HAEUSLER

the forming factory

From Plate to Pipe

How to produce LSAW pipes successfully

Foreword

As stringent environmental regulations increase more and more all over the world, steel pipes with consistent high quality satisfying various international and customer standards are requested by the market. Basing on this development, pipe mills fulfilling the new market demands have to be available or supplemented by new manufacturers.

This document is written as a basic overall guide to operating the various pipe production steps from a process stand point. It is not intended to supersede Original Equipment Manufacturer (OEM) operating instructions or the Quality System established by the company. It is rather intended to supplement them. This document gives some initial machine set up and operating parameters. However, these are only meant as a guide for starting-up. They should be used as a basis for future development of parameters by the operating departments.

This document is divided in different chapters, starting with an introduction of HAEUSLER and its role as general contractor in Roll Bending pipe mill business. Important facts are summarized in “fact boxes” at the end of each chapter.

Some general comments on main materials used in a pipe mill -such as plates, flux and wire- and their meaning and importance on the pipe quality follow subsequently.

Further statistical process control and gathering of process and quality relevant data will be described and possibilities to include the results in improving production, procurement of raw material and consumables in order to improve final product are shown.

All process relevant production steps are introduced and analyzed in the following chapters, highlighting start-up parameters and all measurements necessary which assure that every subsequent production step receives a production meeting the tolerances.

The document ends with troubleshooting guidelines and common defect charts which refer to the definitions and criteria of API 5L in the end of this document.

1st Edition, 2013

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1. Introduction

1.1. HAEUSLER – Global leader in Roll Bending pipe mills

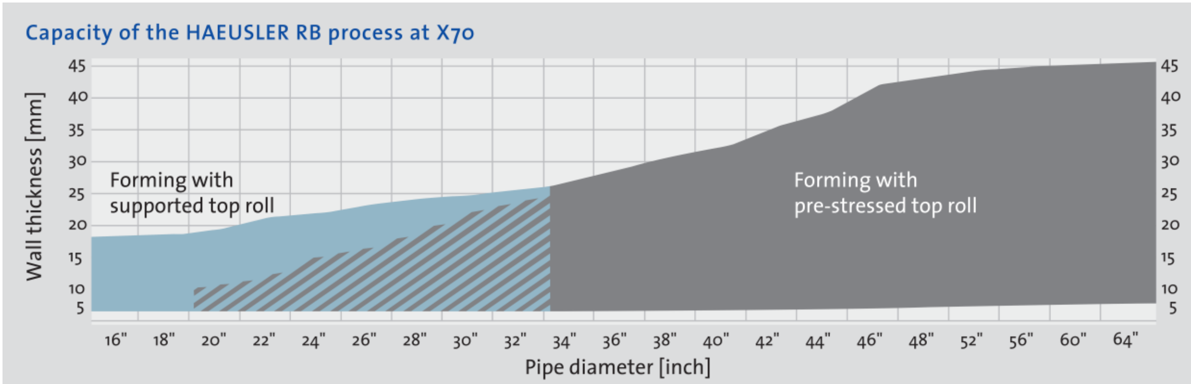
HAEUSLER is the world's leading company in metal forming technology. What started as a small locksmith shop in 1936 grew up into pioneers in developing innovative bending machines. With more than 70 years of experience, today, HAEUSLER is a successful, future-oriented family-owned company in the field of metal bending, forming and general assembly technologies. Our aim is to provide best in class machines utilizing the latest CNC technology, innovative custom solutions, and complete high-efficient production lines to our customers, which are designed and manufactured by HAEUSLER.

In 1990, HAEUSLER first developed two complete Longitudinal Submerged Arc Welding lines (LSAW) pipe mills for the Korean market, equipped with Roll Bending technology. The concept was basing on the experience of previous Roll Bending machines. Today, with a market share of over 60%, today HAEUSLER is a world leader in the construction of LSAW Roll Bending pipe mills.

HAEUSLER Three Roll Bending Machine

Our first LSAW pipe mills already bettered other forming processes, especially in regards of out-of-roundness tolerances, productivity, and initial capital cost. However, maximum pipe wall thickness was limited at that time.

Over the past decade, HAEUSLER has continued to improve their Roll Bending process. As a result, today wall thicknesses of up to 45 mm can be processed at an output of up to 20 pipes per hour by. Along with these improvements, all typical benefits of Roll Bending such as high production flexibility and bending quality are still maintained.



Capacities of HAEUSLER LSAW pipe mills		
Pipe diameter range	16 to 64"	406 to 1'626 mm
Pipe length	20 to 40 ft.	6 to 12'200 mm
Wall thickness	¼ to 1 ¾"	6 to 45 mm
Output	up to 20 pipes per hour	

Capacities of HAEUSLER LSAW pipe mills

In addition to designing, manufacturing and commissioning, HAEUSLER offers a wide range of supplementary services for successful completion of pipe mill projects and for long-term operation, such as

Engineering

- Plant engineering
- Civil engineering documents
- Basic engineering for grounding
- Basic engineering for media networks like water, air, electrical power, cooling systems and technical gases
- Basic engineering for drain systems and waste water treatment

Accessories

- Quality Assurance Laboratory
- Maintenance workshop
- Spare parts logistics
- Consumables
- Transport and lifting equipment

Services

- Site management and installation
- Training
- Production support
- Repair services
- Certification support
- Plant modernization

1.2. Production Quality Assurance

Successful production of pipe which meets customer specifications requires that pipes manufactured have the correct properties and meet specification in four general areas:

1. ***Chemical properties*** (such as % carbon and % manganese) are a characteristic of the plate and must be supplied within pipe specifications given. The pipe manufacturing process has no effect on the chemistry (except in the weld area) and relies on the plate supplier to be within required tolerances.
2. ***Physical properties*** (such as yield and tensile) are primarily a plate characteristic. The forming and expansion processes will have some effect on physical properties. From a production standpoint the Full Body Expander is operated at a specific expansion ratio to give known physical property results.
3. ***Dimensional properties*** (straightness, roundness, etc.) of the pipe are a direct result of the production process and are one of the major determining factors of pipe quality, for which production is responsible. Quality assurance by production is focused on meeting these dimensional requirements. Each step in the process should be controlled with the objective of providing a pipe that meets customer dimensional specifications.
4. ***Welding properties*** generally revolve around producing a defect free weld as defined by American Petroleum Institute (API) or the customer specification. Development of suitable welding parameters is normally the result of various welding trials. From these trials, production develops a set of repeatable welding parameters within which they operate. Through testing, these parameters will have proven to give defect free welds. With proven and tested parameters and a consistent undamaged bevel, repeatable and consistent welding results can be obtained. A major focus of the first steps in the production process is to provide a geometrically consistent weld joint to the welding machines.

Longitudinal Submerged Arc Welding (LSAW) pipe manufacture is a step by step process involving approximately ten manufacturing steps and a minimum of ten inspections plus auxiliary process steps. In order to have overall success, each production step in the process requires a product within manufacturing tolerances.

First and foremost, the raw material or plate has to meet minimum requirements. Then, beginning with the first step in the production process, Plate Edge Preparation, it is imperative that each subsequent production step is provided with a product within manufacturing tolerances. Only in this way the next step in the process will be able to perform its own function properly and pass on to the next process step a correctly manufactured product, up to the end of production line.

One of the major requirements for successful pipe production is to develop and establish effective manufacturing parameters and tolerances for each step of the process. In this manual start-up parameters are presented. Over time, these should be refined and improved. Later, as data is gathered, statistical process control should be utilized to obtain effective operating parameters and tolerances. This data can also be used to refine and optimize the process itself.

Data and measurements are gathered for two primary reasons. The first and most obvious is to determine if the product is within tolerance. The second is to gather data to enable development of correct operating parameters. This area is often overlooked, especially in a startup situation. However, it is the only efficient way to control the long term operation of a pipe mill. For example, production management may be asked about the minimum pipe straightness the factory can provide economically. Only with past operating data a correct and reliable answer can be given.

Each production step requires a product within manufacturing tolerances such that it can perform own function properly.

Establish effective manufacturing parameters and tolerances.

Refine and improve them over time.

Statistical process control helps to obtain effective operating parameters and tolerances.

1.3. General comments on Plates, Flux & Wire

The three major purchased components influencing the pipe quality are Plates, Flux and Wire. Some general discussion and basic information concerning these components follows.

Plates

Pipes are unique in having one raw material component, plates. Overall, plate quality probably makes up to 75% or more of the final pipe quality component. If the plate quality is poor, most probably the resulting pipe quality will be poor as well. Additionally, there will probably be an elevated number of pipe defects and rejects. Some plate problems can be compensated in the pipe mill; however, this will usually result in lowered mill productivity and probably a higher mill reject rate.

The primary control a pipe mill has over plate quality is in the strictness and testing procedure required by the plate specification given to the plate mill. A very tight plate specification can be written that requires extensive testing. This can result in a higher plate cost that can exceed the cost benefit to the mill. The plate cost component of the final pipe price is around 60% to 70%, and as a result, plate cost has a very big effect on pipe price and overall mill competitiveness in the market place. As a result, those who are responsible for plate purchasing focus primarily on the price of the plate. From a strictly cost standpoint, a tight plate specification serves to increase the plate cost. Obviously, there is a cost to benefit trade off. Historical data and analysis must be provided by production to demonstrate the value of tighter specifications.

Some plate mills have a generally higher level of quality than others. This is due to many factors, the major ones being the condition and type of the equipment in the plate mill and raw material quality. As one would expect, plate mills which consistently produce a higher quality product often carry a price premium. This can vary a lot depending on plate market conditions. Also, plate mills generally consider plates for pipe a more difficult product to produce than plate for many other applications. Tight plate specifications accentuate this problem and can result in higher plate costs. It is important to gather historical quantitative data on the plates received from various plate suppliers. This way a numerical value can be put on the specific components of plate quality and their effect on mill productivity and rejects correlated.

One major component of plate quality is consistency. It is simply not enough that plate meet the specification. Wide variations from plate to plate in certain parameters, such as yield or thickness over the plate have a big effect on mill productivity. It is one thing that the plate yields are high or low. It is quite another when they vary from high to low from plate to plate. If plate yields are consistently low then the mill can adjust for this. A constantly changing plate yield creates havoc in the forming machines, and will normally reduce productivity as the operator has to adjust for each changing plate. It takes sufficient historical data and analysis to put a true production cost on such affects. One easy way to identify the better plate suppliers is to simply ask the forming machine operators whose plate they like the best. Surely after some experience they can tell clearly. However, this approach is subjective and does not give any meaningful numbers. Accordingly, historical operating data are a must-have.

Generally within a heat, the plate parameters do not change much, although they can. It is not uncommon to get a plate out of a heat lot what could be called a maverick. This is probably due to some malfunction in the plate mill when this particular plate was produced. In a plate mill, quality testing is done by random sampling and it is very possible for such plates to occur. One way to improve productivity is to keep the plates sorted by heat and feed them into the mill as a unit by heat. When ordering, plate mills with poor consistency should be requested to ship plates from the same heat as a unit. Further it should be requested to put the heat number near the edge where it can be easily read. It is also possible to request some color coding of heats, especially on a certain edge to help identify heats. Again, having some numerical data and cost figures to back up this request is a big help. In case sorting is not done the operators can be given pipe numbers of each heat to know when a plate from another heat is mixed in. This helps to identify the cause when forming suddenly changes.

Plate quality makes up to 75% or more of final pipe quality.

Plate quality shall be consistent.

Plates shall be sorted by heat and feed into the mill that way.

Flux

Flux and wire are by far the most expensive consumables used in the pipe mill. Approximate values for Submerged Arc Welding (SAW) flux and wire usage for a nominal 14 mm thick pipe are:

Consumable	kg/pipe-meter
Tack wire	0.06
Flux (Internal + External Welding)	1.37
Wire (Internal + External Welding)	0.81
Manual MAG wire	0.008

Welding consumables used for LSAW

Wire usage will vary considerably with pipe thickness and bevel geometry. Flux usage is more constant and not as dependent on pipe thickness or bevel geometry. The above values are for a bevel with a 35° to 40° bevel angle, which is a commonly used range.

The consumable with the biggest effect on productivity and quality is welding flux. And as such, it normally causes the most problems. There is a wide range of flux manufacturers, different types, qualities and costs. Fluxes are not as easily defined with a specification as plates can be. Flux ingredients are very much a “secret recipe” and considered proprietary information by some flux manufacturers. There is no really true flux specification similar to plates available. Specifications are generally confined to a general welding classification, type of packaging, and grain size.

From a welding standpoint flux selection basically centers around whether it gives the desired physical properties to the weld (tensile, fracture toughness, ductility, hardness) and that weld defects are minimized. In high speed multi wire welding, the big weld defect differentiator among fluxes is the susceptibility to undercutting. The higher the speed, the more undercutting becomes a problem.

Flux is of two types, fused and agglomerated. Fused flux is made by heating the components of the flux causing them to chemically combine and fuse together. They are then ground to get the desired particle size. With agglomerated flux the components are simply mixed together. As a result of the difference in manufacturing, agglomerated flux is cheaper to produce.

Historically, there has always been a controversy as to which is better. A main advantage to fused flux is that it doesn’t absorb water as readily as agglomerated flux. As a result, fused flux is less likely to induce water, and therefore hydrogen into the weld, which can cause hydrogen cracking. In the past, older pipe specifications from some companies’ specified fused flux to be used. However economics generally prevail and agglomerated flux has become the norm, in most of the pipe world. There have been big improvements in agglomerated flux over the years and its water absorbing tendency has been reduced. Also with proper packaging and handling, moisture pickup should be minimized.

If a quantity of flux is exposed to the atmosphere for a long period, e.g. caused by damage to the shipping bag or container, it should be dried as per the manufacturer's instructions. This process usually entails heating the flux to around 100 degrees Celsius for a certain time to drive off the water. In the last 20 to 30 years, thousands of tons of pipe for every type of application have been successfully produced using agglomerated flux. In pipe production, hydrogen induced in the weld from sources such as damp plate or hydraulic leaks pose a higher risk than the use of agglomerated flux. Also, the controversy of fused versus agglomerated is slowly dying out. Additionally, many major flux manufacturers no longer produce fused flux.

In addition to being fused or agglomerated, fluxes can be active or neutral. An active flux is one that contributes some elements and therefore some properties to the weld. Fluxes are generally chosen for the results they give. Some types are active while others are neutral. Whether they are active or neutral does not affect selection of fluxes in pipe making as much as obtaining the desired results.

The topic of moisture in flux and hydrogen cracking leads directly to the subject of flux storage and handling in the mill. If there is excess moisture in the flux, it is probably caused by improper storage and handling. A basic fundamental of flux handling is that it not be exposed to the atmosphere, and if exposed, only for a short time. This is of course dependent on the climate in the storage and workshop. Dry climates or dry times of year will give fewer problems.

Flux should come in sealed bags or containers. Bags usually have a sealed plastic liner. Containers have rubber sealing gaskets. Incoming testing of flux moisture content is advisable if the equipment is available. This is most effective when flux comes in large containers. When flux comes in bags, each manufacturing lot should be tested. The bags should have production lot number on them. Flux should be stored in its own dry, well-sealed room, equipped with an air conditioning system with a humidity gauge in the room keeping the humidity down. The pipe mill should have closed and sealed transport containers to deliver the flux to the flux tanks on the welding machines. These should be filled inside the flux storage room. Extra or standby containers should also be kept in the flux storage room. When the flux is needed, the container is taken to the welding machine and the flux dumped into the sealed flux tank. It is common practice to have a full flux container near the welders for fast filling of the flux tanks. However it should be used within a short period and not allowed to sit in the mill overnight if not used during the shift.

Standby flux containers

Without any flux transport equipment the bags of flux are poured into the flux tanks as needed. If flux is handled in this way some disciplined handling procedures should be in place and enforced. The flux filling process should be done quickly and without any interruption. Flux bags should not be opened ahead of time, only as poured in. Any broken or damaged bags of flux should not be used until dried. Partially using bags of flux shall be avoided and only full bags of flux shall be poured into the tank.

Excess fines or small particles of flux can cause undercuts, especially at higher welding speeds. Also, modern SAW welding systems normally have a recovery system for unused flux, which is mixed with new flux and recycled into the system. These recovery systems normally vacuum the unused flux from the pipe. Along with the flux a certain amount of dirt and magnetic particles from the plate area adjacent to the weld is vacuumed up. The amount of these foreign particles will vary depending on how dirty is the plate, the type of dirt or particles, vacuum nozzle shape, and amount of vacuum. These foreign particles mix with the flux and can cause undercuts, especially magnetic particles. Continuous flux recovery and recycling systems vary in type of equipment, maintenance condition, and effectiveness but in any case they help to avoid welding problems.

Segregated foreign particles from vacuumed, recovered flux

Flux recovery and recycling system

Others use a more batch method, whereby new flux is added to the old flux, but it is not actually well mixed. This can cause the flux to be somewhat segregated in the system. Sometimes it will be welding with mostly new flux and sometimes mostly old flux, and at other times with an undefined mix. This can lead to unexplained intermittent welding problems, primarily undercuts. The higher the welding speed, the more the potential for problems exists. Also, as welding progresses, the concentration of vacuumed dirt from the plate will increase.

A lot depends on the recovery system, how effective it is, and most important, how it is maintained. A good procedure is to periodically dump all old flux from the system and recharge with new flux. A good compromise between wasting flux and quality consistency is to let the flux tank go to minimum and then dump it.

There are numerous types and brands of fluxes available on the world market. For standard X-grades of pipe, numerous suitable flux suppliers can be found. Some pipe mills will recommend one type of flux or a certain flux manufacturer.
Most SAW welding in the world is done by 1 and 2 wires welding, and this is where most experience and welding data comes from. Expect somewhat different results with 4 or 5 wires welding commonly found in pipe mills. For reliable data, welding trials should be run to test the flux. Two, three or more different types of fluxes should be tested and proven to work good to fulfill the requirements.
It is impossible to get good reliable data about flux from short runs or tests. There are too many other variables such as plate, wire, environment, etc. A good procedure is to run long-runs on a flux or flux-wire combination to gather good data and do statistically analyses of the results and comparison to other flux or flux-wire trials. This will show that some fluxes may give better results for a certain grade or thickness. Some will give better physical property results. Some may give a lower defect rate. A prime objective is to use the lowest cost flux that gets the job done. Finally, all this determination can be made only over long periods with historical data of various pipe sizes and grades.

