# ASME B31.3 Process Piping

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## Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

# 15. Nonmetallic Piping

- General
- Design, Fabrication, and Installation for
  - Thermoplastics
  - Reinforced thermosetting resins
  - Reinforced concrete
  - Vitrified clay
  - Borosilicate glass
  - Piping lined with nonmetals
- Limitations



# The Material in This Section is Addressed by B31.3 in:

Chapter VII - Nonmetallic Piping and Piping Lined with Nonmetals

Appendix B - Stress Tables and Allowable Pressure Tables for Nonmetals

## General

- Chapter VII has requirements for
  - Thermoplastics
  - Reinforced thermosetting resins
  - Reinforced concrete
  - Vitrified clay
  - Borosilicate glass
  - Piping lined with nonmetals



## General

- Trend toward the use of nonmetals is increasing
- Nonmetals are used when the metallic alternative is judged to be too expensive
- Allowances for variations of pressure and temperature described in Chapter II are not permitted for nonmetallic piping
- Increased allowable stresses for occasional loads described in Chapter II are not permitted

# Thermoplastics

- Materials that can be repeatedly softened by heating and hardened by cooling
- Pipe is extruded
- Fittings are usually injection molded, but sometimes fabricated
- Valve parts are usually injection molded

(Durapipe)

(Charlotte Pipe)

(Durapipe)



# Thermoplastics

Commonly used thermoplastics

- ABS Acrylonitrile-butadiene-styrene
- CPVC Chlorinated polyvinyl chloride
- FEP Perfluoro ethylene propylene
- (HD)PE (High density) polyethylene
- PFA Polyperfluoroalkoxy Alkane
- PP Polypropylene
- PVC Polyvinyl chloride
- PVDF Polyvinylidene fluoride

# Thermoplastics

B31.3 recommended temperature limits:

| Material | Min (F) | Max (F) | Min (C) | Max (C) |
|---|---|---|---|---|
| ABS | -40 | 176 | -40 | 80 |
| CPVC | 0 | 210 | -18 | 99 |
| FEP | -325 | 400 | -198 | 204 |
| PE | -30 | 180 | -34 | 82 |
| PFA | -40 | 450 | -40 | 250 |
| PP | 30 | 210 | -1 | 99 |
| PVC | 0 | 150 | -18 | 66 |
| PVDF | 0 | 275 | -18 | 135 |



# Thermoplastics

## Characteristics

- High coefficient of thermal expansion
  - 4” in 100’ (3 mm/m) of expansion for 50ºF (25ºC) temperature change [HDPE]
  - More in some thermoplastics, less in others
- Creep at room temperature
- Low elastic modulus
- Longitudinal strain due to internal pressure can be significant

# Thermoplastics

## Allowable Stress

*Hydrostatic design stress (HDS)* is the hoop stress that when applied continuously, will cause failure of the pipe at 100,000 hours multiplied by a suitable design factor (usually 0.5)

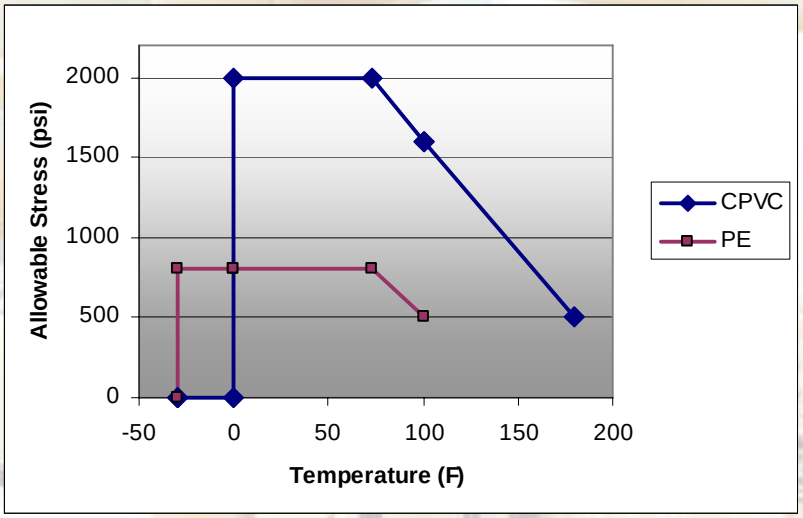
| Material | Short-term (ksi) | HDS* (ksi) | Short-term (MPa) | HDS* (MPa) |
|---|---|---|---|---|
| CPVC | 7.53 | 2.00 | 51.9 | 13.8 |
| PE | 2.96 | 0.80 | 20.4 | 5.5 |
| PVC | 7.53 | 2.00 | 51.9 | 13.8 |

