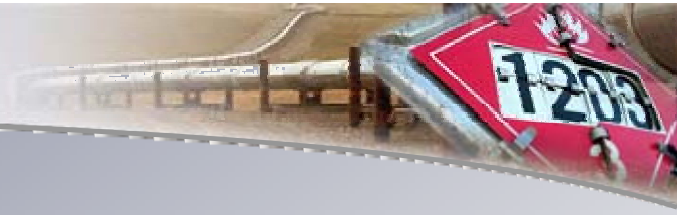


T&Q Pipeline Safety Seminar

High Grade Pipe and Construction Issues

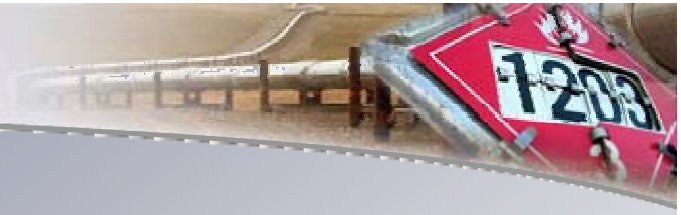
US DOT, PHMSA, Southwest Region

John W. Pepper

Project Manager

New Orleans, La.

July 2009

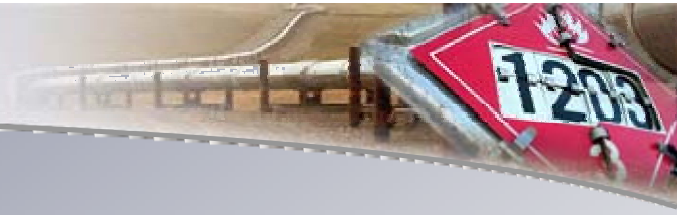


High Grade Pipe Materials & Inspection Observations

1. Positive Observations
2. Pipe Manufacturing Findings
3. Quality Materials
4. Quality Assurance / Inspection
5. Problem Identification – In Service Pipelines
6. Conclusions

Positive Observations (Data Driven)

- **Parallel construction – existing pipelines and power lines**
  - **Few incidents**
- **Pipeline Safety Cooperation**
  - **Operators worked with PHMSA to ensure pipeline safety**
- **MAOP Rule / Special Permit**
  - **Finding low yield strength pipe**
- **DCVG Surveys**
  - **Used on many recent projects**
  - **Finding coating and pipe damage**
- **Workshops**
  - **API & INGAA**



Pipe Manufacturing Findings

Pipe Manufacturing

- **Quality Issues – pipe** **(remains under investigation)**
  - **Chemical composition**
  - **Low and variable yield strength**
  - **Laminations and Inclusions**
  - **Pipe bevel ends – high/low**

Pipe Manufacturing

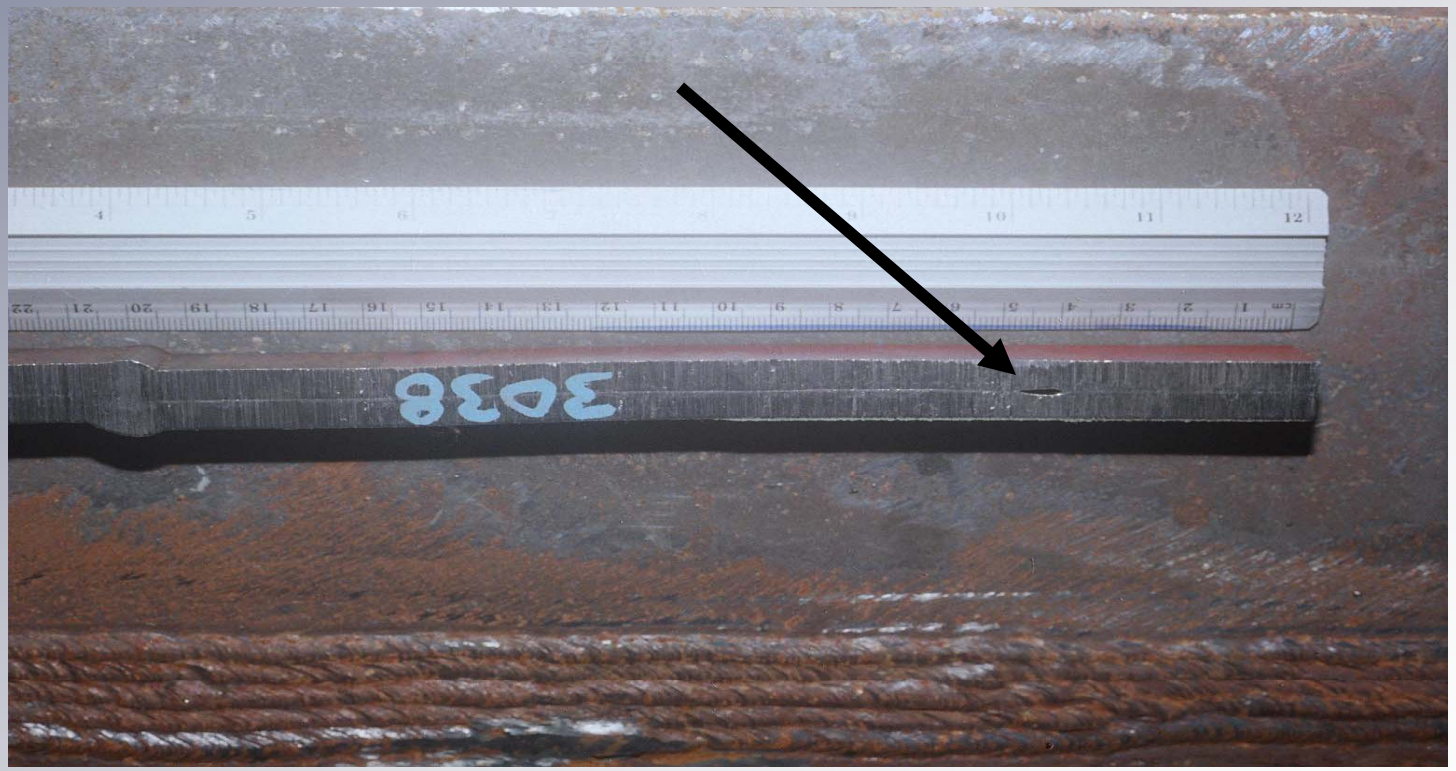
- **Low Yield Strength**
  - **Yield Strength <62Ksi for X70 pipe**
  - **Maximum ID: 109% of normal**
  - **Not an isolated project concern**
- **Out of Spec Chemical Composition**

