STAR NOTE NO. 222

STAR Beam Pipe Study

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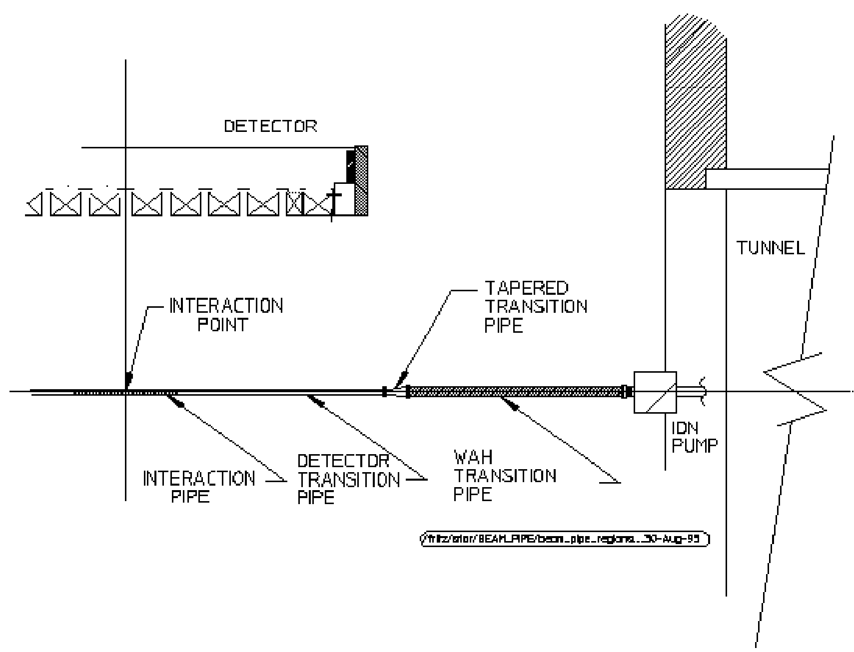
This STAR note contains information known about the portion of the beam pipe between the last RHIC magnets (and vacuum pumps), passing through the STAR detector, in the Wide Angle Hall, and it is intended to be used as a guide for the final beam pipe design.

For this study, both beryllium (Brush Wellman PS-200 grade, 98% purity) and beryllium aluminum (Brush Wellman AlBeMet 162, 62% beryllium, 38% aluminum) were considered for the center section, transitioning to stainless steel up to the RHIC interface. Other possible materials or vendors have not been considered at this time.

Ref.: Pages A-1 and A-2 for beam pipe section summaries.

1. Beam Pipe Assembly:

The beam pipe assembly used in the detector and WAH will consist of 3 major components. The Interaction Pipe, the Detector Transition Pipes, and the WAH Transition Pipes. Each of these components is described in detail below.



Interaction Pipe
Ref.: Pages A-1 and A-16

For the center most portion of the beam pipe, at the interaction region, four major material issues are considered (baseline 8 cm, 3.15 inches outer diameter):

A. Radiation length and material thickness
B. Strength and material thickness
C. Length of center section before transitioning to a less costly material such as stainless steel
D. Cost

A. Radiation Length and Material Thickness

The SVT and TPC have a requirement for a long radiation length material in the interaction region. At this time, both state that they require not more than .3% radiation length with respect to the wall thickness.

The wall thickness of beryllium pipe, (radiation length of 35.3 cm) needs to be (.003)(35.3)=.106 cm, or .042 inch or less.

The wall thickness of beryllium aluminum pipe (radiation length of 18.8 cm, calculated by Howard Matis) needs to be (.003)(18.8)=.056 cm or .022 inch or less.

B. Strength and Material Thickness

Calculating the collapse pressure of thin walled pipe under external pressure (ref: Roark and Young, section 12.5) and using a factor of safety of 3.25, beryllium aluminum material requires a wall thickness of .030 inch or larger. However, this wall thickness violates the TPC and SVT requirement with respect to radiation length.

The same calculation for a straight beryllium pipe requires a wall thickness of .026 inch or larger which meets the radiation length requirement.

C. Length

The SVT is requesting a 1.5m length of beam pipe centered about the interaction point. This length will cover the diamond region and allow the SVT to do physics at higher pseudo-rapidity (in conjunction with the TPC).

D. Cost

The quote from Brush Wellman for a 60 inch (1.5 m) length pipe, thickness .030 inch and outer diameter of 3.150 inches is:

Be section $74,500.00
BeAl section $61,800.00

Ref.: Page A-16, Brush Wellman quote for more details.

Detector Transition Pipes

Ref.: Pages A-3 and A-4

Attached to each end of the Be or BeAl section (Interaction Pipe) will be a stainless steel pipe. These stainless segments will be permanently attached (brazed/welded) to the Interaction Pipe and will remain with the detector as it is moved from the WAH to assembly building or vise versa.

The Detector Transition Pipes are approximately 122 inches (310 cm) in length and will terminate approximately 152 inches (3.8 m) from the interaction point. At this point they will be connected via a bolted flange to a tapered pipe. This tapered pipe will then be bolted to the WAH Transition Pipe. After breaking the bolted connection (between the Detector Transition Pipe and tapered pipe) the detector can be moved, avoiding interference with the Wide Angle Hall/Assembly Building door. Various thicknesses and diameters for the beam pipe are considered (see following deflection section, tables and graphs).

WAH Transition Pipes

Ref.: Pages A-3 and A-4

The WAH Transition Pipe is of a larger diameter than the Detector Transition and Interaction segments and is then located between the Detector Transition Pipe and the RHIC ion pump interface. The WAH Transition pipe contains a tapered pipe that will transition from the diameter of the Detector Transition pipe, approx. 3.15 inches (8 cm) diameter up to a 5 inch (12.7 cm) diameter of the WAH Transition pipe. This stainless tapered pipe will taper with a slope of 5 inches of length for each inch of diameter change and will terminate with a 6-3/4 inch outer diameter ConFlat flange, MDC PN 100029 (suggestion by the RHIC Vacuum Group) Final connection of the WAH transition pipe will be via bolted flange to the RHIC ion pump interface (approximately 293 inches (7.4 m) from the interaction point). Kimo Welch of the RHIC Vacuum group will have the information on this ion pump interface.

At this time, it is assumed that the RHIC Vacuum group will supply the WAH Transition pipes (12.7 cm OD) (including the tapered transition piece) as well as a 7 inch long bellows which accounts for the transverse misalignment in the beam pipe.

Page A-4 shows the different transition and weld/braze options according to center beam pipe section type.

3. Support Locations and Deflections (Due to Weight):

Ref.: Pages A-5 through A-15

Three support locations were considered. The calculations use supports which take a bending moment, although a simply supported condition could be considered where the rotation of one section could be used to counteract the rotation and deflection of the next section.

The first support location at 76 inches from the interaction point, corresponds to the SVT requested .004 inch or less deflection: To maintain a deflection of .004 inch, transitioning to a stainless section of the same diameter, 3.15 inches, a support is required at 76 inches or less from the interaction point. This support location is located inside the SVT support cone which is not optimal for hardware attachment. This location is also used for varying diameter comparisons.

The second support location is 90 inches from the interaction point and corresponds to the TPC wheel. This is the most plausible attach face.

The third support location is 145 inches from the interaction point and corresponds to the outer pole tip attach face. A design with this support location would have to take into account the pole tip movement in and out from the detector.

Several outer diameters for the stainless section were considered since larger diameter pipes result in less deflection.

See attached deflection tables and graphs.

