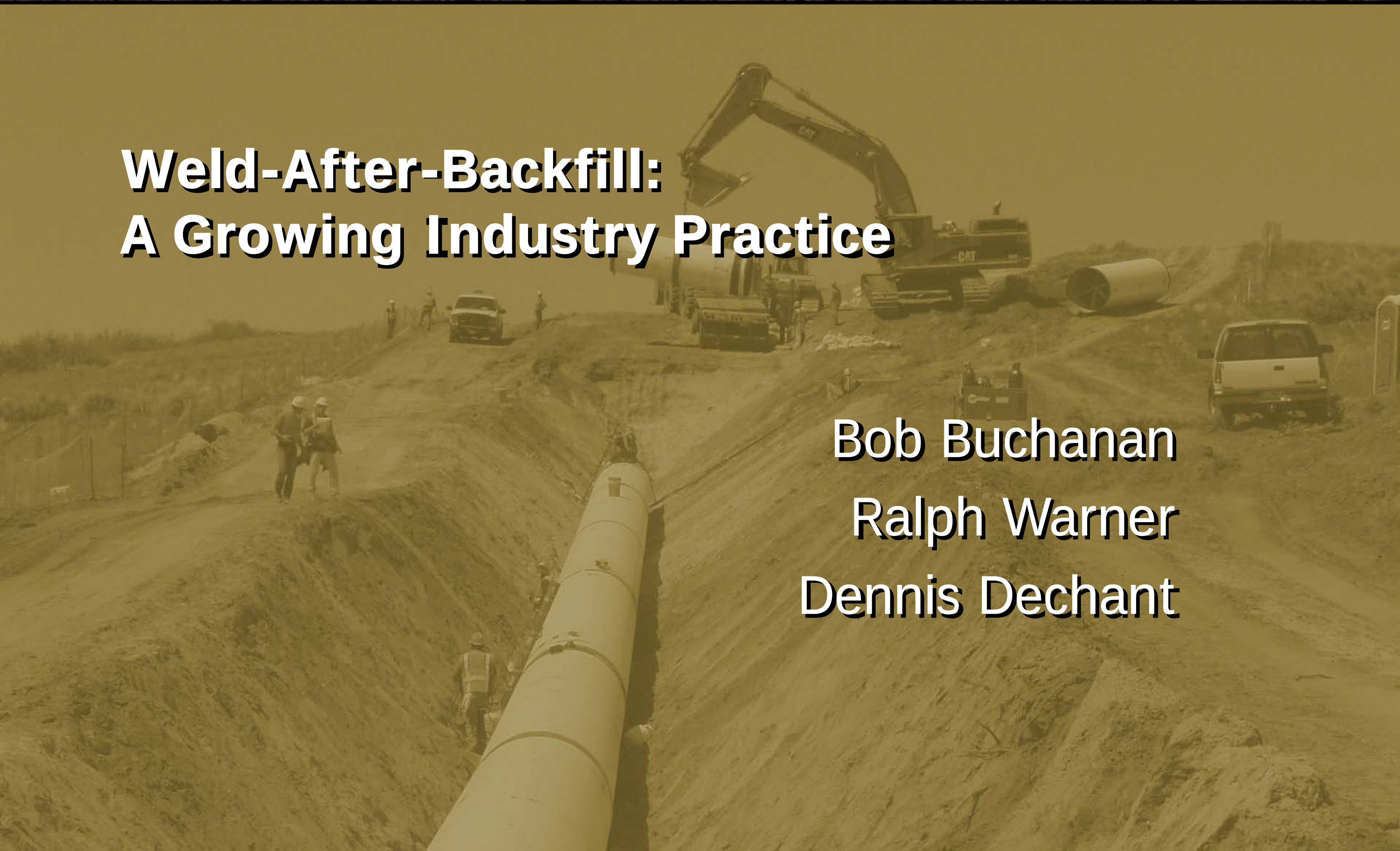


# Weld-After-Backfill:
# A Growing Industry Practice

Bob Buchanan
Ralph Warner
Dennis Dechant

# Weld-After-Backfill

- W-A-B is a growing practice in steel water pipeline construction
- W-A-B sequence:
  - Assemble the joint in the trench
  - Weld the outside of the joint if specified
  - Apply the exterior coating(s)
  - Backfill the pipe
  - Remove interior bracing
  - Weld the inside joint at a later time

# W-A-B History

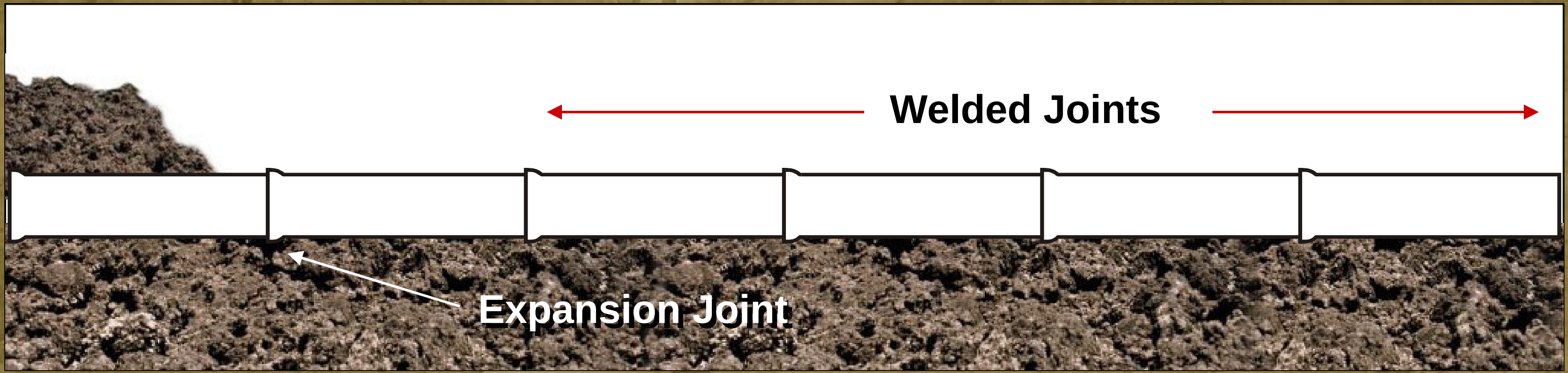
- W-A-B has been used for the past 16 years on projects ranging from 36” pipe in San Diego to 120” pipe in Charlotte.
- Safety, Constructability and Pipeline Integrity are principle reasons to use W-A-B
- 1st project using W-A-B was the Lake Texoma 72” line built in 1989
- More than 50 major projects have been constructed using W-A-B in the past 16 years

