

# WELD WELL

Quarterly newsletter of Weldwell Speciality Pvt. Ltd

SERVICE TO THE WELDING COMMUNITY

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Mr. C.C. Girotra, MD, Weldwell Speciality, offers welcome cake to Mr. Kasuya Tsuyoshi, President, Kobe Steel, Ltd., Welding Company, Japan, during his visit to India on 12<sup>th</sup> February, 2010. Dr. Bhattacharya, Editor, Weldwell Spectrum, looks on.

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Safety in Welding

# SPECTRUM



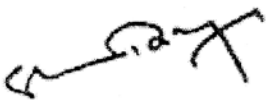
Dear Reader,

The shortfall in the 11<sup>th</sup> Five Year Plan target in creating additional power generating capacity will adversely affect the projected GDP growth rate. This will have a negative influence on welding industry. Fortunately for this industry the general growth in the industrial and manufacturing sectors is healthy. We hope that the combined effect is positive.

Considerable attention has been given to increase the contribution of nuclear power in the national power grid but oil still remains, and probably will remain for considerable time, one of the major source of energy - may it be power generation or transportation industry. Welding has a major role to play in oil industry. The lead article describes some of the areas where welding has contributed significantly. The problem of weld porosity is a common phenomenon. The education section answers some of the common questions which arise in practically every welding engineer and welders' mind. The chemical composition of the weldment influences decision of selecting the right welding consumable. It also influences the heat treatment and microstructure. The influence of some of the common chemical constituents is elaborated in the technical section of this issue. We often ignore safety aspects during welding. A number of accidents, even fatal, have been reported for neglecting safety precautions. The review section enumerates the safety documents which AWS has developed for welding activity. I hope this listing will be helpful to avoid accidents in the future.

We are pleased to announce completion of 20 years of service to the welding fraternity by Weldwell Speciality. During this long journey we had the opportunity to serve many customers in varied sectors. We assure you to continue serving in the future as well. Your good wishes and co-operation will help us to improve further.

With regards.



Dr. S. Bhattacharya  
**Editor**

## Essen Welding India 2010

Messe Düsseldorf India Pvt. Ltd., DVS (Germany), The Indian Ministries of Economics and Industry and of Science and Technology along with Indian Welding Society organized an international welding exhibition – The Essen Welding India 2010, at Bombay Exhibition Centre, Hall - 1, Mumbai, spanning approximately 10,000 sq mtrs. from 10<sup>th</sup> to 12<sup>th</sup> February, 2010. The exhibition was concurrently with Tube India and Metallurgical Products so that exhibitors and visitors could benefit from the resultant synergetic effects.

There were 120 exhibitors from 7 countries and from India. The largest number of foreign exhibitors was from Germany.

Product groups exhibited included

- Filler Materials
- Consumables other than filler materials
- Installations and equipment for the joining, cutting and coating of metallic and non-metallic materials and material compounds
- Plants and equipment for heat treating and other manufacturing processes
- Fully mechanized and automatic plants, Industrial robots, data processing, control and monitoring techniques
- Plants for the production of filler materials and consumables
- Workshop and workplace equipment, safety equipment, health and safety
- Accessories
- Quality assurance
- Sub-contracting (services)
- Organizations, research, information, literature, vocational and further training, regulations

Weldwell Speciality Pvt. Ltd. exhibited the products from Kobe, Japan, as their Indian agent. The stall was very well appreciated by the large number of visitor who came to the stall. The President, General Manager and a number of senior officers from Kobe, Japan, paid visit to the stall. Nivek Agencies also put up a stall for Panasonic products. Both the stalls generated good commercial response.

IWS also organized their annual technical conference in the adjacent hall at the same venue where technical papers on many contemporary subjects were presented by the experts from the industry and academics.

## Oil industry challenges for the 21<sup>st</sup> century\*

*Everyone is keenly aware of how vital oil and gas are to the economy, industry, and fabric of modern industrial societies. The slightest uptick in the prices of these essential hydrocarbons is watched with trepidation, fear, and a clutching of everyone's wallet. Everyone, too, has seen the ubiquitous laced towers gushing black gold in movies and TV shows, the very imagery of some Texas wildcatter striking it rich*

### A DRILLING 101 PRIMER COURSE

Derricks or masts are the tower like principal structures used to drill for oil. Both have the primary function of supporting very long lengths of steel pipes, known as drill strings, that drill into the concealing earth to find that precious liquid beneath. These drill strings, which can reach 45,000 ft in length, are extremely heavy (up to 750 tons), and hence the supporting derricks or masts must be stout and robust steel assemblies.

