An Experience in Fabrication and Welding of a large Aluminium Alloy Storage Tank

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SUMMARY, The paper describes the authors' experience on fabrication and welding of a manual TIG welded aluminium-alloy storage tank of 3,30,000 litre capacity. It is shown that by appropriate choice of welding procedures and rigid quality control, radiographic quality welding with a joint efficiency of 0.85 can be achieved in the field erected tanks in Indian conditions. The distinct advantages of vertical Double-Operator welding technique are confirmed and an advanced method of tank erection is described.

The authors emphasize the need for awareness of quality control on the part of the suppliers and contractors without which aluminium fabrication technology is unlikely to make much headway in the country.

The paper does not claim to submit any research findings but indicates the way in which the published latest knowledge of the advanced countries can be adapted to meet the technological needs of the country.

Introduction

With the high cost of stainless steel in India, the designers of chemical plants are increasingly on the look out for alternative materials of construction. In many applications, aluminium and its alloys can replace the use of stainless steel. This is particularly true for storage tanks where contamination is the criterion of material selection.

In the past, locally made aluminium-alloy storage tanks have been satisfactorily used at the Thana Factory of CAFI. They were, however, relatively small shop-fabricated vessels without radiographic quality welding. Recently the need arose for an aluminium-alloy storage tank of 3,30,000 litre capacity. The tank was designed departmentally using CAFI's know-how and experience. Most of the fabricators were unwilling to guarantee the stipulated joint efficiency and in particular the porosity limits. The specifications were, however, adhered to and the fabrication and erection work was entrusted to a contractor who had agreed to work to the required standard under close supervision, stage inspection and the target completion date.

Code for Design, Fabrication and Erection

No Indian Standard Specification is available for design of welded aluminium-alloy storage tanks. B.S. 1500 Part 3 (1955) which is a pressure vessel code is sometimes used as a guiding specification. American code API-12G was once a widely used standard but this was withdrawn some years ago. USAS Specification B 96.1 for welded aluminium-alloy field erected storage tanks was brought out in 1967 and is now widely used. This code was adapted (along with other standards summarised in Appendix I) for the design and fabrication of the tank.

Materials of Construction

Plates

The design called for non-heat treatable aluminium-magnesium alloy plates to I.S. 736—NP4-M (as manufactured condition). The indigenous manufacturers, however, were not in a position to guarantee the physical properties of the plates. Physical tests

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were, therefore, carried out on receipt of the materials. Appendix II shows the various chemical and physical properties including results of check test.

Filler Wire

The recommended filler wire for IS 738 NP 4 plates is 5% magnesium-aluminium alloy to B.S. 2901 Part 4 (1970)-NG 6 or I.S. 5897 (1970)— SNG 6. The respective compositions are summarised in Appendix III. It would be seen that the British Standard restricts the silicon content to 0.3% as against 0.6% permitted by the Indian Standards. The role of silicon content in the filler wire on crack sensitivity (1) was appreciated and it was decided to play safe by specifying the filler material composition to the British Standard. The check analysis of the filler wire showed that the actual silicon was 0.2% maximum.

In the initial stages, normally available cut lengths of filler rods were used. These were check tested by random sampling before use, and the composition varied widely. The most common problem was low magnesium and high silicon (in some cases exceeding that in the parent metal). Following this experience the filler wire was ordered in spools instead of cut lengths and samples check analysed. This made quality control very effective. Typical composition of the filler wire used is tabulated in Appendix III. Once this composition was established, no problem was faced on filler material.

Tank Dimensions

Appendix IV gives the major dimensions of the tank.

Fabrication

The guide lines laid down in USAS Specification B 96.1 were followed for fabrication.

Welding Inspection & Acceptance Standards

The inspection and acceptance standard for the welds were based on (a) USAS Specification B 96.1 (b) BS 1500 Part 3 for Class II vessels and (c) ICI standard for aluminium welding.

The inspecition and non-destructive tests generally comprised (a) checking weld preparation by gauges (b) visual examination of the welds by magnifying glasses (c) Dye checking of the welds (d) Spot radiography of longitudinal and circumferential seams and T joints (e) checking of dimensional accuracy, distortion and finish (f) water fill-up test and (g) light air pressure test for the roof.

Weld Joint Efficiency

In designing the tank shell, radiographic quality double welded butt joints were specified for both the vertical and the horizontal seams with a joint efficiency of 0.85. The specified joint efficiency was considered to be highly optimistic by the indigenous fabricators, particularly for field welding. However, it was decided to adhere to this figure for the following reasons.

(i) A lower joint efficiency would have necessitated use of significantly thicker shell plates.

(ii) Shell plates thicker than 10 mm would have posed welding problems by manual argon arc method in vertical and horizontal positions.

(iii) Thicker aluminium plates are prone to more distortion due to increased number of weld runs.

(iv) Repair of weld joints in thicker plates is laborious and time consuming.

It would, therefore, appear from the above that for relatively large tanks, a thinner shell plate with a high joint efficiency has distinct advantages over conservative designs with a low joint efficiency.

Welding Process

USAS Specification B 96.1 calls for inert gas metal arc (MIG) or inert gas Tungsten Arc (TIG) welding by manual, automatic or semi-automatic procedures qualified under the non-ferrous section of ASME Code Section IX.