4. Requirements and Requests:

- SVT and TPC- not more than .3% (.003) radiation length of material (wall thickness) of center Be/BeAl section.
- SVT- baseline outer diameter 8 cm (3.150 inch) of center Be/BeAl section.
- SVT- 60 inch length center Be/BeAl section.
- SVT- Wrap center Be/BeAl pipe with aluminized mylar for stray RF radiation.
- RHIC Vacuum group and SVT- bake entire beam pipe 300 degree Celsius after every breaking of vacuum. SVT will have to be removed during bakeout.

- SVT- Sag (deflection) of pipe should not be more than 100 microns (.004 inch).

- SVT- for removal/insertion, any flanges within 5 meters of the interaction point on the west side of the detector to be no more than 1.5 cm additional material radially.

- The FTPC is requesting a 'trumpet shaped' section in the Be/BeAl section so that they can better detect their shallow angle particles. This should be discussed with Dan Cebra and Jim draper of the FTPC group and others, possibly the Technical Committee.

- Still need more information and requests/requirements from the VPD and FTPC groups as more development is done in these groups.

5. Other Issues to Ponder:

- SVT and beam pipe removal in Assembly Building. See above SVT flange requirement.

- How to accomplish the 300 degree Celsius bakeout. RHIC vacuum group thinks the bakeout blanket thickness will be approximately 2 cm thick. Perform additional strength analysis for thin walled pipe under external pressure at 300 degrees C (collapse pressure discussed above done at room temperature).

- RHIC Vacuum group to supply: Bakeout blankets, 12.7 cm stainless steel pipe (second stainless section attaching to RHIC interface), misalignment bellows, RF shielded bellows which take up longitudinal expansion during bakeout, RF shielded gate-valves which bracket the experimental region, roughing provisions and gauging.

- Is it acceptable to the SVT and TPC group, radiation length wise, that the beryllium beam pipe is flat plate, formed and brazed down the seam with some type of braze alloy? What type of material is the braze alloy and will it be acceptable to them?

- Can all the welds and brazes withstand the bakeout temperatures and detector movement/removal?

- Check further with Brush Wellman on the straightness they can hold over the entire section- they presently believe they can hold .030 inch.

- Check beam pipe during run mode for vibrational deflections.

- A straight Be pipe can be brazed directly to a stainless pipe. However, a BeAl pipe requires an aluminum transition piece between the BeAl section and the stainless section electron beam welded at each interface. Need to look further into this issue. Can this aluminum transition piece maintain sufficient strength?

- Squeeze all subsystems requirements: Can the Be or BeAl section possibly be shorter than 60 inches? Can the wall thickness (or percent of radiation length) increase so that BeAl at .030 inch, or even .040 inch is acceptable? Can we tolerate more deflection so that we can support the beam pipe in a design logical location?

Conclusion

A beryllium aluminum center section beam pipe would be more desirable from a cost perspective than a straight beryllium pipe. However, if sufficient strength is maintained, the beryllium aluminum pipe does not meet the present SVT/TPC radiation length requirement. Transitioning from a beryllium section to a stainless section is easier than transitioning from a beryllium aluminum section to a stainless section.

Beam pipe supports needs to be designed so that they do not interfere with the physics of the detector, maintain acceptable deflections and do not pose as obstacles during pole tip or detector movement and operation.

Many issues such as bakeout and beam pipe and SVT removal still need considerable thought before finalizing the beam pipe design.

Existing requirements need to be scrutinized by the requesting groups in order to ensure the best and least costly design, and any new requirements need to be identified.

Summary

BeAl Section:

- Brush-Wellman alloy - 62% Be and 38% Al
- 60 inches total length centered about interaction point
- Wall thickness = 750 microns (.030")
- Outer diameter = 80 mm (3.150" or r = 1.575")
- Calculated radiation length of BeAl = 18.794 cm (7.400")
- SVT and TPC require .3%, or less, radiation length of material -wall thickness of (.003)(18.794) = .056 cm (.022") or less
- Elongation due to 300 degree C bake = .24"
- Deflection due to weight negligible
- Al transition piece required btw BeAl and stainless sections
- Cost $49,100.00

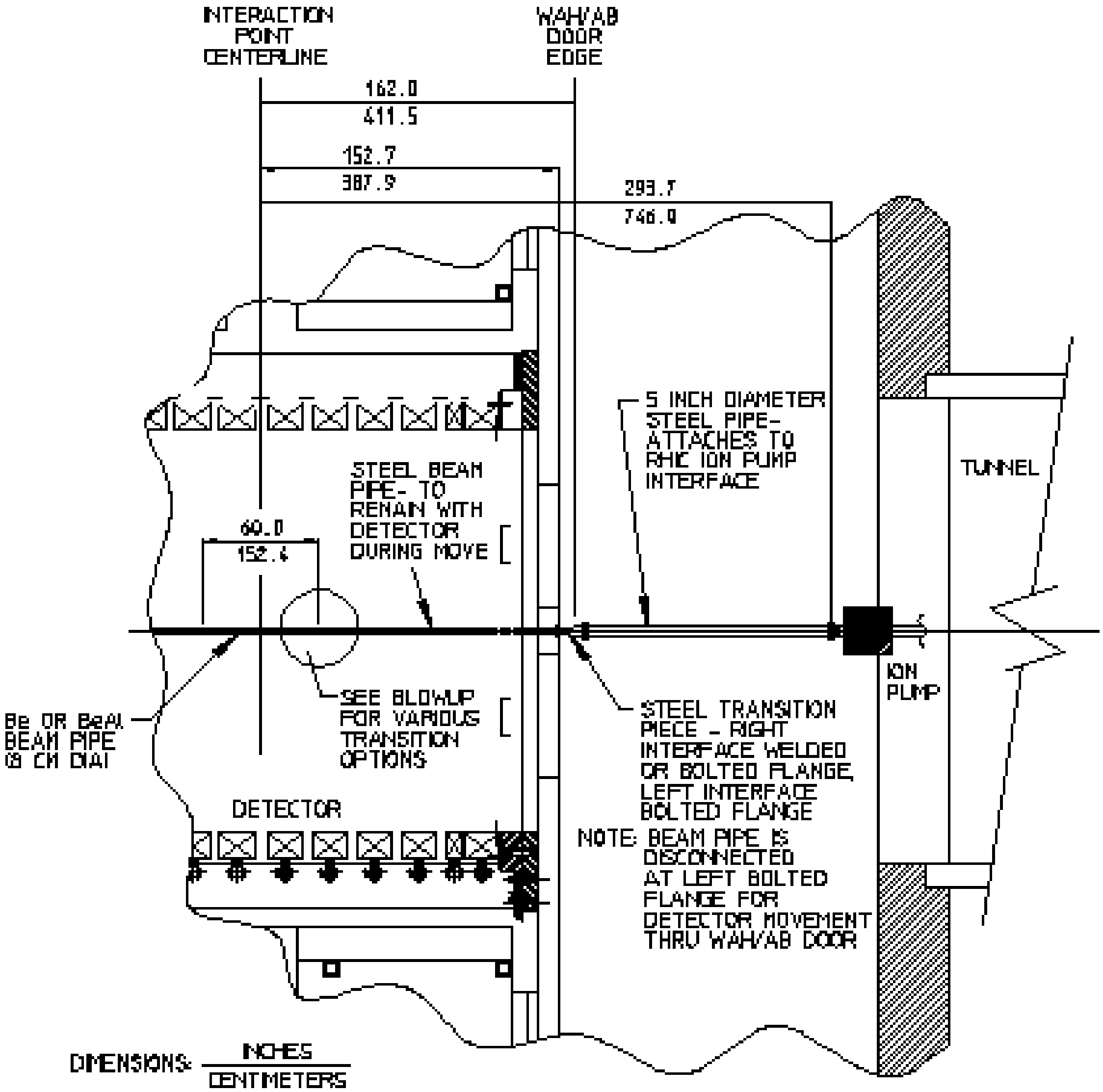
Be Section:

