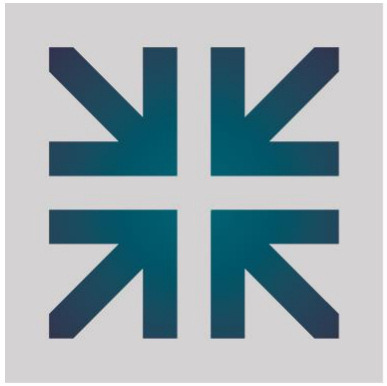
WELCOME



THE EXCHANGE

A NASSCO EDUCATIONAL EVENT

Basics and Benefits of Spiral Wound Technology

Agenda

Introduction

Spiral Wound Pipe Liners for Rehabilitation

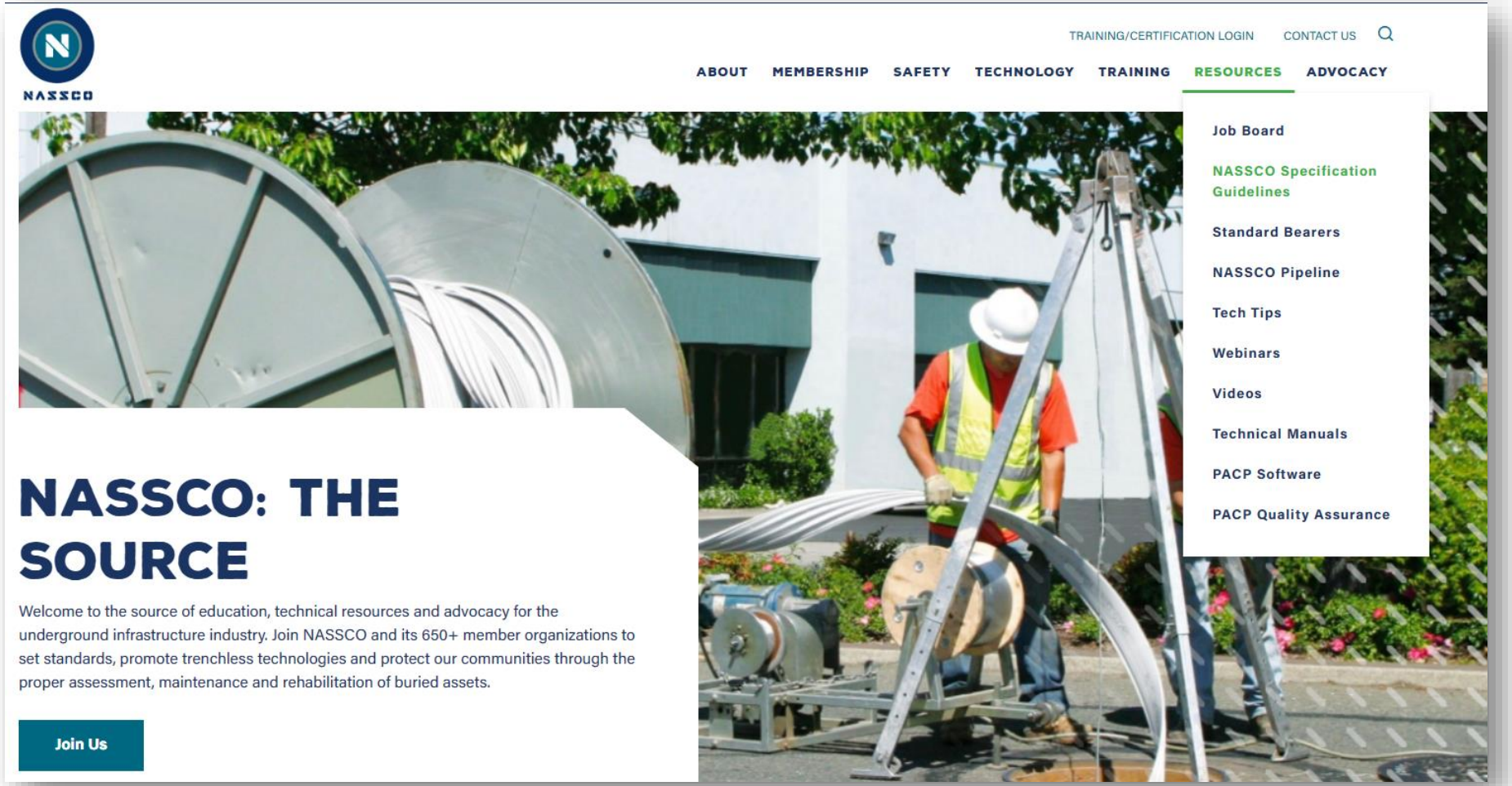
Design Considerations

Installation and Quality Assurance

NASSCO

Introduction

Finding the Spiral Wound Pipe Liner Performance Specification Guideline



