Electric Resistance Welded Pipe (ERW)

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ERW AS A RISK OR THREAT CONSIDERATION

- In a lot of cases operators tend to lump all longitudinal seam pipe into one category as ERW, such as submerged arc welded (SAW) pipe; which would include single submerged arc welded (SSAW) and double submerged arc welded (DSAW) seams.
- Through just a cursory visual inspection it is difficult to make the distinction between any of these longitudinal seams.
- The seam of SAW line pipe has a slightly visible cap remaining at the outside diameter (OD) making it easier to locate, were ERW line pipe's seam is difficult to find, and can easily be mistaken for seamless.

ERW AS A RISK OR THREAT CONSIDERATION

There still exists some older pipelines in service with single submerged arc welded (SSAW) seams. However most common here of late is the double submerged arc welded (DSAW) pipe in larger diameter pipe, and is also the process used for the seam of the now newly popular spiral wound pipe.

ERW AS A RISK OR THREAT CONSIDERATION

Although the anomalies found in any longitudinal seam are synonymous to all types, some of these anomalies are more prevalent in one type than some of the others.

While ERW has a fused seam of the same material and does not use filler material for achieving a weld, a SAW pipe seam does, so for a couple of examples:

- low or high frequency during the seam welding process has not been an issue with the SAW seam, and
- lack of fusion or hook cracks are generally more common in the SAW seams than the ERW

Again, these are anomalies that may exist in both processes, but will be found more often in one than the other - just because of the differences in their manufacturing processes.

ERW AS A RISK OR THREAT CONSIDERATION

Should a determination be made that longitudinal seam failure is a threat or a risk, what would be the preventative and mitigative measures needed?

This question tends to have an effect on how some operators consider the possibility of seam issues as a threat or risk.

This seems to be a "can of worms" that is really not wanted to be opened.

ERW AS A RISK OR THREAT CONSIDERATION

Pressure testing is an acceptable assessment method for longitudinal seam risks or threats since it will find those anomalies that will fail at the higher pressure.

However, it will not give any indications of lesser anomalies that may exist, subject to later fail, or where they may be located.

ERW AS A RISK OR THREAT CONSIDERATION

Most operators who pressure test for this threat tend to do so only because it satisfies the rule requirements. It Is sometimes disappointing that some operators really do not feel they have a potential seam failure issue, or really are of the opinion that this is all that is needed to resolve further risk assessment of this particular risk or threat.

ERW AS A RISK OR THREAT CONSIDERATION

- The reality is that some forethought or investigation prior to determining an assessment tool for this threat or risk would certainly be a more effective means for dealing with these issues. And of course, if material testing reports (MTR) for the pipe (including the skelp) are available that would be a very good start in this process.
- Not all anomalies found need to be cut out; if it is well understood what these anomalies are, or how they came to be, in some cases just removing them from the environment would be all that is needed.

ERW AS A RISK OR THREAT CONSIDERATION

Should an operator have a pipeline of 1940 or 1950 vintage that has not experienced any documented seam issues, then the operator tends to feel safe in assuming that seam issues are of little, or no consequence, and to consider it a threat or risk is not necessary.

And some operators whose ERW pipeline is post 1970 feel this fact also eliminates any considerations of seam failure as a real risk.

ERW AS A RISK OR THREAT CONSIDERATION

Sadly, research papers and other documentation seem to support this, if taken at face value. Of course there are other considerations that need to be taken into account, and are generally mentioned within these same documents, but some operators choose to accept this one factor as an end-all to seam failure concerns, and so ends the need for further risk considerations.

ERW AS A RISK OR THREAT CONSIDERATION

There have been occasions, both recent and past where operators have had seam failures during pressure testing of a newly installed ERW pipeline, just prior to commissioning. The failures were repaired, the pipe manufacture sued, and the pipeline is put into service with seam failure not considered to be a risk.

Again the thinking here is that it finally passed a pressure test, and all anomalies were repaired, so risk of another failure due to seam problems are not a high risk or threat.

