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Design of Diesel Storage Tank in Consonance with Requirements of American Petroleum Institute (API) Standard 650

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Abstract

This paper presents the design of a 4.45million liters Diesel storage tank in consonance with the requirements of API 650. The design of the tank, including proper material selection was achieved by applying 11th edition of API 650. Accurate bill of engineering measurement and evaluation was also carried out to serve as a guide to prospective investors in Nigeria. The tank has since been erected and put to effective use.

Keywords: Shell, Roof, Manhole, Annular plate, Bottom plate, Sump

1.0 Introduction

API 650 Standard establishes minimum requirements for material, design, fabrication, erection, and testing for vertical, cylindrical, aboveground, closed- and open-top, welded storage tanks in various sizes and capacities for internal pressures approximating atmospheric pressure. Diesel storage tanks falls under the category of tanks subjected to internal pressures approximating atmospheric pressure. This work therefore strictly applied the eleventh edition of API 650 standard in both design and fabrication and aims at revealing the procedure involved in correctly applying the API 650 standard for welded tanks intended for oil storage.

2.0 Methodology

2.1 Tank Data:

The desired capacity of the tank under design is 4.45 million liters, to this end, given the space constraint in the existing tank farm, a tank of diameter 18m and height 17.5m was selected. The following design was carried out in consonance with the requirements of the 11th edition of API 650.

Tank Capacity:

The tank capacity was calculated using the formula:

$C = 0.785D^2H$

Where:

C =Capacity of the tank in m^3

D = Diameter of tank in m

H = Height of tank in m

$C = 0.785 \times 18^2 \times 17.5 = 4450.95 m^3$

= 4,450,950 liters

Section 5.6.3.1 the 11th edition of API 650 recommend the use of one-foot method for calculating shell thickness for tanks of diameters less than 61m, therefore this technique was adopted rather than the variable design-point method.

2.2 Tank Shell Design:

According to section 5.6.3.2 the required minimum thickness of shell plates shall be the greater of the values computed by the following formulas:

$$t_d = \frac{4.9D(H-0.3)G}{S_d} + CA$$

$$t_t = \frac{4.9D(H-0.3)G}{S_t}$$

Where:

t_d = design shell thickness, in mm,

t_t = hydrostatic test shell thickness, in mm,

D = nominal tank diameter, in m =18m

H = design liquid level, in m = 17.5m

= height from the bottom of the course under consideration to the top of the shell including the top angle, if any; to the bottom of any overflow that limits the tank filling height; or to any other level specified by the purchaser.

G = design specific gravity of the liquid to be stored, =0.85 for Diesel

CA = corrosion allowance, in mm =3mm as in section 5.3.2

S_d = allowable stress for the design condition, =160 MPa for ASTM A 36 Carbon steel as in table 5-2a

S_t = allowable stress for the hydrostatic test condition, =160 MPa for ASTM A 36 Carbon steel as in table 5-2a

Jumbo plates of dimension width 2.5m and length 10m were selected as this means less joint to be welded and hence most economical.

With the jumbo plate of width 2.5m and tank height of 17.5m, the number of shell courses will be: 17.5 ÷ 2.5 = 7 courses.

1ST SHELL COURSE:

$t_d = \frac{4.9X18(17.5-0.3)X\,0.85}{160} + 3mm$ =11.06mm

$t_t = \frac{4.9X\,18(17.5-0.3)X0.85}{171}$ =8.87mm

$t_d > t_t$ therefore using the design thickness as basis 12mm plate is selected for the first shell course.

2ND SHELL COURSE:

$t_d = \frac{4.9X18(15.0-0.3)X\,0.85}{160} + 3mm$ =9.90mm

$t_t = \frac{4.9X\ 18(15.0-0.3)X0.85}{171}$ =7.58mm

$t_d > t_t$ therefore using the design thickness as basis 10mm plate is selected for the second shell course

3RD SHELL COURSE:

$t_d = \frac{4.9X18(12.5-0.3)X\ 0.85}{160} + 3mm$ =8.71mm

$t_t = \frac{4.9X\ 18(12.5-0.3)X0.85}{171}$ =6.04mm

$t_d > t_t$ therefore using the design thickness as basis 10mm plate is selected for the third shell course.

