TASK 2 FILTER MATERIAL CHARACTERIZATION

Mechanical and thermal testing of Dupont/Lanxide PRD-66, Dupont composite, 3M composite, and IF and P Fibrosics is continuing. A test matrix for these materials is shown in Table 18. Hoop tensile strengths for PRD-66, Dupont composite, and 3M composite and axial compressive results for IF and P Fibrosics have been reported in a separate sub-task report. Thermal expansion values measured at 1500 °F are presented in Table 19. Thermal expansion values for the complete temperature range measured are shown in Figure 17.

Table 18
Preliminary Screening Test Matrix for Dupont PRD-66, Dupont Composite, 3M Composite, and IF and P Fibrosics Materials

Material	Test/Property	Orientation	Temperature, °F 70 1700
PRD-66, Dupont composite, and 3M composite	tension	hoop	5*
PRD-66, Dupont composite, and 3M composite	tension after 100 hr. heat soak at 1700 °F	hoop	5*
PRD-66, Dupont composite, and 3M composite	thermal expansion	hoop	2------------------->
IF and P Fibrosics	compression	axial	3
IF and P Fibrosics	thermal expansion	axial	2------------------->

* Three replicates for 3M composite

Table 19
Measured Thermal Expansion Values

Material	Orientation	Thermal Expansion at 1500 °F
IF and P	axial	0.0047 in./in.
PRD-66	diametral	0.0033 in./in.
3M composite	diametral	0.0025 in./in.

Testing of new Refractron and Schumacher candle filter materials is also in progress. A test matrix for these materials is shown in Table 20. Cutting plans are shown in Figures 18 through 20. Hoop tensile results are shown in Table 21 for Refractron and Table 22 for Schumacher. Creep testing of Refractron is now in progress. No creep was detected after ~150 hours at 1550 °F and creep testing is proceeding at 1600 °F. Schumacher creep

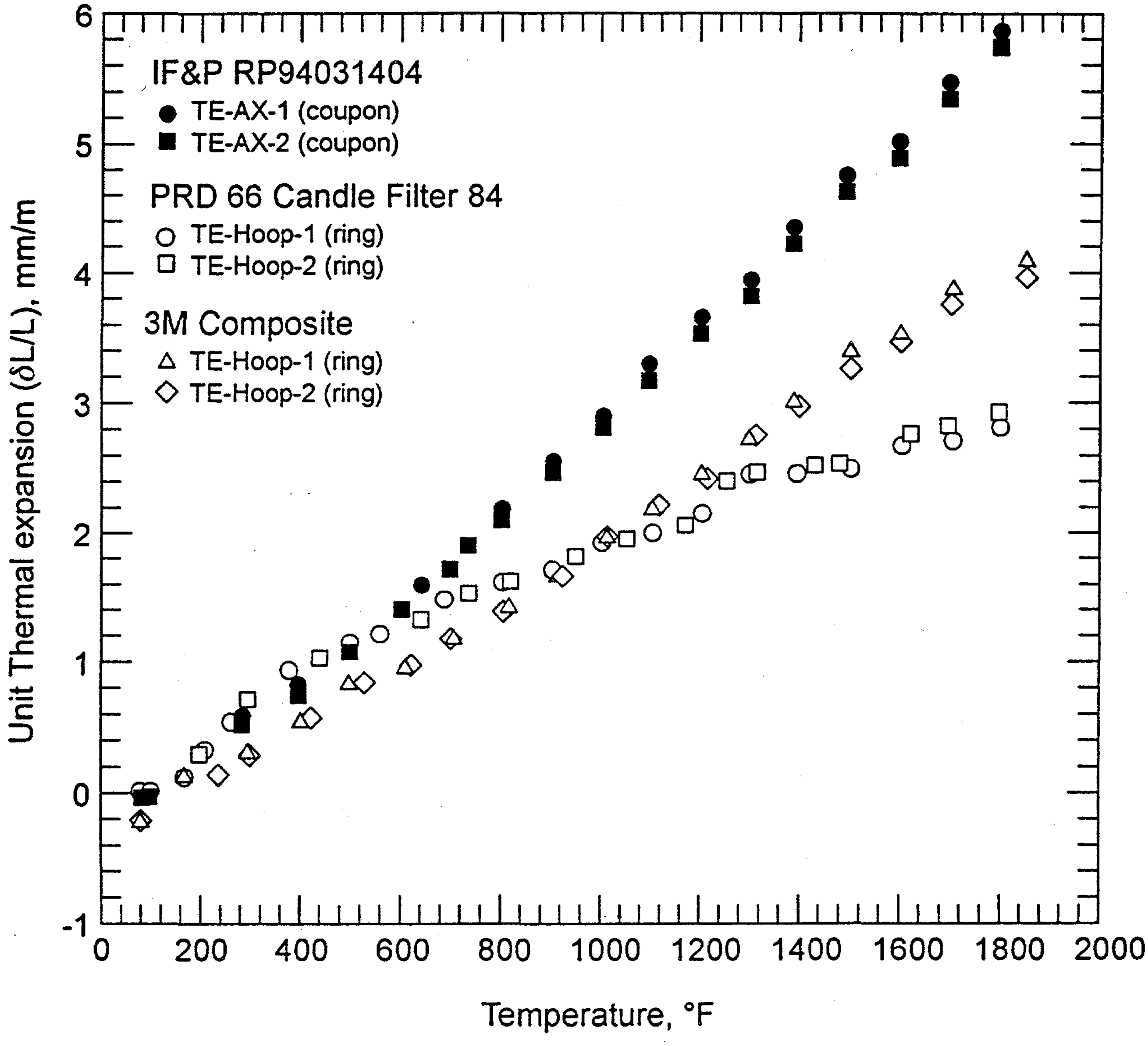


Figure 17. Thermal expansion of IF and P Fibrosics, Dupont PRD-66, and 3M composite materials.

