

# KOBELCO

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# WELDING TODAY



***The KOBELCO Arc: Energy that Strengthens the World***



LB-52U (E7016) is an unsurpassed covered electrode for melt-through root-pass welding, or one-sided root pass welding with penetration beads. With LB-52U your welding will be easier and faster, and you will have confidence in the quality of your welds in any kind of pipe welding of mild steel and 490MPa high tensile strength steel. Here we describe the characteristics that have made LB-52U the best for one-sided pipe welding.

**(1) EXCELLENT USABILITY IN ALL-POSITION WELDING**

LB-52U features a very stable arc and low spatter over a wide range of welding currents. In particular, it really shines in the melt-through root-pass welding of horizontally fixed pipes due to the smooth, glossy penetration beads that protrude on the reverse side of the groove (Figure 1) and the wider tolerance of the root opening—an advantage in site welding.

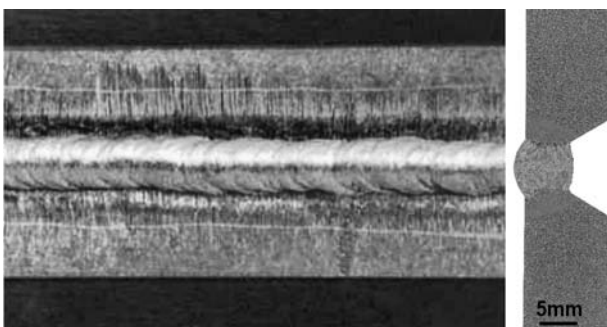


Figure 1: The surface and macrosectional profiles of a penetration bead protruding on the reverse side of a single-V-groove weld.

**(2) SUPERIOR CRACK RESISTANCE AND MECHANICAL PROPERTIES**

LB-52U offers superior crack resistibility due to a lower amount of diffusible hydrogen in the weld metal. In addition, it excels in mechanical properties, particularly in impact strength at low temperatures (Table 1). Therefore, it can be used for low-temperature applications as well as moderate high-temperature applications.

Table 1: Chemical and mechanical properties of LB-52U

Chemical composition of weld metal (%)				
C	Si	Mn	P	S
0.07	0.55	0.92	0.011	0.006
Mechanical properties of weld metal				[H] <sub>d</sub> <sup>1</sup> (ml/100g)
YS (MPa)	TS (MPa)	EL (%)	vE-29°C (J)	
480	560	31	80	3.5

1. Diffusible hydrogen in the weld metal made in the welding atmosphere of 21°C × 10%RH (Gas-chromatographic method)

**(3) FIELD-PROVEN ELECTRODE IN WORLD-WIDE MARKETS**

The outstanding usability of LB-52U in the melt-through root-pass welding of pipe joints has satisfied users around the world. LB-52U has been popular for a variety of piping jobs across Russia, Asia and the Pacific region. Particularly in Russia, LB-52U, with its extraordinary reliability, has made a great contribution to the construction of long, oil and gas pipelines in freezing weather. Since 1982, about 33,000 metric tons of LB-52U has been consumed in the construction of the Russian pipelines (Figure 2).



Figure 2: A pipeline-welding site in Russia where LB-52U is used for joining the girth joints in freezing weather.



## The Propitious Year 2008



Toshiyuki Okuzumi  
General Manager  
International Operations Dept.  
Welding Company  
Kobe Steel, Ltd.

A Happy New Year, my dear readers of Kobelco Welding Today. The year 2008 is considered a lucky year, because the number of eight is written in Japanese Kanji as “八,” which can be considered as “fan-out and good fortune.” Hence, for all of us and for our welding industry as well, this year should be a year in which we glow with enthusiasm. Because of significant growth in the economy, and for hosting a big global event, the Beijing Olympic Games, China will be the focus of global attention. By the way, the games will open on 8/08/2008—a series of eights. Reportedly the date was intentional; the Chinese, too, see the number 8 as a lucky number.

As for the economic circumstances revolving around the welding industry, the global economy expanded last year, especially in the BRICs countries. I hope this expansion had a positive effect on your companies, too. Even though there are some difficulties related to the sub-prime loan problem in the USA and the soaring prices of iron ore and crude oil, I predict the global welding industry will continue to expand steadily, in particular because of growing demand for welding materials used in the booming infrastructure, shipbuilding and energy industries in the BRICs countries. As always, I would like to express our appreciation for your considerable patronage of Kobelco products.

To contribute to the growth of the world economy while continuing to seek customer satisfaction and welding solutions, we will concentrate on developing and marketing new products and on establishing an optimum supply chain, all the while emphasizing flux-cored wires, our strategic product. The biggest task I will tackle this propitious year will be to increase the number of new Pro-Kobelco customers around the world, regardless of how large or small the sales. In April this year, the International Welding Show will be held in Osaka, and I will do my best effort to develop Pro-Kobelco customers through this event. I sincerely hope for your continued patronage of Kobelco products.

## See You at the Show

The Japan International Welding Show will be held at the international exhibition center “Intex Osaka” from April 9 to 12 this year. This time many welding-related companies will participate as exhibitors. It will be very attractive because four big forums on laser processing, micro joining, steel structure fabrication and nondestructive testing will be held simultaneously.