ERW AS A RISK OR THREAT CONSIDERATION

There are other operators who have eventually abandoned pipelines or sold them to be used in lesser service because of seam issues. Most of these instances are only known to us when these systems become scheduled for inspections or safety audits.

A lot of these cases would bear very valuable fruits if particulars were better documented and shared with the rest of the industry, and in a lot cases they are not.

ERW AS A RISK OR THREAT CONSIDERATION

Few operators consider ERW pipe seam issues as high risk or threats as a result of their overall *Risk Assessment* process. For various reasons, and just to name a few of the more common ones:

- First off, there are higher threats to consider (third party damage, internal and external corrosion, etc.)
- Lack of past failures due to seam issues
- While pressure testing, for whatever reason, little is recorded as to how many repairs were needed, or the reason for any failures to finally achieve a successful test, and
- Since failures that have occurred were repaired - the threat is thought to be eliminated.

ERW AS A RISK OR THREAT CONSIDERATION

Currently the most telling and informative means for assessing the threat of seam failures are new sophisticated inline inspection tools capable of detecting seam anomalies in the longitudinal plane of the pipeline.

However, with that said, the tool used is only as good as the analyst who is to Interpret the data.

Thank You!

Additional Slides

Inherent Problems with ERW Pipe

Momentary reductions of current or forming the seam too fast could sometimes result in isolated or repeated areas of non-bonding called "**cold welds**". Cold welds can occur in small areas, or all of the way through the finished seam. Even if a through-wall cold weld was formed, it may exist without ever resulting in a leak. However, a significant number of cold welds in close proximity could sufficiently reduce the strength of the fused surfaces potentially resulting in a rupture when the pipe is subjected to pressurization.

Inherent Problems with ERW Pipe

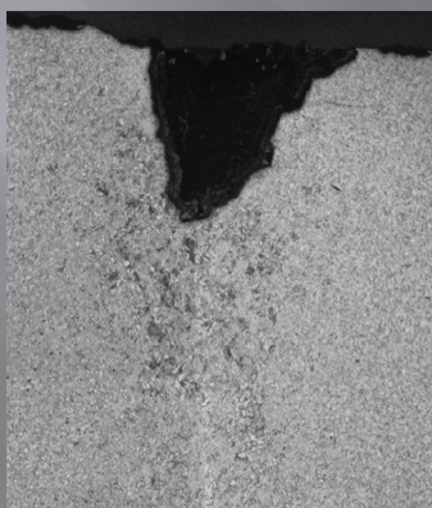
Running skelp too fast through an AC welder could sometimes cause the heat to fluctuate with the current cycle resulting in a periodic variation in properties along the seam. The resulting pattern is referred to as "**stitching**". A stitched weld does not necessarily create a pipeline-integrity problem in itself, but coupled with another defect could start a fracture in the stitched fused surfaces. A stitched fused surface is generally characterized by low toughness, and only a small defect may be all that is needed to start a fracture.

Inherent Problems with ERW Pipe

Poorly trimmed skelp may contain **edge defects** that end up on the fused surfaces. Cambered or twisted skelp can also result in offset edges at the fused surfaces. The offset can be significant in some cases, sometimes reducing the net thickness by as much as ***30 to 40*** percent in extreme cases.

Offset edges are seldom caught by visual inspection because the outside surface trim tool removes the excess material only from one side leaving the visible mismatch at the ID surface making it difficult to detect by visual inspection.