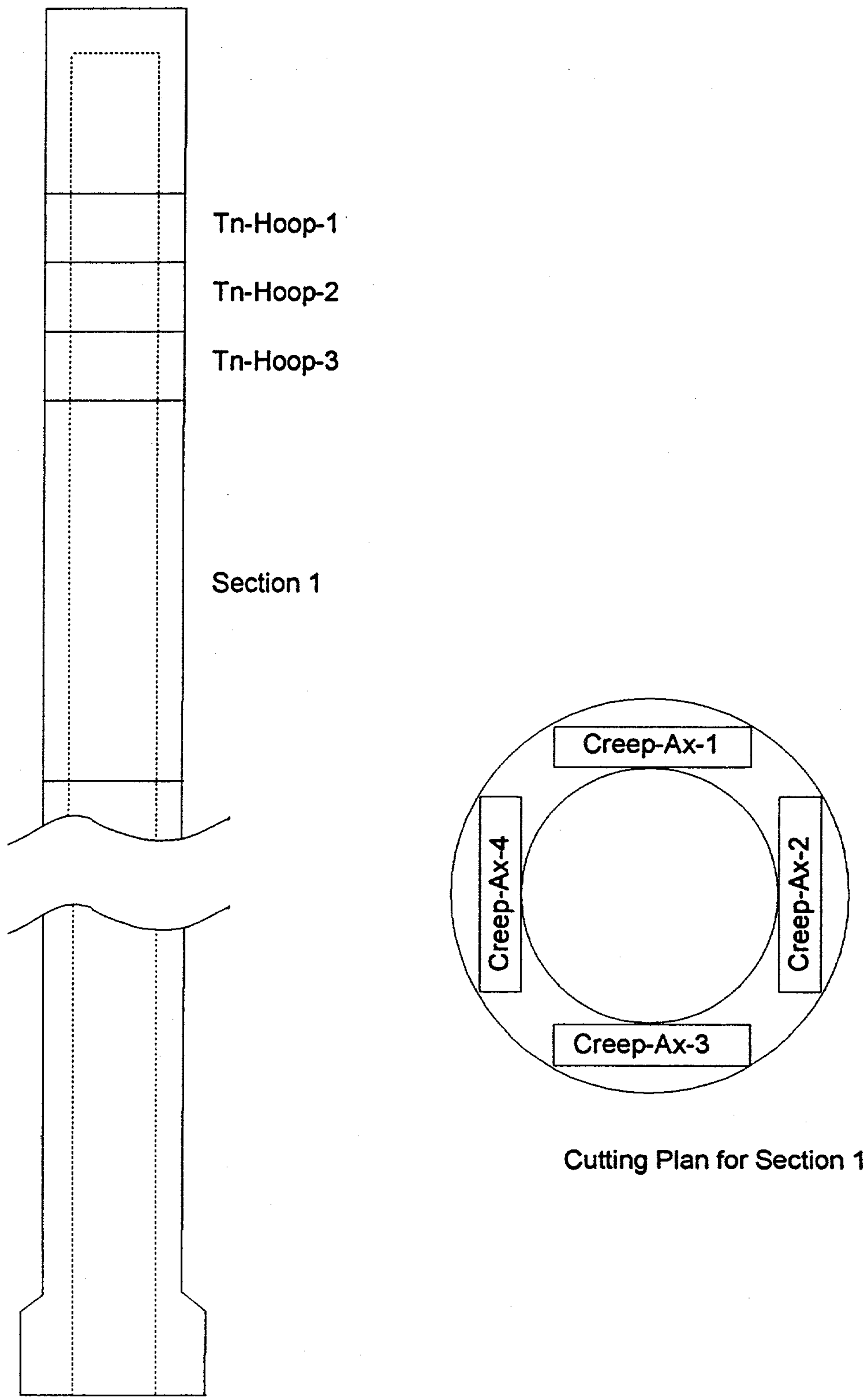


Figure 18. Cutting plan for Refractron candle filter 2-469.