Additionally, these towers are supported on a drill floor that is part of a larger substructure, often called a drilling equipment structure (DES) that contains various ancillary equipment required to support the drilling operations, such as the drilling mud supply tanks, circulation pits, "iron rough necks", etc. The popular term for the whole kit 'n' kaboodle is "drilling rig". The drilling rig, in turn, is supported on some kind of foundation. Onshore, it's supported on top of compacted or wood-matted dirt, and offshore, it is supported on top of steel girders. That, in the proverbial nutshell, is a very rough 'Drilling 101' primer intended to give the reader a sense of the complex and heavy welded steel structures required to seek the lifeblood of 21st century civilization.

### FACTORS AFFECTING WELDED VS. BOLTED DESIGNS

Since welding plays such a significant role in the oil and gas industry, this article showcases some of the popular fabrication approaches, problems, and economic solutions unique to the industry. Masts are typically welded, as opposed to derricks that are bolted. The reasoning is that masts are typically permanent structures that are shipped

as a single, complete assembly to the drill site, whereas derricks may be erected either as a single piece or as an erector-set-type assembly on site. However, with the cost of such piece-by-piece erection going up every day, this theory behind the bolted justification is questionable. The DES substructures, on the other hand, are always welded except where the bolted equipment supports or other maintenance-removable items are called for. Mud tanks, circulating pits, anchor supports, crown blocks, racking boards, and all the other sundry bits and pieces of a rig are almost always welded.

### FACTORS AFFECTING THE DESIGNS

A fundamental issue with most rigs is weight. Whether a rig is intended for onshore or offshore drilling, weight imposes a significant penalty on transportation and structural / foundation design. Thus, efforts to minimize weight are a principal design goal, and this often requires the use of high-strength steels and carefully controlled welding procedures (WPSs).

The skid bases are typically heavy girders that support a drilling equipment structure and allow it to move to different well locations, using heavy-duty horizontal jacks. These skid bases are nonredundant built-up girders supporting heavy loads in all kinds of severe conditions, including very cold temperatures in places like Alaska and Siberia. Failure of these beams would be crippling, if not catastrophic, to the drilling program. As such, they require very high toughness steels and welds. Though the traditional quenched and tempered ASTM steels such as 100-ksi A514 have been popular for these applications for

\*Adapted from an article by Hardy H. Campbell III in *Welding Journal*, No. 2, Vol. 89, Feb., 2010

onshore rigs, the need in the offshore industry for a premium toughness steel has necessitated the use of lower-strength alternatives. Typically, for such applications, API 2Y and 2W plate steels are preferred in the 60-ksi grade, even though weight savings are not maximized to the extent that A514 could provide. This is because there are steel producers who have a proven history in rolling 2Y and 2W with the crack-tip opening displacement (CTOD) properties that clients require for such critical elements. The CTOD tests are a fracture-mechanics based quantitative assessment of resistance to brittle fracture and propagation, as opposed to the popular Charpy V-notch (CVN) tests, which are a qualitative cracking evaluation.

Having said that, the 2Y and 2W S-11 supplement that must be invoked to require the steel producer to provide these CTOD tests calls for the American Petroleum Institute's API RP 2Z, Recommended Practice for Preproduction Qualification for Steel Plates for Offshore Structures, to be used, and this document also requires CVN tests. All of these are expensive and time consuming tests that only specialist labs should be trusted to perform.

The reader may well ask why ASTM A514 could not be CTOD tested as well. The fact is that the CTOD values required (for example, 0.30 mm at  $-10^{\circ}\text{C}$  or lower) would be difficult to achieve in this high yield steel, so the client, in effect, is willing to accept the weight penalty for the enhanced confidence in service reliability. It should be noted that, even though the API RP 2Z tests are made with welds, the procedures are not intended to be WPSs for production welding. Rather, the welds are made to test the base metal heat-affected zone (HAZ) for microstructural sensitivity to cracking. The fabricator would be responsible for the testing of WPSs, which would have to be controlled by the fairly strict boundaries established by the steel producer's RP 2Z testing protocol.