The main theme of the Show this time is “Manufacturing renaissance & welding total solutions.” Kobe Steel will exhibit a variety of welding systems and materials for the manufacture of steel structures and automobiles as well as new welding materials for shipbuilding, offshore structures, and chemical machinery. We are expecting your visit to the Kobelco booth. Please come to see us!

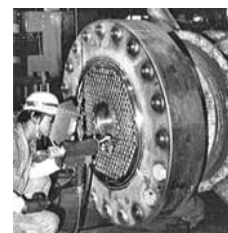


Intex Osaka: The venue of the 2008 Japan International Welding Show

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# WELDING OF HEAT EXCHANGERS



## What are heat exchangers?

In the Middle Ages, a method for distilling alcohol was invented in Europe, in which a condenser was used to cool and liquefy alcoholic vapors to produce spirits. This condenser may be the origin of heat exchangers used today. In the later half of the 19 century, the US oil industry successfully began extracting heating oil from crude oil. In the simple distillation method of that time, crude oil was kept airtight in a distillation still, heated to the point of vaporization, and sent through a cooling tube to distill the heating oil (Figure 1). This cooling system was the origin of heat exchangers used in refineries today. Since then, many types of heat exchangers have been developed and used in tandem with the advancement of the refinery process.

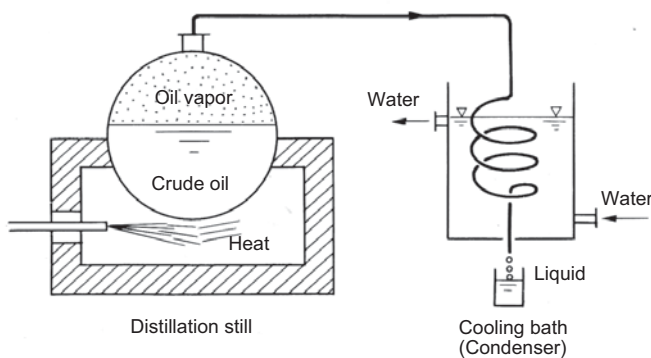


Figure 1: A schematic distillation process for obtaining heating oil from crude oil [1].

Today, heat exchangers are used in many industries including oil refineries, petrochemical plants, and chemical plants. In a petrochemical plant for instance, the ethylene equipment capable of producing 300 thousand metric tons of ethylene may be equipped with as many as 200 heat exchangers of various types. Heat exchangers are indispensable in the petrochemical process, effectively

transferring warm or cool temperatures but without the ability to generate heat.

Because of the different effects heat exchangers can have on fluids, they can be found in heaters, vaporizers, coolers, and condensers. Figure 2 shows the typical functions of a heat exchanger with a distillation column. Hot steam heats the raw material (liquid oil), transforming it into a vapor, which is why this type of heater is called a vaporizer. The condenser uses water to cool the oil vapors back into liquid form. The cooler also uses water to transform the liquid oil into the final product. The reboiler heats the liquid oil stored in the bottom of the column.

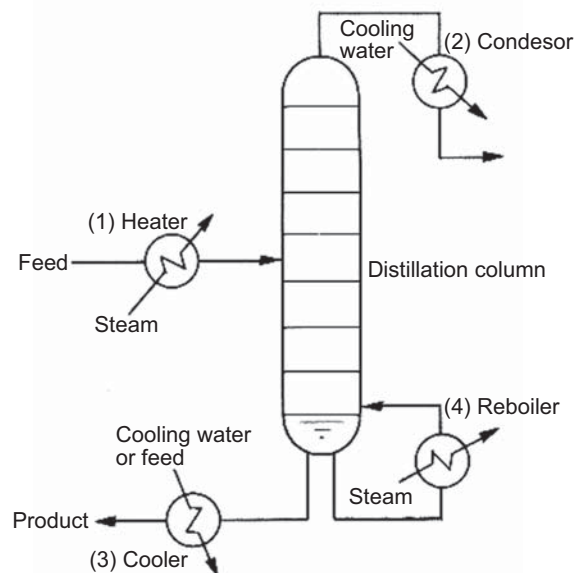


Figure 2: Typical functions of heat exchangers connected to distillation column [1].

## Structural profiles

There are two main types of heat exchangers: plate heat exchangers and shell-and-tube heat exchang-

ers. Shell-and-tube heat exchangers are the most common in the majority of process plant applications, and they can be classified into three main types: floating head, fixed tube sheet, and U-tube. Of these three types, the floating head heat exchanger is used most widely in oil refineries and petrochemical plants. Figure 3 shows a schematic drawing of a floating-head type heat exchanger; it consists mainly of tubes, tubesheets, a shell, and a channel. This type of heat exchanger works by transferring heat from the fluid (or gas) flowing through the tubes to another fluid (or gas) flowing inside the shell of the vessel, or vice versa.

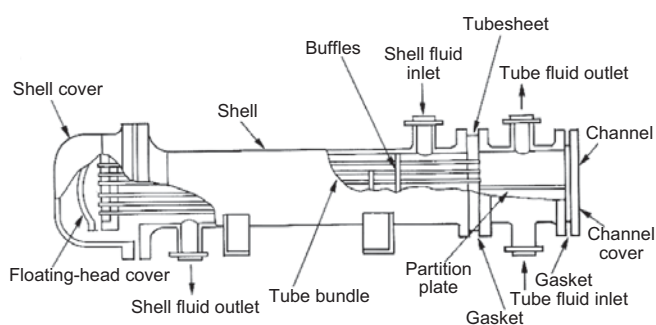


Figure 3: Schematic drawing of a floating-head heat exchanger, which is made up of tubes, tubesheets, a shell, and a channel [1].