Pipe Manufacturing

- **Low yield strength pipe; 56Ksi to 62Ksi for X70 pipe**

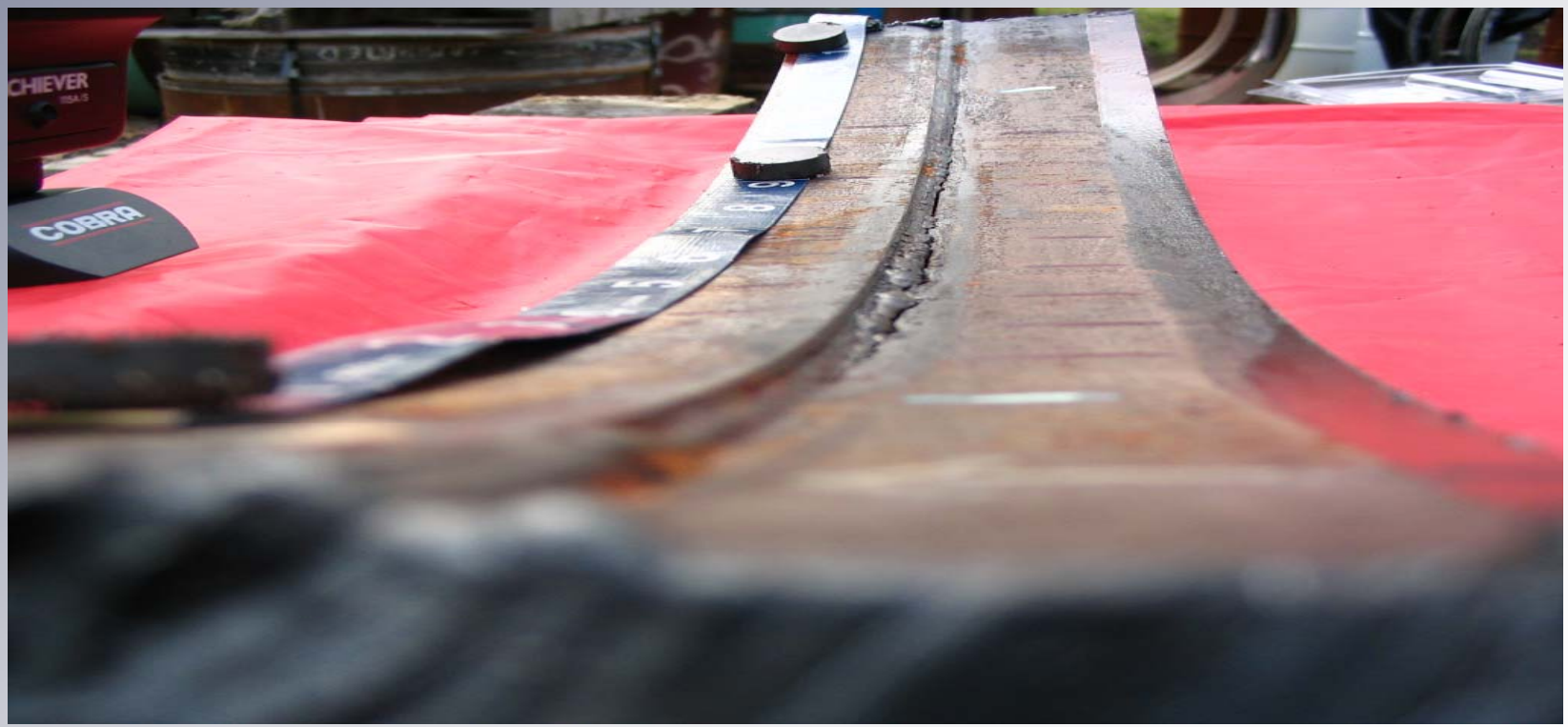
Pipe Manufacturing

- **Laminations and Inclusions**



Pipe Manufacturing

- **Pipe bevel ends – high / low and flat spots**



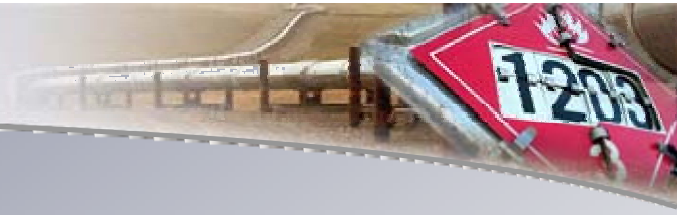
Pipe Manufacturing

- **Pipe bevel ends – high / low**

Pipe Manufacturing
Pipe End Conditions – High Low

Pipe Manufacturing – Attendant Problems X-70 and X-80 Pipe Grades

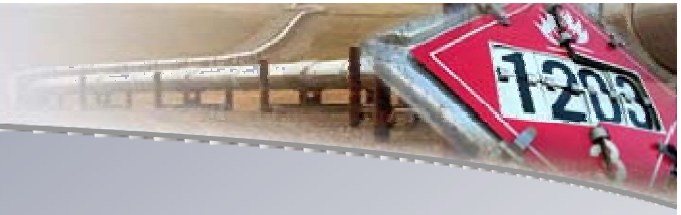
- More susceptible to hydrogen cracking than lower pipe grades
- Hydrogen is present in the coating of all E XX10 electrodes
- Three conditions must be present in the weld to initiate hydrogen cracking:
  - Source of hydrogen,
  - Micro-structure susceptible to the effects of hydrogen, and
  - Stresses in the weld.



Quality Materials

Possible Causes

- **Factors found to contribute to low and variable yield strength pipe**
  - **Wrong heat chemistry from steel supplier**
  - **Pipe test locations for yield / ultimate tensile strengths at steel and pipe mills**
  - **Plate / coil ordered under strength based on the type pipe rolling process**
  - **Incorrect plate / coil rolling process**
  - **Improper plate / coil cooling rates**
  - **Plate / coil switch at pipe mill**



Pipe Manufacturing – API 5L

- **Section 6.1 – Chemical Properties**
- **Section 9.3 – Testing of Mechanical Properties -**
  - **Is one test per heat adequate for high grade microalloyed steel?**
  - **Should additional requirements be included in API 5L based upon type steel grade, plate or coil?**
- **Section 9.10 – Retests**

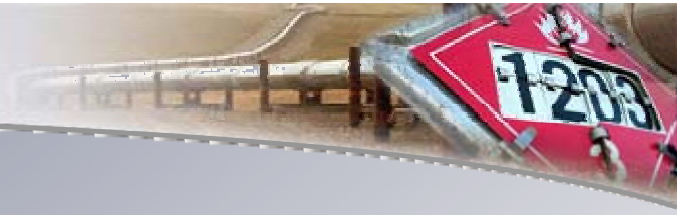
Pipe Manufacturing – API 5L

- **Section 9.11.3 - Diameter – Tolerances for Pipe Ends**
  - **44th Edition - Tolerances for pipe ends of large diameter pipe such as 36” and 42” (pipe >24” to 56”) has a tolerance of +/-63 mils on welded pipe.**
  - **43th Edition - Tolerances for pipe ends of large diameter pipe such as 36” and 42” (pipe >24” to 56”) has a tolerance of -1/32” to +3/32” on welded pipe.**