The indigenous fabricators use manual TIG welding process extensively. Because other methods of welding are not yet fully established in India, manual TIG welding with argon was specified for plates upto 10 mm thickness and the option was left to the fabricator for using the MIG welding process for the thicker bottom plates.

Procedure qualifications were called for each welding method to establish the welding variables defined in ASME Code Section IX (1971). After establishing a procedure, it was issued as a standard data sheet for carrying out the welding on the actual job. In general, all procedures called for random checking of the welding variables by the welding engineer and the inspector independently. Wind shields were called for to ensure minimum disturbance to argon blanket in the event of draught.

Weld Details

Appendix V illustrates the weld details used for the tank fabrication.

Longitudinal Seams

For the longitudinal seams of the shell, TIG welding by Double-Operator technique was specified. In this process, two welders carry out the welding simultaneously from both sides. The welder on the face side of the joint normally feeds the filler wire in the usual way while the welder on the root side draws the material from the molten pool by manipulating the torch. The direction of welding is vertically upwards. The most important factor is the synchronization of the welding speeds of both the welders. In certain application, filler wire is fed from both the sides. Photograph 1 illustrates the Double-Operator vertical welding in progress on the tank shell.

A survey of the indigenous fabricators showed that the experience on this technique was limited, particularly for welding aluminium-alloys. It was, however, recognised by the fabricators that the technique is superior to the single operator process. The advantages of the technique are summarised below :

(a) Upto a certain thickness the welding can be completed in a single pass with addition of filler wire from one side only.

(b) Less chances of oxide inclusion due to simultaneous argon blanket on either side.

(c) Relatively higher speed of welding.

(d) Reduction/elimination of pre-heating.

(e) Less distortion.

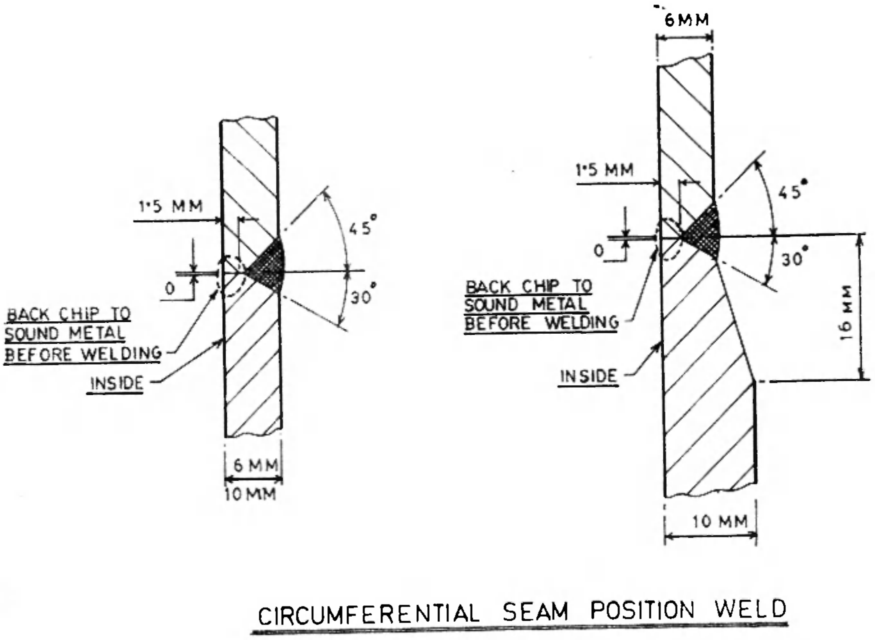
(f) Elimination of back chipping and interpass wire brushing.

(g) Improved finish and hence elimination of subsequent weld dressing.

(h) Reduced filler wire consumption.

(i) Higher joint efficiency.

It took considerable time to train the welders and establish the technique. The major problem appeared to be in synchronising the speed of the two welders, and in producing consistent quality welding. However, the procedure was eventually qualified with highly satisfactory results. During field welding production test pieces were frequently drawn for quality control. The radiography of the tank welds and the test pieces



CIRCUMFERENTIAL SEAM POSITION WELD

as well as their physical test results showed that the quality stipulated was being fully achieved. Plates illustrates radiographs for this type of joint and Appendix VI summarises the typical results of weld test specimens.

While the present job was nearing completion, the authors came across an article (2) which gives a brief description of the vertical Double-Operator technique. This article gives good hints on the technique but does not give any data on essential welding variables for establishing the procedure.

Circumferential Seams

For the circumferential seams of the tank shell, initially horizontal Double-Operator technique was specified. In the limited time available, attempts were made to qualify the welding procedure without much success. It may be pointed out that in horizontal welding while one welder uses leftward welding, the other has to use rightward welding and this makes synchronization extremely difficult. Added to this is the fact that the molten weld pool tends to run downwards (across the line of welding) because of the heat from two torches. The result is poor quality welding with oxidation and porosity mainly on the upper half of the weld seam. The weld test specimens drawn from this method of welding did not give fully satisfactory results and hence it was decided to revert to conventional single operator technique.