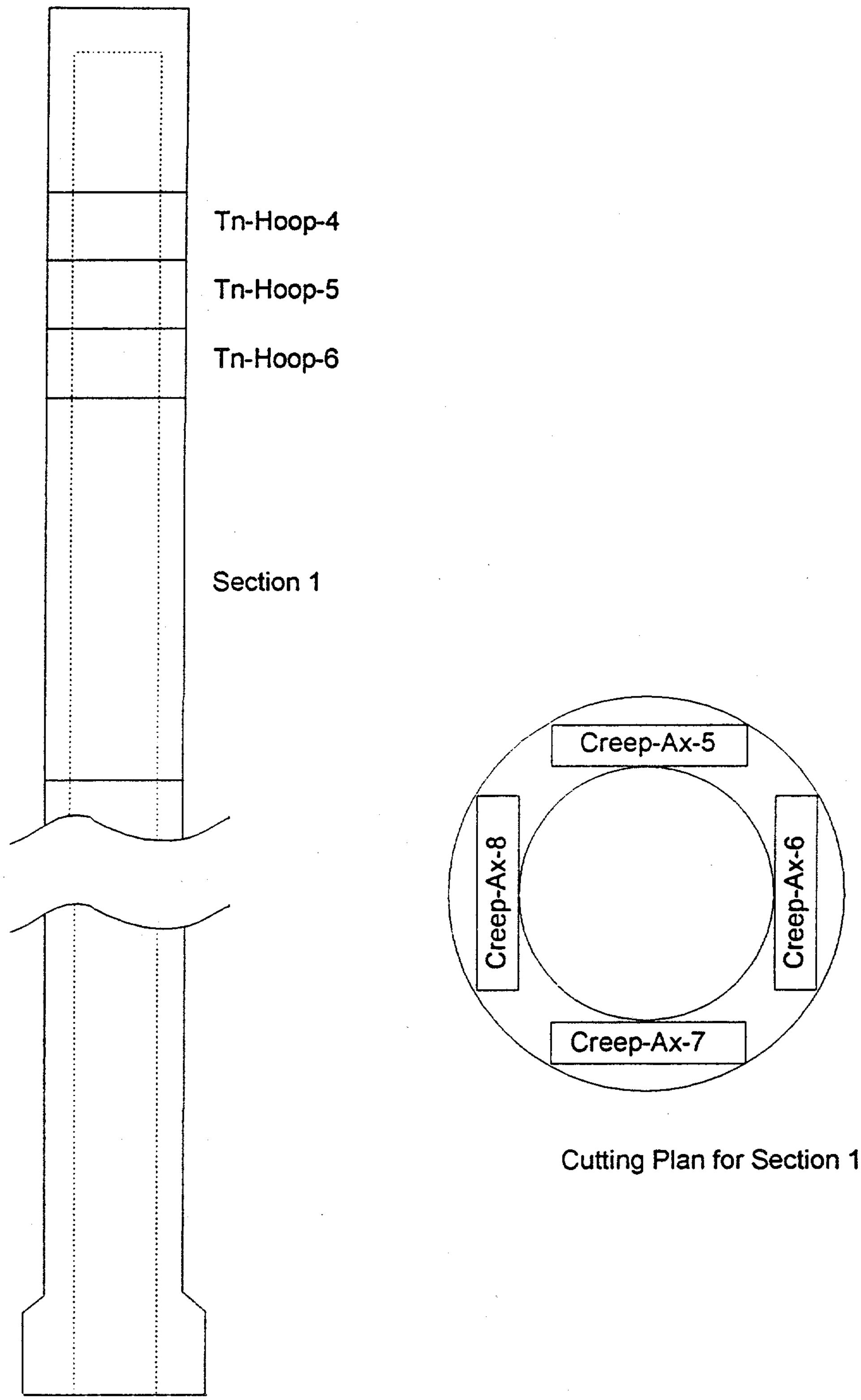
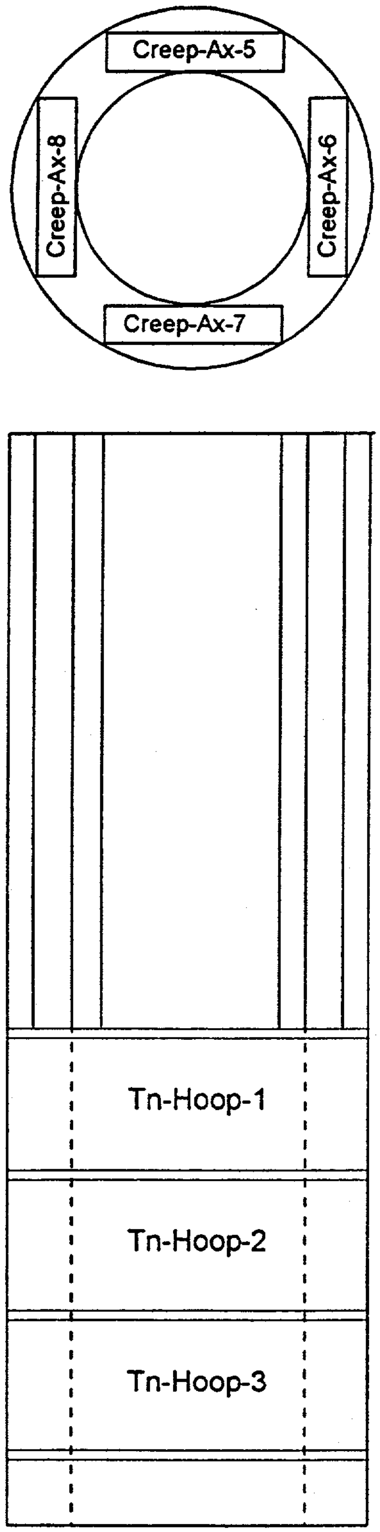


Figure 19. Cutting plan for Refractron candle filter 4-471.



