Thermal Properties of Automotive Polymers
IV. Thermal Gravimetric Analysis and Differential Scanning Calorimetry Of Selected Parts from a Chevrolet Camaro

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Abstract

Thermal properties of polymeric materials were measured to identify phase changes and decomposition characteristics as the materials are heated through their decomposition temperatures. Fifty-seven polymeric components used on the 1997 Chevrolet Camaro were studied. Consideration was also given to parts different from those analyzed previously for the Dodge Caravan investigation. The base polymers in these parts were identified by Fourier transform infrared spectroscopy and pyrolysis/gas chromatography/mass spectroscopy. Filler content and type were determined by thermogravimetric analysis (TGA).

High-resolution TGA was used to determine thermal decomposition temperatures, and rates of decomposition. These analyses were conducted in nitrogen and air atmospheres. Decomposition temperature and rate of decomposition were found to be a function of the chemical structure of the polymer. For the polymeric materials examined in this study, we observed thermal decomposition temperatures in the range of 270 to 500°C when the samples were heated in air and in the range of 284 to 450°C when the samples were heated in nitrogen. We also used TGA to determine the amounts of organic residues including carbon black, and the amounts of inorganic fillers in the different components.

Differential scanning calorimetry (DSC) measurements were conducted using a modulated differential scanning calorimeter. Melting points, glass transition temperatures, heat capacities, heats of fusion, and thermal conductivity values were calculated from the DSC data. These variables measure the amount of heat absorbed or evolved during heating of the sample.

Introduction

This study was funded by GM pursuant to an agreement between GM and the U.S. Department of Transportation. The work described in this report is part of a project entitled "Study of Flammability of Materials". The overall objective of this project is to study the flammability of certain materials, including engine compartment fluids (other

than gasoline), and certain vehicle exterior and interior materials using existing laboratory test methods as appropriate, as to their flammability properties and limits. For selected materials, efforts will be made to identify potential cost effective, less flammable substitutes which will not compromise other important physical properties.

Research on this project is being conducted at the National Institute for Science and Technology, Factory Mutual Research Corporation, and at the General Motors Research and Development and Planning Center. The study reported here is a second of its kind. The first report of the series was on thermal properties of polymeric parts used on a 1996 Dodge Caravan [1]. Fifty-seven polymeric materials used in a 1997 Chevrolet Camaro were selected for this study. These polymeric materials were from the heating/ventilation/air conditioning (HVAC) system, the instrument panel, the seats, the bumpers, the body front end and body rear end, interior trim, and underhood components.

Thermal properties were investigated using thermal gravimetic analysis (TGA), and differential scanning calorimetry (DSC) to determine decomposition and thermodynamic characteristics. TGA was used to determine the decomposition temperatures and rates of decomposition of polymeric materials when heated under air or nitrogen atmospheres. DSC was used to determine melting points, heats of fusion, glass transition temperatures, heat capacities at various temperatures, and thermal conductivity values for all investigated polymer parts. These variables measure the amount of heat absorbed or released by the polymer when it burns. Also the melting points and glass transition temperatures are a measure of temperatures at which softening and dripping may be expected.

Experimental

Weight of Polymer Parts and Their Composition. Most parts were weighed individually. In some cases, when an assembly contained numerous parts, the total weight of the assembly was determined.

Identification of base Polymers. The compositions of most of the polymeric parts chosen for this investigation were not readily identifiable from information attached to the parts (e.g., identification number, tag or stamp). For this reason, we analyzed all parts for polymer type used, and for amounts and types of filler. Two analytical techniques were used. Pyrolysis / gas chromatography / mass spectroscopy was used to identify polymer type and the chemical nature of additives. The advantage of this technique is its high sensitivity and its ability to identify low concentrations of additives, such as stabilizers normally present in very low concentrations in the polymer matrix [2]. A Nicolet Magnum-IR 550 Fourier transform infrared spectrometer (FTIR) was used for other samples to identify some of the polymers and additives in these materials. For solid samples, a microanalysis technique was used by placing the sample in a diamond cell and conducting the analysis on small areas under a microscope. The diamond cell was used because it does not scratch or get damaged by solid samples, and because diamond has a high refractive index and is transparent to infrared light. The visible/infrared light

microscope was used to identify the area of the sample to be analyzed, and for focusing the infrared beam on that area for microanalysis. For further confirmation, some samples were also extracted with chloroform, and the FTIR spectrum of the extract was obtained.