- Brush-Wellman PS-200 grade (98% purity)
- 60 inches total length centered about interaction point
- Wall thickness = 750 microns (.030")
- Outer diameter = 80 mm (3.150" or r = 1.575")
- Radiation length of Be = 35.3 cm (13.9")
- SVT and TPC require .3%, or less, radiation length of material - wall thickness of (.003)(35.3) = .106 cm (.042") or less
- Elongation due to 300 degree C bake = .27"
- Deflection due to weight negligible
- Brazed transition directly to stainless section
- Cost $74,500.00

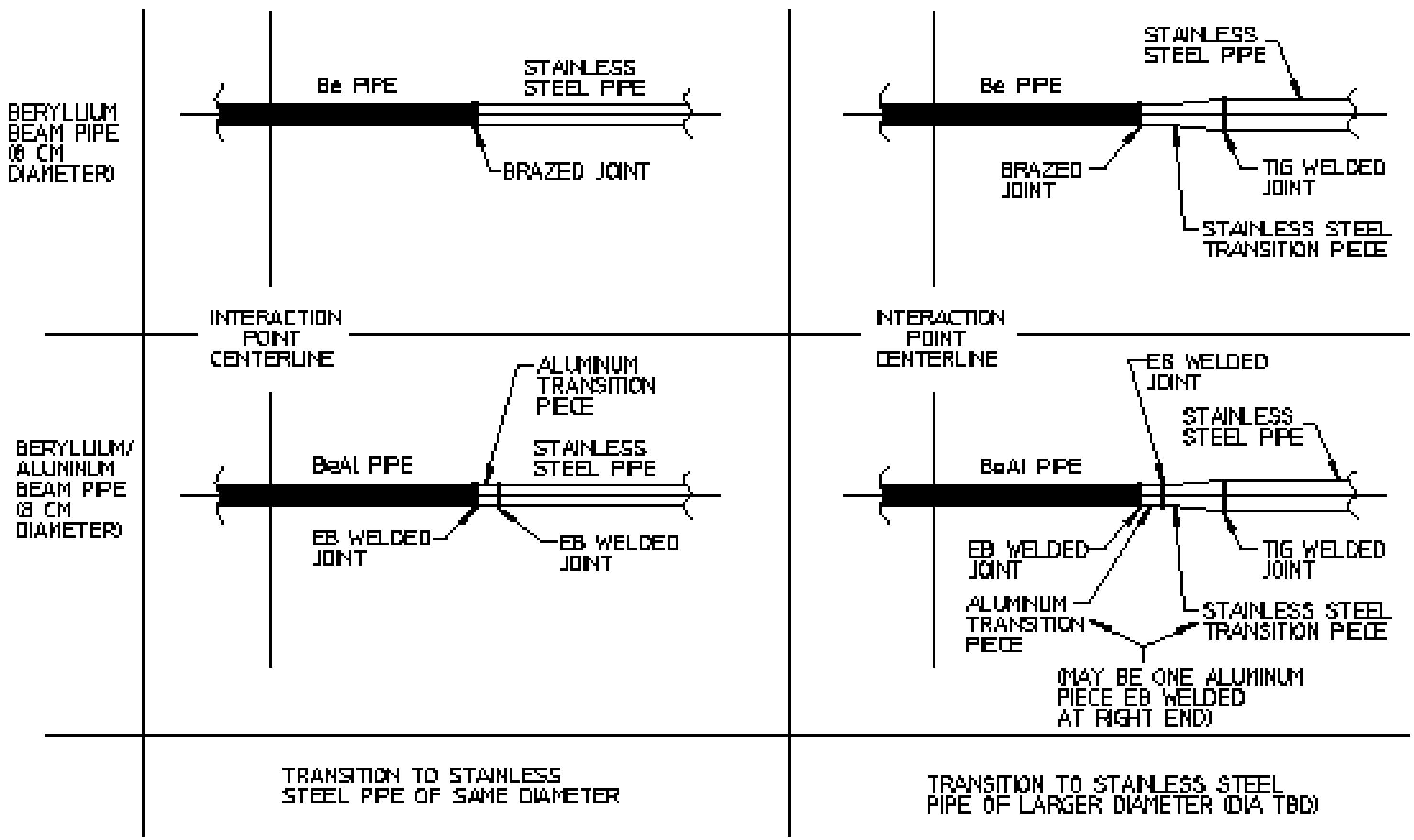
Stainless Steel Sections:

- 300 series stainless
- 264" each side from BeAl section to RHIC interface (ion pumps)
- Wall thickness - .030", .060", .090"
- Outer radius - 2.000", 2.200", 2.500"
- Attached tables and graphs tabulate deflections versus varying radii, wall thicknesses and support positions
- Elongation due to 300 degree C bake = 1.34" each side

BEAM PIPE IN WIDE ANGLE HALL



BERYLLIUM AND BERYLLIUM ALUMINUM BEAM PIPE TRANSITION OPTIONS



Weight Deflections

All cases:

- Be and BeAl section is 60" in total length, outer radius = 1.575" (8 cm dia)
- Wall thickness = .030" (750 microns)
- Deflection negligible compared to stainless sections

For stainless steel sections adjacent to Be and BeAl section:

- t = wall thickness of steel in inches
- r = outer radius of steel in inches
- z = length in z from the interaction point to the first support in inches
- defl = total sag in composite beam, between supports, due to weight of pipe (inches)

Beam Pipe Deflection Tables

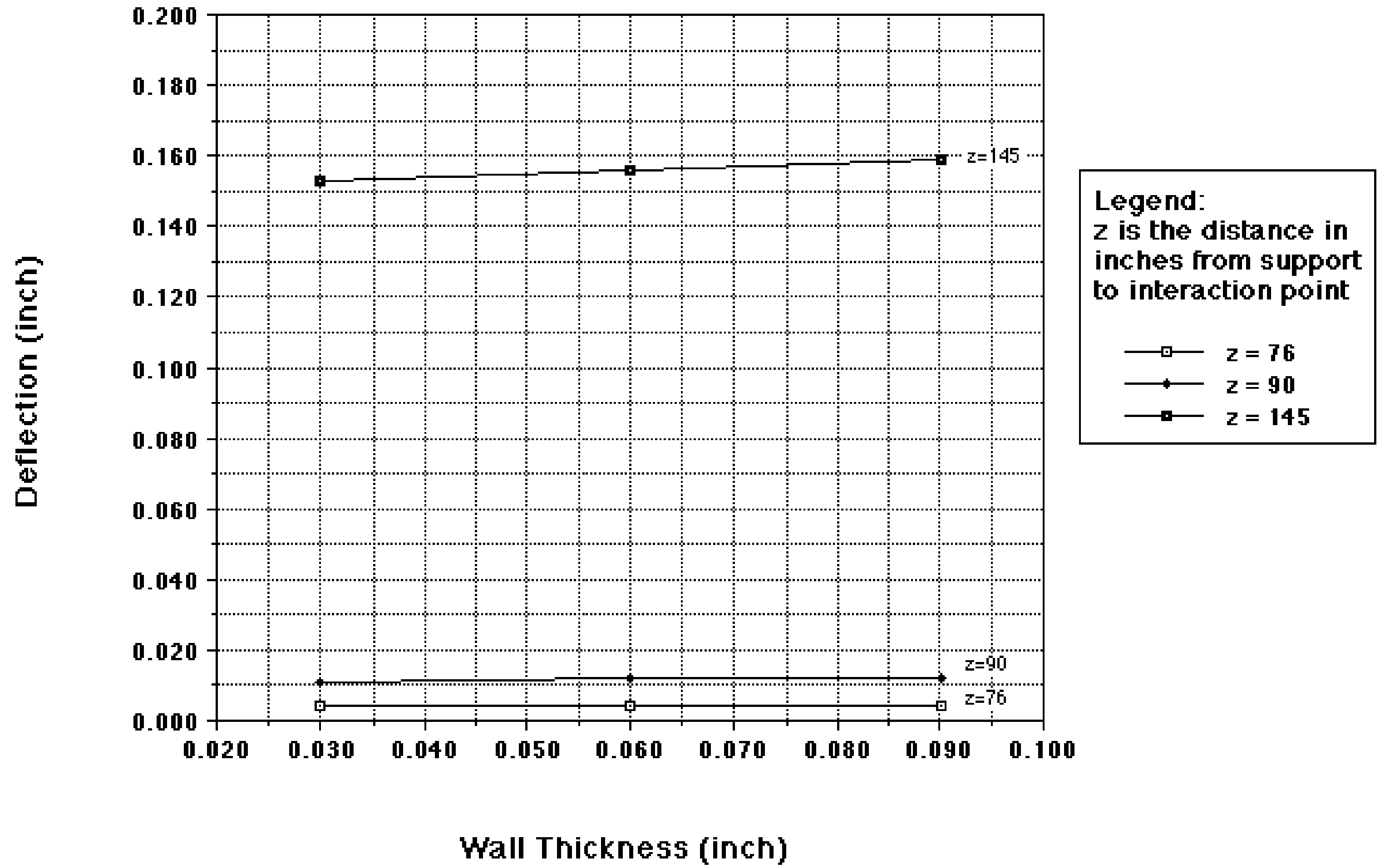
For outer radii = 1.575"