Flux and wires used in pipe making generally fall under one of two classes of carbon and low alloy steel welding wires and fluxes for SAW as established by the American Welding Society (AWS). These classes are AWS A5.17.89 for carbon steel and AWS A5.23.90 for low allow steel. Fluxes used in pipe making are normally either type F7A0 or F7A2. There is numerous literature available from AWS and other industry sources giving detail information on the difference and usage. Both types have been used very successfully in pipe making. Quite often a specific flux will meet both specifications.

After long-time exposure to the atmosphere, flux shall be heated to drive-off humidity.

Store flux in a dry, well-sealed, air-conditioned room.

Bags should have a sealed plastic liner, containers should have a rubber sealing gasket.

Flux filling process should be done quickly without any interruption.

Bags should be opened for use only, not ahead of time.

Broken or damaged bags should not be used until dried.

Run long-runs on a flux or flux-wire combination for statistical analyses.

Wire

Five machines or processes in pipe making require a specific welding wire:

1. Automatic Tack Welder
2. Tack Welding for repair (manual)
3. Tab welding (manual)
4. Internal Welding
5. External Welding

The internal and external welders generally use the same types and sizes wire in the amount as per table in chapter "Flux" in *1.3 General comments on Plates, Flux & Wire*.

Internal, External, and Automatic Tack Welding Wire

Three types and three sizes of wire are widely used in pipe welding. The three types are AWS types:

1. EMK 12
2. EMK 13
3. EA1

The most commonly used sizes are 3.2 mm (1/8") diameter, 4.0 mm (5/32") diameter and 4.8 mm (3/16") diameter wires. The chemical compositions of these wires are readily available from manufacturers and are basically a low carbon, low alloy steel coated with a thin layer of copper to improve electrical conductivity from the weld electrode to the wire.

EMK 13 is seldom used, but when used, it is normally used in automatic Tack Welding. It differs from EMK 12 and EA1 wire in that it has higher silicon content. The purpose of the additional silicon is to give better welding on dirty steel.

EMK 12 and EA1 wires are widely and commonly used throughout the pipe industry. The two wires have the same basic chemistry. The difference is that EA1 has the addition of molybdenum, which gives slightly higher tensile strength and increases fracture toughness. As molybdenum is a relatively expensive alloy, EA1 is more expensive.

As with flux there are many worldwide wire manufacturers. Wire quality is much easier to specify and evaluate than flux, and there is really not much difference among major suppliers. The wire must meet the chemistry requirements, which are not very stringent and normally not a problem. The diameter must not vary too much. However, diameter tolerance is the most difficult to monitor over a few thousand meters of wire.

An often overlooked item is contaminated wire. In the drawing and copper coating of wire, sometimes some of the chemicals and drawing lubricants used are not completely cleaned from the wire. When welding, this contamination can cause poor contact in the tip and may cause electrode tips to blacken and clog prematurely. Unexplained welding problems such as wires sticking in tips or an electrode quits welding, may be solved by changing the barrel of wire.

Procedures for storage and handling of wire are similar to flux, though not as critical. Obviously wire will not absorb moisture, but it will over time rust through the thin copper coating on the wire. Rust is a fairly good insulator and rusty wire can give welding problems. Wire should be shipped in sealed barrels or on sealed coils and kept sealed until used. It should be stored in the same humidity controlled area as flux. During extended mill downtimes, the wire in use should be removed to the storage area or the wire wrapped and sealed with plastic in the mill. Rusty wire can be cleaned with sandpaper, but this is a big job for large quantities. Slightly rusted wire still can be used successfully, but the welding quality should be monitored closely when doing so. It will be a cost trade-off to use up rusty wire versus having excessive welding stops and defects. As with flux, the environment, whether dry or humid, will have a big effect.

Manual GMAW Wire

Wire for manually attaching tabs or minor Tack Weld repairs is a standard Gas Metal Arc Welding (GMAW) wire, commonly called MAG (Metal Active Gas). Wire types ER 70S-4 and ER 70S-6 are commonly used in either 1.2 mm (0.047”) diameter or 1.6 mm (0.063”) diameter. The same previous comments concerning handling and storage of welding wire also apply to the MAG wire.

> ***Delivery, storage and handling procedures of wire are similar to flux.***
>
> ***During extended mill downtimes, wire shall be removed or wrapped and sealed with plastic.***

1.4. Frequency of Inspections & Measurements

The frequency of any inspections or measurements is a direct function of how well production is operating. In start-up situations the frequency should obviously be much higher than in later normal stable operations.
However, management should adapt the frequency to any change in the operating situation. In case a repetitive defect or problem occurs, it would be appropriate to increase the frequency of that particular inspection until the problem is resolved.

As stated above, during a plant start-up, having inspections and measurements on every pipe until stable operations are achieved is recommended. This will serve two purposes:

1. To help train the operators.
2. To gather data to begin a data base from which to develop and refine manufacturing parameters and tolerances.

A recommended inspection and measurement frequency for normal operations is given below. This should only be used as a basis and modified by management as needed.

> ***After any start-up or machine adjustment, the first 10 pipes should be checked or until the machine has produced 10 consecutive in specification pipes. Thereafter every 10th pipe should be checked, at least one per hour.***

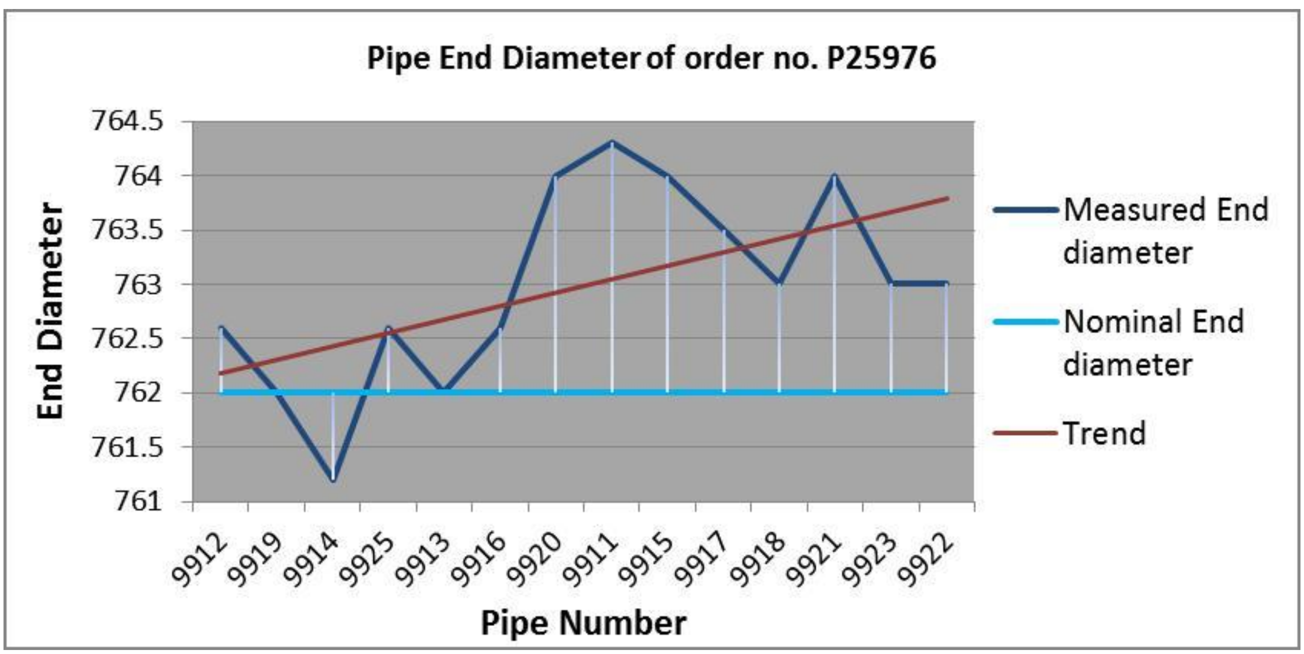
2. Statistical Process Control

Throughout this manual, much emphasis is placed on the gathering of data and taking pipe measurements throughout the production process. As a result a great deal of data will be available and need to be assimilated and analyzed. Measurements and other pipe data obtained from the results of production inspections are almost impossible to analyze unless some sort of statistical process control is used. In pipe manufacture there are a number of uncontrollable variables, the major one being the various properties of the plate used. In the production process, one must assume that the plates used are within the specification tolerance. However, there can be wide variations within this tolerance. Also, occasionally, one must expect for a plate to be out of tolerance, especially if it is on the high end of the tolerance spectrum. As a result, operations cannot simply make a change in the process and measure a few pipe and if the results is good assume all is well. The use of control charts is a very useful way to monitor and control the production, a simple example of controlling the pipe end diameter will demonstrate this point.

2.1. Conclusion of Process Data Gathering

Below is an actual production chart of pipe end diameter for a 30 inch pipe (762 mm). According API 5L allowed tolerances are +2.4 mm and -0.8 mm and the diameter on the ends may vary from 761.2 mm to 764.4 mm. On the attached chart, it is obvious that the diameter has begun to become larger. The trend line easily shows this point. In the production, one of the following things must have happened.

1. The milled width of the plates has become wider for some reason
2. The amount of expansion has increased
3. The spring back in the plates has become less



Trend of Pipe End Diameter

2.2. Recommendation of Process Data to be collected

Below is a summary table of data recommended to be collected. This data results from production measurements and inspections. The data should be entered into the computer system if one is available. Some measurements may come from automatic measuring devices on the machine. This data is primarily for internal mill use in controlling and monitoring production. It does not include machine operating parameters such as speeds, volts, amps, etc. Measurements are not generally made on every plate or pipe unless an automatic measuring device is available. Visual inspections of the plate or pipe may or may not be made on every plate or pipe. Data will only be entered if a visual defect is found.

1. Plate Receiving	2. Plate Entry	3. Milling
plate sampled	plate sampled	manual measurements are sampled - plate width automatically measured
squareness		plate width incoming
length	length	plate milled width
width	width	weld bevel root - 2 sides
thickness	thickness	weld bevel angle - 2 sides
camber	camber	manual measure & verify plate milled width
waviness	waviness	
plate surface visual inspection	plate surface visual inspection	strip surface visual inspection
4. Roll Bend	**5. Post Bend**	**6. Tack Weld**
pipe sampled – each end	each pipe – each end	pipe sampled
vertical dimension	gap	plate edge offset
Gap	vertical diameter	diameter (circumference)
plate surface visual inspect	radius profile	out-of-roundness
	pipe surface visual inspect	radius profile gap

7. Internal Welder	8. External Weld	9. Expander
no measurements taken	no measurements taken	diameter measured by the circumference
visual inspection of weld by operator	visual inspection of weld by operator	out-of-roundness
	macro examination of the weld profile	local out-of-roundness
		straightness
		pipe length

10. End Beveling
sampling measurement
pipe bevel root - 2 ends
bevel angle

Data for measuring and inspection to be collected

Notes:

1. Plate visual inspect:
   a. defect type
   b. reject/accept/hold/further process
2. Plate width delivered:
   record actual & check if within plate specification
3. Plate thickness & length:
   record actual & check if within plate specification
4. Plate camber:
   record actual & check if within plate specification
5. Weld area radius (often called local out-of-roundness):
   measured against a standard template gauge

3. Plate Receiving

3.1. Process description

As it affects the final pipe quality, the component of plate accounts for about 75% of the total quality in a pipe. Plate problems will cascade down the process causing numerous problems. Therefore incoming plate quality is of the utmost importance. During plate receiving and unloading from the supplier it is advisable to perform as many plate inspections and measurements as possible without hindering the unloading process.
Information on excess camber will be needed to set up the plate milling operation. Variations in thickness will be needed to set up the correct bevel geometry. Out of square plate as measured by the difference in the diagonals will effect output in the mill as excess cutting will be required to square up the ends. Normally plates are lifted in lifts of 5 – 10 plates depending on plate thickness and crane capacity. It is feasible and advisable to check the top plate of each lift or each second lift to at least provide some indication of the plate quality and information for a possible statistical sample. Later, as experience is gained, the amount of inspection can be adjusted depending on the quality supplied by various plate suppliers. These inspections can be done by production or in conjunction with the quality control department.

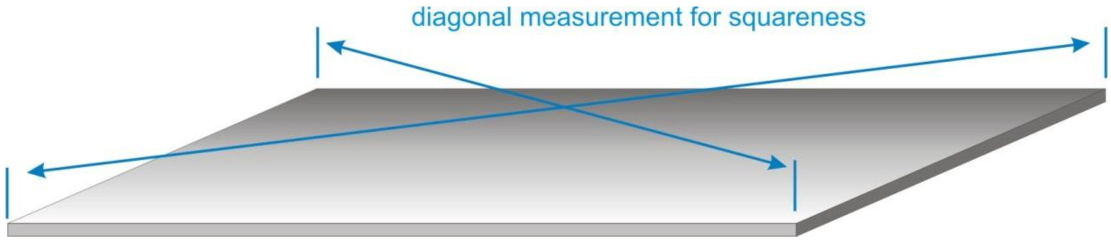
3.2. Measurements to be taken when Plate receiving

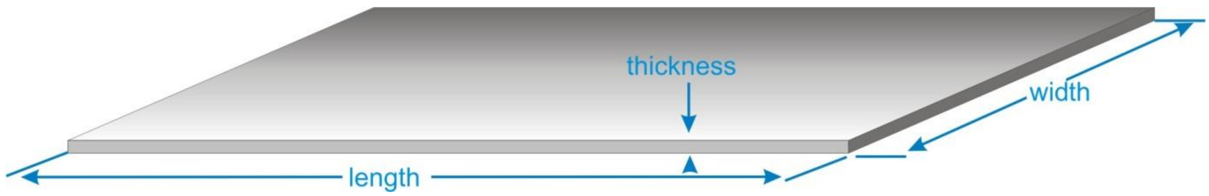
To assure plates received are in specification some or all of the following measurements and inspections should be performed.

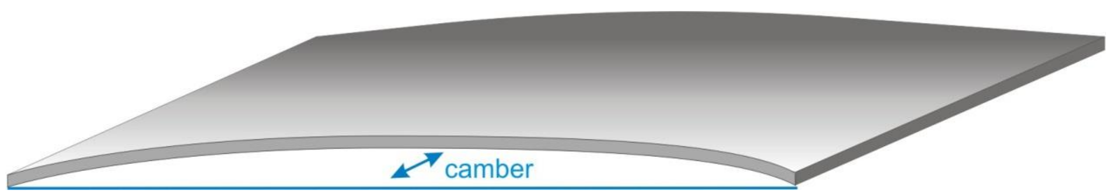
Inspection	Units	Comments
squareness	*mm*	Measure both diagonals excess out of square will increase yield loss
length	*mm*	
width	*mm*	too much variation will effect milling bevel
thickness	*mm*	can be checked at one or several points
camber	*mm*	milling must be set to maximum camber
waviness	*mm*	thicker wall pipe more of a problem
plate surface		visual inspection (pass or hold) – report problems

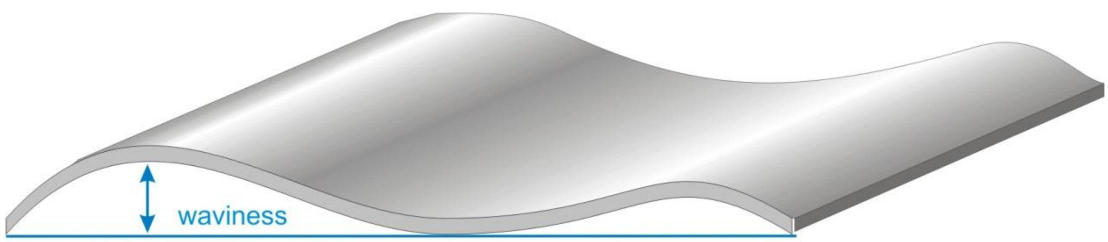
Data for inspection and measuring when Plate receiving

Measurements should be taken as per the following sketches:





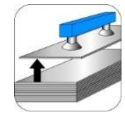




Take as many inspections and measurements as possible during receiving the plates.

Check top plate of each or each 2nd lift to gain information about the general quality.

4. Plate de-stacking



4.1. Process description

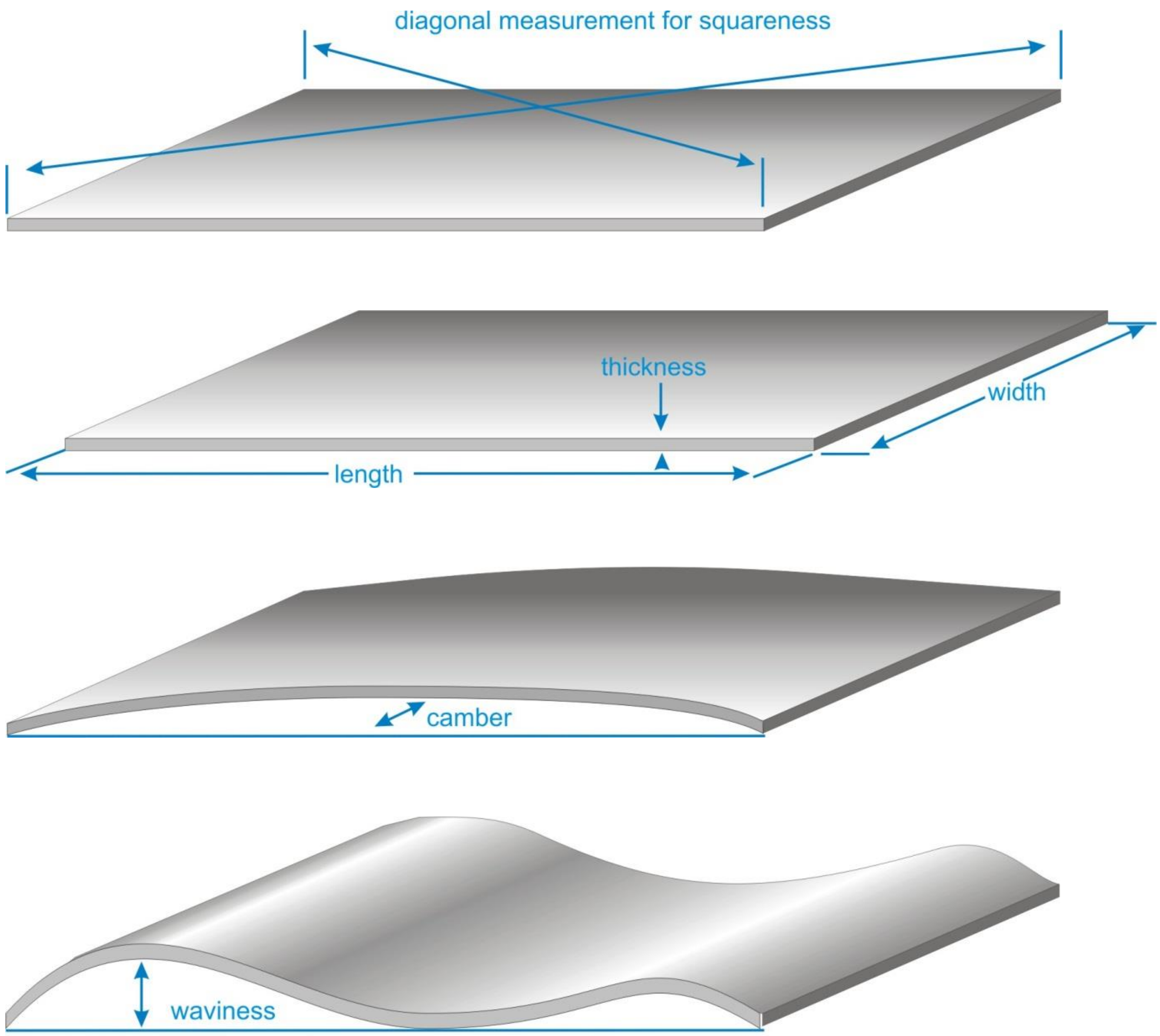
From the plate storage area plates are delivered to the entry table of the milling machine. Plate thickness should be checked at this process step. This can be done quickly with a snap type gauge. Excess variation in plate thickness can result in bevel profile variation and later downstream welding problems. Normally, the pipe number is assigned to the plate/pipe at this point in the process. From a production standpoint, here is a good location to perform some plate integrity and quality assurance checks. Although not necessary, from a quality assurance standpoint, recording the plate length on each plate provides a basis for calculating plate to pipe yield and amount of pipe shortening due to the expansion process.
Plate width will be automatically measured by the entry table of the milling machine. It only needs to be checked at plate entry if there is suspicion that the plate is too narrow. This will prevent narrow plate being sent to the milling later having to be removed, which causes production delays. Measurements for plate camber and waviness need only to be done if there is obvious camber or waviness in the plate. Plate waviness in thin plates (< 13 mm) is not a problem unless it causes an inconsistent milling bevel. Also, the Roll Bender will roll out most waviness in the rolling process. Waviness in thicker plates (> 16 mm) can cause milling problems. Additionally, this process step is a good location to perform a visual plate inspection on what will later be the inside of the pipe.

