No Solar Energy without Polysilicon

Verolme® Special Equipment b.v. in the Netherlands manufactures reactors and equipment for the polysilicon industry

Verolme® Special Equipment (VSE), is an important supplier of reactors for the polysilicon sector which produces the raw material for the solar and electronics industry worldwide. This equipment is used to manufacture polysilicon, primarily in hydrochlorination processes which operate at temperatures between 550 and 750 °C.
For this challenging application, VSE developed its own material specification – Verolme® 800H Modified – a high purity version of Alloy 800H with increased resistance against stress relaxation cracking. The thick-walled reactor shells are welded with the hot wire GTAW process using UTP A 2133 Mn welding wire which has an optimized chemical composition and an ultra clean surface finish optimized for this process.

Verolme® Special Equipment b.v.

VSE is a specialist in the fabrication of equipment for high temperature and high pressure service and in corrosive environments. They supply heat exchangers, pressure vessels and reactors for the chemical, petrochemical and polysilicon industries, worldwide. These are manufactured from a wide range of materials, including exotic alloys such as titanium and zirconium.

This highly specialized fabrication is supported by advanced welding techniques, such as:

- High purity hot wire GTAW
- Orbital tube to sheet welding with 100 % guaranteed repeatability.
- Electroslag cladding with customized equipment

The engineering and design department is one of the most valuable assets of VSE. A team of skilled engineers contributes to the development of the process equipment and provides valuable insights, know-how, and advice. VSE client support is backed by more than 50 years of experience in manufacturing critical equipment.

Polysilicon heat exchanger.
Source: http://www.verolme.com

Relaxation cracking

Alloy 800H is a fully austenitic nickel-iron-chromium alloy with good resistance to oxidation, carburization and other high temperature corrosion. It has good long term creep resistance up to a service temperature of 980 °C.

Relaxation cracking is a phenomenon that can lead to failure of welded or cold formed components in Alloy 800H and other mainly austenitic materials during service at elevated temperatures in the range of 550 - 750 °C. It was intensively studied by TNO in The Netherlands, during the 2nd half of the 1990's [1].

It was discovered that welding increases the dislocation density in the HAZ and weld, resulting in a hardness increase. During service of the equipment, dislocation knots act as favourable spots for the rapid formation of very fine matrix precipitates ($M_{23}C_6$) around the grain boundaries. The stresses introduced by welding are sufficiently high to cause brittle fracture along the grain boundaries during high temperature service.
This can evolve very rapidly. Components commonly failed within one year of service.

A joint industrial research project was started to tackle this problem and "find recommended practice for the identification and prevention of relaxation cracking". The participating group consisted of over 30 equipment manufacturers, steel producers, engineering bureaus and welding consumables suppliers (Böhler, Thyssen and UTP) . More than 20 material types and more than 60 combinations of welding conditions and consumables were studied.

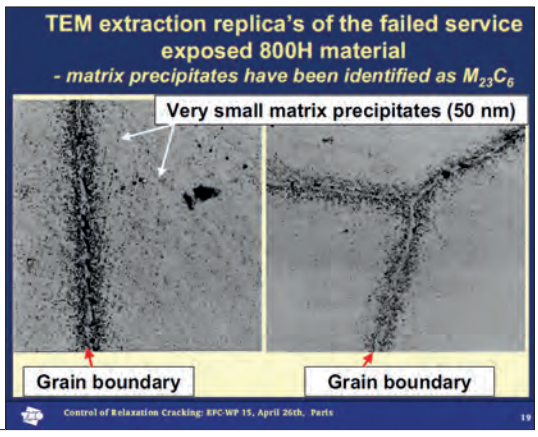
[1] TNO report / Hans van Wortel

Source: Control of relaxation cracking in austenitic high temperature components. H. van Wortel (TNO). Minutes of EFC WP15 Corrosion in the Refinery Industry, 26 April 2007.

The investigation led to a number of conclusions and recommendations which would bring relaxation cracking under control for the participating equipment fabricators. Heat treatments were identified to be particularly effective:

- A stabilizing heat treatment for base materials both in as delivered condition or after cold forming.
- A postweld heat treatment for welded joints

A third important outcome of the project were practical recommendations for correct welding procedures; amongst others the use of matching composition filler materials for Alloy 800H.



VSE welding practice

VSE used the outcome of the joint industrial project as a basis for their advanced daily practice in welding Alloy 800H where – next to the prevention of relaxation cracking during future service of the equipment– the avoidance of hot cracking during welding is essential with this thick-walled, fully austenitic material.

