Salvation of S. S. Surge Tank for HTHP Loop

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ABSTRACT

As constituents of nuclear industry, we all know the significance of the stringent specification to the practical level on the manufacture of nuclear components. More so for the primary system of High Temperature High Pressure Loop (HTHP) situated at Water & Steam Chemistry Division (WSCD). The pressurizing of the system is done by heating through immersion heaters provided in the surge tank. The surge tank, at its rated condition, has steam on the top, above the water level. The surge tank has got a150 NB size nozzle at the bottom dished end. A 1500 # flange is welded to this nozzle. The heater unit of the surge tank is connected to this flange. The heater unit consists of a 150 NB, 1500 # blind flange (tube sheet) with eight number of SS U-type immersion heater pins welded to it. Welding of stainless steel heater pin is a demanding task. The task becomes even greater when the job involves welding of 16 pins with a triangular pitch of 25 mm, such as those for the high temperature & pressure loop. Actually, the tank was manufactured by a private firm. During final leak testing, it was found that there were leaks through the heater pins to sleeve welding in three of the heater pins. They could not rectify the leak. Subsequently, the rectification of the weld was referred to CWD. A novel technique was developed and due care was taken to weld the heater pins. The tank was successfully salvaged and tested hydrostatically at 170 bars and pneumatically at 7 bars. The method of fabrication of heater assembly, problems anticipated, problems encountered and measures taken to solve them are dealt with.

INTRODUCTION

The Surge Tank (Fig. 1) is one of the most critical components in the primary system of High Temperature & High pressure Loop for Water & Steam Chemistry Division. The tank is subject to high pressure & high temperature (HTHP) in the order of 112.5 kg/cm2 & 292° C respectively and acts as a pressurizer in the Loop. It also serves as surging equipment of the system for absorbing the fluctuations of pressure & level on the system. Hence, specifications for the three main areas namely fabrication, welding and inspection have been arrived at to achieve high reliability. This paper highlights the efforts taken to achieve the desired objective.

Description

The storage Tank is used at its rated condition has steam on the top, above the water level. This gives a cushioning effect and avoids pressure fluctuations, which takes place during normal operation. When there is a loss of water from the primary system due to leakage and sampling, the surge tank also provides makes-up water. It also absorbs the volumetric change that takes place in the system during heating & cooling. The tank is held in upright position and its volume is around 220 liters. The tank has an inner diameter of 350 mm, with an outer diameter of 400 mm and 2500 mm long cylindrical vessel (aspect ratio ~ 6) with tori-spherical dished ends on both sides. The tank has around thirteen nozzles. The surge tank has got a 150 NB size nozzle at the bottom dished end. A 1500 # WNRF ring flange (A182 F 316) is welded to this nozzle. The pressurizing of the system is done by heating through immersion heaters provided at the bottom of the tank in a 150 NB 1500 # RF Blind Flange (A182 F316) is bolted to the WNRF ring flange by 12 nos of M36 high tensile bolts & nuts.

There are eight U type heater pins, which makes totally sixteen heater pin joints were welded with the blind flange (tube sheet). The sheath thickness of heater pin is around 1 mm (Fig. 2). Each heater pin is 9.5 mm OD, 2000 mm long, 6 KW capacities and made of AISI 316 material. The heating element in the heater pin is Ni-Cr wire and insulated with magnesium oxide (MgO) powder having a melting point of 2827 oC and density of 3.58 g/cm2, rock packed around the concentrically placed Ni-Cr wire. The heaters work on power supply of 415 V, 3 ph AC. Out of total 8 pins, 2 are spare. The remaining 6 pins are divided into two banks. One bank of 2 heater pins (12 KW) is for control bank and other 4 pins (24KW) are for main bank. The control bank is used for slow initial heating and maintaining the pressure after attaining rated operating conditions through thyristors & PID controllers. The main bank is used when a quick heating is required.

