Weak Link Calculation
ASTM F1804

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Public Service Commission of Wisconsin

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Federal Code

49 CFR 192.321(c)

Plastic pipe must be installed so as to minimize shear or **tensile stresses**.

49 CFR 192.329(b) [main] & **49 CFR 192.376(b)** [services]

For each pipeline section, plastic pipe and components that are pulled through the ground must use a **weak link**, as defined by § 192.3, to ensure the pipeline will not be damaged by any excessive forces during the pulling process.

49 CFR 192.3

Weak link: means a device or method used when pulling polyethylene pipe, typically through methods such as horizontal directional drilling, to ensure that damage will not occur to the pipeline by exceeding the **maximum tensile stresses allowed**.

Viscoelasticity

Impacted by:

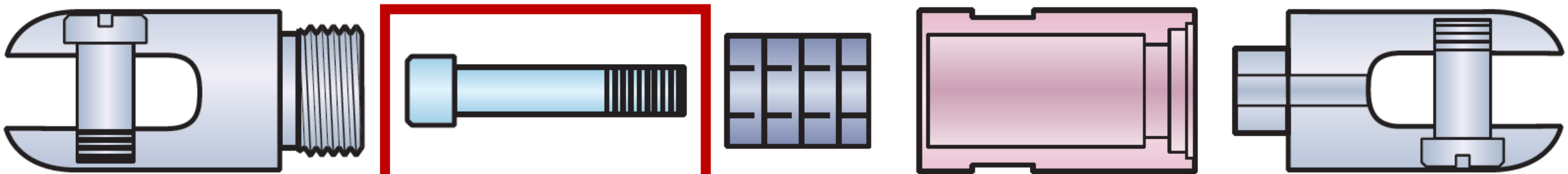
- Material properties
- Stress (force and area)
- Temperature
- Time under strain

ASTM F1804

Standard Practice for Determining Allowable Tensile Load for Polyethylene (PE) Gas Pipe During Pull-In Installation

This practice provides a means to determine an **allowable tensile load** (ATL) value for a polyethylene gas pipe that is to be installed underground using methods that pull the pipe into a trench (cut or plowed), bore hole, casing pipe, or the like. The ATL value takes into account:

- Material tensile yield strength
- Pipe size and wall thickness
- Pipe temperature
- Duration of pull



