Indigenous Development of E 7018 Welding Consumable for Sour Gas Service Application

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INTRODUCTION

The demand for oil from transport and other sectors is expected to grow rapidly during this decade. Availability and production of oil in our country cannot meet the demand pattern and therefore we have to import oil from Middle East and other countries at exorbit ant cost. Bridging the gap by imports between demand and availability takes away major chunk of foreign exchange earned by exports. The international price of oil fluctuate often and any upward revision affects balance of payment severly. Therefore, in order to increase the availability of oil more and more efforts are put in for exploration and extraction of oil from off-shore areas.

For exploration and extraction of oil from off-shore areas, sufficient number of platforms are required. Fabrication off- shore platforms is difficult and need lot of expertise. Because of specific nature of corrosion encountered in process piping, the material selection is important. For such stringent applications international NACE specification No. MR-OT-75 is used for carbon steel process piping of the off-shore platform. Similarly for welding of such pipes, special grades of E-7018 type electrodes which deposit weld metal having extremely low, sulphur content in the range of 0.005 to 0.006 and can pass stringent special additional test such as Hydrogen Induced Cracking Test and Sulphide Stress Corrosion Cracking tests, are recommended. There are very few welding consumable manufacturing units in the world which manufacture and market such E7018 electrodes for off-shore fabrication. Our requirement of E-7018 electrodes till today is met by importing E 7018 electrodes from M/s. Lincoln of USA, M/s. Bohler of Germany etc.

Material Specification For Off-shore Fabrication

Process piping and other parts such as fittings, flang es, valves etc of off-shore platform are expected to withstand the extreme corrosive properties of sour gas. The sour gas contains H_2S and CO_2 and is extremely corrosive. Therefore, in order to withstand such severe corrosion environment during process operation carbon steel pipes and fittings should conform to special chemical, physical and corrosion properties. Taking in consideration the specific severe corrosion encountered in sour source gas application, specification for piping material has been published which is NACE-MR-01-75 which falls under the category of ASTMA 106, API5LX Gr 52 both pipes which have been modified to meet severe corrosion environment.

Carbon equivalent formula to be used when C > 0.12

$$Ce = c + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$$

The Carbon equivalent of the material should not exceed 0.36

$$Ce < 0.36$$

The parent metal as well as weld metal shall undegfo following qualification approval tests :

☐ Chemical composition and microstructure examination. An optical examination of the microstructure is performed at a magnification of 200. Untempered martensite, even in small amount is not acceptable.

☐ **Mechanical Properties**

Following tests are required for acceptance :

- Tensile test
- Charpy V-notch impact test
- Bend test

☐ **Hardness Test**

- Cross section hardness survey with Rockweld hardness testing procedure - Weld metal, heat affected zone and base metal. The hardness test is to be performed as per ASTM Standard E 18. The hardness should not exceed RC 22.

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☐ Corrosion Tests

- Hydrogen induced cracking test (HIC) is performed as per British Petroleum Procedure (BP) accpetance criteria.
- Crack sensitive ratio (CSR) 3%
- Crack length ratio 10%

Sulphide Stress Corrosion Cracking (SSCC) test as per NACE TM-01- 77 to be carried out.

- Minimum stress for cracking after 720 hours (1 month) should be atleast equal to 80%. (For procedure qualification, the total specimen should include the parent metal, heat affected zone and the weld metal).

A 106 Gr B **Specification (NORMAL QUALITY)**

C = 0.30%

Mn = 0.29 - 1.06% Tensile Strength = 60,000 psi

P = 0.048% max. Min (414 mPa)

S = 0.058% max. Yield Point = 35,000Psi

Si = 0.10% max,Min (241 mPa)

API 5 LX GR 52 **Specification**

C = 0.28

Mn = 1.25

UTS = 66000 psi (450 MPa)

Yield Stress = 52000 psi (360 MPa)

Elongation = 22%

Welding

Manual Metal Arc Welding electrode recommended for welding NACE Grade carbon steel piping should conform to AWS/SFA 5.1=1981 specification type E7018.