Fig 1 : S.S. Surge tank as received condition

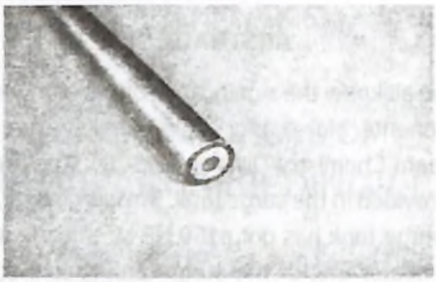

Fig 2 : Cut view of Heater Pin

The dimensions of the tank are:

- Internal diameter of the tank	:	350 mm
- Overall height (dished end to dished end)	:	2250 mm
- Thickness of the shell	:	25 mm
- Thickness of the dished ends	:	36 mm
- Shell & dished ends Material	:	A240, AISI 316
- Tube sheet material	:	A182, F316
- Nozzle Material	:	A312, TP 316
- Crown radius of the dished heads	:	400 mm
- Knuckle radius of the dished heads	:	40 mm

The surge tank has two lifting lugs welded to the top dished end and two support lugs welded @ 180° apart, with reinforced pads at the center of the vessel.

Applicable Specifications

The tank has been fabricated, tested and inspected in accordance with ASME Code, Section VIII, Division 1. The tank needed a homogenous weld that would offer excellent strength and meet the requirements of the Code.

Design Pressure	:	112.5 Kg/cm^2 (g)
Operating Pressure	:	84.0 Kg/cm^2(g)
Design Temperature	:	316° C
Operating Temperature	:	295° C

Fabrication Procedure

The important fabrication aspects are : a). use of high standard materials , b). use of high quality welding, supported by a Q.A. Programme, c). use of pre-service inspection to detect sub-critical defects, which have the potential for developing into critical sizes during service tenure and leading to failure.

Problems Encountered during Fabrication of the Tank

The fabrication of the surge tank consists of two parts i.e. S.S. tank and Heater pin assembly. The tank has been successfully fabricated as per code requirements by a private firm, carried out NDT and also leak tested by hydrostatically & pneumatically to the test pressures. The Heater pin assembly was also fabricated by the same firm. The welding of the heater pin and the sleeve of Tube sheet was not successful. Hence, the welding of the heater pins was outsourced to another private firm. After completion of the welding, the assembly was brought back to the original manufacturer and assembled with the surge tank and hydro testing was conducted. During pressure testing @ 50.0 Kg/cm2 (g), it was found that three heater pins welding was leaking and two more pins were having lesser IR values than required. Hence, again the firm has procured six more heater pins and sent the whole assembly along with the tank which has been duly pickled & passivated to the earlier out sourced company. This time also, the company failed to make a defect free weld with the new heater assembly. Hence, the tank along with the heater pins assy could not be leak tested to the test pressure. In this context, the original manufacturer informed to our purchase division saying that they are not in a position to complete the job and requested to undertake the fabrication of heater assembly by our Department. They also agreed to supply one set, comprising 8 new heater pins, sleeve rods and a blind flange (tube sheet) afresh and also to pay the charges incurred towards the salvation of the surge tank to our department. The tank was inspected by our departmental inspector during various stages of manufacturing with the following testing requirements.

Liquid penetrant Inspection	:	First & Final passes of all welds
Radiography Test	:	100 % on all butt welds.
Hydrostatic Test	:	185 kg/cm2
Air Leak Test	:	7.0 kg/cm2

Evaluation of root cause and solutions adopted

The job has been referred to CWD, IGCAR to salvage the S.S. surge tank through our Purchase Division. Welding of heater pin with sleeve was a challenging task. The manufacturer had attempted twice to rectify the intricate welding but failed on both occasions. After a close scrutiny at CWD, it was decided to replace the entire heater assembly along with the 150 NB 1500 # RF Blind Flange (tube sheet) with sleeves. The Heater sheath is of 9.5 mm out side diameter with wall thickness varying from 0.8 to 1.0 mm. The gap between the heating element and the sheath was packed with MgO powder as insulating material. The Heater sleeve was made from AISI 316 rod with an outside diameter of 12.5 x 1.35 mm wall thickness. The Welding of thin walled heater sheath with sleeve demands an expertise in welding. During mock-up welding, it was noticed that the heater sheath around the fillet weld was punctured and the presence of porosity was also noticed (Figures 3-4).