4TH SHELL COURSE:

$t_d = \frac{4.9X18(10.0-0.3)X\ 0.85}{160} + 3mm$ =7.54mm

$t_t = \frac{4.9X\ 18(17.5-0.3)X0.85}{171}$ =5.0mm

$t_d > t_t$ therefore using the design thickness as basis 8mm plate is selected for the fourth shell course

5TH SHELL COURSE:

$t_d = \frac{4.9X18(7.5-0.3)X\ 0.85}{160} + 3mm$ =6.37mm

$t_t = \frac{4.9X\ 18(17.5-0.3)X0.85}{171}$ =3.7mm

$t_d > t_t$ therefore using the design thickness as basis 8mm plate is selected for the fifth shell course

6TH SHELL COURSE:

$t_d = \frac{4.9X18(5.0-0.3)X\ 0.85}{160} + 3mm$ =5.2mm

$t_t = \frac{4.9X\ 18(5.0-0.3)X0.85}{171}$ =2.42mm

$t_d > t_t$ therefore using the design thickness as basis 6mm plate is selected for the sixth shell course

7TH SHELL COURSE:

$t_d = \frac{4.9X18(17.5-0.3)X\ 0.85}{160} + 3mm$ =4.03mm

$t_t = \frac{4.9X\ 18(17.5-0.3)X0.85}{171}$ =1.14mm

$t_d > t_t$ therefore using the design thickness as basis 6mm plate is selected for the seventh shell course

2.3 Quantity Of Plates For The Shell

The circumference of the tank is D =$\boldsymbol{\pi}$ x 18m = 56.55m.

Since the length of each jumbo plate is 10m, then 56.55 ÷ 10 = 6 jumbo plates are required for each shell course, hence;

1st Shell: 6numbers 12mm x 2.5m x 10m

2^{nd} & 3^{rd} shell: 12numbers 10mm x 2.5m x 10m

4^{th} & 5^{th} shell: 12numbers 8mm x 2.5m x 10m

6^{th} & 7^{th} shell: 12 numbers 6mm x 2.5 x 10m

The shell plate development is presented in figure 3.

2.4 Bottom Plate Sizing:

According to section 5.4.1, the minimum thickness of the bottom plate is 6mm. From experience therefore, 8mm plates was selected. The bottom plate development is presented in Figure 2.

2.5 Annular Bottom Plate :

Butt-welded annular bottom plate will be used as recommended by section 5.5.1. The radial width between the inside of the shell and lap welded joint is 600mm. The thickness of the annular plate is obtained from table 5-1a, by selecting the corresponding thickness for the material of yield strength 250MPa and tank of diameter less than 19m. Based on this, the selected annular plate thickness is 10mm. The annular plate development is presented in Figure 2.

2.6 Shell Manhole:

The shell manhole was created in consonance with requirements in section 5.7.1.8 which allows the manufacturer to select dimension of manhole and reinforcement plate other than those specified in figure 5.7A and B. 12mm thickness was chosen for reinforcement plate. The shell plate development is presented in Figure 5.

2.7 Roof

Cone roof supported principally by rafters with a slope of 1:6 was used in accordance with the requirement in section 5.10.1. Roof plate with nominal thickness of 5mm was selected (5.10.2.2). Roof plates were attached to the top angle of the tank with a continuous fillet weld on the top side. The roof plate development is presented in Figure 4

2.8 Roof Manhole

The roof manhole is as recommended by figure 5–16 and table 5-13a of API 650. A manhole size of 600mm and 1150mm outside diameter of reinforced plate were therefore selected. Detailed drawing of the roof manhole is presented in figure 6.

2.9 Drain Sump

The water drain-off sump was sized as 1,520mm diameter and 900mm dept in accordance with section 5.8.7 of API 650. The largest size sump was selected since only one is desired due to space constrain. The drain-off sump development is presented in figure 7.

3.0 Fabrication

The tank was fabricated by welding and erection in consonance with the requirements of sections 6 and 7 of API 650, 11^{th} edition, addendum1. The general elevation of the tank is presented in figure 1

4.0 Discussion

Having designed the tank with material selection based on local availability, its fabrication was done with ease and was successfully subjected to inspection tests recommended in section 8 of API 650. The bill of Engineering measurement and evaluation (BEME), presented in Table 1, gives a fair assessment of the cost of the tank as at the end of the year 2008 in Nigeria. The tank has since been put to effective use.