* HDS at 23ºC (73ºF)



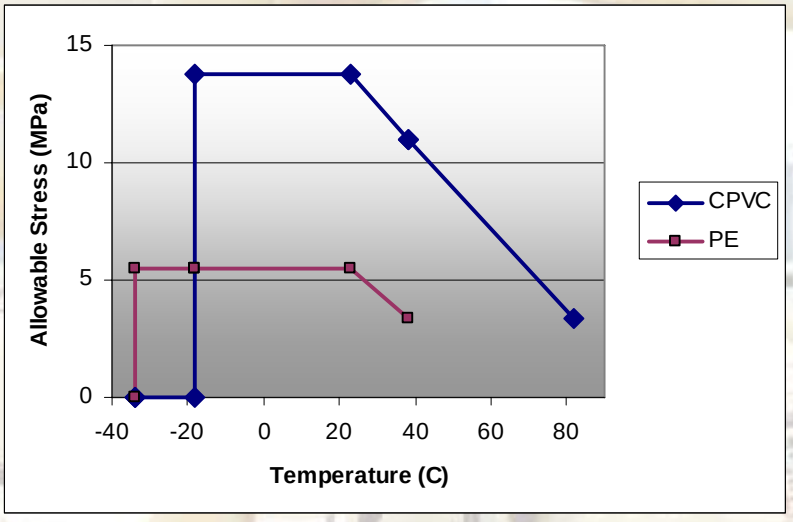
# Thermoplastics

## Allowable Stress – US Customary Units



# Thermoplastics

## Allowable Stress – Metric Units






# Thermoplastics

## Pressure Design – Straight Pipe

$$t = PD / [2 (S + P)]$$

Where:

- t = pressure design thickness
- P = design pressure
- D = outside diameter of pipe
- S = HDS value for material from Appendix B

No specific rules for external pressure design

# Thermoplastics

## Support

Because of the low modulus and low allowable stress, thermoplastics require more support than similar sized metallic pipe. For 68ºF (20ºC):

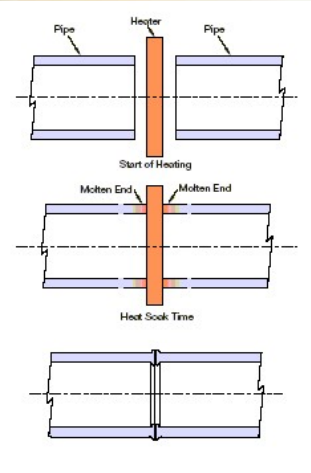
| NPS | PP (Asahi) | | Typical Metallic | |
|---|---|---|---|---|
| | ft | m | ft | m |
| 1 | 3.5 | 1.1 | 14 | 4.3 |
| 2 | 4.5 | 1.4 | 20 | 6.1 |
| 4 | 6.0 | 1.8 | 26 | 7.9 |
| 6 | 7.0 | 2.1 | 30 | 9.1 |



# Thermoplastics

Fabrication – Butt fusion fittings are joined to the pipe using a butt fusion welding process. (PE, PP, PVDF, others)

(Asahi)

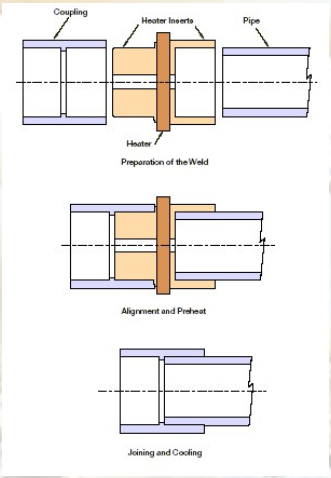



(Asahi)