Qualitative and semi-quantitative elemental analysis of fillers was conducted by X-ray fluorescence spectroscopy. This technique is capable of identifying all elements with atomic numbers greater than nine. In some instances the crystalline structure of the filler, determined by X-ray diffraction, was used to identify the filler type.

High Resolution Thermal Gravimetric Analysis. Thermal gravimetric analysis was conducted using a TA 2100 controller (TA Instruments, Inc.). The TGA unit is a TA 2950 operated in high-resolution mode where the heating rate was automatically slowed when the instrument detected the onset of weight loss from the sample. The initial heating rate was set at 50 °C/minute, and the resolution factor was set at an intermediate value of 4. All samples were heated from room temperature to 980°C. Decomposition temperatures and the maximum rates of decomposition were determined for each sample.

Thermal gravimetric analysis was also used to determine the amount of inorganic filler in the polymer compositions. When the sample reached its maximum temperature of 980°C, all organic materials in the sample had volatilized. The amount of residue left behind was used to calculate the inorganic filler concentration in the parent material.

Modulated Differential Scanning Calorimetry. Modulated differential scanning calorimetry measurements were conducted using a TA 2920 modular DCS cell (TA Instruments, Inc.). The samples were heated from –62 to 270 °C. The heating rate was set at 5°C /minute. The degree of modulation was set at +/- 0.531 °C, every 40 seconds. Values of the glass transition temperatures, melting points, heats of fusion, heat capacities, and thermal conductivities were all determined from the DSC data. The principles behind the thermal conductivity measurements and experimental techniques employing MDSC were discussed in a previous report [3].

Density Measurements: Specific gravity values of solid samples (except foams) were determined from weight in air divided by the difference between the weight in air and the weight in water conducted per procedures outlined in ASTM D792. For foam samples the density was determined from measurements of weight and volume of uniform cylinders cut from these samples.

Results & Discussion

Location, Weight and Density of Polymeric Parts: The locations of the selected polymeric components on a Chevrolet Camaro are schematically shown in Figures 1A through 1C. These include parts from the heating-ventilation-air conditioning (HVAC) system, bumpers, body front end, underhood plastic parts, windshield wiper system, instrument panel, seat system, car floor, roof, and body rear end.

Table 1 lists the polymeric components selected for the study along with the name and part numbers of all polymeric parts that make up these components, and in most cases the type of polymer used to make the parts. A more complete description of polymer composition of the parts will appear in a later report [2]. Weights of most of the components and some of the parts are shown in the table.

Densities of the polymer compositions tested in this study ranged between 0.03 to 1.40 g/cc. Two polyurethane foams used in the headliner trim finish (P/N: 10277772B) and a heating and ventilation seal (P/N: 52472378) had the lowest density. Nylon 6/6 filled with 33% kaolin used for making the power steering fluid reservoir (26024352) had the highest density of 1.40 g/cc. Densities of all parts were obtained to calculate their thermal response parameter and the fire propagation index. A. Tewarson used both terms for quantifying the behavior of burning polymers [7].

Composition of Polymers. Automotive polymers are commodity polymers capable of being produced in mass, are easily processable, and have good aging resistance to withstand severe automotive environments. Table 2 of Abu-Isa et al [1] listed the most highly used polymers arranged in a descending order with respect to the amount used per average 1996 model car. Typical applications for each of the polymers are also shown in that table. Table 2 of this report shows the amounts of polymers consumed in the making of passenger cars and light trucks manufactured in the United States and Canada during the first quarter of the 1999 calendar year [4]. Comparing the 1996 with the 1999 data one observes that the top ten most widely used polymer types remain the same. The ranking has changed as follows: Polypropylene became the most widely used polymer in cars instead of polyurethane (PU); there is more acrylonitrile-butadiene-styrene (ABS) copolymer and blends than polyethylene; and the polyesters, polycarbonates, polybutylene terephthalate and polyethylene terephthalate have gained usage volume over the thermoset sheet molding composites (SMC/BMC) as seen in Table 2.