# Sample Listing of W-A-B Projects

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **SAMPLE LISTING OF PROJECTS USING WELD AFTER BACKFILL SEQUENCE** | | | | | | | |
| | Steel Water Pipe Manufacturers Technical Advisory Committee, AWWA, 2004 | | | | | | |
| | Compiled by: Weld After Backfill Task Group, Ralph Warner, Chair (National Welding Corp.) | | | | | | |
| **State** | **Project** | **Year** | **Footage** | **Dia.** | **Wall (t.)** | **Owner** | **Engineer** |
| **California** | | | | | | | |
| | Flume Replacement Project | 2000 | 24,000' | 42" & 48" | 0.250" | Helix Water District | Montgomery Watson |
| | San Diego Pipeline #2 Segment A | 2002 | 25,000' | 48" | 0.375" | City of San Diego | Wilson Engineering |
| | Miramar WTP Improv. Project | 2002 | 3,200' | 36" & 48" | 0.250" | City of San Diego | CDM |
| | Miramar Road Pipeline | 2002 | 25,000 | 36" | .19" to .63" | City of San Diego | ASL |
| **Colorado** | | | | | | | |
| | East Cherry Creek Transmission Main | 2003 | 59,000 | 54" & 48" | .400" | ECCV Sanitation District | Camp Dresser & McKee |
| | Chimney Park Pipeline | 003/200 | 11,000 | 60" | 0.313 | Greeley CO | Boyle Engineering |
| | Pleasant Valley Pipeline *** | 2003 | 46,000 | 67" | .283" | No Colo WCD | CH2MHill |
| **Florida** | | | | | | | |
| | Replacement of 54" & 60" Main | 1993 | 18,000 | 60" | 0.375" | Pinellas County | Greeley & Hansen |
| | Replacement of 54" & 60" Main | 1995 | 45,000 | 60" | 0.375" | Pinellas County | |
| | Cypress Bridge A | 1994 | 33,000 | 66" | 0.340" | West Coast Reg. Water | Montgomery Watson |
| | North Central Hillsborough Intertie #1 | 2001 | 32,000 | 84" | 0.445" | Tampa Bay Water | Greeley & Hansen |
| | North Central Hillsborough Intertie #2 | 2001 | 32,000 | 84" | 0.445" | Tampa Bay Water | Greeley & Hansen |
| | Groundwater Treatment Plant | 2001 | 16,000 | 84" & 72" | 0.445" | Tampa Bay Water | Parsons Engineering |
| | South Central Hillsborough Intertie #1 | 2001 | 35,000 | 72" | 0.370" | Tampa Bay Water | Camp Dresser & McKee |
| | South Central Hillsborough Intertie #2 | 2001 | 35,000 | 72" | 0.375" | Tampa Bay Water | Camp Dresser & McKee |
| | Tampa Bay Reservoir | 2003 | 10,000 | 84" | .438" & 1.00" | Tampa Bay Water | Greeley & Hansen / HDR |
| | Tampa Bay Reservoir Pipeline | 2003 | 32,000 | 84" | .438" | Tampa Bay Water | Greeley & Hansen |
| **Georgia** | | | | | | | |
| | Lawrenceville - Lake Lanier Trans | 1997 | 45,000 | 78" | 0.625" | Gwinnett County | Metcalf & Eddy |
| | Shoal Creek RWI #1 | 2003 | 4,000 | 72" | 0.375" | Gwinnett County | Parsons Engineering |
| | Shoal Creek RWI #2 | 2003 | 28,000 | 72" | 0.375" | Gwinnett County | Parsons Engineering |
| **Oregon** | | | | | | | |
| | Sunset Highway 26 Transmission Line | 1999 | 25,000 | 48" | 0.250" | Tualatin Valley Water Dist. | Consulting Engineers, EES Inc. |
| | No. Hills Water Taransmission Main | 2003 | 9,800 | 36" | 0.250" | City of Corvalis | City of Corvalis |
| **New Jersey** | | | | | | | |
| | Jersey City Aqueduct Relocation | 2005 | 7,600 | 72" | .410" | N.J. Turnpike Authority | The RBA Group |
| **New York** | | | | | | | |
| | Sithe/Independence Main | 1993 | 18,000 | 36" | 0.375" | City of Oswego | Nussbaumer & Clark |
| **North Carolina** | | | | | | | |
| | 120" Raw Water Line | 1998 | 29,000 | 120" | 0.675 | Charlotte-Mecklenburg MUD | Hazen & Sawyer |
| **Texas** | | | | | | | |
| | Lake Texoma Pipeline * | 1989 | 30,000 | 72" | 0.313" | North Texas MWD | |
| | Cooper Lake Water Transmission 3 | 1992 | 58,000 | 84" | 0.375" | North Texas MWD | Freese & Nichols |
| | Surface Water Treatment Program | 1994 | 6,000 | 66 | 0.375" | City of Houston | Lockwood, Andrews & Newnam |
| | Plano - McKinney Phase 3 ** | 1996 | 25,000 | 96" | 0.438" | North Texas MWD | Freese & Nichols |
| | East Water Program, Contract 2A | 1996 | 8,000 | 84" | 0.375" | City of Houston | Lockwood, Andrews & Newnam |
| | 84" Water Main, Contract 2B-1 | 1998 | 2,933 | 84" | 0.423" | City of Houston | Lockwood, Andrews & Newnam |
| | Lake Chapman Water Project | 2001 | 174,000 | 72" | 0.438" | City of Irving | CH2MHill/M.W.H. |
| | Carrizo Design 2B | 2003 | 32,000 | 60" | Various | San Antonio Water System | Lockwood, Andrews & Newnam |
| | Carrizo Design 2 | 2003 | 41,000 | 60" | Various | San Antonio Water System | CEC |
| | 6B-1 | 2003 | 5,000 | 84" | .438" | Houston | Lockwood, Andrews & Newnam |
| | Ella Blvd | 2003 | 8,000 | 54" | .283" | Houston | Lockwood, Andrews & Newnam |
| | Hempstead Highway | 2003 | 16,000 | 54" | .283" | Houston | Lockwood, Andrews & Newnam |
| | Williamson Cnty 48" Waterline Reloc. | 2005 | 5,000 | 48" | .269" | Williamson Cnty - BrazosRA | Lockwood, Andrews & Newnam |
| **Utah** | | | | | | | |
| | Sandridge Pipeline | 1999 | 9,000 | 48" | 0.188, 0.313" | Weber Basin WCD | Bowen & Collins |
| | 15000 South Water Transmission Line | 2001 | 22,000 | 48" | 0.375" | Jordan Valley WCD | Boyle Engineering |
| | Point of The Mtn Aqueduct **** | 2005 | 63,000 | 60" | .025" - .040" | Metro Water Dist of SLC | CH2MHill |
| **Virginia** | | | | | | | |
| | Military Highway Route 13 | 1993 | 12,000 | 48" | | VA Dept of Transportation | HDR Engineers |

