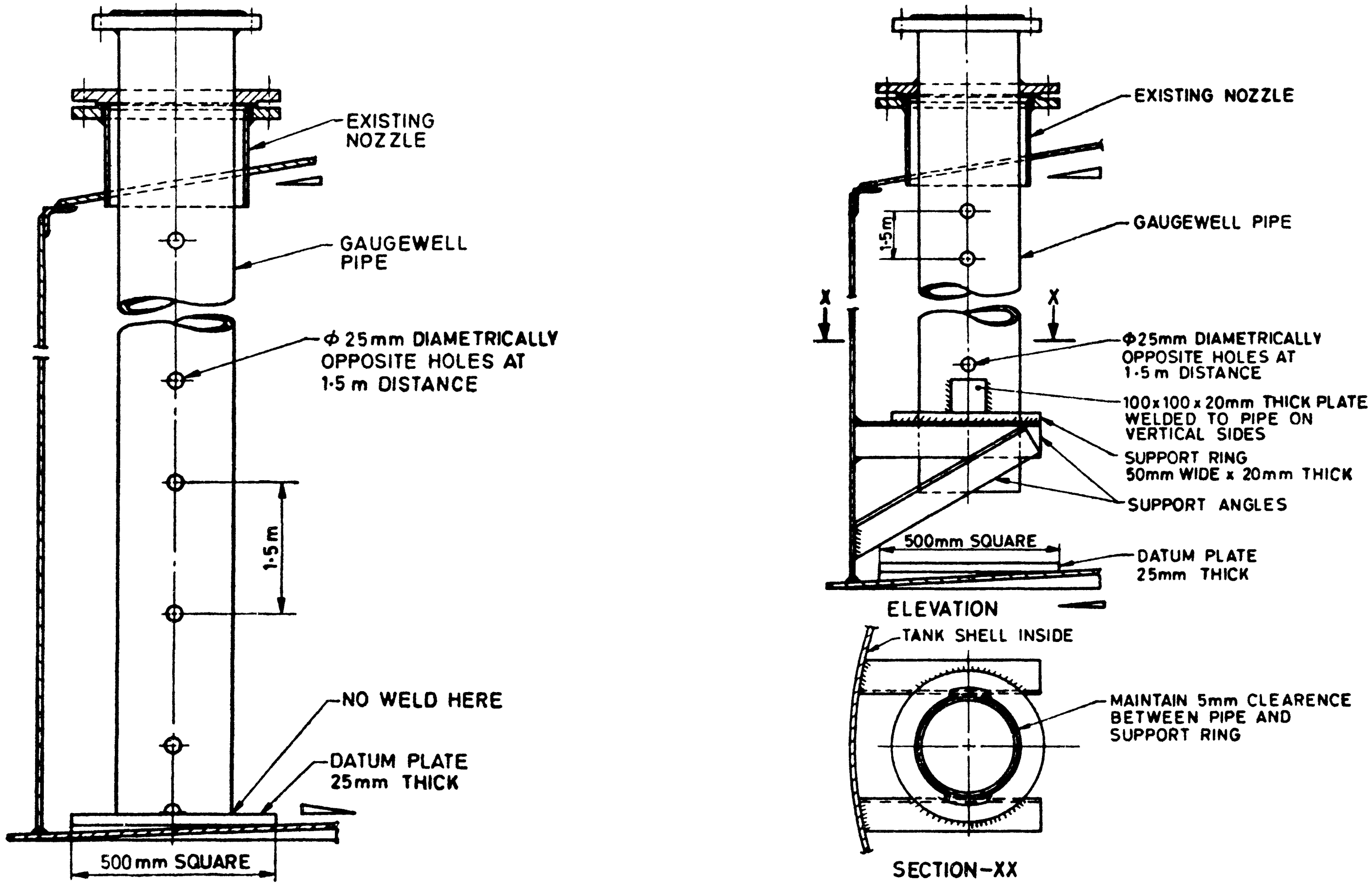
NOTE 2 — The reinforced opening shall be completely preassembled into a first course shell plate.

NOTE 3 — If any plate in the unit has a thickness greater than 16 mm, then the attachment welds shall be thermally stress relieved at a temperature of 600 to 650°C for 1 hour per 25 mm of thickness.



All dimensions in millimetres.

FIG. 18 TYPICAL FLUSH TYPE CLEANOUT FITTINGS (*see* Tables 14, 15 and 16)



19A 19B

FIG. 19 TYPICAL GAUGE-WELL INSTALLATION ON EXISTING NOZZLE OF CONE ROOF TANKS

8.2 Straightening — Straightening of material shall be done by pressing before being laid out or worked on in any way, or by methods that will not injure it. Heating or hammering is not permissible unless the material is heated to a forging temperature.

8.3 Plate Edge Preparation — The edges of plates may be sheared, marked, chipped or machine oxygen-cut. Shearing shall be limited to 10.00 mm for butt-welded joints. When edges of plates are oxygen-cut, the resulting surface shall be uniform, smooth and free from scale and slag accumulations before welding. A fine film of rust adhering after wire brushing on cut or sheared edges that are to be welded need not be removed. Circumferential edges of roof and bottom sketch plates or annulars may be manually oxygen-cut.

8.4 Shaping of Shell Plates — Shell plates may be shaped to suit the curvature of the tank and erection procedure to the following schedule:

Nominal Plate Thickness, Min mm	*Nominal Tank Diameter* m
5	12 and less
10	20 and less
13	40 and less
16	All

Except where otherwise specified by the purchaser, all shell plates shall be rolled to correct curvature.

8.5 Shop Painting — Unless otherwise specified by the purchaser, painting shall be as specified in **8.5.1** to **8.5.3**.

8.5.1 All roof structural members, stairways, handrails, etc, shall be thoroughly cleaned and freed from rust and scale and painted with a primary coat of an approved paint before despatch. Tank plates shall be despatched unpainted.

8.5.2 Where facilities are available, it is recommended that the whole of the tank material including mounting should have the mill scale removed by pickling or alternatively by sand or shot-blasting and be painted with an approved primer immediately after cleaning. Protective coatings may be used on surfaces to be welded subject to their inclusion in a welding procedure qualification test, and acceptance thereof.

8.5.3 All machined surfaces and bolts and nuts shall be left unpainted and coated with an approved corrosion inhibitor in a petroleum base before despatch.

8.6 Marking

8.6.1 All plates and structural members shall be marked in accordance with a marking diagram to be supplied by the manufacturer, which shall also bear such other marks as may be required to facilitate erection.

8.6.2 Erection marks shall be painted clearly on plates and structural members in white paint and shall be at least 50 mm high. In addition, they shall be hand stamped in symbols not less than 12 mm high, which in the case of plates, shall be in the corner approximately 150 mm from either edge. For curved plates, such marks shall be on the concave side.

8.7 Packing — All projecting plates and all ends of members at joints shall be stiffened, all straight plates shall be bundled, all screwed ends and machined surfaces shall be suitably packed, all rivets, bolts, railing connections and other small parts shall be packed separately and all other tank material shall be suitably packed so as to prevent damage or distortion during transit.

8.8 Inspection

8.8.1 The inspector shall have free access at all reasonable times to those parts of the manufacturer's works which are concerned with the fabrication of the steel work and shall be afforded all reasonable facilities for satisfying himself that the fabrication is being undertaken in accordance with the provisions of this standard.

8.8.2 Unless otherwise specified, inspection shall be made at the place of manufacture prior to despatch and shall be conducted so as not to interfere unnecessarily with the operation of the work.

8.8.3 The manufacturer shall guarantee compliance with the provisions of this standard if required to do so by the purchaser.

8.8.4 Should any structure or part of a structure be found not to comply with any of the provisions of this standard, it shall be liable to rejection. No structure or part of the structure once rejected shall be resubmitted for test except in cases where the purchaser or his authorized representative considers the defect as rectifiable.

8.8.5 Defects which may appear during fabrication shall be made good in a manner acceptable to the purchaser's inspector.

8.8.6 All gauges and templates necessary to satisfy the inspector shall be supplied by the manufacturer. The inspector may at his discretion check the test results obtained at the manufacturer's works by independent tests at the National Test House or elsewhere and should the material so tested be found to be unsatisfactory, the cost of such tests shall be borne by the manufacturer, and if satisfactory, the cost shall be borne by the purchaser.

9. SITE ERECTION

9.1 Foundations

9.1.1 The foundation for receiving the tank bottom shall be provided by the purchaser unless otherwise stated in the purchase order. It shall be properly consolidated. Where the bearing power of the soil is poor, special soil investigation shall be carried out to determine the most practical and economical procedure for stabilization of the tank foundation and determination of maximum allowable tank height.

9.1.2 All reasonable care shall be taken to prevent damage to the foundation during erection.

9.1.3 Level foundations shall be provided for tank erection. The foundation should have adequate bearing power to maintain the levelness of foundation till hydraulic test, which is essential for tank shells being built to tolerances specified in **9.3.5.1**.

9.1.3.1 Where concrete ringwalls are provided under the shell, the top of the ringwall shall be level within ±3 mm in any 10 metres of circumference and within ±6 mm in the total circumference.

9.1.3.2 Where concrete ringwalls are not provided, the foundation under the shell shall be level within ±3 mm in any 3 metres of circumference and within ±12 mm in the total circumference.

9.2 Preparation of Materials — All materials shall be inspected and faired as necessary at site to ensure that any damage received during transportation is corrected before erection to the satisfaction of the purchaser's representative. Particular attention shall be given to the removal of buckles and other forms of distortion in shell and bottom plates. Irregularities and dirt which would prevent metal to metal contact at the jointing faces shall be removed.

9.3 Erection of Plates

9.3.1 *Plate Holding Devices* — The method of holding the plates in position during welding and all devices used for this purpose should be approved by the purchaser.

9.3.2 The first course of shell plates shall be held in position by metal clamps or other devices attached to the bottom plates whilst it is plumbed and checked for circularity and before it is tack welded to the bottom.

9.3.3 *Lap Joints* — All lap joints shall be held in close contact during welding and the surface in contact shall be thoroughly cleaned before assembly.

9.3.4 *Erection Holes and Attachments*

9.3.4.1 Holes in platework to assist in erection should be avoided as far as possible. The method of filling any holes made shall be approved by the purchaser.