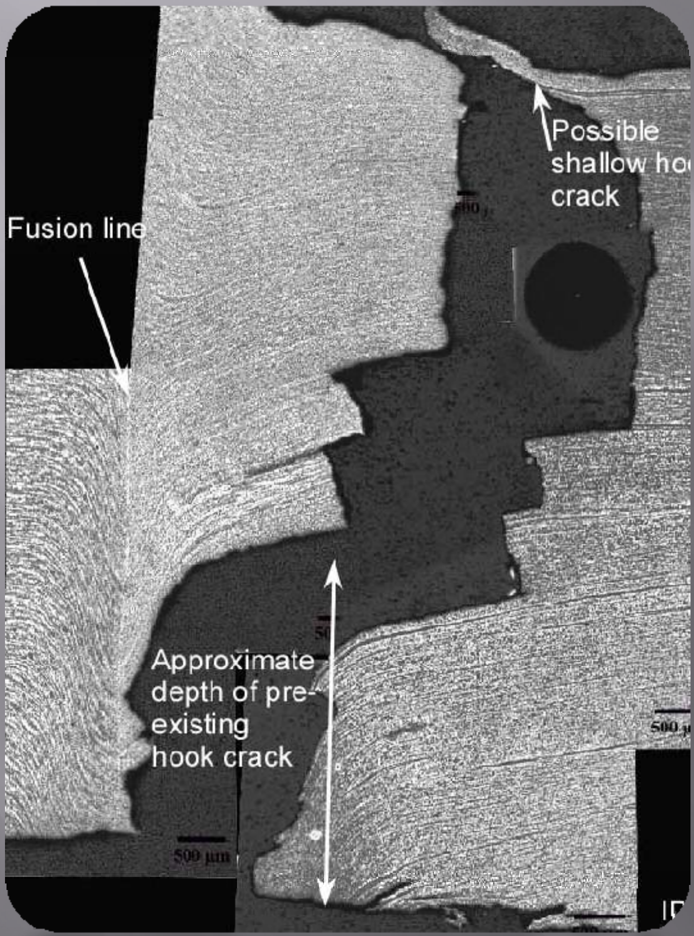
Grooving corrosion at an ERW longitudinal seam



The variation in microstructure between the base metal and the heat affected zone (HAZ) may create minor localized galvanic differences, with the seam structure being more anodic.

The microstructure and chemistry of the steel was typical of the vintage and grade and the chemistry met the API 5L specifications in place at the time of manufacture.

Hook Crack Failure



The analysis for this failure indicated that the rupture initiated at an ID connected pre-existing hook crack. This and all hook cracks are slightly offset from the bond line of the ERW seam.

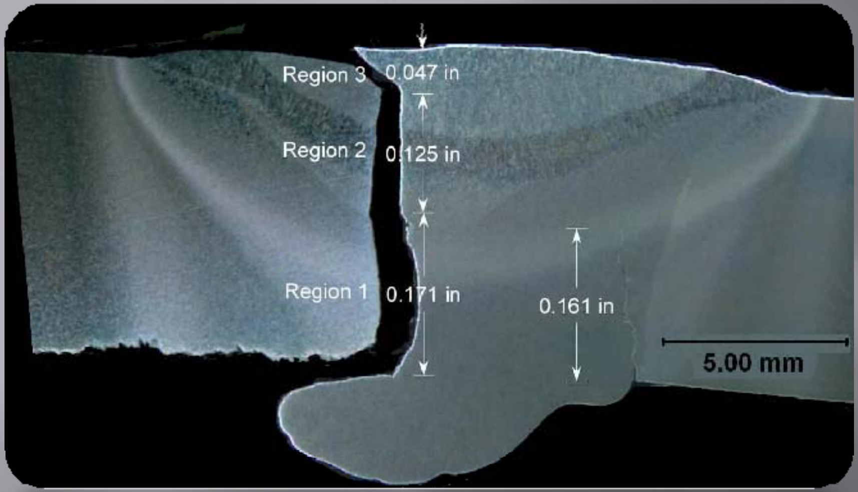
No evidence of in-service growth by fatigue was found, although the quality of the image is poor as a result of corrosion of the fracture surfaces that occurred after the ruptures.

Hook Crack Failure

There was no evidence of external corrosion of the pipe section, which indicates that the coating was intact prior to the rupture and was removed by the rupture or by subsequent handling.