The API design and fabrication document for drilling rigs is API 4F, Specification for Drilling and

Well Servicing Structures. This document provides inspection requirements for welds that should guide the design engineer in weld type selection.

Clause 11.3.4 of the current third edition requires that all complete-joint-penetration (CJP) or partial-joint-penetration (PJP) groove welds on a rig that are loaded in tension and that are loaded up to or beyond 70% of their allowable stresses, be inspected with a volumetric nondestructive examination (NDE) method per Section 6 of AWS D1.1, Structural Welding Code — Steel. For portability as well as safety reasons, ultrasonic testing (UT) is the preferred method.

For the CJP welds, this imposes no undue hardship. Welds that penetrate the entire thickness are easy to scan with UT's acoustic energy. Any reflectors found at the root will be discontinuities that could be rejectable based on size and reflected energy, i.e., indication rating. However, PJP welds only partially penetrate thicknesses. The UT scans of PJP welds will inevitably provide a screen indication at the root, where the welds have failed to completely seal the abutting gap between the two elements to be attached. Such reflectors can be interpreted as cracks, which are always prohibited, even though such "natural" reflectors are a built-in part of the PJP design. So the UT operator will face a conundrum: reject the reflector as a weld defect based on its size and indication or accept the indication as being an innocuous part of the design. Clearly, the latter interpretation is not part of an NDE operator's purview; he or she can only report what they see on the screen and grade it based on the code's strict evaluation protocol. So, the weld may be rejected when it is perfectly suitable for its intended use.

Such complications unnecessarily drive up costs and add delays. Additionally, the UT accept-reject criteria for Section 6 are based on CJP welds; therefore, strictly speaking, Section 6 should not be used for UT evaluation of PJP welds in the first place. But, as indicated above, even if it

was, it would be unwise to do so. So, there are two solutions. The least-preferred option is to have the NDE Level III inspector responsible for writing NDE procedures to develop a procedure based on PJP welds and recognize the built-in reflectors prior to production scanning. There are several ways to do this, but the D1.1, Annex S, UT Examination of Welds by Alternative Techniques, provides guidelines on how to do this for mock-up PJP welds.

My personal preference for a whole host of other non-NDE-related reasons is to do away with PJP welds altogether. The perceived economies of such welds are illusory, but the final PJP coup d'grace, for rig designers at least, should be this NDE clause, which faces a number of difficulties independent of fabrication costs. I personally recommend using CJP and fillet welds exclusively for drilling rigs. CJPs are readily inspected volumetrically with UT, while fillets are routinely tested using magnetic particle.

An additional requirement even when only CJP welds are used is frequently neglected; the design engineer has to identify which CJP welds are subject to the tensile 70% threshold so that the fabricator can instruct its NDE operators as to which welds require UT. Such indications are preferably done on drawings. This requirement may be negated if the designer requires all CJP welds to be ultrasonically tested, but this approach is probably overkill. Not all CJP welds merit UT, unless they are critical elements. In any case, the engineers designing rigs need to be aware of their NDE responsibilities.

### WELDING AND IT'S QUALIFICATION

The preferred shop welding process is gas shielded flux cored arc welding (FCAW-G). For most applications, 70 ksi tensile strength electrodes are adequate. However, for good toughness joints in 50 - ksi steels, 80-ksi electrodes have been frequently selected because of the higher nickel contents in the wires. The use of equivalent toughness 70-ksi

electrodes is now coming into vogue. The use of AWS D1.1 prequalified joint details is encouraged, even when WPSs require qualification testing. Prequalified WPSs are not uncommon, though, since most of the ASTM, API, and ABS steels used in rigs are selected from D1.1's Table 3.1, and toughness testing is not always a client or code mandate. But drilling companies that do business overseas frequently deal with foreign contractors, who face the issue of having non-D1.1 steels readily available, rather than the standard grades American fabricators are accustomed to using. Using such steels requires WPS testing, regardless of how similar in chemistry, strength, and properties these might be to the D1.1 "prequalified steels." This imposes extra costs that many think are unjustified, considering the high quality of many of these foreign "equivalents." Alas, other than the engineers of record having the freedom to do as they please with code requirements, the fabricator has no option but to qualify the WPS that uses this unlisted steel. Unfortunately, many structural and mechanical engineers have only a cursory knowledge of metallurgy or welding and are reluctant to grant such waivers. However, the AWS D1 Structural Welding Committee Task Group on Materials recently made the addition of prequalified non-U.S. steels a priority for inclusion in future D1.1 editions. Hopefully, these steels will first appear in the 2015 edition. This will be a boon to rig fabricators outside the United States as well as drilling contractors working overseas.