Externally Threaded Head

Break Pin

Bearings

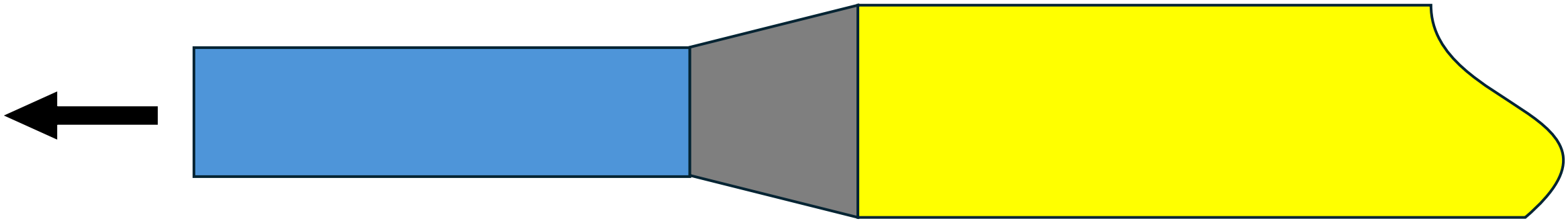
Body

Internally Threaded Head

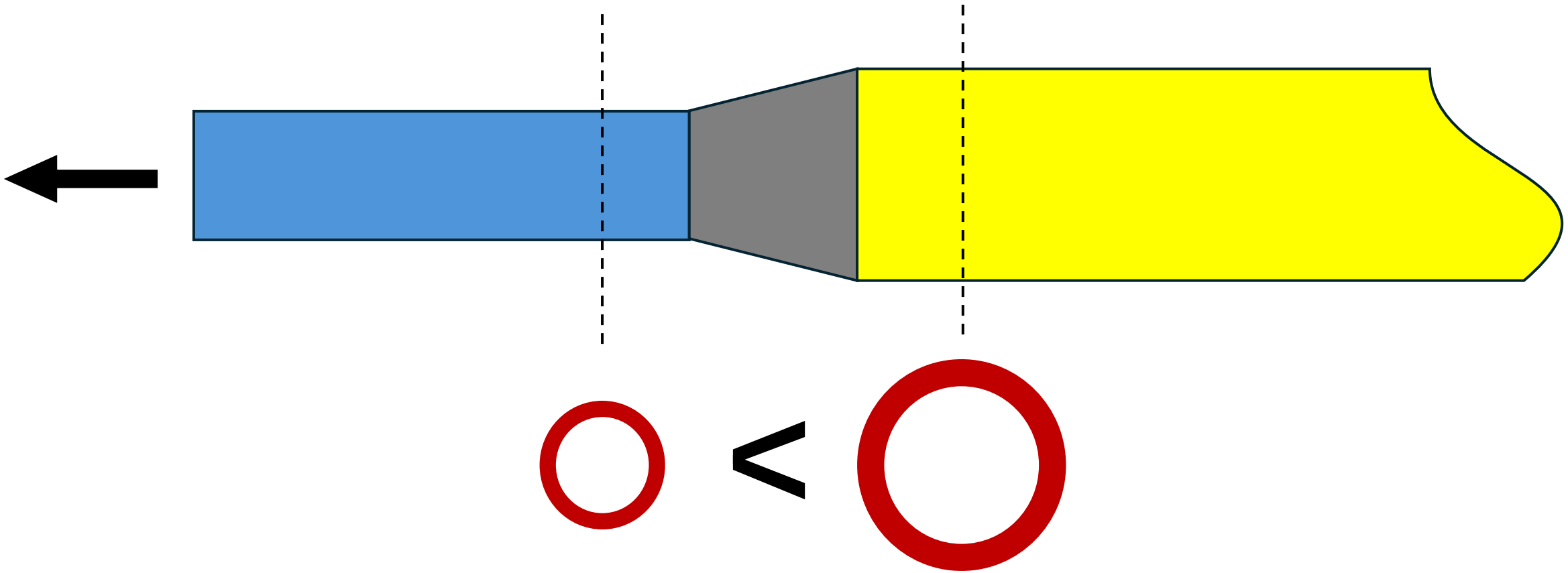
Pin Break Force Identified by Color

Part No. (5 pins/kit)	Breaking Point (+/- 5%)	Color Code
00565-015*	150 lb	Black/Red
00565-025*	250 lb	Brown
00565-030*	300 lb	Black/Orange
00565-040*	400 lb	Gray
00565-070	700 lb	Green/Orange
00565-075	750 lb	Yellow
00565-100	1,000 lb	Orange
00565-120	1,200 lb	Purple
00565-130	1,300 lb	Black
00565-150	1,500 lb	Red
00565-200	2,000 lb	Blue
00565-200S	2,000 lb	Gray/Yellow
00565-250	2,500 lb	Green
00565-250S	2,500 lb	Blue/Red