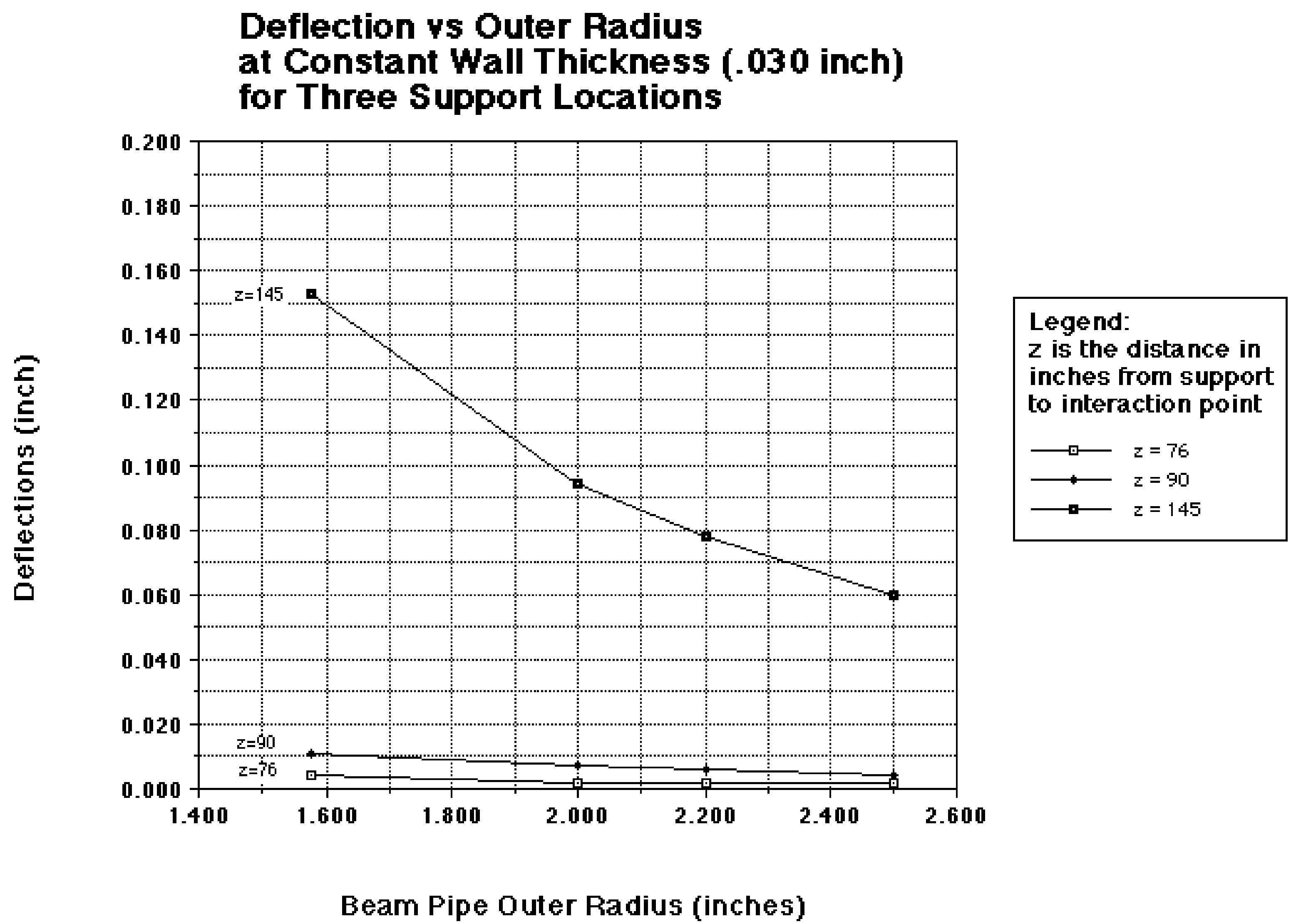
z	t	defl
76	.030	.004
	.060	.004
	.090	.004
90	.030	.011
	.060	.012
	.090	.012
145	.030	.153
	.060	.156
	.090	.159

For wall thicknesses = .030"

