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SAND2015-6267PE

Deep Borehole Field Test
Waste Package Design Options

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DBFT Engineering Support Services Contract Kickoff

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Requirements

- **11” OD Package (DBFT Requirements, Section 1.10)**
  - Loading conditions
    - *153,000 lbs axial load*
    - *9600 psi collapse pressure*
- **4.95” OD Package (DBFT Requirements, Section 1.10)**
  - Loading conditions
    - *27,600 lbs axial load (40 canisters x ~690 lb/canister)*
    - *9600 psi collapse pressure*

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Collapse Pressure Calculation

- **Yield Strength Collapse Pressure (D/t)<12.42 (API Bulletin 5C3 Section 2)**

$$P_{yp} = 2Y_p \left[\frac{\left(D/t\right) - 1}{\left(D/t\right)^2} \right]$$

More conservative than Corradi et al 2008 design procedure by about 10%

- **Collapse Pressure Under Axial Tension Stress**

$$P_{CA} = P_{yp} \left[\sqrt{1 - 0.75 \left[\frac{\left(S_A + P_i\right)}{Y_p} \right]^2} \right] - 0.5 \left(\frac{S_A + P_i}{Y_p} \right)$$

Bending Due to Build Rate

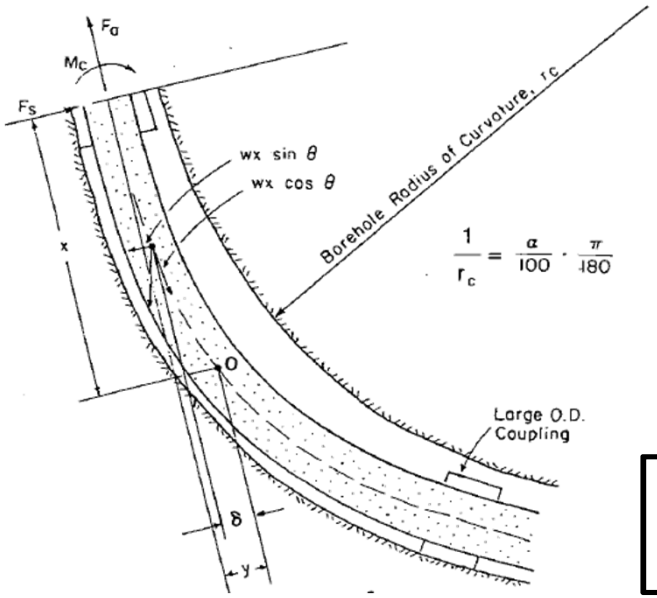
- **Build Rate:**
- **Radius of curvature:**
- **Stress due to uniform bending:**
- **Stress due to bending at couplings**

$$\alpha = \frac{x^{\circ}}{100\,ft}$$

$$\rho = \frac{18,000}{\pi \cdot \alpha}$$

$$M = \frac{E \cdot I}{\rho}$$

$$(\sigma_z)_0 = \frac{M \cdot \left(OD/2\right)}{I}$$



$$K = \sqrt{\frac{F_a}{EI}}$$

$$(\sigma_z)_{max} = (\sigma_z)_0 \frac{6KL_j}{\tanh\left(6KL_j\right)}$$

Net effect is additional axial stress added to S_A term in previous slide.

Gourgoyne Jr., Adam T., *Applied Drilling Engineering*, Chapter 7: Casing Design

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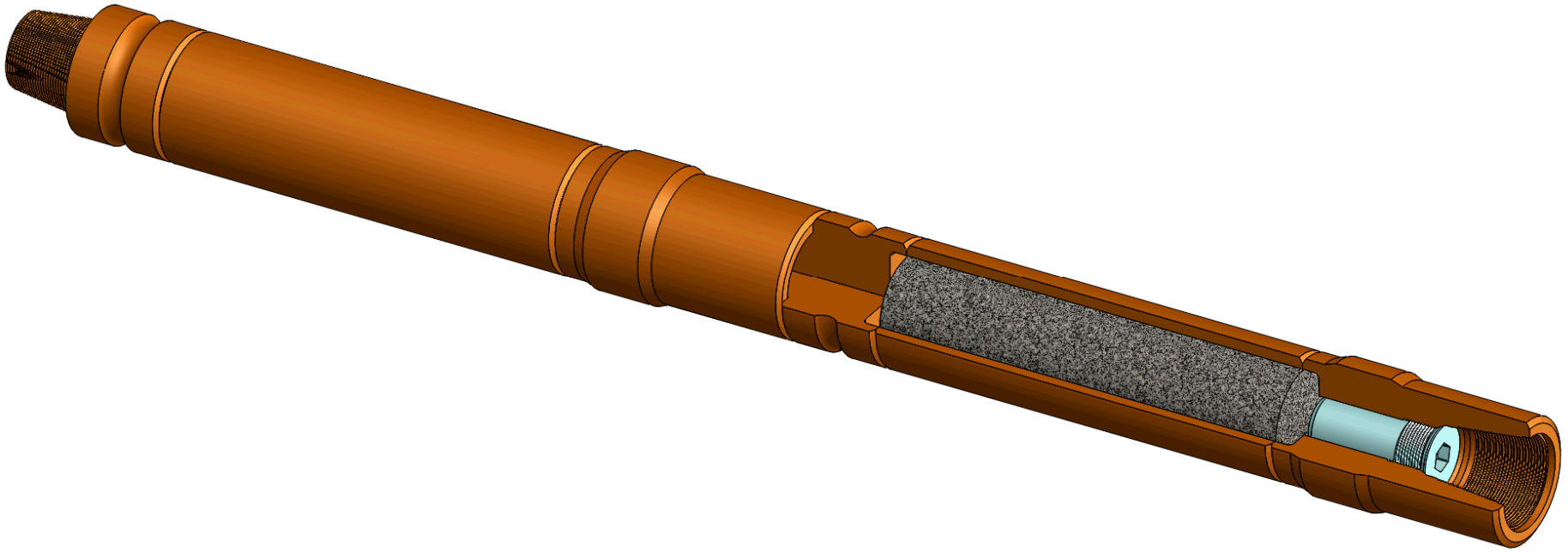
Large Waste Package Bulk Waste Design Option 1



Aspect ratio squeezed to enhance detail on connections. The waste-containing length may be increased to as much as 5 m (16.4 ft), corresponding to overall waste package length of 5.6 m (18.5 ft).

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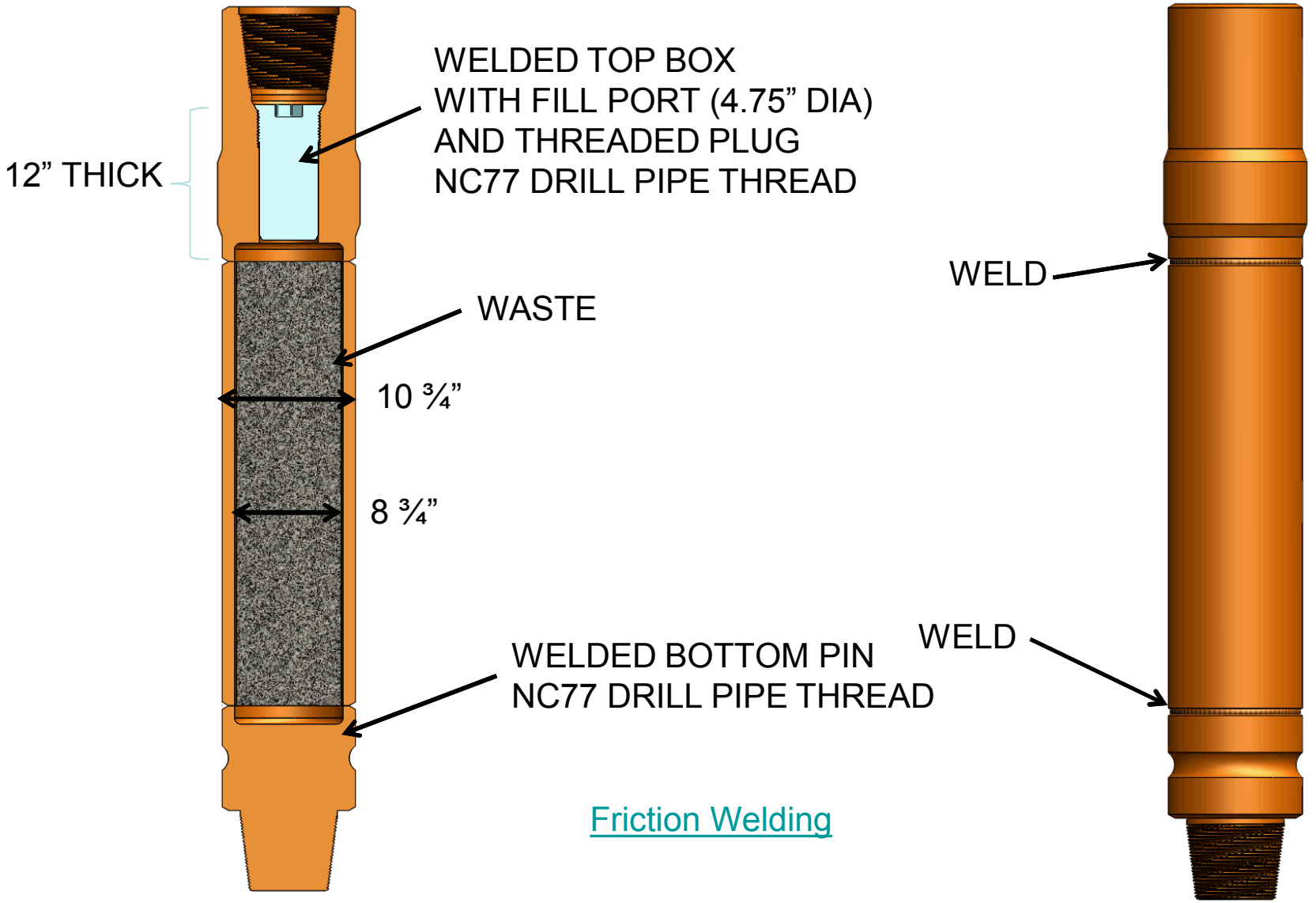
Individual Waste Package