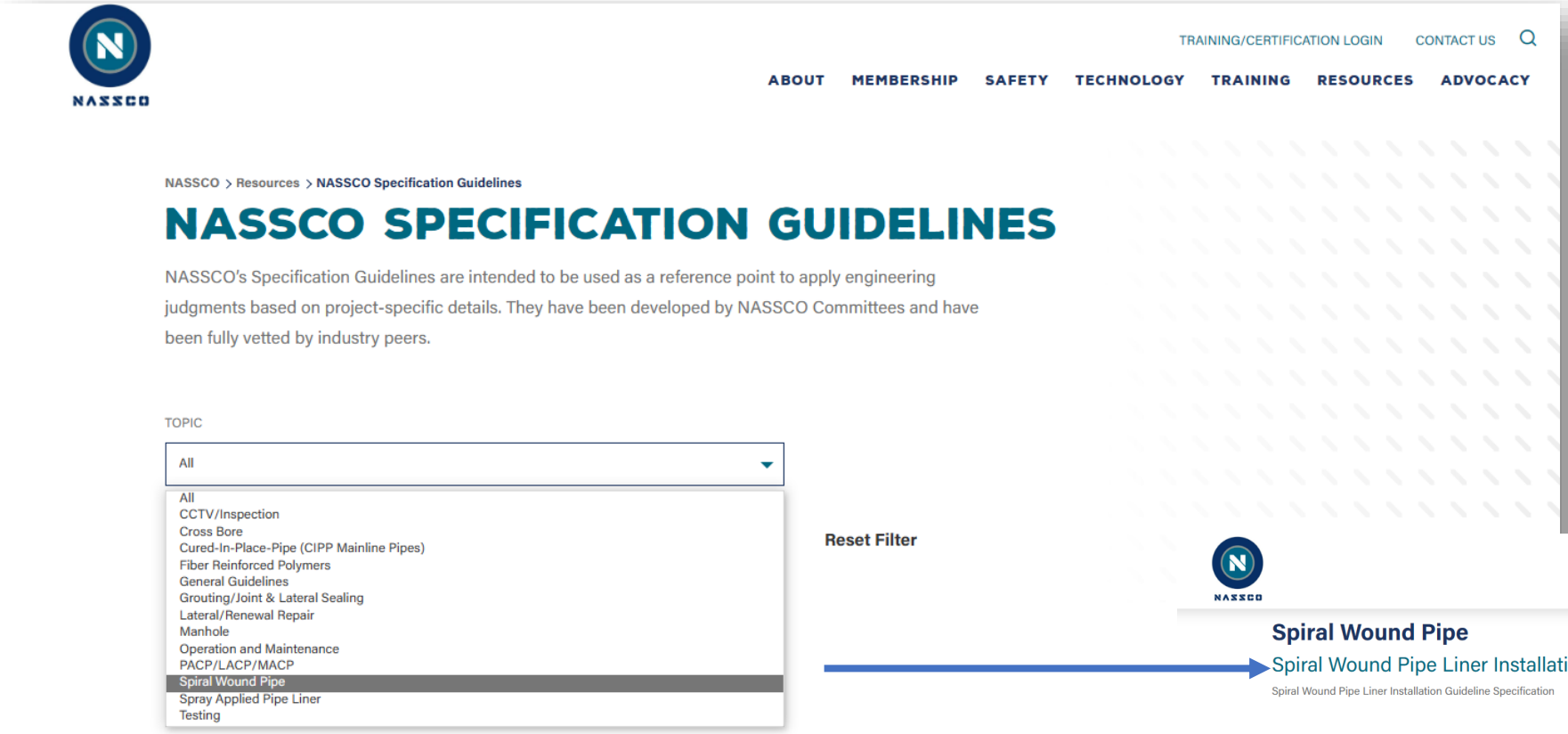
www.NASSCO.org

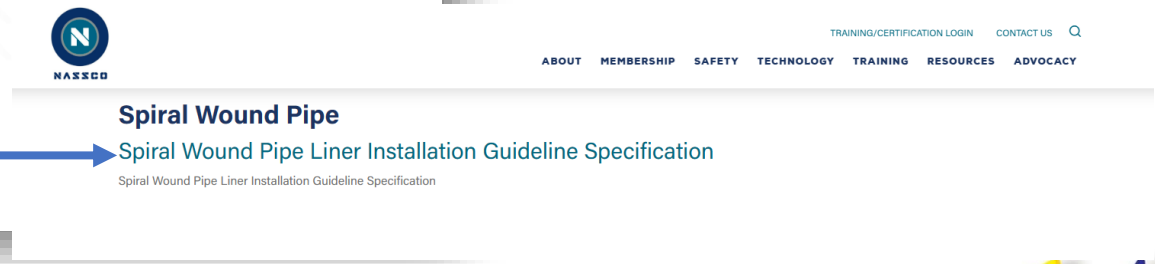
Select “Resources”

Select “NASSCO Specification Guidelines”

Finding the Spiral Wound Pipe Liner Performance Specification Guideline

www.NASSCO.org

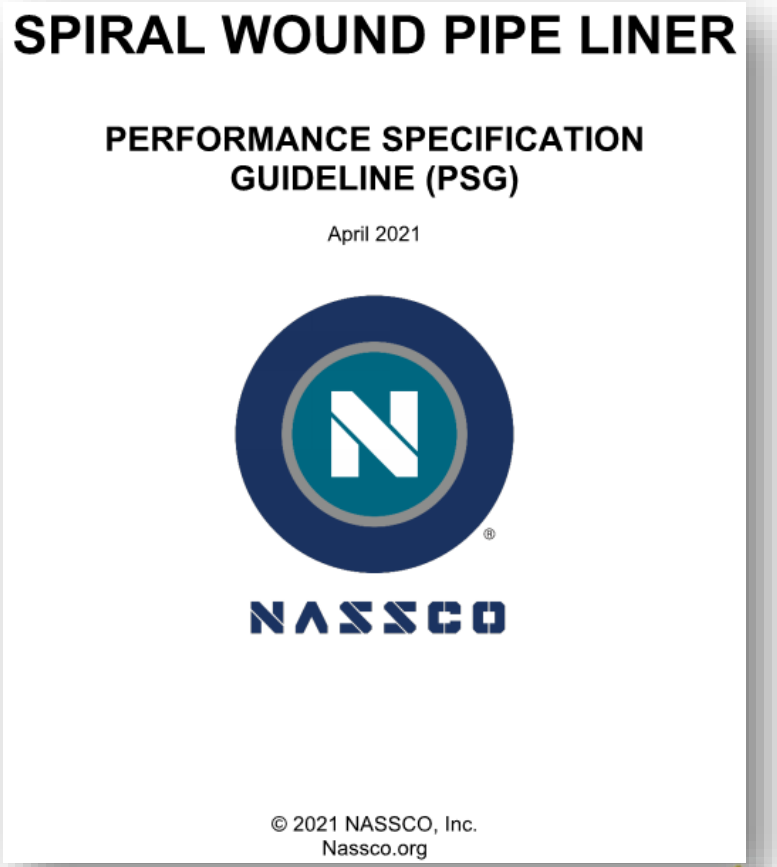




Use Dropdown

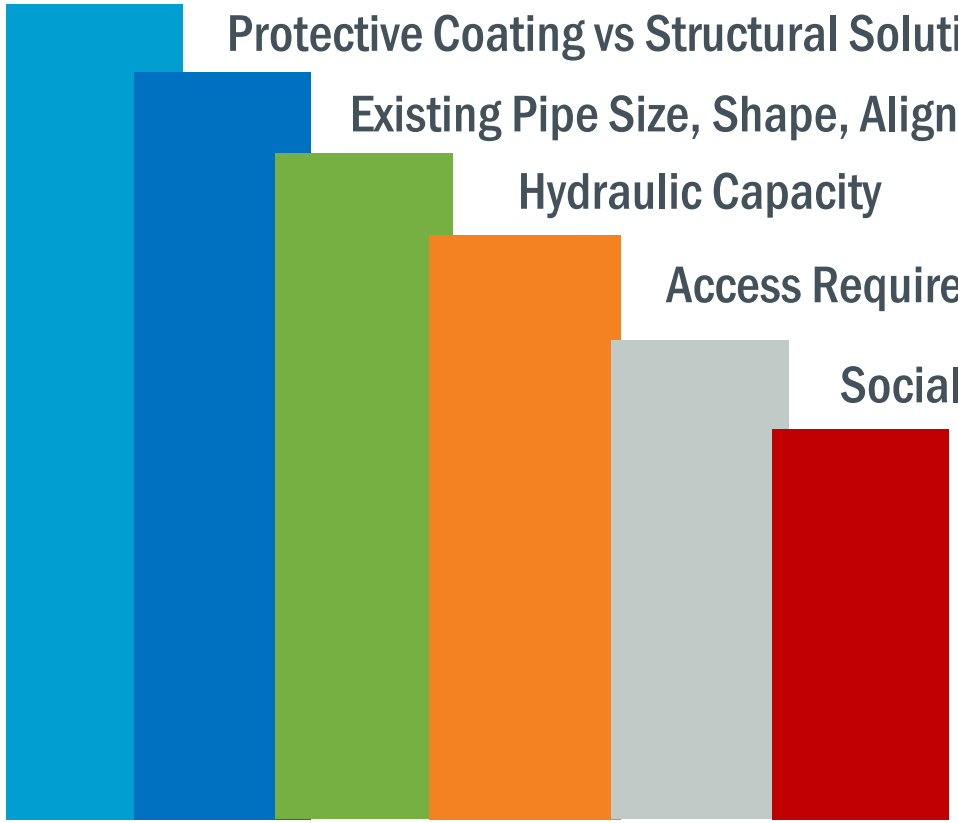
Select "Spiral Wound Pipe"