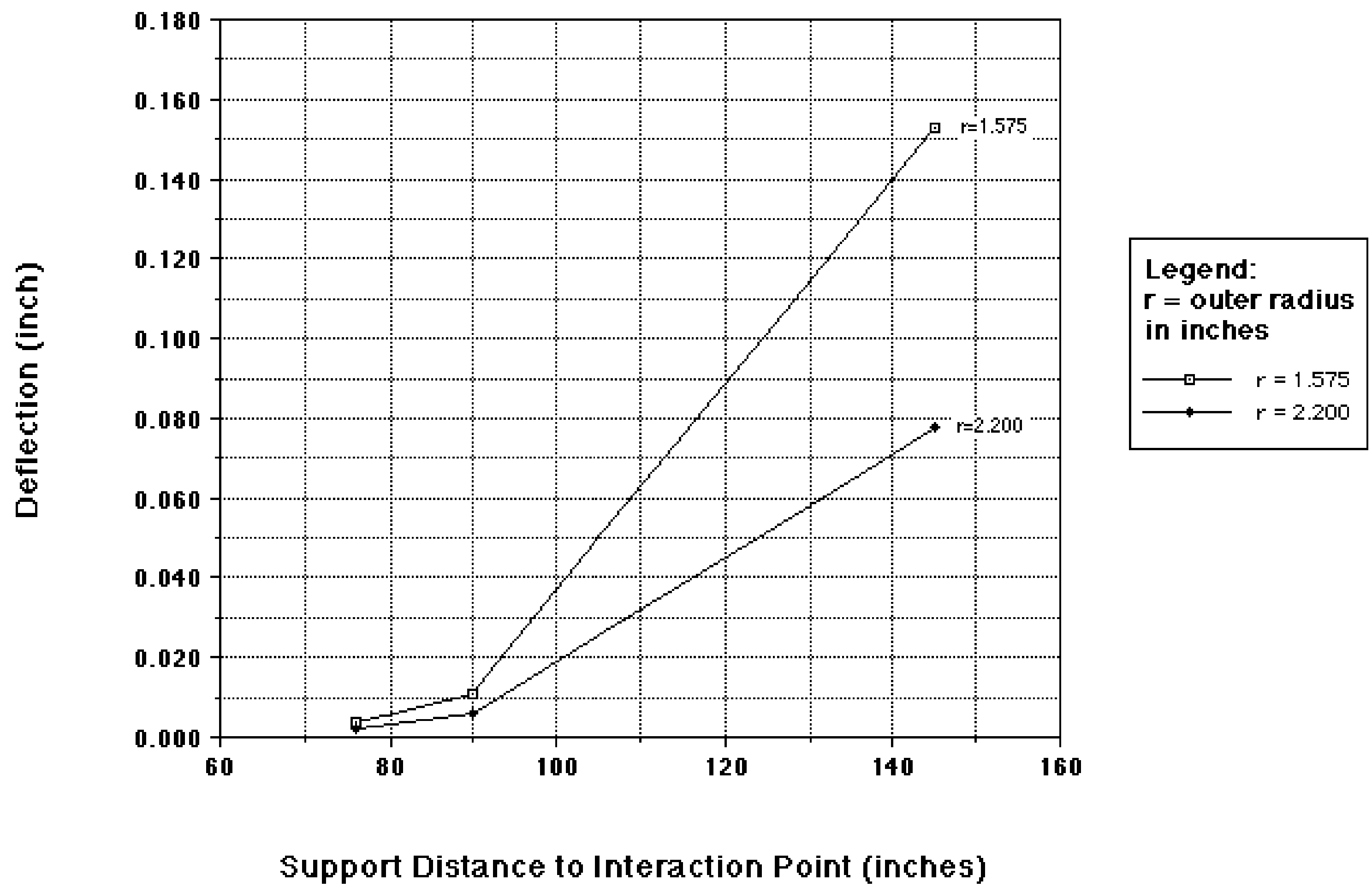
z	r	defl
76	2.000	.002
	2.200	.002
	2.500	.002
90	2.000	.007
	2.200	.006
	2.500	.004
145	2.000	.094
	2.200	.078
	2.500	.060

Deflection vs Thickness at Constant Outer Radius (1.575 inch) for Three Support Locations

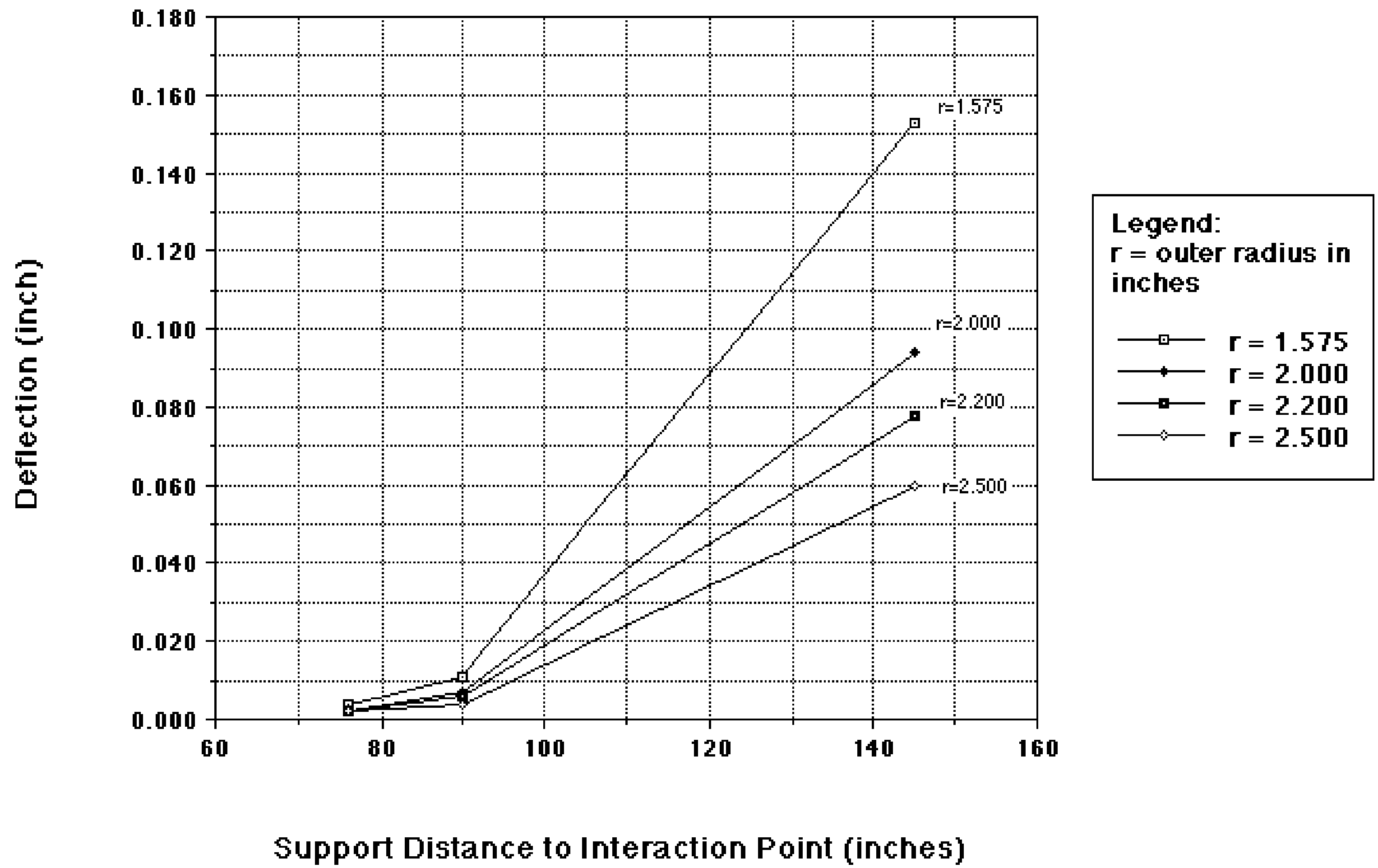



Deflection vs Outer Radius
at Constant Wall Thickness (.030 inch)
for Three Support Locations
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
1.400
1.600
1.800
2.000
2.200
2.400
2.600
z=145
z=90
z=76
Deflections (inch)
Beam Pipe Outer Radius (inches)
Legend:
z is the distance in
inches from support
to interaction point
z = 76
z = 90
z = 145

