IN-SERVICE CRACK DETECTION AND REPAIR IN SPHERICAL STORAGE TANK

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During regular in-service inspection and non-destructive examination of spherical storage tank for vynilchloride monomer (VCM), of 2000 m^3, on inner wall in weldments area numerous cracks, different in size and location, had been detected. In order to assure safe operation of storage tank, after testing and analysis, optimal procedure for repair by welding has been established for typical kinds of cracks. Paper presents inspection procedure and results and repair procedure by grinding and welding.

INTRODUCTION

Spherical storage tank of 2000 m^3 (Fig.1) is applied for vynilchloride monomer (VCM) storage. Distribution of VCM to final user is organized by railroad wagon tanks, that are charged at the ramp. Before charging by VCM, spherical tank must be held certain time filled by nitrogen under required pressure in order to assure inert environment. In first charging nitrogen has been let out and storage tank is charged with 30 to 50 ton of liquid VCM. After that flashing of liquid VCM takes place, followed by cooling of liquid VCM and spherical tank material. During the initial stage of VCM charging, in lower tank part the temperature of -10°C to -15°C has been established. Depending on outer environment temperature and humidity, the condensation of air moisture can occur, as well as development of ice layer on spherical tank outer wall surface. Since the sphere is not insulated, the pressure in it is dependent on environment temperature (e.g. at +10°C corresponding pressure is 1.51 bar, at +35°C it measures 4.23 bar).

Spherical storage tank is designed with 24 segments and 2 covers (upper and lower lids), produced of 20 mm thick high-strength low-alloy (HSLA) steel NIOVAL 47. Chemical composition and mechanical properties of used heats are given in Table 1.

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Table 1 Chemical composition heat analysis and mechanical properties of NIOVAL 47 steel

C	Si	Mn	P	S	Nb	V
0.18-0.19	0.44-0.45	1.42-1.43	0.012-0.015	0.009-0.014	0.048 0.055	0.08

Yield strength, Y.S. MPa	Ultimate tensile strength, U.T.S. MPa	Elongation A_5, %	Impact toughness at 0°C J/cm^2
461-496	627-648	25-27	118-163

Workshop welding of longitudinal steel segments weldments had been performed by submerged-arc-welding (SAW). Field welding of one half of longitudinal weldments and of all circular weldments had been performed by manual-arc-welding (MAW) using EVB-60 electrodes (AWS E 8018-G). Total length of longitudinal weldments is 483 m, of circular weldments 120 m.

INSPECTION AND TESTING RESULTS

After completion of spherical storage tank following inspecting and testing actions had been applied:

- November 1976 - first proof pressure hydrotest; at 12 bar no leakage had been registered.
- September 1977 - tank was put in operation.
- September 1983 - second hydrotest, no leakage.
- April 1987 - third hydrotest, no leakage registered. In-service ultrasonic testing of two circular weldments (RI and RII) on outer surface had been performed by slant sondas just after beginning of operation.
- October 1989 - fourth hydrotest according to special requirement of Inspectorate Office, no leakage registered. For next non-destructive inspection by ultrasonics and magnetic particles methods the grinding of inner side weldments reinforcements was required. In this inspection numerous longitudinal and transversal cracks of different lengths and depths had been detected. After repair by grinding and welding, during repeated ultrasonics and magnetic particles inspections no defects had been revealed.
- March 1991 - fifth hydrotest upon Inspectorate Office request - no leakage observed. Again, ultrasonics and magnetic particles non-destructive inspection revealed numerous cracks of different location and size. Repeated non-destructive inspection after repairing by grinding and welding did not reveal crack indications.

In the last non-destructive inspection before and after fifth hydrotest on 331 location longitudinal and transversal cracks had been detected in weldments area on inner wall surface. Location, number and crack direction before and after hydrotest and length of notches over 5 mm deep for repair by welding are given in Table 2.

Table 2 Data about cracks revealed by non-destructive inspection before and after fifth hydrotest

Weldment designation	Number of cracks revealed before (after) hydrotest			Length of notch for repair by welding (m)
	longitud.	circular	total	
R I	2 (3)	9 (2)	11 (5)	0.53 (0.50)
R II	36 (2)	85 (-)	121 (2)	12.89 (0.25)
R III	109 (35)	- (12)	109 (47)	19.56 (0.16)
R IV	6 (10)	- (-)	6 (10)	0.52 (0.08)
L I/II	33 (106)	5 (-)	38 (106)	2.36 (0.74)
L II/III	29 (2)	17 (8)	46 (10)	- (-)
L III/IV	- (-)	- (-)	- (-)	- (-)
Total:	215 (158)	116 (22)	331 (180)	36.84 (1.73)

R - Circular weldment, L - Longitudinal weldment

REPAIR PROCEDURE BY GRINDING AND WELDING

Detected cracks had been grinded and the result of this operation is controlled by magnetic particles method. Up to 5 mm deep cracks had been repaired only by grinding in a way that the axis of rotating stone was perpendicular to axial weldment direction. Smooth radius to base metal is assured by grinding without sharp notches or cuts.

For cracks deeper of 5 mm repair by welding had been applied. In this case the rotation axis of grinding stone coincides with the crack indication direction. Welding preparation had been formed by grinding. Depending on crack depth, repair had been performed from one or from both (inner and outer) sphere surfaces.

In Table 3 number of cracks repaired by grinding only, and by grinding and welding is presented.