With single operator technique, although the specified weld joint efficiency was achieved, the quality of welding was not always as good as that obtained by the vertical Double-Operator technique. The welding in horizontal position generally appears to be highly sensitive to both the skill of the welder and the welding parameters and in particular the normal tendency of the weld pool to flow across the line of welding. The resultant welding is frequently associated with certain amount of oxidation and porosity. It was also observed that some welders who had qualified for horizontal position welding in performance tests (in the field) failed to produce acceptable quality welds on the job.

Appendix VII gives typical result of weld test specimens of horizontal butt welds by single operator technique.

Bottom Plate Joints

For welding of 20 mm thick bottom plates, double Vee butt joints were used for prefabricated sections and single Vee butt joints with backing strip were used for in situ welding. Welding was done in downhand flat position, which is by far the simplest way of welding aluminium. Apart from distortion, which is discussed elsewhere in the paper, there was no other significant problem. Typical results of weld test specimens are given in Appendix VIII.

Fillet Weld between Shell and Bottom Plate

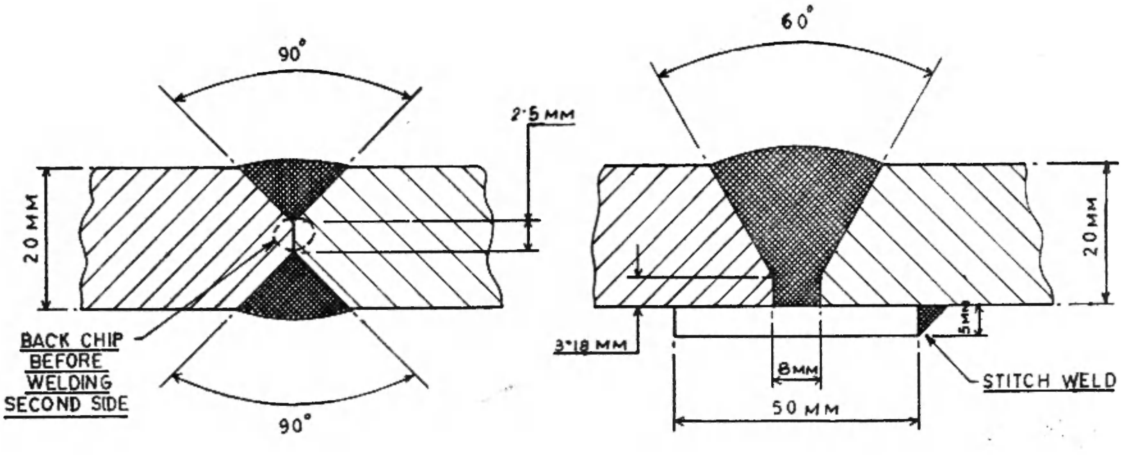
For fillet weld of shell to bottom plates, the Double-Operator technique using filler wire from both sides was successfully qualified and used.

Welders' Performance Qualification

The most unpredictable factor in manual TIG welding of aluminium is probably the welders' performance. It was observed that even the most skilled welder failed to perform satisfactorily on occasions without any apparent reason. It was also seen that some of the welders who had fully met the performance tests (in the field) failed to achieve the required quality on the actual job. When retested however, they passed the tests. This occurred frequently with horizontal circumferential seam welding with the result that some of the welders were declared unfit for welding in this position.

Because the manual TIG welding is highly sensitive to welder's skill, their performance test specimens were fully evaluated by radiography, physical and macro tests. This was beyond the requirements of ASME Code Section IX (1971) which allows a welder to be qualified by radiography only of the test specimen. The contractor and his team of welders cooperated in this elaborate method of testing and the results were revealing. For a given established welding procedure, the physical test results varied significantly even when the radiographs appeared to be of acceptable quality. The information was fed back to the welders and the possible causes were discussed with them until they were fully conscious of the influence of their style of welding on the quality. The result was improved performance with consistent quality of welding.

Incidentally, difference of opinion between the fabricator and the client may arise on the question of acceptable porosity limit while qualifying a welder, although the limits are well defined in USAS Specification B 96.1. Porosity is a fairly doubtful area in so far as aluminium welding is concerned. Whether or not a given distribution of porosity is acceptable can be easily determined by carrying out the physical tests of



WHERE ACCESSIBLE FROM BOTH SIDES

IN SITU WHERE ACCESSIBLE FROM ONE SIDE ONLY

BOTTOM PLATE WELDS

the weld specimens. It may be of interest to note that BS 1500 Part 3 (1965) lays down this guideline for class II vessels (joint efficiency 0.85).

The authors are of the opinion that for manual TIG welding of aluminium and its alloys in indigenous conditions, physical tests of the specimens should be carried out for performance qualification. This is recommended because the standard of aluminium fabrication technology is not very advanced in the country.