In addition to the test prescribed in SFA 5.1 - 1981 specification, during electrode qualification test the weld metal should pass following stringent corrosion tests (which are also carried out for parent pipe material :-)

- Hydrogen Induced Cracking Test (HIC Test)
- Sulphide Stress Corrosion Cracking Test (SSCC Test)

There are few welding electrode manufacturing organisation in the world who market E7018 class electrode for sour gas service applications. In our country ONGC and their contractors import E7018 electrodes mostly from USA based company M/s. Lincoln or M/s. Bohler of West Germany.

Product features of E 7018 electrode for sour gas service application.

E 7018 type electrodes for sour gas service application should deposit weld metal having extremely low sulphur and phosphorus content. All the batches or imported electrodes deposit weld metal having following chemistry :

- Sulphur content 0.005 - 0.006%
- Phosphorus 0.008 - 0.01%

In addition to limiting extremely low levels of sulphur and phosphorus, it is necessary the trace elements such as Cr. Ni, Mo, V, Al, Cu, B and Ti should be controlled in the weld metal. Each individual element can have detriment effect not only on the mechanical properties but can greatly influence corrosion properties also.

M/s. Lincoln and M/s. Bohler regularly manufacture and export E 7018 electrode conforming to NACE specification and these electrodes deposit weld metal having extremely low level of sulphur and phosphorus and control trace elements to desired levels. Each batch of electrode is tested for both corrosion tests namely HIC and SSCC. The test certificates are supplied alongwith each batch certifying compliance with corrosion tests.

Indigenous Development of E 7018 electrode for Sour Gas Service application.

Normal E 7018 electrodes produced in our country are not suitable for sour gas service applications for following reasons.

- Sulphur and phosphorus content in the weld metal is in the range of 0.015-0.025 which is very high.
- Hydrogen in the weld metal is in the range of 5cc to 10 cc / 100 grms of the weld metal.
- Presence of trace elements in the weld metal is not checked for each batch.

In order to develop suitable E 7018 electrode indigenously for sour gas service application, following experiments were carried out.

Selection of raw materials/core wire

For production of E7018 anual metal arc welding electrodes following materials are required :

- Mild steel core wire - rimming or non-rimming quality
- Binders - usually postassium or sodium silicate
- Coating flux mixture
- extrusion aids such as alginates, OMC etc.

Mild Steel core wire

Usually rimming quality low carbon mild steel core wire is used for the production of E7018 electrode. The chemical composition of the wire is as under :

C = 0.10%max
Mn = 0.38-0.62
Si = 0.03% max
S = 0.03% max
P = 0.03% max

It is necessary to select suitable ' heats' of core having extremely low levels of sulphur and phosphorus. The lowest sulphur level in the core wire should be 0.008% and phosphorus level 0.009%. Therefore, only wire having such levels of sulphur and phosphorus have to be used.

Binders : it is observed that often binders are the source of impurities and therefore each batch of binder should be checked for the impurity level specially sulphur, phosphorus etc. Only selected batches having traces of sulphur and phosphorus should be used for the production of E70189 electrodes for sour gas service applications.

Coating flux mixture : E7018 is a basic coated iron powder electrode. The main ingredients of the flux coatings are as under :-

- carbonates such as Calcium, Magnesium
- Fluorspar
- Deoxidisers like Ferro-silicon, ferro-titanium etc.
- Iron Powder

Most of the ingredients of flux coating such as fluorspar, deoxidisers, iron powder, do add sulphur and phosphorus in the weld metal. Therefore it is utmost important that each batch of such ingredient is tested and only those raw materials which have extremely low sulphur and phosphorus are used for manufacturing E7018 flux batches.

Extrusion Aids : Depending upon extrusion process whether it is high speed, one or more extrusion aids are used during wet mixing process. Extrusion aids facilitate extrusion process of electrodes and control to a large extent concentricity of the flux coating on the core wire. Usually alginates are having higher content of sulphur and therefore care should be taken while selection extrusion side. As far as possible-minimum quantity of extrusion aids having extra low sulphur and phosphorus content should be used.