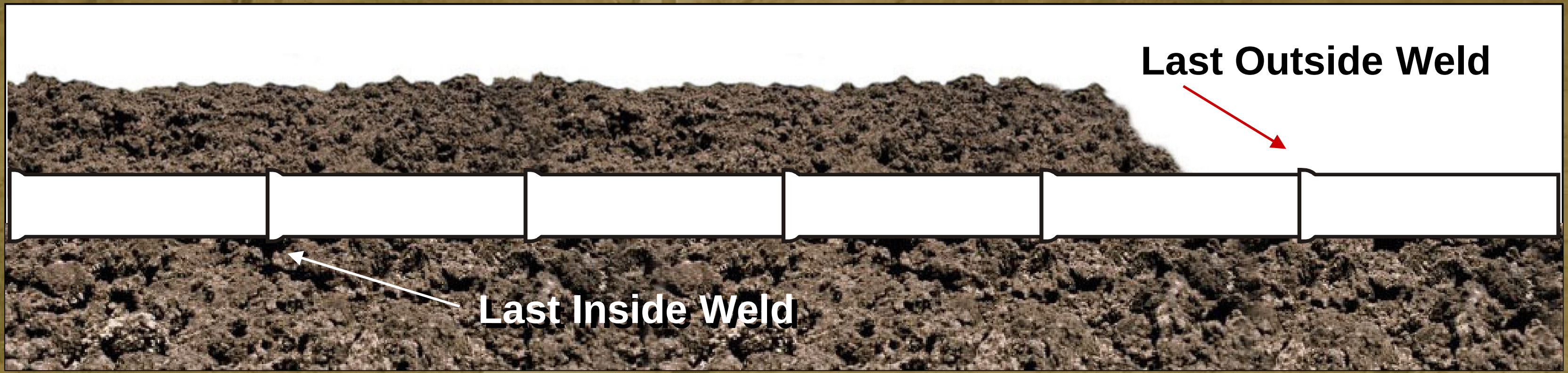
# Constructability – Open Trench

- Conventional Construction
- Pipe exposed to thermal stress
- Risk of flooding & floating pipe
- Interrupted backfill
- Welding in critical path



# Constructability – Closed Trench

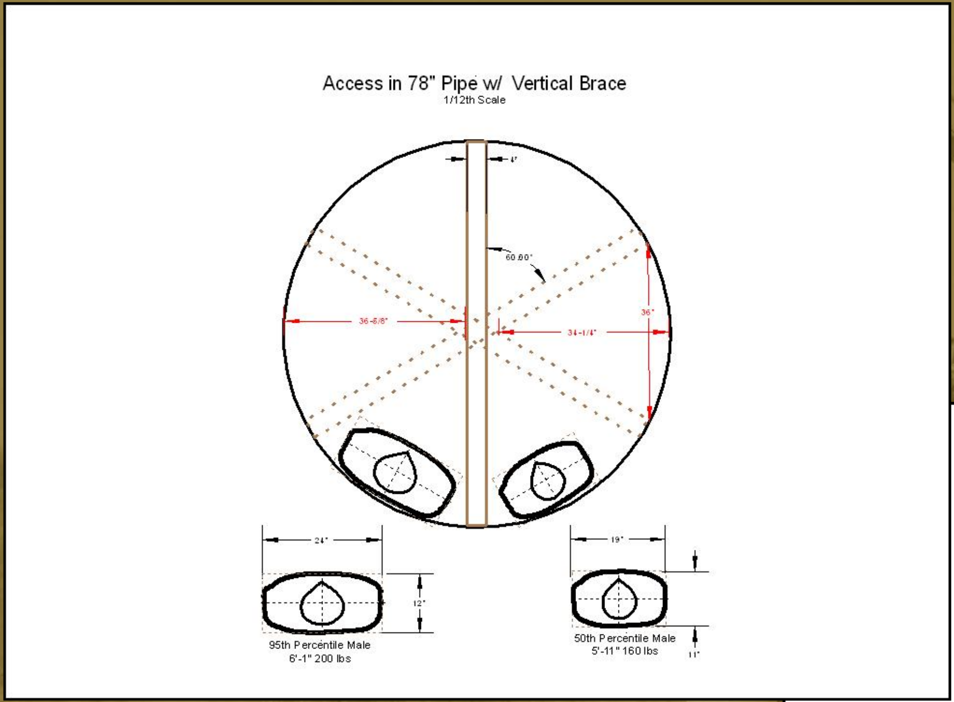
- Weld After Backfill Sequence
- No Thermal Stresses
- No risk of floating pipe
- Consistent Backfill
- Installation independent of welding