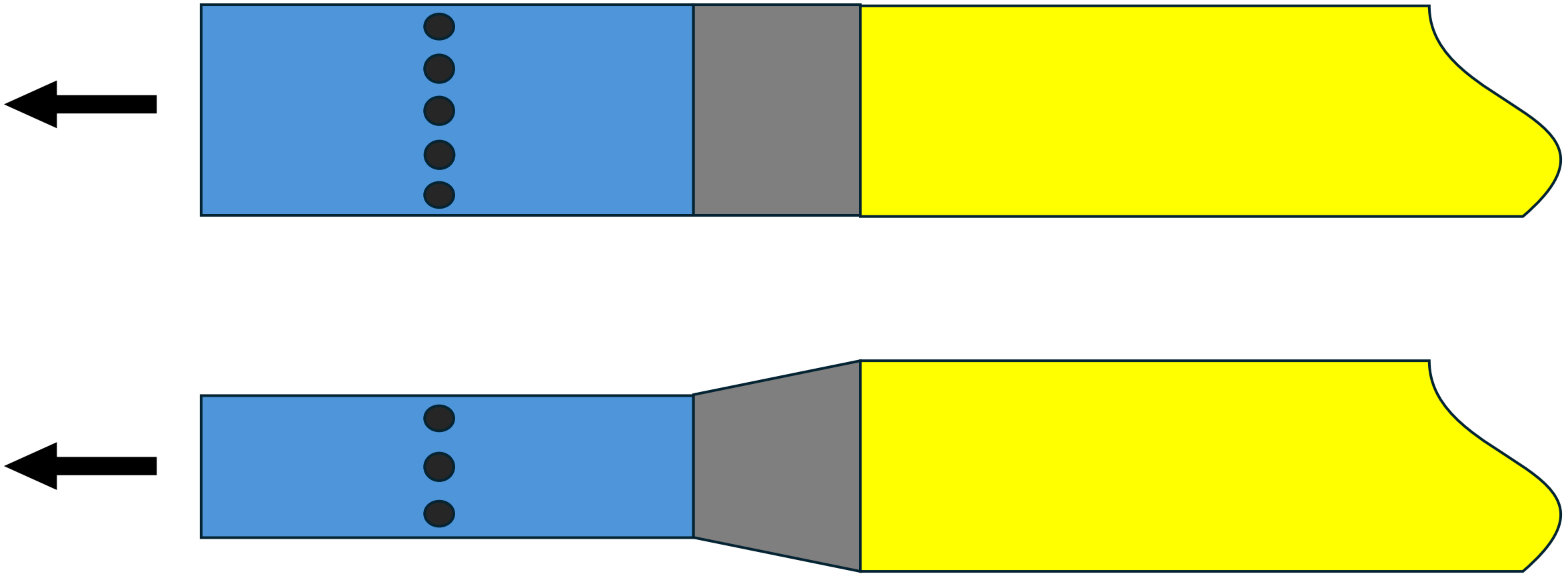
Smaller Pipe



Smaller Pipe



Drill Holes



$$ATL = f_y \; f_t \; T_y \; \pi \, D^2 \left[\frac{1}{R} - \frac{1}{R^2} \right]$$

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Allowable Tensile Load (*lbf*)

maximum tensile load that does not permanently stretch pipe

(may be rounded to the nearest 50 lb)

$$ATL = f_y \, f_t \, T_y \, \pi \, D^2 \left[\frac{1}{R} - \frac{1}{R^2} \right]$$

Tensile yield design (safety) factor

=0.4 recommended for HDD

$$ATL = f_y \boxed{f_t} T_y \ \pi D^2 \left[\frac{1}{R} - \frac{1}{R^2} \right]$$

Time under tension design (safety) factor

1.0 for pulls ≤ 1 hr

0.95 for pulls ≤ 12 hr

0.91 for pulls ≤ 24 hr

$$ATL = f_y \; f_t \; T_y \; \pi \; D^2 \left[\frac{1}{R} - \frac{1}{R^2} \right]$$

Tensile yield strength (lbf/in^2)

pipe temperature at installation

PE2708 $\leq$ 80°F: 2600 lbf/in^2

PE4710 $\leq$ 80°F: 3500 lbf/in^2

Maximum Sustained Temperature, °F (°C) [1]	Multiplier [2,3]
40 (4)	1.25
50 (10)	1.17
60 (15)	1.10
73 (23)	1.00
80 (27)	0.94
90 (32)	0.86
100 (38)	0.78

$$ATL = f_y \; f_t \; T_y \; \pi D^2 \left[\frac{1}{R} - \frac{1}{R^2} \right]$$

Outer Diameter (*in*)