REFERENCES

API 650, *Welded Steel Tanks for Oil Storage*, 11th Edition, Addendum 1 (2008)

Table 1:BILL OF ENGINEERING MEASUREMENT AND EVALUATION FOR THE TANK

S/N	DESCRIPTION	MATERIALS			LABOUR, EQUIPMENT & CONS.
	Diameter: 18m Height : 17.5m Circumference: 56.55m Capacity: 147,000L Material: ASTM A 36 SPEC : API 650	QTY (₦)	RATE (₦)	AMT (₦)	(₦)
A	ANNULAR PLATE 10mm X 2.5m X 10m	3	345,000	1,035,000	724,500
B	BOTTOM PLATE 8mm X 2.5m X 10m	10	275,000	2,750,000	1,925,000
C	SHELL PLATE				
	Course 1: 12mm x 2.5m x 10m	6	415,000	2,490,000	1,743,000
	Course 2 & 3: 10mm x 2.5m x 10m	12	345,000	4,140,000	2,898,000
	Course 4 & 5: 8mm x 2.5m x 10m	12	275,000	3,300,000	2,310,000
	Course 6 & 7: 6mm x 2.5m x 10m	12	208,000	2,496,000	1,747,200
D	ROOF PLATE 5mm X 1.8m X 6m	27	75,000	2,025,000	1,417,500
E	ROOF STRUCTURE & STAIRCASE: Cut angle, trusses, stairways, handrail, etc	LUMP SUM	-	3,850,000	2,695,000

F	SUPPLY AND FIXING OF TANK ACCESSORIES (Shell & Roof Man holes, Dip Hatch, Sprinkler, Drain sump, etc)	LUMP SUM	-	2,750,000	1,925,000
G	SAND BLASTING TO SA 2.5 AND COATING: DFT 350µm	LUMP SUM		2,800,000	1,350,000
H	TEST Hydrostatic Testing X-ray/ NDT Calibration Vacuum Box Test (Floor Plates) Vacuum Box Test (Roof Plates) Dye Penetrant Test for Base & Annular Plates	LUMP SUM		1,800,000	1,260,000
I	EARTHING			450,000	150,000
J	CATHODIC PROTECTION (Sacrificial Anode)			380,000	266,000
K	CIVIL WORK (RAFT FOUNDATION)			3,700,000	2,590,000
	SUB TOTAL			33,966,000	23,001,200
	TOTAL			₦ 56,967,200	