Spiral Wound Pipe Liner
NASSCO's Performance Specification Guideline (PSG)



Spiral Wound Pipe Liners for Rehabilitation

Rehabilitation Considerations



Protective Coating vs Structural Solution (Partially or Fully Deteriorated)

Existing Pipe Size, Shape, Alignment

Hydraulic Capacity

Access Requirements, Bypass Pumping / Flow Control, & Permitting

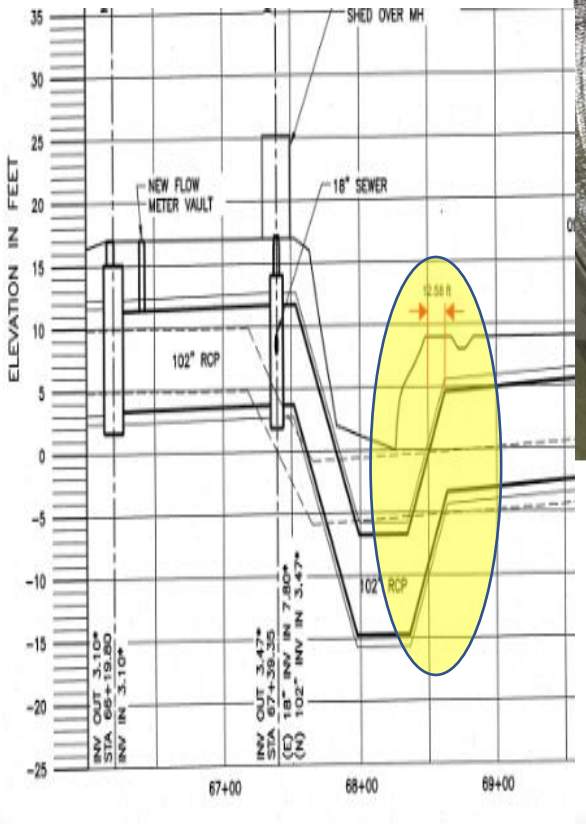
Social Costs, Restoration and Construction Scheduling

Initial Cost vs Long-term Value

Recommended Approach

Spiral Wound Pipe Liner Rehabilitation – Overview

- Gravity Sewer, Storm, and Culvert rehabilitation
  - ✓ Partially or fully deteriorated solution
  - ✓ Full circumference or partial
  - ✓ Pipe diameters of 6 inches to greater than 200 inches
- Can be Installed in most types of gravity pipe
  - ✓ Circular and non-circular
  - ✓ Variable alignments
- Nominal to more considerable reduction in hydraulic flow area
- Typically, can be installed from existing maintenance holes, accesses, etc.
- Can be constructed in partial flow conditions
- Spiral wound liners can be tight fit or have a grouted annular space
  - ✓ Fixed diameter
  - ✓ Expandable (6” to 42” diameters) e.g. SPR™ EX
  - ✓ Perform work to standard of care per ASTM references



Spiral Wound Pipe Liner – ASTM References

Manufacturing

ASTM F1697 – "Standard Specification for Poly (Vinyl Chloride) (PVC) Profile Strip for Machine Spiral-Wound Liner Pipe Rehabilitation of Existing Sewers and Conduit"

Documents requirements and test methods for materials, dimensions, workmanship, extrusion quality and marking for extruded profile strips for rehabilitation of 6-to-180-inch diameter and similar size non-circular shaped conduits

ASTM F1735 – "Standard Specification for Poly (Vinyl Chloride) (PVC) Profile Strip for PVC Liners for Rehabilitation of Existing Man-Entry Sewers and Conduits"

Documents requirements and test methods for materials, dimensions workmanship, extrusion quality and marking for extruded profile strips for rehabilitation of 36-to-144-inch vertical dimension conduits

Installation

ASTM F1698 – "Standard Practice for Installation of Poly (Vinyl Chloride) (PVC) Profile Strip Liner and Cementitious Grout for Rehabilitation of Existing Man-Entry Sewers and Conduits"

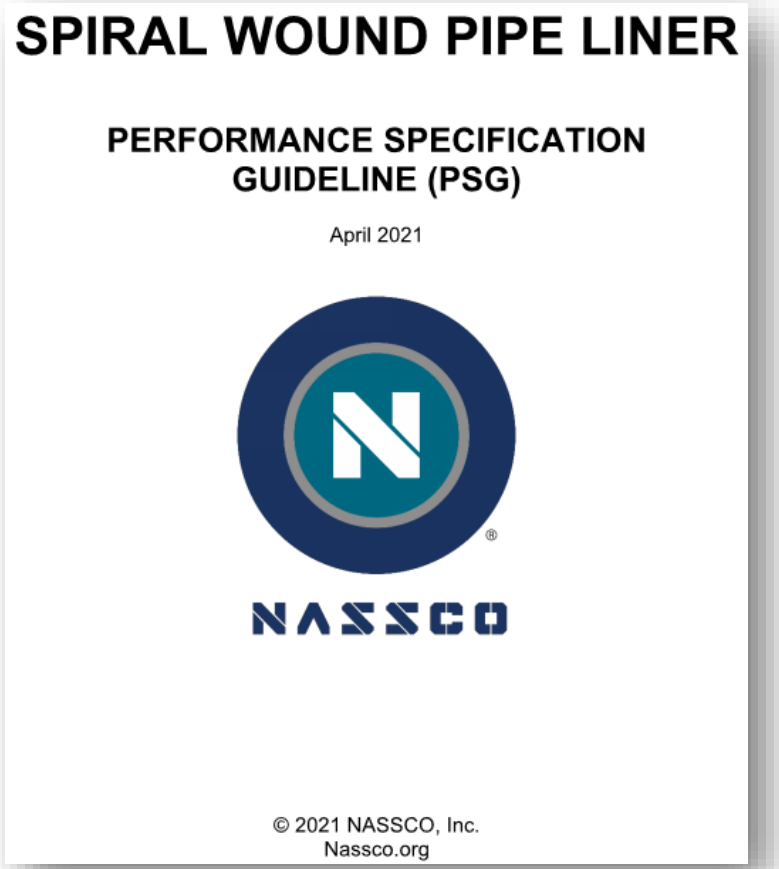
Describes procedures for rehabilitation of 36-to-144-inch vertical dimension conduits