9.3.4.2 Lugs attached by welding to the tank and required only for the purpose of erection shall be removed on completion of erection without damaging the parent metal. Such areas shall be inspected carefully and shall be reinforced by weld deposit if required. All such weldments on the exterior of tank shall be ground smooth to present a neat appearance.

9.3.5 *Circularity and Shape*

9.3.5.1 Tank shells shall be built to the following tolerances to produce a tank of acceptable appearance and to permit proper functioning of floating roofs. These tolerances may be waived by agreement between the purchaser and the manufacturer:

a) The maximum out-of-plumbness of the top of the shell relative to the bottom of the shell shall not exceed 1/200 of the total tank height.

b) Radii measured at 300 mm above the bottom corner weld shall not exceed the following tolerances:

Diameter Range, m	*Radius Tolerance*, mm
0 to 12 excluding	±12
12 to 45 excluding	±18
45 to 75 excluding	±25
Over 75	±32

c) Peaking of vertical weld joints measured over an arc length of 1 m shall not exceed 12 mm.

d) Bending of horizontal weld joints measured by a straightedge of 1 m length shall not exceed 12 mm.

9.3.5.2 The top of the tank shell shall be carefully checked for circularity, dimensions and level before the roof members (fixed roof tank) or the primary wind girder (floating roof tank) are erected.

9.3.6 *Alignment*

9.3.6.1 Plates to be joined by butt welding shall be matched accurately and retained in position during the welding operation. Misalignment in completed vertical joints shall not exceed 10 percent of the plate thickness or 1.5 mm for plates 20 mm thick and under, and 3 mm for plates over 20 mm thick, whichever is the larger.

9.3.6.2 In completed horizontal butt joints, the upper plate shall not project beyond the face of the lower plate at any point by more than 20 percent of the thickness of the upper plate, with a maximum of 3 mm, except that a projection of 1.5 mm is permissible of upper plate less than 8 mm thick.

9.3.7 Tank shells shall be safeguarded from damage due to wind by provision of steel wire guys or any other means until completion of roof framing or the wind girder in the case of an open top tank.

9.4 Tolerances in Floating Roof Tanks

9.4.1 The differences in the gap between the shell and the periphery of the roof during erection of the roof shall not exceed 12 mm from the nominal gap.

9.4.2 The distance from the centre of the floating roof assembly to the vertical face of its outer circumferential rim, prior to fitting the sealing mechanism, shall have a tolerance of 12 mm for tanks up to 44-metre diameter and 25 mm for tanks with diameters over 44 metres.

9.4.3 Notwithstanding the various tolerances for shell dimensions, and the floating roof, the difference in the gap between the shell and the periphery of the roof shall not exceed 50 mm from the nominal value or such other limit specified by the manufacturer depending on the adaptability of the sealing mechanism provided by the manufacturer.

10. SITE WELDING

10.1 General

10.1.1 Tanks and their structural attachments shall be welded by the metal arc or submerged-arc process. The welding may be performed manually, automatically or semi-automatically using suitable equipment.

10.1.2 The welding procedure in general and the qualification of welders shall be as specified in IS : 823-1964* and IS : 817-1966†.

10.2 Welding Sequence

10.2.1 The welding sequence for tack welding and final welding of the bottom, shell and roof plates shall be such as to minimize the distortion due to welding shrinkage.

10.2.2 The welding sequence to be adopted shall be the subject of agreement between the purchaser and the erector.

10.3 Weather Conditions — Welding shall not be carried out when the surfaces of the parts to be welded are wet from any cause and during periods of rain and high winds unless the welder and work are properly shielded. Welding shall not be done when the base metal temperature is less than – 18°C. When the base metal temperature is between – 18°C and 0°C or the thickness is in excess of 32 mm, the surface of the two plates to be joined shall be pre-heated to a temperature warm to the hand to a distance of not less than four times the plate thickness, or 75 mm, whichever is the greater, in any direction, before welding is begun, and during the course of the welding operation this pre-heat temperature shall be maintained in the specified area.

*Code of procedure for manual metal arc welding of mild steel.

†Code of practice for training and testing of metal arc welders (*revised*).

10.4 Electrodes — Electrodes shall be in accordance with IS : 814 (Part I)-1974* or IS : 814 (Part II)-1974† as required. They shall be stored in a dry place in their original packets or cartons.

10.5 Tack Welds — Tack welds used in the assembly of the vertical joints of tank shells, and those used for assembling the shell to the bottom shell be removed and shall not remain in the finished joint. Tack welds in the bottom, roof and circumferential joints of the shell, and other joints, need not be removed provided they are sound and the subsequent weld beads are thoroughly fused into the tack welds.

10.6 Welding Procedure

10.6.1 Each layer of weld metal in multi-layer welding shall be cleaned of slag and other deposits before the next layer is applied. Slag shall also be removed from the finished welds before inspection.

10.6.2 The reverse side of full penetration butt joints shall be cleaned thoroughly prior to the application of the first bead to this side, in a manner that will leave the exposed surface suitable for the fusion of the weld metal to be added. This may be done by chipping, grinding or gouging, or when the back of the initial bead is smooth and free from crevices which might entrap slag, by other methods which may, upon field inspection, be acceptable to the purchaser.

10.6.3 The weld metal of both sides of all butt joints shall be built up so that the finished face in the area of fusion extends above the surface of the adjoining plates, or the thinner plate joined, preferably by not more than 1.5 mm.

10.6.4 There shall be no undercutting of the base metal, except on horizontal welds where undercutting up to 1 mm is permissible.

10.6.5 The edges of all welds shall merge with the surface of the adjoining plates without a sharp angle.

10.6.6 Peening of welds shall not be carried out except by agreement between the tank erector and the purchaser. In no case shall the final layer of the weld be peened.

10.6.7 Welding procedures used shall produce weldments whose mechanical properties are consistent with the plate material joined. Welding procedure qualifications for vertical and horizontal welds for design metal temperatures less than 10°C shall include impact tests in the weld metal and heat affected zone. The impact tests shall show an average of at least 25.5 N.m (2.5 kgf.m) at the design metal temperature.

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*Specification for covered electrodes for metal arc welding of structural steel: Part I For welding products other than sheets (*fourth revision*).

†Specification for covered electrodes for metal arc welding of structural steel: Part II For welding sheets (*fourth revision*).

Weld metal impact specimens shall be taken across the weld with the notch in the weld metal. The specimen shall be oriented so that the notch is normal to the surface of the material. One face of the specimen shall be substantially parallel to and within 1.5 mm of the surface of material 25 mm and thinner. For material more than 25 mm thickness, the impact specimens shall be taken as near midway between the surface and the centre of thickness as practical.

Heat-affected zone impact specimens shall be taken across the weld and as near the surface of the material as is practical. The specimens shall be of sufficient length to locate, after etching, the notch in the heat-affected zone. The notch shall be cut approximately normal to the material surface to include as much heat-affected zone material as possible in the resulting fracture.

10.7 Inspection

10.7.1 The purchaser's inspector shall have at all times free entry to all parts of the job while work under the contract is being performed. The manufacturer shall afford to purchaser's inspector, free of cost, reasonable facilities to assure him that the work is being performed in accordance with this standard.

10.7.2 Material damaged by defective workmanship, or otherwise defective, shall be rejected. The manufacturer shall be liable to furnish new material promptly or correct defective workmanship to the satisfaction of the purchaser's inspectors.

11. RADIOGRAPHIC INSPECTION OF SHELL JOINTS

11.1 Application — Spot radiographic inspection by X-ray or gamma-ray shall be confined to shell joints on tanks where a joint efficiency factor of 0.85 is specified. Procedure and technique adopted shall be in accordance with IS : 1182-1967* and IS : 2595-1963†.

11.2 Preparation for Examination — All butt-welded joints to be radiographed shall be prepared as follows:

The weld ripples or weld surface irregularities on both the inside and outside shall be removed by any suitable mechanical process to such a degree that the radiographic contrast resulting from any irregularities cannot mask or be confused with the image or any objectionable defect. Also, the weld surface shall merge smoothly into the plate surface. The finished surface of the reinforcement may be flush with the plate or may have a reasonable uniform crown not to exceed the following values:

*Recommended practice for radiographic examination of fusion welded butt joints in steel plates (*first revision*).

†Code of practice for radiographic testing.

Plate Thickness mm	*Maximum Thickness of Reinforcement* mm
Up to 12, including	1.5
Over 12 and up to 25 including	2.5
Over 25	3

11.3 Number and Location of Radiographs

11.3.1 Radiographs shall be taken as follows:

a) *Vertical joints* — One spot radiograph shall be taken in the first 3 m of completed vertical joint of each type and thickness welded by each welder or welding operator. Thereafter, without regard to the number of welders or welding operators working thereon, one additional spot radiograph shall be taken in each additional 25 m (approximately), and any remaining major fraction thereof, of vertical joints of the same type and thickness. At least 25 percent of the selected spots shall be at junctions of vertical and horizontal joints, with a minimum of two such intersections per tank.

b) *Horizontal joints* — Where complete penetration and complete fusion are specified, one spot radiograph shall be taken in the first 3 m of completed horizontal joint of the same type and thickness (based on the thickness of the thicker plate at the joint), without regard to the number of welders or welding operators working thereon. Thereafter, one radiograph shall be taken in each additional 50 m (approximately) and any remaining major fraction thereof, of horizontal joint of the same type and thickness.

c) For the purpose of this section, plates shall be considered of the same thickness when the difference in the specified or design thickness does not exceed 0.8 mm.

d) When two or more tanks are erected in the same location for the same purchaser, either concurrently or continuously, the number of spot radiographs to be taken may be based on the aggregate length of welds of the same type and thickness in each group of tanks rather than on the length of weld in each individual tank.

11.3.2 It is to be recognized that the same welder or welding operator may or may not weld both sides of the same butt joint. It is therefore permissible to inspect the work of two welders or welding operators with one spot radiograph if they weld opposite sides of the same butt joint. When a spot radiograph is rejected, it shall be determined by further spot radiographs whether one or both welders or welding operators were at fault.

11.3.3 As far as possible, an equal number of spot radiographs shall be taken from the work of each welder or welding operator, except that this requirement shall not apply where the length of joint welded by a welder or welding operator is much less than average.