Friction Welding

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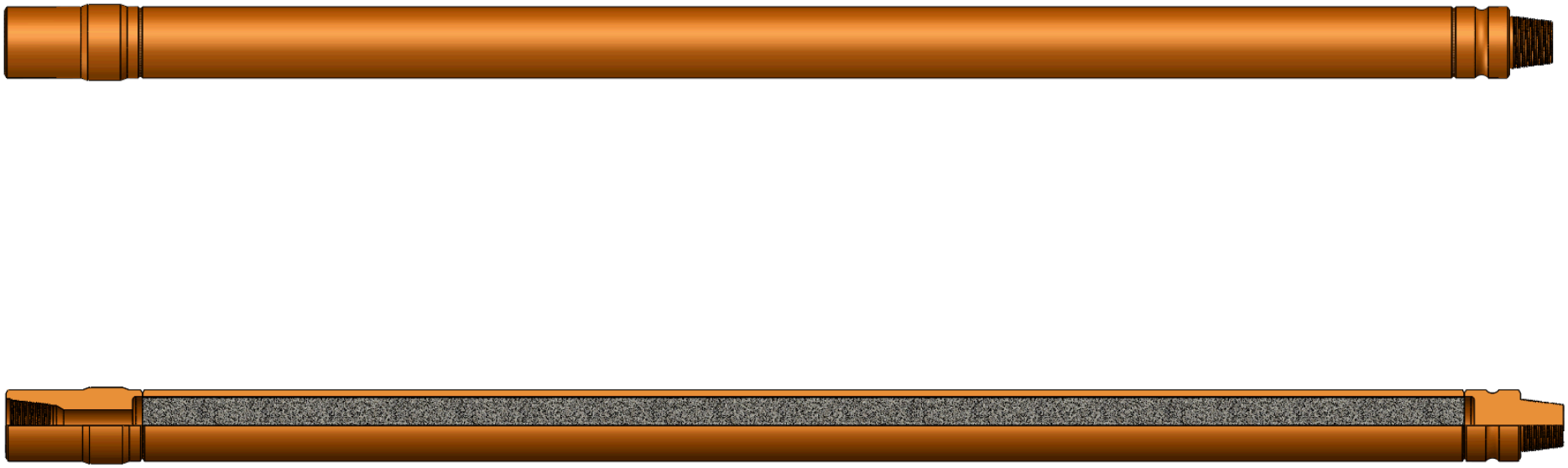
Waste Package (True Aspect Ratio)



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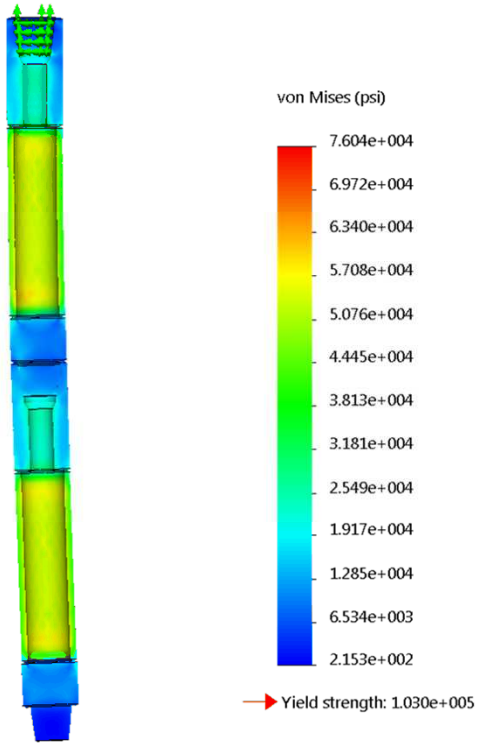
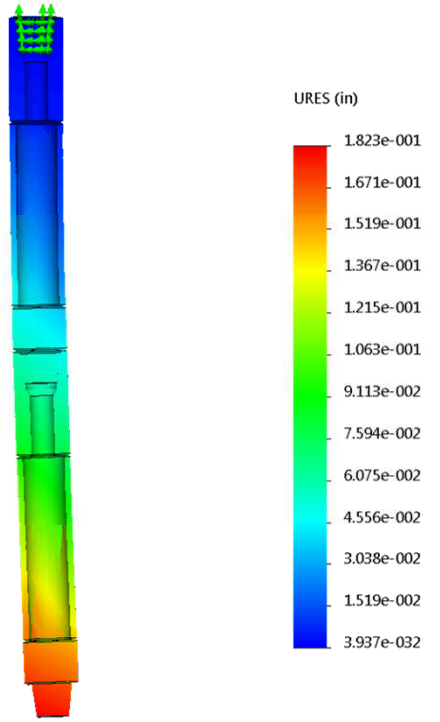
Bending + Pressure + Axial

Model name:canister_string_asm
Study name:external_pressure(-Simulation-)
Plot type: Static nodal stress Stress1
Deformation scale: 20



Model name:canister_string_asm
Study name:external_pressure(-Simulation-)
Plot type: Static displacement Displacement1
Deformation scale: 20



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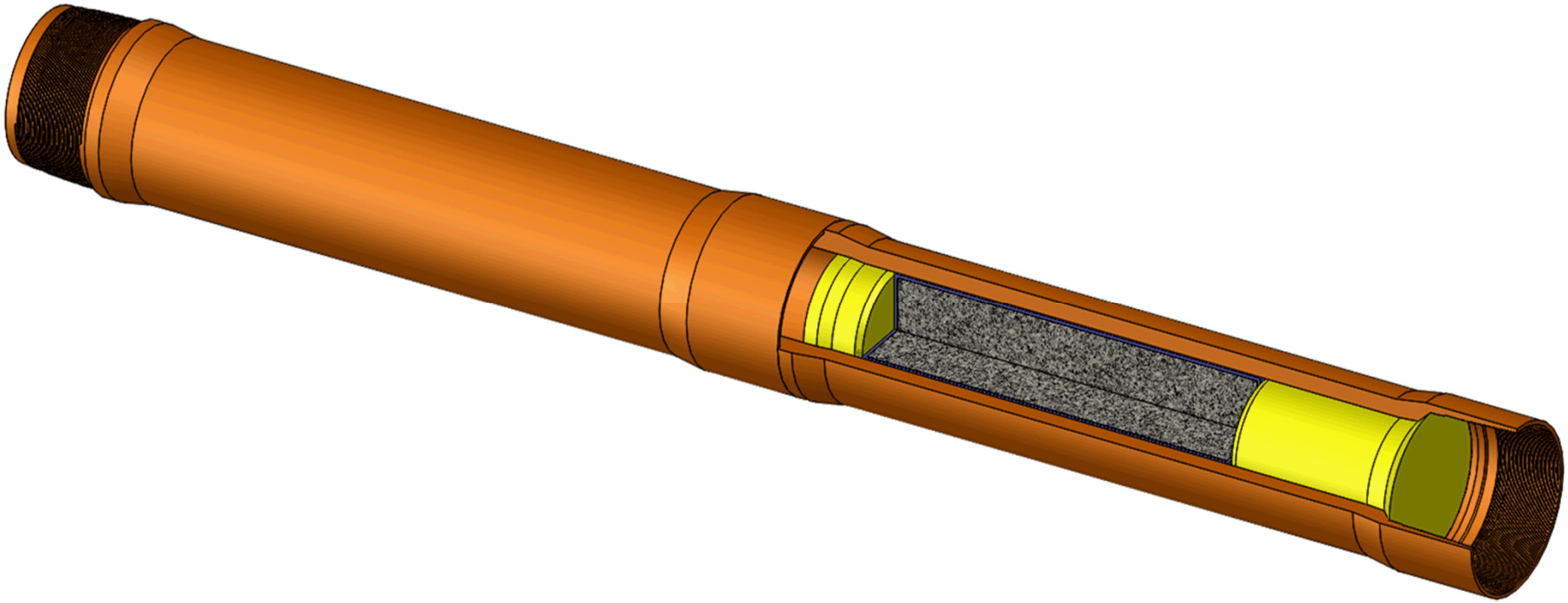
Large Waste Package Bulk Waste Design Option 2