Final Specimen Dimensions (Inches):

Creep-Ax—0.250 x 0.9995 x 7.00

Tn-Hoop—as received i.d.x as received o.d. x 1.000

Figure 20. Cutting plan for Schumacher candle filter S199/315E.

specimens have been machined and testing of these specimens will follow testing of Refractron.

Table 20
Test Matrix for New Schumacher and Refractron Candle Filters

Material	Test/Property	Orientation	Temperature, °F		
			70	1550	1700
Refractron	tensile	hoop	6		
Refractron	tensile creep	axial		4--------------->	
Schumacher	tensile	hoop	3		
Schumacher	tensile creep	axial		4--------------->	

Table 21
Hoop Tensile Results for New Refractron Candle Filter Material

Candle identification	Specimen number	Test temperature, °F	Specimen ID, in.	Specimen OD, in.	Ultimate tensile strength, psi
2-469	Tn-hoop-1	70	1.54	2.39	2000
2-469	Tn-hoop-2	70	1.54	2.38	2100
2-469	Tn-hoop-3	70	1.54	2.38	1980
4-471	Tn-hoop-4	70	1.54	2.38	2190
4-471	Tn-hoop-5	70	1.55	2.38	2470
4-471	Tn-hoop-6	70	1.54	2.38	2040

Average ultimate tensile strength = 2130 psi, standard deviation = 183 psi, COV = 8.6%.

Table 22
Hoop Tensile Results for New Schumacher Candle Filter Material

Candle identification	Specimen number	Test temperature, °F	Specimen ID, in.	Specimen OD, in.	Ultimate tensile strength, psi
S199/315E PT-20	Tn-hoop-1	70	1.54	2.37	1740
S199/315E PT-20	Tn-hoop-2	70	1.54	2.37	1720
S199/315E PT-20	Tn-hoop-3	70	1.53	2.37	1620

Average ultimate tensile strength = 1690 psi, standard deviation = 64 psi, COV = 3.8%.

Mechanical and thermal testing of the new Refractron and Schumacher candle filter material is continuing. The test matrix used to evaluate the material is shown in Table 23.

Table 23
Test Matrix for Refractron and Schumacher Filter Materials

Test Type	Orientation	RT	1600 °F	1700 °F	1800 °F
Tensile	Hoop	6			
	Axial	4	4	4	4
Tensile Creep	Axial		4	4	
Thermal Expansion	Hoop	2--------------------------------			
	Axial	2--------------------------------			
Microstructure					

Hoop and axial tensile results for the new Refractron material are given in Table 24. The average axial strength at room temperature was 1150 psi; the average hoop strength was 2130 psi. A plot of tensile strength versus temperature is given in Figure 21. Creep evaluations are in progress and no creep was detected after about 150 hours at 1550 °F. Testing will continue by increasing temperature and/or stress levels. Axial thermal expansion is summarized in Table 25 and Figure 22.