11.3.4 The locations for taking spot radiographs may be determined by the purchaser's inspector.

11.3.5 As welding progresses, radiographs shall be taken as soon as practicable.

11.4 Film — Each radiograph shall clearly show a minimum of 150 mm of weld length. The film shall be centred on the weld and shall be of sufficient width to permit adequate space for the location of identification marks and thickness gauge or penetrometer.

11.5 Film Defects — All radiographs shall be free from excessive mechanical processing defects which would interfere with proper interpretation of the radiographs.

11.6 Submission of Radiographs — Prior to any repairs of welds, the radiographs shall be submitted to the inspector, who may be nominated by the purchaser, with such information as he may request regarding the radiographic technique used.

11.7 Radiographic Standards — Sections of welds which are shown by radiography to have any of the following imperfections, shall be judged unacceptable:

a) Any crack, incomplete fusion, or incomplete penetration.

b) Any individual elongated inclusion having a length greater than two-thirds the thickness of the thinner plate of the joint. However, regardless of the plate thickness, no such inclusion shall be longer than 20 mm, and no such inclusion shorter than 6 mm shall be the cause for rejection.

c) Any group of inclusions in line, where the sum of the longest dimensions of all such imperfections is greater than T (where T is the thickness of the thinner plate joined) in a length of $6T$, except when each of the individual spaces between imperfections is greater than three times the length of the longer of the adjacent imperfections. When the length of the radiograph is less than $6T$, the permissible sum of the lengths of all inclusions shall be proportionately less than T, provided the limits of the deficient welding are clearly defined.

d) Porosity in excess of that shown as acceptable in the following specifications:

1) The total area of porosity as determined from the radiographic film shall not exceed $0.060T$ mm^2 in any 150 mm length of weld, where T is the thickness of the weld. If the weld is less than 150 mm long, the total area of porosity shall be reduced in proportion. The maximum pore dimension shall be 20 percent of T or 3 mm, whichever is smaller, except that an isolated pore

separated from an adjacent pore by 25 mm or more may be 30 percent of T or 6 mm, whichever is less. Dark images of a generally circular or oval shape shall be interpreted as porosity for the purposes of this standard.

2) The porosity charts in Fig. 20 to 23 illustrate various types of assorted and uniform, randomly dispersed porosity indications. These charts represent the maximum acceptable porosity for each thickness. The charts represent full-scale 150 mm radiographs and shall not be enlarged or reduced. The porosity distributions shown are not necessarily the patterns that may appear on the radiograph but are typical of the number and size of indications permitted. When porosity indications differ significantly from the porosity charts, the actual numbers and sizes of the pores may be measured and the total area of porosity calculated.

3) In any 25 mm length of weld or $2T$, whichever is smaller, porosity may be clustered to a concentration four times that permitted by $0.060T$. Such clustered porosity shall be included in the porosity in any 150 mm length of weld which includes the cluster.

4) Aligned porosity shall be acceptable, provided the summation of the diameters of the pores is not more than T in a length $12T$ or 150 mm, whichever is less. However, each pore shall be separated by a distance at least six times the diameter of the largest adjacent pore. Aligned porosity indications shall be counted in the total area of permissible indications in any 100 mm length of weld.

5) Permissible porosity indications for weld thicknesses intermediate to those illustrated may be evaluated either by comparison with the next thinner material or by calculation, as shown in Table 17.

11.8 Determination of Limits of Defective Welding — When a section of weld is shown by a radiograph to be unacceptable under the provisions of **11.7**, or the limits of the deficient welding are not defined by such radiograph, two adjacent spots shall be examined by radiography. However, if the original radiograph shows at least 75 mm of acceptable weld between the defect and any one edge of the film, an additional radiograph need not be taken of the weld on that side of the defect. If the weld at either of the two adjacent sections fails to comply with the requirements of **11.7**, additional nearby spots shall be examined until the limits of unacceptable welding are determined; or the erector may replace all the welding performed by the welder or welding operator on that joint. If the welding is replaced, the inspector shall have the option of requiring that one radiograph be taken at any selected location on any other joint on which the same welder (or operator) has welded. If any of such additional spots fails to comply with the requirements of **11.7**, the limits of unacceptable welding shall be determined as specified for the initial section.

11.9 Repair of Defective Welds — Defects in welds shall be repaired by chipping or melting out such defects from one or from both sides of the joint, as required, and rewelding. Only sufficient cutting out of defective joints is required as is necessary to correct the defects.

All repaired welds in joints shall be checked by repeating the original test procedure.

11.10 Record of Radiographic Examination — A record shall be made by the erector of all films, with their identification marks, on a developed shell plate diagram.

After the completion of the structure, the films shall be the property of the purchaser, unless otherwise agreed between the purchaser and the erector.

TABLE 17 MAXIMUM PERMISSIBLE POROSITY INDICATIONS IN RADIOGRAPHS PER 150 mm LENGTH OF WELD (*see* Fig. 20 to 23)

[*Clause* 11.7(*d*)(5)]

WELD THICKNESS	TOTAL AREA OF PERMITTED POROSITY	LARGE PORES		MEDIUM PORE		FINE PORE	
		Size	Number	Size	Number	Size	Number
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	cm^2	mm		mm		mm	
3	0.05	—	—	—	—	0.40	40
6	0.10	—	—	0.6	31	0.40	100
12	0.20	2.5	4	0.80	40	0.50	101
20	0.30	3.2	4	0.90	50	0.60	99
25	0.40	3.2	5	1.0	50	0.70	101
40	0.60	3.2	7	1.20	50	0.90	99
50	0.80	3.2	10	1.4	51	1.0	100

12. TESTING OF TANKS

12.1 Bottom Testing

12.1.1 After the bottom and at least the bottom course of shell plates have been welded, the bottom shall be tested by pumping air beneath the bottom plates to a pressure just sufficient to lift them off the foundation and in any case, not less than 100 mmH_2O gauge. The pressure shall be held by the construction of a temporary dam of clay or other suitable material around the tank periphery. Soap suds or other suitable material shall be applied to all joints for detection of leaks.

12.1.2 Subject to agreement of the purchaser, fuel oil may be used instead of air and soap suds to test for leaks.

12.1.3 Alternatively, the bottom seams may be tested by the vacuum box method. Figure 24 shows typical details of a vacuum box.

12.2 Shell Testing

12.2.1 The shells of fixed roof tanks shall be tested after the completion of the roof; those of open-top or floating roof tanks after completion of the wind girder. Whenever possible, testing shall be by filling the tank with water to the level of the top leg of the top-curb angle and noting any leaks. When floating roofs are erected by floatation method, the shell shall be tested concurrently with erection.

12.2.2 Where local conditions are such that testing with water is impractical, the tank shall be tested by painting or spraying all joints on the inside with a highly penetrating oil and noting any leaks, or by pressurising the tank with air, the air pressure not exceeding the weight of the roof plates, and carefully examining the joints for any leakage by means of soap suds.

12.3 Fixed Roof Testing

12.3.1 When the tank-shell is tested with water, the roof shall be tested by pumping air under the roof plates while the tank is still full of water. In the case of non-pressure tanks, the roof shall be tested to a pressure of 73 mmH_2O gauge; in the case of pressure roof tanks to a pressure of one-and-a-quarter times the pressure at which the pressure side of the pressure/vacuum-relief valve is designed to open. Soap suds or other suitable material shall be applied to all joints for the detection of leaks. Alternatively, the roof weld seams may be tested by vacuum box method.

12.3.2 When water is not available for testing the tank-shell, the roof shall be tested by air as described in **12.2.2**.

12.4 Repair of Leaks

12.4.1 All leaks detected during testing shall be repaired to the satisfaction of the purchaser and on completion the entire tanks shall be tight and free from leaks.

12.4.2 In the joints between roof plates only, pinhole leaks may be repaired by mechanical caulking. However, where there is any indication of considerable porosity the leaks shall be sealed by laying down an additional layer of weld metal over the porous sections.

12.4.3 In all other joints, whether between shell plates or bottom plates or both, leaks shall be repaired only by welding, if necessary, after first cutting out the defective part.

12.4.4 When the tank is filled with water for testing, defects in the shell joints shall be repaired with the water level at least 300 mm below the joint being repaired.