- Integral semi-flush connection
- Welded end plugs
- 18,560 psi collapse pressure (10.75” OD x 8.75” ID)
- 11.232” connection OD

Aspect ratio squeezed to enhance detail on connections

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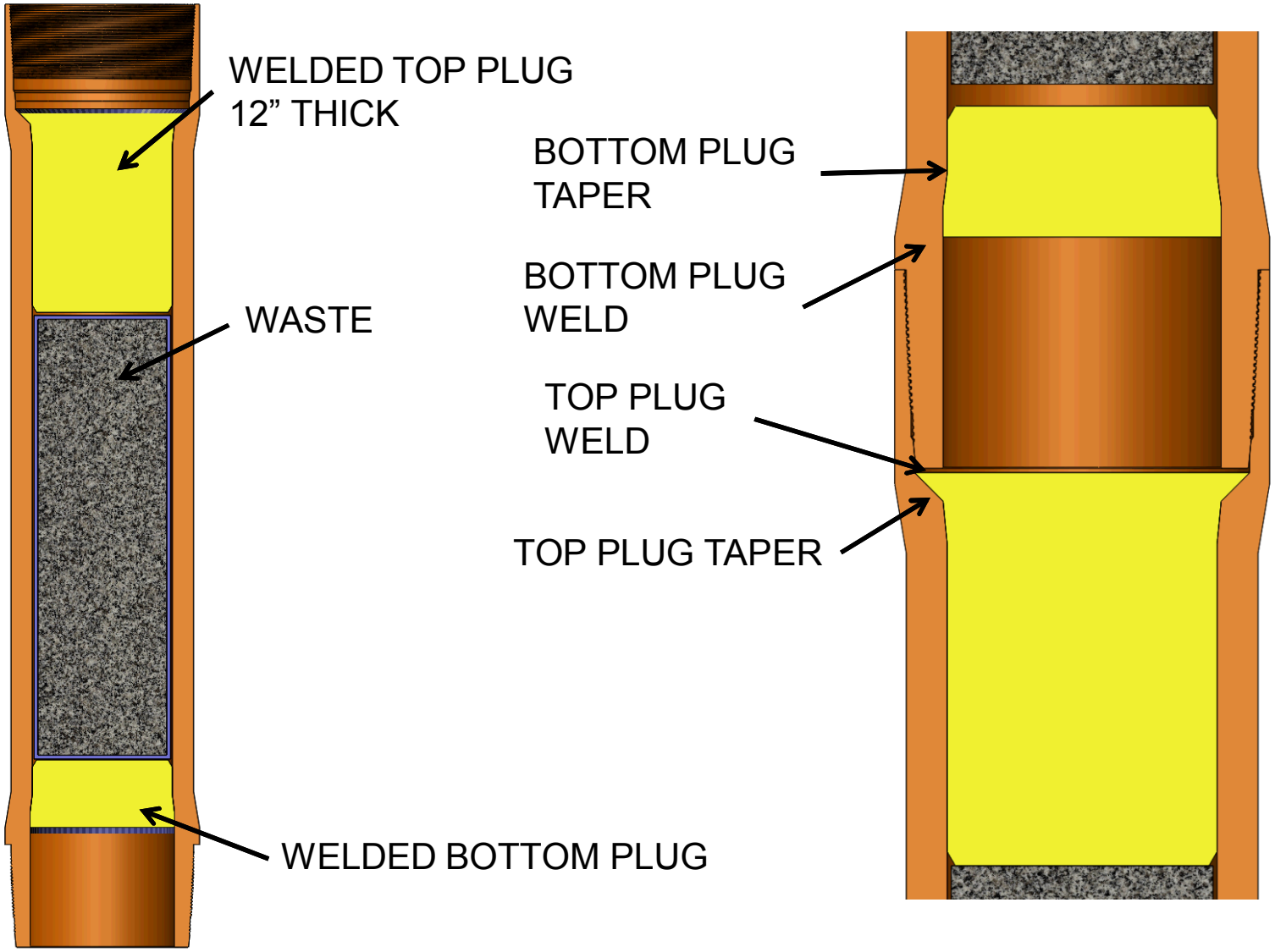
Individual Waste Package



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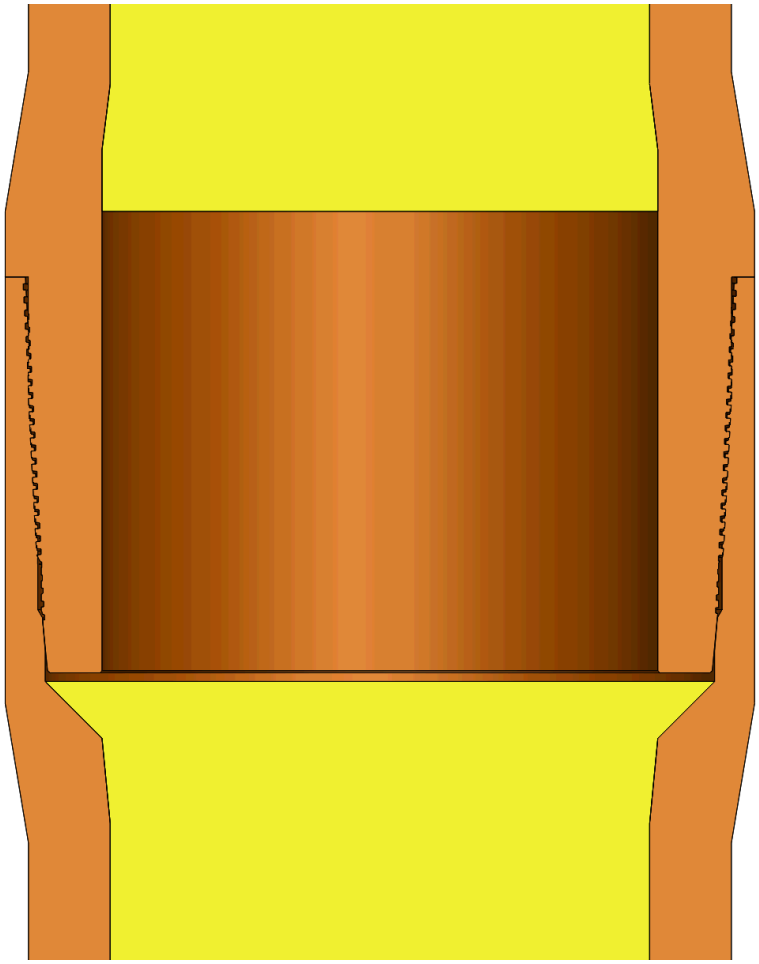
API Extreme-line Casing Joint or Tenaris MAC II



- External upset & integral semi flush
- Smooth transition
- Metal-to-metal face seal
- P110 or equivalent (e.g. 4145M)

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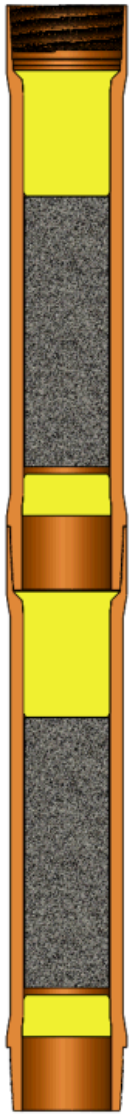
Package Stack (x2)