The tube bundle is comprised of an astonishing number of heat exchanger tubes and two tubesheets, as shown in Figure 4. Pressurized steam or water is fed through the tubes which are held inside the cylindrical shell. The shell not only holds the tube bundle but also forms a vessel for the flow of oil or vaporized oil, which extracts heat from or transfers it to the fluid flowing inside the tubes. The tubesheets support the tubes and separate the fluid flowing inside the tubes from that flowing inside the shell. Finally, the channel is equipped with an inlet and outlet for the pressurized fluid that is fed into the tubes.

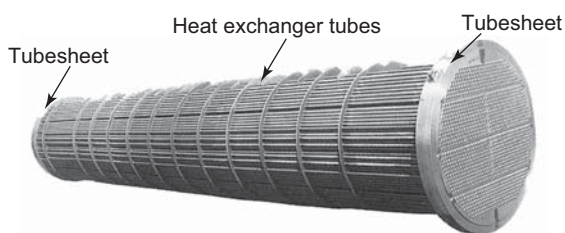


Figure 4: The tube bundle is comprised mainly of a large number of heat exchanger tubes and two tubesheets for the floating-head heat exchanger [1].

### Component materials

A number of ferrous and nonferrous metals can be used to make heat exchangers, depending on the process conditions associated with the pressure, temperature, and corrosiveness of the fluids. The structural components of a heat exchanger are likely to be made of diverse steels, while the tube bundle uses not only steels but also copper alloys. Table 1 shows typical materials used for the shell, tubesheets, and tubes of floating-head heat exchangers (heater and condenser). Metal parts can include plates, forgings and tubes and they can be made of carbon steel, heat-resistant low-alloy steel (0.5Mo, 1Cr-0.5Mo, 1.25Cr-0.5Mo, 2.25Cr-1Mo, and 5Cr-0.5Mo), stainless steel (304 and 321), and copper alloy. In addition, ferritic stainless steels (405 and 410) can also be used, depending on the process.

Table 1: Typical materials for main components of floating-head heat exchangers (Heater and condenser) [1]

	Heater	Condenser
Shell	SB 410, SB 450M <sup>1</sup>	SB 410 <sup>1</sup>
	SCMV 3, SCMV 4 <sup>2</sup>	SPV 235 <sup>3</sup>
	SPV 235 clad with SUS321 <sup>4</sup>	SUS304L <sup>4</sup>
Tubesheet	SF 440 <sup>5</sup>	SF 440 <sup>5</sup>
	SFVA F 11, 12, 22, 5 <sup>6</sup>	S 25C <sup>7</sup>
	SF 440 clad with SUS321 <sup>4</sup>	SF 440 clad with SUS304 <sup>4</sup> or C 6161 <sup>8</sup>
Tube	STBA 12, 23, 24 <sup>9</sup>	STB 340 <sup>10</sup>
	SUS321TB <sup>11</sup>	SUS304TB <sup>11</sup>
	—	C 6870, 7150 <sup>12</sup>

1. JIS G 3103 Carbon Steel and Molybdenum Alloy Steel Plates for Boilers and Other Pressure Vessels
2. JIS G 4109 Chromium-Molybdenum Alloy Steel Plates for Boilers and Pressure Vessels
3. JIS G 3115 Steel Plates for Pressure Vessels for Intermediate Temperature Service
4. JIS G 4304 Hot Rolled Stainless Steel Plates, Sheets, and Strips
5. JIS G 3201 Carbon Steel Forgings for General Use
6. JIS G 3203 Alloy Steel Forgings for Pressure Vessels for High-Temperature Service
7. JIS G 4051 Carbon Steels for Machine Structural Use
8. JIS H 3100 Copper and Copper Alloy Sheets, Plates and Strips
9. JIS G 3462 Alloy Steel Boiler and Heat Exchanger Tubes
10. JIS G 3461 Carbon Steel Boiler and Heat Exchanger Tubes
11. JIS G 3463 Stainless Steel Boiler and Heat Exchanger Tubes
12. JIS H 3300 Copper and Copper Alloy Seamless Pipes and Tubes

As regards heat exchangers used in oil refineries, there have been some modifications in the process conditions due to the increasing demand for lighter grades of oil, although component materials have not been affected much. Nevertheless, several



innovations in component materials have led to improved heat exchanger performance, such as:

- (1) Development of special steel that is more resistant to hydrogen-induced cracking
- (2) Advancement in 2.25Cr-1Mo steel by improving the resistance to temper embrittlement at high temperatures as well as notch toughness
- (3) Development of special austenitic stainless steel that is more corrosion resistant to polythionic acid

### Welding processes and filler metals

In recent years, applications requiring shielded metal arc welding (SMAW) have declined, whereas those requiring automatic and semiautomatic gas shielded metal arc welding (GMAW) and gas tungsten arc welding (GTAW) have become more widespread. In particular, semiautomatic welding has expanded because it requires less capital investment compared with automatic welding and moderate controls similar to those used for SMAW in terms of the welding groove configuration and welding conditions. The submerged arc welding (SAW) process has also been used steadily for particular applications.