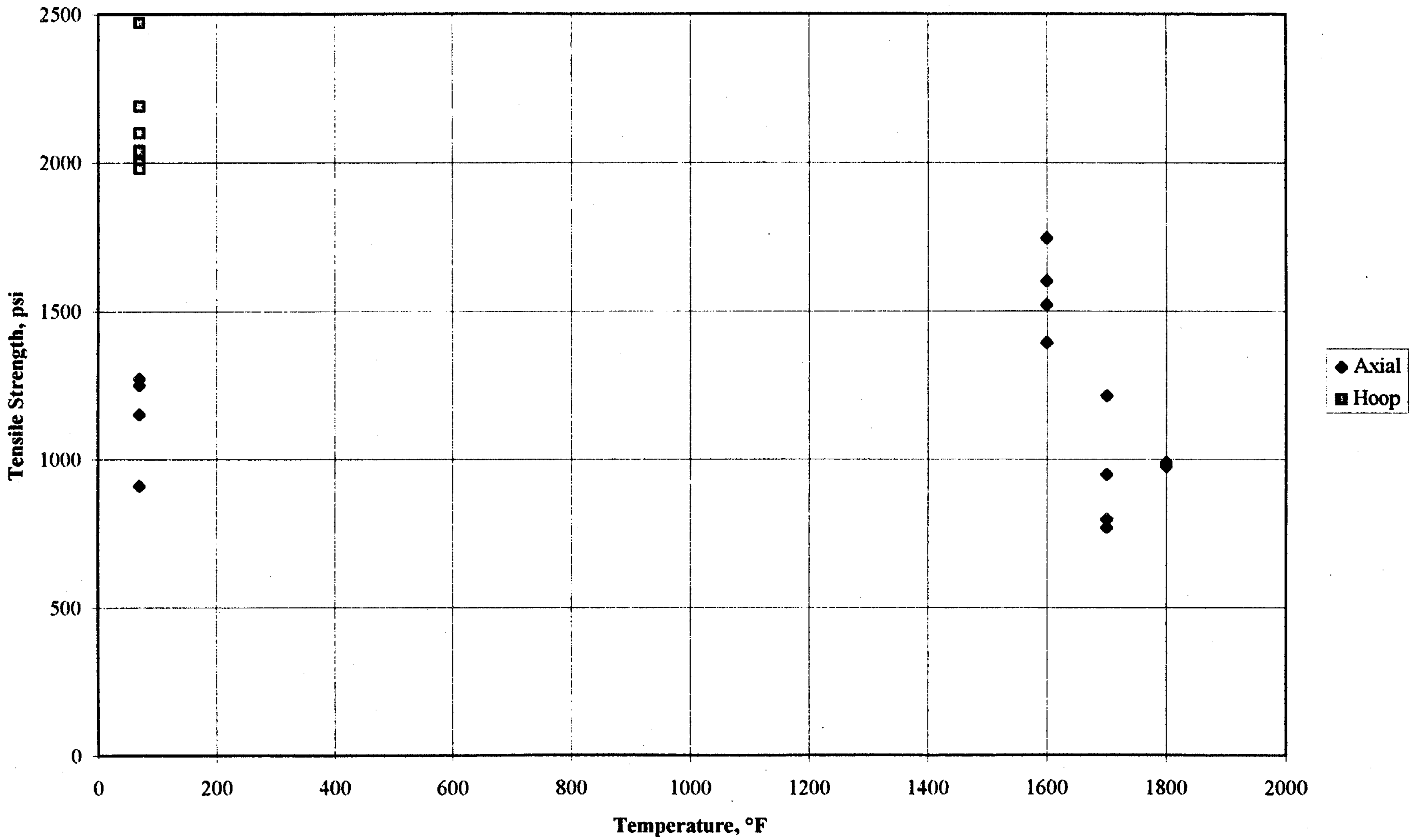


Figure 21. Tensile strength vs. temperature for new Refractron material.

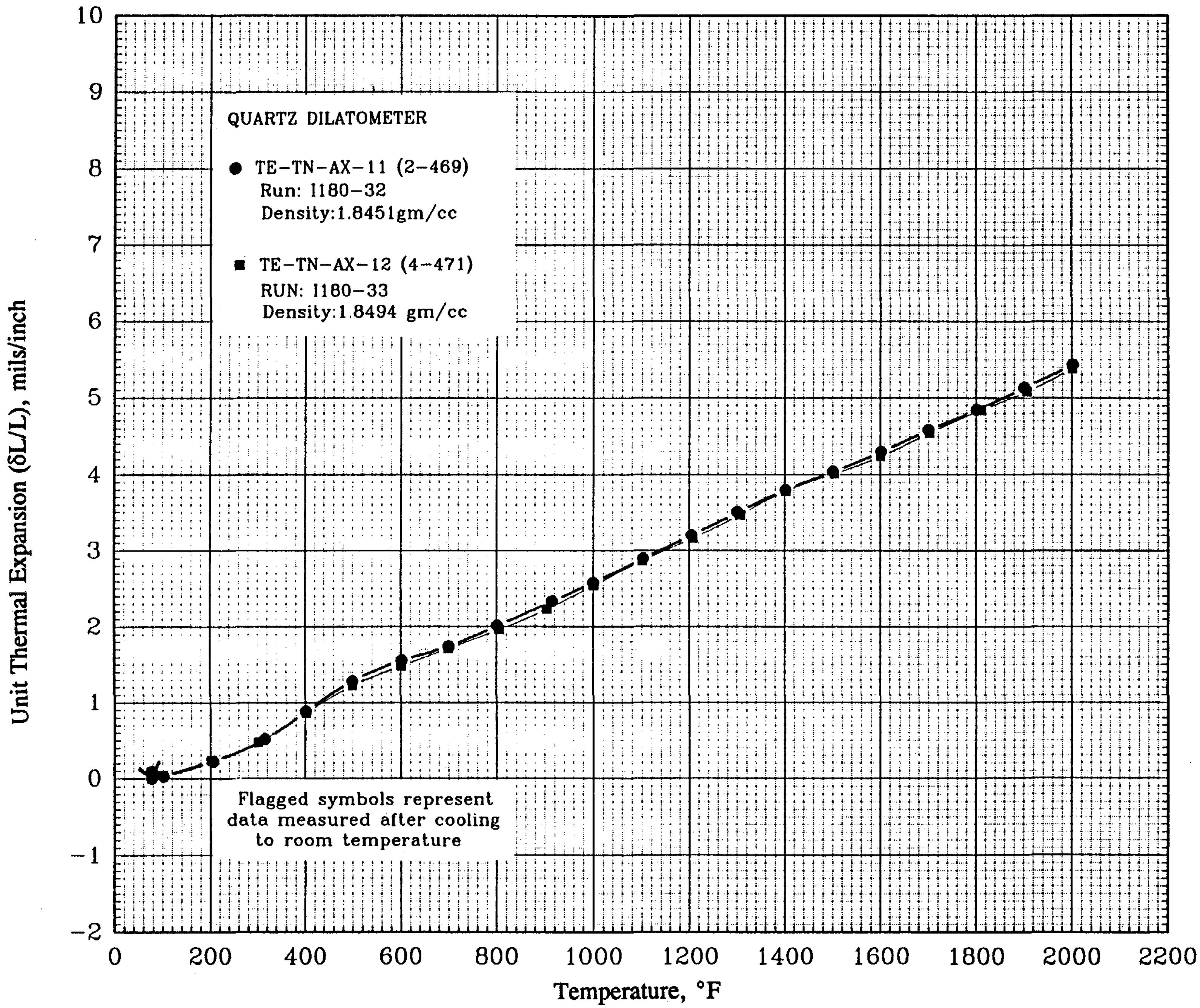


Figure 22. Axial thermal expansion of new Refractron candle filter.