Pipe Manufacturing – API 1104

- **Section 7.2 – Alignment**
  - **The alignment of abutting ends shall minimize the offset between surfaces.**
  - **For pipe ends of the same nominal thickness, the offset should not exceed 1/8".**
  - **Mechanized welding units can not space high/low variations around the pipe.**

Quality Assurance / Inspection



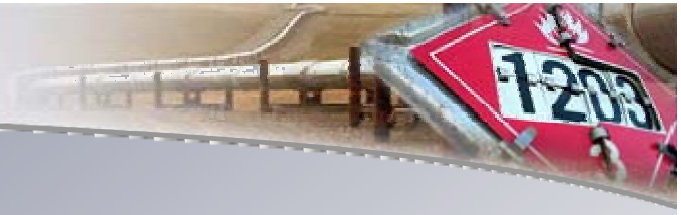
Pipe Manufacturing - Inspection

- API Monogram Certification
- Steel Supplier/Manufacturer
- Pipe Mill
- Purchaser

Pipe Manufacturing – Inspection

- Did the "rolling mill/purchaser" set up procedures to properly monitor and test the incoming coil/plate for mechanical and chemistry properties?
- Was inspection used by the "purchaser" at the steel mill and pipe rolling mill?
- Are there problems with the API 5L standard for high grades/microalloyed steel?

Problem Identification In Service Pipelines

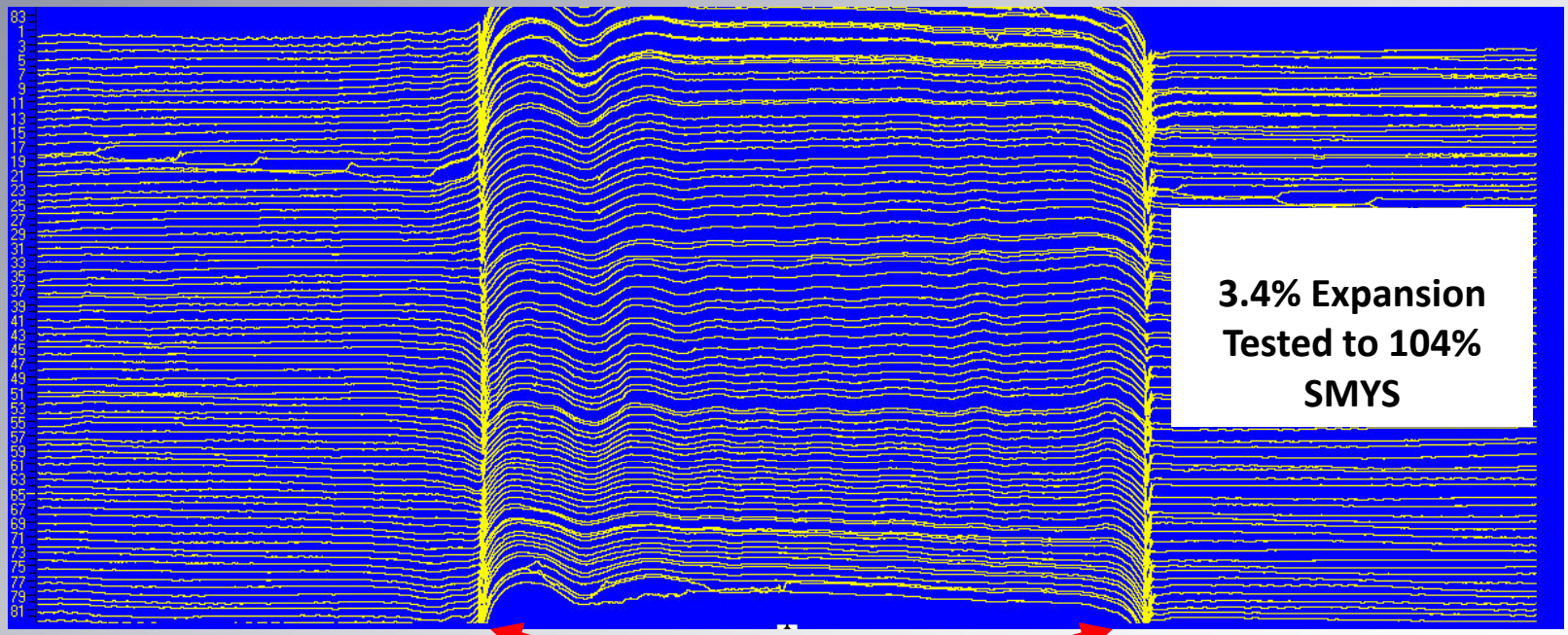


Problem Identification
Low Yield Strength Pipe

- 100% SMYS Hydrotest of in place/in service pipe
- Running of Deformation Tools after Hydrotest
  - calibrated to find expanded pipe

Deformation Tool – expanded pipe

Expanded Joint - Deformation



Non-Expanded Long Seam View

Girth Welds

Conclusions

- Pipe Manufacturing
- Coating
- Welding
- Construction

Broader Construction Findings

Construction Issues

- Worker, Inspector and General Public Safety
- Welding
- Best Practices

Worker, Inspector and General Public Safety

- **Safety is extremely important.**
- **Heavy loads and large equipment can present special risks**
- **Do not place yourself in harms way**
- **Make eye contact with heavy equipment operators**
- **Wear PPE and safety vests**
- **Be extremely cautious about entering the area between the pipe and ditch, standing next to the ditch and entering the ditch to observe welding**

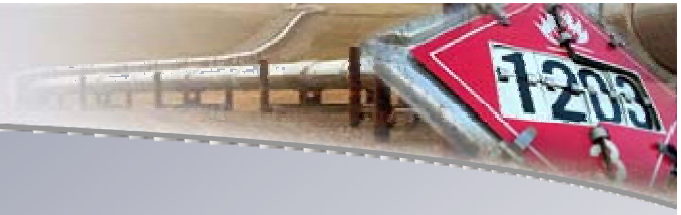
U.S. Department of Transportation
Pipeline and Hazardous Materials
Safety Administration

Safety – Where are you standing?

Pipe on skids can move and fall. You want to park where!

New Construction-Safety First

- Know where you are with respect to the equipment around you.
- Make sure to look around and take stock of what is going on.
- Review what is going on & what could go wrong?
- Is the ground around the bell hole cracked?
- Are they using a shoring box when they need to?
- Are they trying to save time & cut corners vs. working efficiently?
- Is the equipment in good shape, breaking down, damaging the pipe?
- Do the company inspectors have the correct inspection equipment?
- Are procedures available?