4.2. Measurements to be taken at Plate de-stacking

Inspection	Units	Comments
length	*mm*	
width	*mm*	normally measured automatically
thickness	*mm*	can be checked at one or several points
camber	*mm*	
waviness	*mm*	
plate surface		visual inspection (pass or hold) – report problems

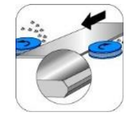
Data for inspection and measuring at Plate de-stacking

Measurements should be taken as per the following sketches:



> ***Check plate thickness with a snap type gauge to prevent later welding problems due to bevel profile variation.***

5. Edge Preparation



5.1. Process description

Plates first enter the pipe production process at the milling machine. In newer pipe mills, milling is one of the most automated processes in the pipe mill and milling is controlled by some type of CNC control. The incoming plate width should be automatically measured by the milling machine entry table. The desired bevel geometry is set by the installing the appropriate cutting tools. This information is available from the milling machine supplier. However, actual bevel geometry is set by operations.

Calculation of Milling Width

The correct plate width to give a desired final diameter could be given by the formula:

$$PW = \pi * \left(\frac{d}{1 + e_r} - t \right)$$

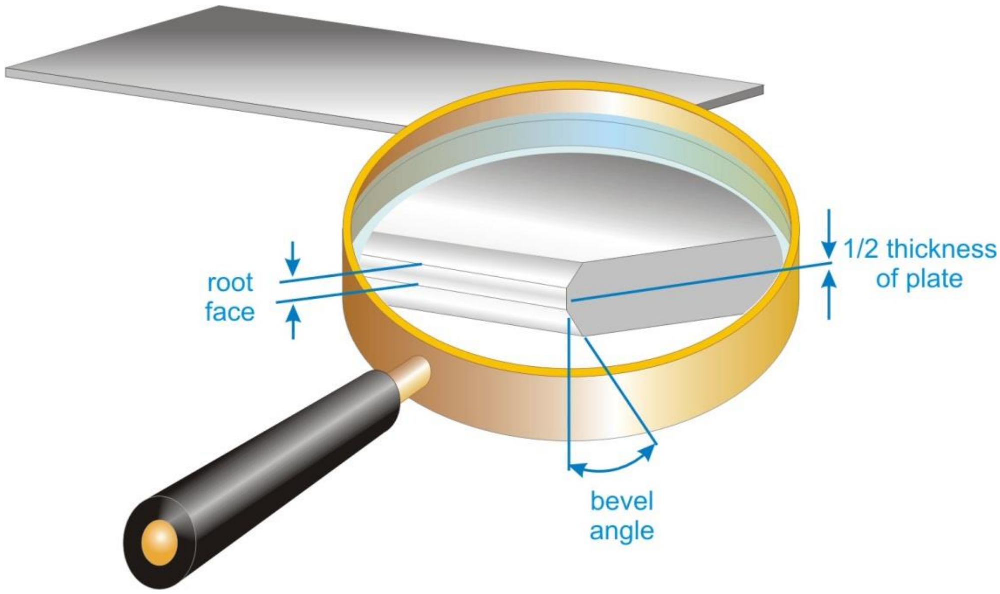
Symbol	Unit
PW = plate width to mill	**mm**
d = pipe diameter	**mm**
t = plate thickness	**mm**
$\mathbf{e_r}$ = expansion ratio	**%**

General bevel geometry

Bevel Geometry is a very important factor in welding quality. Of utmost importance is that the weld bevel be consistent, especially the root face. Inconsistent root face will often result in bleed through in Tack Welding and if uncorrected will cause blow-through in Internal Welding. The actual welding geometry is normally set by the welding engineer. The bevel angle is not as critical as the root face. It can vary based on thickness, welding wire size, and welding parameters. Angles may easily vary from 30 to 45 degrees. Often the angle is decreased for thicker walls to reduce the amount of weld metal needed to fill the bevel.

Normally, the bevel is centered (the midpoint of the root face is in the middle of the plate edge). Sometimes, the bevel is offset toward the Internal Welding side or External Welding side. This is done to put an unbalanced welding load on either the internal welder or the external welder. This decision is based on the number weld machines, cycle time of the weld machines, and number of wires used by each machine. These decisions should be made under the control of a weld engineer.

Some suggested bevels for start-up follow subsequently. Based on later welding results and experience, these will be adjusted based on results using varying welding parameters.



Pipe thickness	Suggested root face
< 8mm	3 mm
8 to 14 mm	4 mm
> 14 mm	5 mm

Pipe thickness	Suggested angel
6 to 20 mm	35° - 40°
< 20 mm	30° - 35°

Start-up parameters for Edge Preparation

5.2. Measurements to be taken at Edge Preparation

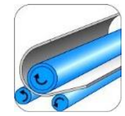
Basing on above sketches the following items should be measured over the complete plate length

Inspection	Units	Comments
plate width	*mm*	aim ± 1.5 mm should be manually verified by sampling
root face	*mm*	aim ± 0.5mm
bevel angle	*degrees*	fixed by milling cutters – verify in initial milling set up
plate surface		visual inspection (pass or hold) – report problems

Data for inspection and measuring at Edge Preparation

To prevent bleed through in Tack Welding and blow through in Internal Welding weld bevel, especially the root face, has to be consistent (rust-free, no waves, smooth surface).

6. Roll Bending



6.1. Process description

After edge milling, plates are transported to the Roll Bender. Here the plate is rolled into a pipe shape. Obtaining the correct shape and diameter in the Roll Bending operation is the target and will help to ensure correct pipe dimensions after expansion. This is the initial process where the overall form and shape of the pipe is determined. There are several components of the pipe shape which need to be controlled at this step. Also, the better the shape and roundness from the Roll Bender, the better pipe can be transported by the welding systems, which helps to assure defect free welding.

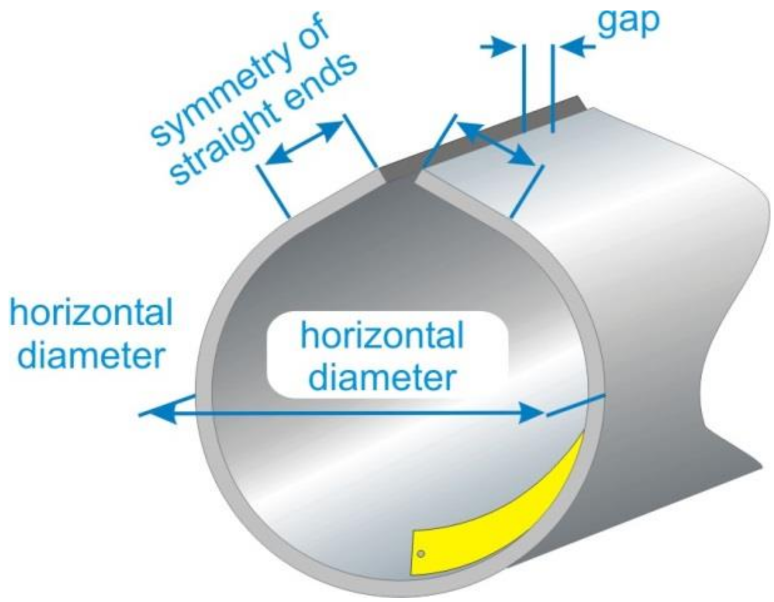
A common problem resulting from wrong set-up during Roll Bending is that the pipe has excess out-of-roundness or is egg shaped. The Expander will alleviate much of this defect; however, for a given expansion ratio, the Expander is only capable of correcting so much excess out-of-roundness. As an example, for an expansion ratio of 1% most Expanders are capable of correcting up to 25 - 40 mm of out-of-roundness. On the other hand, it is very difficult to correct > 40 mm of out-of-roundness. The amount of excess roundness an Expander can correct is very much dependent on the spring back in the steel. Thinner wall thickness and higher yield strength pipes have more spring back than thicker walls and lower yield strength pipes. Thinner wall and higher yield strength pipes are more difficult to roll without increased roundness.

As production experience is developed operators will gain information as to what the Expander is capable of and how much out-of-roundness is acceptable. As data on gap and vertical diameter is gathered, this can be correlated to roundness dimensions after expansion. Below, some initial operating parameters are suggested which experience has shown gives generally good results. Additionally, this process step is a good location to perform a visual plate inspection on what will later be the **inside** of the pipe.

6.2. Measurements to be taken at Roll Bending

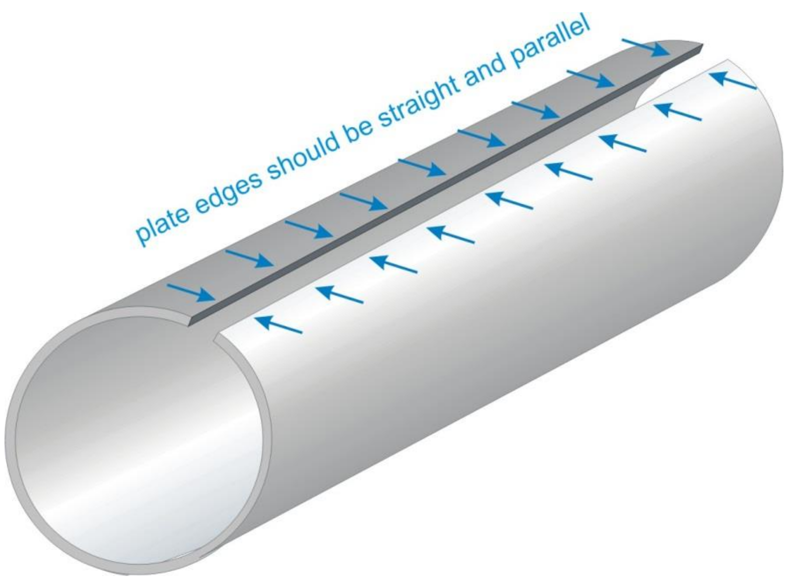
Inspection	Units	Comments
gap	*mm*	aim 75 – 100 mm
vertical diameter	*mm*	25 – 40 mm above nominal
symmetry		related to the vertical axis of the pipe
plate surface		visual inspection (pass or hold) – report problems

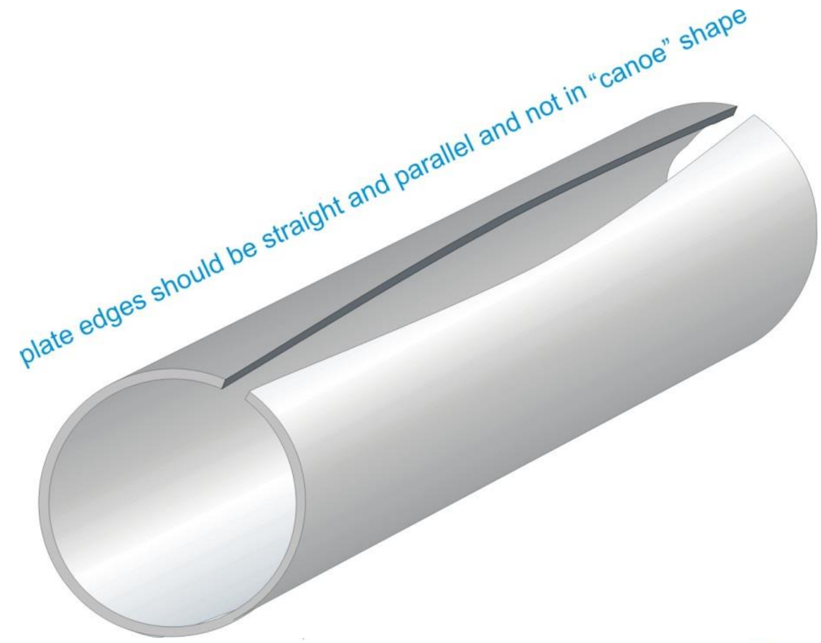
Data for inspection and measuring at Roll Bending

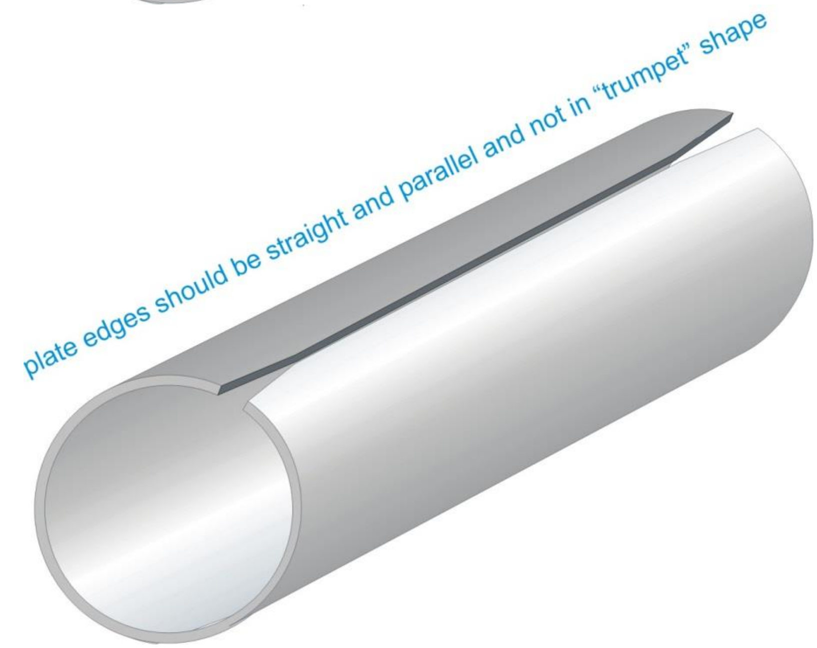


Measurement of vertical diameter and gap after Roll Bending

A second important component of the pipe shape is the straightness of the plate edges. They should be straight and parallel as shown in the following sketches. Excess opening in mid pipe (often called "**canoe**") or excess opening on the pipe ends (often called "trumpet") can cause problems in the Tack Welder in closing up the pipe and or getting a good weld without bleed through.







Different pipe shapes after Roll Bending causing subsequent problems

Expander is not capable to correct excess out-of-roundness or egg shape.

Non-straight edges cause problems in the Tack Welder in closing up the pipe and or getting bleed through.

7. Post Bending

7.1. Process description

After rolling, the open pipe is transported via longitudinal roller conveyors to the Post Bender. Here the edges of the rolled plate are crimped or formed. In any Roll Bending operation, it is impossible to fully bend the last 100 to 200 mm near the edge. They remain straight as there is no leverage for the bending moment and the forces necessary become too high. Therefore in all pipe mills some type of edge bending is done. Obtaining the correct edge bending radius in the Post Bending operation will help to ensure correct pipe dimensions after expansion.

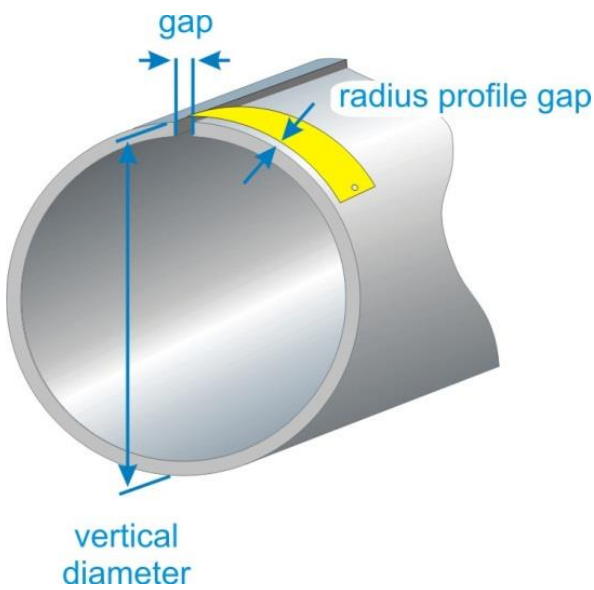
A common problem with LSAW pipe shape is the radius profile in the area where the edges meet and are welded. This problem is prevalent in longitudinal pipe and is referred to in pipe specifications as “local out-of-roundness”. It is often called “peak”. When pipes are peaked coming from the Post Bend, the heat of welding often accentuates a poor profile. Later in the process, the Expander will improve the radius profile, but should the profile be too poor the Expander may not be able to correct it for a given expansion ratio. To the extent that the Expander can correct a poor edge profile will very much depend on the spring back in the steel. Thinner wall thickness and higher yield strength pipes have more spring back than thicker walls and lower yield strength pipes. Thinner wall and higher yield strength pipes are more difficult to correct. Compounding the problem, is the fact that thinner wall and higher yield pipes with a lot of spring back are also much more difficult to obtain a good radius profile in the Post Bending process.