“Two inch” = 2.375 in

“Four inch” = 4.500 in

“Six inch” = 6.625 in

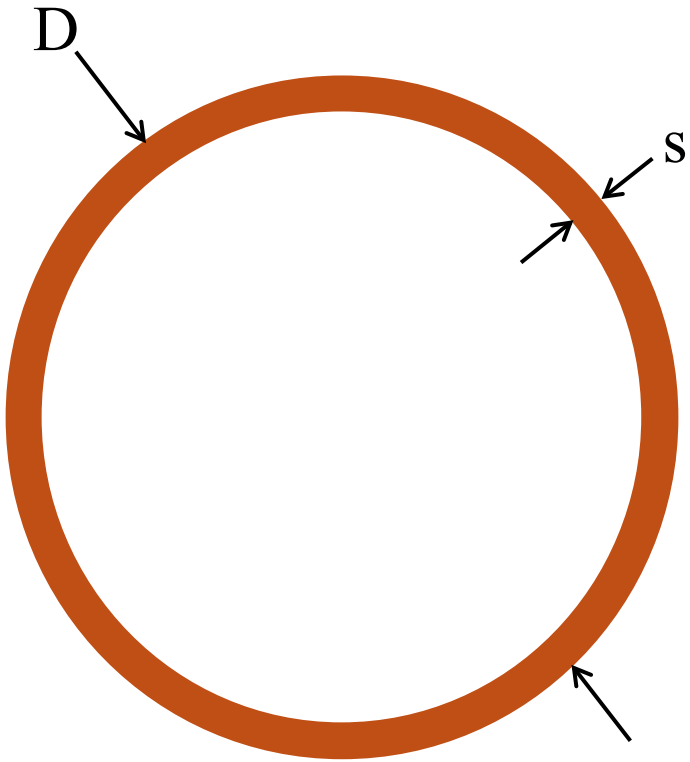
Nominal Pipe Size (IPS)	Outside Diameter
½	0.840
¾	1.050
1	1.315
1¼	1.660
1½	1.900
2	2.375
2½	2.875
3	3.500
3½	4.000
4	4.500
5	5.563
6	6.625
8	8.625
10	10.750
12	12.750
14	14.000
16	16.000
18	18.000
20	20.000
22	22.000
24	24.000

Nominal Tubing Size (CTS)	Outside Diameter
¼	0.375
⅜	0.500
½	0.625
¾	0.875
1	1.125
1¼	1.375
1¾	1.875

$$ATL = f_y \; f_t \; T_y \; \pi \, D^2 \left[\frac{1}{R} - \frac{1}{R^2} \right]$$

SDR (Standard Dimension Ratio)

$$ATL = f_y \; f_t \; T_y \; \pi \, D^2 \left[\frac{1}{R} - \frac{1}{R^2} \right]$$



SDR (Standard Dimension Ratio)

$$\text{SDR} = \frac{D}{s}$$

7, 9, 11, 11.5, 13, etc.

$$ATL = f_y \; f_t \; T_y \left[\pi \, D^2 \left[\frac{1}{R} - \frac{1}{R^2} \right] \right]$$

$$ATL = f_y \; f_t \; T_y \; \pi \, D^2 \left[\frac{1}{R} - \frac{1}{R^2} \right]$$

ATL = (safety factors) * (strength) * (area)

ATL = (safety factors) * (yield force)

Example:
2” SDR 11 MDPE

$$\text{ATL} = 0.4 * 1.0 * 2600 \frac{lb}{in^2} * \pi * (2.375\ in)^2 * \left(\frac{1}{11} - \frac{1}{11^2}\right)$$

$$= \mathbf{1523\ lb}$$

f_y=0.4, f_T=1.0, T_y=2600 psi (MDPE)

