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THERMAL PROPERTIES OF KEVLAR®

Decomposition Temperature

KEVLAR does not melt; it decomposes at relatively high temperatures (800°F to 900°F [427°C to 482°C] in air and approximately 1,000°F [538°C] in nitrogen), when tested with a temperature rise of 10°C/minute. Decomposition temperatures vary with the rate of temperature rise and the length of exposure.

Figures 2.5 and 2.6 show typical thermogravimetric analyses (TGAs) of KEVLAR 49 in air and nitrogen, respectively. TGAs are generated by an instrument that measures weight loss as a function of temperature rise over time. The analyses can be performed in air or in a variety of other atmospheres.

For KEVLAR, as temperature increases, there is an immediate weight reduction, corresponding to water loss. The curve then remains relatively flat until decomposition, where a significant weight loss is observed.

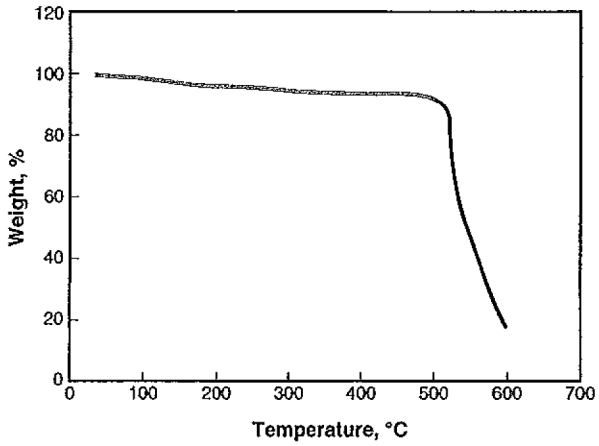

FIGURE 2.5. Typical Thermogravimetric Analysis of KEVLAR® 49 in Air at a Temperature Rise of 10°C/Min.

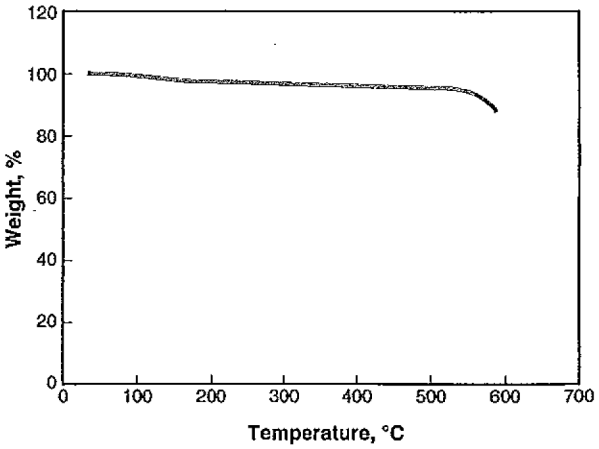

FIGURE 2.6. Typical Thermogravimetric Analysis of KEVLAR® 49 in Nitrogen at a Temperature Rise of 10°C/Min.

Effect of Elevated Temperatures on Tensile Properties

Increasing temperatures reduce the modulus, tensile strength and break elongation of KEVLAR® yarns and other organic fibers. This should be taken into consideration when using KEVLAR at or above 300°F to 350°F (149°C to 177°C) for extended periods of time.

Figures 2.7 and 2.8 compare the effects of exposure to elevated temperatures on the tensile strength and modulus, respectively, of KEVLAR and other yarns.

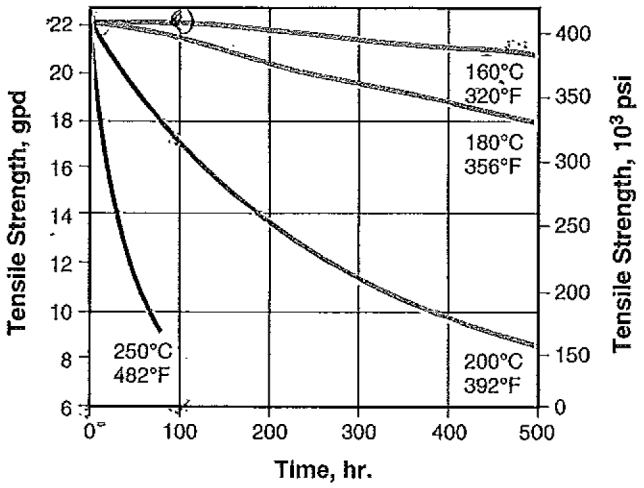

FIGURE 2.7. Effect of Elevated Temperatures on the Tensile Strength of KEVLAR® 29.