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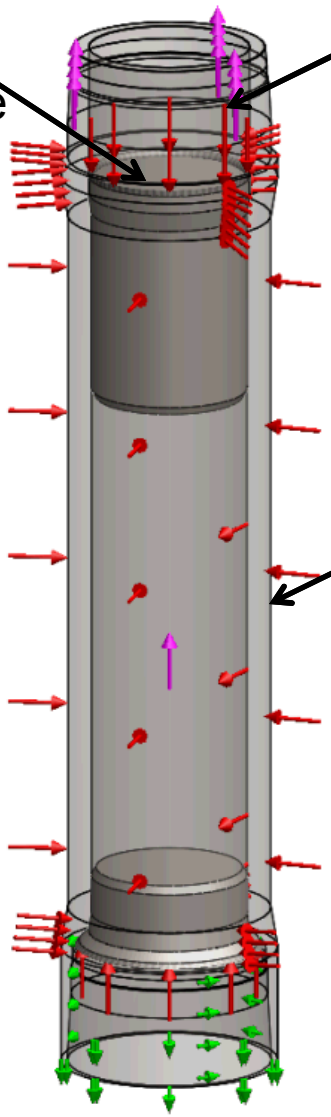
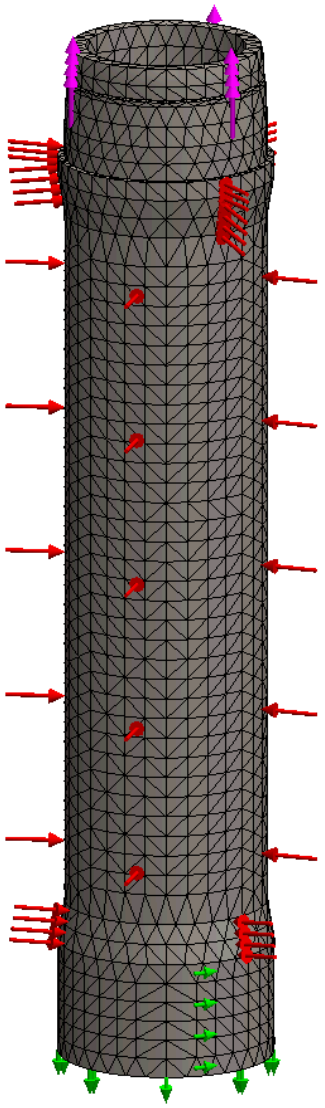
Stress Analysis

9600 psi
External Pressure

153,000 lbf
Axial Force



9600 psi
External Pressure



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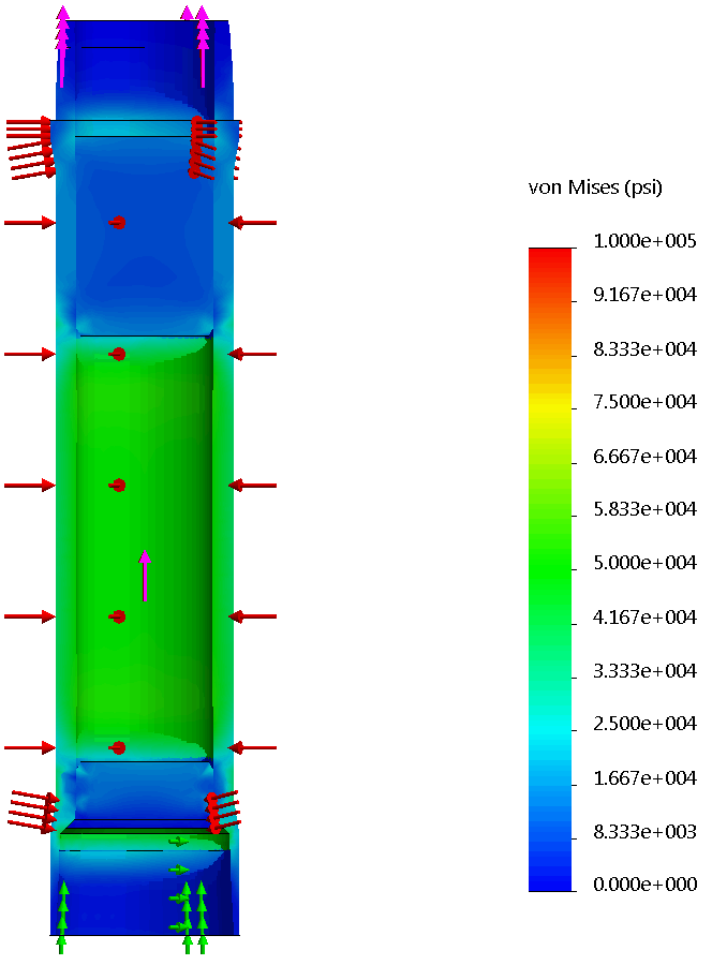
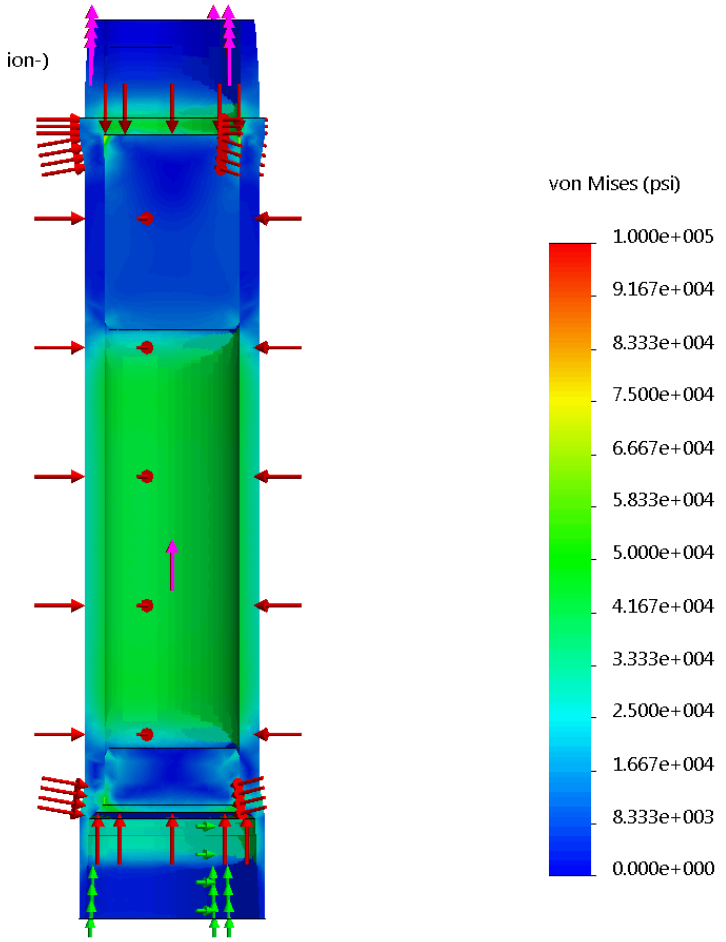
Stress Results

Without Pressure on Plug



With Pressure on Plug



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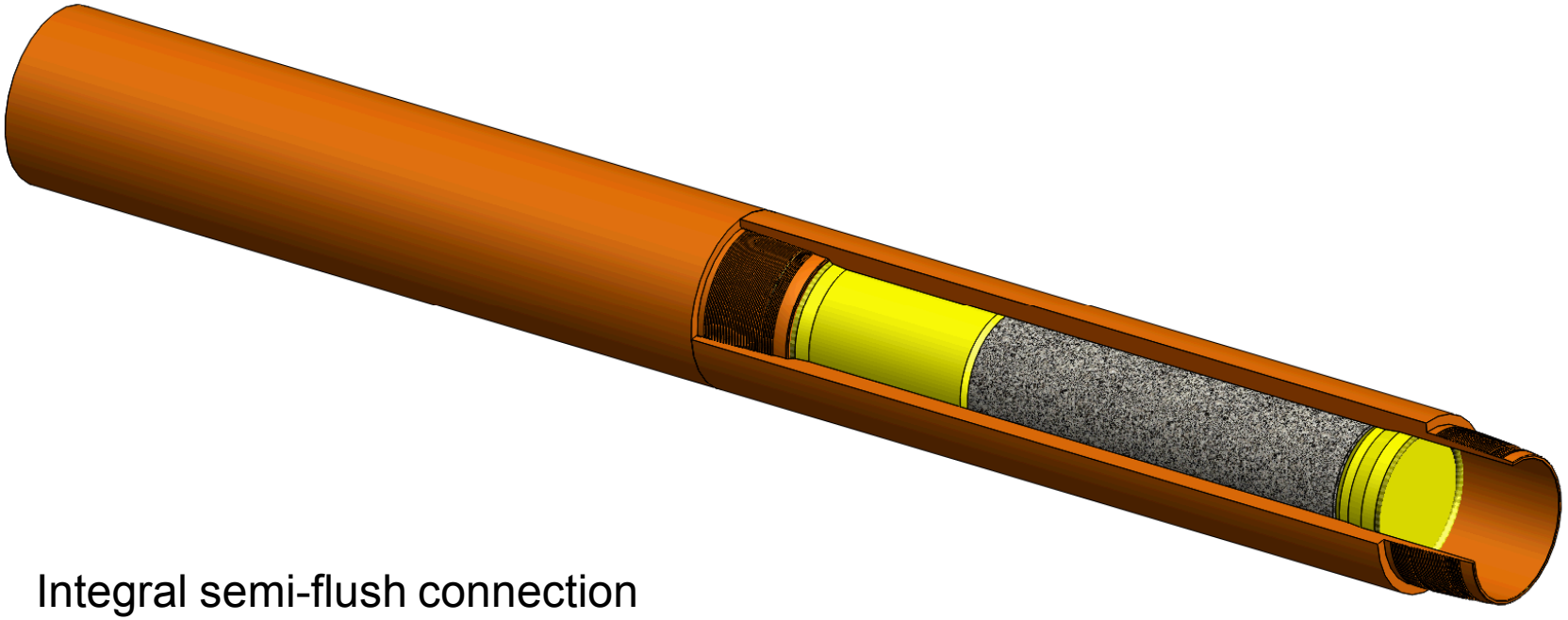
Large Waste Canister Bulk Waste Design Option 3