# Thermoplastics

Fabrication – Socket fittings can be joined to the pipe using a socket fusion welding process. (PE, PP, PVDF, others)

(Spears)

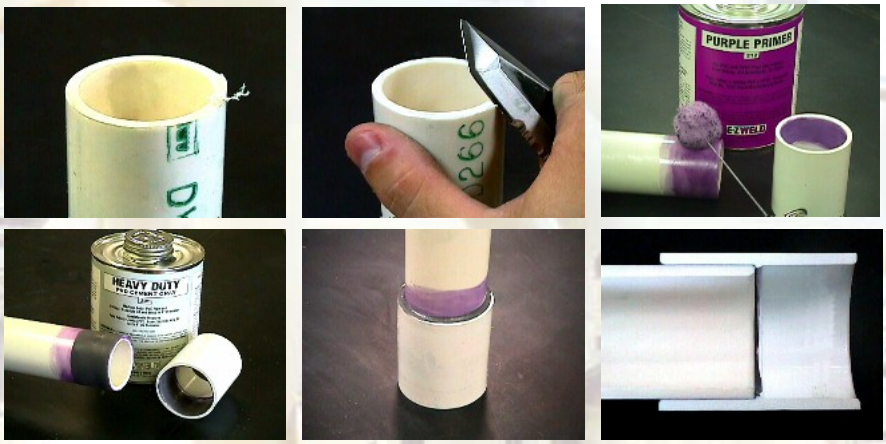



(Asahi)



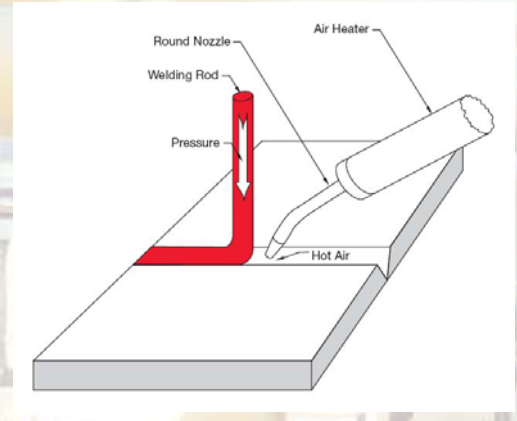
# Thermoplastics

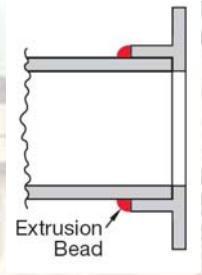
Fabrication – Socket fittings can be joined to the pipe using a solvent cementing process. (ABS, PVC, CPVC)



# Thermoplastics

Fabrication – Piping can also be joined using a hot gas welding process. (PE, PP, PVDF, others)






# Thermoplastics

Bonders are required to use a qualified bonding procedure specification. The BPS shall specify

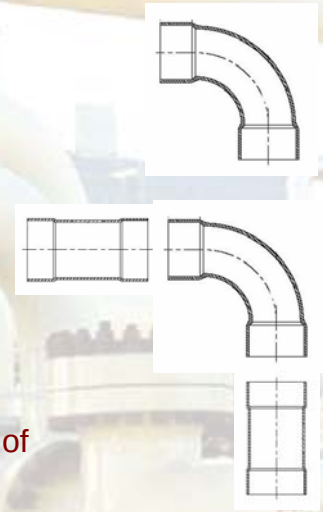
- Procedure for making the bonds
- Materials, including storage requirements
- Tools, including proper care and handling
- Environmental requirements (clean, dry, warm)
- Joint preparation
- Dimensional requirements, including tolerances
- Cure time
- Protection of work
- Acceptance criteria

[A328.2].