The pre-existing hook crack that was surface breaking on the ID surface was evident on the fracture surface. The hook crack was approximately forty-four inches in length, with a maximum depth of 40% of the wall thickness.

Lack Of Fusion



The sample analysis indicated that the rupture initiated at an ID surface breaking lack-of-fusion (LOF) defect that was located at the root of the SSAW seam. The LOF defect was one of three regions observed on the fracture surface at the failure origin.

The three regions were: a smooth and relatively featureless region near the ID surface that was;

- Region 1 - LOF defect ,
- Region 2 - a mid-wall region that contained fatigue striations, and
- Region 3 - an overload region produced by the final failure.

Region 3 was ductile in nature at the deepest portion of the flaw and located adjacent to the OD surface.

Credits

1. J. F. Kiefner and E. B. Clark, "An ASME Research Report: History of Line Pipe Manufacturing in North America," CRTD-Volume 43, 1996.
2. P. G. Fazzini, J. C. Belmonte, M. D. Chapettie, and J. L. Otegui, "Fatigue Assessment of a Double Submerged Arc Welded Gas Pipeline," *International Journal of Fatigue*, **29** 1115-24 (2007).
3. API Specification 5L, 42nd edition, July 1, 2000.
4. Lu Shuanlu, Han Yong, Qin Changyi, Yuan Pengbin, Zhao Xinwei, and Luo Jinheng, "Crack and Fitness-for-Service Assessment of ERW Crude Oil Pipeline," *Engineering Failure Analysis*, **13** 565-71 (2006).
5. M. D. Chapettie, J. L. Otegui, and J. Motylicki, "Fatigue Assessment of an Electrical Resistance Weld Oil Pipeline," *International Journal of Fatigue*, **24** 21-28 (2002).
6. ASM: "Principles of Failure Analysis: Glossary of Failure Analysis Terms."

High Resistance ERW Pipe

With the use of high-frequency current, the problem of contact resistance is virtually now nonexistent. As a result, high-frequency-welded pipe tends to be relatively free of the fused surface defects that were common in the low-frequency and DC-welded material.

The performance of ERW materials has improved steadily with time. The number of test failures per mile decreased from levels as high as **6.5 per mile** in the 1940s to a level of **0.01 per mile** in 1970 for pipelines tested to levels of 90 percent of SMYS or more.

The Making of ERW

Electric welding is a process of forming a seam by electric-resistance or electric-induction welding wherein the edges to be welded are mechanically pressed together and the heat for welding is generated by the resistance to flow of the electric current.

The Making of ERW

Early seam welding was done using two electrodes, usually made from copper, to apply both pressure and current while producing the weld. These early electrodes were disc shaped and rotated as the material passed between them. Because they were rotating discs it allowed the electrodes to stay in constant contact with the material while making a long continuous weld. The process has evolved now to where the seam is pressed and held together mechanically rather than using the electrodes for double duties.

The Making of ERW

The contact surfaces of the work piece has high electrical resistance relative to the rest of the circuit and is heated to its melting point by the current. The semi-molten surfaces are pressed together with enough pressure that a fusion bond is created, resulting in a uniformly welded structure.

The Making of ERW

The upside of using this seam welding process is that it produces an extremely durable weld because the joint is forged due to the heat and pressure applied. A properly welded joint formed by resistance welding is like other welded seams or joints, in that it is typically stronger than the material from which it is formed.

A General History of Pipelining and ERW

Over the past several decades, U.S. Pipe manufacturing, construction practices and corrosion protection technology have implemented significant improvements. The following is an outline of those advancements.