- Integral semi-flush connection
- Welded end plugs
- 15,600 psi collapse pressure (10.125” OD x 8.54” ID)

Aspect ratio squeezed to enhance detail on connections

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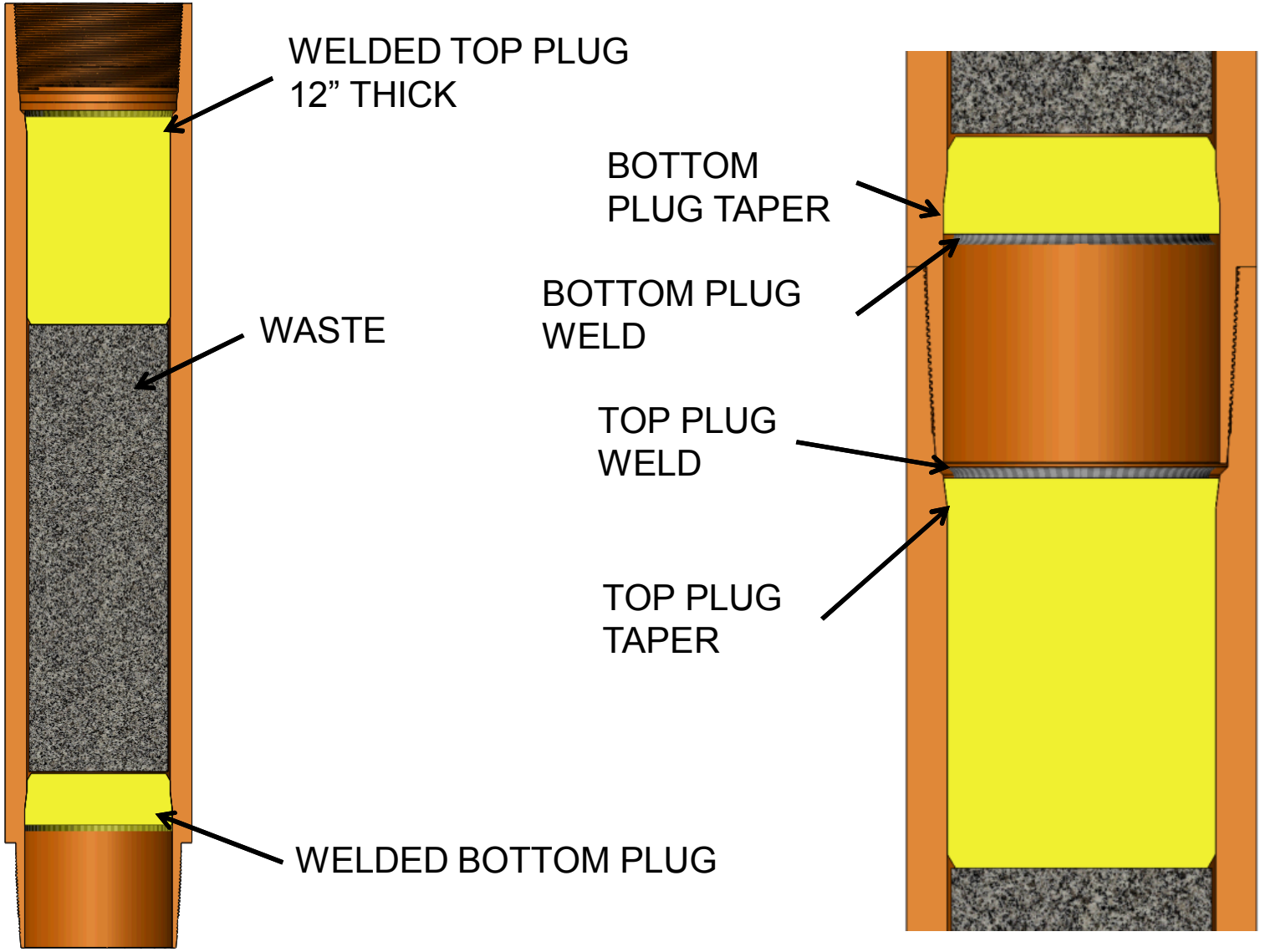
Individual Waste Package



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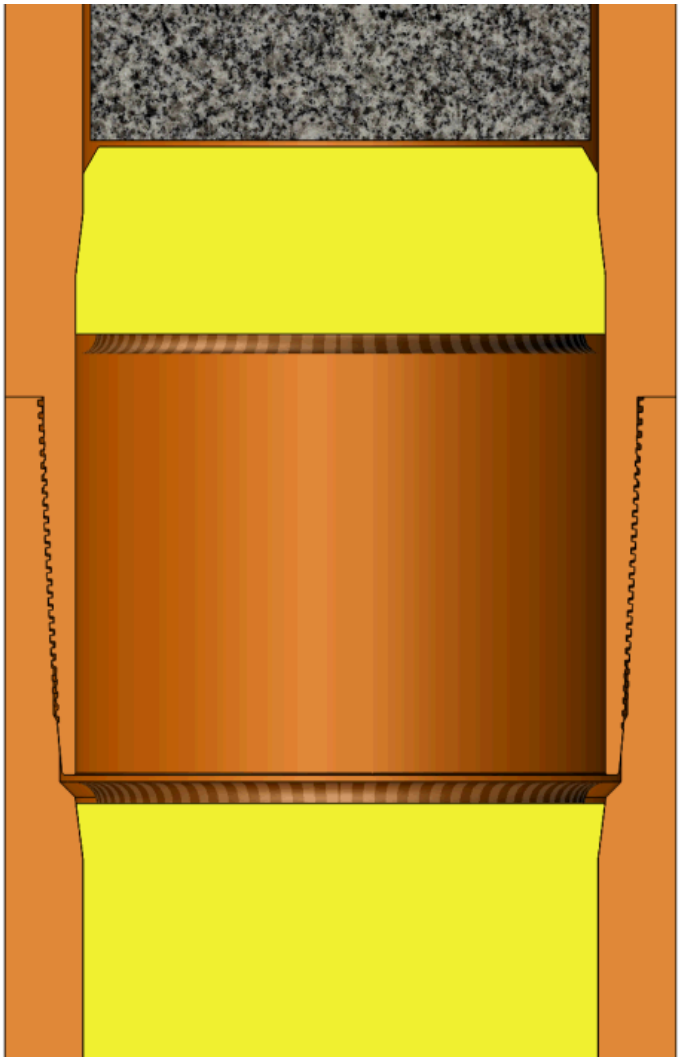
Modified API Extreme-line Casing Joint or Tenaris Wedge 513



- Integral flush
- Smooth transition
- Metal-to-metal face seal
- P110 or equivalent (e.g. 4145M)

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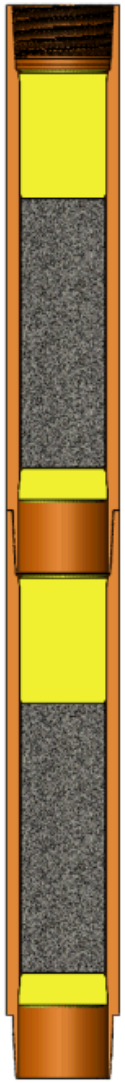
Waste Package Stack (x2)