TABLE 1

C	0.20%	Cu	0.35%
Si	0.35%	Ni	0.15%
Mn	1.4%	B	0.002%
Cr	0.20%	Al	0.055% (tOTAL)
Mo	0.05%	Ti	0.002%
v	0.08%	S	0.003%
(cb) Nb	0.05%		
S			

Cr = Mo < 0.25%
V + Nb < 0.08% P 0.015
Ni + Cu < 0.40%

Even after selecting all materials extremely low in sulphur and phosphorus content, a batch of E7018 electrode was prepared and was analysed for the weld metal chemistry. It was found out that sulphur and phosphorus content in this particular batch of electrode was more than 0.015 and 0.016 percent respectively. Hence the batch was rejected for further tests.

Therefore for bringing down sulphur and phosphorus content in the weld metal of E7018 electrode, eight different types of E7018 electrodes, each having different slag base, were manufactured in 4 mm size. The electrodes were called a E7018-A, E7018-B upto E7018-H. The weld deposit pads were prepared as per AWS/SFA 5.1- 1981 specification and weld metals of all the eight different types of electrodes were analysed. In table 2 results of sulphur and phosphorus of eight different types of electrodes are given :-

TABLE 2

Slag	Type	Sulphur	Phosphorus
A	E-7018-A	0.014	0.015
B	E-7018-B	0.016	0.018
C	E -7018-C	0 014	0.014
D	E-7018-D	0.011	0.015
E	E-7018-E	0.005	0.008
F	E-7018-F	0.012	0.014
G	E-7018-G	0.014	0.013
H	E-7 018-H	0.014	0.016

From the eight different results for electrodes having eight different slag bases, it was observed that slag base "E" deposited weld metal having very low level of sulphur and phosphorus, Therefore by using slag base "E", E-7018 electrode in sizes 5 mm, 4 mm, 3.15 mm and 2.50 mm were manufactured. All four sizes of electrodes were tested for weld metal chemistry. The results obtained for 'four sizes' of E7018 having slag base "E" are tabulated in Table 4.

TABLE 4 E 7018 Slag base E

Size	Sulphur content in teh weld metal	Phosphorus content in the weld metal
5.00mm	0.005%	0.009%
4.00mm	0.005%	0.009%
3.15mm	0.006%	0.008%
2.50mm	0.005%	0.010%

The four sizes of E7 018 electrodes having slag "E" base were tested completely in accordance with

AWS/SFA 5.1-1981 specification. The weld metal chemistry and mechanical properties results obtained are given in Table 5 & 6 respectively.

TABLE 5

Size	C %	Mn %	Si %	S %	P %
5.00mm	0.80	0.91	0.21	0.005	0.009
4.00mm	0.070	1.09	0.19	0.005	0.009
3.15mm	0.084	1.01	0.18	0.006	0.008
2.50mm	0.069	0.92	0.18	0.005	0.010

TABLE 6

Size in mm	UTS Mpa	Yield stress Mpa	Elonga--tion L=4d%	Chrpy V-notch impact strength at -29oC in Louies
5.00	524.1	457.1	37.5	273.1
4.00	532.8	430.2 3	6.2	160.9
3.15	505.2	422.6	33.6	213.9
2.50	535.1	437.5	24.5	157.0
As per AWS/ SAF 5.1-1981	500	430	22	27
Specification	Min	Min	Min	Min

Usability fillet test conducted for all the four sizes are results were meeting requirements of the specification.

The electrodes under development have flux coating which is low mositur absorption type or moisture absorption type or moisture resist ant type. The weld deposit obtained from such electrode is very low in hydrogen content.

Usually most of the R7018 type electrode manufactured deposited deposit weld metal having hydrogen content in the range 5 to 10CC per 100 gms of the weld metal whereas E 7018 electrode having slag base "E" deposit weld metal having hydrogen content less than 2.00 CC per 100 gms of the weld metal. Such very low level of hydrogen content in the weld metal eliminates risk of hydrogen induce4d cracking either in the HAZ or in the weld metal Table-7 gives results of moisture content in the flux coating and hydrogen content in the weld metal of E7018 electrodes.

TABLE

Size mm	Moisture content in the flux coating	Hydrogen content in the weld metal measured mm by glycerine method cc/100 grams of weld metal (IS 814 Specn.)
5.00	0.18	1.45
4.00	0.13	1.3
3.15	0.15	1.4
2.50	0.16	1.4

Hardness of the weld metal of all the 4 size electrodes was less than 170 Brinell.