As production experience is developed operators will gain information as to what the Post Bender is capable of and how much local out-of-roundness and radius profile gap is acceptable. As data is gathered on gap, radius profile gap, and vertical diameter, these data can be correlated to roundness dimensions after expansion. Radius profile gap is checked against the correct radius profile for the diameter of pipe being produced with the use of a template as shown in the following sketches. Below some initial operating parameters are suggested which experience has shown gives generally good results. Additionally, this process step is a good location to perform a visual plate inspection on the **outside** of the pipe.

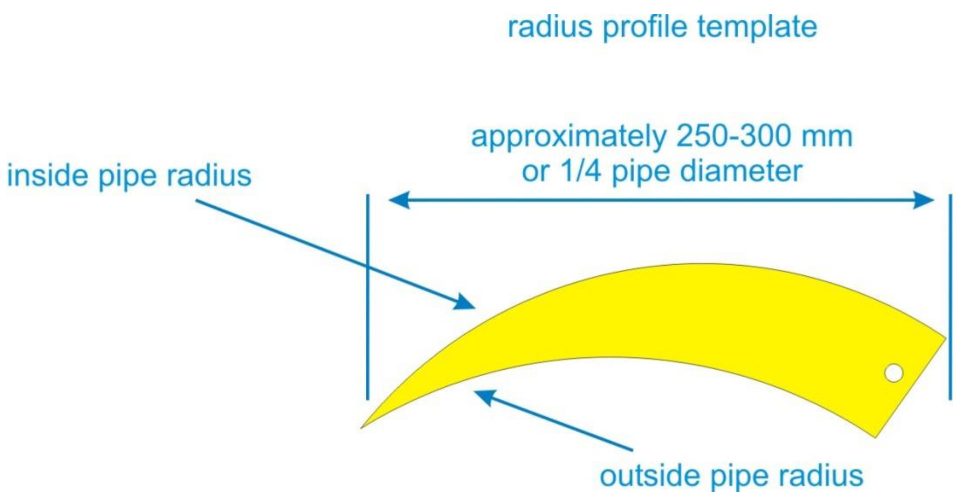
7.2. Measurements to be taken at Post Bending

Inspection	Units	Comments
gap	*mm*	aim 25 – 50 mm
vertical diameter	*mm*	10 – 30 mm above nominal
radius profile gap	*mm*	0 – 6 mm - aim for 0 mm
symmetry		related to the vertical axis of the pipe
plate surface		visual inspection (pass or hold) – report problems

Data for inspection and measuring at Post Bending



Measurement of vertical diameter and gap after Post Bending



Typical radius profile template

Note on **radius profile**: Normal operating expansion ratios are 0.9% to 1.2%. If the expansion ration is not yet determined, use a ratio of 1%. This will be within the accuracy needed to determine the correct profile. For use after expansion, the radius profile is equal to the nominal pipe diameter. For use after welding, the template is normally notched to accommodate the weld bead.

Gap shall be parallel along pipe and prepared edges shall be on same height.

Obtaining the correct edge bending radius will help to ensure correct pipe dimensions after expansion.

Heat input from welding often accentuates local Out-of-roundness.

8. Tack Welding

8.1. Process description

After Roll and Post Bending, the rolled plate is ready for Tack Welding. The purpose of Tack Welding is to apply a temporary weld to align the edges, hold the formed pipe together, and provide a weld backing for later Internal Welding. The Tack Weld is said to be consumed or re-melted by the later Internal and External Welding processes. Tack Welding is defined in API 5L but is not designated as a special process or final operation that affects attribute compliance under the definition of a special process.
As a result Tack Welding normally is not closely scrutinized by the customer or quality department. However, from a production standpoint good fit up and consistent Tack Welding are very important as they have a big effect on later pipe dimensions, Internal Welding and External Welding.
A big issue for the Tack Weld is to have a consistent and undamaged bevel. Sometimes due to handling, or equipment problems the bevel is damaged. Thus it is important to initiate some type of bevel inspection prior to Tack Welding. Pipe with damaged or poor bevels should be pulled aside and an attempt made to correct the problem by hand welding and grinding.
Process quality control at the Tack Welder can be broken down into 3 areas, as Fit up, weld quality and pipe dimensions and shape.

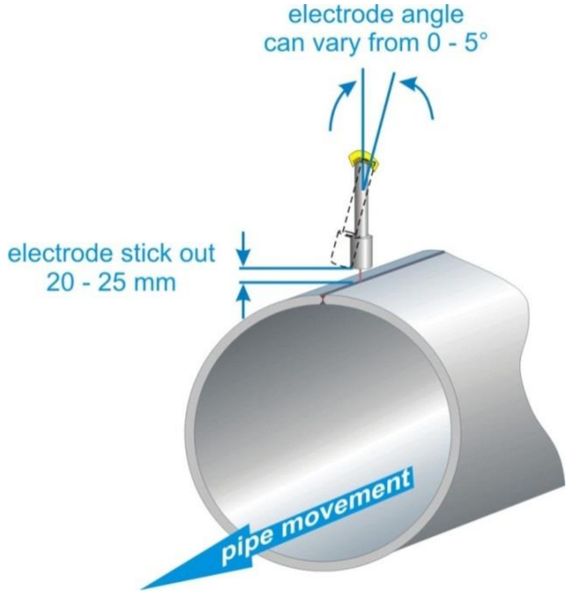
8.2. Fit up

1. As it applies to plate edge fit up or plate edge offset (in the pipe industry generally named as “hi-lo”) it is extremely important in its effect on pipe quality. Excess plate edge offset is a reason for rejection of that portion of the pipe with offset above what is specified (depending on wall thickness and standard). There is no ability to repair plate edge offset after the pipe is internally and externally welded, as it is with many other pipe defects. The only solution is to cut off that portion of the pipe containing the offset. Should the offset occur in a location which will cause the pipe to be under the minimum length, then the offset will result in a reject pipe. In case “hi-lo” occurs during Tack Welding process shall be stopped immediately hence. After edge offset is unseamed and the edges are cleaned and prepared welding can be repeated.
2. As it applies to the plate edges coming together very tightly, it is also extremely important in its effect on later welding quality. Even a piece of paper shouldn’t fit in the gap on the welding point. The result of the edges not being fit together tightly is easily observed in that it creates a Tack Welding defect called bleed through. In areas where is poor fit up, there is insufficient weld backing for the Tack Weld. As a result, the molten weld pool does have time to solidify and molten weld metal seeps through the weld joint. Bleed through can later cause serious weld problems in the Internal Welding process. In the Internal Welding process, the inside bevel groove is used as a guide for the welding to keep it aligned to the center. Bleed through will often cause the welding to get off track, resulting in off seam welding or lack of penetration. Additionally, where there is excessive bleed through there is normally

insufficient weld backing for the Internal Welding process. The result is a serious welding defect called burn or blow through. Burn through is similar to bleed through; however, it will be much larger and much more difficult to correct or repair. Such is the reason why at the Tack Welder, bleed through needs to be corrected. Normally it is the result of not enough pressure forcing the edges of the pipe together. It can also be the result of an improper bevel or damaged bevel. After Tack Welding all pipes should be internally visually inspected for bleed through. Any bleed through should be ground out prior to Internal Welding.

8.3. Weld quality

1. Weld quality has two major components: bleed through problems caused by poor fit up and the Tack Weld itself. The Tack Weld should be a consistent, homogeneous and uniform weld for the entire length of the pipe. This can be easily visually observed. During the welding process, the sound of the welding should be a constant sizzling sound without any loud popping and cracking. The lower the noise level the better the welding. In initial start-ups, a macro examination of the Tack Weld should be made to assure good weld penetration. Anytime parameters are changed, it is good operating practice to perform a macro examination of the Tack Weld. Developing welding parameters and weld monitoring are normally done under the supervision of a welding engineer.
2. After and or during the Tack Welding process, the weld should be inspected internally on the ends and externally over the entire length. Any bleed through, lack of weld or poor weld should be corrected prior to inside welding. Such correction normally consists of grinding to remove any bleed through and a standard manual weld repair of the Tack Weld itself to a good consistent shape if needed. Affecting Tack Weld repairs is not difficult and compared to the later welding problems prevented, is very cost effective.
3. Suggested electrode geometry and starting welding parameters for Tack Welder:



Geometry of Tack Welding electrodes for start-up

Tack Welding is normally done using 3.2 mm or 4.0 mm diameter wire. Often the same wire used in the submerged arc process is used for Tack Welding. Others prefer to use a wire designed for Tack Welding. Both have proven to give good results. The Tack Welding process normally uses 100% carbon dioxide (CO_2) gas or a mixture of carbon dioxide and a small percentage of Argon (Ar.) – normally up to 20%. Weld spatter can be reduced by the use of Argon, but it reduces the welding speed however. Finally a uniform consistent weld has to be accomplished by adjusting the parameters.

Pipe thickness mm	weld speed m/min	volts	Wire speed cm/min	Approx. amps	
6.3	4.8	24	180	900	DC+
12.5	5.0	24.5	200	1000	DC+
19.1	4.5	26.7	240	1150	DC+
25	4.0	27	280	1250	DC+

Starting parameters for Tack Welding with 4.0 mm wire and CO2 shielding gas

8.4. Pipe dimensions and shape

After Tack Welding it is the first process step where it is possible to obtain a good check on pipe dimensions and general shape.

1. Diameter as measured with a circumferential or phi tape. Diameter measured circumferentially before expansion is a sole function of the milled width of the plate, and is very easy to adjust. The diameter should be equal to the required diameter reduced by the amount of anticipated expansion. If the diameter is too large, simply reduce the milling width and if the diameter is too small it has to be increased. A too large diameter can be the result of poor fit up. Poor fit up can be visually observed if it exists in the area you are measuring. If poor fit up is evident, obviously it needs to be corrected first or make measurements in another area.
2. Out-of-roundness (sometimes called ovality) needs to be measured and is defined as the difference between the maximum and the minimum diameter as measured linearly or along the line of a true diameter measurement passing through the center of the pipe. Out-of-roundness is generally specified as a per cent of the nominal pipe diameter, which is then converted to actual mm (API is approximately 1%). The Expander will correct a considerable amount of out-of-roundness; however, if out-of-roundness is too excessive, the Expander may have problems to correct it for a given expansion ratio. Good operating practice is to aim for out-of-roundness as measured after Tack Welding to be at or below the maximum allowed in the specification. Adjustments for out-of-roundness in the rolling and Post Bending can be difficult. If out-of-roundness is accompanied by poor local out-of-roundness in the weld area, then the Post Bending need to be adjusted accordingly – more or less

Post Bending. If the Post Bending radius is OK, then it is necessary to adjust the Roll Bending.

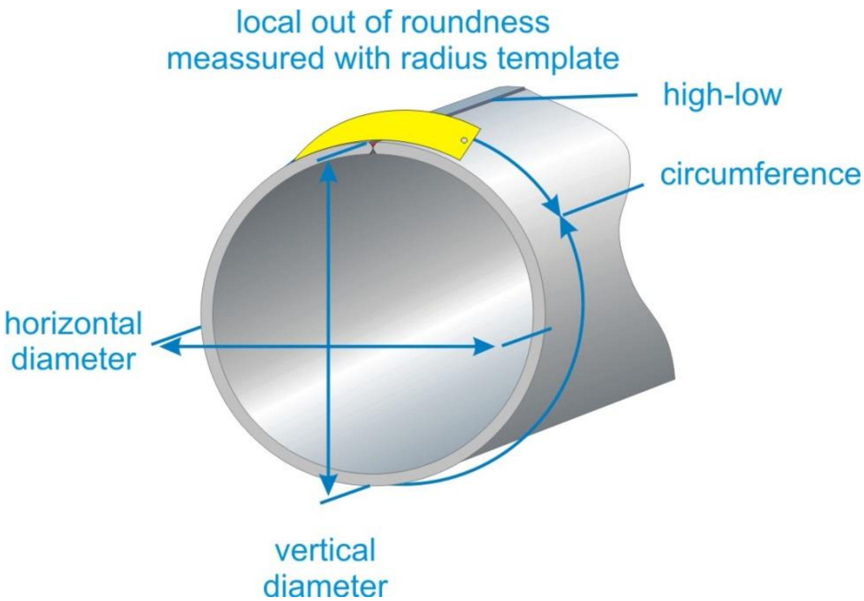
Roll Bending is generally adjusted in two ways. The first is to increase or reduce the depth of the bending on the final bending pass. The second is to what is commonly referred to as ”working the edges”. This basically involves rolling the edges of the pipe with a deeper bending than with the remainder of the plate. Techniques for adjusting the Roll Bending are generally determined by the operator through trial. As the operator gains experience, he will become better able to adjust the Roll Bending to accommodate correcting out-of-roundness. Adjusting the Roll Bending to obtain the best possible pipe shape is one of the more difficult skills to learn in pipe making. Such skill is acquired through experience, supplemented by data gathering.

3. Also, local out-of-roundness as measured by the radius profile gap of a radius template in the weld area needs to be checked. Poor local out-of-roundness in the weld area is normally corrected by adjustments to the Post Bending. Also, as noted in the section above, “working the edges” affects local out-of-roundness in the weld area. As production experience is developed operators will gain information and experience as to what the Roll Bender and Post Bender are capable of and how much out-of-roundness is acceptable. As data is gathered on roundness and radius profile gap, it can be correlated to roundness dimensions after expansion. Radius profile gap is checked against the correct radius profile for the diameter of pipe being produced with the use of a template as shown in the following sketches. Below some initial operating parameters are suggested which experience has shown gives generally good results. Additionally, after the Tack Welding process is a good location to perform a visual pipe inspection.

Inspection	Units	Comments
Plate edge offset	*mm*	aim for zero up to ½ of maximum is a good operating range
Diameter/circumference	*mm*	aim for zero – adjust plate milling as needed
out-of-roundness	*mm or %*	measured by major diameter minus minor diameter max.: < 3% - aim for < 1%
radius profile gap	*mm*	0 – 6 mm - aim for 0 mm
plate surface		visual inspection (pass or hold) – mark & report problems
symmetry		Related to vertical axis of the pipe. Check prior to welding
bevel		Visual inspection prior to welding (pass or hold) - mark & report problems
bleed through		internal visual inspection after Tack Weld (pass or hold) - mark, report and grind out bleed through as needed
Tack Weld quality		visual inspection (pass or hold) – mark, report, and repair as needed

Data for inspection and measuring at Tack Welding

8.5. Measurements to be taken at Tack Welding



Measurement of pipe dimensions after Tack Welding

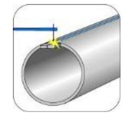
Edge offset ("hi-lo") shall be minimized.

Tight closing of pipe edges to avoid bleed-through.

Weld bevel shall be consistent, homogenous and uniform.

Visual inspection of the ends (internally) and the entire weld length (externally).

9. Tab Installation



9.1. Process description

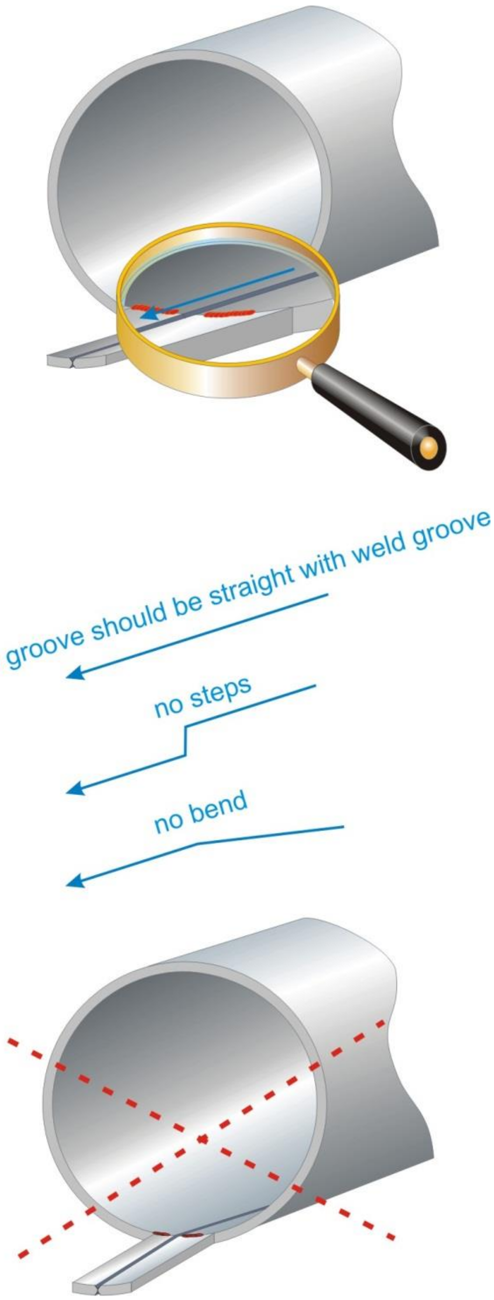
After Tack Welding, welding start and stopping tabs are welded on the pipe ends. The purpose of the tabs is to provide an area where the internal and External Welding can be initiated and ended without affecting the weld quality of the pipe itself. Tabs are intended to provide a temporary platform where the weld starts and stops. When welding begins, there is a certain amount of time required for the welder to strike the arc and stabilize. At the end of the welding process, when the arcs are switched off, the arcs are again unstable. During these periods of starting and stopping, the weld is generally of poor quality. After the welding is completed, the tabs are removed and the pipe itself shows a consistent, homogeneous and uniform weld.
The tabs essentially provide an extension of the weld bevel groove in the pipe and therefore need to be as an exact continuation of the weld bevel as possible.

In most pipe mills installation of tabs is a manual operation. As tab installation area is a very small, simple and unimpressive area compared with other machines, such as Roll Bender, it very often gives the impression to be an unimportant and minor process step. In fact it is a very quality-determining production step. Observing above given important rules should be in the focus of the welding engineer and the production quality assurance department. This allows reaching high quality welding and high mill output due to reduced repair or rejection rates.
Weld tab should be no longer than what is needed to complete the weld. Otherwise they are difficult to handle and waste plate steel. Normally approximately 250 mm to 300 mm is sufficient.