Table 3 Number of repaired cracks

Weldment designation	Repairing procedure		
	only by grinding	by one-side welding	by both-sides welding
R I	5 (-)	6 (-)	- (1)
R II	15 (-)	87 (2)	19 (-)
R III	36 (45)	58 (2)	15 (-)
R IV	- (-)	5 (1)	1 (-)
L I/II	12 (101)	25 (5)	1 (-)
L II/III	34 (10)	12 (-)	- (-)
L III/IV	- (-)	- (-)	- (-)
Total:	102 (165)	193 (14)	36 (1)

R - Circular weldment, L - Longitudinal weldment

Typical repairing procedures by welding are presented in Fig.2. Repair welding had been performed using MAW procedure and AWS E 8018-G electrode ϕ3.25 mm. Calculated minimal preheat temperature 142°C was continuously controlled during welding. Heaters were positioned before welding on the opposite wall side.

Prescribed welding regime parameters and welding passes sequences were strictly followed. Final "normalizing" pass was applied and after controlled cooling it was flat grinded (shaded area in Fig.3). For microalloy steel the determination of transition thickness limit from 3D to 2D heat conduction (d_1) is important. According to the d_1 value cooling time $\Delta t_{8/5}$, affecting microstructure and mechanical properties, can be evaluated. Cold crack occurrence can be a consequence of short cooling time $\Delta t_{8/5}$, whereas for long $\Delta t_{8/5}$ toughness values can be too low. According to standard JUS C.T3.102 calculated values are d_1 = 19.4 mm and $\Delta t_{8/5}$ = 4.83 sec.

During welding, temperature had been measured by contact thermometer at the preparation edge on the inner wall side and evaluated cooling time as $\Delta t_{8/5}$ = 7.5 sec corresponded well with calculated value, indicating correct prescribed parameters of welding technology and from this point of view one can expect avoidance of cold cracks and convenient impact toughness level.

After welding and grinding of reinforcement, performed ultrasonic and magnetic particles testing did not reveal cracks or other defects indications. By periodical in-service ultrasonics inspection during last 18 month, performed from outer side, no changes were found.

CONCLUSIONS

1. After limited operation time of spherical storage tank for VCM, produced by welding of microalloy fine grained HSLA steel cracks of different size and direction had been detected on inner wall surface in weldment regions. This is reported elsewhere (1,2).
2. The occurrence of new cracks after proof hydrotest is evidenced in weldments, exposed to environment effects during service, and no cracks were found after hydrotest in repaired weldments.
3. By repair welding according to prescribed welding technology good results are achieved and during 18 months of service the ultrasonics inspection from outer side did not reveal defect indications.

REFERENCES

(1) Hrivnak, I., Document IIW-IX-1516-88.

(2) Lukačević, Z., Zavarivanje, Nr 5-6, 1989, pp 161-169.

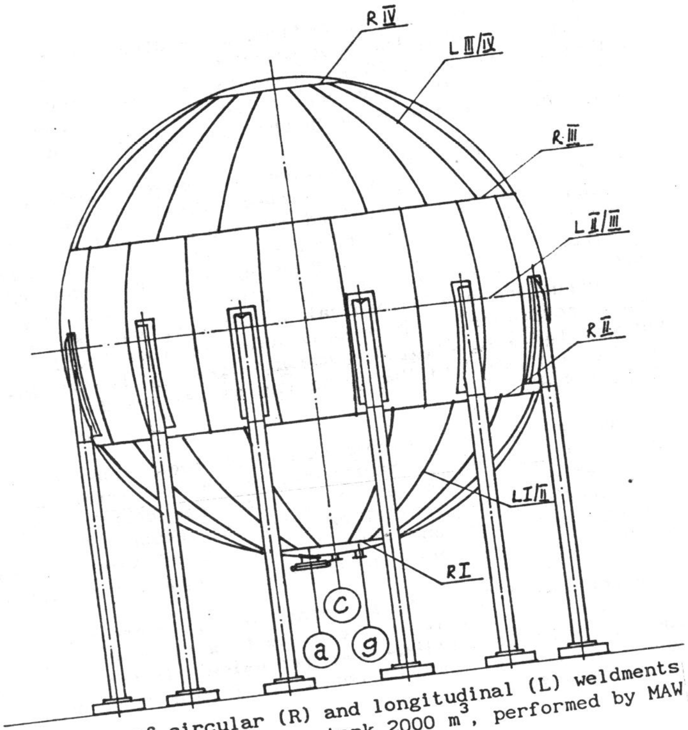
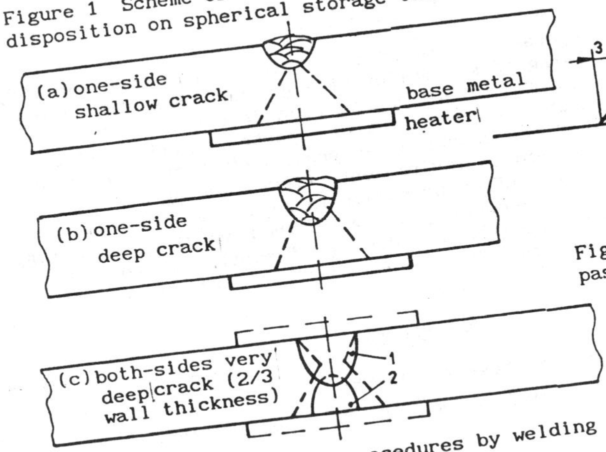


Figure 1 Scheme of circular (R) and longitudinal (L) weldments disposition on spherical storage tank 2000 m^3, performed by MAW



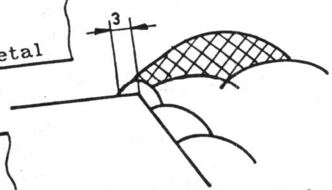


Figure 3 "Normalizing" pass removing sketch

Figure 2 Typical repair procedures by welding