Testing and approval of E 7018 electrodes for sour Gas Service Application

In order to establish suitability of E 7018 electrodes having Slag Base E, for sour Gas Service Application, these electrodes were tested for following corrosion tests at M/s. Reliable Testing Service, 58, Bindal Industrial Estate,. Saki Naka, Bombay 400 072 :-

- Hydrogen induced cracking test (HIC)
- Sulphide stress corrosion cracking test (SSCC)

TABLE 7

TESTING FIXTURE NO.	11
1D. MARKS/STAMPED BY	B.No. 10825 5.0mm Tenacito HH Spl/EIL-9
GAS	H2S Bubbling
SOLUTION	5% Nacl + 0.5% CH3COOH
MATERIAL	Tenacito HH Spl
LOCATION OF TEST PIECE	All weld
DIAMETER OF TEST PIECEmm	6.404
TEMPERATURE (deg. cent)	24 + /-2
APPLIED LOAD MPa	336
TEST DURATION (Hrs)	720
START TIME	09/08/91 01.20 PM
STOP TIME	08/09/91 01.20PM
INITIAL pH	2.75
FINAL pH	3.31
FINAL DIAMETER mm	6.22
REMARK Test Passes	

Reliable Test House in an established Testing Laboratory in Bombay. Here required corrosion testing facilities have been set up quite some back. More than 100 HIC and SSCC tests have been conducted for material i.e. NACE carbon steel piping materials as well as for weld metal. It is an approved Test Laboratory by EIL, DNV and Lloyds and hence HIC and SSCC corrosion test were carried out at this Laboratory.

Preparation of Test Assemblies for corrosion test for SSCC test all-weld test assembly as per procedure given in SFA 5.1-1981 was prepared.

For HIC test assembly the gap between the two plates was 102 mm . After completion of weld assembly backing plate was removed by machining and the assembly was radiographed ensuring defects free weld.

The tensile test specimen from the test assembly was machined as per the drawing.

Details of SSCC test

Stressed specimens are immersed in acidified sodium chloride solution saturated with hydrogen sulphide at ambident pressure and ambident temperature. Applied stresses at convenient increments of the yield strencth can be used to obtain sulphide stress cracking data. Time of failure at a fixed stress is an important factor (SMYS) for expermental corelation purposes. A30 days test period is considered sufficient to revela failures in materials susceptible to sulphide stress cracking.

SSCC test apparatus

- Flow of H2S gas 4 to 5 bubbles per minute in acidified Nacl solution - This is to be maintained throghout the test period i.e. 720 hrs.
- Initial PH of acidified Nacl solution is approx. 3
- At the end of the experiment, i.e. after 720 hrs. PH of acidified Nacl is checked and it should not exceed 4.5.

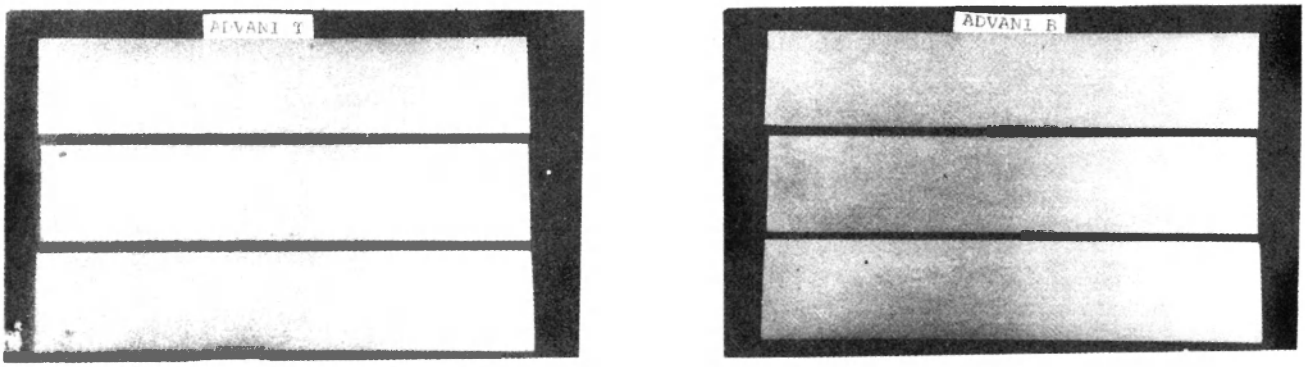
The test results obtained for SSCC test are given in Table No.7