### WELDING IS ESSENTIAL

This article presents a very brief overview of some welding topics pertinent to a small slice of the oil and gas industry. Pipelines, offshore platforms, floating drilling units, refineries, coastal offloading terminals, and a whole host of other essential petroleum infrastructural elements also rely on welding for safety and integrity, and each has its own unique requirements, challenges, traditions, and idiosyncrasies. Suffice it to say that welding is to oil as rain is to crops. Without the one you can hardly have the other.

## Causes and remedies of weld porosity\*

*I have never met a welder or a welding engineer to whom the problem of porosity is new. Yet, there are many questions on porosity which remain unanswered. May be it is a classical example of “wanted to know but afraid to ask”. In this article we have tried to answer some of the commonly asked questions*

**Question 1: We face porosity problems in certain welds. I need a definitive explanation of weld porosity.**

**Answer :** Weld porosity can be defined as the appearance of tiny bubble/s in a weldment as a result of gas entrapment. When dissolved gases present inside the weld has insufficient time for its escape during weld pool solidification, porosity will result. To elaborate further, as the weld pools start solidifying it get supersaturated with the dissolved gases. Bubbles of hydrogen, nitrogen and carbon monoxide form at solid to liquid interface. Gas bubbles remain there until they grow to a sufficiently big in size to float. If the weldment solidifies before the gas bubbles escape, then they are trapped in the weldment and results in weld porosity. The positions in the weld pool where the gas bubbles form (nucleate) play an important part in the formation of porosity. When gas nucleation occurs away from the weld pool, it is probable that the gas bubbles will escape to surface, leaving defect free solid metal without pores. If nucleation of gas bubbles continues up to weld solidification boundary, then they may be trapped. Excessive porosity can weaken a weld. The photographs (Fig. 1 and 2) shown here illustrate weld porosity. From the size, shape and location of porosity, it can be described either as interdendritic or surface porosity or bulk pores.



Fig. 1: Surface porosity

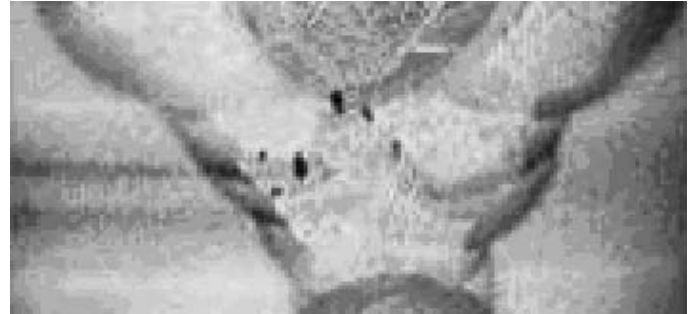


Fig. 2: Internal porosity

**Question 2: How to distinguish porosities caused by different gases?**

**Answer:** Oxygen causes indirect porosity, as the bubble is usually a reaction product, as carbon monoxide formed by oxygen + carbon reaction. Porosity due to hydrogen is associated with the welding of steel, aluminum, copper, titanium and magnesium alloys. In welding steel, porosity is due to excess hydrogen migrating to the heat affected zone. Nitrogen porosity is often associated with the MIG welding of carbon steel, stainless steel and nickel alloys. Porosity in aluminum weld is primarily due to hydrogen.

**Question 3: What are the factors governing weld porosity?**

**Answer :** The most important factors governing weld porosity are the dissolved gases in weld metal and the process variables that control the solidification rates. Irregularly shaped voids in welds can be due to mechanically entrapped gases or due to arc instability during welding. Hydrogen is the most common cause of porosity in welding aluminum. Leaking gas line, too high a gas flow rate, draughts or excessive turbulence in the weld pool are frequent causes of porosity. Moisture and organic compounds are the main sources of hydrogen.