Also, we could observe the gas coming out through the opening during welding. Many attempts were made to seal off the punctured sheath but all led to repeated failure. The chemical analysis of the MgO powder was carried out and the results showed the presence of Magnasite ($MgCO_3$) as impurity. When this MgO is heated to the temperatures above 4500C, the magnasite impurity present in it thermally decomposes into magnesium oxide and carbon dioxide ($MgCO_3$ $MgO + CO_2$). After building up sufficient pressure, this evolved CO_2 gas escapes through the heater sheath which is in muzzy form during welding. This evolution of CO_2 gas is the root cause for the puncturing of the sheath as well as the weld metal and also the presence of porosity at the weldment.

Hence, it was decided to remove the MgO powder from the heater pins up to a level of welding zone (30 mm). It was considered to be the best method based on productivity and weld metal quality criteria, as well as previous experience from other critical applications. To fulfill the requirements, a new compact special tool (Fig. 5) was designed and made, to suit the existing slow speed portable drilling machine to remove the tightly packed hard MgO powder from the heater pins to a depth of 30 mm. By using the above machine, the MgO powder was successfully removed from all the pins (Figs. 6) up to a depth of 30 mm.

Welding trials

Welding trials undertook to evaluate the performance of the newly designed weld joint by adopting GTAW and to demonstrate the acceptability for heater-sleeve welding. A narrow gap was selected for use without a root gap between the heater sheath and the

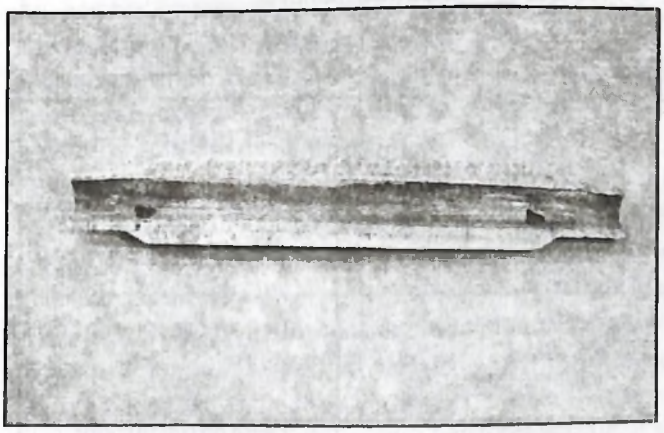

Fig 3

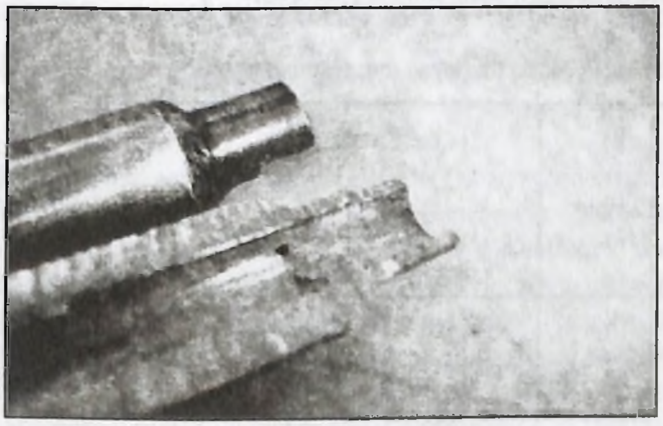

Fig 4

Cross sectional cut view of Heater Pin to Sleeve welding showing the pin hole sleeves. An expanding mandrel was used to take care of the OD variation of the heater pins and ensured precise sheath alignment, in order to get uniform root bead penetration. A sleek torch with micratig power source was used for the trials. The 250 is an inverter power source, which means that there is a pre-programmed relationship between the pulsing parameters/power outputs. Test welds and its parameters were used to develop the welding procedure.

Welding procedure, Testing and Inspection

The welding was performed with the heater pin and the sleeve in 1 G position. Pure argon was used as the shielding gas and the heat input was maintained within 480 J/mm of weld (Table I). The weld was subjected to an extensive testing programme, including non-destructive testing, micro structural analysis and micro hardness measurements. Radiographic inspection and sectioning of the welds were revealed no defects. Weld regions for all four samples (Figs. 7&8) were revealed delta ferrite having dentritic morphology and is uniformly distributed. Microstructures of the base metal for all the four samples showed typical austenitic grains with annealing twins and hardness measurements (Table II),

Table I. Typical welding Parameters: Shielding & Purging gases 99.996% UHPA. Total welding time/pin: 3 minutes.