# Thermoplastics

## Fabrication

- A warm, dry and clean environment is required for fabrication
- A leak at an elbow requires
  1. Cutting out the elbow and adjacent pipe
  2. Fabricating a piece with an elbow and two couplings
  3. And installing it, hoping none of the six new joints leak





# Reinforced Thermosetting Resins

- Materials that harden when heated and cannot be re-melted
- Pipe is filament wound, contact molded, or centrifugally cast
- Fittings are molded, filament wound or fabricated
- Few RTR valves are available

(Smith Fibercast)

## Reinforced Thermosetting Resins

Commonly used resins

- Polyester
- Vinylester
- Epoxy
- Furan

Commonly used reinforcements

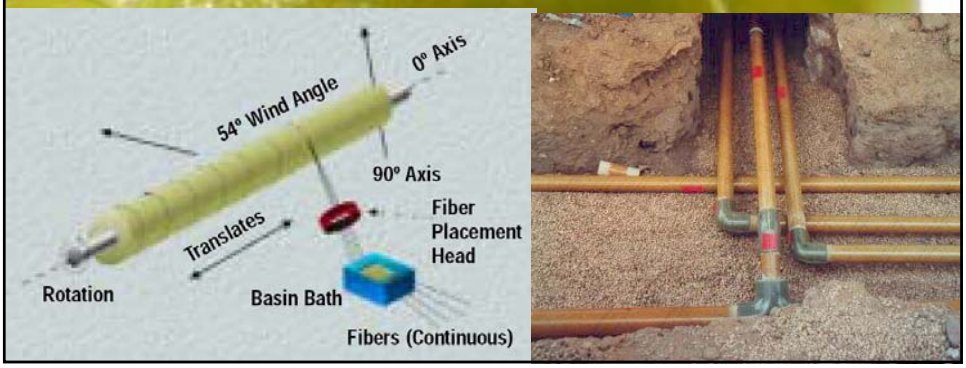
- Glass fiber
- Carbon fiber



## Reinforced Thermosetting Resins

Filament wound

(Smith Fibercast)




Reinforced Thermosetting Resins
Contact Molded
BECHT ENGINEERING COMPANY, INC.
Nonmetallic Piping - 25


Reinforced Thermosetting Resins
Centrifugally Cast
FROM SMITH FIBERCAST
BECHT ENGINEERING COMPANY, INC.
Nonmetallic Piping - 26

# Reinforced Thermosetting Resins

## Reinforced plastic mortar pipe

- Has aggregate (usually sand) in addition to fiber reinforcement to stiffen the wall of the pipe
- Is used mostly underground
- Usually has bell and spigot joints, but may have socket joints like other RTR piping



# Reinforced Thermosetting Resins

## Vendor recommended temperature limits

- Range from 180 to 275ºF (82 to 135ºC)
- Are somewhat dependent on the resin
- But are more dependent on the construction of the pipe and fittings…amount of reinforcement in the liner and structural layers
- Can be significantly lowered depending on the chemical being handled

## Reinforced Thermosetting Resins

Characteristics

- Higher coefficient of thermal expansion…about twice that of steel, but 1/5 of thermoplastics
- Creep at room temperature
- Low elastic modulus (3 to 10% of steel), but 3 to 10 times thermoplastics



## Reinforced Thermosetting Resins

Allowable Stress – Filament Wound and Centrifugally Cast

*Hydrostatic design stress (HDS)* is the hoop stress that when applied continuously, will cause failure of the pipe at 100,000 hours multiplied by a design factor. The design factor is:

- Not more than 1.0 if stress is determined using the pressure cycling method
- Not more than 0.5 if stress is determined using the static pressure method

Typical HDS values are 8,000 to 13,000 psi (55 to 90 MPa)