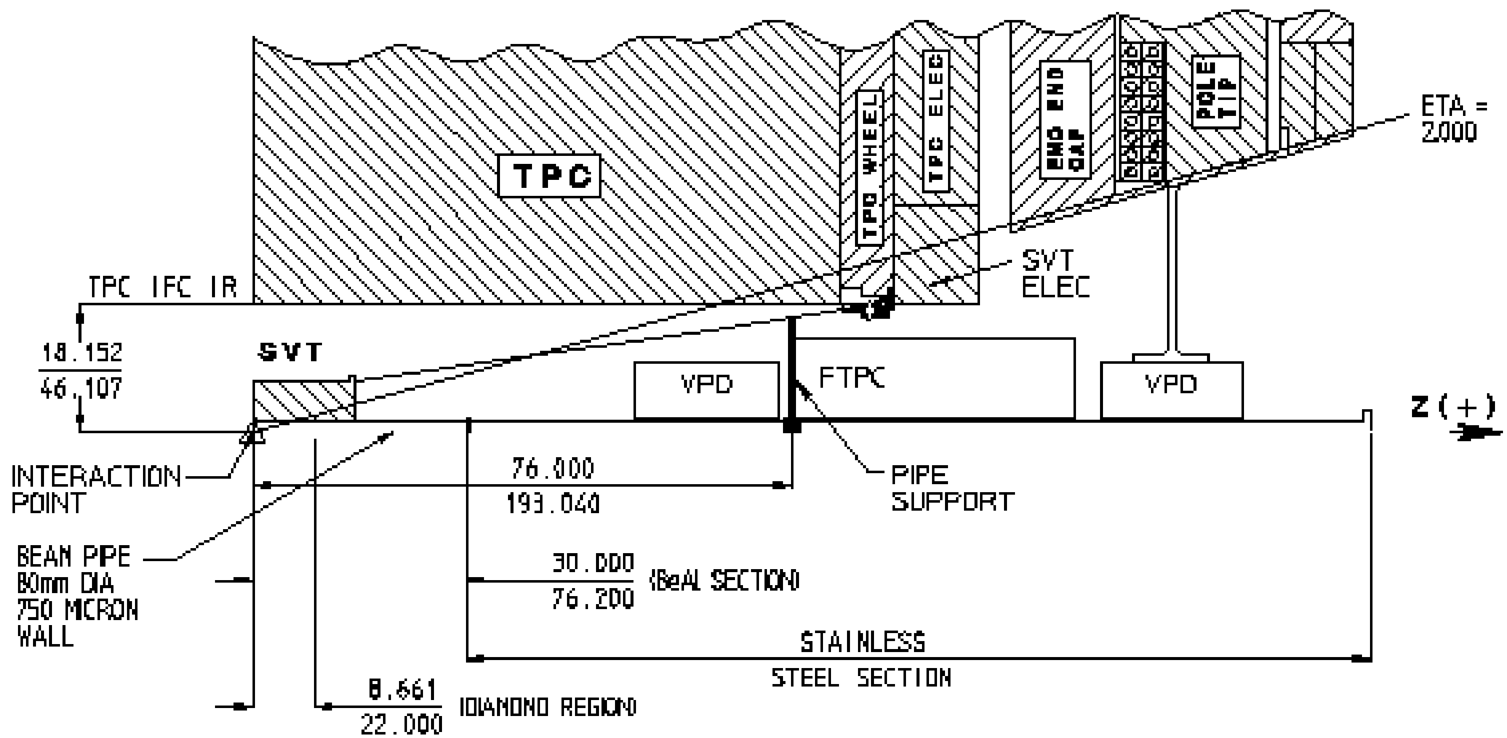
Deflection vs Support Distance at Constant Wall Thickness (.030 inch) for Two Outer Radii



Deflection vs Support Distance at Constant Wall Thickness (.030 inch) for Four Outer Radii



BEAM PIPE SUPPORT (1)



FOR BeAl SECTION WITH WALL THICKNESS - .030 IN (750 MICRON), OUTER RADIUS - 1.575 IN (8 CM DIA)
AND STAINLESS STEEL SECTION WITH WALL THICKNESSES - .030, .060, .090 IN
OUTER RADII - 1.575

SUPPORTED AT Z - 76 IN:

DEFL - .004 IN FOR T - .030 IN
DEFL - .004 IN FOR T - .060 IN
DEFL - .004 IN FOR T - .090 IN

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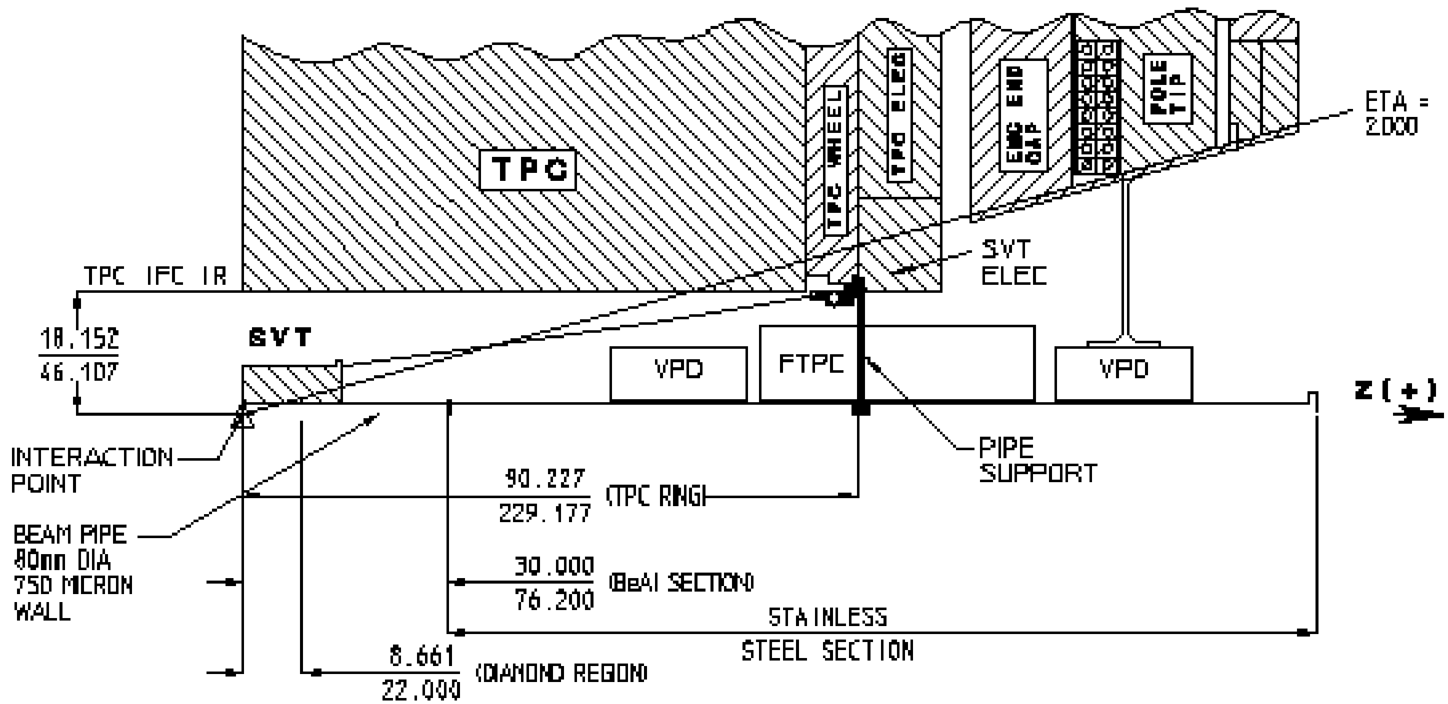
BEAM PIPE SUPPORT (2)



FOR BeAl SECTION WITH WALL THICKNESS = .030 IN (750 MICRON), OUTER RADIUS = 1.575 IN (8 CM DIA)
AND STAINLESS STEEL SECTION WITH WALL THICKNESSES = .030, .060, .090 IN
OUTER RADII = 1.575

SUPPORTED AT Z = 90 IN:

DEFL = .011 IN FOR T = .030 IN
DEFL = .012 IN FOR T = .060 IN
DEFL = .012 IN FOR T = .090 IN

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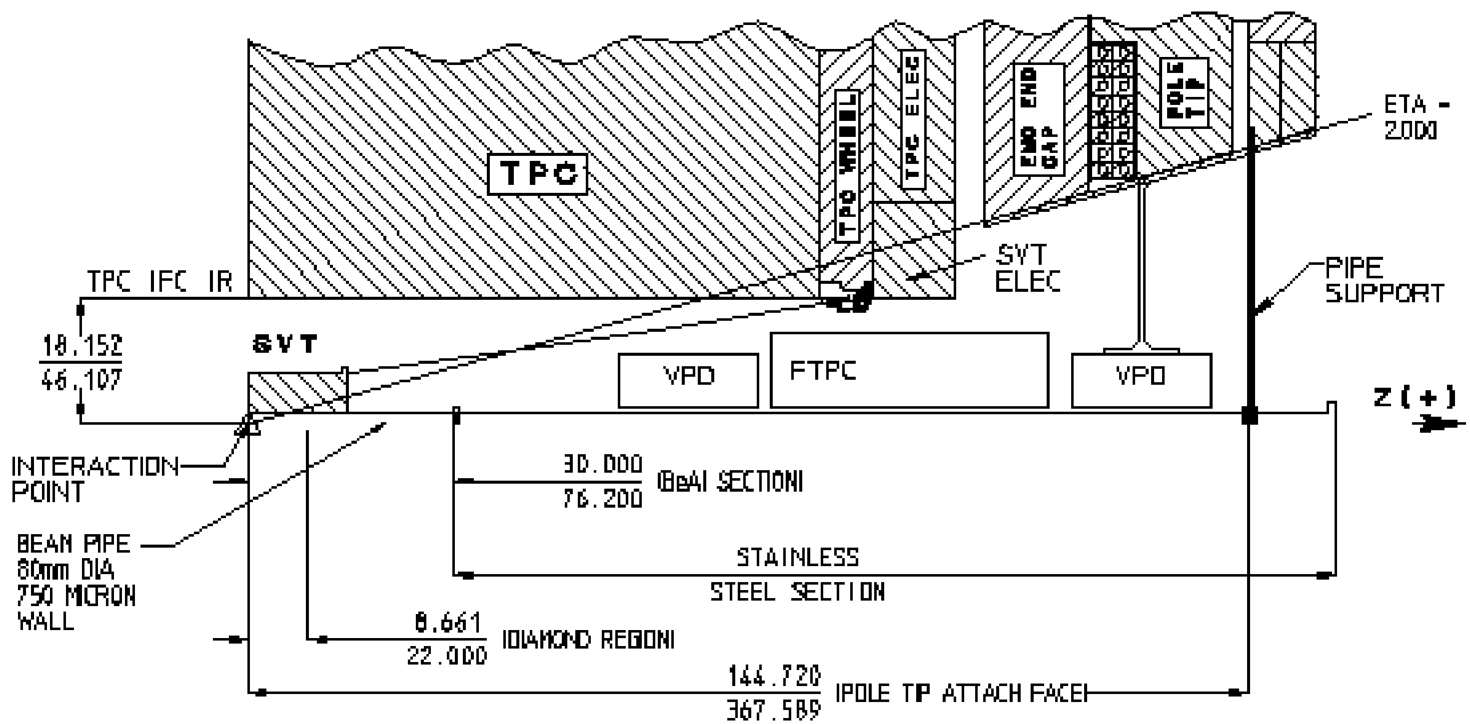
BEAM PIPE SUPPORT (3)



FOR BeAl SECTION WITH WALL THICKNESS = .030 IN (750 MICRON), OUTER RADIUS = 1.575 IN (8 CM DIA)
AND STAINLESS STEEL SECTION WITH WALL THICKNESSES = .030, .060, .090 IN
OUTER RADII = 1.575

SUPPORTED AT Z = 145 IN:

DEFL = .153 IN FOR T = .030 IN
DEFL = .156 IN FOR T = .060 IN
DEFL = .159 IN FOR T = .090 IN

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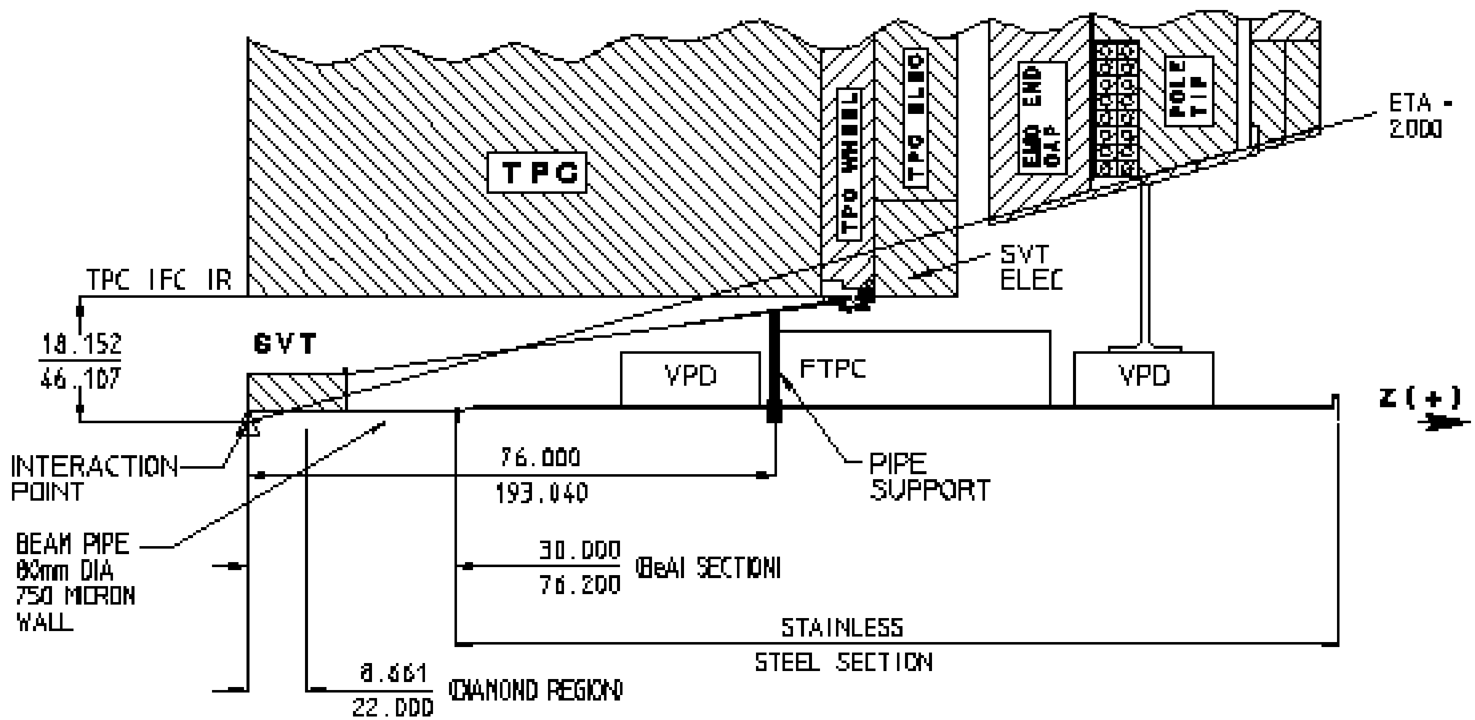
BEAM PIPE SUPPORT (4)



FOR BeAl SECTION WITH WALL THICKNESS = .030 IN (750 MICRON), OUTER RADIUS = 1.575 IN (8 CM DIA)
AND STAINLESS STEEL SECTION WITH WALL THICKNESSES = .030 IN AND
OUTER RADII = 2.000, 2.200, 2.500 IN

SUPPORTED AT Z = 76 IN:

DEFL = .002 IN FOR R = 2.000 IN
DEFL = .002 IN FOR R = 2.200 IN
DEFL = .002 IN FOR R = 2.500 IN

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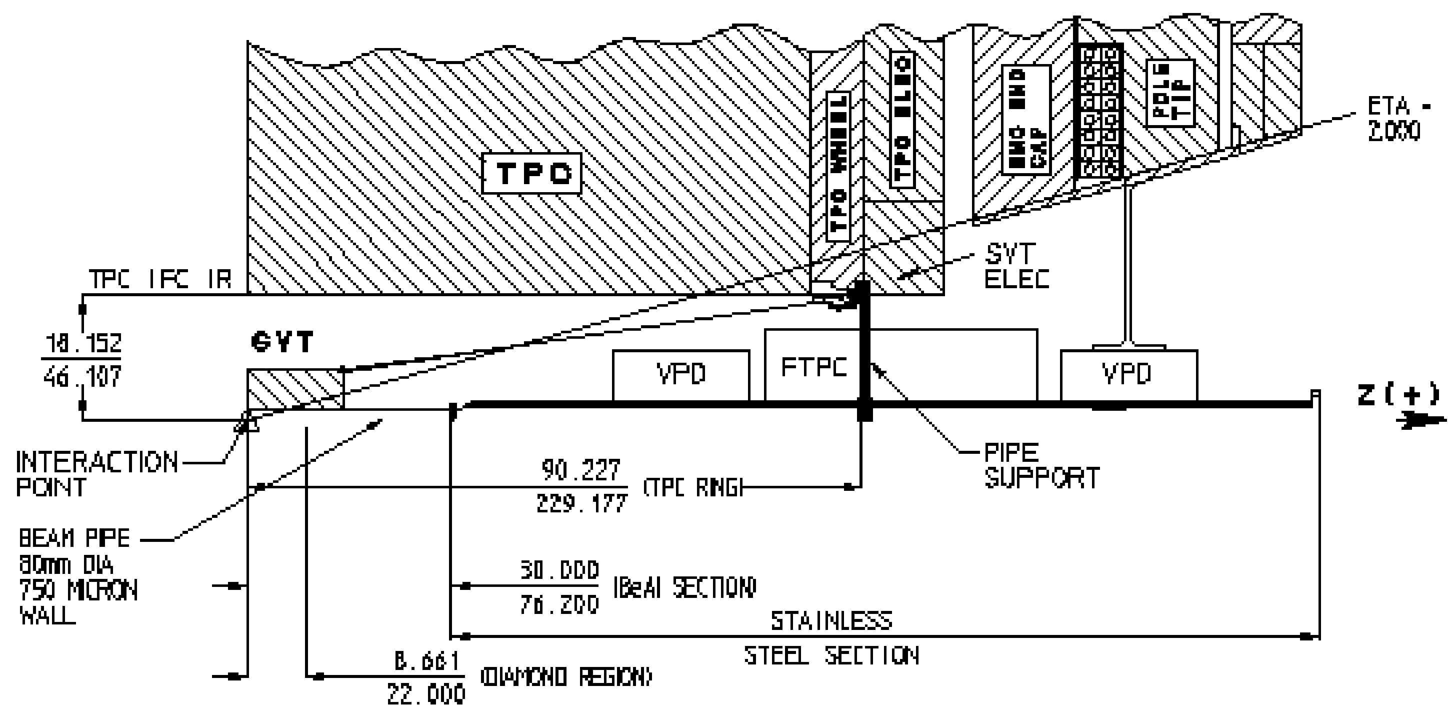
BEAM PIPE SUPPORT (5)



FOR BeAl SECTION WITH WALL THICKNESS = .030 IN (750 MICRON), OUTER RADIUS = 1.575 IN (8 CM DIA)
AND STAINLESS STEEL SECTION WITH WALL THICKNESSES = .030 IN AND
OUTER RADII = 2.000, 2.200, 2.500 IN

SUPPORTED AT Z = 90 IN:

DEFL = .007 IN FOR R = 2.000 IN
DEFL = .006 IN FOR R = 2.200 IN
DEFL = .004 IN FOR R = 2.500 IN

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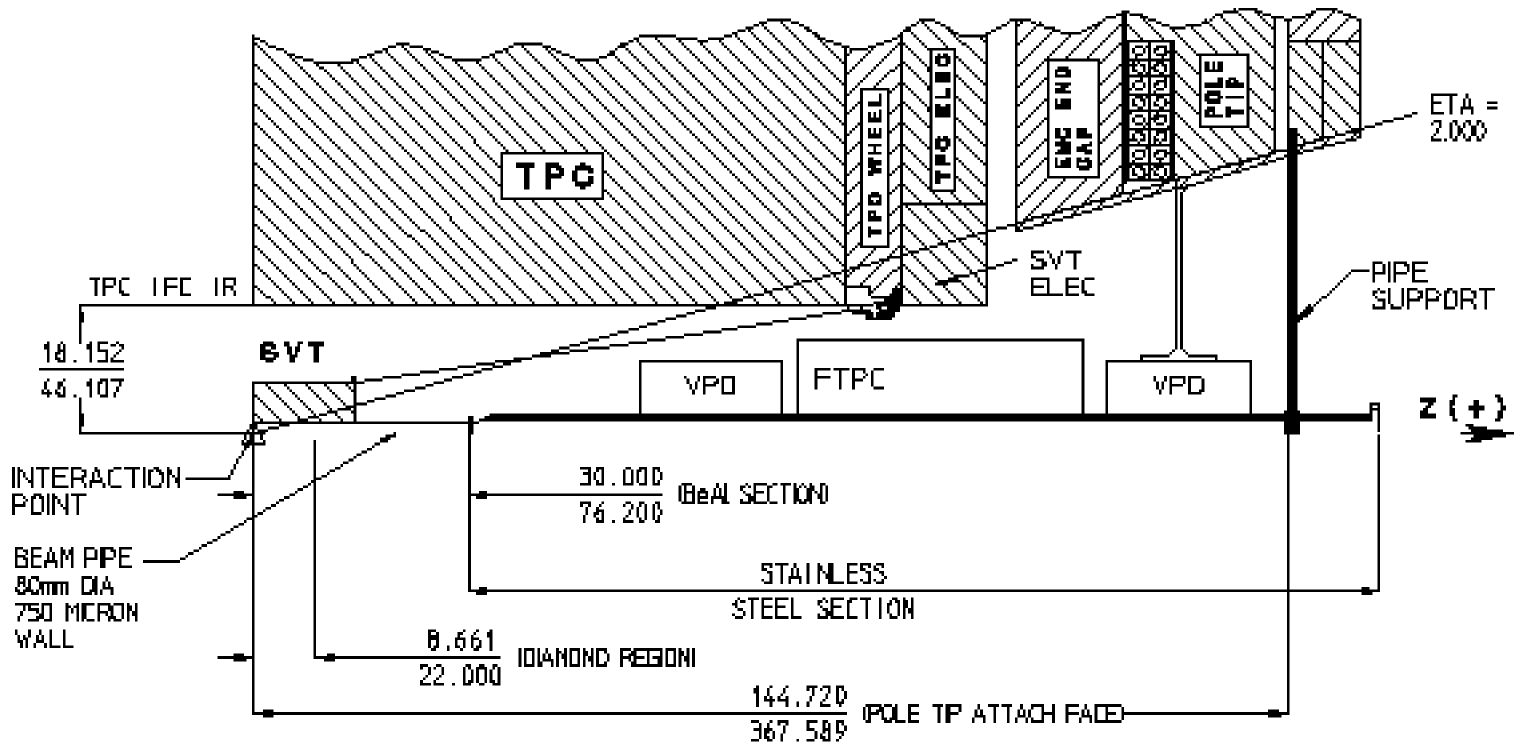
BEAM PIPE SUPPORT (6)



FOR BeAl SECTION WITH WALL THICKNESS = .030 IN (750 MICRON), OUTER RADIUS = 1.575 IN (8 CM DIA)
AND STAINLESS STEEL SECTION WITH WALL THICKNESSES = .030 IN AND
OUTER RADII = 2.000, 2.200, 2.500 IN

SUPPORTED AT Z = 145 IN:

DEFL - .094 IN FOR R - 2.000 IN
DEFL - .078 IN FOR R - 2.200 IN
DEFL - .060 IN FOR R - 2.500 IN

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