In GMAW, both solid wires and flux-cored wires are used; flux-cored wires in particular have proliferated due to excellent bead appearance, low spatter, and superior usability. Filler metals for heat exchangers have been improved to meet the advances in steel materials, improve weldability, and fulfill diversified customer requirements. The following paragraphs highlight some of the improvements in filler metals.

(1) Improved filler metals suitable for 13Cr stainless steels such as Types 405 and 410 were developed. These include **CR-40Cb**, **CR-43CbS**, **TGS-410Cb**, **DW-410Cb**, and **DW-430CbS**. These filler metals are characterized by the sophisticated design of the weld metal chemical composition, which contains a considerable amount of Nb (Cb) and small amounts of Al and Ti. This unique chemical composition enables the weld metal to have a fine ferritic stainless steel microstructure (Figure 5). Due to the ferritic microstructure, the quench hardenability of the weld metal has been reduced considerably, thereby reducing the delayed-crack susceptibility of the 13Cr stainless

steel weld. With this breakthrough, the welding of Type 405-cladded steels has become easier compared to when the conventional 309-type austenitic stainless filler metals were used.

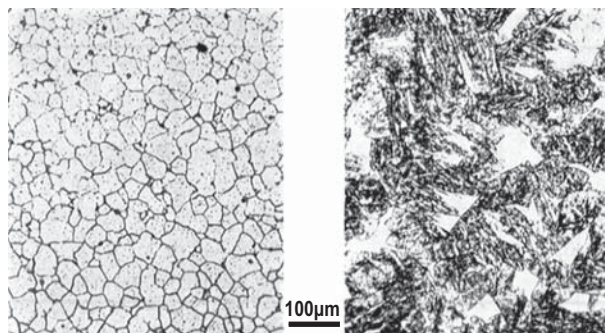


Figure 5: Comparison of microstructures: **CR-40Cb** (left) and conventional JIS D410 weld metals.

(2) The resistance of 2.25Cr-1Mo filler metals to temper embrittlement at high temperatures was improved. These filler metals include **CMA-106N**, **CMA-106ND**, **MGS-2CMS**, **TGS-2CM**, **PF-200/US-521S**, and **PF-200D/US-521S**. Temper embrittlement tends to occur in 2.25Cr-1Mo materials after long periods of service at high temperatures; as a result, the notch toughness of the material is decreased. To reduce the susceptibility to temper embrittlement of the weld metal, such impurities as P, Sb, Sn, and As were reduced to low levels. In addition, these filler metals offer excellent notch toughness even after extended service at high-temperatures.

(3) Low-ferrite filler metals with sufficient weldability were developed. In order to improve the notch toughness and corrosion resistance of austenitic stainless steel weld metals at cryogenic temperatures such as  $-196^{\circ}\text{C}$  and  $-268^{\circ}\text{C}$ , the ferrite content had to be decreased. On the other hand, it was understood that lower levels of ferrite make weld metal more susceptible to hot cracking. To overcome this inherent problem, the chemical compositions of **NC-38LT**, **NC-36LT**, **DW-308LT**, and **DW-316LT** were carefully designed and engineered.

(4) There was a breakthrough in electroslag filler metals for overlaying in the flat position. In overlay welding on ring forgings, sufficient but shallow penetration and a flat bead contour are required. To meet these requirements, Kobe Steel developed **PFB-7FK** (bonded flux) and **MFB-3** (fused flux) together with a variety of strip electrodes.

Table 2: Filler metals suitable for welding of heat exchanger components <sup>1</sup>