## Reinforced Thermosetting Resins

Allowable Stress – Contact Molded

*Design stress (DS)* is 1/10 of the minimum tensile strength

Pressure Design – Same as for thermoplastic pipe



## Reinforced Thermosetting Resins

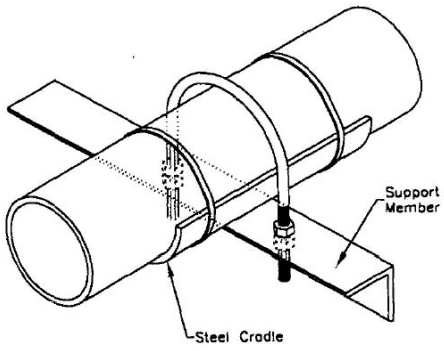
Support

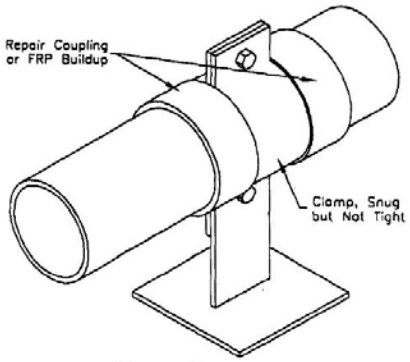
Because of the lower modulus and lower allowable stress, RTR pipe requires more support than similar sized metallic pipe. For 75ºF (24ºC):

| NPS | Green Thread (Smith Fibercast) | | Typical Metallic | |
|---|---|---|---|---|
| | ft | m | ft | m |
| 1 | 10.9 | 3.3 | 14 | 4.3 |
| 2 | 14.1 | 4.3 | 20 | 6.1 |
| 4 | 17 | 5.2 | 26 | 7.9 |
| 6 | 20.5 | 6.2 | 30 | 9.1 |

# Reinforced Thermosetting Resins

Support – Support elements must be designed to provide low concentrated stresses and protect the piping from abrasion.



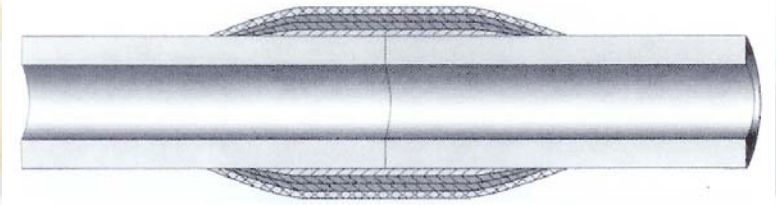

(Typical guide and anchor – Conley)



# Reinforced Thermosetting Resins

Fabrication - Butt fittings are joined to the pipe using a butt wrapping process.

(Smith Fibercast)



## Reinforced Thermosetting Resins

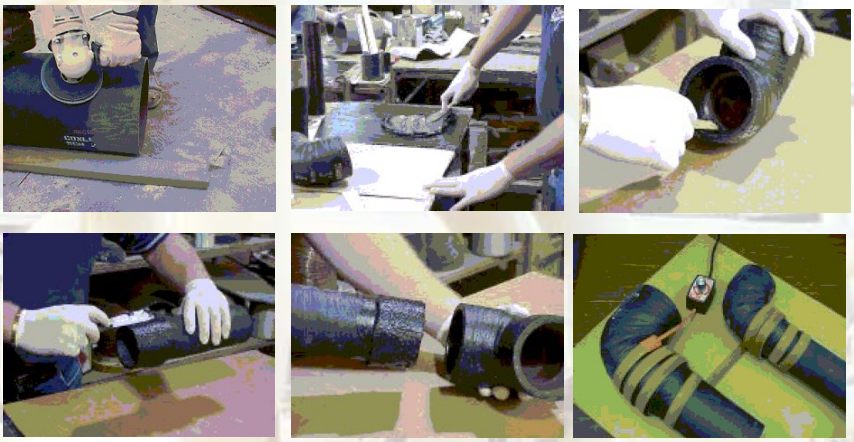
Fabrication – Doing it in a warm, clean, dry environment is sometimes a challenge.



## Reinforced Thermosetting Resins

Socket fittings are joined to the pipe using an adhesive.