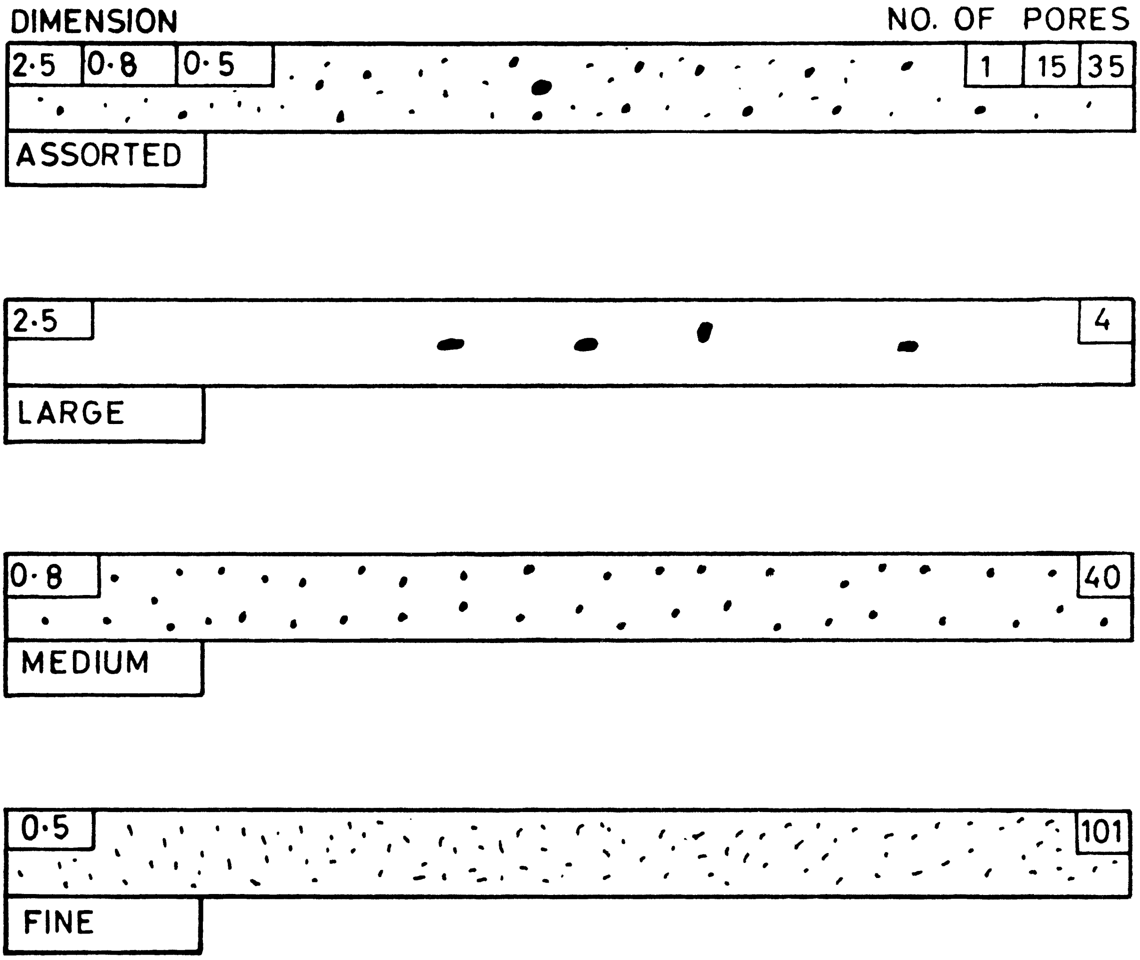


FIG. 20 RADIOGRAPHIC POROSITY STANDARDS — TYPICAL NUMBER AND SIZE PERMITTED IN ANY 150 mm LENGTH OF WELD, 12 mm WELD THICKNESS (*see* TABLE 17), TOTAL PORE AREA PERMITTED 0.20 cm^2

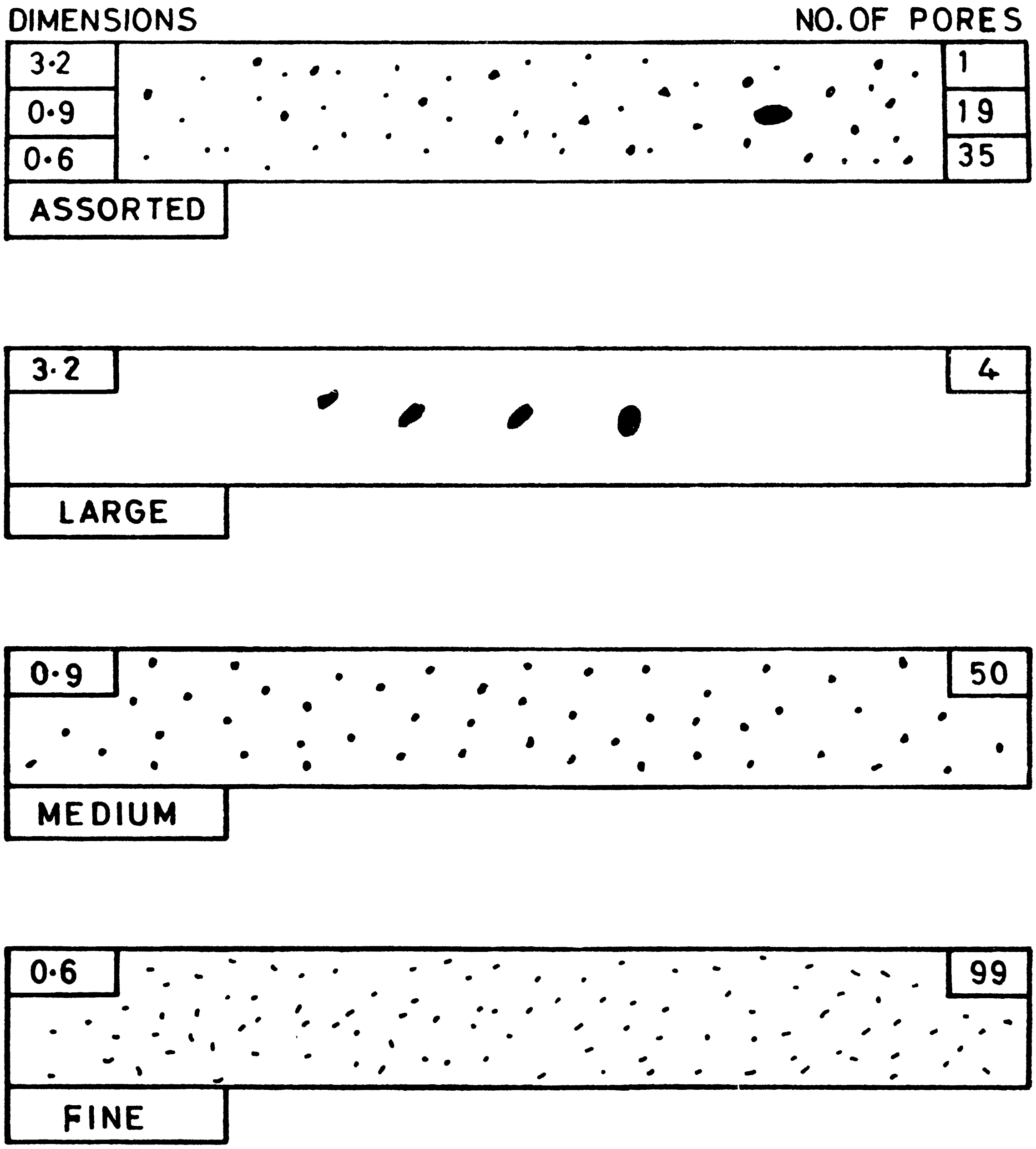


FIG. 21 RADIOGRAPHIC POROSITY STANDARDS — TYPICAL NUMBER AND SIZE PERMITTED IN ANY 150 mm LENGTH OF WELD, 20 mm WELD THICKNESS (*see* TABLE 17), TOTAL PORE AREA PERMITTED 0.30 cm^2