Argon : Specification for TIG Welding

For inert gas welding of aluminium in general, the gas (in this case argon) must have a well defined composition. USAS Specification B 96.1 does not specify the quality of argon. Van Lancker (1) recommends purified and dry argon of 99.9% purity for TIG welding. This would suggest that impurities upto 1000 ppm are acceptable. Giachino, Weeks and Brune (3) state that welding quality argon should have a purity of 99.995%, implying that impurities upto 50 ppm only are acceptable. BS 3019 Part 1 (1958) specifies an acceptable impurities content of 500 ppm. None of the above references, however, elaborate on the composition of the permissible impurities. I.S. 2812 (1964) had also initially stipulated an acceptable impurities content of 500 ppm but in a subsequent amendment (1971) calls for using argon to I.S. 5760 (1969), which limits the maximum impurities to 320 ppm with a well defined composition and an oxygen content of 10 ppm maximum. Appendix IX reproduces the argon composition specified in IS 5760.

The acute shortage of argon gas in India is a well known problem. In such a situation any rigid specification on purity of argon would be academic. Initially, therefore, argon of certified quality was procured from one producer without any check testing of quality. However, repeated failure of the weld test specimens in the way of lack of fusion, brittleness, porosity, oxidation and poor mechanical strength led the authors to investigate the purity of argon. BARC (Trombay) provided valuable help by carrying out the analysis using the spectroscopic technique.

Appendix IX summarises the results of the analysis carried out on twenty cylinders at random. It would be seen that the oxygen content was 30—550 ppm and nitrogen > 1500 ppm. The moisture and other gases were not analysed, but moisture was observed during the trial welding. After a series of investigations and tests it was concluded beyond doubt that unless the quality of argon was improved, the required quality of welding would not be feasible.

A superior quality Argon was then obtained. As a special case, each cylinder was tested by this supplier prior to despatch and further check tested at random by the authors. Extensive trial welding showed that the stipulated quality of welding was feasible with argon from this source. It was also established that dry argon with a total impurity of 500 ppm could be tolerated with oxygen not exceeding 10 ppm for the specified quality of welding. However, the actual impurities content of argon from this source was well within 500 ppm. The radiographs and physical tests of the weld specimens were fully satisfactory.

The above experience would suggest that it would be impractical to expect radiographic quality aluminium welding without any control on the quality of Argon. It would also appear that the client should satisfy himself on the purity of argon by frequent check testing. The authors would strongly advocate the use of argon to I.S. 5760 (1969) and for this the argon manufacturer's cooperation is necessary.

Porosity

USAS specification B 96.1 (1967) lays down quantitative limits for acceptable porosity. BS 1500 Part 3 (1965), however, does not quantify the porosity limit for class II vessels (joint efficiency 0.85). The criteria of acceptance used in the present job were based on USAS specification B 96.1. Initially there was doubt as to whether or not this limit could be achieved and opinions on this aspect differed widely. The experience on the actual job, however, has shown that the limits could be met. The experience also suggests that it would be feasible to achieve the narrower limits of acceptable porosity laid down in USAS Specification B 96.1 for hundred percent radiographed welds.

Plates illustrate typical radiographs showing the type and quantum of porosity obtained in the welds.

Distortion

Because of high thermal conductivity and coefficient of linear expansion, welding of aluminium is always associated with significant distortion. Further, the hot metal is very flimsy and weak, and when it begins to melt it collapses suddenly. The distortion can, however, be minimised by (a) preheating where necessary (b) adequate supporting (c) controlling the heat input (d) sequence welding and (e) using an appropriate welding process. These techniques were effectively applied during fabrication and welding of the tank with very satisfactory results for plates upto 10 mm thickness. For 20 mm thick bottom plates, however, considerable distortion had occurred. This could be attributed to manual TIG welding requiring a large number of weld passes and the fast rate at which the job was completed. The experience, however, suggests that even by controlling the heat input to a fair extent, the distortion cannot be completely brought under control if TIG welding is used on such thick plates. For example, the in situ welding of the bottom plates with backing strip was carried out extremely slowly to control the heat input. This gave better results, but there was significant distortion. Further, it took 8 weeks to complete three in situ joints of 22 metres total length.

For welding of 20 mm thick plates, the appropriate process would be the MIG technique which uses a minimum number of passes. The MIG process is recommended in literature (1) as well as by the plate manufacturers (5) and there is a case for developing this process in the country. This would, however, have to be done by the fabricators in this field.

Straightening of distorted plate sections

The prefabricated bottom plates which had distorted were straightened by passing them between a pair of rolls. The straightened plates were dye penetrant tested on both the sides and examined by spot radiography to detect any cracks. No cracks could be detected but a few dents were observed. These were repaired. It was appreciated that the plates would have got slightly cold worked during straightening and to determine the extent of cold working welded test plates were identically straightened and then tested. The results of transverse tensile tests showed an UTS of 21 kgfmm^2 with an elongation of 15% as against 19 kgfmm^2 and 27% respectively for welded plates without cold working. Transverse bend tests, of old worked specimens, to ASME code section IX has passed satisfactorily.

Erection technique

An advanced erection technique hinted in INCO Nickel Bulletin No. 37(4) was adapted. The sequence developed and used is described below :

(a) Complete the fabrication of the bottom plates in segments and lay them on the foundation. Commence in-situ welding of the final joints.

(b) Place the prefabricated roof structure welded with the top most strake on the bottom plate.

(c) Lift the above assembly.

(d) Insert the prefabricated next strake (i.e. second strake from top), align, tack weld and support.