Type of steel	SMAW	GMAW <sup>2</sup>	GTAW <sup>3</sup>	SAW or ESW <sup>4</sup>
Mild steel 490MPa HT steel	<b>LB-52</b> (E7016) <b>LBM-52</b> (E7016) <b>LB-52A</b> (E7016) <b>LB-57</b> (E7016)	<b>DW-100</b> (E71T-1C) <b>DW-50</b> (E71T-1C/1M) <b>DWA-50</b> (E71T-1M) <b>DWA-51B</b> (E71T-5M-J) <b>MGS-50</b> (ER70S-G)	<b>TGS-50</b> (ER70S-G) <b>TGS-51T</b> (ER70S-6) <b>NO65G</b> (ER70S-2)	<b>MF-38/US-36</b> (F7A6/F7P6-EH14)
Low-temp steel	<b>LB-52NS</b> (E7016-G) <b>NB-1SJ</b> (E8016-G) <b>NB-3N</b> (E7016-G) <b>NB-3J</b> (E7016-C2L)	<b>DW-55LSR</b> (E81T1-K2C) <b>DWA-55LSR</b> (E81T1-Ni1M) <b>MGS-50LT</b> (ER70S-G) <b>MGS-1N</b> (ER70S-G) <b>MGS-3N</b> (ER70S-G)	<b>TGS-1N</b> (ER70S-G) <b>TGS-3N</b> (ER70S-G)	<b>MF-38/US-49A</b> (F7A6/F7P6-EH14) <b>PFH-55S/US-49A</b> (F7A6/F7P6-EH14) <b>PFH-55LT/US-36</b> (F7A8-EH14) <b>PFH-203/US-203E</b> (F7P15-ENi3-Ni3)
0.5Mo steel	<b>CMA-76</b> (E7016-A1)	<b>MGS-M</b> (ER80S-G)	<b>TGS-M</b> (ER80S-G)	<b>MF-38/US-49</b> (F8P6-EG-A4) <b>MF-38/US-40</b> (F8P6-EA3-A3) <b>MF-38/US-A4</b> (F8P6/F8A4-EA4-A4)
1Cr-0.5Mo steel 1.25Cr-0.5Mo steel	<b>CMA-96</b> (E8016-B2) <b>CMA-96MB</b> (E8016-B2) <b>CMA-96MBD</b> (E8016-B2)	<b>MGS-1CM</b> (ER80S-G)	<b>TGS-1CM</b> (ER80S-G) <b>TGS-1CML</b> (ER80S-G) <b>TGS-80B2</b> (ER80S-B2)	<b>PF-200/US-511N</b> (F8P2-EG-B2) <b>PF-200D/US-511ND</b> (F8P2-EG-B2)
2.25Cr-1Mo steel	<b>CMA-106</b> (E9016-B3) <b>CMA-106N</b> (E9016B3) <b>CMA-106ND</b> (E9016-B3)	<b>MGS-2CMS</b> (ER90S-G)	<b>TGS-2CM</b> (ER90S-G) <b>TGS-2CML</b> (ER80S-G)	<b>PF-200/US-521S</b> (F9P2-EG-B3) <b>PF-200D/US-521S</b> (F9P2-EG-B3)
5Cr-0.5Mo steel	<b>CM-5</b> (E8016-B6)	<b>MGS-5CM</b> (ER80S-B6)	<b>TGS-5CM</b> (ER80S-B6)	<b>PF-200S/US-502</b> (F7P2-EG-B6)
304 stainless steel	<b>NC-38</b> (E308-16) <b>NC-38L</b> (E308L-16) <b>NC-38H</b> (E308H-16) <b>NC-38LT</b> (E308L-16)	<b>DW-308</b> (E308T0-1/-4) <b>DW-308L</b> (E308LT0-1/-4) <b>DW-308LP</b> (E308LT1-1/-4) <b>DW-308H</b> (E308HT1-1/-4) <b>DW-308LH</b> (E308LT1-1/-4) <b>MGS-308</b> (ER308) <b>MGS-308LS</b> (ER308LSi)	<b>TGS-308</b> (ER308) <b>TGS-308L</b> (ER308L) <b>TGX-308L</b> (R308LT1-5)	<b>PFS-1/US-308</b> (ER308) <sup>5</sup> <b>PFS-1/US-308L</b> (ER308L) <sup>5</sup> <b>PFS-1LT/US-308L</b> (ER308L) <sup>5</sup>
347 or 321 stainless steel	<b>NC-37</b> (E347-16) <b>NC-37L</b> (E347L-16)	<b>DW-347</b> (E347T0-1/-4) <b>DW-347H</b> (E347T1-1/-4) <b>MGS-347S</b> (ER347Si)	<b>TGS-347</b> (ER347) <b>TGX-347</b> (R347T1-5)	<b>PFS-1/US-347</b> (ER347) <sup>5</sup>
13Cr stainless steel	<b>CR-40</b> (E410-16) <b>CR-40Cb</b>	<b>DW-410Cb</b>	<b>TGS-410</b> (ER410) <b>TGS-410Cb</b>	<b>PFS-4M/US-410</b>
Dissimilar- metal joint and overlaying	<b>NC-39</b> (E309-16) <b>NC-39L</b> (E309L-16) <b>NC-39MoL</b> (E309MoL-16) <b>CR-43CbS</b> <b>NIC-70A</b> (ENiCrFe-1) <b>NIC-703D</b> (ENiCrFe-3) <b>NIC-625</b>	<b>DW-309</b> (E309T0-1/-4) <b>DW-309L</b> (E309LT0-1/-4) <b>DW-309LP</b> (E309LT1-1/-4) <b>DW-309LH</b> (E309LT1-1/-4) <b>DW-309MoL</b> (E309LMoT0-1/-4) <b>DW-309MoLP</b> (E309LMoT1-1/-4) <b>MGS-309</b> (ER309) <b>MGS-309LS</b> (ER309LSi) <b>DW-430CbS</b> <b>DWN-82, DWN-625</b> <b>MGS-70Ncb</b> (ERNiCr-3)	<b>TGS-309</b> (ER309) <b>TGS-309L</b> (ER309L) <b>TGS-309MoL</b> (ER309LMo) <b>TGX-309L</b> (R309LT1-5) <b>TGS-70Ncb</b> (ERNiCr-3) <b>TGS-N625</b> (ERNiCrMo-3)	<b>PFB-1/USB-309L, USB-308L</b> <b>PFB-1FP/USB-347LP</b> <b>PFB-1FK/USB-347LD</b> <b>PFB-4/USB-430, USB-410</b> <b>PFB-7FK/USB-309L, USB-308L</b> <b>PFB-7/USB-347LD</b> <b>PFB-7FK/USB-309Lcb</b> <b>MFB-3/USB-309L, USB-308L</b>

1. The quality of filler metals can change depending on electric polarity (AC, DCEP, or DCEN). Users of these filler metals are requested to confirm the quality of a filler metal to be used in a particular welding procedure beforehand.
2. GMAW flux-cored wires are designated with DW, DWA, or DWN while solid wires with MGS.
3. GTAW solid wires are designated with TGS while flux-cored wires with TGX.
4. SAW fused fluxes are designated with MF while bonded fluxes with PF, PFS, PFH, or PFB. PFB-7FK and PFB-7 are ESW (electroslag welding) bonded fluxes while MFB-3 is ESW fused flux. SAW solid wires are designated with US while SAW and ESW strip electrodes with USB.
5. AWS classifications entered in the parentheses are only for solid wires not for flux-wire combinations.