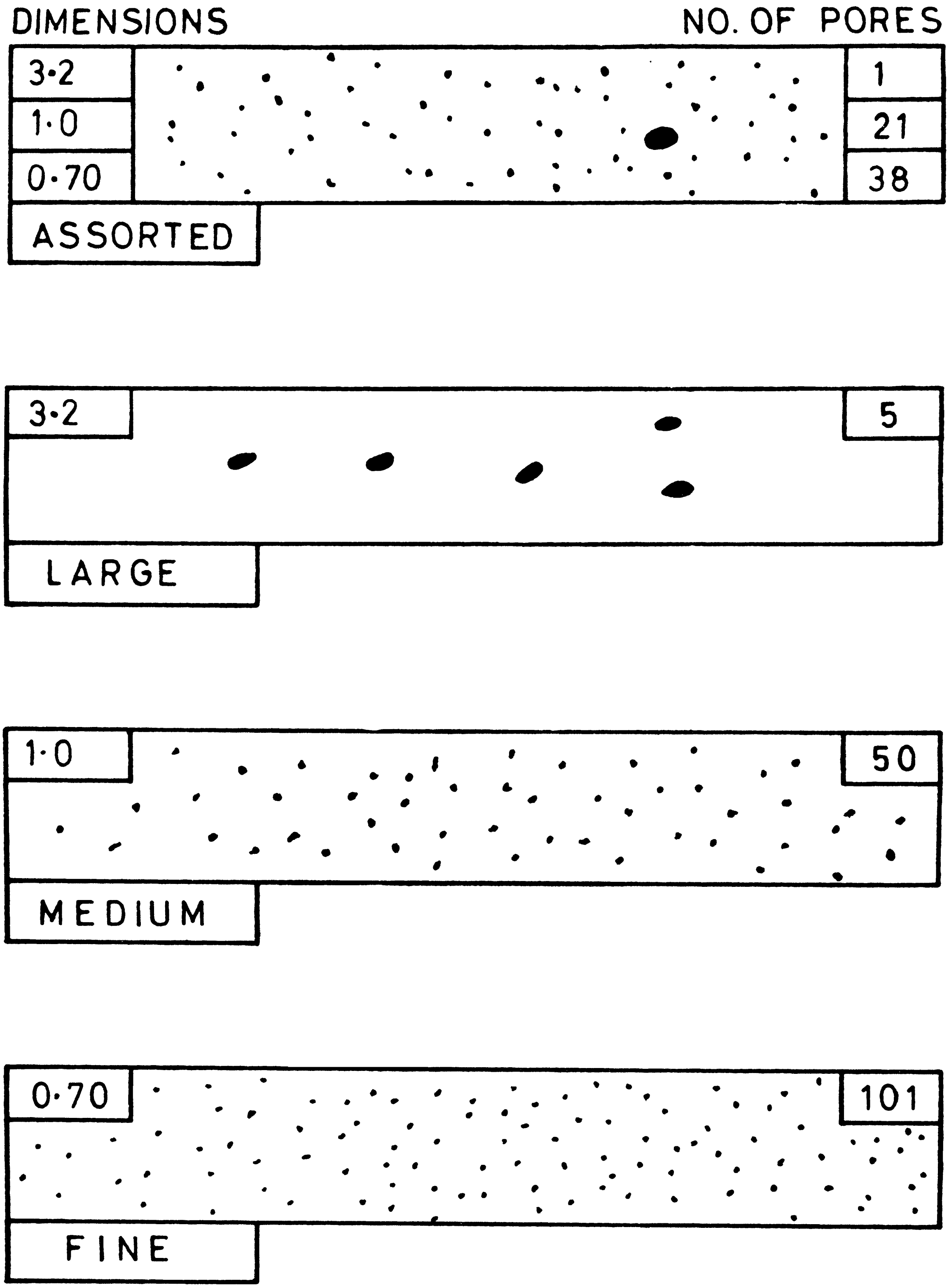
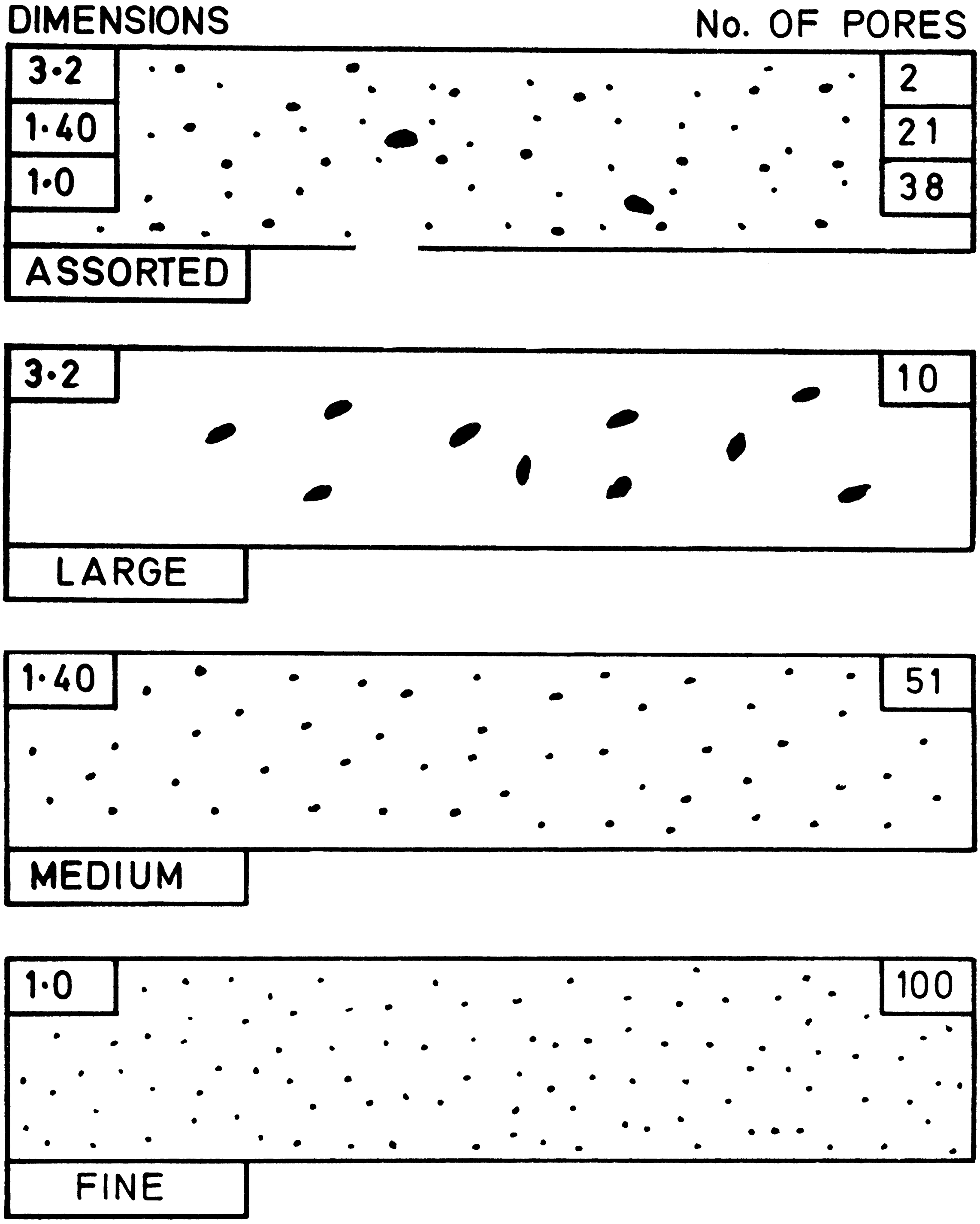
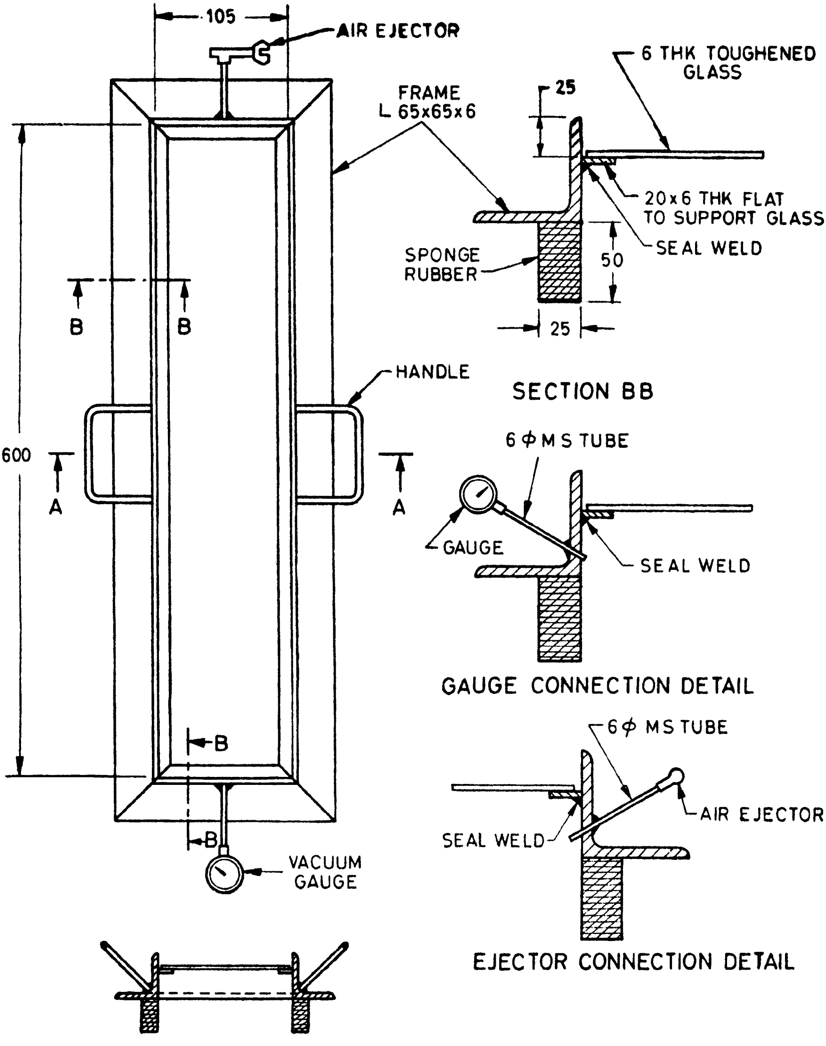


FIG. 22 RADIOGRAPHIC POROSITY STANDARDS — TYPICAL NUMBER AND SIZE PERMITTED IN ANY 150 mm LENGTH OF WELD, 25 mm WELD THICKNESS (*see* TABLE 17), TOTAL PORE AREA PERMITTED 0.40 cm^2



NOTE — This chart is provided for interpolation of plate thickness up to 40 mm.

FIG. 23 RADIOGRAPHIC POROSITY STANDARDS — TYPICAL NUMBER AND SIZE PERMITTED IN ANY 150 mm LENGTH OF WELD, 50 mm WELD THICKNESS (*see* TABLE 17), TOTAL PORE AREA PERMITTED 0.80 cm^2



All dimensions in millimetres.

FIG. 24 DETAIL OF TYPICAL VACUUM BOX

12.4.5 No welding shall be done on any tank unless all lines connecting thereto have been completely blanked off. No repairs shall be attempted on tanks while filled with oil, nor any tanks which have contained oil until the tanks have been emptied, cleaned and gas freed in a safe manner. No repairs shall be attempted by the erector on a tank which has contained oil except in a manner approved in writing by the purchaser, and in the absence of the purchaser's inspector.

APPENDIX A

(*Clause* 3.3)

INFORMATION TO BE FURNISHED BY PURCHASER

A-1. The following information shall be supplied by the purchaser in his enquiry:

a) Location of tank;
b) Nominal capacity of tank;
c) Tank diameter and/or height restrictions;
d) Internal tank pressure and/or vacuum;
e) Rate of filling and emptying tank;
f) Product to be stored, its design specific gravity;
g) Minimum ambient temperature where tank is located or design metal temperature;
h) Corrosion allowance for shell, bottom, roof, structure and other parts;
j) Maximum wind speeds;
k) Earthquake factor;
m) Any additional loads to be considered for tank design;
n) Type of foundation, and bearing capacity of the soil;
p) List of mountings required and their location on the tank;
q) Type of bottom construction — lap or butt welded;
r) Type of roof, namely, cone, dome or open-top. In case of supported cone column supported or truss supported;
s) Extent of painting required and surface preparation; and
t) Scope of supply of tank manufacturer.

APPENDIX B

(*Clause* 6.3.9)

ALTERNATE DESIGN FOR TANK SHELLS

B-1. GENERAL

B-1.1 The rules given in this appendix permit the use of a higher design stress and a design based on the specific gravity of the product to be stored. These rules can be applied only when specified by the purchaser.

B-1.2 The purchaser should give special consideration to foundations, corrosion allowance, or any other protective measures deemed necessary. Shells designed on the basis of these rules shall incorporate all provisions of this appendix. For all other details, provisions of the code shall apply.

B-2. MATERIALS

B-2.1 Plate materials specified in **4.1** shall be used without impact testing on tank shells and its reinforcements under these rules for design metal temperatures greater than 10°C.

B-2.2 For temperatures lower than 10°C, up to – 20°C materials listed in **4.1**, with the exception of steel conforming to IS : 226-1975*, steels shall be used and shall demonstrate adequate notch toughness at the design metal temperature. Each plate as rolled shall be impact tested at the design metal temperature to show that the average of three Charpy V-notch full sized specimens is a minimum of 4 kgf.m (longitudinal) or 2.5 kgf.m (transverse).

B-2.3 Plate materials used for insert type reinforcement in thickness greater than 50 mm shall conform to IS : 2002-1962† Grade 2B or IS : 2041-1962‡ and shall meet test requirements as specified above.

B-2.4 Piping and flanges used shall meet specifications listed under **4.5** and **4.6** respectively and shall have a minimum Charpy V-notch impact strength of 20 N.m (2 kgf.m) (full sized specimen) at the design metal temperature when it is below 10°C.

B-3. ALLOWABLE STRESS

B-3.1 The maximum allowable stress including the joint efficiency factor for designing shells shall be 0.7 of the minimum yield stress or 0.4 of the minimum ultimate tensile stress whichever is less, except that an additional safety factor of 1.05 shall be considered in computing maximum allowable stress values for designing the bottom course of tank shells.

*Specification for structural steel (standard quality) (*fifth revision*).
†Specification for steel plates for boilers.
‡Specification for steel plates for pressure vessels.