Lift the entire assembly free from the bottom plate. Complete the longitudinal and circumferential weld joints. Inspect and radiograph the welds and repair as necessary.

(e) Repeat steps (c) and (d) with all the remaining strakes.

(f) By now the in situ welding of the bottom plate joints commenced in (a) above are complete Check the bottom plate finally.

(f) Check the plumb finally, align, tack-weld, support and complete the fillet weld between the shell and the bottom plate.

Photographs 2 to 6 illustrate the stages of erection and welding as described above.

The advantages of the above-mentioned method of erection are :

(1) The welding is always carried out at foundation level. This allows the welder full freedom to use his both hands freely for manual TIG welding. Further, the argon blanket is more effective at a lower height and in the event of a draught, wind shields are easy to improvise and manipulate at this level.

(2) Safety hazards are minimised.

(3) No cumbersome scaffolding within and outside the tank is required and hence the erection is relatively neat.

(4) Handling is minimised. Lifting tackles such as chain pulley blocks are adequate.

(3) Ease of supervision, inspection and radiography at foundation level.

(6) The alignment of successive strakes is better as each strake is checked against the same markers on the bottom plate.

(7) The height of a safety barrier, if required between the tank site and existing plant (as was used in this case), is minimised.

Supervision & Inspection

The stipulated standard of fabrication and welding was achieved on the job mainly due to strict supervision and rigid stage inspection imposed. A full-time welding engineer was deputed to supervise and control the quality of welding and in addition an inspector was assigned in each shift. Thus the qualified welding procedures and the agreed inspection schedules were strictly implemented. The feed back from the inspectors was used to improve the method of working where necessary. The welders were taken into confidence at all stages of work by showing them the radiographs of their welding and were made to participate in decision making while accepting or rejecting a weld. This proved highly satisfactory with continually improved performance of the welders.

Conclusions

(1) Until an Indian Standard is published, USAS Specification B 96.1 can be adapted for indigenous conditions.

(2) Radiographic quality welding with a joint efficiency of 0.85 or more can be achieved in the field conditions in India by :

  (a) Using tested quality argon gas and filler wire of appropriate composition.

  (b) Adopting suitable welding process.

  (c) Using skilled welders with adequate training.

  (d) Thorough supervision, inspection and testing of materials.
  For (a) above, the suppliers' co-operation and support are vital, without which not much progress can be made. For (b) (c) and (d) the fabricator's/contractor's awareness and attitude will go a long way in developing the indigenous technology.

(3) The vertical Double-Operator technique has distinct advantages over the conventional single operator process.

(4) Information further work on horizontal Double-Operator technique will be most welcome to the users.

(5) The MIG welding of aluminium and its alloys must be established in the indigenous industry to enable easy welding of thicker plates. This initiative, however, should be taken by the fabricators in this field.

(6) The published knowledge on welding of aluminium and its alloys from the advanced countries can be easily adapted in the less sophisticated indigenous conditions to meet the country's needs.

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APPENDIX I

List of Standards used for Design and Fabrication

1.	USAS Specification B 96.1	— Specification for welded aluminium alloy field erected storage tanks.
2.	ASME Code Section IX	— Welding Qualifications.
3.	BS 1500 Part 3 (1965)	— Fusion welded pressure vessels for general purposes (aluminium).
4.	IS 736 (1965)	— Wrought aluminium and aluminium alloys, plate (for general engineering purposes).
5.	IS 733 (1967)	— Wrought aluminium and aluminium alloys being rods and sections (for general engineering purposes).
6.	IS 5897 (1970)	— Aluminium and aluminium alloys welding rods and wires and magnesium alloy welding rods.
7.	IS 738 (1966)	— Wrought aluminium and aluminium alloys, drawn tube (for general engineering purposes).
8.	IS 2812 (1964)	— Recommendations for manual tungsten inert-gas-arc welding of aluminum and aluminium alloys.
9.	IS 5760 (1969)	— Compressed argon.
10.	BS 3019 Part 1 (1958)	— General recommendation for manual inert-gas tungsten-arc welding (wrought -aluminium alloys and magnesium alloys).

11. Indian Aluminium Co. Ltd.'s Catalogue, April 1971.
12. Hindustan Aluminium Corporation's Catalogue.

APPENDIX II

Chemical Composition and Physical Properties of Aluminium Alloy Plates

Chemical Composition

Elements	*As per I.S. 736*	*As per manufacturer*	*Typical check analysis of plates*
Copper	0.10 max	0.10 max	Not traceable
Magnesium	1.7 to 2.8	2.1 to 2.7	1.83
Silicon	0.6 max	0.10 to 0.17	0.61
Iron	0.7 max	0.25 to 0.50	0.14
Manganese	0.5 max	0.10 max	0.15
Chromium	0.25 max	0.01 max	0.05
Aluminium	Remainder	Remainder	Remainder

Physical Properties

Property	*As per IS.736*		*As per manufacture*	*Typical check test*	
	Upto 12.5 mm thickness	*Above 12.5 mm thickness*		*10 mm Plate*	*20 mm Plate*
Tensile	19 kgf/mm^2 (minimum)	19 kgf/mm^2 (minimum)	—	18.9 kgf/mm^2	20 kgf/mm^2
Elongation	12% (minimum)	15% (minimum)	—	35%	35%