Table 24
Tensile Data for New Refractron Candle Material

Candle	Specimen #	Temp., °F	Ultimate strength, psi	Modulus, Msi	Strain-to-failure, in./in.	Remarks
4-471	TN-AX-12	70	1152	5.88	0.000196	
4-471	TN-AX-17	70	1250	6.67	0.000187	
2-469	TN-AX-5	70	910	4.82	0.000189	
2-469	TN-AX-11	70	1272	5.06	0.000251	
4-471	TN-AX-18	1600	1394	1.82	0.001300	
4-471	TN-AX-13	1600	1746	1.68	0.001400	
2-469	TN-AX-7	1600	1600	3.48	0.002250	
4-471	TN-AX-21	1600	1520	2.72	0.001640	
2-469	TN-AX-2	1700	768	1.79	--	1
4-471	TN-AX-20	1700	796	2.77	0.000690	
2-469	TN-AX-6	1700	948	2.45	0.000975	
4-471	TN-AX-19	1700	1214	4.30	0.000925	
2-469	TN-AX-10	1800	976	2.24	0.000600	
4-471	TN-AX-14	1800	989	3.33	0.000400	
2-469	TN-Hoop-1	70	2000	--	--	2
2-469	TN-Hoop-2	70	2100	--	--	2
2-469	TN-Hoop-3	70	1980	--	--	2
4-471	TN-Hoop-4	70	2190	--	--	2
4-471	TN-Hoop-5	70	2470	--	--	2
4-471	TN-Hoop-6	70	2040	--	--	2

1 Flags slipped during test
2 Load-time only

Table 25
Axial Thermal Expansion for New Refractron Candle Material

Filter #	Temperature, °F	Unit Thermal Expansion, mils/inch
2-469	78	0.00
	102	0.03
	206	0.22
	315	0.51
	401	0.88
	500	1.28
	602	1.55
	700	1.74
	801	2.01
	915	2.33
	1000	2.58
	1104	2.90
	1205	3.20
	1301	3.50
	1402	3.80
	1501	4.04
	1602	4.30
	1700	4.58
	1801	4.84
	1901	5.13
	2002	5.43
	78	0.09
4-471	77	0.00
	101	0.04
	202	0.23
	301	0.47
	402	0.86
	500	1.22
	602	1.48
	700	1.71
	806	1.96
	905	2.23
	1001	2.54
	1102	2.87
	1207	3.16
	1307	3.47
	1402	3.78
	1503	4.01
	1601	4.24
	1702	4.54
	1811	4.84
	1907	5.08
	2001	5.38
	76	0.09

New Schumacher filters were received and specimens are currently being machined according to the cutting plans given in Figures 23 and 24. When machining is complete, nondestructive density and ultrasonic velocity measurements will be made and then mechanical and thermal tests will commence.