B-4. PLATE THICKNESS

B-4.1 The minimum thickness of shell plates shall not be less than that calculated from the following formula or according to **6.3.3.2** whichever is greater:

$$t = \frac{4.9\ (H - 0.3)\ D \times G}{S} + c \text{ where } S \text{ is in N/mm}^2$$

or

$$= \frac{50\ (H - 0.3)\ D \times G}{S} + c \text{ where } S \text{ is in kgf/cm}^2$$

where

t = minimum thickness in mm;
D = nominal diameter of tank in m;
H = height from the bottom of the course under consideration to top curb angle or to bottom of any overflow which limits tank filling height in m;
G = specific gravity of liquid to be stored;
S = allowable stress as computed from **B-3.1**; and
c = corrosion allowance in mm to be specified by purchaser, but not less than 1.5 mm.

B-4.2 The manufacturer may use a combination of high strength steel for lower courses and low strength steel for upper courses, provided that the thickness of any course is not less than the course immediately above it.

B-5. HYDROSTATIC STRESSES

B-5.1 Stresses in plates due to hydrostatic loading shall not exceed 3/7 of minimum ultimate tensile stress of the material used. Plate thicknesses determined by **B-4.1** or **6.3.3.2** shall be checked for hydrostatic stresses S_1 by the following equation and shall be increased as required to keep it within specified limits:

$$S_1 = \frac{4.9\ (H - 0.3)\ D}{t} \text{ N/mm}^2 \leq 3/7\ \textit{Min} \text{ UTS}$$

or

$$= \frac{50\ (H - 0.3)\ D}{t} \text{ kgf/cm}^2 \leq 3/7\ \textit{Min} \text{ UTS}$$

B-6. SHELL CONNECTIONS

B-6.1 All shell opening connections which require reinforcement shall be attached by welds fully penetrating the shell. Where insert type reinforcements, shown in Fig. 25, are used, they shall be butt-welded into the shell as shown, with the welds having complete penetration and fusion. Welds attaching manholes and nozzles into these insert plates may have partial penetration as shown in Fig. 25.

B-6.2 All opening connections 300 mm or larger in nominal diameter welded into a shell plate exceeding 25 mm in thickness shall be prefabricated into the shell plate of thickened insert plate and this complete assembly shall be stress-relieved before erection. Alternatively, all weldments and the heat-affected zones on this assembly may be locally stress-relieved by electric induction heating method, however, prior to welding the plate assembly into the tank. The stress-relieving requirements do not apply to the weld to the bottom annular plate, except for flush type cleanout openings. All flush types cleanout openings, including the bottom reinforcing plate or annular plate shall be stress-relieved.

B-6.2.1 Where stress relief has been performed, the spacing from the periphery weld to a shell butt-weld shall be at least 150 mm from vertical joints or 75 mm from horizontal joints provided that, in either case, the spacing is not less than 3 times the shell thickness. These rules shall also apply to the bottom-to-shell joint except that, as an alternative the insert plate or reinforcing plate may extend to and intersect the bottom-to-shell joint at approximately 90°.

B-6.3 All welds attaching manholes and nozzles shall be examined by magnetic particle inspection, after stress-relieving if any, but before the hydrostatic test of the tank.

B-6.4 Flush type cleanout openings in accordance with **7.8** are permissible with the following exception:

a) The material for shell plate in the cleanout opening assembly, the shell reinforcing plate, the tank bottom reinforcing plate and the neck plate shall conform to requirements of **B-2**.

b) The maximum height of the opening in the shell shall not exceed 900 mm.

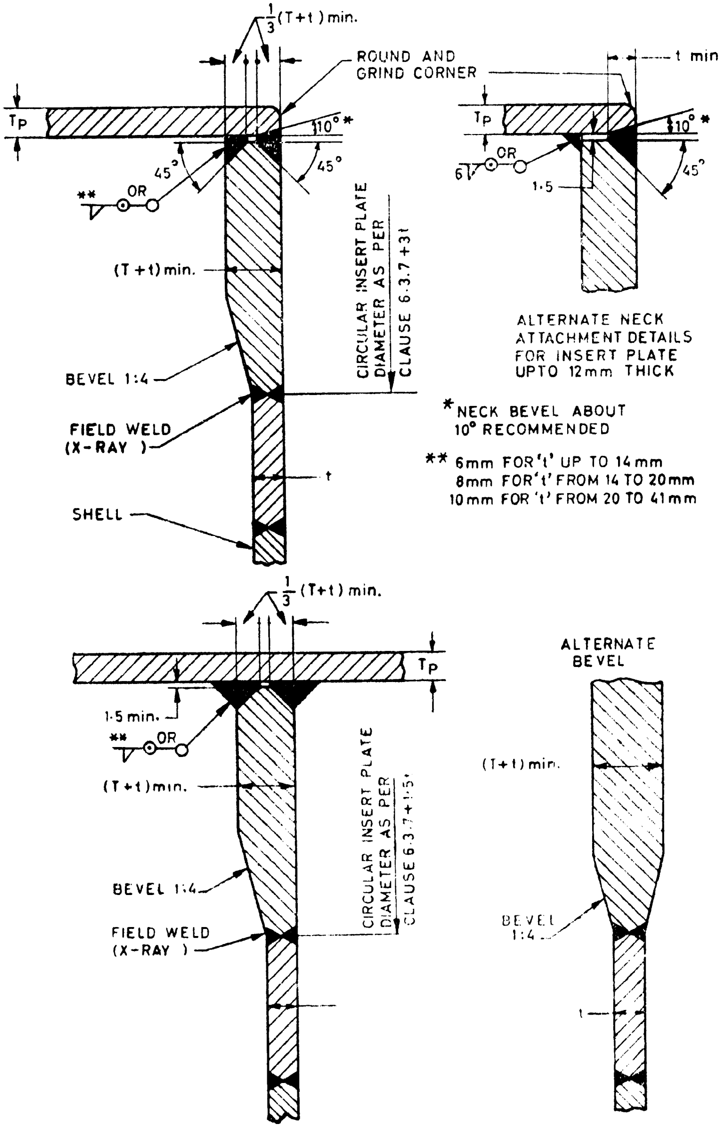
c) The upper corner radius r_1 of a 900 × 1 200 mm shell opening (*see* Table 14) shall be 600 mm.

B-6.5 Piping attached to nozzles on the shell shall be designed to have maximum flexibility to eliminate or minimize loads on the shell connections imposed by its restraint. Nozzle reinforcements shall also be designed to take care of any additional loading caused by piping or other attachments.

B-7. RADIOGRAPHY

B-7.1 The following additional radiography over the requirements specified in **11** shall be carried out on tanks built under the rules of this appendix:

a) On shell plates up to 10 mm thickness, one additional radiograph shall be taken on all vertical joints.



All dimensions in millimetres.

FIG. 25 INSERT TYPE REINFORCEMENT FOR MANHOLES AND NOZZLES

b) On shell plates greater than 10 mm and up to and including 25 mm, all the joints shall be radiographed showing at least 50 mm of horizontal weld on either side of the intersection. On the lowest course, one additional radiograph shall be taken as close as practicable to the shell/bottom fillet weld.

c) On shell plates greater than 25 mm, vertical welds shall be fully radiographed. Additionally, all the joints shall be radiographed showing at least 50 mm of horizontal weld on either side of the intersection.

d) Butt welds around insert type reinforcements shall be fully radiographed.

B-8. WELDING PROCEDURES AND INSPECTION

B-8.1 Low-hydrogen electrodes shall be used for all manual metal-arc welds of shell courses having a thickness of 14 mm or more.

B-8.2 Welding procedures used shall produce weldments whose mechanical properties are consistent with the plate material joined. Welding procedure qualifications for vertical and horizontal welds for design metal temperatures less than 10°C shall include impact tests in the weld metal and heat-affected zone. The impact tests shall show an average of at least 25 N.m (2.5 kgf.m) at the design metal temperature.

B-8.2.1 Weld metal impact specimens shall be taken across the weld with the notch in the weld metal. The specimen shall be oriented so that the notch is normal to the surface of the material. One face of the specimen shall be substantially parallel to and within 1.5 mm of the surface of material 25 mm and thinner. For material more than 25 mm thickness, the impact specimens shall be taken as near midway between the surface and the centre of thickness as practical.

B-8.2.2 Heat-affected zone impact specimens shall be taken across the weld and as near the surface of the material as is practical. The specimens shall be of sufficient length to locate, after etching, the notch in the heat-affected zone. The notch shall be cut approximately normal to the material surface to include as much heat-affected zone material as possible in the resulting fracture.

B-8.3 When the service conditions might include the presence of hydrogen sulphide, it is recommended that consideration be given to the hardness of the inside welds, including the heat-affected zone, in order to minimize the possibility of stress corrosion cracking. The weld metal and adjacent heat-affected zone often contain a zone of hardness well in excess of RC 22 and could be expected to be more susceptible to cracking than unwelded material. Any hardness criteria should be a matter of agreement between the purchaser and the manufacturer and should be based on an evaluation of the expected hydrogen sulphide concentration in the product, the possibility of moisture being present on the inside metal surface, and the strength and hardness characteristics of base metal and weld metal.

B-9. FOUNDATION

B-9.1 The selection of the tank site and the design and construction of the foundation shall be given careful consideration in order to ensure adequate tank support. Concrete ringwall foundations shall be considered. The adequacy of the foundation is the responsibility of the purchaser.

APPENDIX C

(*Clause* 6.4.2.5)

VENT SIZING FOR ATMOSPHERIC AND LOW PRESSURE TANKS

C-1. SCOPE

C-1.1 This appendix applies to the normal and emergency venting requirements for above ground fixed-roof tanks for liquid petroleum storage, designed to specifications of this code. The following rules outline safe and reasonable practices for the normal climatic and normal operating conditions.

C-1.2 Where abnormal conditions exist or are anticipated, such as tanks containing heated oil, receiving oil from wells or traps, using flame arrestors or such restrictions and tanks subjected to pipe line surges, larger venting capacity than that indicated by the provisions of this appendix may have to be provided.

