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Compression and Creep Tests on Injection Molded Composite Posts

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Conclusions

1. An injection molded composite (IMC) post, of either Ultem or Noryl, is about twenty times stronger in compression than is required to support the static weight of the cold mass at room temperature.

2. The posts fail by buckling of the cylindrical shell.

3. The vertical stiffness of the IMC post is 415 000 pounds/inch if made of Noryl and 323 000 pounds per inch if made of Ultem.

4. At least in the case of Ultem, the vertical stiffness of the IMC post was accurately predicted at room temperature using the modulus of elasticity from a test piece. Presumably the stiffness at cryogenic temperatures can be similarly predicted.

5. The creep rate of an Ultem or a Noryl post can be projected to be about 8 mils at room temperature, under the constant cold mass weight of 3500 pounds, over ten years. The creep at cryogenic temperatures should be too small to detect. Therefore, creep should be a negligible effect in the operation of RHIC.

Background

A cold mass support post was designed of two sections (Sometimes called "hats.") to be injection molded from a composite material which exhibits high strength and low thermal conductivity. The IMC post is intended to replace the G11 fiberglass folded posts while eliminating the need for diagonal restraining straps in accordance with the structural concept presented in Technote AD/RHIC-65[1]. The IMC post is much less expensive and offers a greatly simplified design.

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[1] Wolf; *Structural Concept for Support of the RHIC Cold Mass Using Injection Molded Composite Posts*; Brookhaven National Laboratory; Technote AD/RHIC-65; February, 1990

The design of the IMC post is shown in Figure 1. Each section consists essentially of a cylindrical shell, approximately 8-1/2 inches in diameter and 4-1/2 inches long, having a thickness of 3/16 of an inch. The shell has a 1/2 inch thick flange at each end for bolting. The flange is external at one end of the shell and internal at the other. The sections are connected with twelve-7/16 bolts on the external flange and twelve-3/8 bolts on the internal flange. The shell has a slight conical angle of 1-1/2° which is a draft angle to facilitate removal of the casting from the mold.