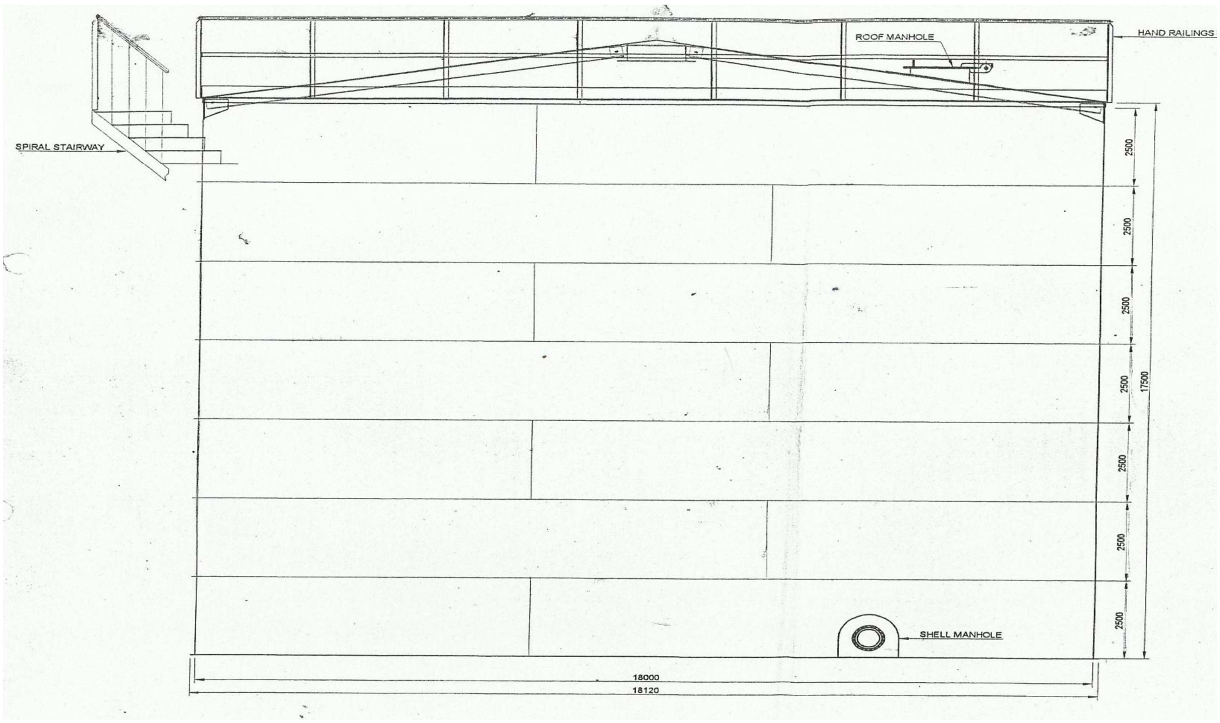

Fig1: General Elevation of the tank

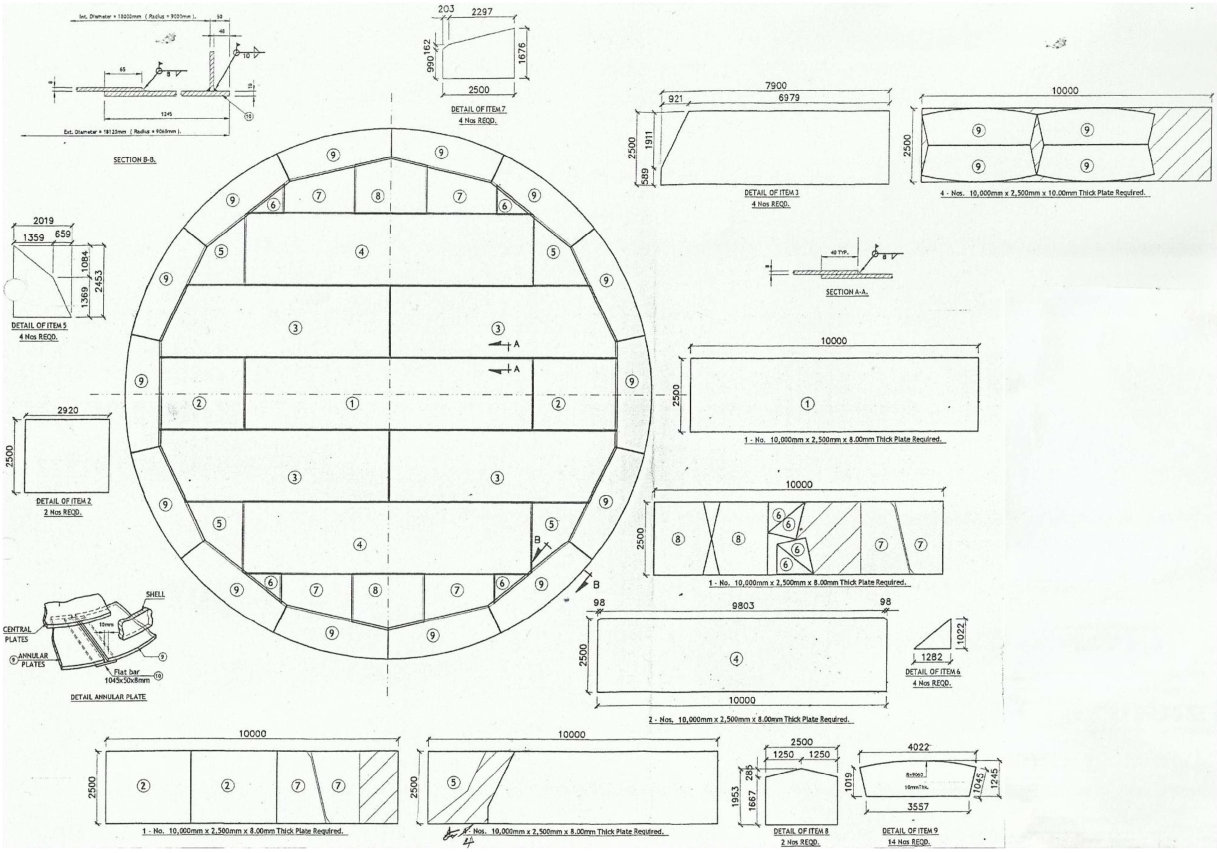