*\*Compiled by S.N.Bagchi, a well know welding consultant based in Mumbai*

**Question 4: What are the available methods of detecting weld porosity.**

**Answer:** Surface porosity (Fig. 1) is detected by visual inspection, DP test or magnetic particle inspection. Internal porosities (Fig. 2) are detected by ultrasonic flaw detector, radiography or metallography. Microstructure reveals even microscopic porosities.

The effects of porosity on weld properties are an area of concern, as it has a strong bearing on mechanical properties and weld integrity.

**Question 5: Is there any special method to reduce weld porosity?**

**Answer:** There are several methods that can reduce formation of pores in welds. In metallurgical methods, one attempts to minimize weld porosity by means of controlling solidification (rate of solidification) through welding variables. To reduce porosity, we study the effect of welding variables and solidification rate in welding on the size and distribution of porosity in welds. The rate of solidification in the weld pool is one major factor controlling the porosity formation, and floatation of pores from the solid to liquid interface to the weld pool surface is another variable. Excessive gas flow rate can create turbulence and lead to weld porosity.

**Question 6: Please elaborate the knowledge of pre-cleaning methods to avoid porosity for different alloys.**

**Answer:** Pre-cleaning methods are standard practice to prevent formation of porosity. It is different for different alloys. Gases causing porosity and recommended cleaning methods for various alloys are as shown in the attached table.

**Question 7: What are the recommended practices to reduce weld porosity?**

**Answer:** To reduce porosity in welds some of the suggestions are as follows:

1. Verify gas flow rate and ensure that there are no leaks in shielding gas system
2. Check that the primer coating is within recommended thickness
3. In the shop floor, proper electrical stick out and choice of proper gun angle is important to make a good weld with no porosity
4. Proper adjustment of electrode speed, welding current, and machine variables can reduce weld porosity
5. Avoid weld geometry that creates cavity
6. Use filler with adequate level of deoxidants
7. Reduce excessively high gas flow
8. Avoid draughts

**For porosity due to hydrogen:**

9. Dry the electrode and flux
10. Clean and degrease the work-piece surface
11. Ensure welding is done in an environment where there is not much air movement
12. In aluminum welding, constant voltage power supply may be used with electrode speed adjustable in the range of 50 in/minute.

Alloys	Gases	Recommended pre-Cleaning method
Carbon-manganese steels	Hydrogen, Nitrogen and Oxygen	Grinding to remove scale and coatings
Stainless steels	Hydrogen	Degreasing, wire brushing, again degrease
Aluminum alloys	Hydrogen	Chemical cleaning, wire brushing, degrease and scrape
Copper alloys	Hydrogen, Nitrogen	Degreasing, wire brushing again degrease
Nickel alloys	Nitrogen	Degreasing, wire brushing again degrease

## Converting Waste into a Welding and Cutting Fuel\*

The technology pioneered at MagneGas enables liquid waste to become a clean burning fuel

Wouldn't it be neat if cities across the world could take their own nonhazardous liquid waste to create fuel? "Green" gas practices could occur on a daily basis, thereby saving the environment, reducing global warming impacts, and revolutionizing how operations run. This reality could happen with new, transforming technology that turns different waste types into an efficient fuel for industrial application needs.

The developer of the technology, Dr. Ruggero Santilli of MagneGas Corp., USA, a former Harvard and M.I.T. physicist, was twice nominated for a Nobel Prize. It's a metal cutting fuel and natural gas alternative, which is lighter than air, benefits welding, metal working, automobile, and shipbuilding industries. His research led to creation of our own fuel while we recycle liquid waste. The patented Plasma Arc Flow™ recycler turns liquid waste into a combustible fuel. He has worked on this concept for 25 years before getting success.

### How the Technology Works

Generation of gas takes place through a submerged electric arc between carbon electrodes, superheating the waste to 10,000°F. The liquid breaks down to the atomic level, and fuel bubbles to the surface for collection. A back-pressure regulator runs at 30 lb/in.<sup>2</sup> or higher as determined by the operator. Using more pressure yields more gas production.