Note : The chemical analysis was carried out in two independent laboratories simultaneously

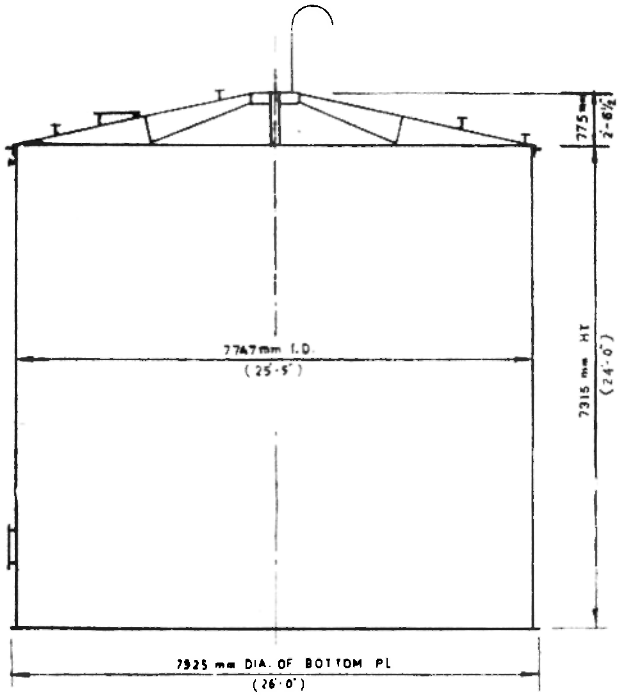
APPENDIX III

Filler Wire Compositon

Elements	*As per IS 5897 SNG.6*	*As per BS 2901 Part 4, NG-6*	*Typical check analysis of filler material used*
Copper %	0.10	0.10 Max.	Nil
Silicon %	0.60	0.30 Max.	0.20
Iron %	0.70	0.50 Max.	0.27
Manganese %	0.40	0.50 Max.	0.40
Magnesium %	4.5 to 5.5	4.5 to 5.5	5
Chromium %	0.25	0.25 Max.	trace
Zinc %	0.20 Max.	0.20 Max.	trace
Titanium	—	0.20 Max.	—
Aluminium	Remainder	Remainder Mn+Cr =0.5% Max. 0.1% Min.	Remainder

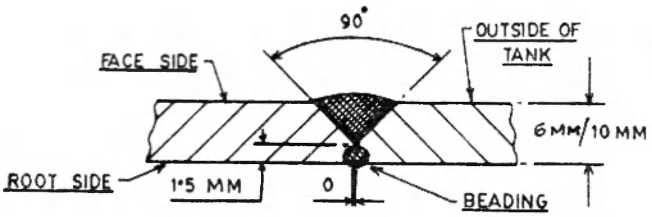
Note : The check analysis was carried out in two independent laboratories simultaneously.

APPENDIX - IV

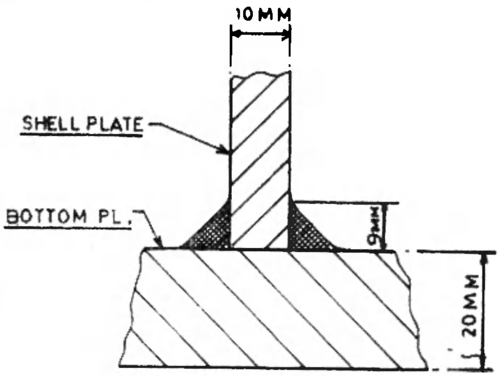


3.30,000 - LITRES CAPACITY
ALUMINIUM-ALLOY STORAGE TANK

APPENDIX-V
WELD DETAILS



SHELL LONG SEAM FOR VERTICAL DOUBLE-OPERATOR TECHNIQUE



SHELL PLATE TO BOTTOM PLATE FILLET WELD

APPENDIX VI

Typical Results of Transverse Weld Test Specimens of 10 MM Thick Plates by Vertical Double-Operator Technique

Properties	*Specimen I*	*Specimen II*	*Specimen III*
UTS kg f/mm^2	19.2	19.3	19.5
Elongation on 2″ gauge length*	18.75	22.5	20.75
Fracture	Outside the weld	Outside the weld	Outside the weld
Transverse root & face bend tests (Mandrel dia. 40 mm)**	Pass	Pass	Pass
Radiography**	Acceptable	Acceptable	Acceptable

* This is merely index of the total elongation of the weld and the parent metal.

** To ASME Code Section IX (1971).

APPENDIX VII

Typical Results of Transverse Weld Test Specimens of 10 MM Thick Plates by Horizontal Single Operator Technique

UTS kgf/mm^2	19.4
*Elongation on 2″ gauge length	22.7
Fracture	Broken outside weld
Transverse root and face bend tests (Mandrel dia=40 mm)**	Pass
Radiography**	Acceptable

* This figure should be used cautiously as it is merely an index of the total elongation of weld and parent metal.