ASTM F1741 – "Standard Practice for Installation of Machine Spiral Wound Poly (Vinyl Chloride) (PVC) Liner Pipe for Rehabilitation of Existing Sewers and Conduits"

Describes procedures for rehabilitation of 6-to-180-inch diameter conduits as traveling (>30" dia.) or stationary winding machines

Spiral Wound Pipe Liner
NASSCO's PSG

- Machine Spiral Wound Liners (MSWL)
  - ✓ Pipe diameters of 6 inches to greater than 200 inches
  - ✓ Tight fit to existing pipe with no annulus leaking (6" to 60" diameters)
  - ✓ Grouted or ungrouted annulus for close-fit to existing pipe
    - ➢ May require additional reinforcing for design conditions
  - ✓ **Design in accordance with ASTM F1741, Appendix X1**
- Structural Grout Spiral Wound Liners (SGSWL)
  - ✓ Conduit vertical dimensions 36 inches and greater
  - ✓ Fixed diameter rigid composite liner system (liner/grout/existing pipe)
    - ➢ May require additional reinforcing for design conditions
  - ✓ Worker entry thru adequate access openings
  - ✓ **Design in accordance with ASTM F1698, Appendix X1**
- Required contractor experience
  - ✓ Minimum 5,000 linear feet of similar size and shape rehabilitation using SWL
  - ✓ Must be vetted and approved (or certified) as installer by manufacturer



Spiral Wound Rehabilitation – Terms per ASTM F1698 & F1741

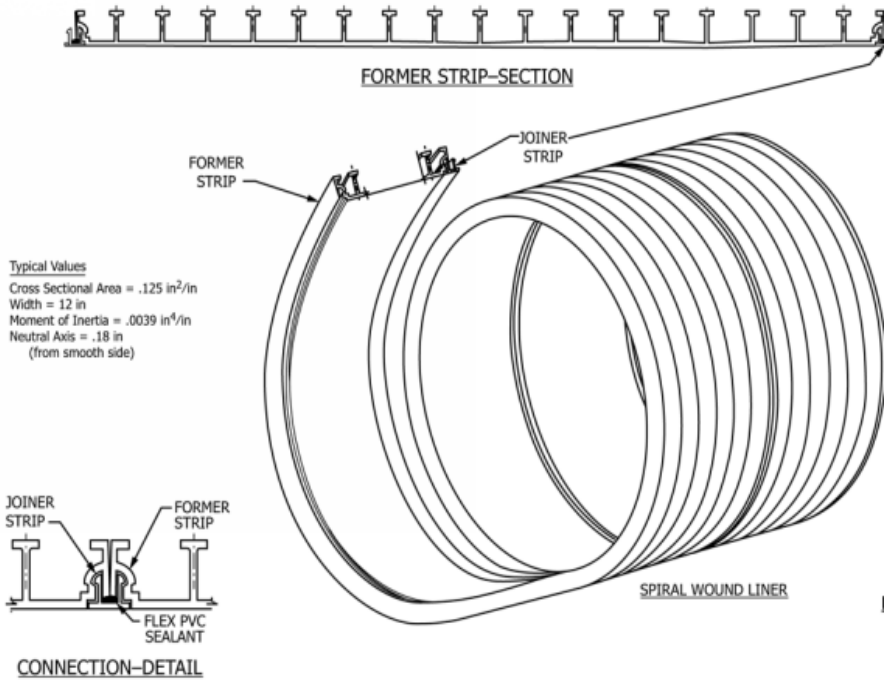
Man-Entry (F1698)

Extruded Profile Former Strip – Product available in various sizes, consisting of a smooth inside surface and a ribbed outer surface with edge configurations to allow mechanical locking of adjacent strips.

Extruded Joiner Strip – A companion product to the Former Strip of such configuration to provide the locking mechanism at the edges of the former strips. It contains within it a coextruded flexible seal that forms a compression seal when mated with the edges of the former strip.

Materials in accordance with ASTM F1735, coiled on a reel in continuous lengths and/or modular flat panels

Adhesive or sealants used for interlocking elements are compatible with other materials



Source: ASTM F1698-02 (R2015)

Machine (F1741)

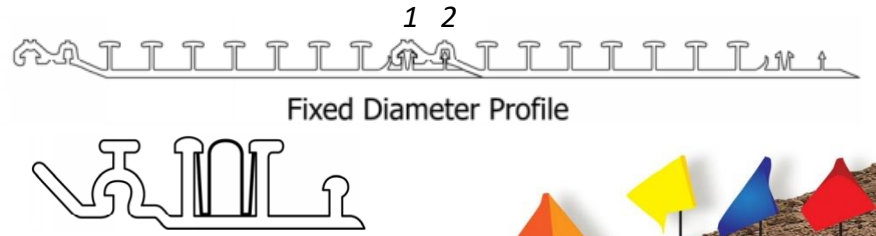
Extruded Profile Strip – Product available in various widths, consisting of a smooth inside surface and a ribbed outer surface joined by self interlocking male and female edges.

Materials in accordance with ASTM F1697, coiled on a reel in continuous lengths and/or modular flat panels

Adhesive or sealants used for interlocking elements are compatible with other materials

Spiral Wound Liner Pipe (SWL) – Product field fabricated from extruded profile strips to a circular or non-circular (arched, oval, rectangular or a combination thereof), which may include reinforcement for design stresses and stiffening

The design of the SWL for non-circular shaped pipes is complex and specific to each situation. The manufacturer shall be consulted for design recommendations for the rehabilitation of non-circular pipes. In larger sizes of non-circular pipes, a reinforcing framework for the steel reinforced profile strip liner may have to be temporarily installed to support the live grout load.



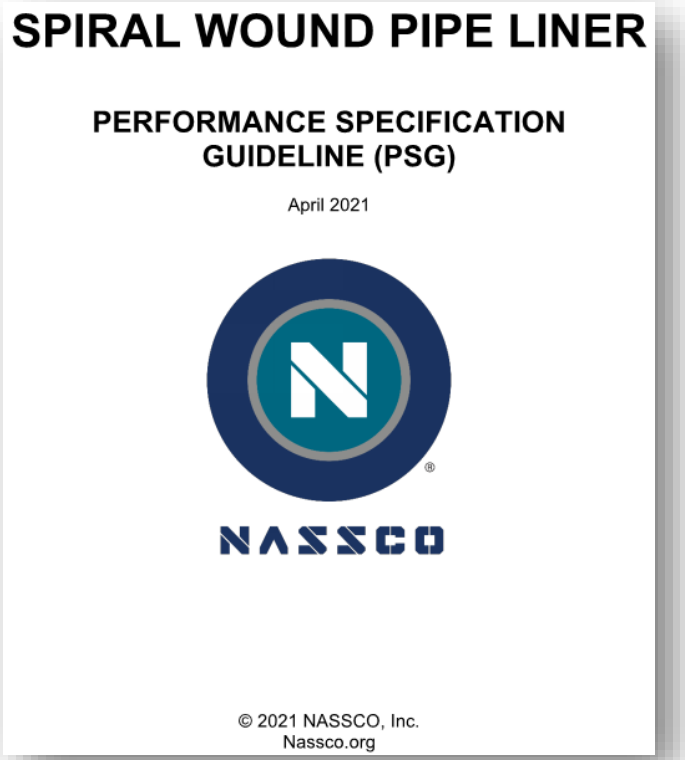
Source: ASTM F1741-18

Spiral Wound Rehabilitation – Terms per ASTM F1698 & F1741

Grouting – Seals annulus between SWL and existing (host) pipe - structural or non-structural