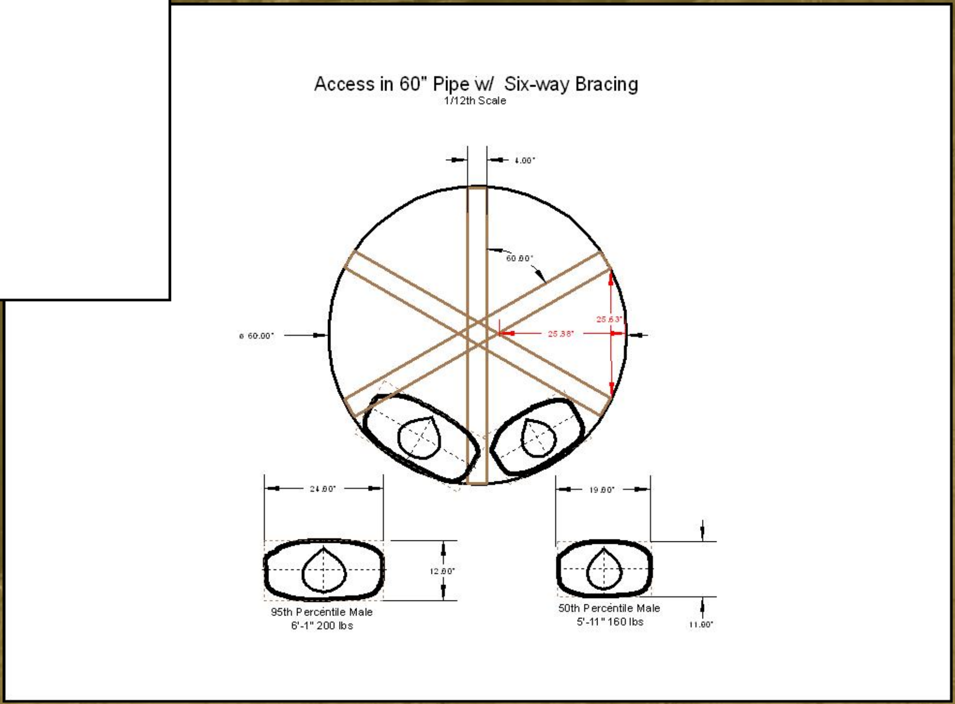


# Safety Considerations

- W-A-B provides better and safer access to work inside the pipe
- Provides shortened open trench exposures
- Benefits the contractor, designer and owner

# Safety - Internal Access



# Weld-After-Backfill

- Challenges the exterior field joint coating
- AWWA (SWPMTAC) has been trying to bring the standards up to date with field practice
- Research by Canusa-CPS, National Welding and Northwest Pipe done to determine best practices

# Weld-After-Backfill Trials

- Trials conducted to evaluate the effects of welding on the external field joint coating
- Common field welding techniques evaluated
- Several coating system designs tested
- Objective to optimize current practices
- Observations, results and conclusions determined variables that affect performance

# Weld-After-Backfill Trials

- Systems applied to a 48” OD, .250” wall pipe
- Standard heat-shrink sleeves alone
- Standard heat-shrink sleeves with underlays
- Buried with compacted sand backfill
- Welded – FCAW, SMAW
- Excavated and inspected
  - Visual assessment
  - Holiday test
  - Adhesion test

# Coating Systems Tested

- Heat-Shrinkable Sleeves of various design
  - Backing and adhesive type variables
- Underlay materials evaluated
  - Various types or no underlay
- System design evaluated

# Typical Welding Methods

- FCAW (Flux Core Arc Welding)
  - High production benefit
  - Requires more equipment - shielding gases, wire feeder
  - Requires more expertise to weld effectively

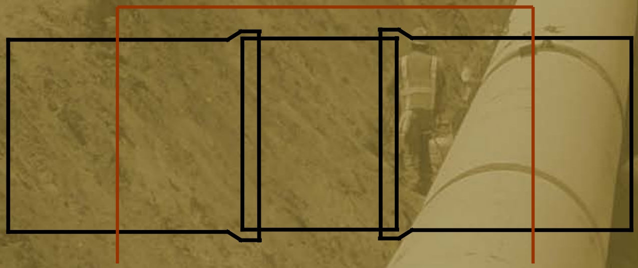
- SMAW (Shielded Metal Arc Welding)
  - Simplest (most common) welding method
  - Generally less efficient that FCAW
  - Commonly done by “rig” welders

# Test Assembly

## Backfill Box over Pipe

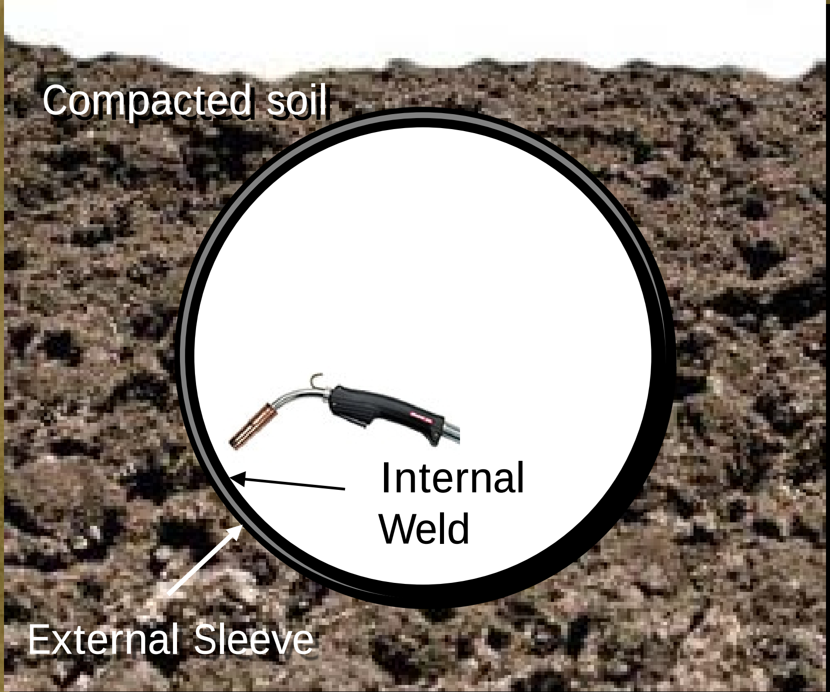
## Two Pipe Joints

Two Bell Ends with ‘Pup’ between them



# Weld-After-Backfill Trials

- Systems applied to a 48" OD, .250" wall pipe
  - Standard heat-shrink sleeves alone
  - Standard heat-shrink sleeves with underlays
  - Applied, buried & welded internally