Numerous components are used to generate MagneGas™ fuel. A container holding liquid waste provides the feedstock. This could be city sewage and/or sludge, liquid and solid animal waste, automotive liquid waste, petroleum, oil based liquid waste, byproducts of petroleum, glycerin, bio-fuel, and ethanol, and paint and thinner waste. The waste determines which of the three recycler types 'total, linear, or total-linear' to be used. Users pick the settings for their application. Everything is fully automatic. If an error occurs, an alarm button will be on, and the machine shuts down.

Machines can be built for various configurations meeting user's specific requirements. They are available in 50-, 100-, 150-, or 200-kW units. Each 50-kW refinery delivers 1000 A to the arc. Virtually the power and size of the machine determines the cubic foot per hour it provides.

The whole operation runs quietly in a sealed environment and takes up a small footprint for flexible installation. A generator can also run this, making it mobile.

### Various Uses for the Fuel

The gas produced provides a replacement for oxyfuel processes, natural gas, carbon-based fuels, oxyacetylene, propylene, and propane. This makes it useful for oxyfuel welding, cutting, brazing, soldering, thermal spraying, hardening, cooking, and water/home heating.

The clean burning fuel, essentially interchangeable with natural gas, is made on-site at its facility. This product can be compressed

up to 5000 lb/in.<sup>2</sup>, does not require special care for shipping, and gets stored in 125 and 250 ft<sup>3</sup> high pressure cylinders.

This fuel is used locally by welding students at Pinellas, for training operations and for cutting.

The fuel can be used for running bi-fuel automobiles as well. In fact Santilli drives this vehicle every day.

### Beneficial Aspects

This high-burning fuel is primarily composed of hydrogen as shown in Table 1. Its byproduct emits oxygen into the atmosphere and is suitable for indoor use because of low toxicity levels. The fuel is safe to store and handle as well. In addition, the product enables users to cut metal fast, concentrates heat at the precise point of the cut for a better quality, and provides no flashbacks.

Its advantages as a metal cutting fuel are abundant as consumption of cutting fuel and oxygen is reduced, high-quality and clean cuts with less slag, narrower kerfs, no top edge rollover, and a smaller heat-affected zone are produced. Furthermore, its natural scent enables any leaks to be detected rapidly.

Table 1 — Chemical Composition of MagneGas™

Ingredients	Concentration
Hydrogen (H <sub>2</sub> )	55 - 65%
Carbon Monoxide (CO)	30 - 35%
Carbon Dioxide (CO <sub>2</sub> )	1 - 2%
Water Vapor	2%
Trace Gases	0.5 - 1%

### Marketing

The company's first equipment purchase order, from American Investment Co., is for a refinery to service the Philippines and Vietnam markets. Jeruz Energy Co. is the licensee of its technology for India, Pakistan, Bangladesh, and Sri Lanka.

### Future Ambitions

Participating in "green" technology is the way to go for helping current environmental conditions and showing upcoming generations to be energy efficient. It is obvious that there is always going to be a plentiful supply of leftover waste. Farms, cities, and communities leave a constant supply of feedstock from which to make fuel. What could be more resourceful than using one variable to make another? MagneGas hopes to continue its success achieved in the international arena with an expanding technological presence. This year, it plans to install three industrial demonstration centers across the United States, and for 2010 aims to further research and development for specific applications. It would like also to form partnerships with existing wind and solar power companies.

\*Adapted from a publication by Kristin Campbell, *Welding Journal*, Vol. 88, No. 9, Aug. 2009

## Influence of weld composition on properties and microstructure in low alloy steel\*

### INTRODUCTION

Chemical composition of weld deposit is important for the selection of either preheat or post weld heat treatment conditions required for a specific steel composition. For higher strength low carbon steels, which have properties based on strengthening mechanisms different from the normal austenitic decomposition, improved welding techniques are required. Acceptable welds can be made in steels with a large range of welding consumables, weld composition and welding parameters. However some filler metal combinations are more resilient to weld-parameter variation. Selection of welding consumables can be such that it should be possible to achieve a specific alloy weldment composition.

### GENERAL EFFECT OF ALLOYING ELEMENTS

Carbon is the most important alloying element in steel, and it provides the basis of all heat-treating processes. Increasing carbon increases the strength of steel while ductility and toughness are reduced.

Manganese strengthens steel and increases hardenability. However, manganese in excess of 2% can induce brittleness. It combines with sulphur present as impurities to make MnS, restricting formation of detrimental iron sulphide.