Consult liner manufacturer for recommendations of grout mix, grout placement and grouting pressure considerations:

- Grout mix heat of hydration
- Grout specific density
- Liner stiffness
- Slope of the liner
- Stage pour heights
- Enhancement Factor, K, and particular grout placement methods (critical for composite designs)



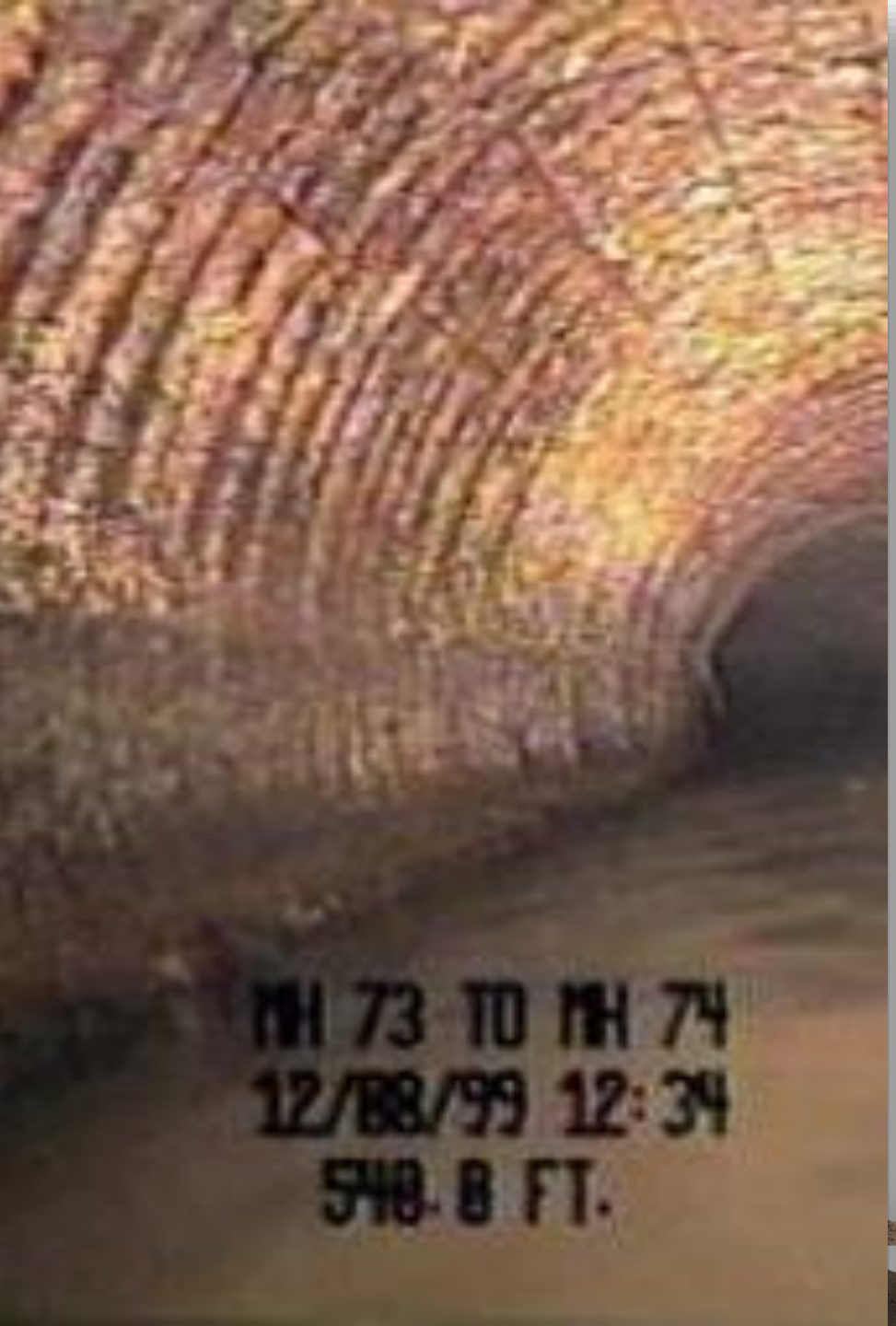
Line Obstructions (F1741) – Cleaning and obstruction removal per NASSCO standards and specifications.

Confirm with CCTV inspection that pipe is suitable for SWL installation

- No intruding taps (TBI) more than one inch or 12.5%, whichever is less
- No Collapses (X) or severe Deformation (D)
- No Offset Joints (JO) more than 12.5% inside pipe diameter
- No significant Sags (MWLS)

Bypassing – Some flow in existing pipe and laterals connections is OK
May be able to accommodate up to 30% vertical depth of conduit at low-velocity flow rates.
Consult liner manufacturer!

Design States – Partially and Fully Deteriorated



Design States for ASTM F1698 vs ASTM F1741

Fully Deteriorated

"The existing pipe is not structurally sound and cannot support soil, surcharge and live loads or is expected to reach this condition over the design life of the spiral wound liner pipe. This condition is evident when sections of the existing pipe are missing, the existing pipe has lost its original shape, or the existing pipe has corroded due to the effects of the fluid, atmosphere, or soil."

In short, the liner must be designed to resist all applied loads – soil, superimposed dead load, vehicular and hydrostatic – continuously over its service life (usually 50 years for design)

Design States for ASTM F1698 vs ASTM F1741

Partially Deteriorated

ASTM F1698 (SGSWL)

Circular and non-circular conduits

1 - Host pipe can support loading

2 - Soil outside pipe provides adequate side support

3 - Host pipe may have longitudinal cracks and **up to 10% deformation**

ASTM F1741 (MSWL)

Circular and non-circular conduits

1 - Host pipe can support loading

2 - Soil outside pipe provides adequate side support

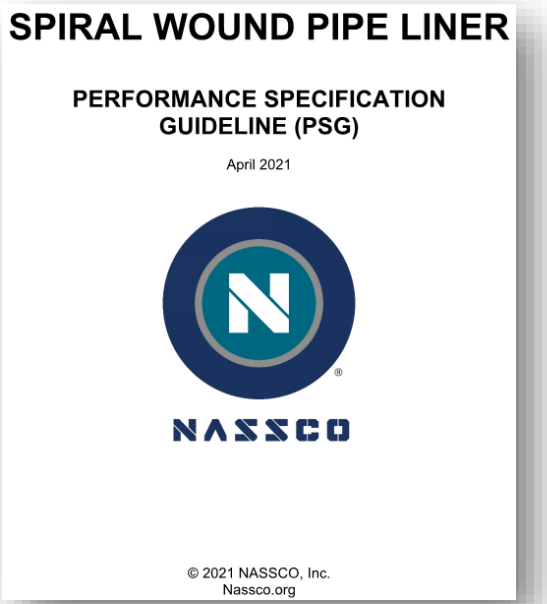
3 - Host pipe may have longitudinal cracks and **some distortion of the diameter**