Welding Issues

Welding Procedure Development

- API 1104 main body, Appendix A or ASME (? Appendix B ?)
- List of Rules – Essential variables – other variables (non-essential variables)
- Recently Identified Problems (IP)
  - Did not state all required variables
  - Did not qualify sufficient procedures for project
  - Failed test coupons
  - Special issues API 1104 Appendix A (next slide)

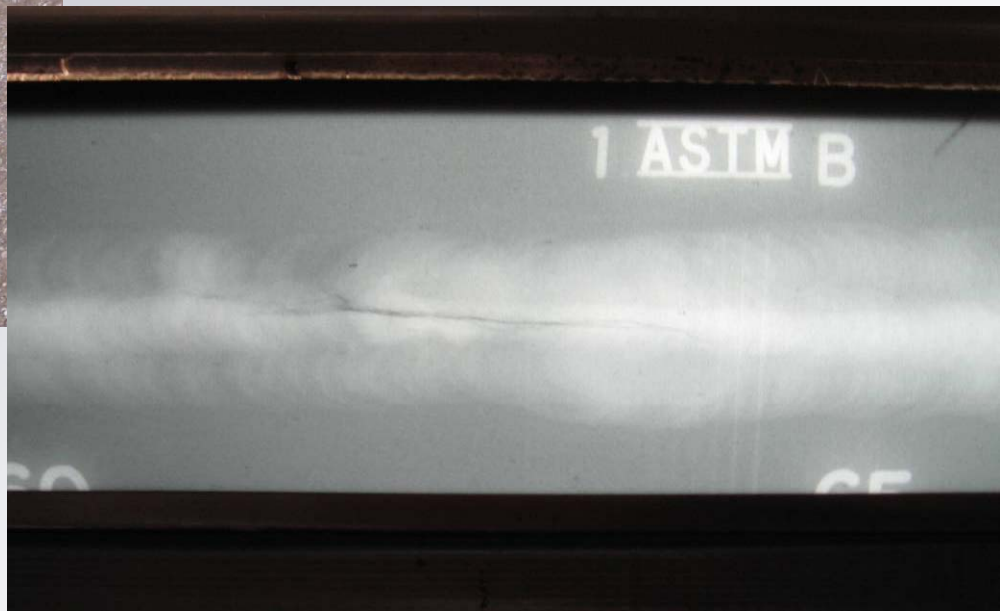
API 1104 Appendix A

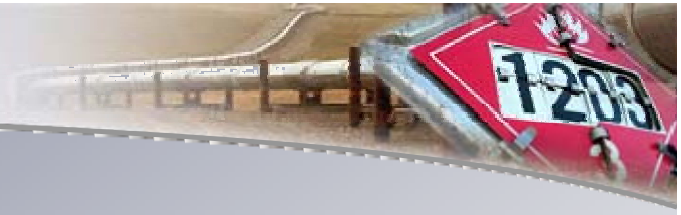
To use Appendix A must have:

- **Stress analysis, ECA or Engineering Critical Assessment**
- **AUT error determination**
- **Written welding procedure with weld testing results**
- **Identified Problems**
  - **No stress analysis**
  - **No AUT error determination**
  - **Insufficient Charpy tests or CTOD tests that "bust out"**
  - **Testing lab issue - CTOD test locations are different in the 20th edition**
  - **Failed bend, nick, or tensile test results**
  - **No radiographs of qualification welds**
  - **Using the example calculation in Appendix A is not acceptable**

Projects with failed welds that were not detected by NDT

Repair Weld Cracking Issues





Solutions

- In a high strength pipeline weld use low hydrogen welding process (GMAW – FCAW - E XX18)
- Allow time at temperature to allow hydrogen to diffuse from the weld (higher preheat temperatures, preheat maintenance, avoid weld interruption)
- Follow welding procedures
- Welding inspection
- Delay NDT to allow for the possibility of delayed hydrogen cracking to be detected
- Verify NDT technician's KSA and actual actions

Preheat

- Heating the weld joint before welding
- Temperature of the weld joint immediately before the arc is struck. (Arc start temperature)
- Procedures can state Infrared thermometer, Contact Pyrometer, or Temperature Indicating Crayon
- Range of preheat values found in the welding procedure

Use of Temperature Indicating Crayon

- Temperature indicating crayons (Tempilstik) are specially formulated to change color and melt at a specific temperature.
- On a cold pipe surface upon heating, the mark changes color and melts at the specific temperature
- Used on a hot surface the crayon only indicates the temperature is greater than the specified temperature on the crayon if the crayon melts
- Applying the crayon on an area adjacent to a weld joint and then heating with a propane torch directed on the mark will give a false temperature indication. In this case the flame heats the crayon mark faster than the pipe. The pipe will not be up to the required temperature.
- On a hot surface the crayon should be used after heating and two different temperature crayons may be necessary to determine the preheat is within the welding procedure.

Temperature Indicating Crayons

- **The crayon holder specifies the melt temperature**

Preheat

- **In the event of inadequate preheat; document occurrence and notify inspector and operator**

High Mechanized Defect Rate

PHMSA Concerns:

- **Having defects not an issue.**
- **Defect repair, NDT and tracking is an issue.**
- **Industry experience usually shows**

  - 2 – 10% defect rate on mechanized welding

  - 2 – 5% on manual welding

  - less than 2% - examine NDT – are operators procedures adequate? – are radiographic and ultrasonic procedures good? – are NDT technicians following procedures? - are the NDT technicians proficient?

Radiographic Requirement

- **Both Parts 192 and 195 require a certain percentage (based on location or class location) of welds be nondestructively tested and that a percentage of a welders daily work product must be nondestructively tested.**
- **If the radiographs' image quality indicators are not acceptable, then there may be insufficient numbers of radiographs to meet the percentage and/or daily requirements of the applicable code.**
- **Use of API 1104 Appendix A requires essentially 100% NDT - AUT**

§192.235 Preparation for welding.

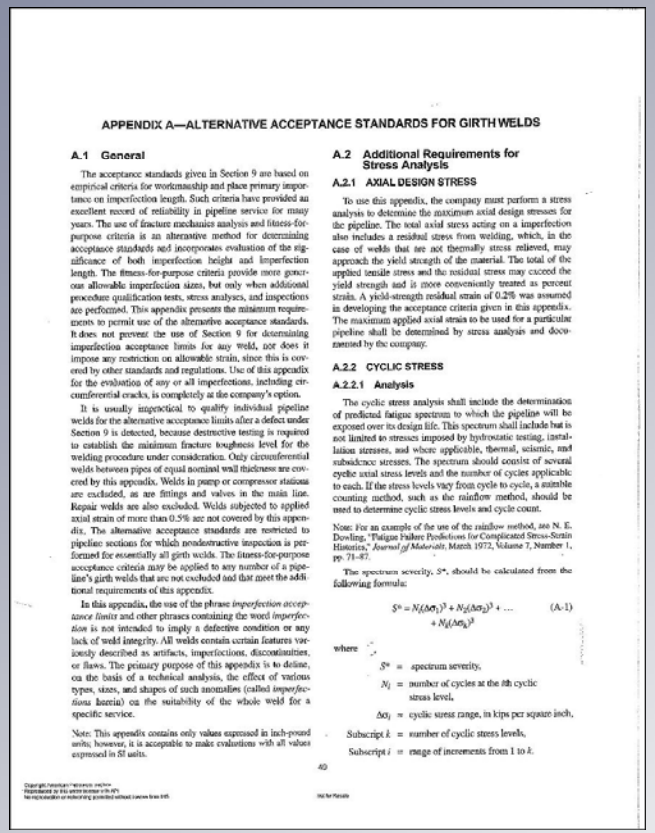
Before beginning any welding, the welding surfaces must be clean and free of any material that may be detrimental to the weld, and the pipe or component must be aligned to provide the most favorable condition for depositing the root bead. This alignment must be preserved while the root bead is being deposited.