Most of the parts selected from the Camaro are composed of polyolefin polymers (polyethylene/polypropylene), polyurethanes, nylons, ABS and styrene-based polymers, and phenolics (Table 1). Some of the parts contained fillers. Inorganic fillers or carbon black are placed into polymers to accomplish one or more of the following improvements: to modify the modulus and other mechanical properties, to increase heat deflection temperature, to improve dimensional stability, or to improve chemical resistance or processability of the composite. The filler type, concentration, and density of the total composition are shown in Table 3. Glass, talc, kaolin clay, and silica were typical fillers used in the parts. Concentrations of inorganic filler are calculated from the amount of residue left behind after the sample was heated to 900 °C in air. Table 3 shows the variation in inorganic filler concentrations. Filler concentration as high as 82.0% was found in the compositions of headliner trim finish (P/N: 10277772C).

The organic residue column in Table 3 is the difference between the residue left after degradation in nitrogen and that left after degradation in air. In most cases, this is a measure of the carbon black contained in the polymer composition. However as we discussed in a previous report [1], polymers in general, but more so aromatic polymers such as polycarbonate and polyimide will form condensed aromatic structures that are stable in nitrogen but completely decompose in air, and as such will yield an organic residue.

Thermal Gravimetric Analysis. As discussed in the experimental section of this report, high resolution TGA was used to characterize the decomposition temperatures and decomposition rates of polymers as they are heated under controlled conditions in nitrogen and in air atmospheres. These measurements are related to polymer flammability behavior [5]. The decomposition temperature relates to the ignition temperature of the sample [5 and 6]. The decomposition rate (which is the rate of mass loss during heating) is a measure of fuel available in the gas phase which is related to the heat release rate of a polymer during burning.

A summary of the TGA data on all samples run in nitrogen is presented in Table 4. The TGA results for samples run in air are shown in Table 5. For most polymers, especially polyolefins or alpha substituted polyolefins, thermal degradation starts at a lower temperature in air than in nitrogen. TGA thermographs for a polypropylene part (P/N: 10278989B), used in a rear window panel, are shown in Figure 2 for a sample run in nitrogen and Figure 3 for a sample run in air. The figures show plots of weight loss (Weight (%)), as well as the rate of weight loss (Derv. Weight (%/°C)) versus temperature. The temperature at which the major portion of the sample is lost is designated as the major peak. For polypropylene the major decomposition peak occurs at a much lower temperature in air (313 °C) than in nitrogen (434 °C). Polypropylene is known to be susceptible to oxidation because of the presence of labile hydrogen on a tertiary carbon in the backbone of the polymer. The polymer readily adds oxygen at that site to form a hydroperoxide. Splitting of the hydroperoxide generates free radicals that accelerate the oxidation of the polymer.

Figures 4 & 5 show TGA thermographs for a nylon part (P/N: 10277772A) used as one of the components of the headliner. For this polymer the temperature at which major degradation occurs is 400 °C when the sample is heated in nitrogen. A similar degradation peak temperature of 396 °C is measured in air. However, degradation and weight loss is observed at a lower temperature of 270 °C and over a wider temperature range (270 to 500 °C) in air than in nitrogen (284 to 450 °C respectively) (see Figures 4 and 5). Also, as seen in these figures, oxidative degradation is more complex than the simple thermal bond breaking and polymer unzipping patterns observed when the sample is heated in a nitrogen atmosphere.

Phenolic resins showed the lowest degree of degradation of all polymers investigated (Figures 6 and 7). The major peaks of degradation were measured at 470 °C in air and

591 °C in nitrogen. Small weight losses of 15.1% in nitrogen and 18 % in air were measured even after heating the sample to 900 °C. In contrast, an ethylene vinyl acetate copolymer foam exhibited the lowest degradation temperature of 253 °C (see Figure 8) when heated in air. The polymer is used as part of the instrument panel trim (P/N: 10269102B). Degradation temperatures of all other polymeric parts fall between these two limits (Tables 4 and 5).