Table 2 shows filler metals suitable for individual types of steels that may be used on heat exchanger components such as shells, tubesheets, and tubes. Dissimilar-metal joints are common in the welding of clad steels. Strip electrodes designated with USB are used typically for overlaying the inner surface of the shell.

### Welding procedures

The rest of this article will focus on describing the welding procedures typically used for individual components. However, it should be noted that welding procedures can vary depending on material, component dimensions, fabrication process, and available facilities.

(1) SHELL BUTT JOINTS

The welding of shell-to-shell girth butt joints, shell-to-shell seam butt joints, channel-to-channel flange girth butt joints, and channel-to-shell girth butt joints begins by preparing the joint with either a double-V groove (for wall thickness of 50 mm or less) or a single-V narrow groove (for thicker walls). Double-V-groove joints are joined by SAW, and narrow single-V-groove joints are joined by SAW or automatic GMAW using solid wires. In the case of shell-to-end plate butt welding from the inner side, SMAW and semiautomatic GMAW are normally used because automatic welding is difficult to apply.

(2) OVERLAY WELDING

100-mm or thicker forged shells are often overlay welded by using a strip electrode and a SAW or ESW flux. ESW in the flat position offers shallow penetration, resulting in less base metal dilution and flat bead contour. In ESW (Figure 6), no arc is generated to fuse the strip electrode and base metal but the electric resistance heat of the molten slag is used. Because of shallow penetration, 308L- or 347L-type stainless overlay weld can be obtained by single layer welding.



Figure 6: Electroslag overlay welding using a strip electrode and special flux in flat position.

Tubesheets are made of clad steel or overlay welded. In the overlay welding of tubesheets, strip electrodes are preferred due to their higher welding efficiency. However, because strip electrode welding becomes difficult as the electrode approaches the central part of a tubesheet, GMAW and SMAW are also used.

(3) CLAD STEEL WELDING

Figure 7 shows the typical groove preparation for a clad steel joint. The double-V groove of carbon

steel or low alloy steel member is welded first with a matching filler metal. This is followed by buffer layer welding with, for instance, a 309-type filler metal on the clad side groove, and then the clad steel member (e.g. 304-type stainless steel) is welded with a matching filler metal (e.g. E308). SMAW, GMAW, and GTAW are generally used for welding clad steel joints.

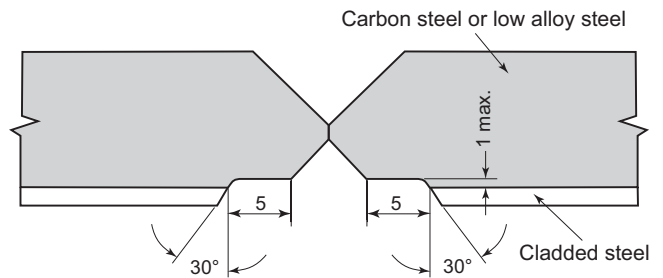


Figure 7: Typical groove configuration of clad steel joint [2].

(4) TUBESHEET-TO-TUBE WELDING

Heat exchanger tubes are welded to the tubesheet to make a leak-proof joint between them. The welding processes used for this joint are manual GTAW and two types of automatic GTAW. One type of automatic GTAW uses two welding heads; while one welding head is at work welding one joint, the operator can set the other welding head for one of the other welding joints. With the other type of automatic GTAW, all welding operations including the setting of the welding head are controlled automatically. Figure 8 shows some variations of the joint configurations.

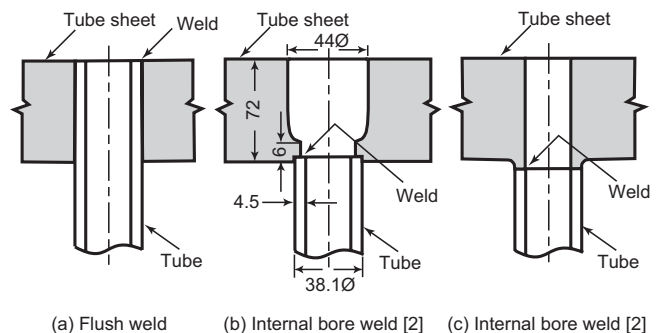


Figure 8: Variations of tubesheet-to-tube weld joints.

» Reference «

[1] Japan Institute of Plant Maintenance. Book of Heat Exchanger (2006)  
 [2] K. Hirai. Heat Exchangers. Welding Technology. Sanpo Publications Inc. (1986)





## Cold Cracks in Fillet Welds

### Variations of cold cracks

Cold cracks are defined as cracks that occur at temperatures of 200-300°C or lower in carbon steel and low-alloy steel welds. Cold cracks can occur in both butt welds and fillet welds; however, this article will focus on those occurring in fillet welds. Typical cold cracks that can occur in fillet welds are illustrated in Figure 1.