C-2. DETERMINATION OF VENTING REQUIREMENTS

C-2.1 Venting requirements shall be computed for the following conditions:

a) Vacuum or inbreathing owing to maximum outflow of oil from tank.

b) Vacuum or inbreathing owing to vapour contraction resulting from a sharp decrease in atmospheric temperature.

c) Pressure or outbreathing caused by maximum inflow of oil into tanks and the resulting maximum evaporation.

d) Pressure or outbreathing due to expansion and evaporation caused by maximum increase in atmospheric temperatures (thermal breathing).

e) Pressure or outbreathing owing to fire exposure.

C-3. NORMAL VENTING CAPACITY REQUIREMENTS

C-3.1 Normal venting capacity shall be computed without exceeding the normal operating pressure or vacuum conditions, thus avoiding physical damage to the tank.

C-3.2 Total normal venting capacity shall not be less than the total of the venting requirements arising out of oil movement and thermal effect. For tanks storing volatile liquids, the required normal venting capacity may be reduced since vapour formation and condensation which occur within the permissible vessel operating pressure, shall provide the venting requirements partially or fully. This should be taken into account where noncondensables are present.

C-3.3 Vacuum Relief

C-3.3.1 Venting capacity required to be provided for maximum oil movement from the tank should be equivalent to 15 m^3 per hour of maximum emptying rate. This also includes gravitational flow of oil to other tanks, for oils of any flash point.

C-3.3.2 For tanks storing oils of any flash point venting capacity required resulting from thermal inbreathing shall not be less than that shown in col 2 of Table 18.

C-3.4 Pressure Relief

C-3.4.1 Venting capacity required for maximum movement of oil into tank and the resulting evaporation, should be equivalent to:

a) 17.5 m^3 of free air per hour for each 15 m^3 per hour of maximum filling rate, for oils with a flash point of 40°C or above; and

b) 35 m^3 of free air per hour for each 15 m^3 per hour of maximum filling rate for oils with a flash point below 40°C.

C-3.4.2 Venting capacity required for thermal outbreathing, including thermal evaporation, for a given tank capacity should be equivalent to:

a) values shown in col 3 of Table 18 for oils with a flash point of 40°C or above, and

b) value shown in col 4 of Table 18 for oils with a flash point below 40°C.

C-4. EMERGENCY VENTING CAPACITY REQUIREMENTS

C-4.0 In the event of a storage tank getting exposed to fire, the venting rate may be in excess of that resulting from a combination of normal thermal effects and oil movement. Provision of additional venting capacity in such cases shall be dictated by the type of construction.

C-4.1 Tanks Having a Weak Roof-to-Shell Attachment — In the case of fixed roof tanks with a roof-to-shell attachment (maximum 5 mm single-fillet weld) excess pressure will be safely relieved by the preferential failure of the weak roof-to-shell junction, should the normal venting capacity prove inadequate. Provision of additional emergency venting requirements will not be necessary for tanks built to such specification.

C-4.2 Tanks Without Weak Roof-to-Shell Connection — For tanks not having a weak roof-to-shell connection as described in **C-4.1**, the required venting capacity for fire exposure will be evaluated as outlined below:

a) For tanks designed for pressures of 10 N/cm^2 (1 kgf/cm^2) or below, the total rate of venting shall be determined in accordance with Table 19. No increase in venting is required for tanks with more than 280 m^2 of exposed wetted surface.

b) For tanks and storage vessels designed for pressures over 10 N/cm^2 (1 kgf/cm^2) the total rate of venting shall be determined in accordance with Table 19 for the exposed wetted area not exceeding 280 m^2. For exposed wetted area exceeding 280 m^2, the total rate of venting shall be calculated by the following formula:

$$CMH = 220\,A^{0.82}$$

where

CMH = venting requirement in m^3 of free air per hour at 10 N/cm^2 (1 kgf/cm^2) and 15°C, and

A = exposed wetted surface in m^2.

Wetted area for the tank shall be the total exposed area of the shell in m^2 within a maximum height of 10 m above grade.

C-4.3 The total venting requirements in m^3 of free air as enumerated in Table 19 and derived from the formula given in **C-4.2** (b) are based on the assumption that the liquid contained in the storage vessel will have similar characteristics as that of hexane since this will provide results which are within an acceptable degree of accuracy as desired, the total emergency venting requirement for any specific liquid may be determined by the following formula:

$$CMH \text{ of free air} = V.\frac{750}{L\sqrt{M}}$$

where

V = volume of free air in m^3 per hour from Table 19 or the formula in **C-4.2** (b),

L = latent heat of vaporization of the specific liquid in calories per gram, and

M = molecular mass of the specific liquid.

C-4.4 Since the normal thermal effect can be disregarded during a fire, full credit may be taken for the vent capacity provided for normal venting and it can also be assumed that there will be no oil movement into the tanks.

C-4.5 Total venting capacity shall in no case be less than the values enumerated in Table 19 and in the event of the normal vents being inadequate, additional emergency vents of the type described in **C-5.1**(b) shall be provided.

C-4.6 The vent size may be calculated on the basis of maximum allowable working pressure.

C-4.7 The total rate of emergency venting as obtained from **C-4.2**(a) and **C-4.2**(b) may be multiplied appropriately by one of the following factors when additional protection is provided:

a) 0.5 when drainage is provided away from the tank or vessel.

b) 0.3, 0.15 and 0.075 when 25 mm, 50 mm and 100 mm thickness of external insulation is provided respectively.

C-5. NORMAL VENTING

C-5.1 Normal venting shall be accomplished by a pilot-operated relief valve, pressure relief valve, pressure vacuum (PV) valve, or an open vent with or without a flame-arresting device in accordance with the following requirements:

a) A pilot-operated relief valve, if used, shall be so designed that the main valve will open automatically and protect the tank in the event of failure of the pilot valve diaphragm or other essential functioning device. Relief valves equipped with a weight and level, as far as possible, should not be used.

b) A pressure relief valve is applicable on tanks operating above atmospheric pressure; in cases where a vacuum can be created within a tank, vacuum protection may be required.

c) PV valves are recommended for use on atmospheric storage tanks in which oil with a flash point below 38°C is stored and for use on tanks containing oil which is heated above the flash point of the oil. A flame arrester is not considered necessary for use in conjunction with a PV valve.

d) Open vents with a flame-arresting device may be used in place of PV valves on tanks in which oil with a flash point below 38°C is stored and on tanks containing oil which is heated above the flash point of the oil.

e) Open vents may be used to provide venting capacity for tanks in which oil with a flash point of 38°C above is stored, for heated tanks where the oil storage temperature is below the oil flash point, for tanks with a capacity of less than 10 m^3 used for the storage of any product, and for tanks with a capacity of less than 500 m^3 used for the storage of crude oil.

f) In the case of viscous oils, such as cutback and penetration grade asphalts, where the danger of tank collapse resulting from sticking pallets or from plugging of flame arrestors is greater than the possibility of flame transmission into the tank, open vents may be used as an exception to the requirement for PV valves or flame-arresting devices as called for in (c) and (d) above.

TABLE 18 THERMAL VENTING CAPACITY REQUIREMENTS

(*Clauses* C-3.3.2 *and* C-3.4.2)

[Expressed in cubic metres of free air per hour at 10 N/cm^2 (1 kgf/cm^2) and 15°C]

TANK CAPACITY	VACUUM (INBREATHING)	PRESSURE (OUTBREATHING)	
		Flash Point 40°C or Above	Flash Point Below 40°C
(1) m^3	(2)	(3)	(4)
7.5	1.75	1.25	1.75
12	3	1.75	3
60	15	8.5	15
120	30	17	30
240	60	35	60
360	86	50	85
480	115	70	115
600	145	85	145
1 200	285	170	285
1 800	425	255	425
2 400	570	340	570
3 000	680	425	680
3 600	795	485	795
4 200	880	540	880
4 800	965	595	965
5 400	1 050	655	1 050
6 000	1 135	680	1 135
7 200	1 245	765	1 245
8 350	1 360	825	1 360
9 550	1 475	880	1 475
10 750	1 590	965	1 590
11 950	1 700	1 020	1 700
14 300	1 925	1 160	1 925
16 700	2 125	1 275	2 125
19 100	2 325	1 415	2 325
21 500	2 550	1 530	2 550

NOTE — For tanks with intermediate capacities, values may be computed by interpolation.

TABLE 19 TOTAL RATE OF EMERGENCY VENTING REQUIRED FOR FIRE EXPOSURE *VERSUS* WETTED SURFACE AREA

(*Clauses* C-4.2, C-4.3 *and* C-4.5)

[Wetted area *versus* cubic metres of free air per hour at 10 N/cm^2 (1 kgf/cm^2) and 15°C]

WETTED AREA	VENTING REQUIREMENT
(1)	(2)
m^2	m^3/h
2	600
3	900
4	1 200
5	1 500
6	1 800
7	2 100
8	2 400
9	2 700
10	3 000
12	3 600
14	4 200
16	4 800
18	5 400
20	6 000
25	6 800
30	7 500
35	8 200
40	8 850
50	10 000
60	11 100
70	12 150
80	13 100
90	14 000
100	14 850
120	15 800
140	16 650
160	17 400
180	18 100
200	18 750
240	19 950
280	21 000

NOTE — For exposed wetted surfaces with more than 280 m^2 area, *see* **C-4.2**(a), **C-4-2**(b) and **C-4.4**. For intermediate values of wetted surface area, venting requirement should be evaluated by interpolation.

C-6. EMERGENCY VENTING

C-6.1 Emergency venting of a tank may be achieved by the use of:

a) larger or additional open vents within limitations specified in **C-5**,

b) larger or additional pressure-vacuum valves or pressure relief valves,

c) a gauge hatch or a manhole whose cover will lift under abnormal internal pressure,

d) a weak roof-to-shell attachment (weaker than the weakest vertical joint in the shell or shell-to-bottom joint) for preferential failure under abnormal internal pressure, and

NOTE — This shall not be used as a means of emergency venting a tank within a building.

e) other types of construction with provision for pressure relief.

APPENDIX D

(*Clause* 6.5)

FLOATING ROOFS

D-1. SCOPE

D-1.1 This appendix furnishes minimum requirements to be considered in the design and construction of pontoon, double-deck type floating roofs, and covered floating roofs where a pan roof is installed within a fixed roof tank.