"The existing pipe can support the soil and surcharge and live loads throughout the design life of the rehabilitated pipe, and the soil adjacent to the existing pipe must provide adequate side support. The conduit may have longitudinal cracks and ***X amount of distortion of the diameter."***

Design Considerations

Spiral Wound Pipe Liner
NASSCO's PSG

- Structural Grout Spiral Wound Liners (SGSWL)
  - ✓ Conduit vertical dimensions 36 inches and greater
  - ✓ Fixed diameter rigid composite liner system (liner/grout/existing pipe)
    - ➢ May require additional reinforcing for design conditions
  - ✓ **Design in accordance with ASTM F1698, Appendix X1**



Partially Deteriorated

Circular and non-circular conduits (Appendix X1.2.1)

1 – Liner resists hydrostatic pressure (and internal vacuum)

2 - Soil outside pipe provides adequate side support

3 – Resist groundwater and buckling for largest ungrouted arch

Safe height of groundwater above liner crown:

$$P = \frac{8E_L I\left(k^2 - 1\right)}{0.433 D_m^{\ 3} N} \text{ water, ft}$$

P = allowable external pressure of water, ft,
E_L = modulus of elasticity of PVC liner, psi (MPa), reduced to account for long-term effects (see Note X1.1),
I = moment of inertia of PVC liner, in.^{4}/in. (mm^4/mm),
k = factor determined from ungrouted arc (k = 25 for 5 % maximum grout void, that is, ungrouted arc = 18°) (see Note X1.2),
D_m = mean diameter of PVC liner, in. (mm),
= inside diameter of liner + 2(y–bar),
= inside diameter of liner + 2(y-bar),
y-bar = distance to neutral axis of profile from inner (smooth) surface, in. (mm), and
N = factor of safety (2.0 is recommended).

Spiral Wound Pipe Liner
NASSCO's PSG

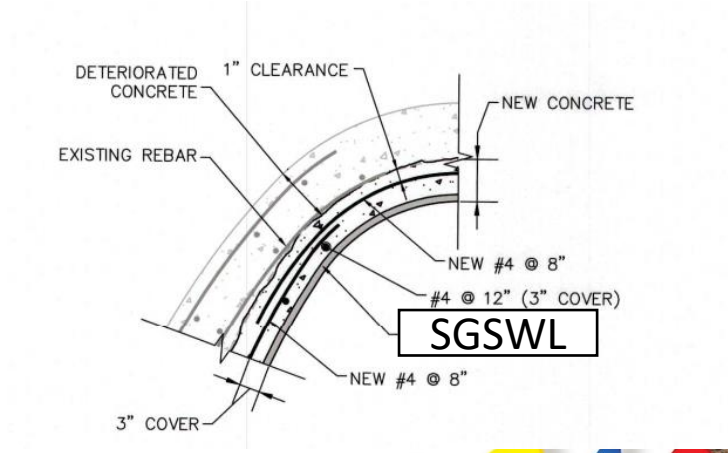
- Structural Grout Spiral Wound Liners (SGSWL)
  - ✓ Conduit vertical dimensions 36 inches and greater
  - ✓ Fixed diameter rigid composite liner system (liner/grout/existing pipe)
    - ➢ May require additional reinforcing for design conditions
  - ✓ **Design in accordance with ASTM F1698, Appendix X1**

Fully Deteriorated

Circular and non-circular conduits (Appendix X1.2.2)

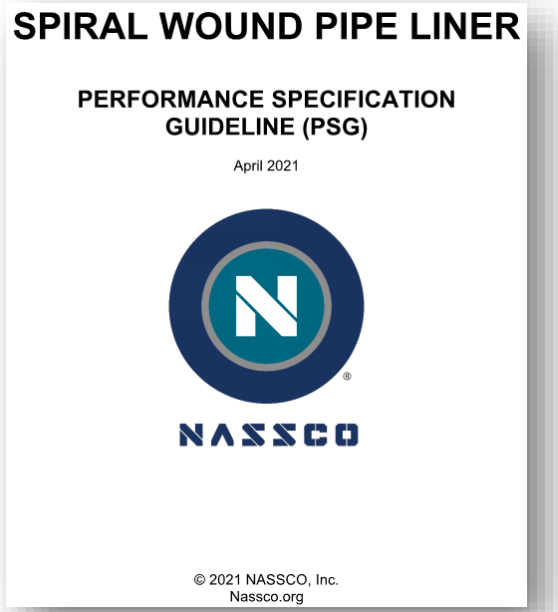
1 – Meets Partially Deteriorated design requirements

2 - *"The rehabilitation of the host structure by this installation practice results in a rigid composite structure (PVC/grout/existing pipe); the composite structure should be designed to sustain the loads (with safety factor) specified by the applicable project specifications. The contractor and product supplier should provide design details and test data to the owner's engineer to prove to his (her, they, etc.) satisfaction that this level of rehabilitation will be accomplished by the design and installation of the grouted PVC liner system…"*



Spiral Wound Pipe Liner
NASSCO's PSG

- Machine Spiral Wound Liners (MSWL)
  - ✓ Pipe Diameters of 6 inches to greater than 200 inches
  - ✓ Grouted or ungrouted annulus for close-fit to existing pipe
  - ✓ **Design in accordance with ASTM F1741, Appendix X1**



Partially Deteriorated

Liner Pipe Expanded Against Existing Pipe (Appendix X1.2.1.1)

1 – Liner resists hydrostatic pressure (and internal vacuum)

2 - Soil outside pipe provides adequate side support

3 – Confirm liner stiffness to resist hydrostatic pressure

$$P = \frac{24KE_LI}{(1-\nu^2)D^3}\cdot\frac{C}{N} \rightarrow E_LI = \frac{P(1-\nu^2)D^3}{24K}\cdot\frac{N}{C}$$

E_L = modulus of elasticity of spiral wound liner pipe, psi (MPa), reduced to account for long-term effects (see Note X1.1),

I = moment of inertia of spiral wound liner pipe, in.^{4} /in. (mm^4/mm) (see Table 1),

E_LI = stiffness factor of spiral wound liner pipe, in.^{3}·lbf/in.^{2} (MPa·mm ^{3}),

P = external pressure, psi (MPa),

C = ovality reduction factor,

D_E = mean inside diameter of liner pipe, in. (mm),

D_{min} = minimum inside diameter of liner pipe, in. (mm),

D_{max} = maximum inside diameter of liner pipe, in. (mm),

N = factor of safety (2.0 is recommended),

D = mean diameter of spiral wound liner pipe, in. (mm), = $D_E - 2(H - \bar{y})$,

H = height of profile, in. (mm) (see Table 1),

$\bar{y}$ = depth to neutral axis of spiral wound liner profile pipe, in. (mm) (see Table 1),

K = enhancement factor of the soil and existing pipe adjacent to the new liner pipe (for value contact the liner material supplier), and

ν = Poisson's ratio (0.38 average).