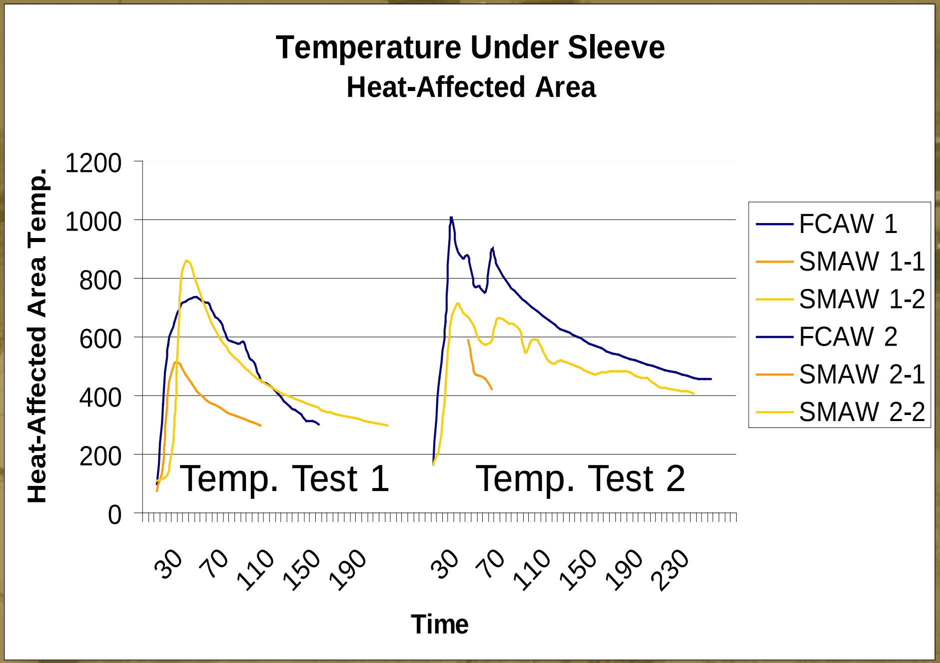

# Heat-Shrink Sleeve Installation

# Backfilling Prior to Welding

# Internal Welding

# Weld-After-Backfill Trials

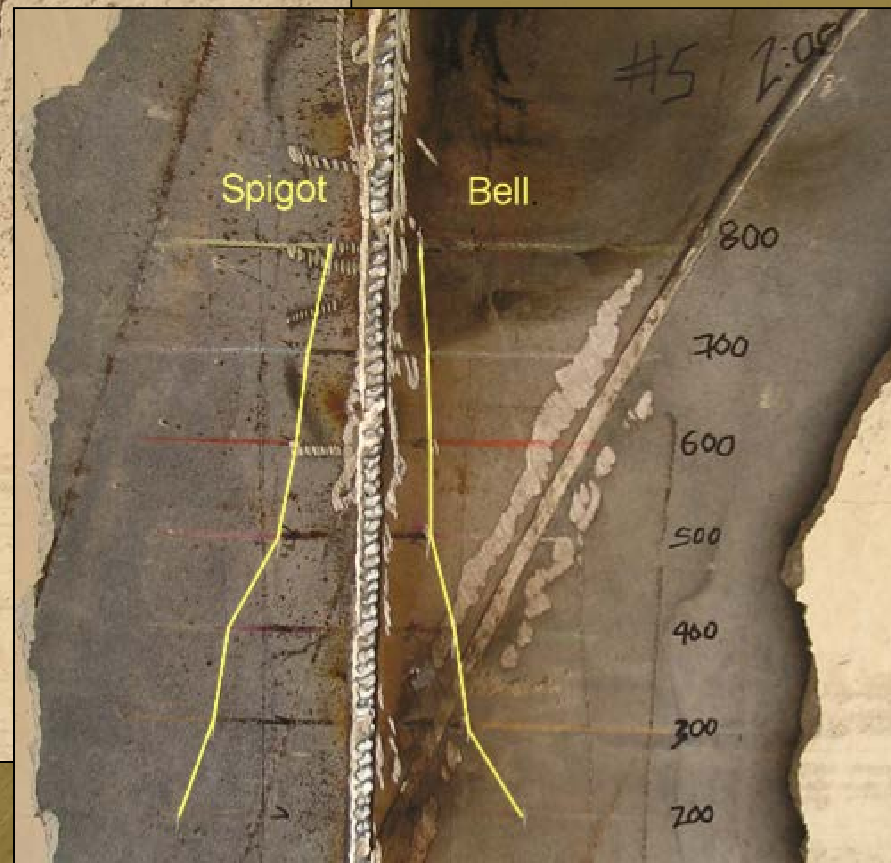
- Temperature measured inside the pipe & under the sleeve