Modulated Differential Scanning Calorimetry. Differential scanning calorimetry measures the amount of heat absorbed or given off as the sample undergoes thermal events, such as melting or crystallization, as it is being heated. The advantages of MDSC are illustrated in Figure 9 for a nylon 6-polymer composition used to make the engine coolant fan. In addition to the value of heat flow, which is the overall heat absorbed or given out, the signal is split into reversible and non-reversible heat flows. Mathematically the relationship of these variables can be presented by the following equation:

$$dQ = Cp\,dT + f(T, t)$$

where dQ is the overall heat flow. It consists of a reversible heat flow Cpdt, representing the changes in heat capacity as the sample is heated or cooled, and a non-reversible part which is a function of both temperature and time. It represents thermal events, attributed to factors such as molded-in stresses or thermal quenching, which once triggered will cause non-reversible changes in the polymer molecule. Separating reversible and non-reversible events allows determination of heat capacity, and thermal conductivity [3].

Nylon 6 exhibited a glass transition temperature at 40 °C (Figure 9). It also shows a non-reversible recrystallization peak, that starts at 150 °C indicating that some of the polymer molecules were quenched in an amorphous state during processing and recrystallized during heating. The melting point for nylon 6 is reversible. It occurs at 219 °C and has a heat of fusion of 71 J/g (Figure 10). Figure 11 shows the plot of heat capacity versus temperature for nylon 6. The heat capacity values were calculated from the reversible heat flow curve.

Table 6 is a summary of melting points and heats of fusion of all crystalline polymers analyzed. Glass transition temperatures are also noted in the table for amorphous polymers and some of the crystalline polymers containing an amorphous phase. The thermal conductivity values of all polymers analyzed are also shown in the table. All values fall in the range of 0.02 W/m°C for a polymer foam used as a seal in the HVAC air distributor case (P/N: 52464968), to 0.41 W/m°C, for a 38.2% silica filled nylon 66 sample used to make the HVAC case (P/N: 52461468A).

The heat capacity values for all polymer compositions analyzed are shown in Table 7. Values are listed for each sample at nine temperatures ranging between –40 and 200 °C. These values will be used to model the flammability behavior of polymers.

In summary, in this study we have characterized decomposition temperatures and decomposition rates for polymer compositions used in a 1997 Camaro. Clear differences in thermal behavior were observed based on the chemistry of the polymers. We have also generated data on thermodynamic parameters of these polymers. Melting points, glass transitions, heats of fusion, heat capacities over a wide temperature range, and thermal conductivities were all obtained.

Acknowledgments

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Table 1: Mass of Selected Polymeric Components and Parts