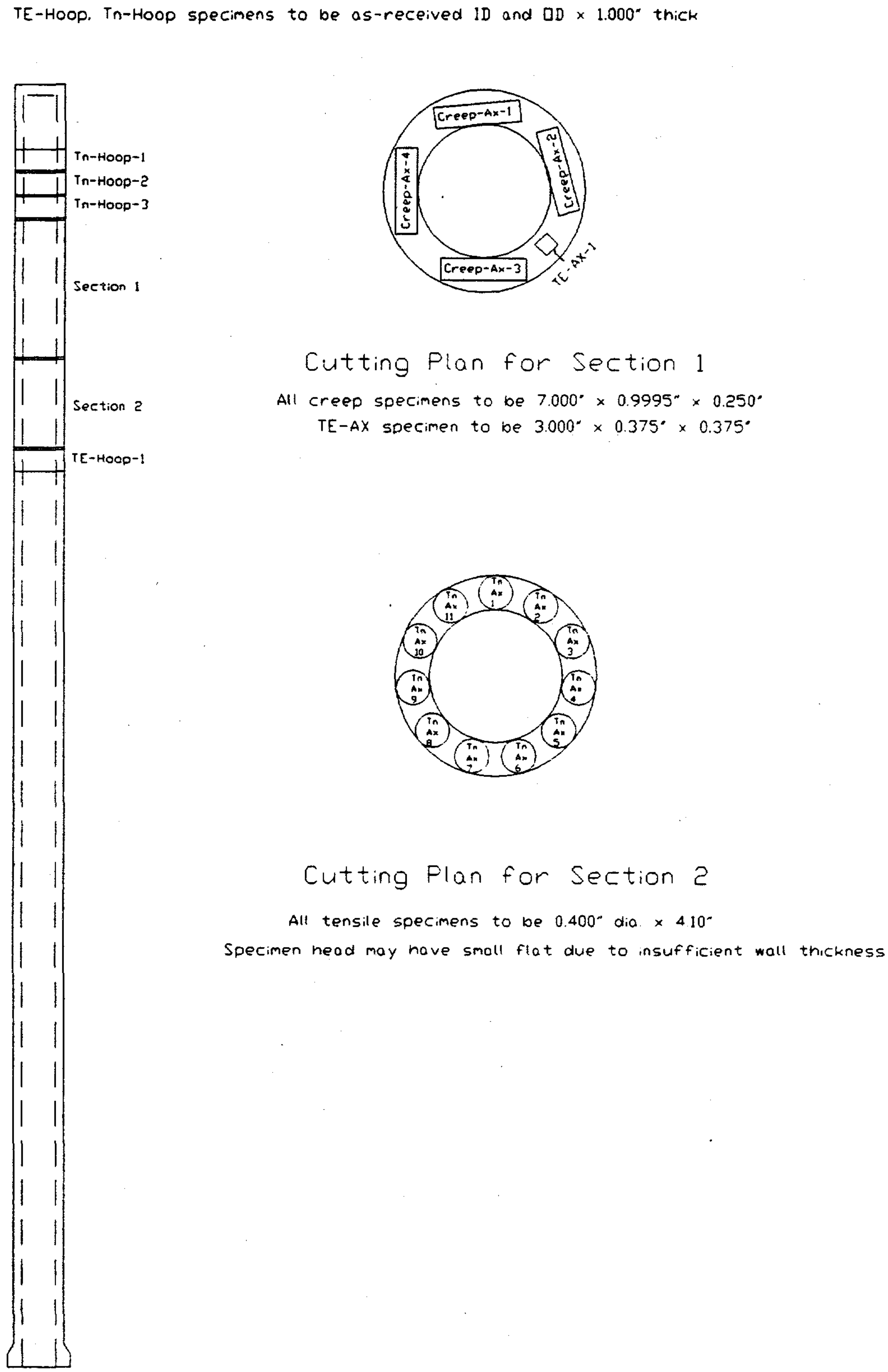


Figure 23. Cutting plan for Schumacher candle 344E-295.