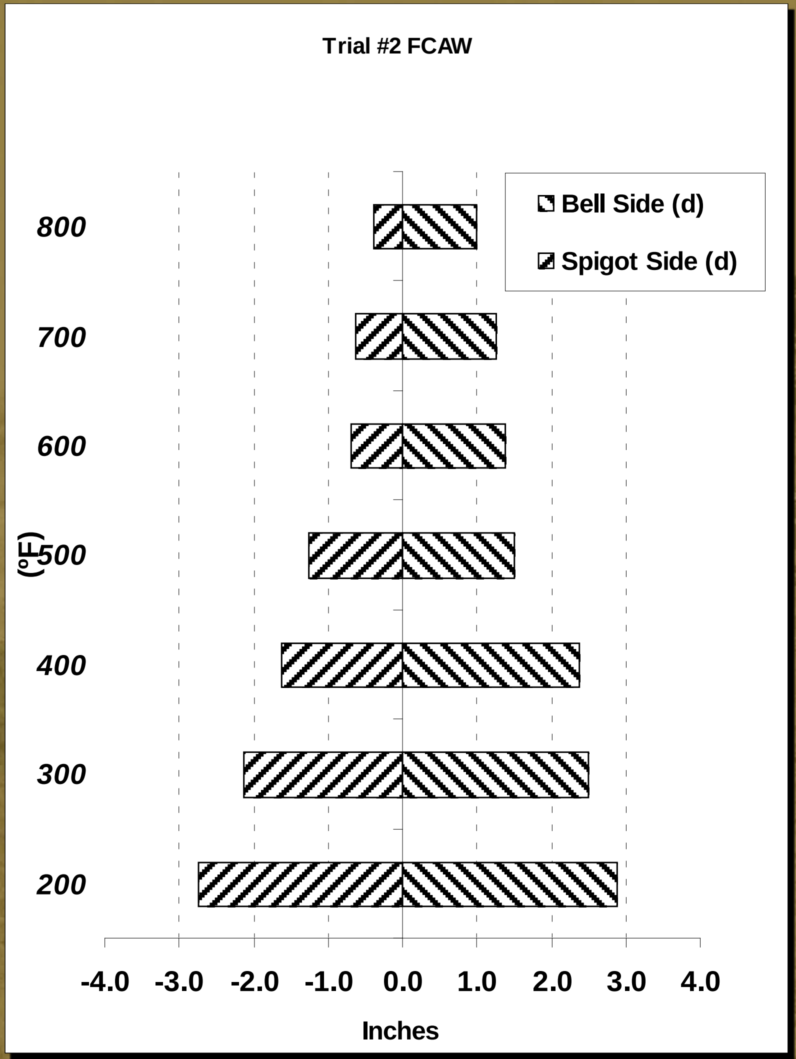
# Temp Stick Photos

## Before Welding


## After Welding



# Temp Stick Data



# Heat Input

$$\frac{\text{Voltage x Amperage x 60}}{\text{Travel Speed}} = \text{(Joules/in.)}$$

| | Welding Process | Number of Passes | Voltage | Amperage | Travel Speed (in./min.) | Heat Input (Joules/in.) |
|---|---|---|---|---|---|---|
| **Trial 1** | FCAW | 1 | 26 | 200 | 8.6 | 36,279 |
| | SMAW | 2 | 28 | 110 | 6.7 | 27,582 |
| **Trial 2** | FCAW | 1 | 24 | 180 | 8.9 | 29,124 |
| | SMAW | 2 | 29 | 110 | 7.5 | 25,520 |
| **Trial 3** | FCAW | 1 | 22 | 200 | 10.0 | 26,400 |
| | SMAW | 2 | 30 | 150 | 7.1 | 38,298 |
| **Trial 4** | FCAW | 1 | 20 | 180 | 9.2 | 23,478 |
| | SMAW | 2 | 30 | 150 | 7.0 | 38,571 |
| **Trial 5** | FCAW | 1 | 24 | 220 | 7.9 | 39,950 |
| | SMAW | 2 | 27 | 140 | 6.5 | 34,892 |
| **Trial 6** | FCAW | 1 | 24 | 190 | 8.4 | 32,727 |
| | SMAW | 2 | 27 | 140 | 5.7 | 39,789 |
| **Trial 7** | FCAW | 1 | 23 | 190 | 9.3 | 28,285 |
| | SMAW | 2 | 26 | 130 | 6.8 | 29,824 |
| **Trial 8** | FCAW | 1 | 23 | 190 | 9.3 | 28,285 |
| | SMAW | 2 | 27 | 140 | 5.2 | 43,448 |

Note: All SMAW Heat inputs were calculated on the second pass values

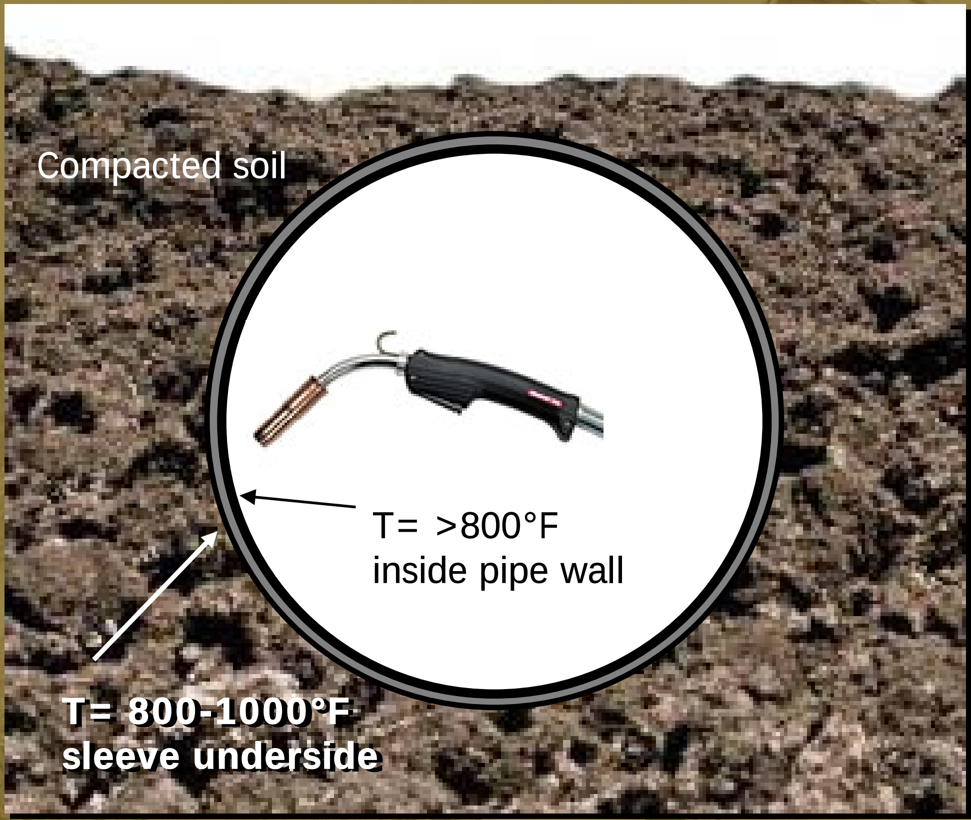
# Welding Heat Input

| Trial 7 | Voltage | Amperage | Travel Speed (in./min.) | Heat Input (Joules/in.) |
|---|---|---|---|---|
| FCAW | 23 | 190 | 9.3 | 28,285 |
| SMAW - 1st Pass | 26 | 130 | 10.7 | 19,013 |
| SMAW - 2nd Pass | 26 | 130 | 6.8 | 29,824 |