Fig 2: Bottom/ Annular Plate Development

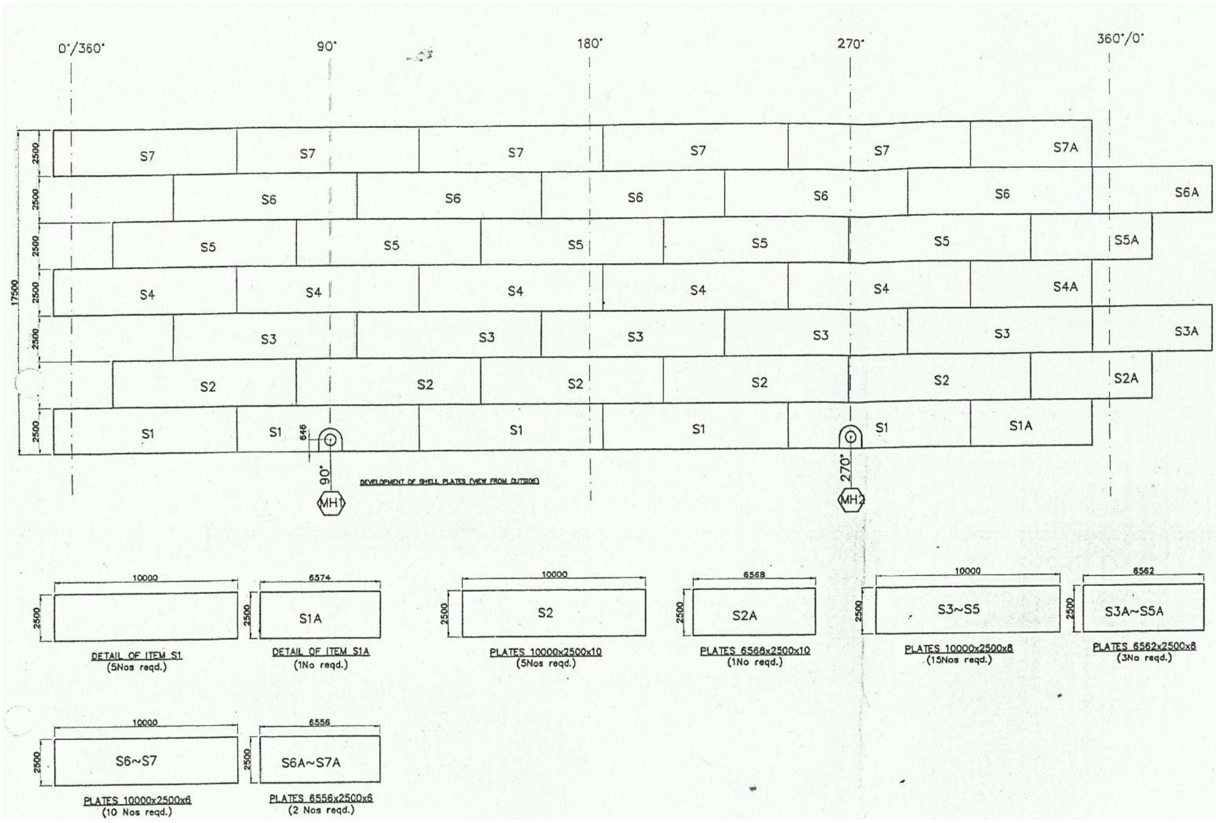

Fig 3: Shell Plate Development