Spiral Wound Pipe Liner
NASSCO's PSG

- Machine Spiral Wound Liners (MSWL)
  - ✓ Pipe Diameters of 6 inches to greater than 200 inches
  - ✓ Grouted or ungrouted annulus for close-fit to existing pipe
  - ✓ **Design in accordance with ASTM F1741, Appendix X1**

Fully Deteriorated

Liner Pipe Expanded Against Existing Pipe (Appendix X1.2.2.1)

1 – Grouted (non-structural) or Ungrouted MSWL

$$E_L I = \frac{(q_t N/C)^2 D^3}{32 R_w B' E'_S}$$

E_L = modulus of elasticity of spiral wound liner pipe, psi (MPa), reduced to account for long-term effects (see Note X1.1),
I = moment of inertia of spiral wound liner pipe, in.^{4} /in. (mm^4/mm) (see Table 1),
$E_L I$ = stiffness factor of spiral wound liner pipe, in.^{3}· lbf/in.^{2} (MPa·mm^3), and
D = mean diameter of spiral wound liner pipe, in (mm) (see X1.2.1).

q_t = total external pressure on pipe, psi (MPa) = 0.433 H_w + wHR_w/144 + W_L (inch-pound units) = 0.00981 H_w + wHR_w/1000 + W_L, (SI units),
R_w = water buoyancy factor (0.67 min) = 1–0.33 (H_w/H),
H_w = height of water above top of liner pipe, ft (m),
H = height of soil above top of liner pipe, ft (m),
w = soil density, lb/ft^3 (kN/m^3),
W_L = live load, psi (MPa),
B' = coefficient of elastic support
= $1/(1+4e^{-0.065H})$, (inch-pound units)
= $1/(1+4e^{-0.213H})$, (SI units),
C = ovality reduction factor (see X1.2.1),
N = factor of safety (2.0 is recommended),
E'_S = modulus of soil reaction, psi (MPa) (see Note X1.4),

Installation and Quality Assurance

Spiral Wound Pipe Liner

Installation Run Lengths

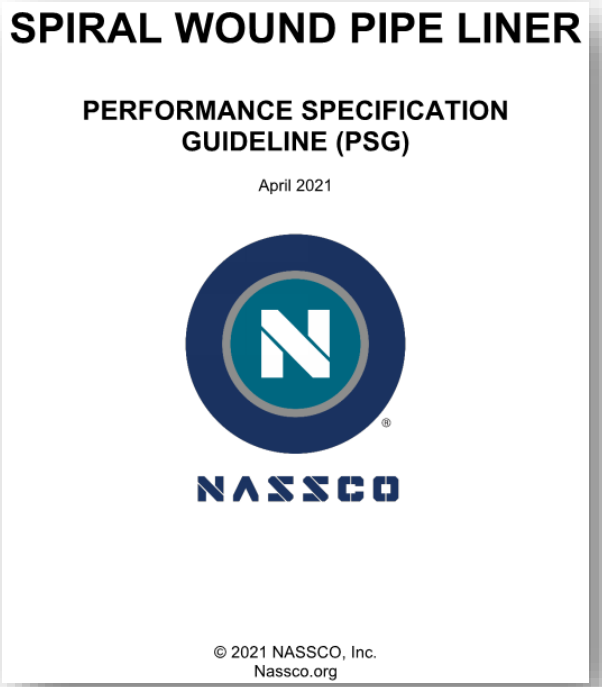
- Expanded MSWL ≈ 150 to >400 feet
  - ✓ Dependent on conduit size and geometry/alignment
  - ✓ Dependent on how material is delivered to job site (reel capacity for material)
  - ✓ Consult manufacturer
- Fixed Diameter MSWL and SGSWL ≈ ≥700 feet

Installation Crew

- Typical set up includes
  - ✓ Material Trailer with Spools
  - ✓ Standard pickup truck/tool truck(s)
  - ✓ Grout truck
  - ✓ Footprint could be as small as 10’ x 7’
  - ✓ Average crew size of 6 people

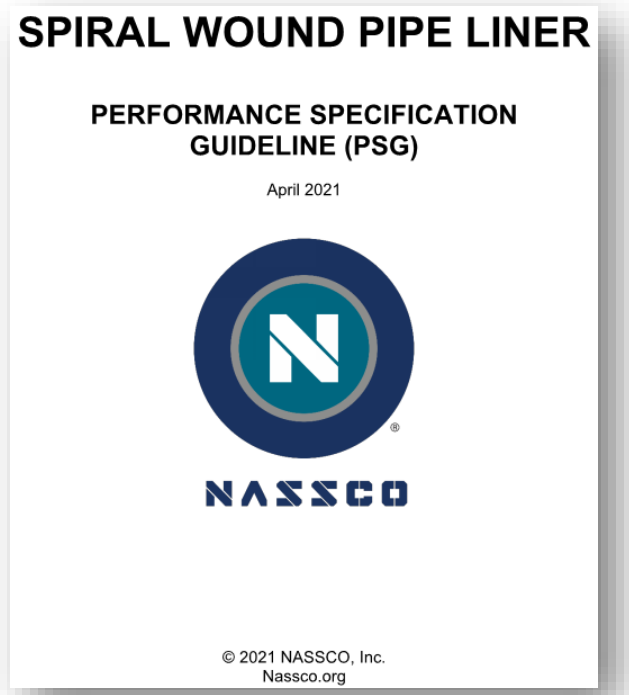
Spiral Wound Pipe Liner
NASSCO's PSG – Typical Bid Items (Paragraph 3.7)

- Mobilization – Lump Sum (LS) – generally 5% of bid amount
- Pre-rehab CCTV – Per linear foot (lf) or incidental to liner installation
- Point Repairs – Each or by Allowance/Contingency
- Pipe Cleaning – Per linear foot or incidental
- Debris Removal – For heavy cleaning requirements by cubic yard (cy) or ton
- SWL Installation – lf or LS (should include Flow Control)
- Traffic control – LS or incidental
- Service Reconnections – Each or incidental
- Service Connection Sealing – Each or incidental
- Post-rehab CCTV – lf or incidental
- Grouting – LS, per cy placed, or incidental