- Travel Speed is the most critical factor to heat applied during welding
- Gaps in the pipe joint cause slower progress and therefore greater heat input
- Quantity of metal deposited in a pass also affects heat input

# Weld-After-Backfill Trials

- Temperature inside pipe & under sleeve measured





- Conclusion: High heat has an affect on the coating

# Eight Trials Completed

**Table 1a - Trials 1 to 4**

| | Trial 1 | | Trial 2 | | Trial 3 | | Trial 4 | |
|---|---|---|---|---|---|---|---|---|
| | Underlay | Sleeve | Underlay | Sleeve | Underlay | Sleeve | Underlay | Sleeve |
| Product | n/a | KLON | WC 20R | AQW-HS | n/a | AQW-HS | WC 20R | AQW-FF |
| Backing Thickness | n/a | 0.036 | 0.016 | 0.036 | n/a | 0.036 | 0.016 | 0.025 |
| Adhesive Thickness | n/a | 0.065 | 0.025 | 0.045 | n/a | 0.045 | 0.025 | 0.050 |
| Total Thickness | n/a | 0.101 | 0.041 | 0.081 | n/a | 0.081 | 0.041 | 0.075 |
| Observations | PE backing visibly affected by heat but no initial holiday. Adhesive affected resulting in lower adhesion strength. Evaluation after 3 months exposure showed movement in the visible damage, which would have resulted in a holiday. | | PE backing visibly affected by heat but no initial holiday. Adhesive affected resulting in lower adhesion strength. Evaluation after 3 months exposure showed no change. | | PE backing visibly affected by heat with a burn through at a point near the pipe bottom. Adhesive affected resulting in lower adhesion strength. Evaluation after 3 months exposure showed no change. | | Slight affect from heat with backfill material "impression" in backing. No initial holiday. Evaluation after 3 months exposure showed no change. | |

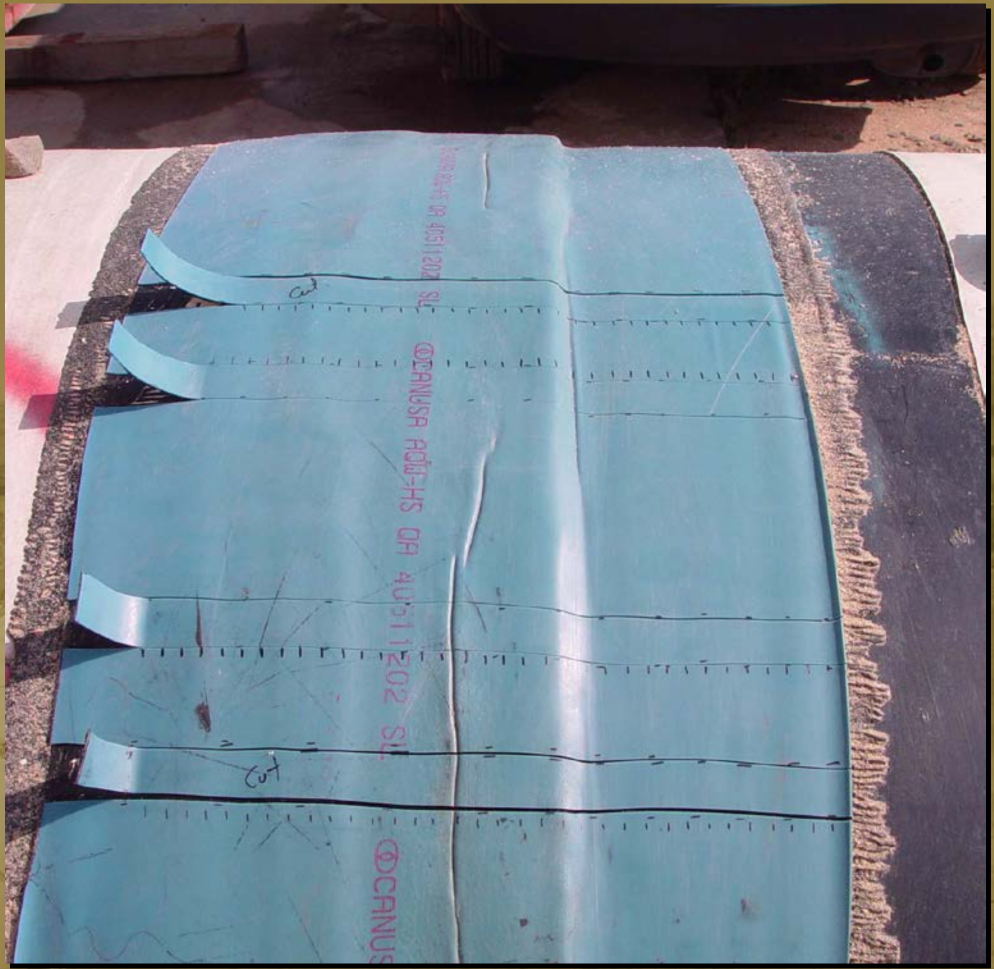
**Table 1b - Trials 5 to 8**

| | Trial 5 | | Trial 6 | | Trial 7 | | Trial 8 | |
|---|---|---|---|---|---|---|---|---|
| | Underlay | Sleeve | Underlay | Sleeve | Underlay | Sleeve | Underlay | Sleeve |
| Product | Test-UL | AQW-HS | CRP-O | AQW-HS | CLS | AQW-HS | AQW-HS | AQW-HS |
| Backing Thickness | 0.032 | 0.036 | 0.032 | 0.036 | 0.032 | 0.036 | 0.036 | 0.036 |
| Adhesive Thickness | 0.025 | 0.045 | 0.045 | 0.045 | 0.030 | 0.045 | 0.045 | 0.045 |
| Total Thickness | 0.057 | 0.081 | 0.077 | 0.081 | 0.062 | 0.081 | 0.081 | 0.081 |
| Observations | PE backing visibly affected by heat as noted by a crease in the backing along the HAA[1]. Underlay material burned but outer sleeve intact. No initial holiday due to double thickness. | | PE backing visibly affected by heat as noted by a crease in the backing along the HAA[1]. Underlay adhesive affected resulting in lower adhesion strength at steel interface. No initial holiday due to double thickness. | | Slight crease or sleeve recovery along the step down due to heat release through the gap in the bell & spigot. Modest reduction in adhesion through the HAA[1]. No initial holiday. | | Visibly affected by heat as noted by a crease along the step down due to a gap in the bell & spigot. Minor reduction in adhesion through the HAA[1]. Burn through near the bottom due to a large gap in the step down and a rock in the backfill. | |