D-1.2 Floating roof tanks are mainly intended for protection of stored products against evaporation and fire. Floating roofs control evaporation which is characteristic of some crude oil and other petroleum products. They eliminate filling losses and the vapour space above the product, thus minimizing possible fire hazard and reaction of the product with air. Use of floating roofs can be extended to products having absolute vapour pressures up to 12.25 N/cm^2 (1.25 kgf/cm^2) and containing small percentages of air-vapour explosive mixtures.

D-2. GENERAL

D-2.1 The floating roof and accessories shall be so designed and constructed as to allow the tank to overflow and then return to a liquid level which floats the roof well below the top of the tank shell without damage to any part of the roof, tank or appurtenances. During such an occurrence, no manual attention shall be required to protect any of these components. If a wind skirt or top shell extension is used for the purpose of containing the roof seals at the highest point of travel, overflow drainage openings or other means of alarm shall be provided to indicate and regulate the rise of liquid level in the tank above the nominal height of tank, unless the tank shell has been designed for a liquid height to the top of the shell extension.

D-2.2 The purchaser shall specify whether the tank shell diameter and height are nominal or whether a net capacity is required up to the bottom of the overflows.

D-2.3 Where specified by the purchaser foam dams around the outer edge of the roof shall be provided so that fire fighting foam can be kept in contact with the top side of the roof seal.

D-3. DECK AND PONTOON DESIGN REQUIREMENTS

D-3.1 It is recommended that roofs be of the contact type designed to eliminate the pressure of any air-vapour mixture under the deck.

Unless otherwise specified by the purchaser, all deck plates shall have a minimum nominal thickness of 5 mm (40 kg/m^2 plate).

D-3.2 Deck plates shall be joined by continuous full fillet welds on the top side. On the bottom side where flexure is anticipated adjacent to girders, support legs, or other relatively rigid members, full-fillet welds not less than 50 mm long on 250 mm centres shall be used on any plate laps which occur within 300 mm of any such rigid support or member.

D-3.3 In the case of a covered floating roof, the outer rim of the floating roof and the necks of any appurtenances installed through the deck shall have a minimum height of 200 mm.

D-3.4 Top decks of double-deck roofs and of pontoon sections, which are designed with a permanent slope for drainage, shall have a minimum slope of 5 mm in 300 mm and preferably shall be lapped to provide the best drainage. Plate buckles shall be kept to a minimum.

D-3.5 The minimum pontoon volume of a single-deck pontoon roof shall be sufficient to keep the roof floating on a liquid with a specific gravity of 0.7 if the single deck and any two pontoon compartments are punctured. The minimum pontoon volume of a double-deck roof shall be sufficient to keep the roof floating on a liquid with a specific gravity of 0.7 if any two pontoon compartments are punctured. The primary drainage shall be considered as inoperative for either type of roof, but no live load need be considered for the preceding design requirements. In addition, either type of roof with the primary drainage inoperative shall accommodate a 250 mm rainfall in a 24-hour period over the entire roof area without sinking (with no compartments or decks punctured). The roof may be designed to carry the entire 24-hour rainfall, or emergency drains may be installed which will limit the roof load to some lesser volume of water which the roof will carry safely. Such emergency drains shall not allow the product to flow on to the roof deck.

Pontoon ring of a single deck floating roof shall have sufficient flexural rigidity to resist compressive loads acting when the deck is punctured or flooded with 250 mm of rain-water.

Large diameter pontoon roof tanks installed in areas subject to high winds shall receive special consideration to stiffen the deck area and provide greater safety against wind induced rippling.

D-3.6 Each compartment shall be provided with a manway with a rain night cover. The manway covers shall be provided with suitable hold-down fixtures or other means to prevent wind from removing the covers. The top edge of manway necks shall be at an elevation to prevent water entering the compartments under the conditions set forth in **D-3.1**.

D-3.7 All internal bulkhead plates or sheets shall be single-fillet welded along their bottom and vertical edges for liquid-tightness. When specified by the purchaser, the top edge of the bulkhead shall also be provided with a continuous single-fillet weld for liquid-tightness.

D-4. ROOF DRAINS

D-4.1 Primary drains shall be of the hose, jointed or siphon type. A check valve shall be provided near the roof end of the hose and jointed pipe drains on single-deck and pan-type roofs to prevent backflow of stored product in case of damage to the drain line. Provisions shall be included to prevent kinking of the hose or pinching under the deck legs. Hose drains shall be designed to permit replacement without entering to tank. The swing joints of pipe drains shall be packed to prevent leakage. The primary drain shall be adequate to drain the maximum rain-fall in a 24-hour period without flooding the deck; the minimum size shall be equivalent in capacity to one 75-mm drain.

D-4.2 Provision shall also be made to drain rain-water from the deck of pontoon roofs into the tank when the roof is resting on its support legs and the primary drain is operating at its lowest efficiency.

D-5. LADDERS

D-5.1 The floating roof shall be supplied with a ladder which automatically adjusts to any position of the roof in such manner as always to provide access to the roof. The ladder shall be designed for full roof travel, regardless of normal setting of roof-leg supports. If a rolling ladder is furnished, it shall have full-length handrails on both sides and shall be designed for a 450-kg mid-point load with the ladder in any operating position.

D-6 VENTING

D-6.1 Suitable vents shall be provided to prevent over-stressing of the roof deck or seal membrane. These vents shall be adequate to evacuate air and gases from underneath the roof when the roof is on its supports during filling operations. They shall also be adequate to relieve any vacuum generated underneath the roof after it settles on its supports during withdrawal operations. The purchaser shall specify filling and emptying rates so that the fabricator may size the vents accordingly.

D-6.2 In the case of covered floating roof tanks, circulation vents or openings shall be located above the seal of the floating roof when the tank is full. The maximum spacing shall be 10 m but in no case shall there be less than four equally spaced vents. The total open area of these vents shall be equal to or greater than 600 cm^2/m of tank diameter. The fixed roof of such tanks shall have an open vent at the centre or at the highest elevation provided with a weather cover and a minimum area of 325 cm^2. These vents shall be provided with suitable coarse mesh screens to prevent ingress of birds or animals.

D-7. SUPPORTING LEGS

D-7.1 The floating roof shall be provided with supporting legs. Legs fabricated from pipe shall be notched or perforated at the bottom to provide drainage. Length of legs shall be adjustable from the top side of the roof. The operating and cleaning position levels of the supporting legs shall be as specified by the purchaser. The manufacturer shall make certain that all tank appurtenances, such as mixers, interior piping, and fill nozzle, are cleared by the roof in its lowest position.

D-7.2 Legs and attachments shall be designed to support the roof and a uniform live load of at least 1 250 N/cm^2 (125 kgf/cm^2) for single-deck and double-deck floating roofs. Where possible, roof load shall be transmitted to the legs through bulk heads or diaphragms. In the case of pan type floating roofs, the supports and attachments shall be designed to support a uniform live load of 625 N/m^2 (62.5 kgf/m^2) on the deck and shall be such as to prevent damage to the fixed roof when the tank is full. Support attachments in the deck areas in the case of single deck and covered floating roofs, shall be given particular attention to prevent failure at the points of attachment. Steel pads or other means shall be used to distribute the loads on the bottom of the tank. Pads, if used, shall be continuously seal welded to the tank bottom.

D-8. ROOF MANHOLE

D-8.1 Single-deck and double-deck floating roofs shall have at least one manhole provided for access to the tank interior and for ventilation when the tank is empty. The number of roof manholes shall be as specified by the purchaser. These manholes shall be of at least 600 mm internal diameter and shall have tight-gasketed and bolted covers equivalent to the roof manholes shown in Fig. 14.

D-8.2 In the case of a covered floating roof, the manhole shall be of at least 600 mm ID or equivalent and may be of the loose-cover type. At least one manhole of the same size shall be provided on the fixed roof for access to the tank interior.

D-9. CENTRING AND ANTI-ROTATION DEVICE

D-9.1 In the case of single-deck and double-deck floating roofs, suitable devices shall be provided to maintain the roof in centred position and to prevent its rotation. These devices shall be capable of resisting the lateral forces imposed on them by the roof ladder, wind loads and the like.

D-9.2 Prevention of rotation of pan roofs shall be achieved by means of a seal or other suitable device.

D-10. SEALS

D-10.1 The space between the outer periphery of the roof and the tank shell shall be sealed by a flexible device which shall provide a reasonably close fit to the shell surfaces. If the sealing device employs steel shoes in contact with the shell, such shoes shall be made from galvanized sheet with a nominal thickness of 1.6 mm. If uncoated shoes are specified, they shall be made of sheet metal of a thickness and quality as specified by the purchaser. An adequate number but a minimum number of three expansion joints shall be provided.

D-10.2 If this sealing device is a coated fabric or other non-metallic material it shall be durable in its environment and shall not discolour or contaminate the product stored. A minimum of four static electricity drains shall be provided when a non-metallic seal is used. The maximum spacing of the static electricity drains shall be 10 m. Any other approved means of draining static electricity may be provided.

D-10.3 In the case of covered floating roofs, seals shall be provided to ensure a reasonably close fit to columns or other appurtenances that penetrate the deck, through all horizontal and vertical movements of the deck. These seals shall also be durable in their environment and shall not discolour or contaminate the product stored.

D-11. GAUGE HATCH

D-11.1 The floating roof shall be provided with a standard gauge hatch and/or gauge well with a tight cap.

D-12. FABRICATION, ERECTION, WELDING, INSPECTION AND TESTING

D-12.1 Applicable fabrication, erection, welding, inspection and testing requirements of this specification shall apply.

D-12.2 Deck seams and other joints, which are required to be liquid or vapour tight, shall be tested for leaks by penetrating oil or by any other method consistent with the methods described in this specification for testing cone-roof seams and tank bottom seams.

D-12.3 The roof shall be given a floatation test while the tank is being filled with water and emptied. During this test, the upper side of the lower deck shall be examined for leaks. The appearance of a damp shot on the upper side of the lower deck shall be considered evidence of leakage.

D-12.4 The upper side of the upper decks of pontoon and double-deck roof shall be visually inspected for pinholes or defective welding.

D-12.5 Drain pipe and hose systems of primary drains shall be pressure tested with water at 35.0 N/cm^2 (3.5 kgf/cm^2). During the floatation test, the roof drain valves shall be kept open and observed for leakage of tank contents into the drain lines.

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