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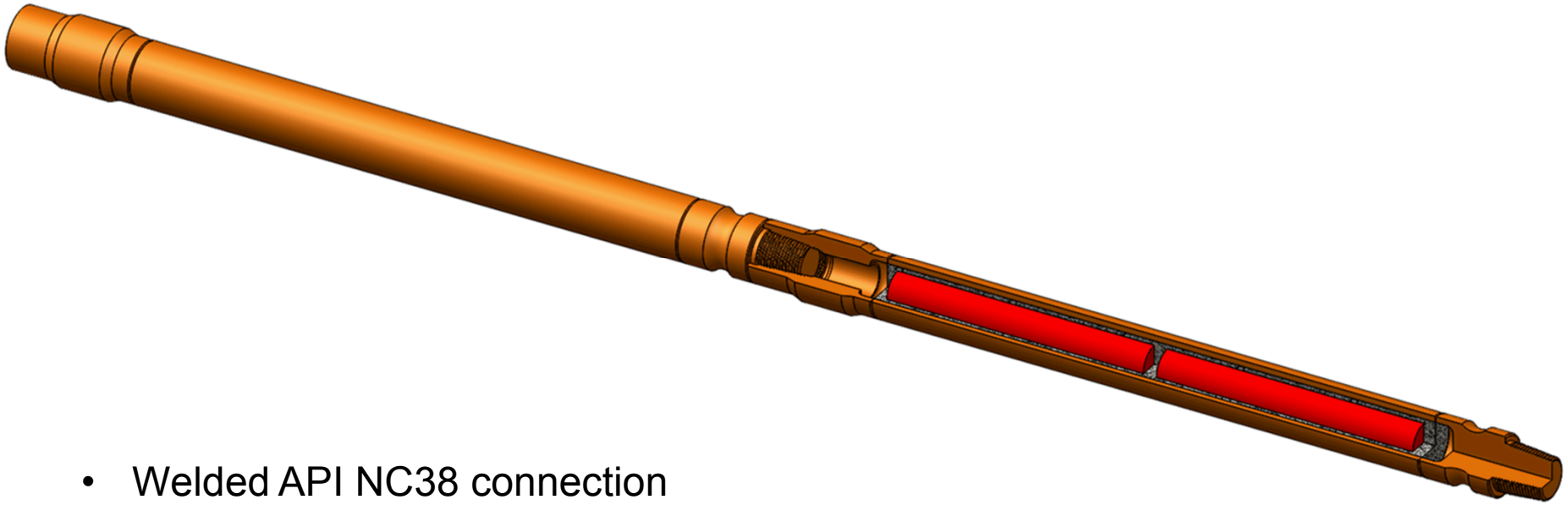
Small Waste Package Over Pack Design Option 4



- Welded API NC38 connection
- 5” OD x 4” ID
- 19,800 psi collapse pressure

Aspect ratio squeezed to enhance detail on connections

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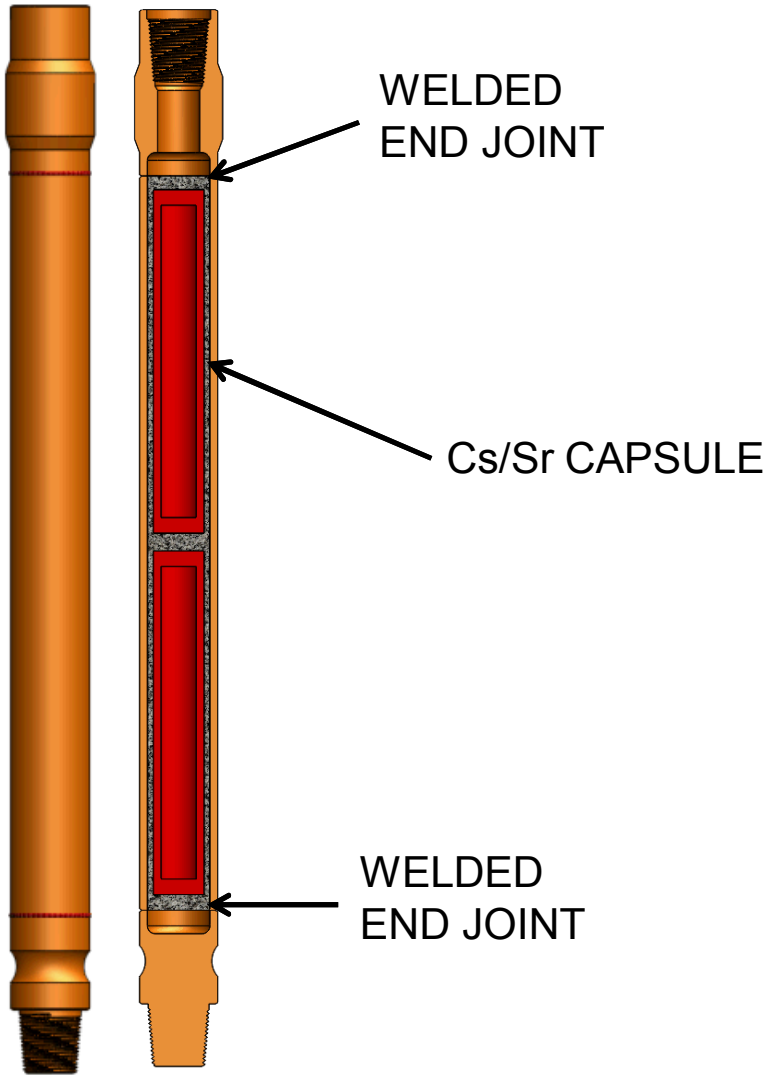
Design Option 4 Details

- Welded API NC38 joint
- 5.0” OD x 4.0” ID
- 19,800 psi collapse pressure

Package may contain up to 8 Cs/Sr capsules



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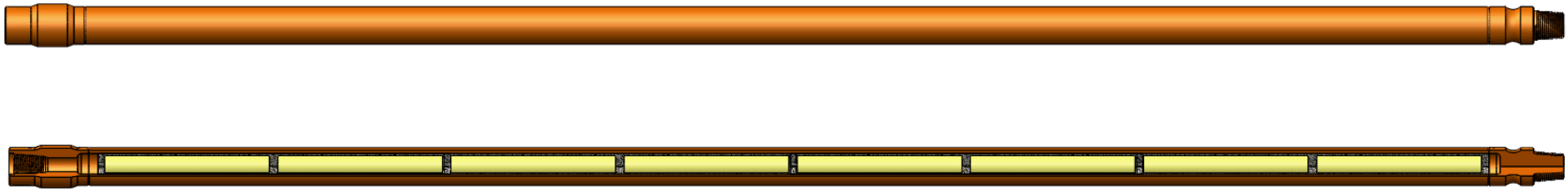
Small Waste Package Over Pack (True Aspect Ratio)



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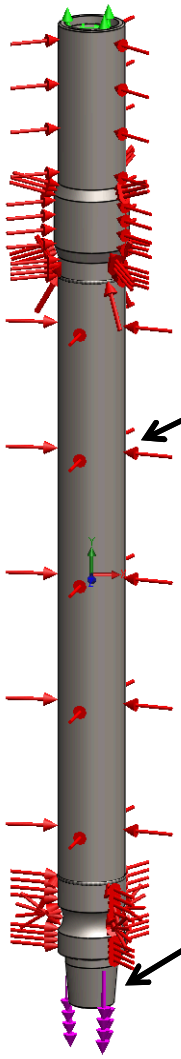
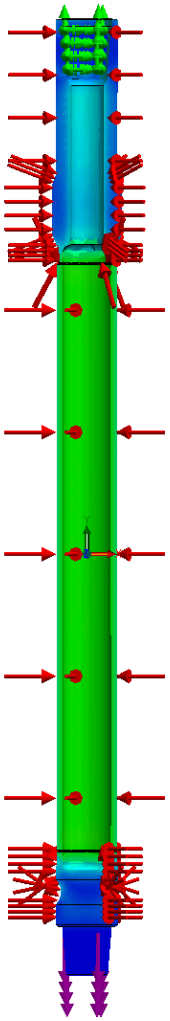
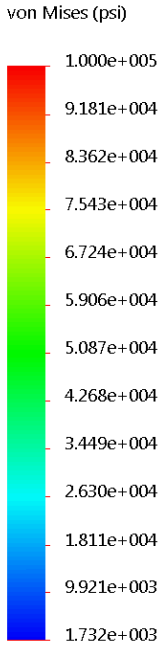
Option 4 Stress Analysis