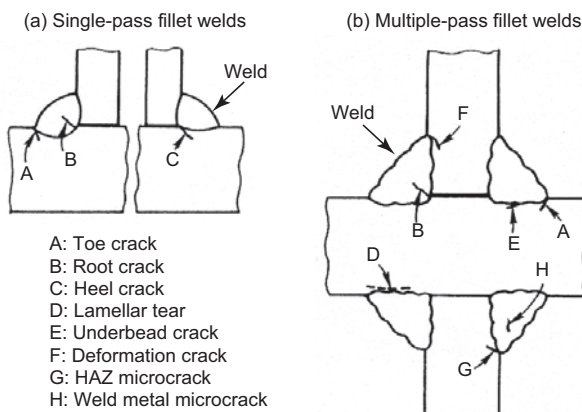


Figure 1: Typical cold cracks in fillet welds [1].

Cold cracks come in several varieties: Toe cracks initiate at the weld toe with dimensional discontinuity where stresses are concentrated. Root cracks are caused by the concentrated stress at the notch of the corner of a fillet joint. A heel crack is an example of a root crack. Lamellar tears are subsurface terrace and step-like cracks in the base metal with a basic orientation parallel to the wrought surface. They are caused by tensile stresses in the through-thickness direction of the base metal weakened by the presence of small dispersed, planar shaped, nonmetallic inclusions parallel to the metal surface. Underbead cracks can be observed lying parallel to the fusion line in the heat-affected zone of a steel material that has high hardenability. Deformation cracks are caused by local plastic deformation concentrated at the toe or root of a multiple-pass weld. They can be toe cracks or root cracks. Finally, the HAZ and weld metal microcracks are microscopic cracks that can occur in a fillet weld under strong restraint.

How cold cracks occur and how they can be prevented

Cold cracks, typically root cracks, can occur under particular metallurgical and mechanical conditions associated with (1) the hardenability of welds, (2) the amount of diffusible hydrogen in welds, (3) the degree of restraint of weld joints, and (4) the cooling rate of welds. As these factors increase, the weld becomes more susceptible to root cracking. Hardenability is determined by a combination of chemical composition and the cooling rate of the weld. The amount of diffusible hydrogen varies depending on the type of welding process, the type of filler metal, contaminants such as moisture and oil in the groove surface, and the cooling rate of the weld. With a slower cooling rate, higher amounts of diffusible hydrogen can be discharged from the weld. The degree of restraint varies depending on the type of welded structure: however, the thickness of the structural component is the predominant factor: the thicker the component, the higher the restraint. The cooling rate varies depending on the welding heat input, plate thickness, and preheating temperature.

In order to prevent root cracks, it is necessary to use a base metal with low-hardenability (good-weldability), choose a low-hydrogen filler metal, and preheat the base metal to an appropriate temperature in consideration of the type of base metal and filler metal, and the thickness of the component to be welded. These measures are also somewhat common against other kinds of cold cracks listed in Figure 1. In addition, to prevent lamellar tears, the base metal must have sufficient through-thickness ductility and its sulfur content must be low. The HAZ and weld metal microcracks are affected also by the content of nonmetallic inclusions.

In contrast, it is believed that deformation cracks (which can be root cracks or toe cracks) are not affected by diffusible hydrogen, temperature, and strength of the weld. To prevent the deformation of the components, weld joints should be sufficiently restrained.

#### » References «

[1] The Japan Welding Engineering Society. MAG/MIG Welding Defects and Preventive Measures. Sanpo Publications Inc.

# NACE Spec. to Prevent SSC

In oil- and gas-production equipment, the many metallic materials that are used can easily be exposed to wet hydrogen sulfide ( $H_2S$ )—otherwise known as sour gas. Exposure to such a corrosive gas causes sulfide stress cracking (SSC) and stress corrosion cracking (SCC) in the metals. To prevent SSC and/or SCC, the National Association of Corrosive Engineers (NACE) has put together the standard material requirements, MR0175 (Metals for Sulfide Stress Cracking and Stress Corrosion Cracking Resistance in Sour Oilfield Environments), which specify materials and fabrication requirements including those for welding. The NACE standard encompasses a wide scope of materials including carbon steels, low alloy steels, cast irons, stainless steels, nickel-based alloys, and titanium alloys.

This article focuses on the NACE requirements for carbon and low alloy steels and weldments to prevent SSC. SSC is defined as cracking of a metal under the combined effects of tensile stress and corrosion in the presence of water and  $H_2S$ . Figure 1 may help you understand how the  $H_2S$  density in water governs the occurrence of SSC (SSCC in the figure) in relation to the hardness of the materials.

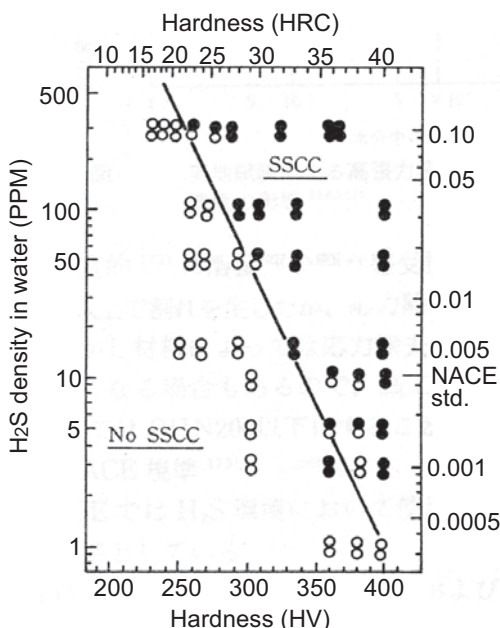


Figure 1: Effects of  $H_2S$  density and hardness on SSCC [1].