Proper weld tab installation has 4 components:

1. In line alignment with the existing weld bevel groove of the pipe.
2. The tab edges should be the same height as the edges of the plate and match them
3. The tab should be in same level and vertical plane as the pipe weld bevel groove.
4. A good tight fit up to the pipe with a solid connecting weld between tab and pipe.

9.2. Tab alignment sketches



Misalignments of tabs

Tab installation is a very quality-determining production step, as subsequent internal and external welding is influenced.

Proper alignment of the tabs has to be assured by welding engineer and quality assurance department.

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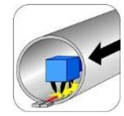
10. Internal Welding



10.1. Process description

After tabs are installed, the pipe is ready for Internal Welding. Seam welding of which Internal Welding is a part is designated by API 5L as a special process or final operation that affects attribute compliance under the definition of a special process in API 5L. As such the Internal Welding process requires special validation through specific procedures and qualification testing as per API.

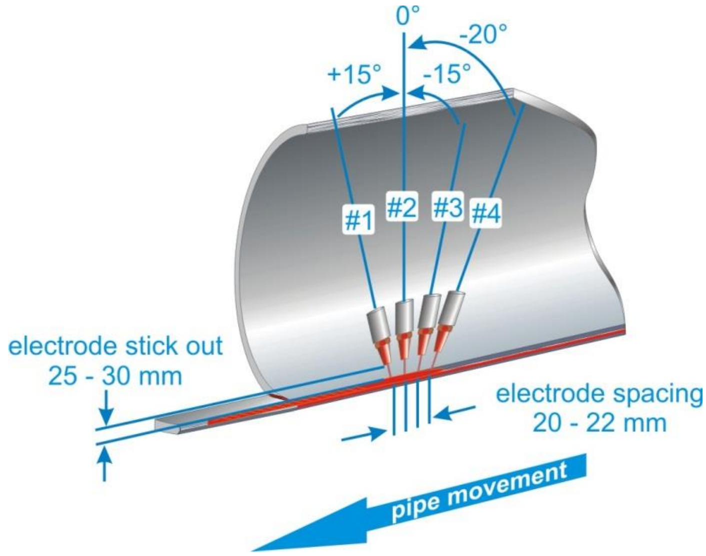
In assuring a quality internal weld, one of the major factors is to have a good consistent Tack Weld and bevel groove. After Internal Welding, the weld should be inspected and any necessary repairs made to assure a good solid weld backing for the next External Welding process. Inspection immediately after Internal Welding is often a problem due to the heat, and there may not be sufficient time to inspect the weld before External Welding. However, some minimal inspection from the ends of the pipe should be done after welding. Also, during the welding process, the operator should continually monitor the welding and report any abnormalities. He should continually monitor the inside camera while welding. Minor, defects and undercuts can be repaired or ground later.

10.2. Reaching the welding quality

Process quality control at the internal welder can be broken down into 3 areas, as correct bevel, correct weld electrode alignment and good welding parameters. Chapter 1.3 "*General comments on Plates, Flux and Wire*" completes this subject.

1. It is important to initiate some type of internal bevel inspection prior to Internal Welding to assure the welding groove is consistent and undamaged, without any Tack Welder bleed through. This can be done during tab installation, especially on the ends. Pipe with damaged or poor bevels should be pulled aside and an attempt made to correct the problem by manual welding and grinding. Tack Weld backing should be consistent through length of pipe.

2. Developing welding geometry by weld electrode alignment and weld monitoring are normally done under the supervision of a welding engineer. Below are suggested alignments of weld electrodes to serve as a starting basis for future development.



Geometry of Internal Welding electrodes for start-up

3. Development of weld parameters is normally done under the supervision of a weld engineer. Normal welder arrangement is DC-AC-AC-AC. There are unlimited variations in weld parameters based on various bevel geometries, wire sizes, and flux combinations. Suggested starting parameters for welding with 4.0 mm wire diameters are given in the subsequent table.

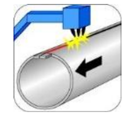
Pipe thickness mm	weld speed m/min	volts #1	volts #2	volts #3	volts #4	amps #1	amps #2	amps #3	amps #4	
6.3	1.5	32	34	36		600	500	450		DC+
12.5	1.8	32	34	36	38	800	700	650	600	AC
19.1	1.6	32	34	36	38	900	750	700	650	AC
25	1.4	32	34	36	38	1100	850	750	650	AC

Start-up parameters for Internal Welding with 4.0 mm wire

To prevent stick out change and weld defects due to bleed through from Tack Welder inspection of weld bevel prior Internal Welding shall take place.

Welding shall be continually monitored and any abnormalities shall be reported.

11. External Welding



11.1. Process description

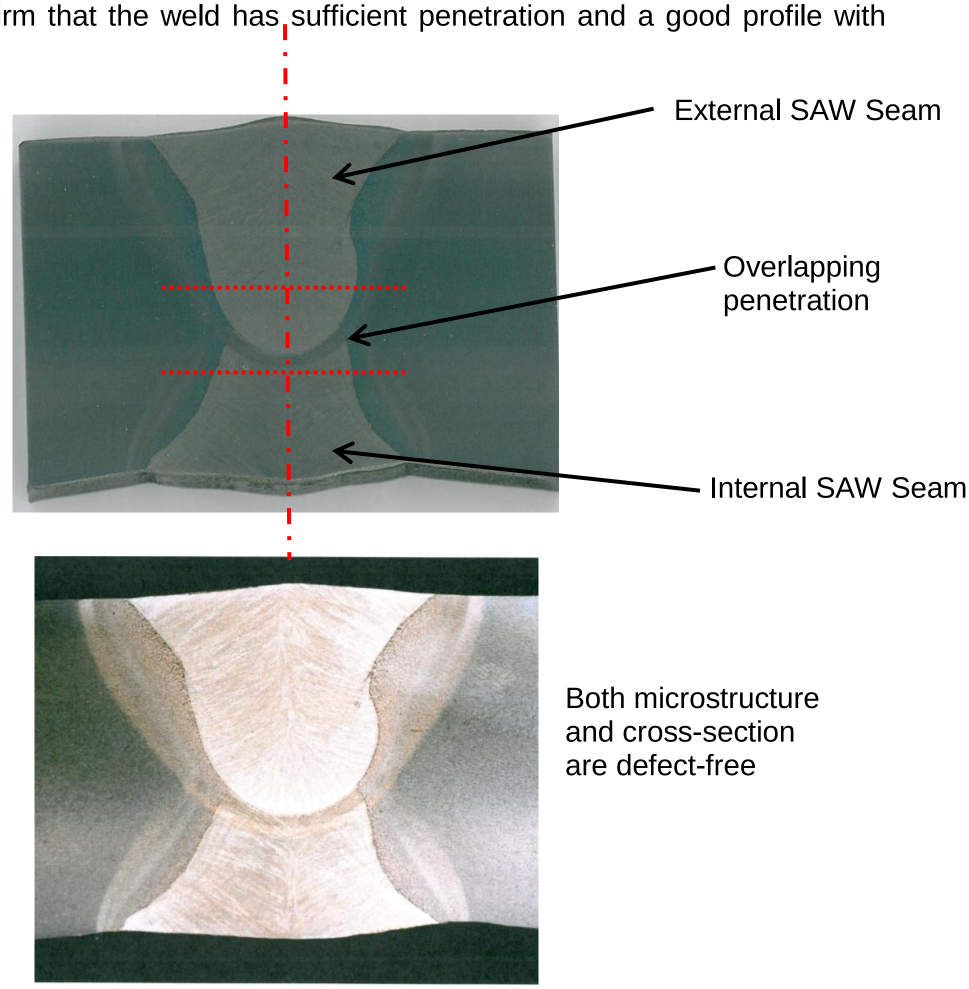
After Internal Welding and some minimal pre-inspection the pipe is ready for External Welding. Seam welding, of which External Welding is a part, is designated by API 5L as a special process or final operation that affects attribute compliance under the definition of a special process in API 5L. As such the External Welding process requires special validation through specific procedures and qualification testing as per API.

In assuring a quality external weld, one of the major factors is to have a good consistent bevel groove.

After Internal Welding, the weld bevel should be visually inspected and any necessary bevel repairs made by grinding and or manual welding.

After External Welding, a sample of the weld should be cut and a macro examination of the weld profile performed. This is normally done under the supervision of a welding engineer.

The macro should confirm that the weld has sufficient penetration and a good profile with rounded corners.



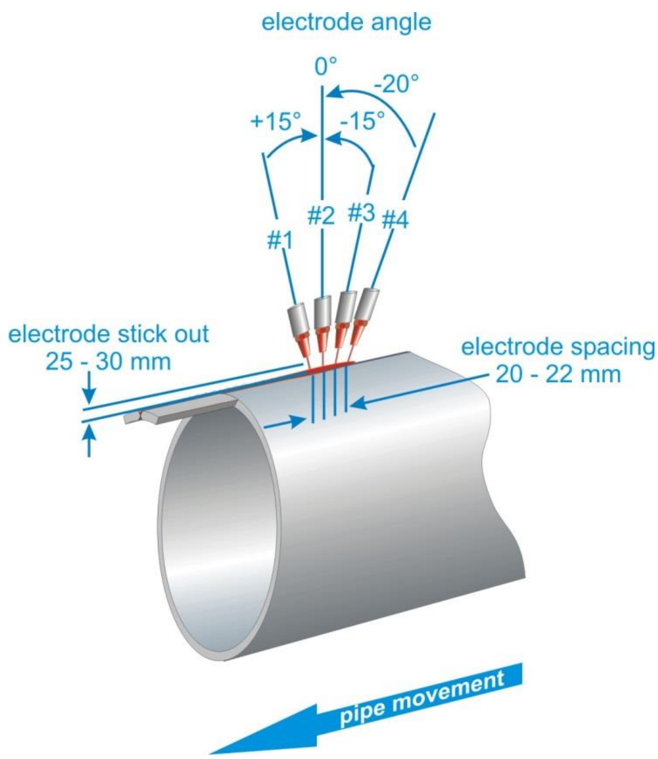
Welding macro of a submerge arc welded seam

11.2. Reaching the welding quality

Process quality control at the external welder can be broken down into 3 areas, as correct bevel, correct weld electrode alignment and good welding parameters. Chapter 1.3 "*General comments on Plates, Flux and Wire*" completes this subject.

1. It is important to initiate some type of external bevel inspection prior to External Welding to assure the welding groove is consistent and undamaged. Pipe with damaged or poor bevels should be pulled aside and an attempt made to correct the problem by manual welding and grinding.

2. Developing welding geometry by weld electrode alignment and weld monitoring are normally done under the supervision of a welding engineer. Below are suggested alignments of weld electrodes to serve as a starting basis for future development.



Geometry of External Welding electrodes for start-up

3. Development of weld parameters is normally done under the supervision of a weld engineer. Normal welder arrangement is DC-AC-AC-AC. There are unlimited variations in weld parameters based on various bevel geometries, wire sizes and flux combinations. Suggested starting parameters for welding with 4.0 mm wire diameters are given in the subsequent table.

Pipe thickness mm	weld speed m/min	volts #1	volts #2	volts #3	volts #4	amps #1	amps #2	amps #3	amps #4	
6.3	1.7	32	34	36	38	700	600	450	400	DC+
12.5	1.9	32	34	36	38	1000	800	650	600	AC
19.1	1.7	32	34	36	38	1100	850	700	650	AC
25	1.5	32	34	36	38	1200	950	750	650	AC

Start-up parameters for External Welding with 4.0 mm wire

Where necessary any bevel damages shall be removed prior External Welding.

After External Welding a macro examination can confirm quality-Conformity.

12. Pipe Cleaning and Visual Inspection

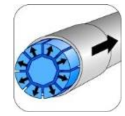
12.1. Dimensions and shape

After, the inside and outside welding is completed, visual inspection of the welds must be made. Before inspection, the pipe inside will be cleaned to remove remaining flux and slag by a brush which cleans weld seam and a rubber pusher which collects dirt.
Often inspections at this point are a Quality Control function, but as it affects production, some comments will be made here. One of the major points in correcting weld defects and overall pipe production efficiency is to detect weld defects as soon as possible after they occur. One obvious point in detecting and correcting defects as soon as possible is that it reduces the number of defects and increases welding efficiency. A second and equally important point is that timely detection of weld defects gives immediate feedback to the welding operators. This feedback is important for two reasons. The first, most obvious reason for timely feedback to the operator is to enable him to quickly correct problems and thereby avoid further defects. A second, equally important reason is that if the operator has made some adjustments or changes to his machine and now defects occur, the operator has a much better chance of knowing what he has done wrong. This process is a part of any learning process and is especially important in new start-ups. The inspection procedure and process needs to be designed to give immediate feedback to the operator. Too often inspections are made and recorded on some report. This report is not available to welding operators until later. A real time defect reporting system must be put in place. As it applies to any inspection process, be it Ultrasonic or X-ray inspection, timely and real time feedback to the operators cannot be over emphasized.

Timely detection of welding defects allows fast interaction in Internal and External Welding to reduce further defects.

It also allows fast evaluation and feedback of adjustments made by the welding operator.

13. Full Body Expander



Expansion is designated by API 5L as a special process or final operation that affects attribute compliance under the definition of a special process in API 5L. As such the expansion process requires special validation through specific procedures and qualification testing as per API. Good dimensional results from the expansion process depend on 2 main factors: first, incoming pipe dimensions are within the Expander's capabilities and second, Expander alignment and especially the tools are within the manufacturer's original tolerance.

13.1. Dimensions and shape

To develop good operating procedures, dimensions should be checked prior to expansion and after. For a given size of pipe, once good operating parameters have been established, the procedure of checking incoming pipe dimensions is normally reduced to a frequency of approximately 5 to 10% of incoming pipe. It is good operating procedure to at least three times a shift (at the beginning, in the middle, and at the end) check incoming dimensions to verify they have not substantially changed. At any time the dimensions after expansion go out of tolerance, the incoming dimensions should be immediately checked.
Diameter is measured with a circumferential or phi tape. Diameter measured circumferentially before expansion is a sole function of the milled width of the plate. The incoming diameter should be equal to the required diameter reduced by the amount of anticipated expansion. If the diameter is too large the milling width has to be reduced, and if the diameter is too small it has to be increased. A too large diameter can be the result of poor fit up. After welding, large diameter caused by poor fit up is nearly impossible to determine. One indication is that it should be localized to one area or section of the pipe. Expander operators should communicate with the Tack Welder operators to see if they are having problems with closing up the pipe.
Out-of-roundness (sometimes called ovality) needs to be measured and is defined as the difference between the maximum and the minimum diameter as measured linearly or along the line of a true diameter measurement passing through the center of the pipe. Out-of-roundness is generally specified as a per cent of the nominal pipe diameter, which is then converted to actual mm (API is approximately 1%). The Expander will correct a considerable amount of out-of-roundness; however, if incoming out-of-roundness is too excessive, the Expander may have problems to correct it for a given expansion ratio. Good operating practice is to aim for out-of-roundness as measured before expansion to be at or below the maximum allowed in the specification.
Local out-of-roundness as measured by the radius profile gap of a radius template in the weld area needs to be checked. Poor local out-of-roundness in the weld area is normally corrected by adjustments to the Post Bending. Also, as noted in the previous section on Roll Bending "working the edges" while rolling the plate into a pipe affects local out-of-roundness in the weld area. As production experience is developed operators will gain information and experience as to what the Roll Bender and Post Bender are capable of and how much out-of-roundness can be corrected by the Expander. As data is gathered on roundness, and radius profile gap, it can be correlated to roundness dimensions after expansion. Radius

profile gap is checked against the correct radius profile for the diameter of pipe being produced with the use of a template as shown in the following sketches. Below some initial operating parameters are suggested which experience has shown gives generally good results.

The control of straightness in a LSAW pipe mill is the dimensional parameter over which production has the least control. A certain degree of pipe camber (often called “banana shape”) will inevitably be introduced due to the heat from the welding process. The more heat obviously, the more the camber introduced. However, welding heat and its effect on pipe straightness is of secondary importance when compared to weld quality. Welding parameters and heat input are established to provide defect free welds with the correct weld physical properties.

Straightness after welding will be what it is. Pipe straightening in an Expander is more of an art than a science. The process of pipe expansion itself will provide some straightening. The adjustment of pipe clamping carriages is very important in straightening the pipe. Also, it is important that the tooling not have excessive wear. LSAW pipes normally are cambered along the weld. If camber occurs in another axis, then this is usually due to wrong parameter set-up in previous production steps. Improper setup of the Expander can also produce camber. If camber is thought to be caused by the Expander, simply checking the pipe straightness before and after expansion will determine if the Expander is causing a problem.

As a normal part of the expansion process, the pipe becomes shorter. From an operational standpoint the amount of pipe shortening for a given expansion ratio should be determined. Some measurements should be taken before and after expansion for a given pipe size to enable the production department to get good information and correlate this data.