Spiral Wound Pipe Liner - NASSCO's PSG

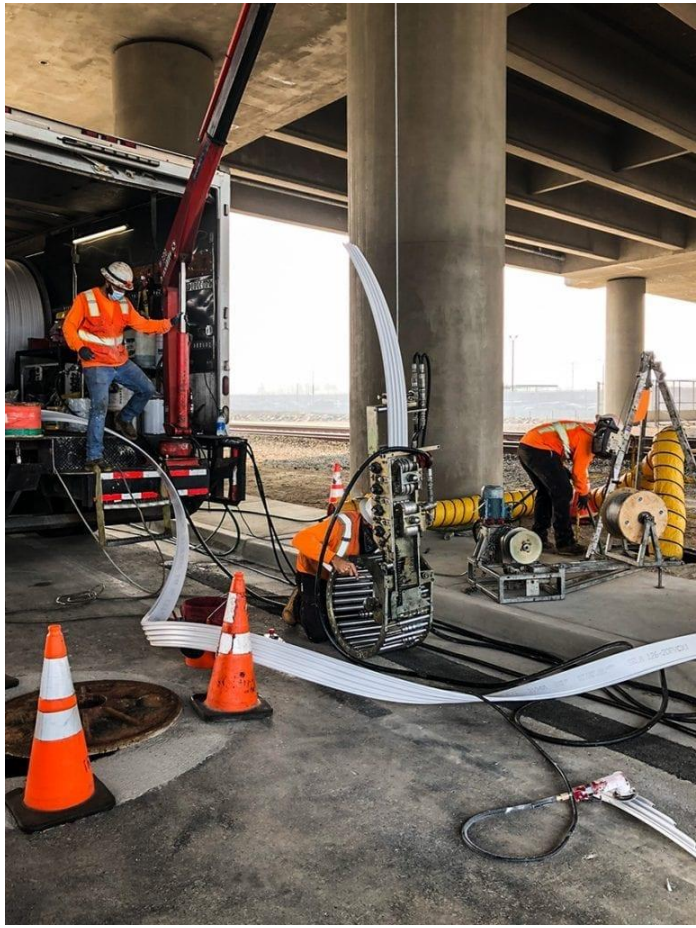
PART 1: GENERAL



Spiral Wound Pipe Liner
NASSCO's PSG – Submittal Requirements

Performance Work Statement - (Shop Drawing)

- Installation method including SWL method, materials and MSDS
- Contractor experience (could be bid submittal)
- Design calculations (could be bid submittal if different methods allowed)
  - Liner
  - Grout Mix and Placement
- Manufacturer data
- Bypassing, odor control, health and safety, traffic management, public outreach, etc.
- Point repair method(s)



Quality Control - (Shop Drawing)

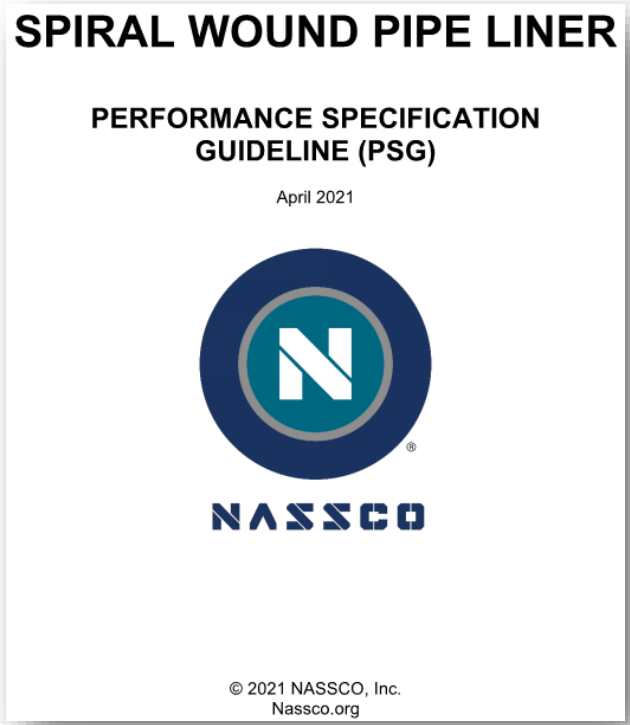
- Contractor personnel assigned responsibilities
- Product sampling and testing, including method and frequency
- Schedule

Spiral Wound Pipe Liner
NASSCO's PSG – Submittal Requirements

- Record Drawings
- Warranty
  - ✓ Certification from manufacturer for materials
  - ✓ One (1) year warranty following Owner acceptance
    - Non-prorated
    - Any defect that affects integrity, strength, function or operation of the asset
    - Repairs per the PWS and as recommended by the manufacturer
  - ✓ Warranty repairs require an extended warranty period (additional one year recommended)
  - ✓ Owner encouraged to inspect asset during warranty period

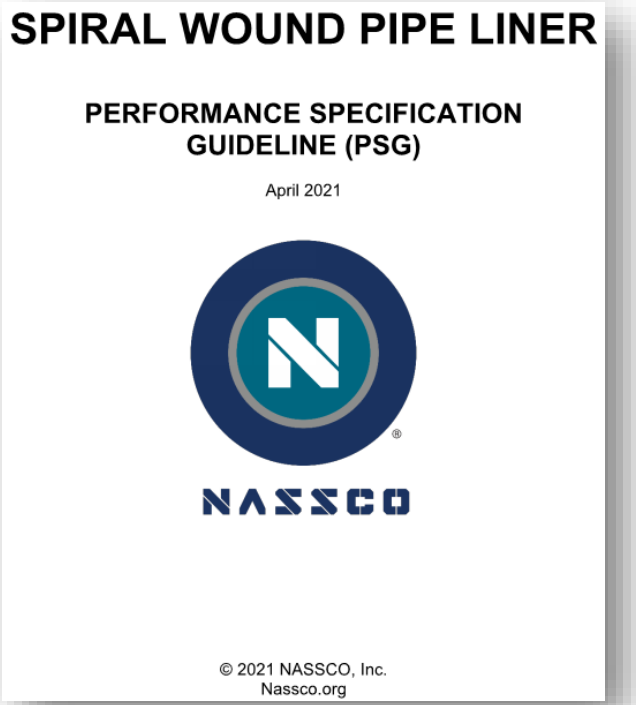
Spiral Wound Pipe Liner
NASSCO's PSG – Testing and Acceptance

PART 3: INSTALLATION



Spiral Wound Pipe Liner
NASSCO's PSG – Testing and Acceptance

- Confirmation of SWL Physical Properties
  - ✓ Test samples from run (profile sample from reel spool)
  - ✓ Certification statement for chemical resistance
- Leakage Testing (Exfiltration or Air) prior to lateral reinstatement
  - ✓ Consider practicality of leakage testing for size of SWL
- Post-rehab CCTV Inspection
- Grout Compressive Strength Testing
  - ✓ Three (3) samples for each grouting day
  - ✓ ASTM Test Method C942 – "Test Methods for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory"
- "Hammer Test" for SGSWL
  - ✓ Minimum of five (5) passes along the lined conduit
  - ✓ Test at 2, 5, 8, 10 and 12 clock positions



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Q & A