Nominal	D_o (in)	SDR	ATL (lb)
1/2" CTS	0.625	7	**156**
1" IPS	1.315	11.5	**449**
2" IPS	2.375	11	**1523**
4" IPS	4.5	11.5	**5253**
6" IPS	6.625	11.5	**11385**
8" IPS	8.625	11	**20087**

Smaller pipe weak link

ATL = (safety factors) * (strength) * (area)

Smaller pipe weak link

$$ATL = (\text{safety factors}) * (\text{strength}) * (\text{area})$$

$$(\text{strength}) * (\text{area_wl}) = (\text{safety factors}) * (\text{strength}) * (\text{area_pipe})$$

Smaller pipe weak link

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~~(strength)~~ * (area_wl) = (safety factors) * ~~(strength)~~ * (area_pipe)

Smaller pipe weak link

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$$(\text{area_wl}) = (\text{safety factors}) * (\text{area_pipe})$$

$$(\text{area_wl}) = 40\% * (\text{area_pipe})$$

Smaller pipe weak link

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$$(\text{area_wl}) = (\text{safety factors}) * (\text{area_pipe})$$

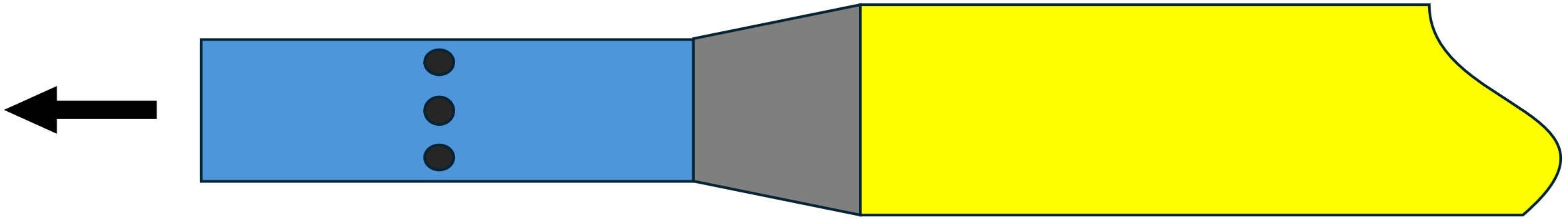
$$(\text{area_wl}) = 40\% * (\text{area_pipe})$$