- **Sometimes called "Hinging"**
- **1 Hydrotest failure on attributed to hinging**

Arc Burns

- **Arc burns are not acceptable on high pressure gas pipelines and liquid pipelines.**
- **The following slides show that arc burns can happen during internal back welding.**

API 1104 Edition, Appendix A



APPENDIX A—ALTERNATIVE ACCEPTANCE STANDARDS FOR GIRTH WELDS

A.1 General

The acceptance standards given in Section 9 are based on empirical criteria for workmanship and place primary importance on imperfection length. Such criteria have provided an excellent record of reliability in pipeline service for many years. The use of fracture mechanics analysis and fitness-for-purpose criteria is an alternative method for determining acceptance standards and incorporates evaluation of the significance of both imperfection height and imperfection length. The fitness-for-purpose criteria provide more generous allowable imperfection sizes, but only when additional procedure qualification tests, stress analyses, and inspections are performed. This appendix presents the minimum requirements to permit use of the alternative acceptance standards. It does not prevent the use of Section 9 for determining imperfection acceptance limits for any weld, nor does it impose any restriction on allowable strain, since this is covered by other standards and regulations. Use of this appendix for the evaluation of any or all imperfections, including circumferential cracks, is completely at the company's option.

It is usually impractical to qualify individual pipeline welds for the alternative acceptance limits after a defect under Section 9 is detected, because destructive testing is required to establish the minimum fracture toughness level for the welding procedure under consideration. Only circumferential welds between pipes of equal nominal wall thickness are covered by this appendix. Welds in pump or compressor stations are excluded, as are fittings and valves in the main line. Repair welds are also excluded. Welds subjected to applied axial strain of more than 0.5% are not covered by this appendix. The alternative acceptance standards are restricted to pipeline sections for which nondestructive inspection is performed for essentially all girth welds. The fitness-for-purpose acceptance criteria may be applied to any number of a pipeline's girth welds that are not excluded and that meet the additional requirements of this appendix.

In this appendix, the use of the phrase *imperfection acceptance limits* and other phrases containing the word *imperfection* is not intended to imply a defective condition or any lack of weld integrity. All welds contain certain features variously described as artifacts, imperfections, discontinuities, or flaws. The primary purpose of this appendix is to define, on the basis of a technical analysis, the effect of various types, sizes, and shapes of such anomalies (called *imperfections* herein) on the suitability of the whole weld for a specific service.

Note: This appendix contains only values expressed in inch-pound units; however, it is acceptable to make evaluations with all values expressed in SI units.

A.2 Additional Requirements for Stress Analysis

A.2.1 AXIAL DESIGN STRESS

To use this appendix, the company must perform a stress analysis to determine the maximum axial design stresses for the pipeline. The total axial stress acting on a imperfection also includes a residual stress from welding, which, in the case of welds that are not thermally stress relieved, may approach the yield strength of the material. The total of the applied tensile stress and the residual stress may exceed the yield strength and is more conveniently treated as percent strain. A yield-strength residual strain of 0.2% was assumed in developing the acceptance criteria given in this appendix. The maximum applied axial strain to be used for a particular pipeline shall be determined by stress analysis and documented by the company.

A.2.2 CYCLIC STRESS

A.2.2.1 Analysis

The cyclic stress analysis shall include the determination of predicted fatigue spectrum to which the pipeline will be exposed over its design life. This spectrum shall include but is not limited to stresses imposed by hydrostatic testing, installation stresses, and where applicable, thermal, seismic, and subsidence stresses. The spectrum should consist of several cyclic axial stress levels and the number of cycles applicable to each. If the stress levels vary from cycle to cycle, a suitable counting method, such as the rainflow method, should be used to determine cyclic stress levels and cycle count.

Note: For an example of the use of the rainflow method, see N. E. Dowling, "Fatigue Failure Predictions for Complicated Stress-Strain Histories," *Journal of Materials*, March 1972, Volume 7, Number 1, pp. 71–87.

The spectrum severity, S^*, should be calculated from the following formula:

$$S^* = N_1(\Delta\sigma_1)^3 + N_2(\Delta\sigma_2)^3 + \ldots + N_k(\Delta\sigma_k)^3 \qquad \text{(A-1)}$$

where

S^* = spectrum severity,

N_i = number of cycles at the ith cyclic stress level,

$\Delta\sigma_i$ = cyclic stress range, in kips per square inch,

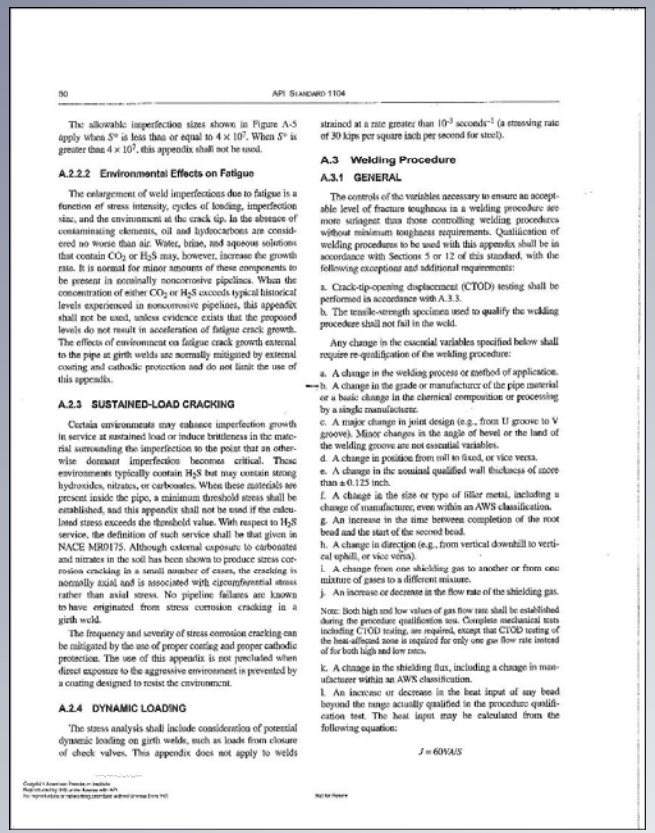
Subscript k = number of cyclic stress levels,

Subscript i = range of increments from 1 to k.