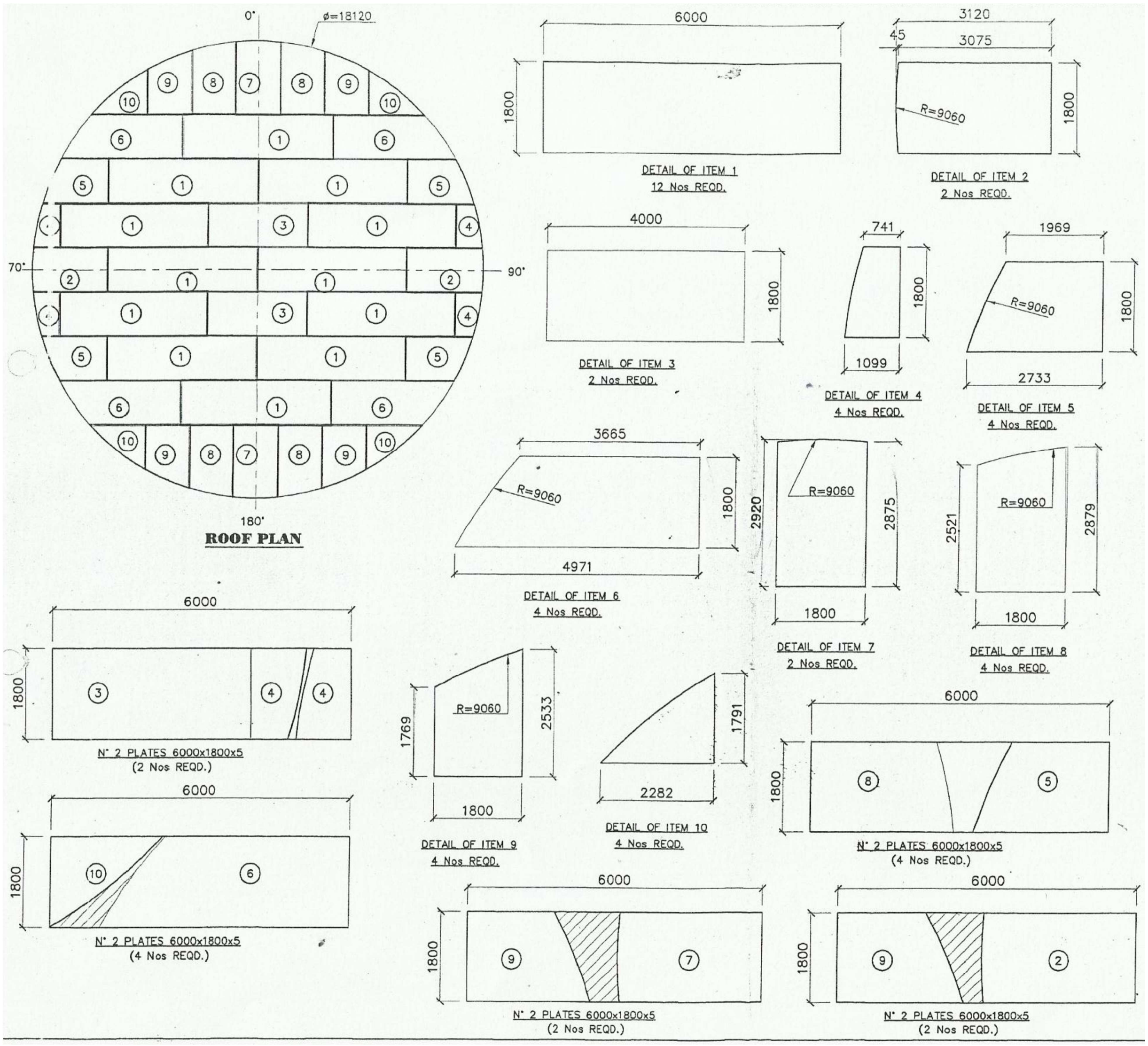

Fig 4: Roof Plate Development

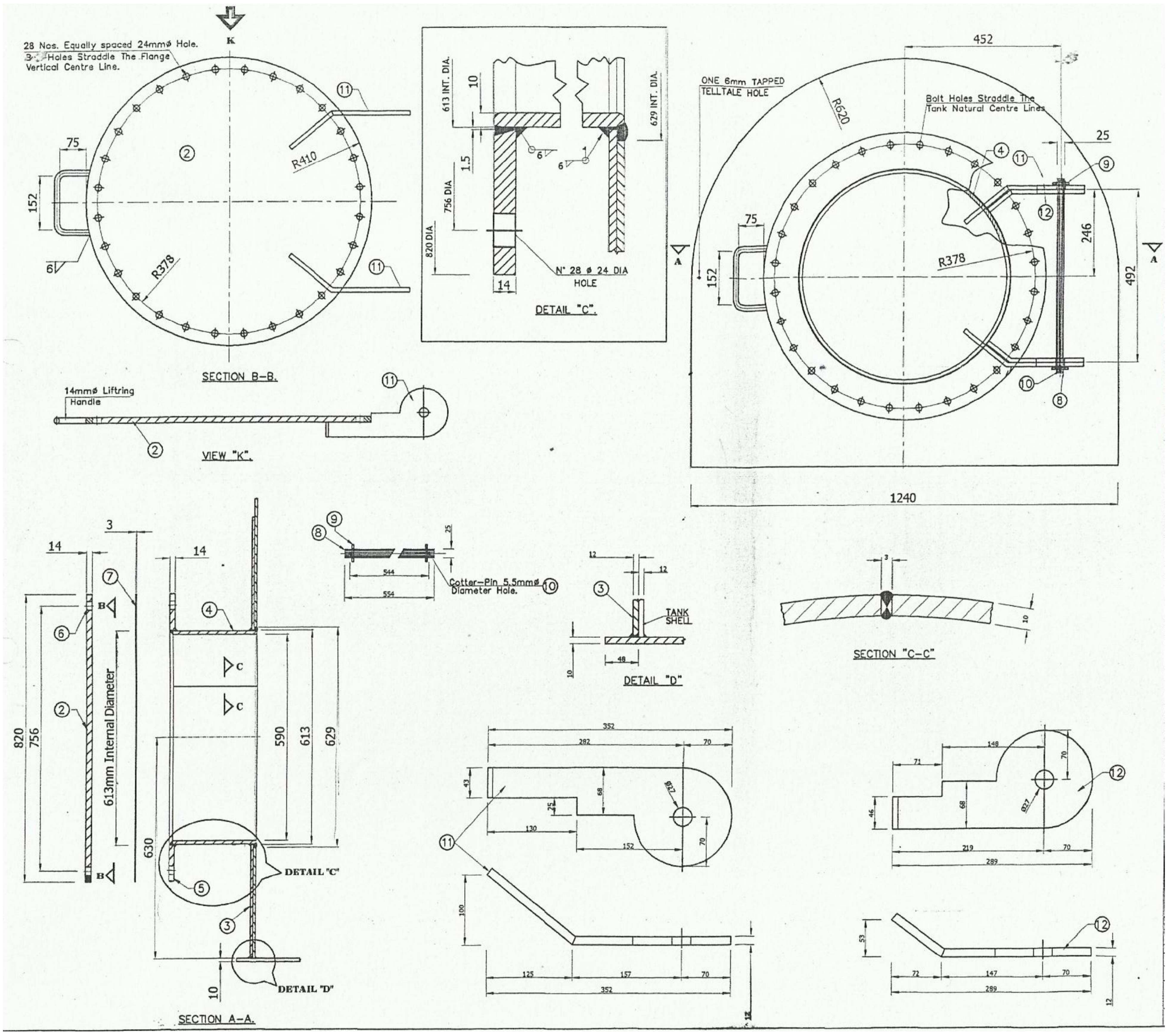