Silicon works as deoxidizer in steel, and removes porosities due to oxygen. It also increases strength, hardenability and toughness.

Sulphur is a deleterious impurity in steel, as it forms hard and low melting FeS, and causes cracking. Presence of manganese off sets, to a certain extent, this deleterious effect by forming MnS as mentioned above.

Phosphorus is also a deleterious impurity in steel as it forms hard and brittle iron phosphides. It is

also responsible for temper embrittlement. The deleterious effects of S and P are synergic in nature. Even if both P and S are individually within specified limits, but if the total of S and P is near the limit, embrittlement may occur.

Control of Oxygen in weld pool is another important factor as oxygen can combine with aluminum, titanium, silicon and manganese to form respective oxide inclusions in low alloy steels, which are trapped in weldments during solidification. The consequent increase in inclusion count is undesirable as it can lower ductility, impact properties and also can stimulate formation of acicular ferrite in low alloy steel weld microstructures.

Other alloying elements like chromium imparts corrosion resistance, hardenability and a ferrite stabiliser in steel whereas Nickel increases hardenability, notch toughness and increase fatigue resistance. Molybdenum is a ferrite stabilizer and a grain size refiner. It improves creep resistance. Vanadium promotes grain refining, increases strength and toughness and contributes to secondary hardening during tempering.

### MICROSTRUCTURE

Microstructure can be controlled by two ways. Firstly, by controlling the cooling rate and secondly, by choosing a steel with a suitable hardenability which depends on the carbon content and other elements like manganese, chromium, molybdenum and vanadium. The following formula proposed by British Standard to determine carbon equivalent, indicating relative influence of various elements as compared to carbon, is extensively used for the purpose to determine weldability of a steel.

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

In this equation C, Mn, Cr etc. are concentrations of the elements expressed in weight percent. For phase transformation in steel weldments carbon

*\*Compiled by S.N.Bagchi, a well know welding consultant based in Mumbai*

equivalent (CE) is a useful data

Redistribution of solutes in fusion zone (FZ) is another important aspect of solidification in welding. During solidification process, this can affect the weld microstructure, grain size, in some cases show segregation and inhomogeneity. In extreme conditions it results in cracks. Most of the hot cracking problems in weldments are associated with elemental segregation, inhomogeneity and inappropriate cooling rates during welding process. The microstructure, fusion zone grain size as well as HAZ grain size, welding conditions and grain structure are important aspects that control cracking in welds.

Development of microstructural features during solidification in FZ is determined by the shape of the solid/liquid interface and rate of solidification in welds. Dendritic segregation during solidification in alloys, second phase particles, such as non-metallic inclusions, and oxygen content also affect the weld metal solid state transformation reactions. Beneficial effects of equiaxed fine grain microstructure in low oxygen welds is desired in many cases to reduce weld cracking, segregation and related problems.

### RECENT WELDING TECHNIQUES

Newer welding techniques increase productivity and it is necessary to consider the effect of cooling rates in steel welds, especially for higher strength steels. In cases of higher strength low carbon steels, which have properties based on strengthening mechanisms different from the austenitic decomposition, it is necessary to control the cooling rate to obtain desired microstructure.

Proper understanding of the weld pool solidification behavior, the macro and micro segregation in fusion zone, weld microstructures and residual stresses in welds can lead to improvement in properties. Distribution of oxygen, nitrogen and hydrogen between weld pool and the parent metal affects the weld pool composition, microstructure and mechanical properties. Vaporization of volatile alloying elements, transport of elements away from the weld pool and also into the weld pool from the surroundings are important factors that affect the weld pool composition, microstructure and consequently, mechanical properties.

The non-metallic inclusion formation can be controlled by deoxidizing elements, using a clean dust free environment and by lowering oxygen content in weld pool. Inclusion shape, size and their characteristics depend on the deoxidizing element concentration, oxygen level in the weld, presence of pre-formed inclusions in parent metal and reaction temperature. In steel welds, it is important to estimate the effect of inclusions and their distribution pattern during solidification as well as during subsequent phase transformations.

Empirical expressions are available to predict hardness, yield strength and ultimate tensile strength as well as ductility and toughness for low carbon and low alloy higher strength steels weld metal based on chemical composition.