40

- **Many operators are choosing Alternative Acceptance Standard For Girth Welds**
- **Fracture mechanics analysis used to determine the acceptance standard instead of the traditional method of empirical criteria for workmanship (API 1104, Section 9)**

API 1104 Appendix A
Essential Variables



50 API STANDARD 1104

The allowable imperfection sizes shown in Figure A-5 apply when S^n is less than or equal to 4×10^7. When S^n is greater than 4×10^7, this appendix shall not be used.

A.2.2.2 Environmental Effects on Fatigue

The enlargement of weld imperfections due to fatigue is a function of stress intensity, cycles of loading, imperfection size, and the environment at the crack tip. In the absence of contaminating elements, oil and hydrocarbons are considered no worse than air. Water, brine, and aqueous solutions that contain CO_2 or H_2S may, however, increase the growth rate. It is normal for minor amounts of these components to be present in nominally noncorrosive pipelines. When the concentration of either CO_2 or H_2S exceeds typical historical levels experienced in noncorrosive pipelines, this appendix shall not be used, unless evidence exists that the proposed levels do not result in acceleration of fatigue crack growth. The effects of environment on fatigue crack growth external to the pipe at girth welds are normally mitigated by external coating and cathodic protection and do not limit the use of this appendix.

A.2.3 SUSTAINED-LOAD CRACKING

Certain environments may enhance imperfection growth in service at sustained load or induce brittleness in the material surrounding the imperfection to the point that an otherwise dormant imperfection becomes critical. These environments typically contain H_2S but may contain strong hydroxides, nitrates, or carbonates. When these materials are present inside the pipe, a minimum threshold stress shall be established, and this appendix shall not be used if the calculated stress exceeds the threshold value. With respect to H_2S service, the definition of such service shall be that given in NACE MR0175. Although external exposure to carbonates and nitrates in the soil has been shown to produce stress corrosion cracking in a small number of cases, the cracking is normally axial and is associated with circumferential stress rather than axial stress. No pipeline failures are known to have originated from stress corrosion cracking in a girth weld.

The frequency and severity of stress corrosion cracking can be mitigated by the use of proper coating and proper cathodic protection. The use of this appendix is not precluded when direct exposure to the aggressive environment is prevented by a coating designed to resist the environment.

A.2.4 DYNAMIC LOADING

The stress analysis shall include consideration of potential dynamic loading on girth welds, such as loads from closure of check valves. This appendix does not apply to welds strained at a rate greater than 10^{-3} seconds^{-1} (a stressing rate of 30 kips per square inch per second for steel).

A.3 Welding Procedure

A.3.1 GENERAL

The controls of the variables necessary to ensure an acceptable level of fracture toughness in a welding procedure are more stringent than those controlling welding procedures without minimum toughness requirements. Qualification of welding procedures to be used with this appendix shall be in accordance with Sections 5 or 12 of this standard, with the following exceptions and additional requirements:

a. Crack-tip-opening displacement (CTOD) testing shall be performed in accordance with A.3.3.

b. The tensile-strength specimen used to qualify the welding procedure shall not fail in the weld.

Any change in the essential variables specified below shall require re-qualification of the welding procedure:

a. A change in the welding process or method of application.

b. A change in the grade or manufacturer of the pipe material or a basic change in the chemical composition or processing by a single manufacturer.

c. A major change in joint design (e.g., from U groove to V groove). Minor changes in the angle of bevel or the land of the welding groove are not essential variables.

d. A change in position from roll to fixed, or vice versa.

e. A change in the nominal qualified wall thickness of more than ±0.125 inch.

f. A change in the size or type of filler metal, including a change of manufacturer, even within an AWS classification.

g. An increase in the time between completion of the root bead and the start of the second bead.

h. A change in direction (e.g., from vertical downhill to vertical uphill, or vice versa).

i. A change from one shielding gas to another or from one mixture of gases to a different mixture.

j. An increase or decrease in the flow rate of the shielding gas.

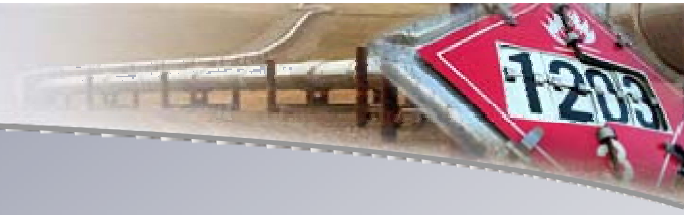
Note: Both high and low values of gas flow rate shall be established during the procedure qualification test. Complete mechanical tests including CTOD testing, are required, except that CTOD testing of the heat-affected zone is required for only one gas flow rate instead of for both high and low rates.

k. A change in the shielding flux, including a change in manufacturer within an AWS classification.

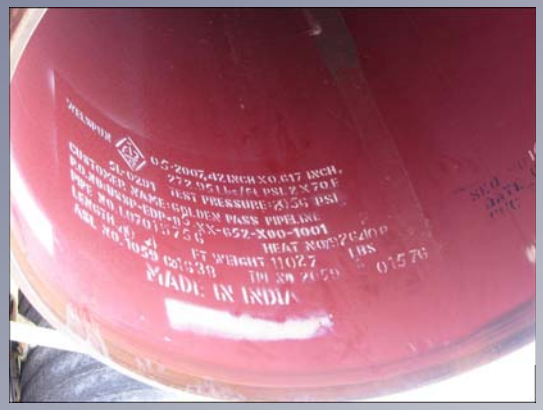
l. An increase or decrease in the heat input of any bead beyond the range actually qualified in the procedure qualification test. The heat input may be calculated from the following equation:

$$J = 60VA/S$$

- **"Any change in the essential variables specified below shall require requalification of the welding procedure…."**
- **"b. a change in the grade or manufacturer of the pipe material or a basic change in the chemical composition or processing by a single manufacturer."**
- **Requalification was not performed.**



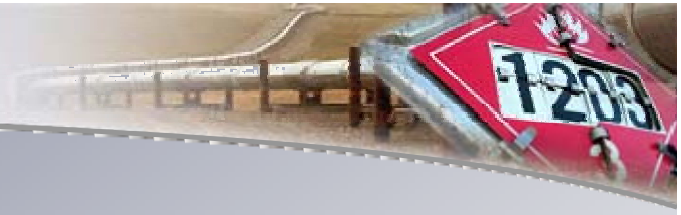
Pipe Manufacturers



- 3 plate manufacturers of 0.617” WT (Mittal, Saltzgitter, VoestAlpine).
- VoestAlpine was not addressed in the welding procedure qualification
- Pipes were supplied to the welding crews and welded in random order