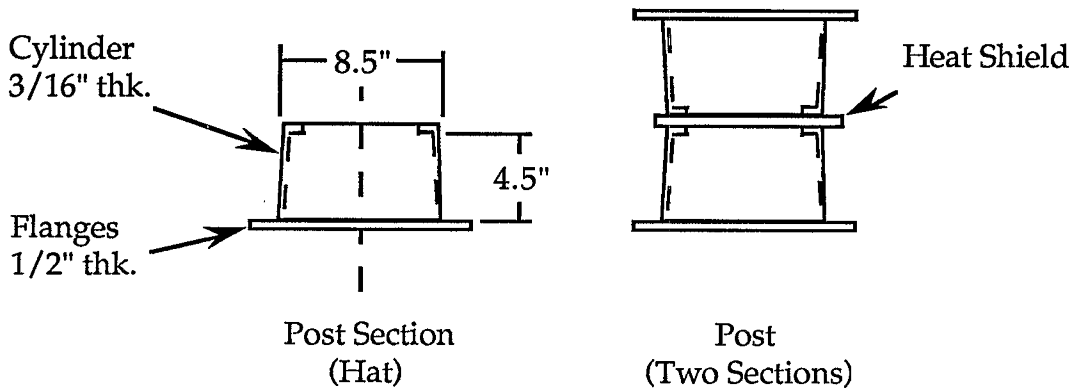
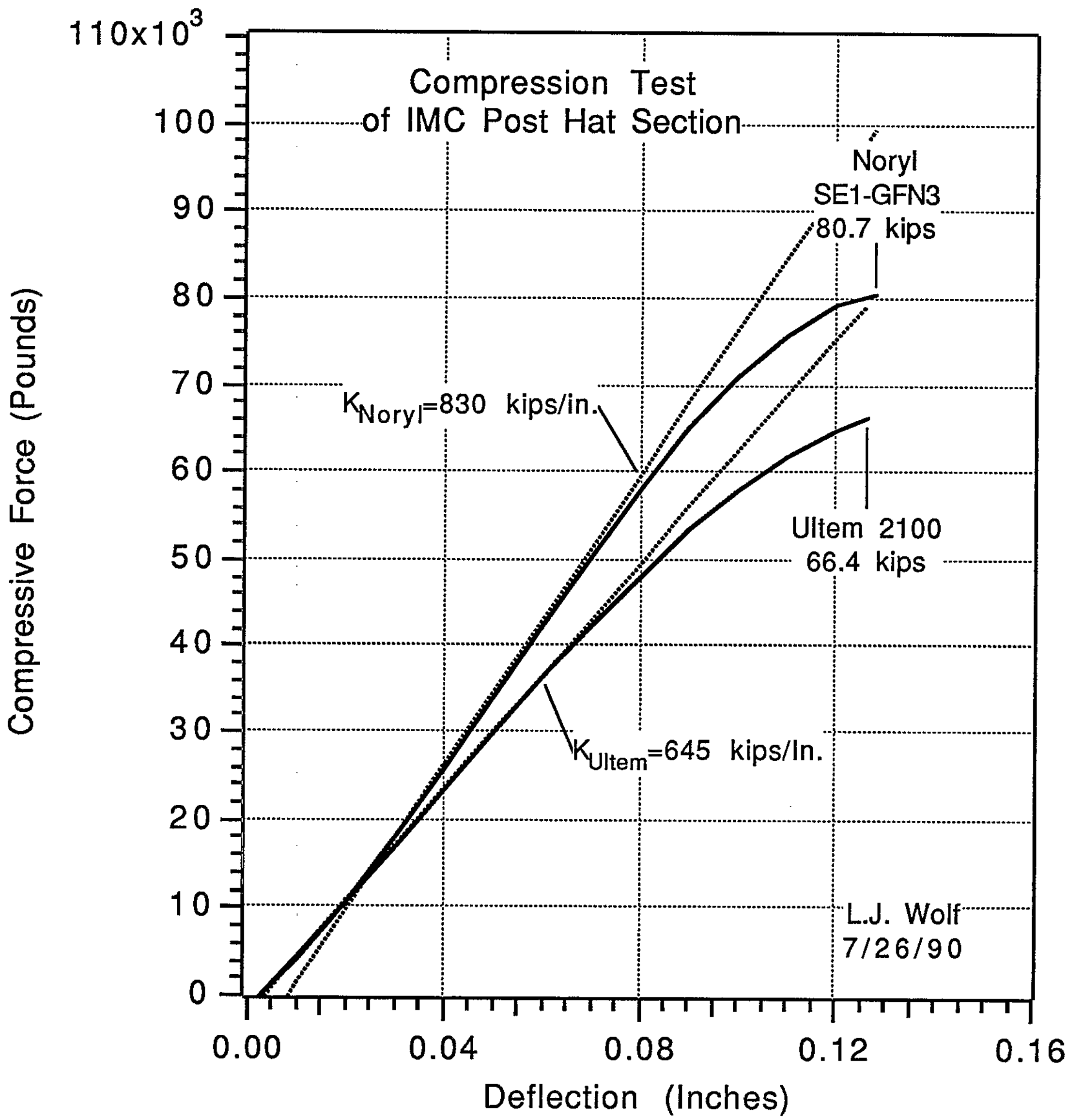


Figure 1
The basic dimensions of the injection molded test posts.

Two candidates, Ultem® 2100 and SE1-GFN3 Noryl®, where chosen for the IMC material. Ultem is a polyetherimide resin. The 2100 grade is reinforced with glass fibers about 3mm in length to make up 10% of its weight. Noryl is an alloyed resin. The SE1-GFN3 grade has glass fibers making up 30% of its weight. Both Ultem and Noryl are thermoplastic rather than thermosetting plastic materials. Developed by General Electric Company, they are marketed in sacks of pellets for injection molding. With a deflection temperatures of 400°F, molders regard Ultem as a relatively high-melting structural plastic.