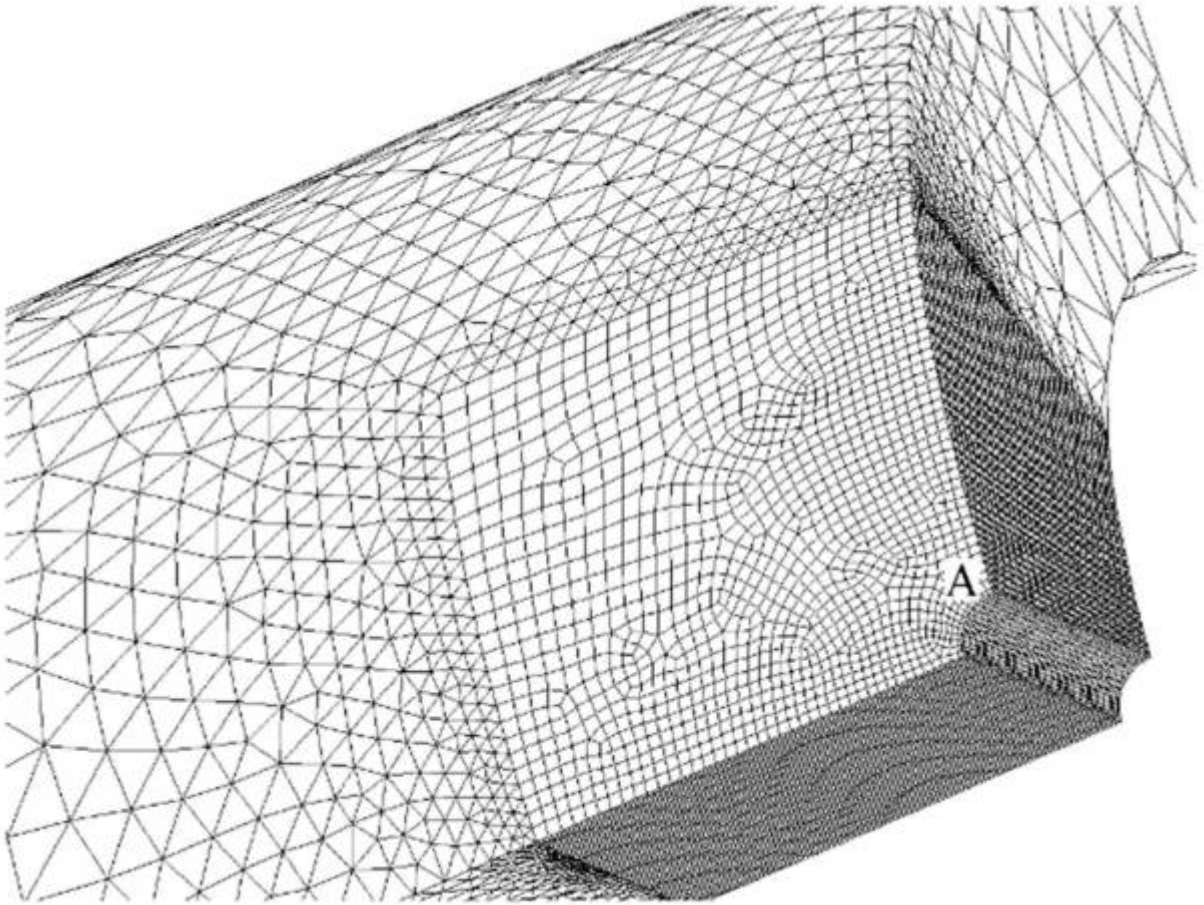
- Eliminates
  - Material strength
  - Temperature
- Should be **40%** of the cross-sectional area of the pipe to be pulled

	Weak Link Pipe	1”	1.25”	2”	3”	4”	6”	8”	12”
Carrier Pipe	Annular Area (in^2) SDR 11	0.45	0.72	1.46	3.18	5.26	11.40	19.31	42.21
2”	1.46	31%	49%	100%					
3”	3.18	14%	22%	46%	100%				
4”	5.26	9%	14%	28%	60%	100%			
6”	11.40	4%	6%	13%	28%	46%	100%		
8”	19.31	2%	4%	8%	16%	27%	59%	100%	
12”	42.21	1%	2%	3%	8%	12%	27%	46%	100%