Fig 5: Shell Manhole Development

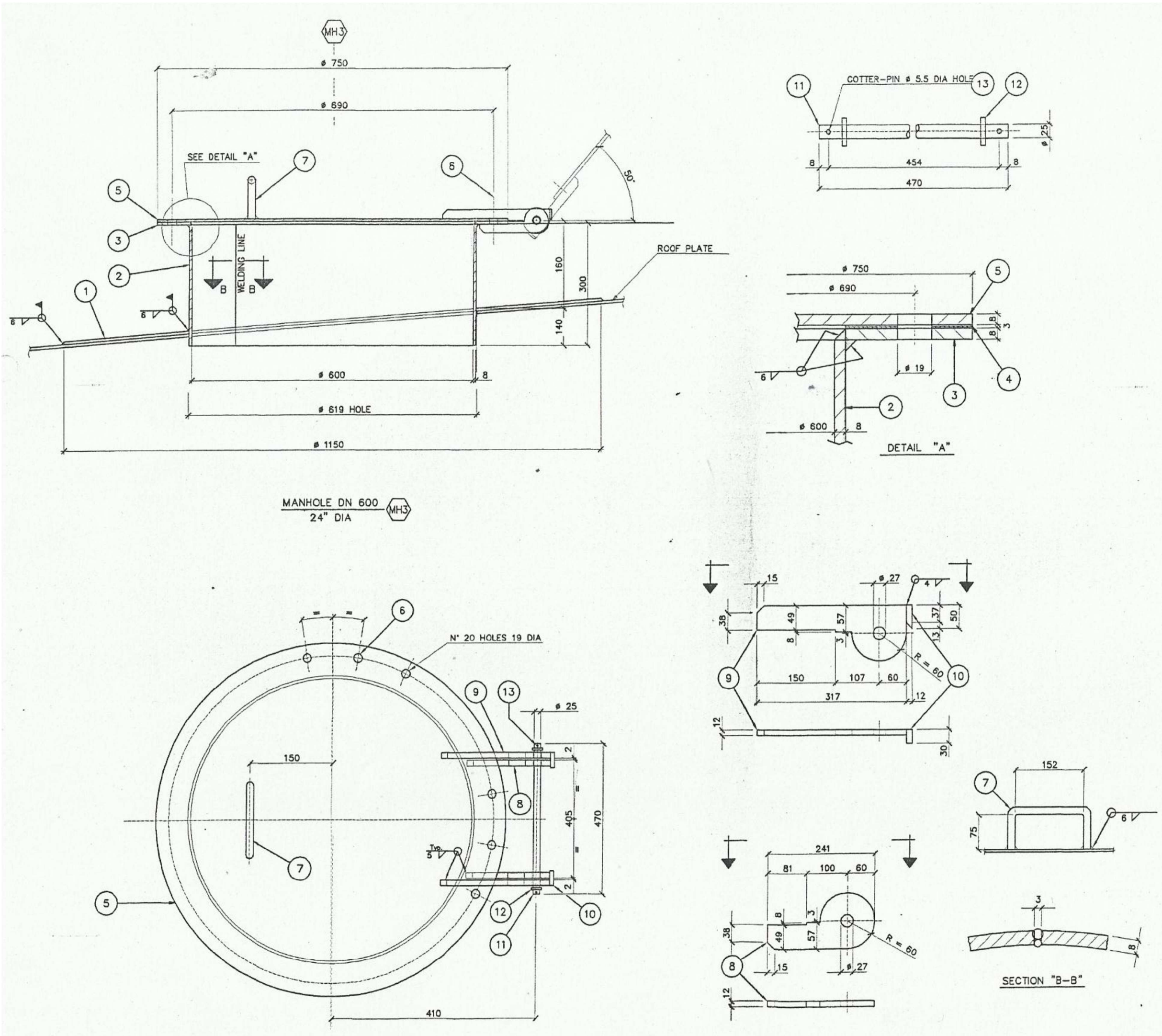

Fig 6: Roof Manhole Development