The Challenge

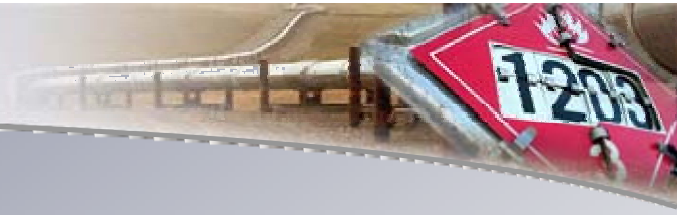
- **Procedures aren't being followed - there is a disconnect between the operators' engineering/design group and field practitioners.**
- **Many operators are now choosing Appendix A acceptance criteria to keep up with the volume of new construction and preference for automated welding. Are all the required variables being checked?**
- **PHMSA is working on a standard for interpretation and enforcement.**



Best Practices

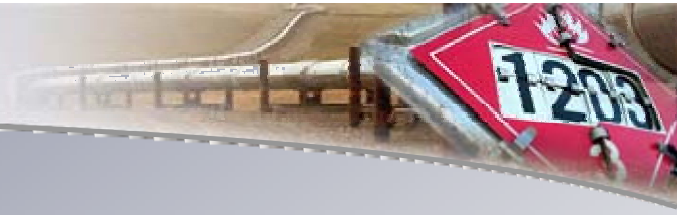
New Construction

- Good Dirt
- Level
- Straight Shot
- No rocks
- Good Trench



New Construction

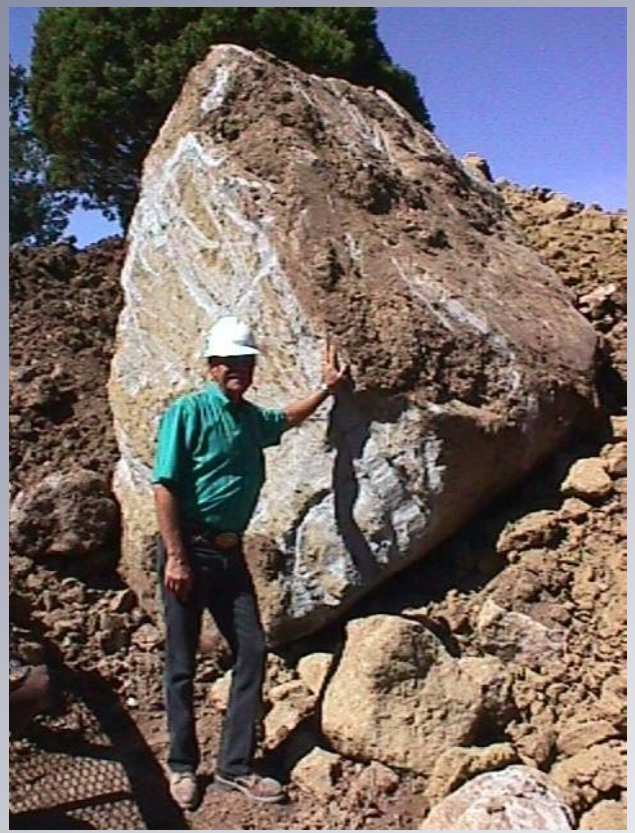
- Good Trench
- With Proper Egress



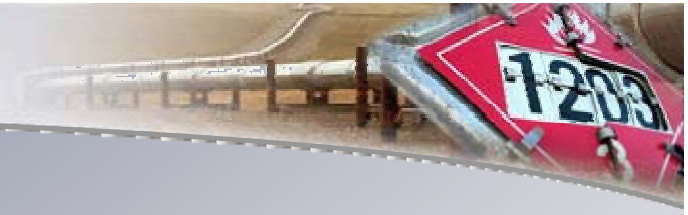
New Construction

- **Uh Oh! Found a rock.**

New Construction



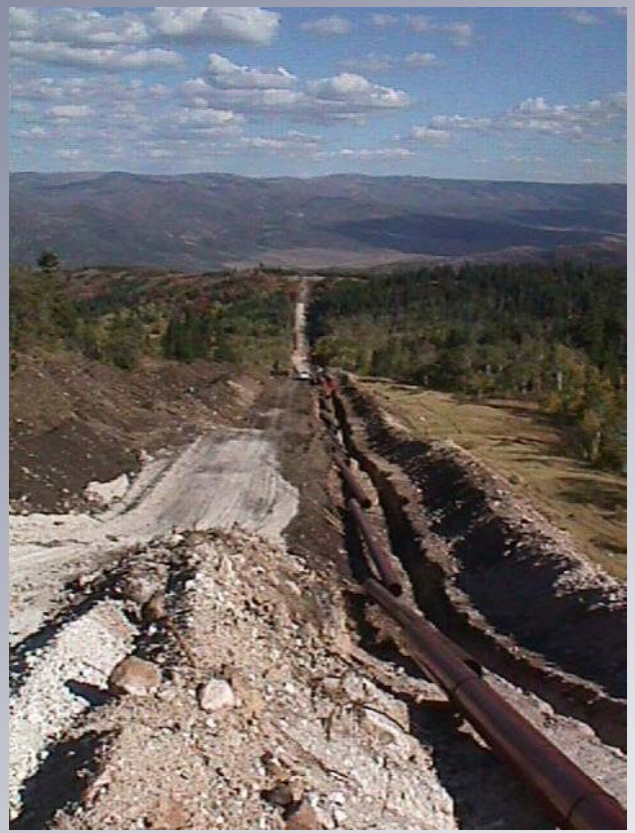
- **Documentation!**
- **How large of a rock can be left in backfill?**
- **Ask the inspector.**
- **Check the procedures.**



New Construction

- **Crossing other utilities safely.**
- **Rock Shield where applicable.**

New Construction-Trenching/Stringing



- **Steep terrain.**
- **Be Careful.**

New Construction

- Might need rock shield in this area?
- Note stationing and ask for records in office if you are not there when backfilling occurs.
- Did you see a padding machine on this job?
- Do they use sifter buckets?
- Is the mesh in the bucket the proper size?

New Construction-Coating & Jeeping

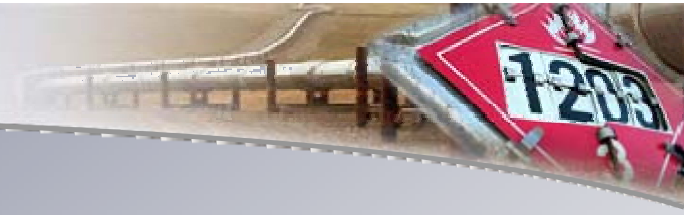
- There. Fixed it with a patch stick! Just dripped it on big time. Has to be well coated now!
- Is this ok?
- Why?
- Why Not?

New Construction

- When do you look for holidays?
- A lot of Contractors allow for Pre-jeeping.
- Code requires to inspect the coating just before lowering in.