(Conley)



## Reinforced Thermosetting Resins

Fabrication

A leak at an elbow requires

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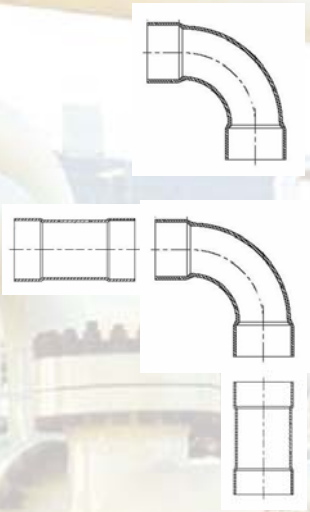
3. And installing it, hoping none of the six new joints leak



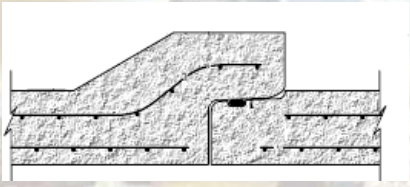


## Reinforced Thermosetting Resins

BPS and Bonder Qualification Tests are required as for thermoplastic piping, except test pressure is 3 times manufacturer's rating

# Reinforced Concrete

- Typically 15 to 250 psi (1 to 17 bar) ambient temperature water service
- Made to ASTM and AWWA standards with specific B31.3 pressure ratings



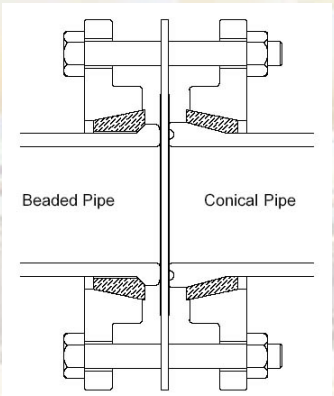


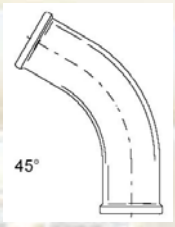
# Vitrified clay

- Manufactured from clay fired in furnaces
- Joined with
  - Rubber seals
  - Caulking
  - Mortar
- B31.3 mentions, but has no specific requirements

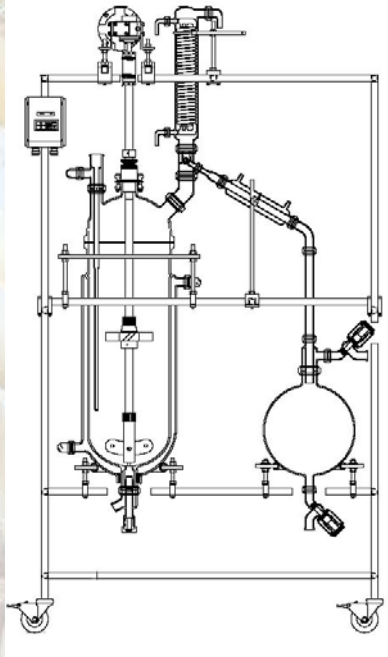
# Borosilicate Glass

- Manufactured from molten glass
- Joined with clamps, rubber seals




(H.S. Martin)



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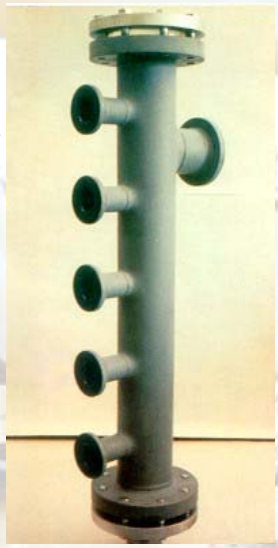
# Piping Lined with Nonmetals

Common liners include

- Fluoropolymer
- Polypropylene
- PVDF
- Glass

Glass Lined (Estrella)



Polypropylene Lined (Resistoflex)

*BECHT ENGINEERING COMPANY, INC.*

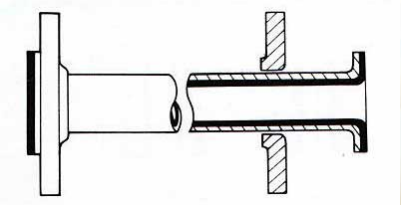
# Piping Lined with Nonmetals

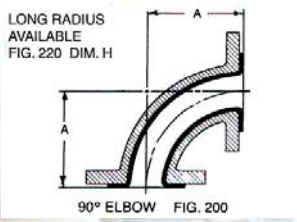
- Thermoplastic liners can be “locked-in” or loose
- PTFE and FEP lined systems require vent holes
- Thermoplastic lined pipe and fittings are usually ductile iron and steel
- Glass lined pipe and fittings are steel
- Systems usually have many flanged joints

