Mechanical Properties of Ultra High Molecular Weight Polyethylene NIST Reference Material # 8456

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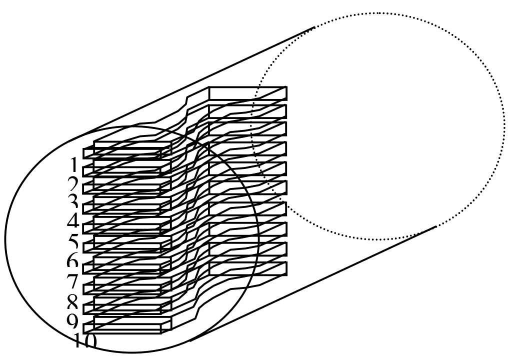
Introduction. The objective of this paper is to present the mechanical properties of Ultra High Molecular Weight Polyethylene (UHMWPE) Reference Material (RM) 8456, newly available from the National Institute of Standards and Technology. The UHMWPE RM that had previously been supplied by the Hospital for Special Surgery has been exhausted.

Materials and Methods. The UHMWPE used for RM 8456 was donated by Poly Hi Solidur, Inc., MediTECH Division (Production Code PG9981, Premium Grade Ultra High Molecular Weight Polyethylene, Virgin UHMWPE Raw Material Lot No. 332945, source identified as TICONA GUR 1050 ##). Type IV tensile specimens, 3.25 mm thick, were prepared according to ASTM D-638. Specimens were fabricated from test bars from each end and at 30.48 m intervals of a continuous production run of 304.8 m (1000 ft) for a total of 11 test bars. Ten test specimens were cut from each bar, spaced evenly across a bar, as shown in the figure, with specimens 1 and 10 from the outermost portion and specimens 5 and 6 from the innermost portion.

A randomized table for testing order and data recording was made. Randomization was done according to test bar letter designations and was blocked according to the numerical specimen order within the test bars.



Young's Modulus: Note 15 of ASTM D 638 states: "Modulus of materials is determined from the slope of the linear portion of the stress-strain curve. For most plastics, this linear portion is very small, occurs very rapidly, and must be recorded automatically." The linear portion of the stress-strain curve for RM 8456 occurred at strains well below 0.5 %. Therefore, Elastic Modulus testing, was conducted by six repeated measurements on each specimen at peak strains between 0.15 % and 0.25 %.

The protocol: 1) Specimen fixed in grips starting at a zero load, 2) Crosshead speed set at 50 mm/min, 3) Load cell and extensometer specifications as described in D 638, calibrated every 10 tests electronically, both before and after the testing session, with dead weights, 4) Data collection rate set at maximum for the instrument.

The modulus was compared at 1 %, 2 %, and 3 % strains. Ten specimens, which exhibited mean 0.3 %-strain Young's modulus values that were nearly identical, were chosen from the 110 specimens that were fabricated. These specimens were tested using the same instrument setup, but with a maximum strain limit of 3.5 %. One test was run on each specimen and the stress-strain curve was analyzed to determine the secant modulus between 0 % to 1 %, 0 % to 2 %, and 0 % to 3 % strain.

Yield strength, Ultimate Tensile Strength, and Elongation. Each characteristic was determined from destructive tests of all of the specimens. The yield point determination is not defined in ASTM D 638. Since every specimen exhibited a characteristic maximum load at yield, the yield point was determined as the highest zero-slope point on the load-deflection curve.

Results.

Table 1 Young's Modulus

Strain	Secant Modulus (Mean)	±	Standard Deviation
0 % to 1 %	945 MPa	±	19 MPa
0 % to 2 %	678 MPa	±	18 MPa
0 % to 3 %	532 MPa	±	12 MPa

The reported values and uncertainties for all properties are shown in Table 2, below. The expanded uncertainty is computed as U = 2u to approximate 95 % confidence interval.

Table 2

Property	Mean	u	U	Units
Young's Modulus	1258.	22.	44.	MPa
Yield Strength	23.56	0.33	0.66	MPa
Ultimate Strength	45.8	3.0	6.0	MPa
Elongation	460.	20.	40.	% (Percent)

Statistical Analysis:

The largest differences in properties were in specimen positions (SPs) 1 & 10 (see figure) and only small differences exist among test bars for SPs 2 through 9. Hence, the certified region excludes the outside 1 cm of the bar's diameter Properties were not significantly different within a bar. The uncertainty is computed and reported as the standard deviation of a single future predicted value at any single position chosen at random from the lot. The uncertainty of the certified values is:

$$u = \sqrt{s^2_{between} + s^2_{mean}}$$

$S^2_{between}$ is the variance that accounts for differences among positions on a single RM; S^2_{mean} is variance of the reported value as calculated from measurements on J (J=11 here) bars at each of 8 central positions.

Commercial materials identified are neither endorsed by NIST nor claimed by NIST to be superior to others.