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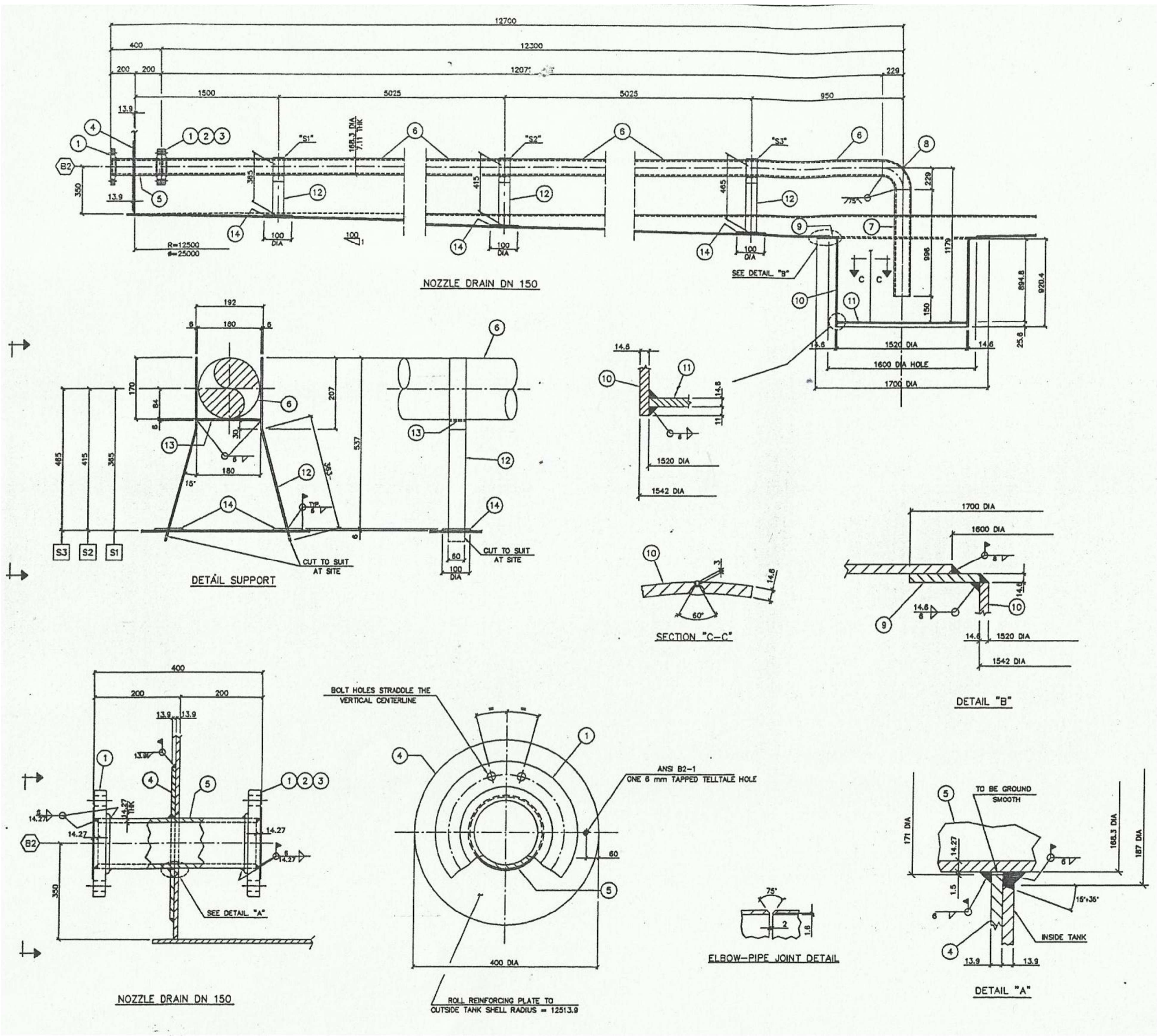

Fig 7: Drain Sump Development