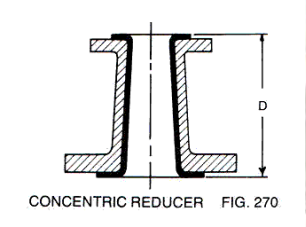


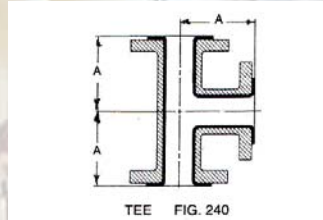
# Piping Lined with Nonmetals

Typical Fittings



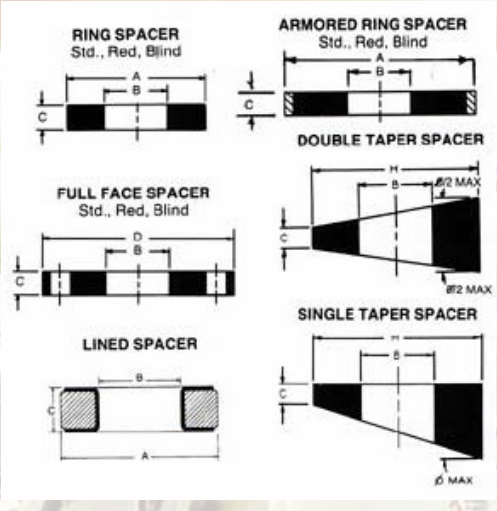


# Piping Lined with Nonmetals

Untypical Fittings






# Piping Lined with Nonmetals

Common Thermoplastic Liners

- Fluoropolymer
  - FEP Perfluoro ethylene propylene
  - PTFE Polytetrafluorethylene
  - PFA Polyperfluoroalkoxy Alkane
- Polypropylene
- PVDF

# Piping Lined with Nonmetals

B31.3 recommended temperature limits for liners:

| Material | Min (F) | Max (F) | Min (C) | Max (C) |
|---|---|---|---|---|
| FEP | -325 | 400 | -198 | 204 |
| PTFE | -325 | 500 | -198 | 260 |
| PFA | -325 | 500 | -198 | 260 |
| PP | 0 | 225 | -18 | 107 |
| PVDF | 0 | 275 | -18 | 135 |
| Glass | Limited by the metal. | | | |



# Piping Lined with Nonmetals

- The metallic portions of piping lined with nonmetals for
  - Design
  - Fabrication
  - Examination, and
  - Testing

  shall conform to the rules of Chapters I through VI
- Liners must be qualified for external pressure in order to prevent liner collapse

# Piping Lined with Nonmetals

Failures frequently occur at the flange joints. Following the ASME PCC-1 bolt-up procedure greatly improves the chances of success

- Snug up bolting
- Tighten to 20% of target torque using cross pattern
- Tighten to 50 to 70% of target torque using cross pattern
- Tighten to 100% of target torque using cross pattern
- Continue tightening to 100% target torque using rotational pattern until no movement
- Wait 4 hours or longer and repeat rotational pattern to 100% target torque until no movement



# Limitations

Thermoplastic Piping

- may not be used in above ground flammable fluid service unless
  - NPS 1 and smaller
  - Owner approves
  - The piping is safeguarded, and
  - The following are considered
    - The possibility of exposure of piping to fire
    - The susceptibility to brittle failure or failure due to thermal shock when exposed to fire
    - The ability of thermal insulation to protect the piping when exposed to fire
- shall be safeguarded when used in other than Category D fluid service

# Limitations

- PVC and CPVC may not be used in compressed gas service
- RPM Piping shall be safeguarded when used in other than Category D fluid service
- RTR Piping shall be safeguarded when used in toxic or flammable fluid services
- Borosilicate Glass Piping
  - Shall be safeguarded when used in toxic or flammable fluid services
  - Shall be safeguarded against large, rapid temperature changes