Pipe with holes drilled

- Gets more complicated due to stress concentrations near the edges of the holes

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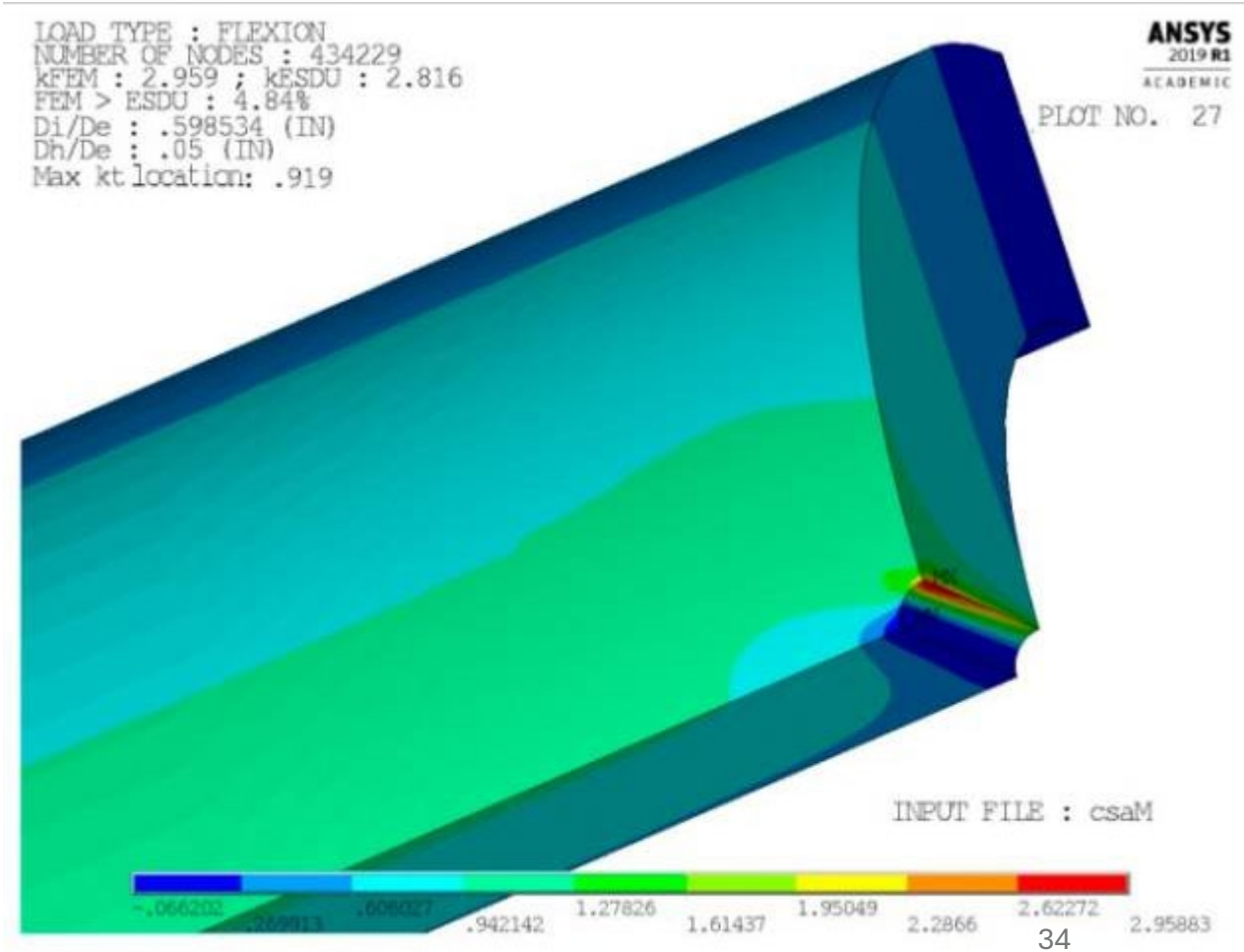
LOAD TYPE : FLEXION
NUMBER OF NODES : 434229
kFEM : 2.959 ; kESDU : 2.816
FEM > ESDU : 4.84%
Di/De : .598534 (IN)
Dh/De : .05 (IN)
Max kt location: .919
ANSYS
2019 R1
ACADEMIC
PLOT NO. 27
INPUT FILE : csaM
.942142
1.27826
1.61437
1.95049
2.2866
2.62272
2.95883

What we look for

What we look for in O&M Plan

- Are values appropriate?
- Are there temperature factors?
- Procedures to check for temperature?
- Do they limit pull duration to under 1 hour or have factors to reduce pull force?
- Lower values for MDPE compared to HDPE

What to look for in Field

- Procedure is followed
- See the weak link (take apart swivel)
  - and mfr guide to link pin color to force
  - Did the drill crew check it?
- Temperature of pipe
  - What measurement device is used per Manual?
  - Is it in calibration?
- Duration of pull

2021 ASTM F1804 Changes

- 100°F → 80°F
  - Direct sun heats pipe
    - Especially black pipe
  - Sunny days often require shading pipe
- HDPE: 3,000 → 3,500 lb/in^2

Questions?

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