9600 psi
External Pressure

27,600 lbf
Axial Force





42 ksi max vonMises
FoS ~ 2.6

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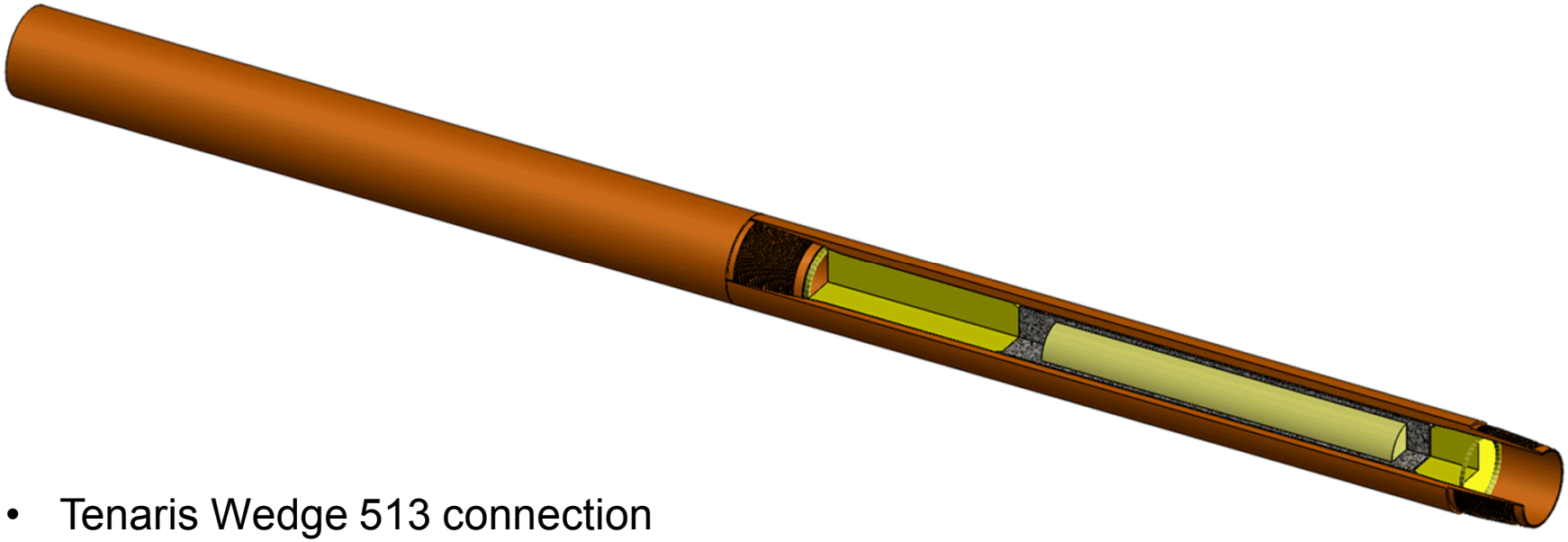
Small Waste Package Over Pack Design Option 5



- Tenaris Wedge 513 connection
- 5” OD x 4” ID
- 19,800 psi collapse pressure

Aspect ratio squeezed to enhance detail on connections

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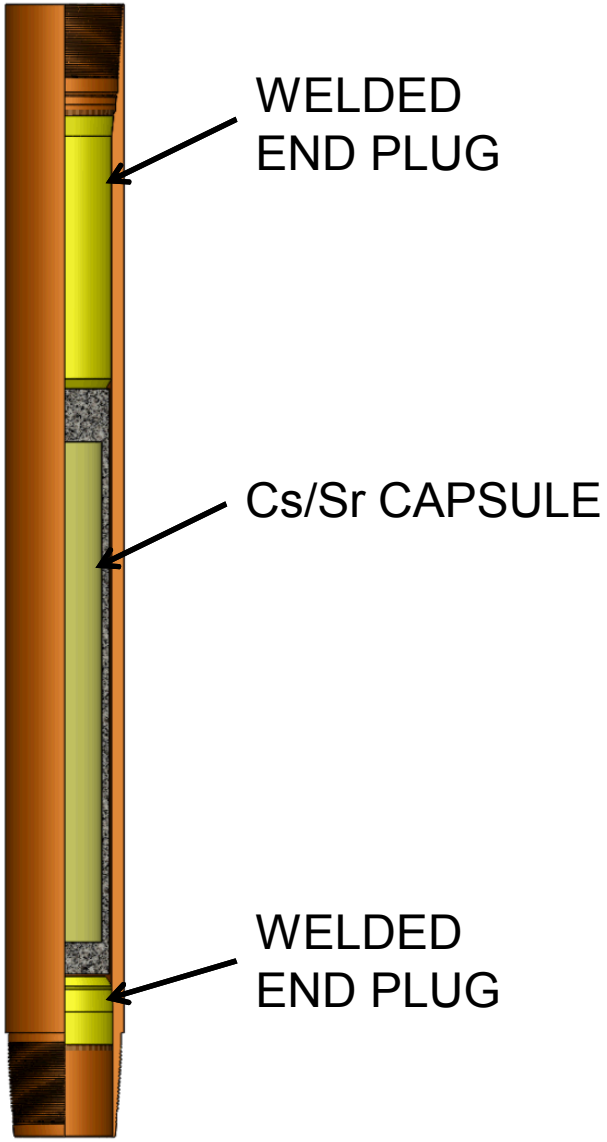
Design Option 5 Details

- Integral flush connection
- Welded end plugs
- 5.0” OD x 4.0” ID
- Tenaris Wedge 513 connection
- 19,800 psi collapse pressure

Package may contain up to 8 Cs/Sr capsules



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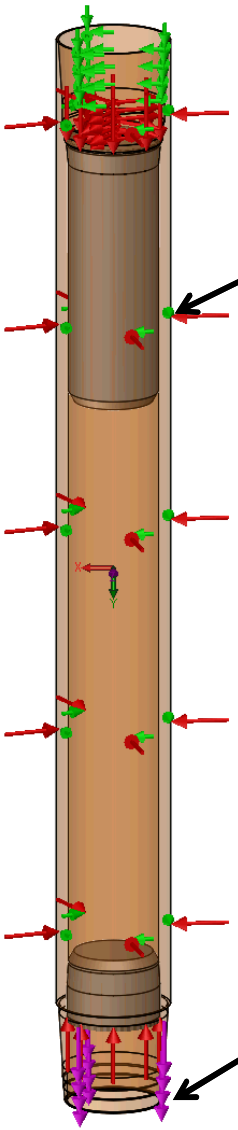
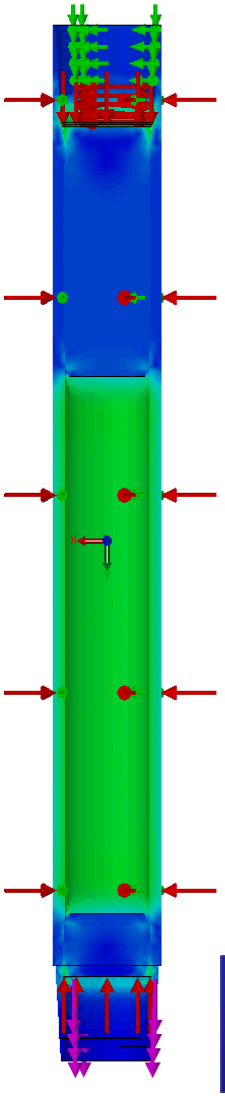
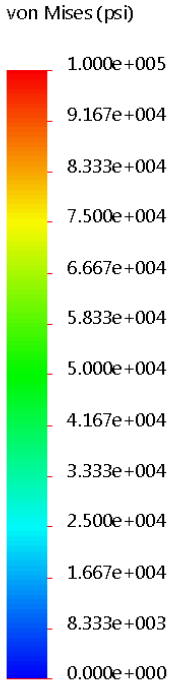
Option 5 Stress Analysis



9600 psi
External Pressure

27,600 lbf
Axial Force





42 ksi max vonMises
FoS ~ 2.6

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Design Options Summary

Design	Application	Cost	Pros	Cons
1	Large package bulk waste/3 capsule groups	~$10k for body	External flush, fabrication, standard drill pipe thread, Loading waste	Weld in load path Post-weld heat treat? Plugging waste holes
2	Large package bulk waste/3 capsule groups	TBD	External upset, loading operations Pressure sealing	External upset, OD ~11.2” 10 ¾” difficult to find (per Tenaris), Custom mill run for size
3	Large canister bulk waste/3 capsule groups	TBD	External flush, pressure sealing	Lower collapse pressure Custom mill run for size Grabbing points
4	Stacked small package encapsulated waste	TBD	External flush, Fabrication, Loading capsules	Weld in load path Post-weld heat treat? Plugging waste holes
5	Stacked small package encapsulated waste	TBD	External flush, welded end caps	Custom mill run for size Grabbing points