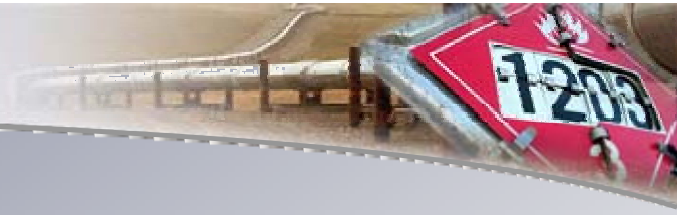
New Construction-Jeeping

- Is the equipment in good condition?
- Ask inspector questions.
- Check procedures.
- Watch how the crew repairs holidays.
- Patch stick is for holidays < / = pin hole holidays.
- 2 part epoxy for larger holidays.



New Construction-Fitting Pipe to the ditch

- **Be observant while driving around.**
- **What happenned to the coating on this pipe?**
- **Ask inspector.**

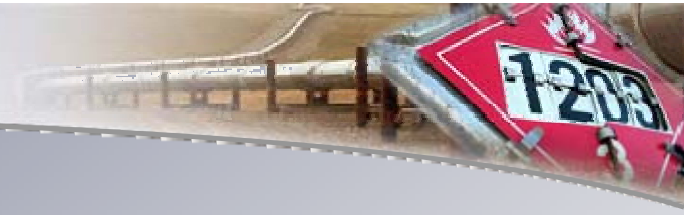


New Construction-Bending

- Check the equipment.
- Is it in good repair?
- Does it need work?
- Is it damaging the pipe?

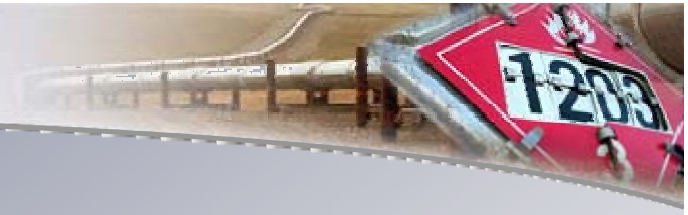
New Construction-Damaged Pipe

- **Dents**
- **Wrinkles**



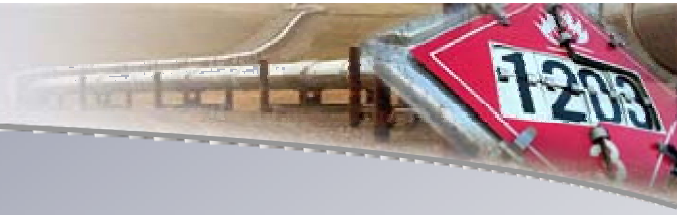
New Construction

- Foam installed after lowering in = trench breakers.
- Installed on slopes
- Protects trench from washouts.
- Correct spacing?
- Ask the inspector.
- Check procedures.



New Construction

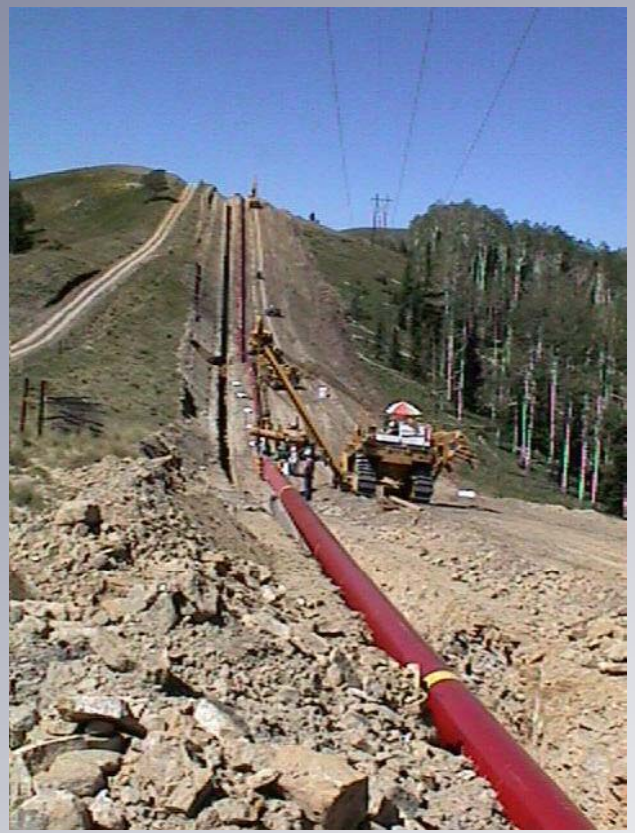
- Fittings-Piggable?
- Short Pups
- How small can a pup be?
- Ask the inspector.
- Check the procedures.
- Why the different coating color? ARO vs. FBE
- Shrink sleeves on welds



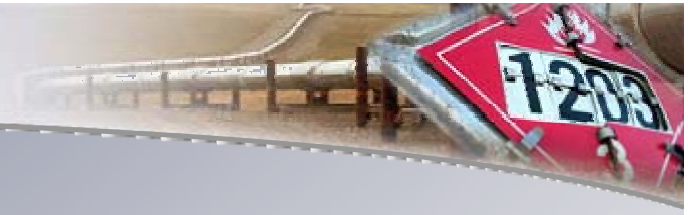
New Construction

Sand Bags for Pipe Support

New Construction



- Power Lines
- Is pipe grounded?
- Can booms reach power lines?

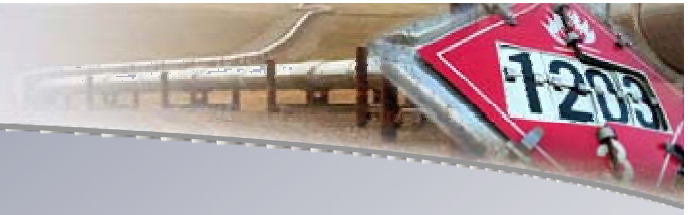


New Construction

- **Length of Unsupported Spans**
- **Are there enough Side Booms?**
- **Ask inspector.**
- **Check Procedures.**

New Construction-Padding/Backfill

- Use all your senses.
- Is the padding getting all the way around the pipe?
- Is it deep enough over the pipe before the dozer completes the job?
- Ask Inspector/Check Procedures



New Construction-Padding/Backfill

- Coating Damage
- Response = that is what CP is for! – Not!
- Easier to fix prior to burial
- Post Construction DCVG Survey Required

New Construction

- You are inspecting for problems that might cause a failure in 1 year (dent w/metal loss);
- 5 years – rock impingement/shielding CP
- 20-50 years – corrosion leak/rupture

Inspection Tips

- Notify Operator contact. Be considerate.
- Construction is unique; the opportunity to inspect is limited.
- Naturally an adversarial relationship.
- Be professional and courteous.
- Know plans and procedures.
- Observe.
- Ask questions then listen.
- Take notes.
- Take photographs.
- Report and document.
- Do not direct contractor or employee's actions.
- Direct contractor questions to the inspection company (take note of occurrence; ask yourself why is the workman asking you questions about construction procedures or practices).

Thanks!

Questions?

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