Pass	Position	Current (A)	Arc Voltage (V)	Filler dia. (mm)	Welding speed (mm/min.)
Single	1 G	40	10	0.8	50

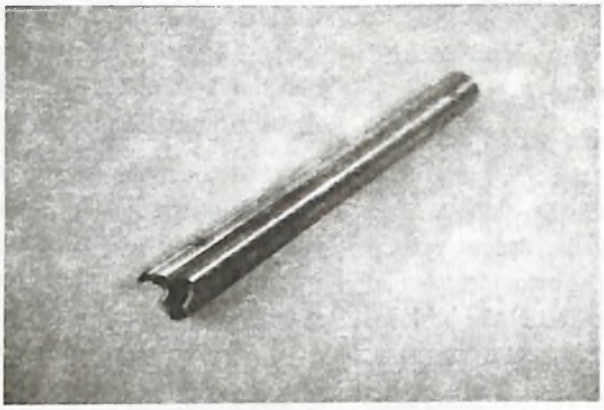

Fig. 5 : Special tool designed and used for removing MgO powder

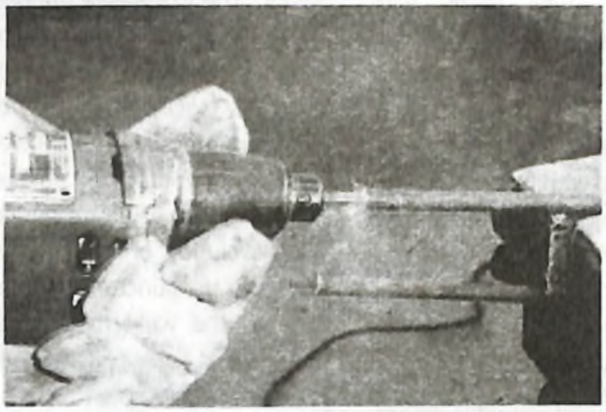

Fig. 6 : Process of MgO powder removal

Table II : Micro hardness measurements of the four welded samples

Sample No.	Base metal $\sum = \pm 10$ VHN		Weld $\sum = \pm 10$	Micro Structure	
	Heater Sleeve	Sheath		Base metal Heater sheath & Sleeve	Weld
1A	310	233	234	Austenite grains	Delta ferrite present
1B	294	215	247	Austenite grains	Delta ferrite present
2A	277	242	255	Austenite grains	Delta ferrite present
2B	279	255	268	Austenite grains	Delta ferrite presen

indicate that all the welds exhibit similar hardness values while the base metal of the inner tube showed higher values than the sleeve.

Manufacturing sequence

Machining of 16 sleeve rods with an internal diameter of 3.0 mm from the supplied rod. Drilling of 12.5 mm diameter blind hole in the tube sheet to a depth of 25 and 23 mm diameters through hole for N3 nozzle and 10 mm holes to a depth of 25 mm for tie rods. The sleeve rod was inserted and welded with the tube sheet. Inspection of welding by DPI. Drilling of 9.7 mm diameter through hole in the sleeve rod and tube sheet of 82.6 mm thick. The Tie rods with baffle plate assembly were also welded with the tube sheet. Inserted one heater pin through the baffle plates & the sleeve, tack welded and inspected. The heater consist of 8 nos of "U" shaped electrical heaters (Fig. 9) of 6 KW capacity in each, which have been welded to the heater sleeve with a triangular pitch of 25 mm (Fig. 10).