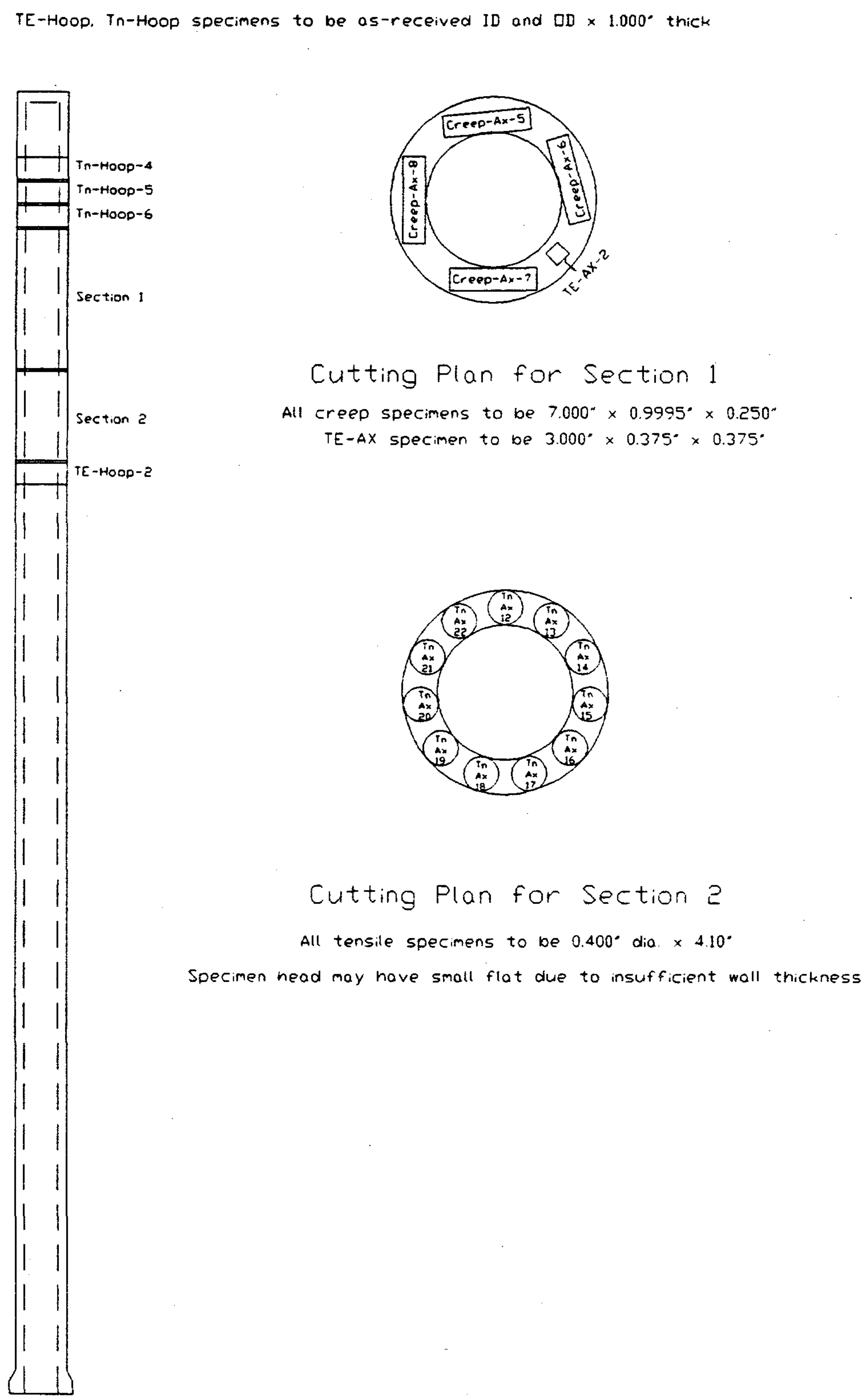


Figure 24. Cutting plan for Schumacher candle 344E-309.

FUTURE WORK

Our research plans include analyses of ashes that we expect to receive from General Electric's gasification facility in Schenectady, NY. We also plan to complete the design of a high-temperature test device intended to measure the uncompacted bulk porosity of aggregates of ash formed at temperatures commonly encountered in operating APFs. Additional plans include evaluation and selection of software for the presentation of the HGCU data base. Nondestructive density and ultrasonic velocity measurements will be made on the Schumacher filters that were recently received. Mechanical and thermal tests will follow these measurements. Creep testing of Refractron and Schumacher candle filter materials will continue.

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APPENDIX A
ANALYTICAL METHODS USED TO CHARACTERIZE ASH

NODULE POROSITY (WATER TECHNIQUE) - In this test, a nodule is selected, cleaned with a gentle jet of air, and weighed. Then water is allowed to soak very slowly into the nodule until the surface of the nodule glistens evenly. The fully wetted nodule is weighed, and the porosity of the nodule is calculated from the initial dry weight, the final wetted weight, and the true density of the ash particles. Determination of the porosity of a filter cake nodule provides a direct measurement of the porosity of the filter cake.

NODULE POROSITY (EPOXY TECHNIQUE) - In this test, a nodule is selected, cleaned with a gentle jet of air, and weighed. Then low-viscosity epoxy is allowed to soak slowly into the nodule until the surface of the nodule glistens evenly. The fully encapsulated nodule is baked to cure the epoxy, and its total volume is measured in a helium pycnometer. Nodule porosity is calculated from the initial dry weight, the final encapsulated volume, and the true density of the ash. Determination of the porosity of a filter cake nodule provides a direct measurement of the porosity of the filter cake. The cured, encapsulated nodule can be cut, machined, and prepared for further analyses, if desired.

STOKES' MASS MEAN DIAMETER - This technique uses a sedigraphic analyzer to provide a measurement of the fly ash size distribution based on aerodynamic classification of fly ash particles. The test procedure involves the suspension of a small amount of ash in a clear fluid. The particles in the fluid gradually settle out, first due to gravitational force alone, and then due to centrifugal force introduced by increasingly rapid rotation of the sample cell. The device combines photometrically-obtained particle concentration data with Stokes' law describing the settling of particles in a viscous medium to calculate the particle size distribution.

SPECIFIC SURFACE AREA - This measurement utilizes the Brunaeur-Emmett-Teller (BET) technique for determining the total surface area of a known mass of fly ash sample. Ashes that exhibit relatively high specific surface areas are usually highly cohesive, and form filter cakes with relatively high porosities.

UNCOMPACTED BULK POROSITY - This value expresses the porosity of a container of sifted ash. Ashes exhibiting a relatively high uncompacted bulk porosity value are generally highly cohesive.

DENSITY - This standard measurement is obtained with a helium pycnometer. The value obtained with this technique is the true density, or specific gravity of the ash particles in the sample tested.

DRAG-EQUIVALENT DIAMETER - This quantity is not a measurement of physical size, but rather a fitted parameter ranking the characteristic specific gas-flow resistances of ashes at equal porosities. Increasing values of drag-equivalent diameter indicate a lower resistance to gas flow at a given porosity. Measurements of physical size generally correlate with this expression; however, the drag-equivalent diameter best expresses the fineness of an ash as it relates to its effect on specific gas-flow resistance. Ashes with smaller values of drag-equivalent diameter are generally more cohesive.

SPECIFIC GAS-FLOW RESISTANCE - This value is obtained by filtering air at a known flowrate through a simulated filter cake of known porosity in a laboratory test device while measuring the resistance to the air flow. When this measurement is made with the porosity of the simulated filter cake equal to the estimated characteristic filter cake porosity of the ash, the resistance is defined as the specific gas-flow resistance. This value is the resistance that this simulated filter cake (with an areal loading of 1.0 lb/ft^2) exhibits for an air flow of 1.0 $acfm/ft^2$.

TENSILE STRENGTH - This test measures the magnitude of the attractive forces between ash particles. An electrostatic tensiometer is used to apply a mechanical stress on a dust layer as an effect of an imposed electrostatic field. This electrostatic technique allows the measurement to be performed on uncompacted ash samples.

PARTICULATE HOT GAS STREAM CLEANUP TECHNICAL ISSUES

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Duane H. Pontius, Director   Particulate Sciences Department