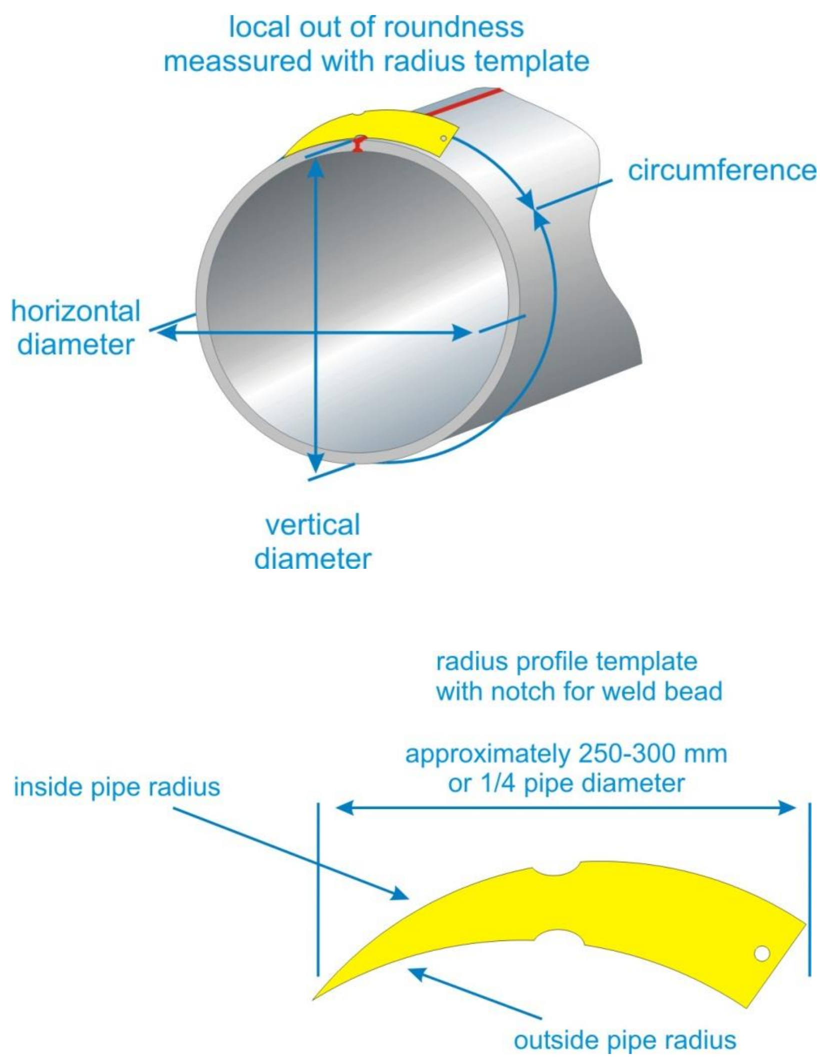
Inspection	**Units**	**Comments**
Diameter/circumference	*mm*	aim for zero – adjust plate milling as needed
out-of-roundness	*mm or %*	measured by the major diameter minus the minor diameter
local out-of-roundness (radius profile gap)	*mm*	0 – 2 mm - aim for 0 mm
straightness	*mm*	aim < 4mm – up to max specified
Pipe length	*mm*	sampled checking before & after expansion

Data for inspection and measuring at Expander

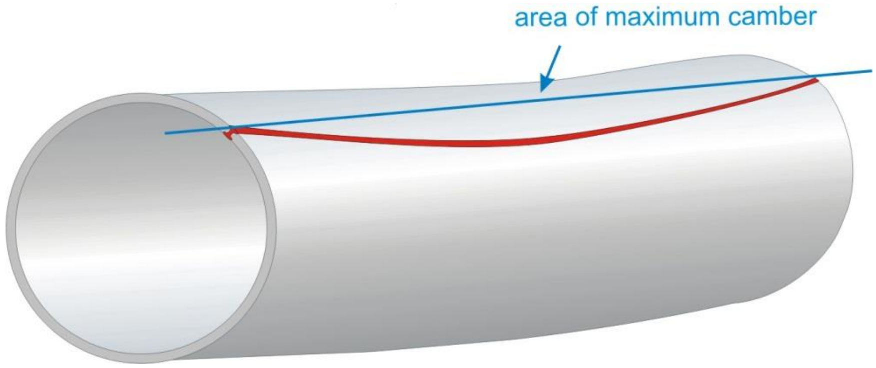
13.2. Maintenance of Expander Tools

The importance of maintaining the Expander tooling cannot be overly stressed. Expander tools are subject to extremely high mechanical forces which results in a lot of wear on the tools. Most problems with poor expansion can be traced to worn tools, especially after the plant has been in operation for some time. A second component in tooling wear is adequate lubrication of the tools. Operators should constantly check visually that the tool is being lubricated. In long production runs, the outer dies need to be removed and the inner wear parts cleaned and their lubrication points inspected. After every production run, the tools should be disassembled and inspected.

13.3. Measurements to be taken at Expander



Measurement of pipe dimensions after Expander



Measurement of camber along the entire pipe length

Checking frequency of incoming pipes shall be 5 to 10%, at least three times a shift (beginning, middle, end).

Expander tools and lubrication system shall be inspected regularly to Prevent unforeseen breakdowns.

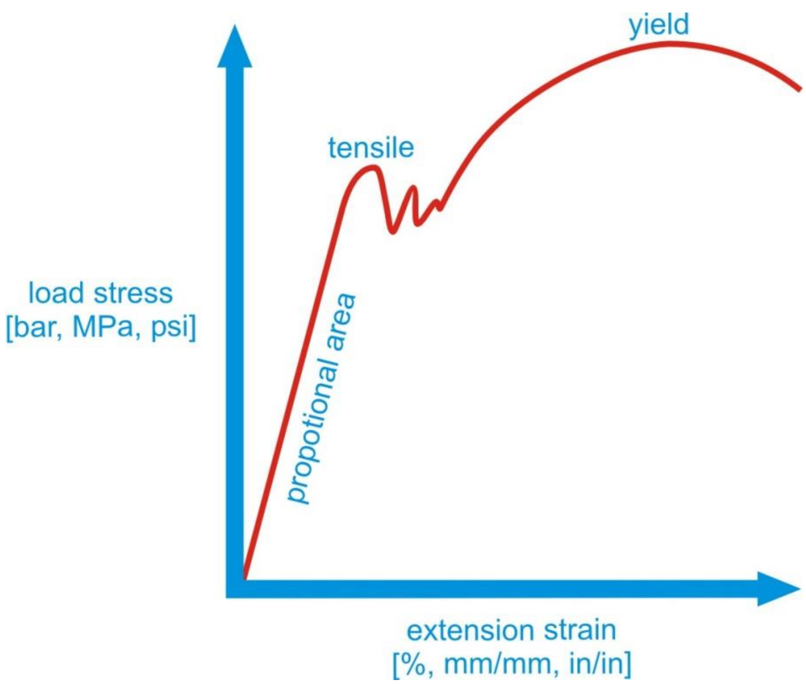
14. Hydrotester

14.1. Process description

API and most pipe specifications require that all pipes be hydrostatically tested without leakage to at least a specified minimum test pressure for a minimum time period (normally 10 seconds). Additionally a recording of the test pressure and time is also required. API requires that the test pressure produce a hoop stress 75-90% depending on the pipe diameter. Some specifications require a hoop stress of 95% or sometimes up to 98%.

14.2. Calculation of test pressures

The basis for hydro testing is based on the typical load-strain curve for low and medium carbon steel depicted below. A typical load-strain curve and the corresponding yield point is shown below [technically the yield point is determined from a 0.2% offset line]. API X-grade pipe designations are based on the specified minimum yield strength (SMYS) as determined from the load-strain curve and yield point as shown on the curve below. For example, X-70 grade pipe signifies a pipe with a specified minimum yield strength of 70,000 psi (483 MPa). If the curve below was from an actual X-70 pipe, the yield point on the left axis would be 70,000 psi (483 MPa) or more.



Typical load-strain curve for carbon steel

The amount of pressure a pipe can withstand is determined by the pipe diameter, pipe thickness, and yield strength. It is calculated using the following hydrostatic stress formula:

in kPA $$P_P = \frac{2000 * s * t}{d}$$ **in psi** $$P_P = \frac{2 * s * t}{d}$$

Unit for 14.1	Symbol	Unit for 14.2
kPA	**P_P** = pressure applied to the pipe	**psi**
MPa	**s** = yield strength	**psi**
mm	**t** = pipe thickness	**inch**
mm	**d** = pipe diameter	**inch**

If a pipe is put under pressure, a stress will be applied and the pipe will actually become larger, proportionally to the pressure applied to the inside of the pipe. Also, as the pressure in the pipe is increased, the pipe will continue to expand in size proportionally to the pressure applied. If the pressure is then reduced to zero, the pipe will return to its original size. This phenomenon is depicted on the load-strain curve as the straight line (proportional area) on the curve. If the pressure of the pipe is increased to the yield point shown on the load-strain curve the pipe will "yield". At or above this yield point the pipe will permanently distort and will not return to its original size. If the actual value of the yield point (yield strength) of a pipe is used in the formula, the resulting calculated pressure is the theoretical pressure at which the pipe will "yield" or distort and not return to its original size when the pressure is reduced to zero.
This yield point (yield strength) of the pipe steel forms the basis from which the designed operating pressure of a pipeline is determined.

As an example, assume a pipe with following dimensions:
d = 914 mm (36 inch)
t = 12.7 mm (0.500 inch)
s = 483 MPa / 70'000 psi (for X-70 steel grade)

Based on the SMYS of an X-70 pipe (70'000 psi or 483 MPa), the yield pressure of the pipe P_P can be calculated in kPA as per one of the formulas given above

$$P_P = \frac{2'000 * 483 * 12.7}{914} = 13'423 kPA$$

Modern pipelines are designed to operate at a pressure P_O of about 70% of this pressure yield:

$$P_O = 13'423 kPA * 0.7 = 9'396 kPA$$

In a pipe mill, the hydro tester is utilized to test that the pipe can withstand a minimum hoop stress resulting from the pressure calculated from the formula above and therefore meets its SMYS.

As stated above Hydrotester pressures are normally between 75 and 90% (depending on wall thickness) of the minimum yield pressure, which is based on the SYMS. For above given pipe with a steel grade X-70 the 90% pressure $P_{90\%}$ is

$$P_{90\%} = 13'423 kPA * 0.9 = 12'080 kPA$$

This is the pressure at which the hydrotester would be set to perform a hydrotest.

To summarize:

Permanent deformation of pipe	P_P	= 13’423 kPA
Pressure test in pipe mill at 90%	$P_{90\%}$	= 12’080 kPA
Pipeline operating pressure 70%	P_O	= 9’396 kPA

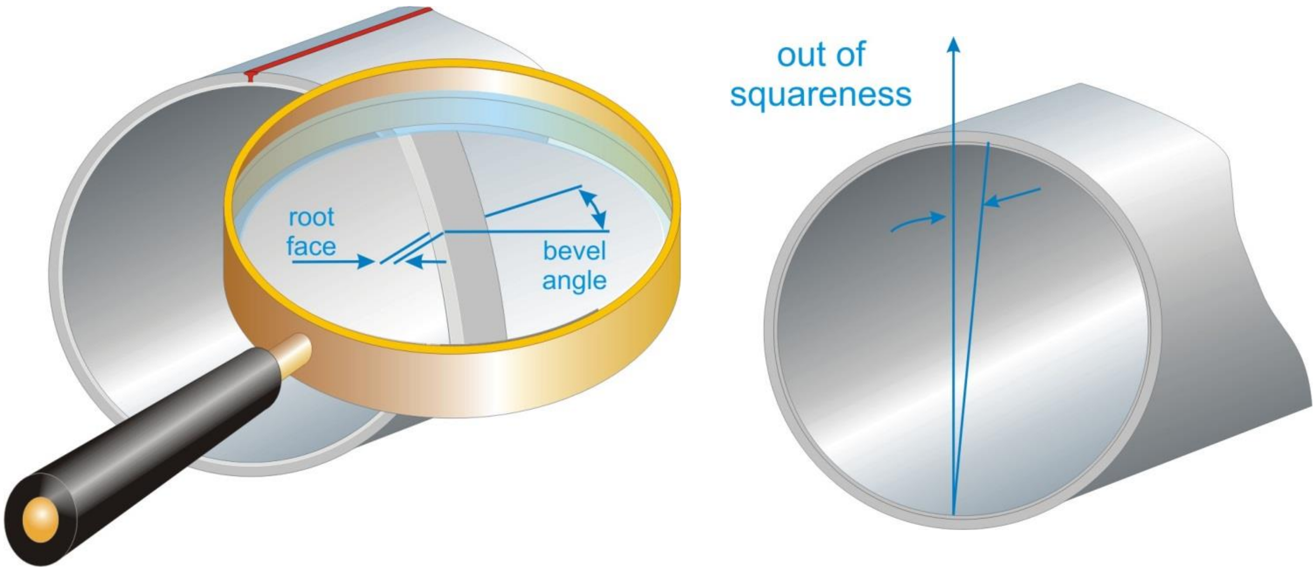
The difference between the pipeline operating pressure and permanent deformation would be the designed safety margin.

15. End Bevelling

15.1. Process description

API and most pipe specifications require that the ends of the pipe be squared and a weld bevel cut to provide for fit up and welding in the field.

General bevel geometry:
Most field welding is done from the outside and therefore the most commonly used type of bevel is the API bevel depicted below. It has a small root face to allow for 100% weld penetration and a single profile angle. Just as weld bevel geometry is a very important factor in welding quality in the pipe mill it is of equal importance to the quality of the field welding the customer will perform, especially if automatic welding is to be done. Of utmost importance is that the weld bevel be consistent, especially the root face.



Bevelling Dimensions acc. API	
Root face	1.6 mm ± 0.8 mm
Bevel angel	30° + 5° / -0°
Out-of-squareness	≤ 1.6 mm

Start-up parameters for End Bevelling dimensions

15.2. Measurements to be taken at End Bevelling

Inspection	Units	Comments
bevel root	*mm*	aim ± 0.5mm API specification
bevel angle	*degrees*	fixed by bevel cutters – verify in initial set up API specification
pipe surface		visual inspection (pass or hold) – report problems

Data for inspection and measuring at End Bevelling

As the shape of pipe end face influences field welding quality, the bevel shall be in same consistent shape as in pipe mill welding.

16. Ultrasonic Testing

16.1. Process description

The primary method in the pipe mill by which the internal soundness of the weld is verified through nondestructive testing (NDT) is with the use of ultrasound to examine the weld metal. The basis of ultrasonic examination is to induce a high frequency sound wave into the metal and analyze the resulting echo to determine if a defect or discontinuity in the steel exists. There is a large amount of literature detailing the theory and application of ultrasonic waves. This manual focuses on how ultrasonic testing is applied and used in the SAW pipe making process.

API specifications and most pipe specifications require that the weld be subjected to a 100% examination by ultrasonic testing. In SAW pipe making, repairs of the weld are allowed. Most pipe specifications dictate that welds cannot be repaired after expansion. For this reason, and along with good operating practice, an ultrasonic test machine is positioned in the process line immediately after welding and before the expansion process. The importance of setting up procedures whereby any defects found by the ultrasonic tester are immediately communicated to production personnel responsible for welding cannot be over stressed. Weld defects need to be identified as to type of defect, location on pipe, and as either an external or internal weld defect. With this information production personnel should determine which weld machine is at fault and begin an examination into the root cause. The sooner this is done the better, especially in the case of intermittently occurring defects.

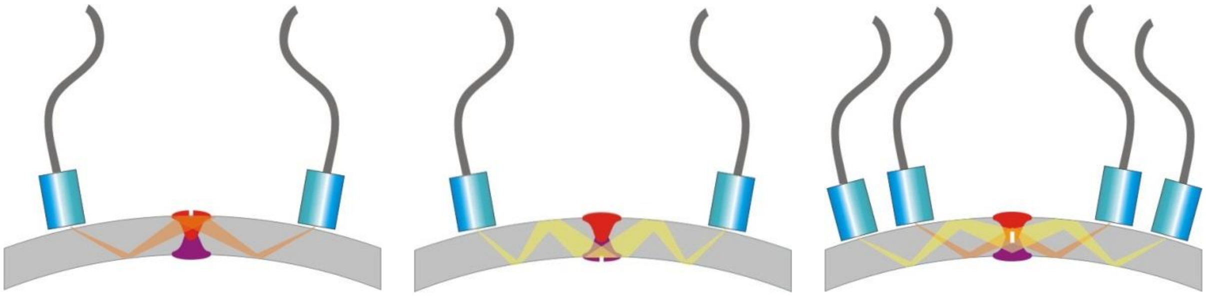
API and other line pipe specifications require the weld be examined after all forming and expansion. For this reason a second ultrasonic test machine is located at the end of the process line. This is the final ultrasonic test which is the final determination as to whether the pipe meets specification or not.

In general, ultrasonic testing is the optimum method for the detection of planar imperfections. The actual procedure and process for the ultrasonic testing of weld seams for the detection of longitudinal and transversal imperfections is beyond the scope of this manual. Specifications for these procedures are covered in ISO 9765. Personnel operating the ultrasonic equipment are required to be certified to ISO 11484 or an equivalent certification. Preparation of NDT procedures and operation of equipment is required to be done under the supervision and responsibility of Level III personnel. Specific NDT procedures must be carried out by Level II or above. Level I personnel can perform NDT examination if done under the direct supervision of Level II personnel.

16.2. Probe arrangements for defect detection

There are several arrangements and geometries available for ultrasonic testing each with its own advantages and weaknesses. Regardless of the equipment and probe arrangement it has to be suitable for covering the entire weld and be capable of detecting defects oriented predominately parallel to and/or at right angles to the weld seam. Testing is done with beams traveling in two opposing directions. The probe angle (standard angles are 45˚, 60˚ and 70˚) has to be chosen to obtain the best result for the wall thickness to diameter ratio of the pipe. Standard frequencies for steel are 2 MHz and 4 MHz. The ultrasonic equipment must have precise weld seam tracking and instrumentation adequate to detect loss of coupling between the sonic probe and the pipe.

Probe arrangements to detect…



…defects on the **Outside** …defects on the **Inside** …defects in the **Middle**

Each transmitter induces an ultrasound in the material. A defect creates a reflection running back to the transmitter. Basing on the time difference between emission and receipt of the reflected ultrasound a visualization unit determines the position of the defect. Compared with an artificial defect (done by calibration) the size of the real defect can be evaluated as well.

Periodic machine calibration (normally a minimum of once a shift) is required using the standard 1.6 mm drilled hole and N5 notch references. Calibrations are normally done statically and then the equipment calibration is verified dynamically. During operation indications recorded by the automatic UT are investigated using radiographic or manual ultrasonic testing to establish if the indication found by the automatic machine is rejectable.

UT I (after welding, repairs allowed) allows detection and verification of welding failures and fast reaction accordingly.

UT II (at the end of process line, no repairs allowed) is required by API.

17. X-Ray Testing

17.1. Process description

As previously stated, the primary method in the pipe mill by which the internal soundness of the weld is verified through nondestructive testing (NDT) is with the use of ultrasound to examine the weld metal. API specifications and most pipe specifications require that the weld be subjected to a 100% NDT examination.

Same as ultrasonic testing, X-Ray I is located after UT I to verify defects found there. In automatic ultrasonic testing, there is a small area near the end of each pipe which is not properly covered by the UT probes and therefore not tested by the ultrasonic test machine. As a result, these pipe end areas are required by API 5L and all most specifications to be examined by radiographic means (X-Ray II). API requires 200 mm of each end of the pipe to be X-rayed. In most gas company specifications repairs within 300 mm of the ends are not allowed. Therefore defects found by end radiography are generally cut off.

The importance of setting up procedures whereby any defects found by the radiographic means are immediately communicated to production personnel responsible for welding cannot be over stressed. Weld defects need to be identified by type of defect, location on pipe, and as either an external or internal weld defect. With this information production personnel should determine which weld machine is causing the problem and begin an examination into the root cause. The sooner this is done the better, especially in the case of intermittently occurring defects.