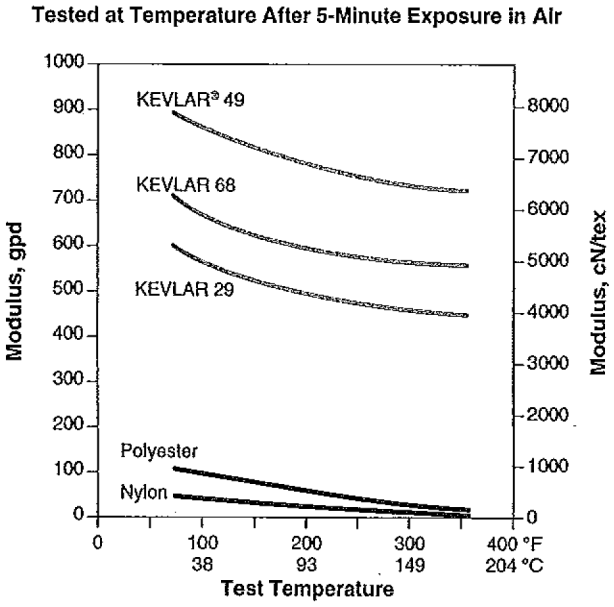

FIGURE 2.8. Comparative Effect of Elevated Temperatures on the Modulus of Various Yarns.

Effect of Elevated Temperatures on Dimensional Stability

KEVLAR® does not shrink like other organic fibers when exposed to hot air or hot water. Most other fibers suffer significant, irreversible shrinkage.

KEVLAR has a very small, negative coefficient of thermal expansion (CTE) in the longitudinal direction. The value of the CTE of KEVLAR is dependent on measuring technique, sample preparation and test method (Table II-4).

Heat of Combustion

The heat of combustion of KEVLAR is measured by an Emerson oxygen bomb calorimeter. Table II-5 compares the heat of combustion of KEVLAR to that of other polyamides and to an epoxy used in making rigid composites.

Specific Heat

The specific heat of KEVLAR is markedly influenced by temperature. It more than doubles when the temperature is raised from 32°F (0°C) to 392°F (200°C), as seen in Figure 2.9. Further increases are more gradual.

TABLE II-4. Coefficient of Thermal Expansion of KEVLAR® 29 and 49*

Type of KEVLAR®	Denier	Temp. Range °F	(°C)	CTE in./in./°F (cm/cm/°C)
KEVLAR 29	1500	77-302	(25-150)	-2.2×10^{-5} (-4.0×10^{-5})
KEVLAR 49	1420	77-302	(25-150)	-2.7×10^{-5} (-4.9×10^{-5})

*Tested with zero twist and 0.2 gpd tension at 72°F (22°C), 65% RH.

TABLE II-5. Heat of Combustion of KEVLAR® 49 and Other Materials

Material	Heat of Combusion BTU/lb	Joule/kg
KEVLAR 49	14,986	34.8×10^{6}
Nylon, Type 738	15,950	37.1×10^{6}
NOMEX® aramid	13,250	30.8×10^{6}
Shell Epon®** 828/NMA/BDMA	12,710	29.5×10^{6}

*Du Pont registered trademark for its aramid fiber.
**Registered trademark of Shell Corporation.

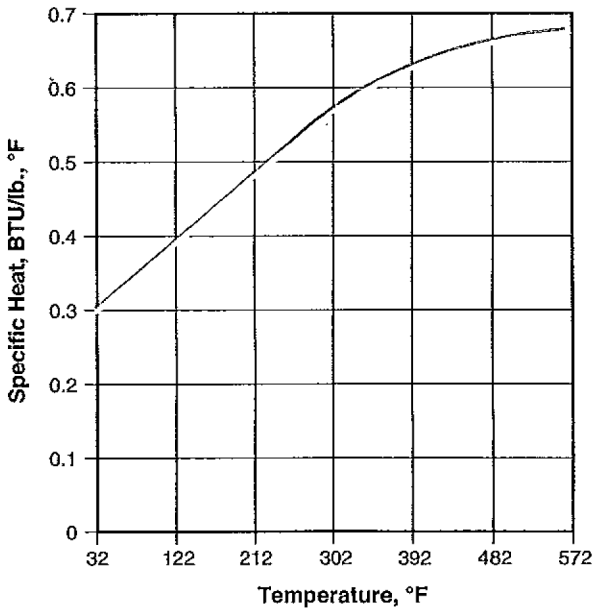

FIGURE 2.9. Effect of Temperature on the Specific Heat of KEVLAR® 49.