Compression Tests

The primary function of the support posts are to support the weight of the cold mass. While this is the easiest accomplishment for any post design, these results are important in order to understand how well the post performs this task and what true load capacity exists for any contemplated change of service or design alteration in the future. Compression tests are inexpensive because they can be conducted in almost any universal materials testing machine without the need for special fixturing . In this case the post sections were simply pressed between the platen and the crosshead of the testing machine. Platen travel and load were plotted during the test. The flanges were left to bear freely against the crosshead and the platen. No bolts were used. The compression test results are given in Figure 2.


Compression Test
of IMC Post Hat Section
110x10³
100
90
80
70
60
50
40
30
20
10
0
Compressive Force (Pounds)
Noryl
SE1-GFN3
80.7 kips
K Noryl=830 kips/in.
Ultem 2100
66.4 kips
K Ultem=645 kips/In.
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0.00
0.04
0.08
0.12
0.16
Deflection (Inches)

Figure 2

Tensile tests were conducted on coupons cut from castings of both materials. The results from those tests compare to the compression test data as presented in Table 1.

Table 1

	SE1-GFN3 Noryl	Ultem 2100
Ultimate Post Load (Pounds)	80 700	66 400
Section Stiffness, (Pounds/Inch)	830 000	645 000
Shell Wall Area (Sq. Inches)	5	5
Ultimate Post Stress (Shell Longitudinal, Psi.)	16 140	13 280
<u>Average of Coupon Tensile Tests (Room Temperature)</u>		
Ultimate Strength, (Psi.)	15 600	15 400
.2% Elongation Stress, (Psi.)	11 600	7 950
Elastic Modulus, (Psi.)	1.23 E6	0.64 E6
Elongation	4.6%	7.7%
<u>Average of Coupon Tensile Tests (Helium Temperature)</u>		
Ultimate Strength, (Psi.)	22 700	19 500
.2% Elongation Stress, (Psi.)	13 000	14 300
Elastic Modulus, (Psi.)[2]	1.28 E6	0.93 E6
Elongation	5.73%	4.80%

Post Stiffness

The compression stiffness of a post, consisting of two sections, can be estimated to be about half that of the single section. Assuming that the elastic modulus of the material in compression is the same as in tension, which is a valid assumption at low stresses, the post stiffness could be estimated from:

$$K=AE/L,$$

where A is the shell cross section area,
E is the elastic modulus,
and L is the length of both post shells taken together.

The results of such calculations are compared to test data in Table 2.

[2] Wolf, Sondericker, and DiVito; *Elastic Moduli of Ultem and Noryl, at Cryogenic Temperatures Using Vibrating Beam Specimens*; Brookhaven National Laboratory; Technote AD/RHIC/RD-21; June, 1990

Table 2

	SE1-GFN3 Noryl	Ultem 2100
Post Stiffness, (Pounds/Inch)		
From Test	415 000	323 000
From Calculation	669 000	347 000

Compression Failure Modes

The post sections failed in a shell buckling mode when tested in compression. The Ultem post demonstrated a plastic buckling mode of four lobes which can be roughly described by the relationship:

$$w = C \sin 4\theta \sin(\pi x/L)$$ [3]