A General History of Pipelining and ERW

1930's

- Before the 1930's what pipe that was available was generally laid bare with little protection against external corrosion
- Electric arc welding arrives on the scene and is used to join pipe segments - a great improvement over other joining techniques employed earlier
- 1935: ASME code B31.8 was issued, providing consensus standards for newly constructed pipelines

A General History of Pipelining and ERW

1940's:

- Cathodic protection is beginning to be more widely used for newly constructed pipelines
- Use of radiography as nondestructive examination (NDE) of welds is first used
- Use of Welder qualification and welding standards became general practice
- Hydrostatic pressure testing began in the late 1940's

A General History of Pipelining and ERW

1950's:

- CP is now becoming more widely used and is being applied to not only newly constructed pipelines, but older pipelines as well
- Hydrostatic pressure testing becomes a more common practice

A General History of Pipelining and ERW

1960's

- improved low-carbon and alloy steel are starting to be produced
- Transition from low frequency to high frequency electric resistance welds during 1965-1970
- Hydrostatic testing becomes mandatory with the Pipeline Safety Act in 1968
- ASME B31.8 is updated, and its use also becomes mandatory by the Pipeline Safety Act in 1968
- API 5L required NDE of longitudinal seam welds By the late 1960's
- API 5L requires Normalizing of the longitudinal weld during the early 1970's

PHMSA ERW Pipe Related Actions

January 1988 – The Office of Pipeline Safety (OPS) Alert Notice to natural gas transmission and hazardous liquid pipeline operators to reevaluate pre-1970 ERW pipe, and to consider hydrostatic testing

March 1989 - OPS issued a second Alert Notice reiterating the 1988 Alert Notice recommendations on hydrostatic testing and corrosion control for pre-1970 ERW pipe.

Other Improvements of ERW Pipe

It should be noted that not only has the ERW process itself improved, but cleaner, tougher steels have been developed such as:

- continuous casting,
- Micro-alloying, and
- Thermo-mechanical processing.

These trends have virtually eliminated three potential problems associated with ERW seams:

- low-heat-affected-zone toughness,
- hook cracks,
- and grooving corrosion.

Testing of ERW Pipe

Hydrostatic Testing

API, Recommended Practice for the Pressure Testing of Liquid Petroleum Pipelines, RP1110 (API RP1110) defines hydrostatic testing as "the application of internal pressure above the normal or maximum operating pressure to a segment of pipeline, under no-flow conditions, for a fixed period of time, utilizing a liquid medium."

Hydrostatic testing is usually conducted at a minimum of 125 percent of the MOP of the line and a minimum duration of 8 hours.

Testing of ERW Pipe

Dynamic Testing

Dynamic testing is defined in API RP1110 as "the application of pressure to a segment of an operating pipeline above normal operating pressure under flowing conditions for a fixed period of time, utilizing a liquid normally handled through the line."

Dynamic testing is usually limited to 110 percent of the MOP of the line and a minimum duration of 2 hours.

Testing of ERW Pipe

Spike Testing

Spike testing is similar to hydrostatic testing in that it would normally be conducted using water as the test medium under no-flow conditions. It has been recommended that spike tests be conducted at the highest possible pressure, frequently 139 percent of the MOP of the line based on the ratio of 100 percent of SMYS to 72 percent SMYS (maximum hoop stress), with a very short duration, usually not more than ½ hour.

PHMSA ERW Pipe Related Actions

Hazardous liquid pipeline safety regulations, from inception in 1970, required all newly constructed pipelines and pipelines that have been replaced, relocated or otherwise changed to be **hydrostatically tested to at least 125 percent of their maximum operating pressure**

PHMSA ERW Pipe Related Actions

Beginning in 1994, OPS issued a series of amendments to the hazardous liquid pipelines safety regulations, requiring pipelines that were constructed before the effective date of the regulations that had not been tested to 125 percent above their MOP **to be so tested**.

PHMSA ERW Pipe Related Actions

Later, OPS issued a risk-based alternate rule which allows operators to elect an approach that takes into account certain risk factors in evaluating the integrity of these hazardous liquid pipelines. All pre-70 ERW pipe in high and medium risk areas that is not reduced in MOP had to be tested by December 2000; all such pipe in low risk areas had to be tested by December 2002.