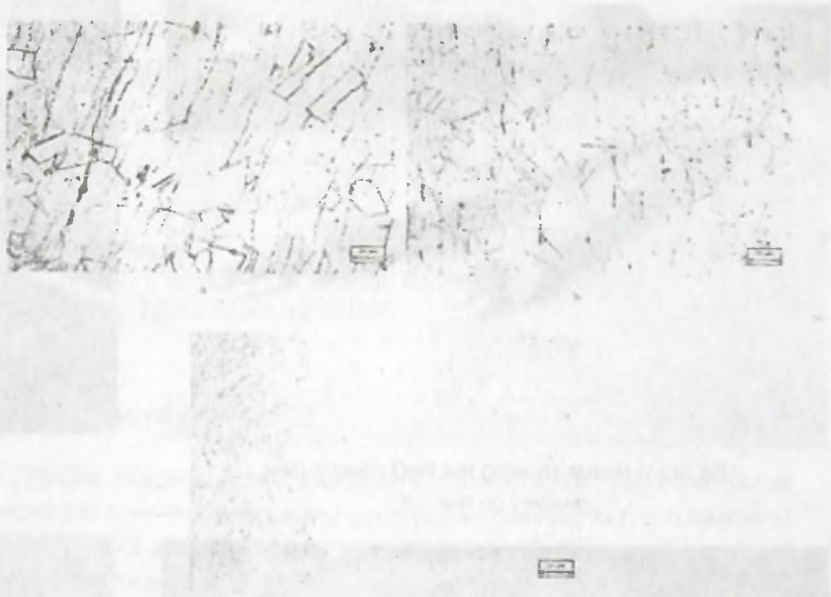

Fig. 7 : Microstructures of the sample 1A

Fig. 8 : Microstructures of the sample 2B

(a) base metals of the outer tube, (b) base metal of the inner tube, (c) weld metal

The wall thickness of heater pin was 0.8 -1.0 mm. The projection of the cold end of the heater is 100 mm. The heater sheath was welded with sleeve by pulsed GTAW process using 0.8 mm filler wire of AISI 316. The limited access for the welding torch among the heater pins is another complicating factor. The conventional TIG welding torch available in India is not suitable, since the sleeve welding is to be carried out at a depth of 100 mm from the top surface. A high-accuracy manipulation and control system is therefore necessary to obtain defect free weld and achieve the required productivity. An imported HELI ARC Torch specially designed for this type of task was deployed; it permits vertical, horizontal and rotating movements. The skill of the welder in torch manipulation at a depth of 100 mm, controlling the welding speed and arc control are noteworthy. The weld was inspected by visual & DPI. Similarly, all the 16 heater pins (Figs. 11-12) were welded and inspected individually. After welding, silicon paste/compound was filled in the top portion of the heater sheath, where the MgO powder was removed and the Heaters were sealed with ceramic sleeves.

The Welding of N3 Nozzle connection by weldolet on tube sheet was also carried out. Finally, the tube sheet along with the heater assembly was assembled with the tank. The surge tank (Fig. 13) was successfully leak tested hydrostatically at 170 bars and pneumatically at 7 bars. The successful completion of the tank was a noteworthy.