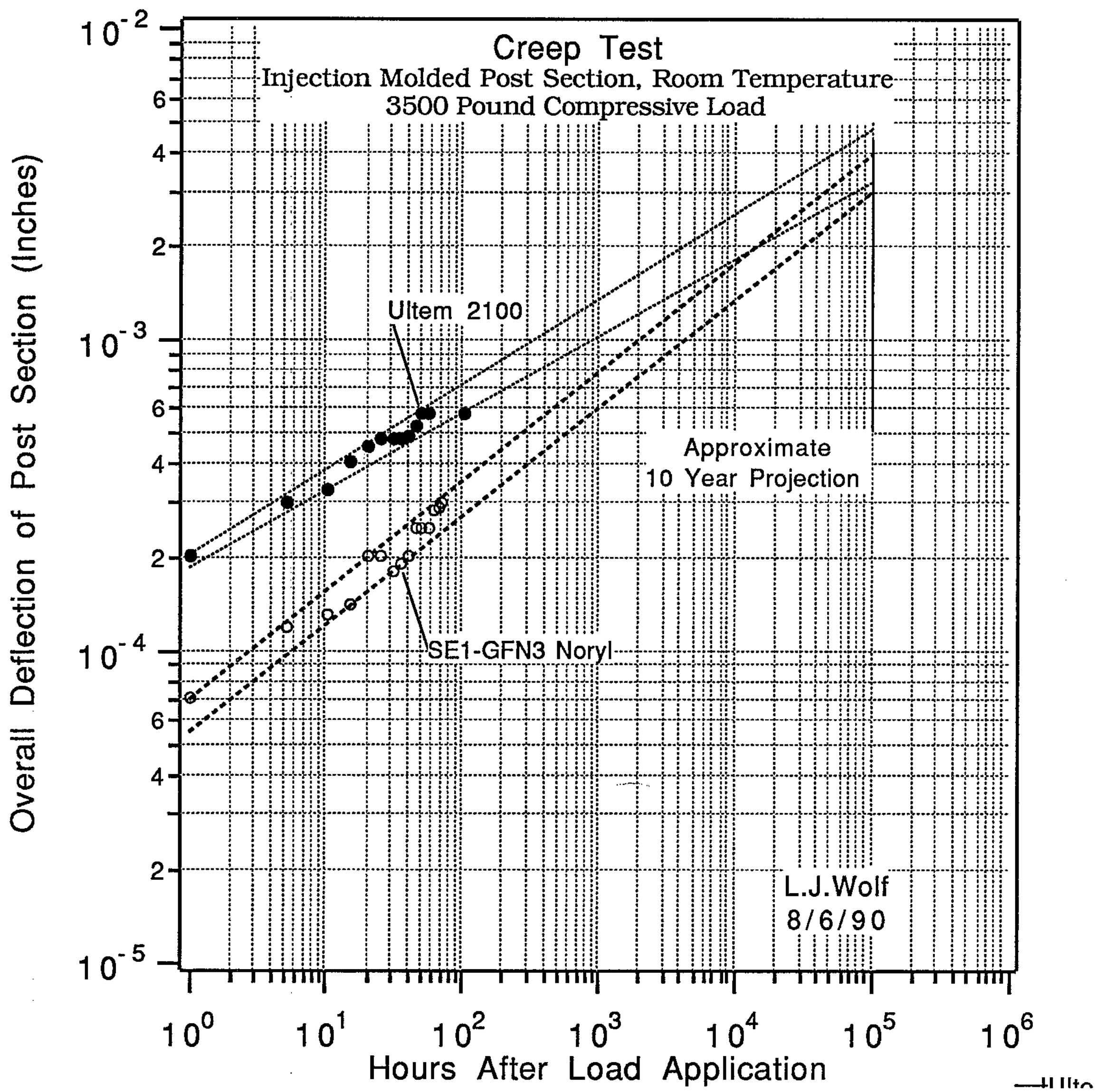
where w is the shell radial deflection,
C is an arbitrary constant,
θ is the radial angle,
L is the length of the cylinder,
and x is the distance along the cylinder axis.

The Noryl post buckled in a brittle fashion in what could be six lobes, although it is difficult to reconstruct the mode shape exactly from the fracture shards.

Creep Tests

Creep test were conducted over a period of 100 hours for Ultem and 70 hours for Noryl. During these times a load programmable testing machine was used to hold a 3 500 pound load simulating the weight of the cold mass at the center support. (Quadripole loading is 1 000 pounds. Dipole outer leg loading is 2 500 pounds each.) A displacement transducer was used to measure the change in distance between the platen and the crosshead. The transducer signal was recorded against time on a strip chart. The displacement curves were exponential in shape as are typical displacement-time histories of creeping materials. The results were, therefore, plotted on a log-log graph as shown in Figure 3.

[3] Timoshenko and Gere, *Theory of Elastic Stability*, McGraw Hill, N.Y.,1961. p464


Creep Test
Injection Molded Post Section, Room Temperature
3500 Pound Compressive Load
Ultem 2100
Approximate
10 Year Projection
SE1-GFN3 Noryl
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Overall Deflection of Post Section (Inches)
Hours After Load Application

Figure 3