HIC Test : From the weld assembly, a test piece having dimension 100 X 20 X 10 mm was machined out and it was polished to 32 microns level. The test piece was immersed in a solution of synthetic sea water. H2S gas passed through the synthetic sea water and flow of gas was 10 to 15 cc per minute. The test was conducted continuously for 96 hrs. After 96 hrs the test piece was checked for surface cracks and other defects visually.

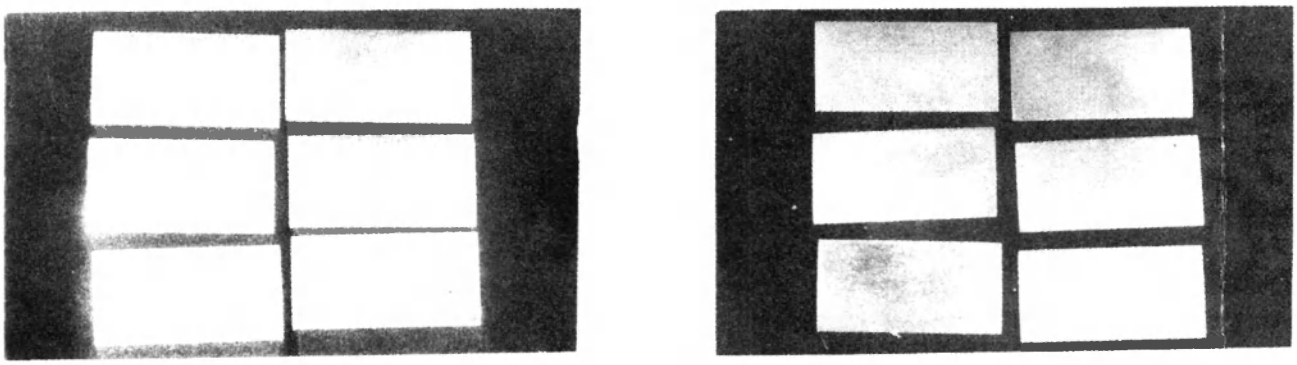
Then the micro examination test was carried out to check for cracks.

- India PH of the HIC test soln should be between 8.1 to 8.3
- After 96 hrs. i.e. after completing test, PH of the soin should be between 4.8 to 5.4

TOP SIDE (HIC TEST) BOTTOM SIDE



PHOTOGRAPHS AT IX AFTER SECTIONING (HIC TEST)



Tensile Test Piece after exposing to sulphide stress corrosion test of 720 hrs.

Microphotographs of the microscopic examination are taken. The test tesults ontained for HIC test as per NACE specification are given in Table No. 8.

TABLE 8

ID. MARK/STAMPED BY	10825 5 MM DIA EIL/97
GAS	H2S BUbbling
SOLUTION	SYNTHETIC SEA WATER AS PER ASTM D-1141
MATERIAL	TENACITO HH SPL
LOCATION OF TEST PIECE	ALL WELD
TEST PIECE SIZE	10 MM X 20 MM X 100M 1g
TEMPERATURE (deg.cent)	24 .+/-2
TEST DURATION (HRS)	96
START TIME	09/08/91
STOP TIME	13/08/91
INITIAL PH	8.15
FINAL pH	5.21
OBSERVATION AT IX	SMALL BLISTERS OBSERVED
OBSERVATION AT 100X	CSR 0.0, CLR 0.0, CTR 0.0
FINAL REMARK	TEST PASSES

The test results obtained fulfil the requirements of HIC test as per NACE specification.

ACKNOWLEDGEMENT

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CONCLUSION

First time in India E 7018, an indigenous electrode, required for sour gas service has been developed successfully

The electrode E7018 is available at a short notice and shall help the country in saving valuable foreign exchange.

Because of easy available users of E7018 electrodes will not have to undergo difficulties in opening Letter of Credit, procuring Exim Scrip etc.