### CONCLUSION

The chemistry of weld metal plays an extremely important role in determining the mechanical properties of a weld metal. It influences the final microstructure as well. The microstructure is also controlled by the cooling rate of the weld metal. Put together the final properties of weldment are determined.

... *Review continued from Pg. 11*

Safety and Health Fact Sheet 33	2008	Personal Protective Equipment (PPE) for Welding and Cutting
Safety and Health Fact Sheet 34	2009	Coated Steels: Welding and Cutting Safety Concerns
Safety and Health Fact Sheet 36	2009	Ventilation for Welding and Cutting
Safety and Health Fact Sheet 37	2008	Selecting Gloves for Welding and Cutting

*The above list gives an idea about how a specific activity oriented safety measures need to be prepared. One can develop more safety fact sheets relevant to ones activity in line with this.*

## Safety in Welding

Safety is everyone's concern. You realize the importance of safety only after you have suffered from an accident or had a near-miss describing how miraculously you were saved. From a safety personnel's point of view both are same. You were lucky to have escaped. Luck may not be on your side next time. It is always better to play safe than be sorry for not taking safety precautions.

There are a number of recognized standards on safety covering practically all activities in general. They deal in safety management systems. Occupational Health and Safety Assessment Standard

(OHSAS) is one of the most popular one. However, one may need industry specific standards or fact sheets to deal with specific requirements of a relevant activity.

### AWS Welding Safety Sheet

American Welding Society has developed a number of fact sheets which describe in detail the various aspects of welding activities and the precautions one needs to take. There are at least thirty five of them are available. The following is the list enumerating them:

Safety and Health Fact Sheet 01	2005	Fumes and Gases
Safety and Health Fact Sheet 02	2003	Radiation
Safety and Health Fact Sheet 03	2003	Noise
Safety and Health Fact Sheet 04	2003	Chromium and Nickel in Welding Fumes
Safety and Health Fact Sheet 05	2006	Electrical Hazards
Safety and Health Fact Sheet 06	2006	Fire and Explosion Prevention
Safety and Health Fact Sheet 07	2009	Burn Protection
Safety and Health Fact Sheet 08	2009	Mechanical Hazards
Safety and Health Fact Sheet 09	2009	Tripping and Falling
Safety and Health Fact Sheet 10	2009	Protecting Against Falling Objects
Safety and Health Fact Sheet 11	2009	Hot Work in Confined Spaces
Safety and Health Fact Sheet 12	2009	Contact Leans Wear
Safety and Health Fact Sheet 13	2008	Ergonomics in the Welding Environment
Safety and Health Fact Sheet 14	1995	Graphic Symbols for Precautionary Labels
Safety and Health Fact Sheet 15	1995	Style Guidelines for Safety and Health Documents
Safety and Health Fact Sheet 16	1997	Pacemakers and Welding
Safety and Health Fact Sheet 17	1998	Electronic and Magnetic Fields (EMF)
Safety and Health Fact Sheet 18	1997	Lockout / Tagout
Safety and Health Fact Sheet 19	1998	Laser Welding and Cutting Safety
Safety and Health Fact Sheet 20	1997	Thermal Spraying Safety
Safety and Health Fact Sheet 21	1999	Resistance Spot Welding
Safety and Health Fact Sheet 22	2002	Cadmium Exposure from Welding and Allied Processes
Safety and Health Fact Sheet 23	2009	California Proposition 65 (Refers to Safe Drinking Water)
Safety and Health Fact Sheet 24	2002	Fluxes for Arc Welding and Brazing: Safe Handling and Use
Safety and Health Fact Sheet 25	2002	Metal Fume Fever
Safety and Health Fact Sheet 26	2004	Arc Viewing Distance
Safety and Health Fact Sheet 27	2003	Thoriated Tungsten Electrodes
Safety and Health Fact Sheet 28	2005	Oxyfuel Safety: Check Valves and Flashback Arresters
Safety and Health Fact Sheet 29	2004	Grounding of Portable and Vehicle Mounted Welding Generators
Safety and Health Fact Sheet 30	2005	Cylinders: Safe Storage, Handling and Use
Safety and Health Fact Sheet 31	2006	Eye and Face Protection for Welding and Cutting Operations

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