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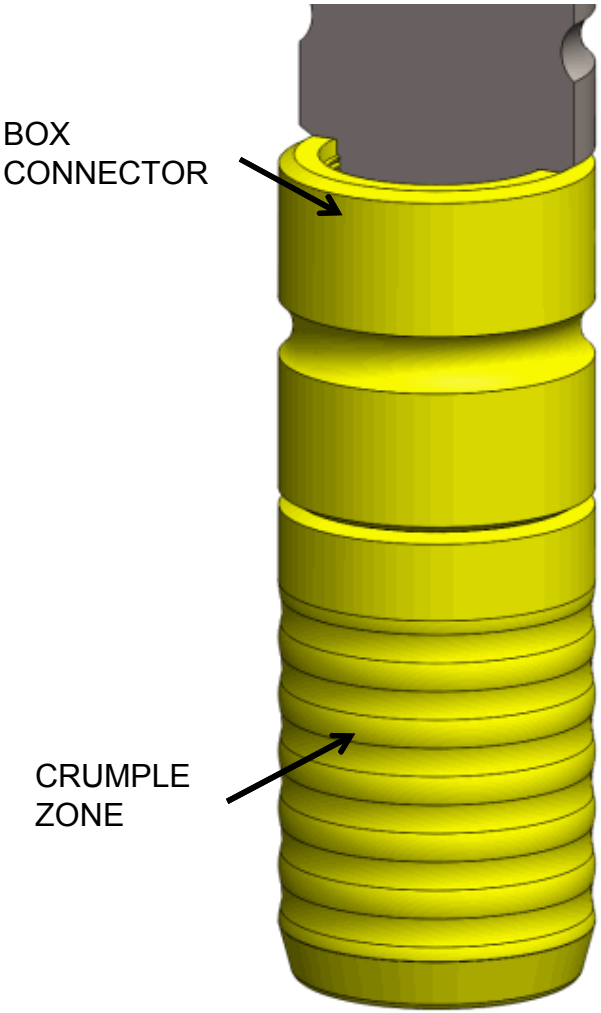
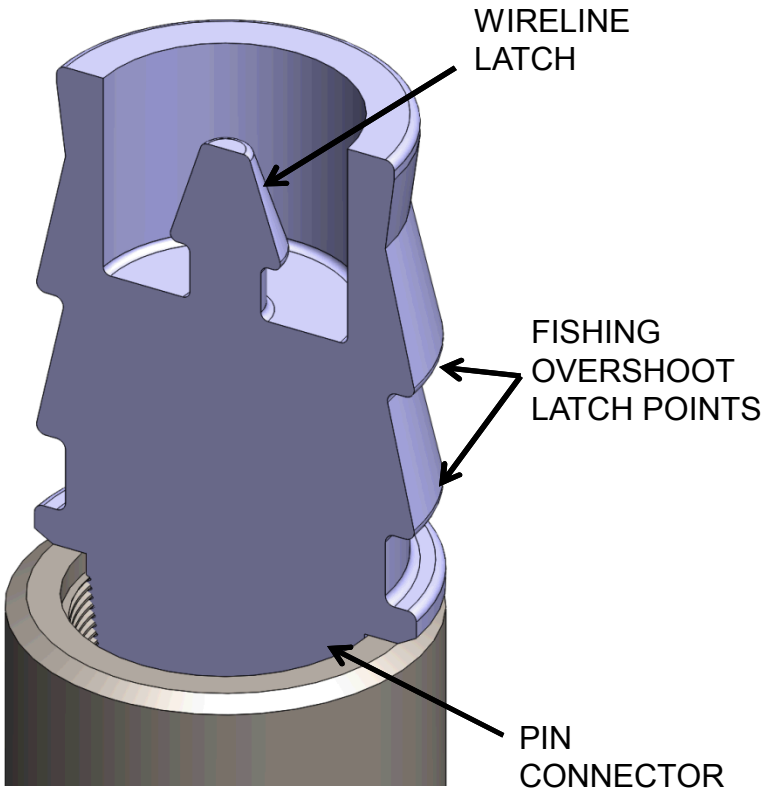
Lowering/Fishing Head and Crush Section





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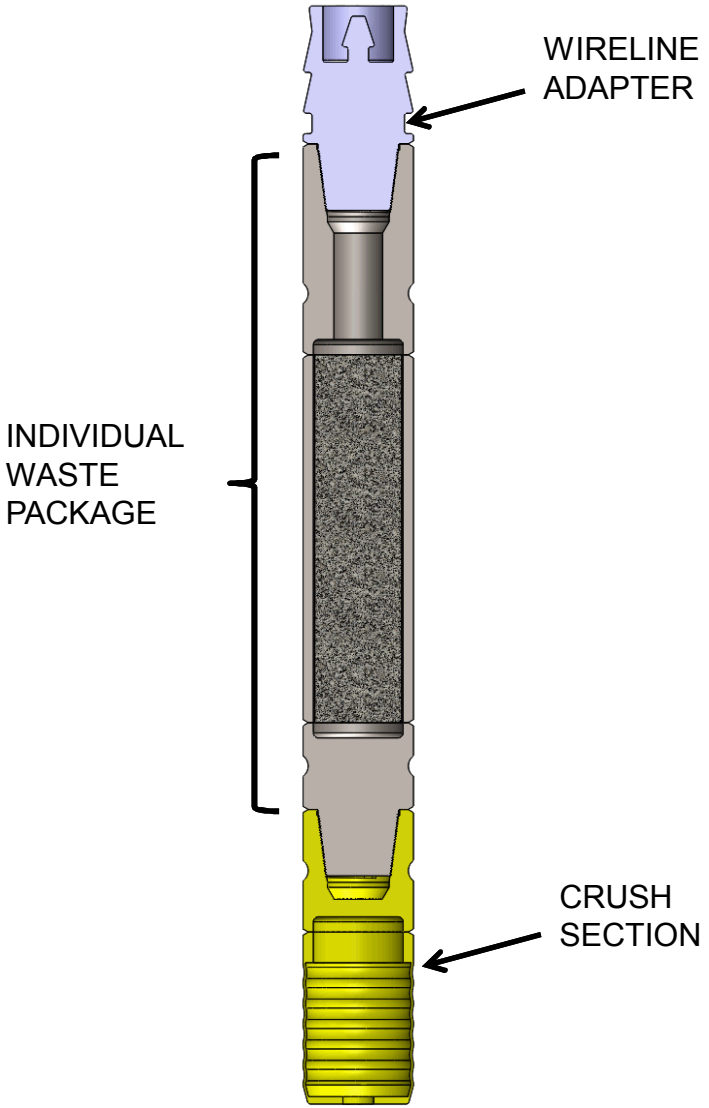
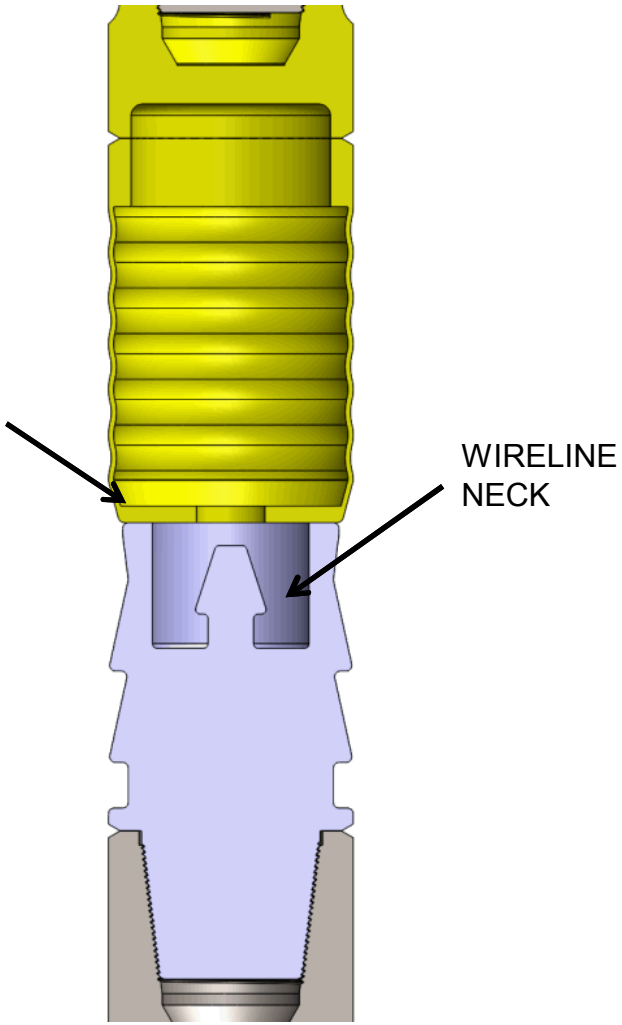
Package Details





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Individual Package Emplacement Option