** To ASME Code Section IX (1971).

APPENDIX VIII

Typical Results of Transverse Weld Test Specimens of 20 MM Thick Plate of Double Vee Butt Weld in Down-Hand Flat Position

UTS kgf/mm^3	19
Elongation on 2″ gauge length ...	27
Fracture	Broken outside weld
Transverse root and face bend tests (Mandrel dia=80 mm)**	Pass
Radiography**	Acceptable

* This is merely an index of the total elongation of the weld and the parent metal.

** To ASME Code Section IX (1971).

APPENDIX IX

Composition of Welding Quality Argon : IS 5760 (1969)

Argon	99.96% min.
Oxygen	10 ppm max.
Nitrogen	300 ppm max.
Hydrogen	5 ppm max.
Carbon dioxide & other compounds as CO_2	5 ppm max.
Water Vapour mg/litre	0.0056 max.

Analysis of Argon : Typical Results

Sample No.	*Oxygen ppm*	*Nitrogen ppm*	*Total Impurity ppm*
1.	140	1500	1640
2.	150	1500	1650
3.	150	1500	1650
4.	140	1500	1640
5.	140	1500	1640
6.	140	1500	1640
7.	150	1500	1650
8.	150	1500	1650
9.	150	1500	1650
10.	130	1500	1630
11.	110	1500	1610
12.	400	1500	1900
13.	130	1500	1630
14.	120	1500	1620
15.	140	1500	1640
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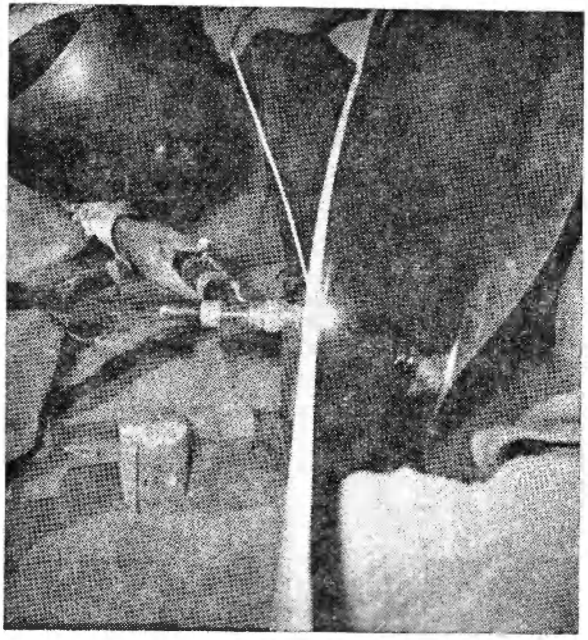
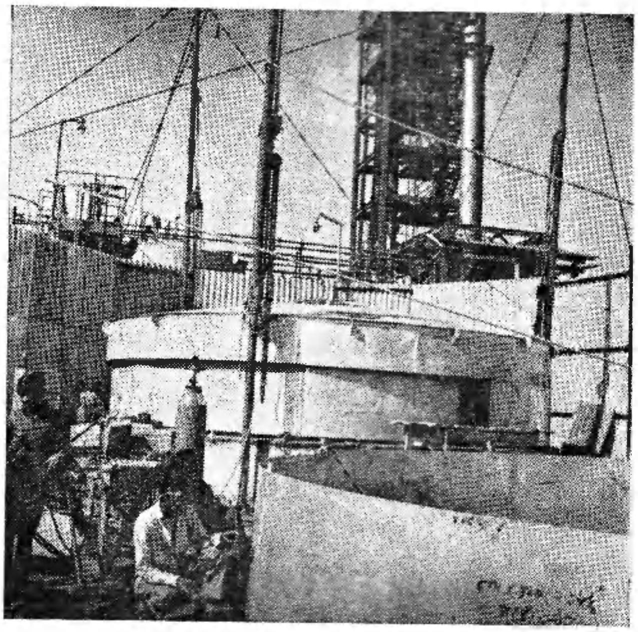
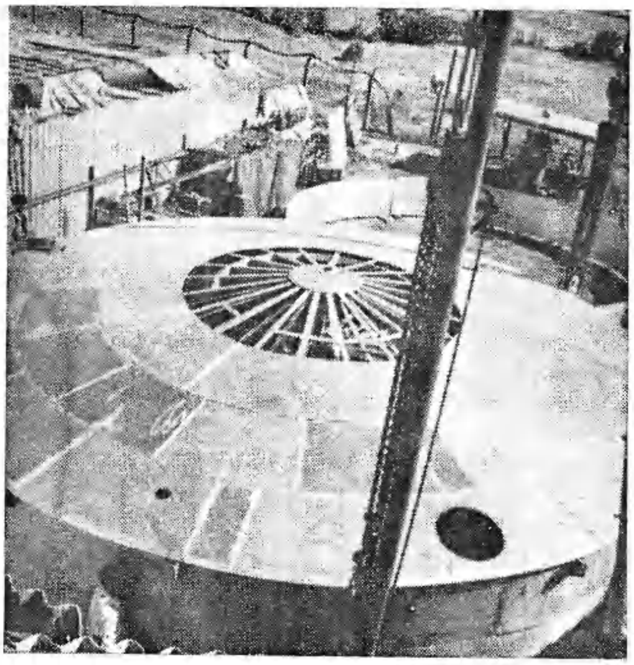
17.	80	1500	1580
18.	500	1500	2000
19.	500	1500	2000
20.	30	1500	1530