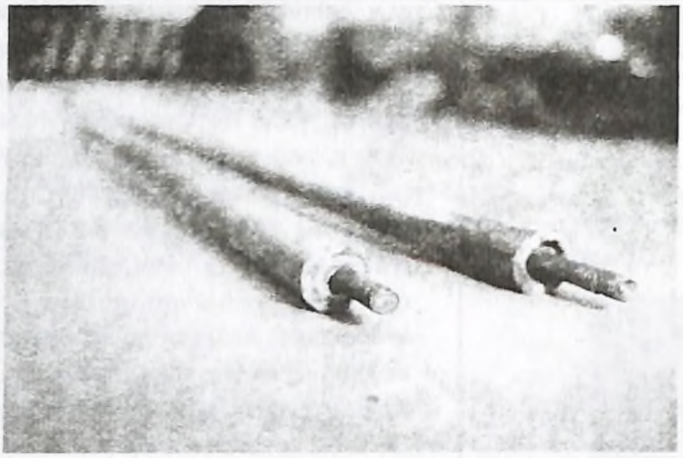

Fig. 9 : U-Heater showing the MgO powder duly removed on one pin

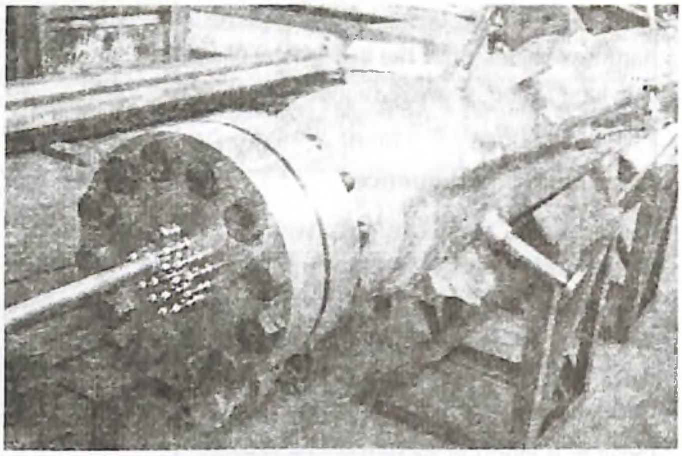

Fig. 10 : All the eight Heater Pins are welded with Tube Sheet

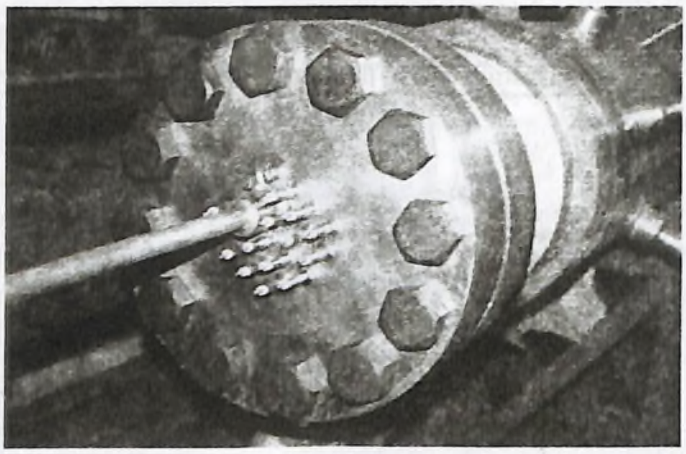

Fig. 11 : Close-up view of welded Heater Pins

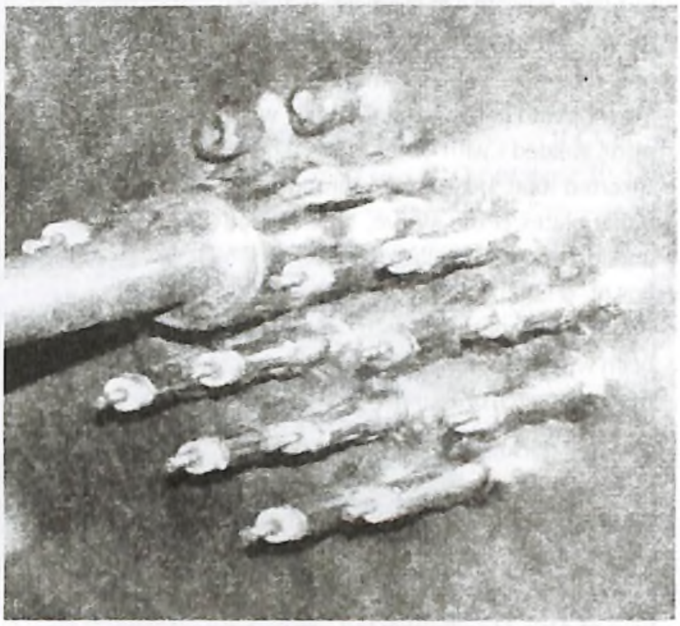

Fig. 12 : Heater Pins welded with flange (tube sheet) and DP checked

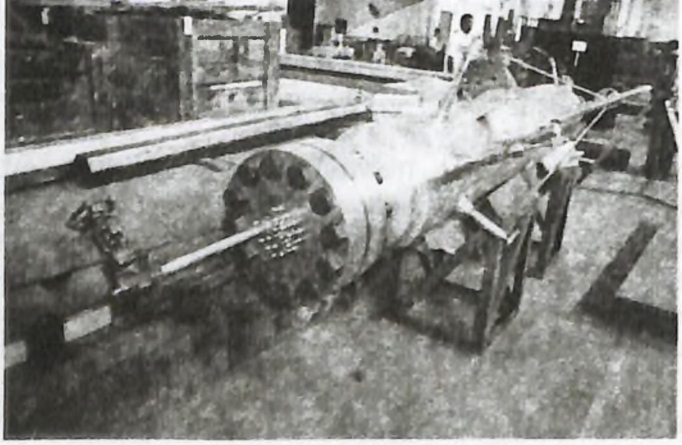

Fig. 13 : Surge tank ready for Hydraulic Test after salvage

Conclusions

It was clearly demonstrated that, with the proper equipment & technique, welds could be performed reliably and effectively in narrow fillet geometry.

Acknowledgements

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