Thin tube under uniform lateral external pressure
(critical external pressure when elastic buckling occurs)

	Aluminum 6061-T6	Aluminum 6061-T6	Stiffened Al. 6061-T6	Carbon fiber NCT-301	Sandwich composite Nomex core [1]	Sandwich composite fuzzy carbon core	Sandwich composite Rohacell core	AlBeMet	Be
Modulus of elasticity (psi)	1.00E+07	1.00E+07	1.00E+07	8.55E+06				2.80E+07	4.40E+07
Poisson's ratio	0.33	0.33	0.33	0.34				0.17	0.02
Elongation (%)	12	12	12	1.8				5	2.5
Wall thickness (in)	0.020	0.013	0.008	0.019	0.386	0.084	0.029	0.020	0.020
Radius (in)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Length (in)	123	123	3.5 (between stiffeners)	123	123	123	123	123	123
Ciritcal ext. pressure (psi)	179.6	49.3	47.1	65.3	114798.1	1811.3	748.2	461.3	704.3
Design safety factor	12.2	3.4	4.4	3.2	7809.4	123.2	50.9	31.4	47.9
Density (lb/in^3)	0.098	0.098	0.098	C.F: 0.065; Al: 0.098	Nomex 0.002; Al: 0.098; epoxy: 0.041	F. C: 0.001; Al 0.098; epoxy: 0.041	Roh: 0.001; Al 0.098; epoxy: 0.041	0.076	0.067
Matl radiation length (cm)	8.9	8.9	8.9	C.F:25; Al: 8.9	Nomex 683; Al: 8.9; epoxy: 45	F. C: 1198; Al 8.9; epoxy: 44	Roh: 4186; Al 8.9; epoxy: 45	18.8	35.2
X/X0 (%)	**0.572**	**0.371**	**0.232**	**0.267**	**0.548**	**0.143**	**0.172**	**0.270**	**0.144**
Comments	This design is used in the most recent BTeV simulation		Max. press calculated using ASME BPVC (stiffening rings t=0.008", h=0.06")	Composite tube: c.f. 0.015" thk, alum foil 0.004" thk	(2 skins 0.006" thk alum; 0.374" thk core; 0.012" thk epoxy); [1]	(2 skins 0.002" thk alum; 0.080" thk core; ttl 0.002" thk epoxy); X/X0=0.085% for skins 0.001"	(2 skins 0.002" thk alum; 0.025" thk core; ttl 0.010" thk epoxy[incl epoxy within core]); X/X0=0.230% for skins 0.003"		
Pros	Ease in manufacturing, w/stand radiation	Ease in manufacturing, w/stand radiation; cost least	Very strong in terms of elastic stability	Low radiation length	Very strong in terms of elastic stability	Low radiation length	Low radiation length	Low radiation length	Low radiation length
Cons			Welding of stiffeners to tube not feasible - epoxying might be an option; uncertain about toughness	Past experience shows adhesion between c.f. & foil lining does not hold up	Expensive; Need more development work to see if can make w/ facings this thin or thinner	Need more development to understand joint integrity, permeability, elastic stability; cost unknown	Need more development to understand joint integrity, permeability; cost unknown	Expensive	Very Expensive
Total tube cost for 20 feet		$1,128	$2,790			~$20,000		No quote	~$300,000
(Notes on cost)		(for 0.015 wall)	(material cost listed - not including cost to assemble)			estimate for $10k each tube (not including cost for test/development)		no data currently exists on AlBeMet under vacuum	estimate over the phone

[1] Bowden, G., et al, "A Sandwich Structure Beam Pipe for Storage Rings," SLAC-PUB-3354, June, 1984.

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