The actual procedure and process for the radiographic testing of weld seams for the detection of volumetric imperfections is beyond the scope of this manual. Specifications for these procedures are covered in ISO 1106-1, ISO 1027, ISO 2504, ISO 5579, and ISO 5580. Personnel operating the radiographic equipment are required to be certified to ISO 11484 or an equivalent certification. Preparation of NDT procedures and operation of equipment is required to be done under the supervision and responsibility of Level III certified personnel. Specific NDT procedures must be carried out by Level II or above. Level I personnel can perform NDT examination if done under the direct supervision of Level II personnel.

The following pictures and sketches depict common X-ray images and interpretation of the images along with corresponding weld details. Two commonly occurring welding defects detected by X-ray are misalignment and porosity.

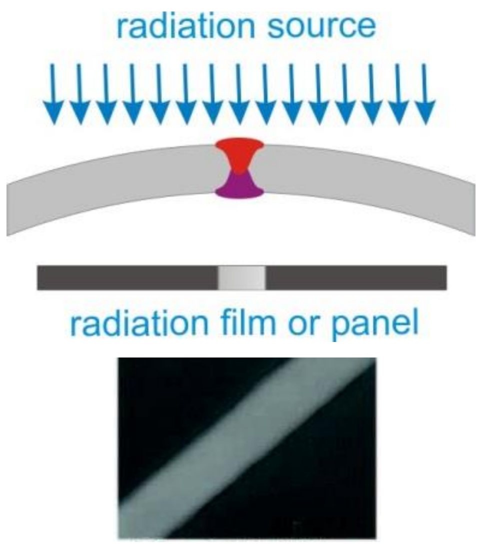
X-Ray I (after UT I) is to verify defects found there and has a purpose of production verification also

X-Ray II is required by API as well and is to test the remaining small areas not tested by UT II.

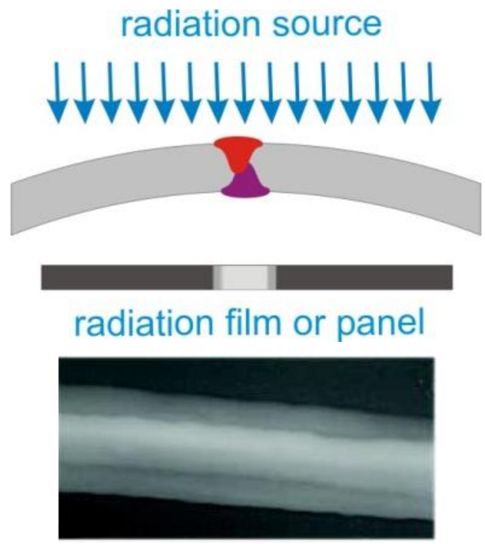
17.2. Interpretation of the radiographic images

Key items to look for during production are Alignment of Welding and Porosity Patterns

Alignment of Welding

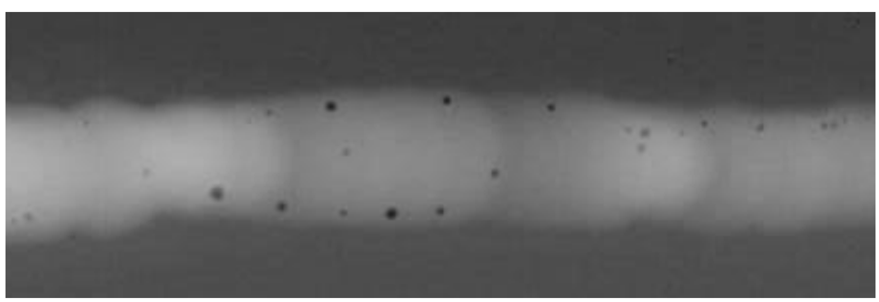


Radiograph of Aligned Welding



Radiograph of Mis-Aligned Welding

Porosity Patterns


Radiography of porous weld toes

18. Final Inspection

After processing, specified visual and dimensional inspections must be made and recorded. API does not specify where the inspections are made: however, most are normally performed at the end of the pipe making process in the final inspection area. Inspections at this point are a Quality Control function and inspectors must be trained as per API 5L as outlined in section 9.7. The accuracy of measuring instruments must be verified as per API 5L section 9.5.

The final inspection procedure and process needs to be designed to give immediate feedback to production. Too often inspections are made and recorded. This report is not available until later. A real time defect reporting system must be put in place. As it applies to any inspection process, timely and real time feedback to production cannot be over emphasized. Below is a list of required inspections.

Item	Where to inspect	What to inspect
1	overall pipe	length
2	overall pipe	straightness
3	both ends pipe body	pipe diameter
4	along weld seam OD	weld area radius (local roundness)
5	both ends pipe body	roundness (min/max)
6	both ends	end square bevel angel bevel land
7	along weld seam ID/OD	weld seam height
8	overall pipe	wall thickness thickness of ground areas
9	overall pipe	visual inspect - inside weld/body - outside weld/body

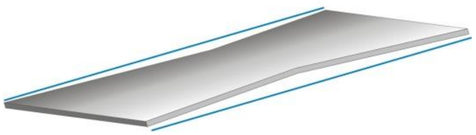
Range of Final Inspections

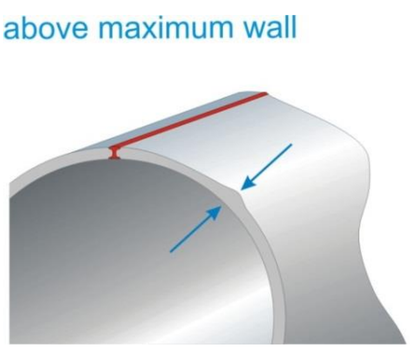
19. Troubleshooting Guide to SAW Pipe Manufacture

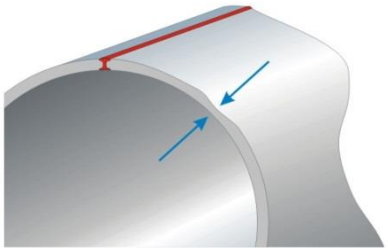
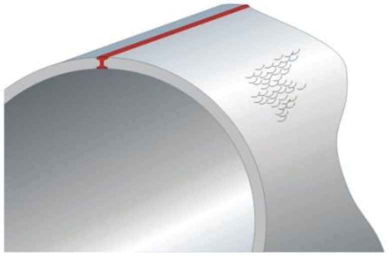
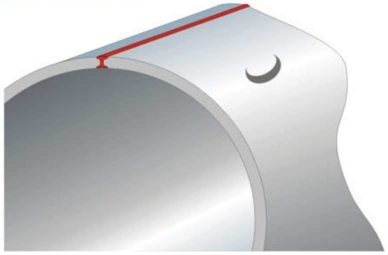
Problem	Suggested Solutions
Out-of-roundness	1. If pipe has poor shape before Expander, reduce vertical diameter coming out of Roll Bender as much as possible. Roll edges of plate deeper. 2. If pipe has poor shape before Expander, increase Post Bending if possible. 3. If pipe shape prior to Expander is good, then check Expander tooling.
Straightness (“banana shape”)	1. Check pipe camber before Expander, if excessive, check Roll Bending to see if it is initiating camber. 2. One Roll Bending technique is to leave a small amount of “canoe” or having the middle of the pipe slightly more open. 3. If the vertical diameter is low, try to increase it. Flat pipe are more susceptible to being bent by the heat of welding. Be careful, in that doing this will affect out-of-roundness. 4. Reduce the heat input during welding if possible. 5. If pipe straightness is good before Expander, check alignment of entry rolls and/or adjust them. 6. Check Expander tooling. Make sure pipe is moving up the Expander boom straight.
Local out-of-roundness	1. Increase the amount bending at Post Bending as much as possible (adjust top roll down). Check that profile in Post Bending roll is still in tolerance and does not have excessive wear. 2. Decrease the vertical diameter coming out of the Roll Bender as much as possible.
Excess Tack Welder bleed through	1. Check for damaged bevels and that the bevel being cut is correct. 2. Make sure closing hydraulic pressure on Tack Welder is sufficient. 3. Examine the pipe to assure that it does not have waviness or excess dips. 4. Increase the root face of the bevel slightly (approximately 0.5 mm). Note this will effect welding: however 0.5 mm will have minimal effect.

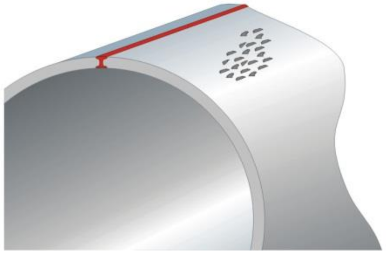
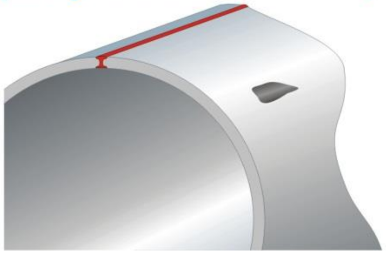
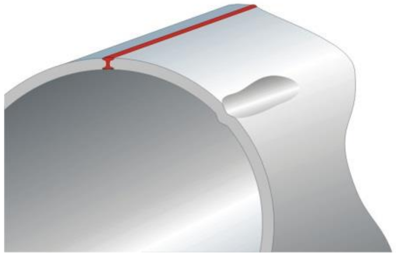
Problem	Suggested Solutions
Burn or blow through at the Internal Welding	1. Check that the Tack Weld is good, there is no bleed through and the bevel is undamaged. 2. Check that the pipe is moving uniformly as it is welded without any hesitation during travel. 3. Lower the welding current on the first wire.
Weld profile too high	1. Decrease the welding current, especially on wires # 2 and # 3. 2. Slow down the welding slightly. 3. Increase the weld bevel angle. 4. Increase the welding speed
Porosity	1. If you have been welding with good results and suddenly you encounter welding porosity, it is normally due to some type of contamination – on the pipe or in the flux. Small amounts of moisture or oil anywhere in the area will cause porosity. 2. Pipe has oil or grease in bevel area. Note that even if the affected area has been wiped clean, unless you use some type of solvent to clean the area, some small residue will remain. 3. Flux has become contaminated or is damp from moisture.

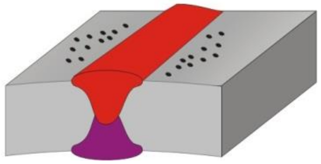
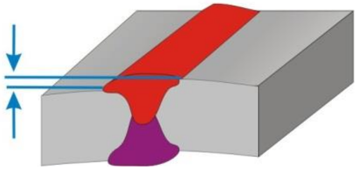
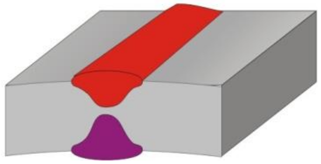
20. Common Defects Chart

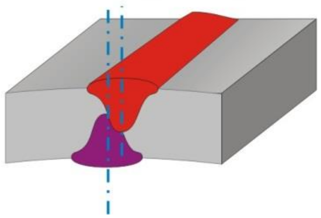
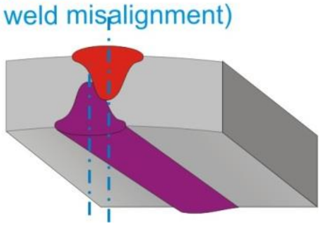
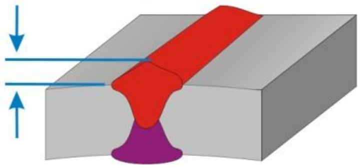
No	Defect Code and Sketch	Detection	Cause	Prevention
1	**SW** scant width 	Visual Inspection	Plate delivered too narrow	Review plate inspection procedures
2	**CP** camber plate 	Visual Inspection	Plate delivered with camber	Review plate inspection procedures
3	**PC** plate crack 	Visual Inspection	Plate delivered with crack	Review plate inspection procedures

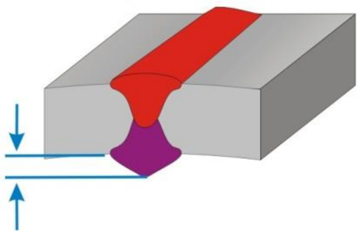
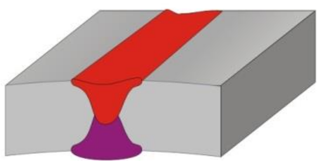
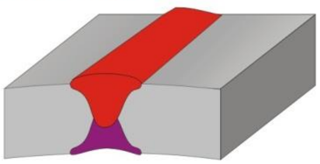
4	**LM** 	NDT or Visual Inspection	Plate delivered with lamination	Review plate inspection procedures If inspected for laminations at plate mill, review plate UT procedures
5	**PD** 	Visual Inspection	Physical damage to plate, normally due to handling Plate delivered with damage	Damaged area can be removed, but plate must meet all dimensional requirements
6	**AMW** 	Visual Inspection	Plate delivered too thick	Review plate inspection procedures

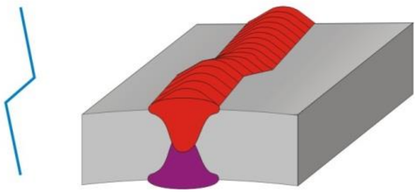
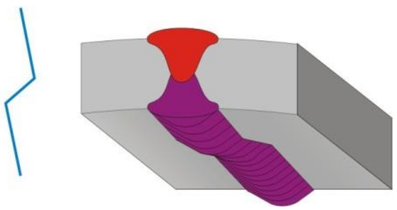
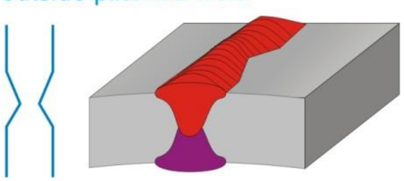
7	**BMW** below maximum wall 	Visual Inspection	Plate delivered too thin	Review plate inspection procedures
8	**SL** slivers 	Visual Inspection	Plate delivered with slivers	Review plate inspection procedures Not considered a defect, but can cause coating problems
9	**SC** scab (surface lamination) 	Visual Inspection	Plate delivered with lamination	Review plate inspection procedures

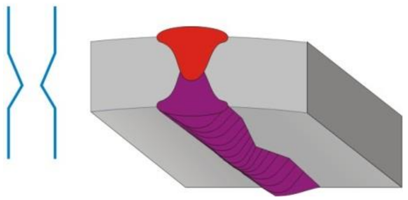
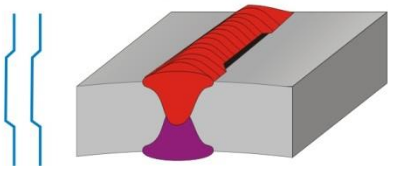
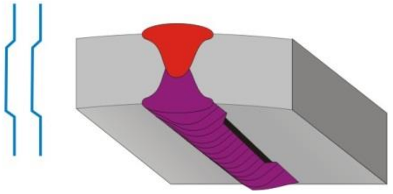
10	**PP** plate pits 	Visual Inspection	Plate delivered with lamination	Review plate inspection procedures
11	**PI** press in (foreign material embedded) 	Visual Inspection	Foreign material on plate prior to roll bending(often metal chips from milling)	Check that air on milling cutter is blowing chips away Plate brush adjusted and working correctly
12	**DT** dent 	Visual Inspection	Somewhere in process skid, kicker or other equipment denting pipe Often due to improper crane handling	Trace process flow back to find source of problem and make correction Operator training

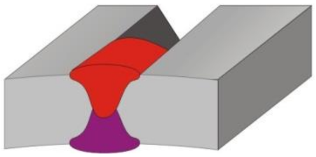
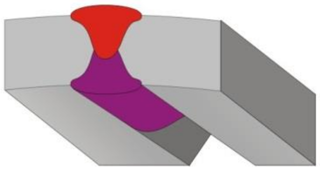
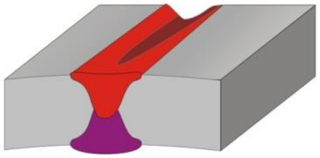
13	**OWS** outside weld spatter 	Visual Inspection	Source is Tack weld MAG	Increase “Ar” in tack weld gas Weld splatter is not defined as a defect, but as a standard of internal mill workmanship should be removed by scraping or light grinding
14	**PEO** plate edge offset (hi-lo) 	Visual Inspection	Poor fit up at tack welder Plate edges not rolled evenly	Adjust tack welder Adjust rolling
15	**LP** lack of penetration 	NDT	Root of bevel too thick Welding speed too high Amps too low (primarily 1^{st} or 2^{nd} wire)	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated

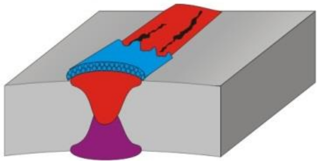
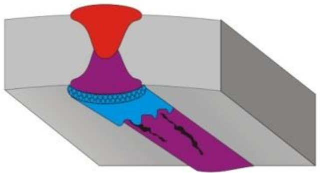
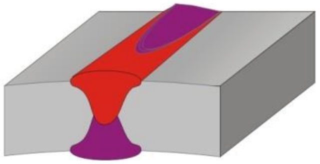
16	**OOS** outside off seam (outside weld misalignment) 	Visual Inspection	OD weld not aligned in middle of seam Weld tracking system not adjusted to center of bevel	Align weld wires to center of bevel Adjust weld tracking system to middle of bevel
17	**IOS** inside off seam (inside weld misalignment) 	Visual Inspection	ID weld not aligned to middle of seam	Align weld wires to middle of bevel
18	**OWH** outside weld cap too high 	Visual Inspection	Improper weld parameters	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Decrease amps on trailing wires Increase welding speed slightly

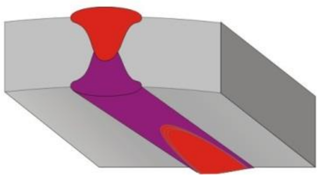
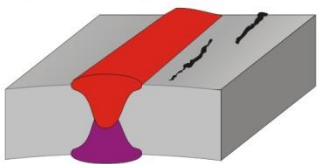
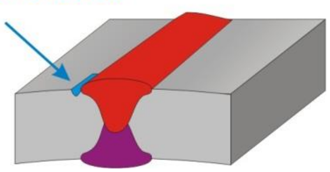
19	**IWH** inside weld cap too high 	Visual Inspection	Improper weld parameters	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Decrease amps on trailing wires Increase welding speed slightly
20	**OLW** outside lack of weld metal 	Visual Inspection	Improper weld parameters	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Increase amps on trailing wires Decrease welding speed slightly
21	**ILW** inside lack of weld metal 	Visual Inspection	Improper weld parameters	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Increase amps on trailing wires Decrease welding speed slightly