As per the NACE standard, carbon and low alloy steel weldments (weld deposit and HAZ) for the sour gas service shall meet the maximum hardness of 22 HRC in the as-welded condition or postweld heat treated condition depending on the degree of procedure control. In addition, the Ni content of the weld deposits shall be 1% or less.

In addition to the above, the NACE standard recommended practice RP0472 (Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments) also provides guidelines for preventing SSC by controlling hardness in the carbon steel weldments of in-service petroleum refining equipment and pipings. The weldments are defined to include the weld deposit, base metal HAZ, and adjacent base metal zones subject to residual stresses from welding. This standard covers only carbon steels classified as P-1 (Group 1 or 2) and excludes steels over 485 MPa minimum specified tensile strength.

In accordance with the NACE standard practice, the hardness of the completed weld deposit shall be tested to confirm the maximum of 200 HB when hardness control is necessary to prevent SSC. Nevertheless, weld deposits from manual welding processes such as SMAW using carbon steel consumables in accordance with ASME SFA-5.1 E60XX or E70XX are not required to be tested unless otherwise specified by the user, because these deposits rarely exhibit hardness values above 200 HB. Production SAW, GMAW, and FCAW weld deposits are required to be of the A-No. 1 (ASME Sec. IX) chemical composition to avoid the problem of highly localized hard zones in the weld deposit unless otherwise agreed upon. The maximum allowable HAZ hardness of the base metal is also specified to be 248 HV.

» Reference «

[1] M. Tanimura. Stress Corrosion Cracking of Pressure Vessels and Pipings. High Pressure Institute of Japan. (1979)

## Technical Service for Customers in Europe & Russia

When I was asked to write a short article with a focus on the kind of technical service Kobelco Welding of Europe B.V. (KWE) provides to its European customers, I thought it best to focus on one recent example rather than many examples. As Mr. Okuzumi stated in the last issue of Kobelco Welding Today, "One of the markets that we are looking at with interest is Russia;" therefore I thought it only fitting to continue along this line and write a little about our activities in Russia.

Our new customer is Izhorskiye Zavody (IZ) located in Kolpino near St. Petersburg and I would like to briefly explain about IZ. The IZ industrial complex was founded as a saw mill on the Izhora River in 1722 by decree of the Russian Tsar/Emperor, Peter the Great. Since then it grew into a huge industrial complex which employed over 30,000 people at the site before it was privatized under President Boris Yeltsin and some branches became independent. IZ later became part of the OMZ industrial group and now focuses on equipment for power generation including nuclear reactors, the manufacture of special steels, mining equipment and excavators.

When IZ was selected to manufacture two hydrocracking reactors for TANEKO (a Joint-Stock Company from TATNEFT the major crude oil and gas producer), for part of a newly built complex for fine oil processing in the city of Nizhnekamsk, IZ decided that KOBELCO would be their preferred manufacturer and supplier for the welding consumables due to the excellent track record that Kobe Steel, Ltd. (KSL) has with Cr-Mo-V welding consumables.

The reactors are to be manufactured under a customized specification from Chevron Lummus Global LLC. These reactors are unique due to their weight (1,200 tons for each unit) and wall thickness of 300 mm (12 inches). The reactors will be manufactured from forged 2.25%Cr-1%Mo-V heat resistant steel (SA336F22V) rings that will be welded together. The major part of the welding will be SAW using

Kobelco US-521HD wire and PF-500D flux and the remainder using CMA-106HD stick electrodes for SMAW.

In order to offer the best support to IZ, KWE visited them together with KRON SPB, our business partner in St. Petersburg, IOD (International Operations Department, Tokyo) and the engineer from our R & D in Japan. As a team, we were able to offer advice based on KSL's own practical experience with the application of Cr-Mo-V consumables. I would like to thank KRON SPB for their strong commercial commitment and their technical expertise, which greatly helped KWE to adequately support IZ.



Top: Pressure vessel under fabrication;  
Bottom: IZ staff and people from KSL,  
KRON SPB, and I.

One of the interesting parts to my job is that I am never done learning. For example, during our first visit to IZ to discuss some key technical concerns that IZ had, I learned that already around 50 years ago, IZ developed and manufactured a similar Cr-Mo-V steel (15X2MFA) for reactor applications. Before this, I had thought that the addition of vanadium to Cr-Mo steel for reactors first occurred around 15 years ago.

KWE started manufacturing mild steel FCW from 2007 and now we are working hard to expand business in the European market. We feel that by offering not only KWE's mild & stainless steel FCWs that KWE are producing, but also specialized KOBELCO welding consumables, this will in turn put us in a stronger market position. But naturally in order to do this, I personally need to expand my knowledge outside the little FCW World that I have grown accustomed to since I joined KSL in 1992. By this, KWE hope to do their bit for European economic growth.

Article compiled and written by:  
Robert Anthony Melvin  
Technical Manager  
KWE




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