1 - Heat affected area

# Trial Photos – Effects of Heat

Step down edge recovery due to heat effect at bell and spigot interface



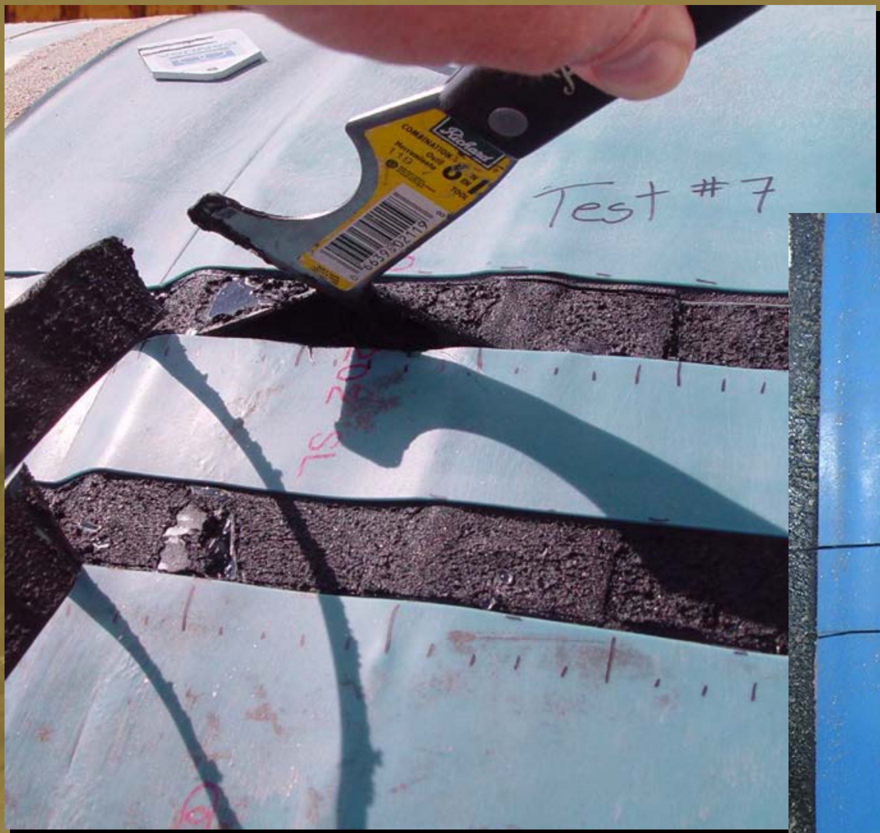

Crease in backing due to surface temp above the weld bead

# Trial Photos – Adhesion Testing



Peel testing, note adhesive differences through heat affected area

# Trial Photos – Effects of Heat




Peel test – note underlay adhesion


PE backing visibly affected but adhesion good

# Field Trial: San Antonio Water System

# Observations - Backings

- Heated backings expand, then contract as they cool. Backfill pressure keeps the sleeve in place.
- Polyethylene backings in a single layer system will be affected as noted such that some reduction in mechanical properties may occur
- Excessive gap in the pipe joint may allow heat flow-through which can affect the sleeve at the bell edge. Keeping joints within tolerance very important to coating integrity.

# Observations

- Performance of a system is a result of:
  - adhesive's resistance to flow & off-gas during welding
  - the resistance of a backing to expand and contract
- Some systems perform better because:
  - adhesives with higher molecular weight fractions have a lower propensity to off-gas and flow
  - HDPE backings have more resistance to expansion & contraction

# Recommendations

- Tight joint gap tolerances
- Some specifiers request filler materials to bridge the stepdown.  Heat tolerant fillers are then required such that they do not affect weld quality
- Supply an underlay material that combines a thick low stretch HDPE backing and a butyl-based adhesive
- Use a standard product as the outer sleeve

# Recommendations

- Recommended system incorporates a specially designed underlay material and standard outer sleeve
- Single layer systems possible and have been used successfully on thicker wall pipe
- An extra layer provides assured protection
- The growing use of WAB has created the need to address the construction method on an industry wide level

# Recommendations

- At recent SWPMTAC meetings, WAB text was proposed for inclusion in relevant standards.
- Requires that the system maintain minimum performance
- In a demo of a single sleeve, a peel test over the heat-affected area will yield a reduction in performance but...
- It may still meet the requirements of the standard

# Recommendations

- When an underlay material is used, the underlay adhesive may be degraded but acts as sacrificial, so the outer sleeve can be considered to be intact.

# Weld-After-Backfill

- The W-A-B construction method has advantages versus conventional welding
  - Improved safety during construction
    - Fewer obstructions inside pipe
    - Less risk from open trench outside pipe
  - Improved Pipeline Integrity
    - Reduced thermal stress
    - Consistent backfill
  - Improved Production
    - Installation & Welding on parallel paths
    - No interruptions for expansion joints

# AWWA WAB Text

**Weld-After-Backfill.** Weld-After-Backfill is the sequence of assembling a welded joint, welding the outside joint (if required), applying the exterior coating(s), backfilling the pipe, then welding the inside joint at a later time (where internal welding is safe and practical). Welding inside field joints after backfill (Weld-After-Backfill sequence) is an acceptable practice provided the requirements of all applicable AWWA standards are followed. Consult with the manufacturers and all other responsible parties regarding recommended products, installation and backfill procedures required for the Weld-After-Backfield sequence. At the request of the purchaser, the coating manufacturer will provide testing or historical information to verify that the exterior joint coating will retain performance requirements as per the applicable standard throughout the heat affected area.