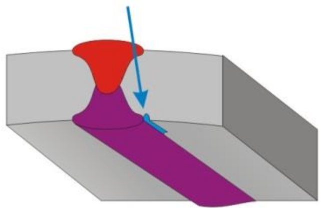
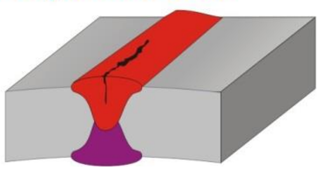
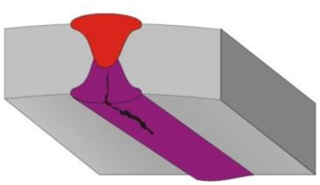
22	**ODL** outside dog leg 	Visual Inspection	Operator error Tracking malfunction	Operator training Check tracking operation
23	**IDL** inside dog leg 	Visual Inspection	Operator error Tracking malfunction	Operator training Check tracking operation
24	**OPW** outside pinched weld 	Visual Inspection	Weld wire not feeding correctly	Check wire feed system Check wire feed drive wheels Check wire feed guide hoses Change weld tip Check wire drum for tangling

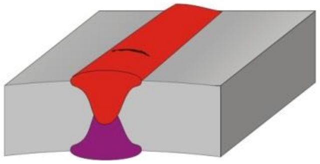
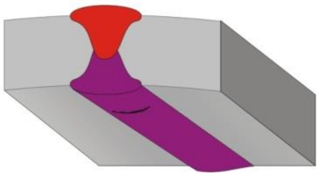
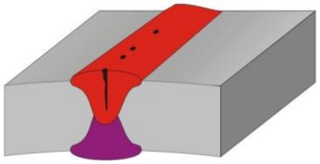
25	**IPW** inside pinched weld 	Visual Inspection	Weld wire not feeding correctly	Check wire feed system Check wire feed drive wheels Check wire feed guide hoses Change weld tip Check wire drum for tangling
26	**OOG** outside out of groove 	Visual Inspection	Operator error Tracking malfunction	Operator training Check tracking operation
27	**IOG** inside out of groove 	Visual Inspection	Operator error Tracking malfunction Inside weld seam not uniform (normally tack weld bleed through) ID guide wheel defective	Operator training Check tracking operation Inspect and repair inside of weld bevel Repair guide wheel

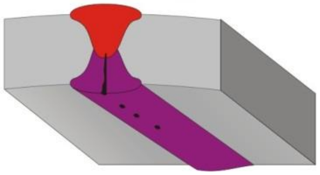
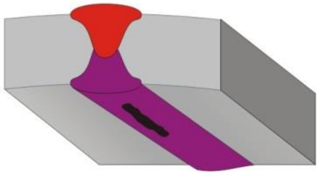
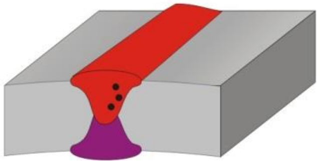
28	**OW** outside wire stop (outside weld crater) 	Visual Inspection	Welding stopped during welding process Weld wire not feeding correctly	Check wire feed system Check wire feed drive wheels Check wire feed guide hoses Change weld tip Check wire drum for tangling
29	**IW** inside wire stop (inside weld crater) 	Visual Inspection	Welding stopped during welding process Weld wire not feeding correctly	Check wire feed system Check wire feed drive wheels Check wire feed guide hoses Change weld tip Check wire drum for tangling
30	**EC** end crater 	Visual Inspection	Welding stopped during welding process Weld wire not feeding correctly	Check wire feed system Check wire feed drive wheels Check wire feed guide hoses Change weld tip Check wire drum for tangling

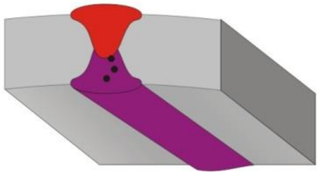
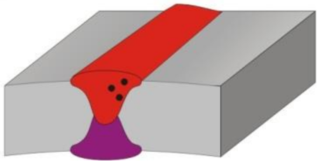
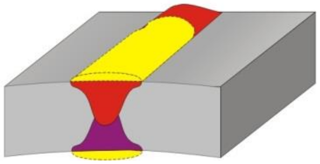
31	**OFS** outside flux stop 	Visual Inspection	Blockage in flux system Flux tank empty	Check flux system for blockage Add flux
32	**IFS** inside flux stop 	Visual Inspection	Blockage in flux system Flux tank empty	Check flux system for blockage Add flux
33	**ORS** outside restart (weld overlap) 	Visual Inspection	Welding stopped during welding process Weld wire not feeding correctly	Check wire feed system Check wire feed drive wheels Check wire feed guide hoses Change weld tip Check wire drum for tangling

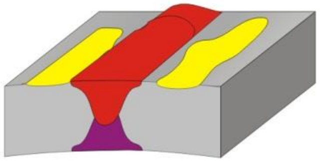
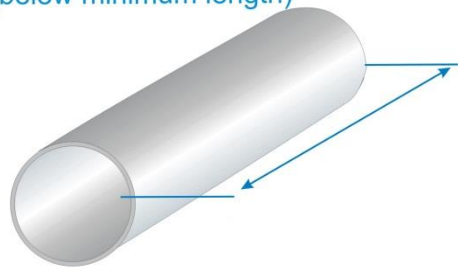
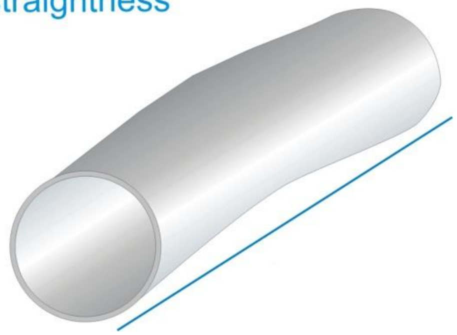
34	**IRS** inside restart (weld overlap) 	Visual Inspection	Welding stopped during welding process Weld wire not feeding correctly	Check wire feed system Check wire feed drive wheels Check wire feed guide hoses Change weld tip Check wire drum for tangling
35	**AB** arc burn (weld burn) 	Visual Inspection	Ground brushes have poor contact Manual welding torch or ground has contacted pipe due to operator error	Maintain ground brushes – change when worn Operator training
36	**OUC** outside undercut 	NDT or Visual Inspection	Weld speed too high Not enough filler metal applied Too many fine particles in flux	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Reduce weld speed Increase amps on trailing wires Test flux for excess fine particles - change flux

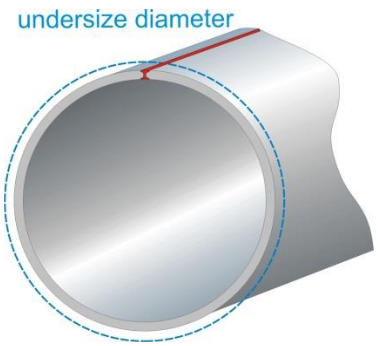
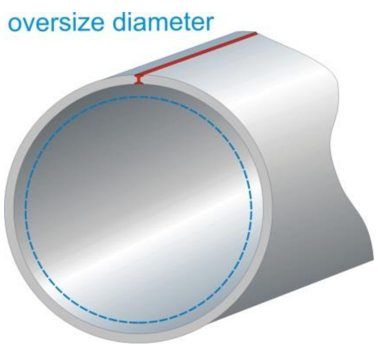
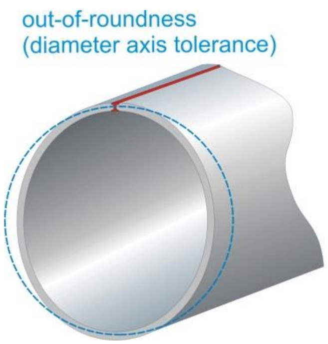
37	**IUC** inside undercut 	NDT or Visual Inspection	Weld speed too high Not enough filler metal applied Too many fine particles in flux	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Reduce weld speed Increase amps on trailing wires Test flux for excess fine particles - change flux
38	**OLC** outside longitudinal crack 	NDT or Visual Inspection	Cracks can be caused from numerous sources varying from heat, material, segregation, microstructure, hydrogen sources and stress. Common causes are: High cooling rate Weld width to depth too high Hydrogen assisted crack	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Increase weld profile width to depth ratio 1:1 to 1.4:1 Reduce sources of hydrogen: moisture in flux, contamination in bevel
39	**ILC** inside longitudinal crack 	NDT or Visual Inspection	Cracks can be caused from numerous sources varying from heat, material, segregation, microstructure, hydrogen sources and stress. Common causes are: High cooling rate Weld width to depth too high Hydrogen assisted crack Material assisted crack	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Increase weld profile width to depth ratio 1:1 to 1.4:1 Reduce sources of hydrogen: moisture in flux, contamination in bevel

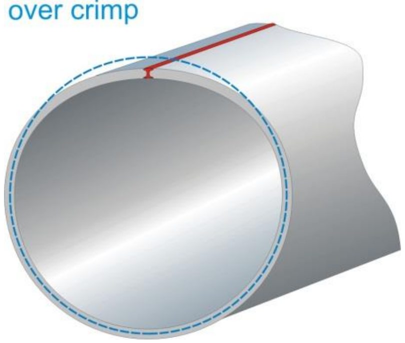
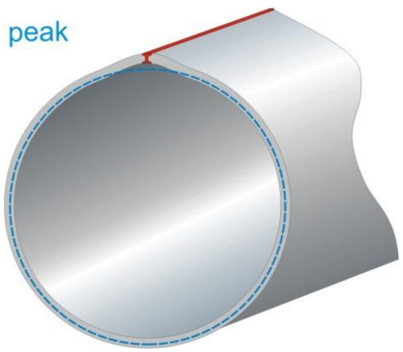
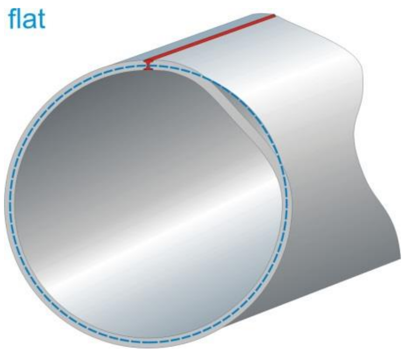
40	**OTC** outside transverse crack 	NDT or Visual Inspection	Cracks can be caused from numerous sources varying from heat, material, segregation, microstructure, hydrogen sources and stress. Common causes are: High cooling rate Weld width to depth too high Hydrogen assisted crack	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Increase weld profile width to depth ratio 1:1 to 1.4:1 Reduce sources of hydrogen: moisture in flux, contamination in bevel
41	**ITC** Inside transverse crack 	NDT or Visual Inspection	Cracks can be caused from numerous sources varying from heat, material, segregation, microstructure, hydrogen sources and stress. Common causes are: High cooling rate Weld width to depth too high Hydrogen assisted crack	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Increase weld profile width to depth ratio 1:1 to 1.4:1 Reduce sources of hydrogen: moisture in flux, contamination in bevel
42	**OPH** outside pinhole (outside visual porosity) 	NDT or Visual Inspection	High cooling rate Weld width to depth too high Hydrogen assisted crack	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Increase weld profile width to depth ratio 1:1 to 1.4:1 Reduce sources of hydrogen: moisture in flux, contamination in bevel

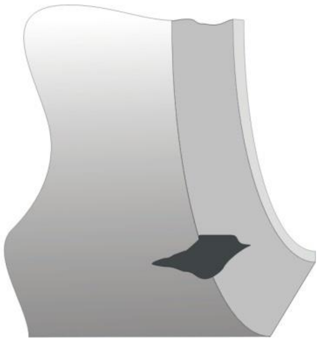
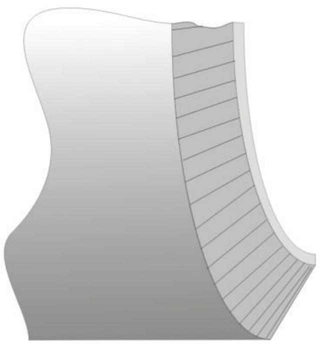
43	**IPH** inside pinhole (outside visual porosity) 	NDT or Visual Inspection	High cooling rate Weld width to depth too high Hydrogen assisted crack	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Increase weld profile width to depth ratio 1:1 to 1.4:1 Reduce sources of hydrogen: moisture in flux, contamination in bevel
44	**BT** burn through 	Visual Inspection	Root of bevel too thin Welding speed too low Amps too high (primarily 1st or 2nd wire) Tack weld fit up poor Poor tack weld	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Inspect that tack weld is sound
45	**OSG** outside slag (inclusion) 	NDT	Contamination in flux Welding too fast for amperage-weld cooling too quick	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Check and/or change flux

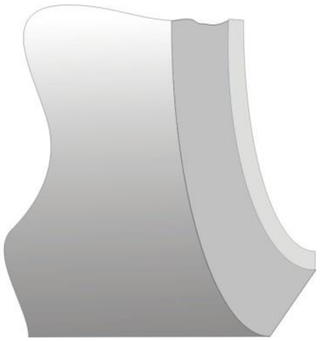
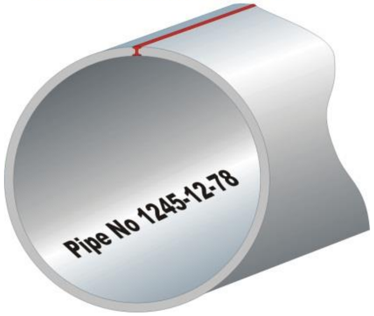
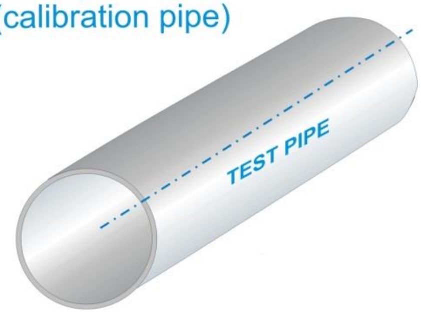
46	**ISG** inside slag (inclusion) 	NDT	Contamination in flux Welding too fast for amperage-weld cooling too quick	Assure welding parameters are within those set by WPS Devices for measurement of parameters should be calibrated Check and/or change flux
47	**PO** porosity 	NDT or Visual Inspection	Contamination of bevel often due to moisture, oil or grease. Moisture or other contamination in flux	Weld bevel kept clean Proper handling and storage of flux
48	**WRN** weld reinforcement not removed 	Visual Inspection	Normally removed per API or customer specification Operator error	Operator training

49	**EG** excessive grind 	Visual Inspection	Operator error – grinding too deep	Operator training
50	**SP** short pipe (below minimum length) 	Visual Inspection	Pipe normally was cut off due to a non-repairable defect	Determine reason for cut off and correct if feasible with objective to prevent future occurrence
51	**ST** straightness 	Visual Inspection	Pipe rolled with poor shape and camber Wrong adjustment of Post Bending Expander process not correcting straightness	Assure process parameters for each rolling, post bend, and expander are sufficient and being followed Adjust rolling, post bend as needed Adjust expander straightening device

52	**US**  	Visual Inspection	Plate milled width too small Not enough expansion	Increase plate milled width Increase expansion
53	**OS**  	Visual Inspection	Plate milled width too large Insufficient expansion	Decrease plate milled width Decrease expansion
54	**OR**  	Visual Inspection	Pipe rolled with poor shape Expander process not correcting roundness	Assure process parameters for each rolling, post bend, and expander are sufficient and being followed Adjust rolling and expander as needed May have to increase expansion

55	**OC** over crimp 	Visual Inspection	Pipe rolled with poor shape and camber Too much Post Bending causing over crimped edges Expander process not correcting straightness	Assure process parameters for each rolling, post bend, and expander are sufficient and being followed Adjust rolling, post bend as needed May have to increase expansion
56	**PK** peak 	Visual Inspection	Pipe rolled with poor shape and camber Less Post Bending causing peak Expander process not correcting straightness	Assure process parameters for each rolling, post bend, and expander are sufficient and being followed Adjust rolling, post bend as needed May have to increase expansion
57	**FL** flat 	Visual Inspection	Pipe rolled with poor shape Insufficient post bend Expander process not correcting	Assure process parameters for each rolling, post bend, and expander are sufficient and being followed Adjust rolling, post bend as needed May have to increase expansion

58	**BD** 	Visual Inspection	Improper pipe handling (normally caused by two pipe hitting)	Operator training
59	**CH** 	Visual Inspection	End bevel machine tooling worn or not adjusted correctly. Beveling speed too fast	Check adjust or repair end bevel tooling
60	**TNR** 	Visual Inspection	Beveling land tool not adjusted properly	Adjust beveling land tool

61	**TKR** thick root 	Visual Inspection	Beveling land tool not adjusted properly	Adjust beveling land tool
62	**NN** number not readable  	Visual Inspection	Normally operator error – number not applied properly	Operator training
63	**TP** test pipe (calibration pipe)  	Internal mill test pipe used for calibrating or setting up machines. Pipe not for delivery to customer		

64	**RR** **Repair of Repair**		Improper weld repair	Repair welder training
65	**OIL** **Oil**	Visual Inspection	Oil or grease comes in contact with pipe	Find source of oil or grease – hydraulic leak, crane gearbox leaking oil
66	**RT** **Return To (see action)**	Pipe to be returned to mill for further processing		
67	**MR** **Mill Reject**	Pipe rejected and disposed of as nonconforming product		
68	**LTF** **Lab Test failure**	Pipe has failed lab test – hold or dispose of as nonconforming product		
69	**WTF** **Weld Test Failure**	Pipe has failed welding test – hold or dispose of as nonconforming product		
69	**PF** **Pipe Failure**	Pipe rejected due to Hydrotester or Expander failure and disposed of as nonconforming product		

List of Abbreviations

Abbreviation	Definition
API	American Petrol Institute
AWS	American Welding Society
CNC	Computerized Numerical Control
GMAW	Gas Metal Arc Welding
hi-lo	High-Low (describes a radial edge offset at Tack Welder)
ID	Inside Diameter
ISO	International Organization for Standardization
LSAW	Longitudinal Submerged Arc Welding
MAG Welding	Metal Active Gas Welding
NDT	Nondestructive Testing
OD	Outside Diameter
OEM	Original Equipment Manufacturer
SAW	Submerge Arc Welding
SMYS	Specified Minimum Yield Strength
WPS	Welding Parameter Setting

HAEUSLER

the forming factory

PLATE BENDING

PROFILE BENDING

SPECIAL FORMING

ASSEMBLING EQUIPMENT

PRODUCTION LINES

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