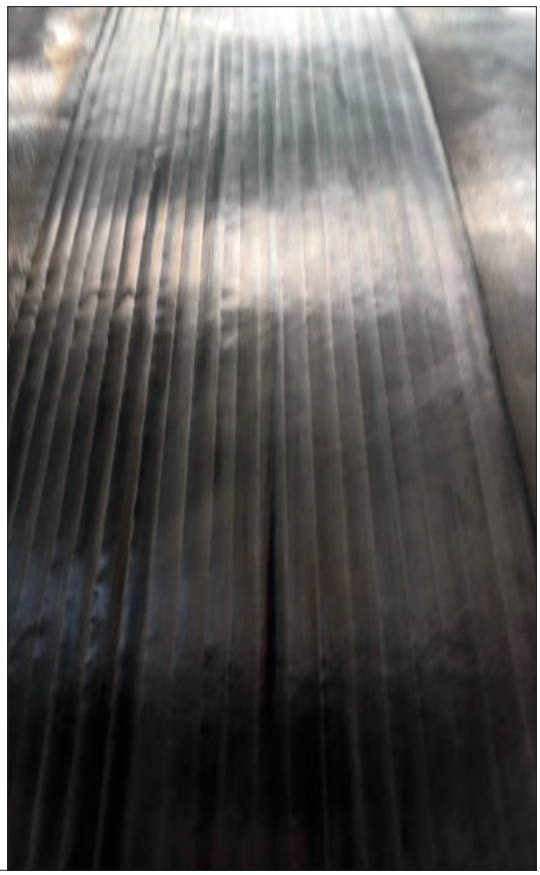
For the base material, VSE developed its own purchasing specification which narrows the band width for specific elements to increase resistance to relaxation cracking. It is purchased in the stabilized condition (980 °C for min. 3 hrs). This improved Alloy 800H is named Verolme 800H Modified and equipment in this material is only available to VSE clients.

The principal welding technology – used for the big longitudinal and circumferential joints in the reactor shells – is the hot wire GTAW (TIG) process, see title page photo. The greatest advantage of the manual GTAW process, in general, is the very high cleanliness of the weld metal with only minor oxide contents. By mechanizing the process using a preheated wire, productivity is significantly increased without compromizing weld metal properties. Investment in this advanced welding equipment appeared the right step for VSE, to balance quality and productivity for their sophisticated material range.

The GTAW process at VSE is a fully mechanized system. It uses digital square wave power sources with DC and AC mode and possibility for pulse arc welding. The latter is a consistently used to control the heat input. The control unit gives the possibility to store and retrieve up to 50 different parameter sets for the circumferential and longitudinal welds, according to the requirements of the welding procedure specifications for the different vessels and materials in the VSE portfolio. The weld area is monitored by a camera and projected on an LED screen near the control unit, from where the operator starts, adjusts and controls the progress of welding.

The actual welding procedures are aim at maximum welding productivity, but without any risk of hot crack formation. This is achieved by limiting the heat input to 1.5 kJ/mmm and the interpass temperature to max 150 °C, while depositing stringer beads only. Pulsed arc welding is universally applied to keep the temperature of the weld pool under control. Shielding gas for the hot wire GTAW process is Ar-2 % H_2 and for purging 100 % Ar is used.

To prevent relaxation cracking of the welded joints at service temperature, the reactor vessels receive a postweld heat treatment of min. 3 hours at 880 °C, depending on wall thickness. VSE has PWHT facilities at their own premises, but also cooperates with an external heat treatment specialist.



Example of a nice circumferential weld in Alloy 800H deposited with the hot wire GTAW process at VSE. The weld quality and appearance is extremely high, due to the precision and repeatability of the process. Welded joints are 100 % NDT inspected, which is performed with phased array ultrasound testing, modified inhouse to ensure dependable results when inspecting thick walled austenitic materials.

Fast delivery to wherever is one of VSE's virtues. This impressive photo shows a number of vessels about to be airlifted to a client in an Antonov freight carrier, ready to be built into a processing installation.

Ultra clean welding wire

For welding alloy vessels in Alloy 800H with the hot wire GTAW process, voestalpine Böhler Welding supplies the welding wire UTP A 2133 Mn along with UTP 2133 Mn stick electrodes for associated manual welding. These consumables both have an all weld metal chemical composition matching that of Alloy 800H, which brings thermal expansion into the same league as the base material. They are manganese-alloyed to give the fully austenitic weld metal increased resistance against hot cracking, under highly restrained conditions.

UTP A 2133 Mn wire is truly optimized for the hot wire GTAW process. It features controlled cast and helix to provide the stable feeding and related arc stability which is needed for disturbance-free welding with the automated equipment. Wires for this process need to be extremely ultra clean, as even minor residual favor the formation of pores in the weld.

UTP A 2133 Mn wire spool

VSE and vaBW look back on a close relationship lasting for decades now. This success is based on customized filler metals along with continuous local technical support and close cooperation with the mother companies, to ensure delivery of appropriate filler metals and relevant input for application critical equipment.

Product	Process	% C	% Si	% Mn	% Cr	% Ni	% Nb	% Fe	$R_{p0,2}$	R_m	A_5	CVN
UTP A 2133 Mn EN ISO 14343: GZ 21 33 Mn Nb	Hot wire GTAW	0.12	0.3	4.5	21.0	33.0	1.2	Bal.	400	600	20	70
UTP 2133 Mn EN ISO 14343: WZ 21 33 Mn Nb	SMAW	0.12	0.3	4.5	21.0	33.0	1.2	Bal.	400	600	20	70

UTP consumables with Alloy 800H matching composition. Typical chemical composition and mechanical properties.

voestalpine
ONE STEP AHEAD.