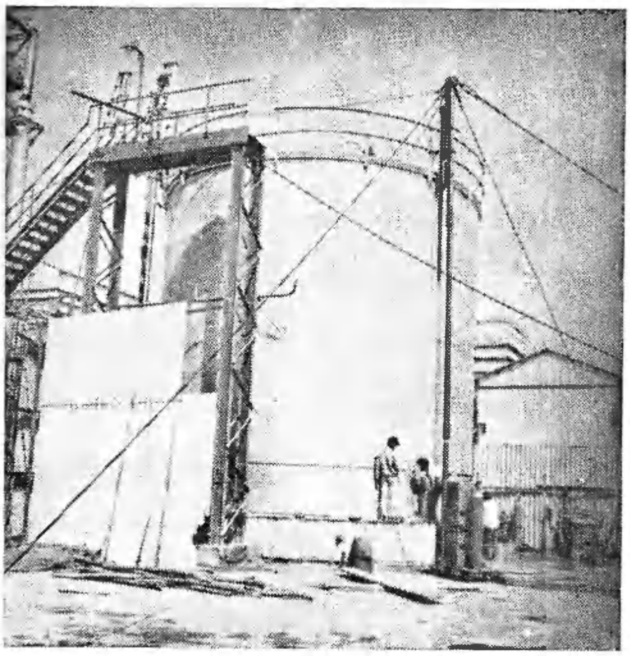
Photograph 1 : Vertical Double-Operator Welding on tankshell in progress.



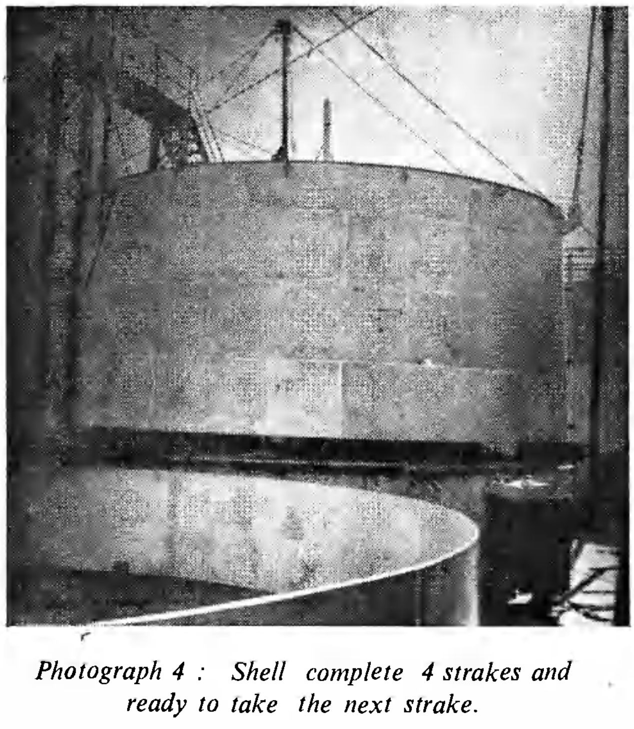
Photograph 2 : Roof structure complete with the topmost strake lifted to insert the next strake.



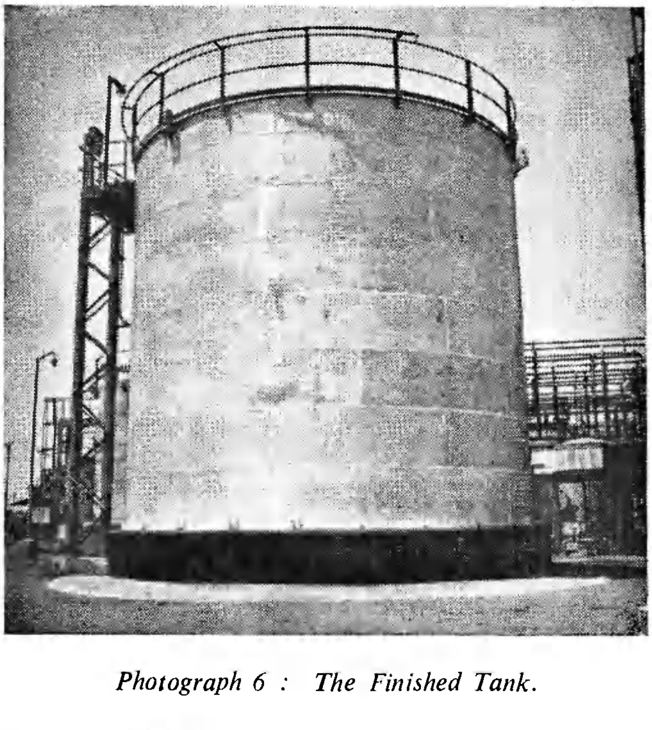
Photograph 3 : View of Roof.



Photograph 5 : The last strake in position, being tack welded.



Photograph 4 : Shell complete 4 strakes and ready to take the next strake.



Photograph 6 : The Finished Tank.