Part Number	Part Description	Polymer Identification	Mass kg
10138735	Heating and Ventilation, side window defogger - outlet duct	Ethylene-Vinyl Acetate Copolymer	0.04
10153750	Heating and Ventilation, floor air outlet distributor - duct	PP/PE copolymer	0.13
10208798	Floor drain plug, - structure	Hydrocarbon Polymer (EPR or EPDM)	0.01
10231299	Bumpers, Rear bumper fascia - structure	Polyurethane - MDI/poly(2-propylene glycol)	6.18
10243962	Radiator and Engine Cooling, Radiator air upper baffle	PP/PE copolymer	0.56
10246204A	Body Front End, Cowl air inlet (left) - seal		
10246204B	Body Front End, Cowl air inlet (left) - Structure	PP/PE copolymer	
10269100A	Instrument Panel and Gages, Instrument panel - structure	Polystyrene	9.06
10269100B	Instrument Panel and Gages, Instrument panel - padding	Acrylonitrile butadiene Copolymer	
10269100C	Instrument Panel and Gages, Instrument panel - covering	Acrylonitrile butadiene Styrene Terpolymer	
10269102A	Instrument Panel and Gages, Instrument panel upper trim panel - structure		2.31
10269102B	Instrument Panel and Gages, Instrument panel upper trim panel - seals	Ethylene-Vinyl Acetate Copolymer	
10269102C	Instrument Panel and Gages, Instrument panel upper trim panel - seal film		
10277446A	Heating and Ventilation, Distributer, windshield defroster nozzle - duct	PP/PE copolymer	
10277446B	Heating and Ventilation, Distributer, windshield defroster nozzle - seal		
10277466	Heating and Ventilation, main instrument panel ventilation ducts - ducts and supporting structure	Polypropylene	2.37
10277772A	Interior trim, Headliner trim finish panel assembly - covering	Nylon 6	
10277772B	Interior trim, Headliner trim finish panel assembly - interior foam	Polyurethane - TDI/poly(2-propylene glycol)	
10277772C	Interior trim, Headliner trim finish panel assembly - structural backing (yellow)	Phenolic resins	
10278015A	Body Front End, Hood insulator - black fiberous structure	Nylon 6 and Phenolic Binder(Novalac)	0.62
10278015B	Body Front End, Hood insulator - insulating fibers	Phenolic Binder(Novalac)	
10278989A	Body Rear End, Rear compartment lift window closeout panel assembly - carpet like coating	Nylon 6	1.80
10278989B	Body Rear End, Rear compartment lift window closeout panel assembly - structure	Polypropylene	
10282257A	Instrument Panel and Gages, Dash sound barrier - black plastic	Polyethylene and Vinyl Acetate copolymer	5.73
10282257B	Instrument Panel and Gages, Dash sound barrier - insulating foam	Polyurethane - TDI/poly(2-propylene glycol)	
10284967	Body Front End, Front Fender - structure		3.27
10296526	Body Front End, Front wheelhouse panel liner (left) - structure	PP/PE copolymer	1.11
16215781A	Instrument Panel and Gages, Instrument clust - black housing	ABS	

Table 1: Mass of Selected Polymeric Components and Parts

Part Number	Part Description	Polymer Identification	Mass kg
16215781B	Instrument Panel and Gages, Instrument clust - white housing	Polystyrene/phenolic resin	
16215781C	Instrument Panel and Gages, Instrument clust - clear housing	Styrene/acrlonitrile copolymer	
16514312	Bumpers, Rear bumper fascia energy absorber - stucture	Ethylene-Vinyl Acetate Copolymer	4.46
16524838	Bumpers, Headlamp support panel - structure	PP/PE Copolymer	1.93
16633455	Interior Trim, Quarter inner trim finishing panel	PP/PE copolymer	
16795366	Seats, Rear seatback cushion - formed foam	Polyurethane	
16795385A	Seats, Rear seatback back cover - foam	polypropylene	
16795385B	Seats, Rear seatback back cover	Polypropylene	
16795385C	Seats, Rear seatback back cover	Polyethylene Terephthalate	
22098787	Radiator and Engine Cooling, Engine coolant fan	Nylon 6	0.43
26024352	Fluid reservoirs, Power steering fluid reservoir	Nylon 6/6	0.27
52458712	Heating and Ventilation, case heater cover (RR) - structure	Polypropylene	0.24
52458713	Heating and Ventilation, case air distributor front	Polypropylene	0.62
52458898	Heating and Ventilation, case, shroud (temp valve)	Polypropylene	0.43
52458938	Heating and Ventilation, heater front case seal	Polyurethane	0.04
52458941	Heating and Ventilation, heater core shroud seal	Polyurethane	0.01
52458960	Heating and Ventilation, case heater (RR)	Polypropylene	
52458961A	Heating and Ventilation, heater core tube seal - Dark foam	Polyurethane	0.00
52458961B	Heating and Ventilation, heater core tube seal - Light colored foam		
52458965	Heating and Ventilation, A/C evaporator and upper blower case - structure	Polypropylene	0.57
52458972	Heating and Ventilation, A/C evaporator seal	Polyurethane	0.00
52458976	Heating and Ventilation, case aux a/c evaporator and blower lower	Polyurethane	1.76
52461468A	Heating and Ventilation, Case, mode with valve inlet and outlet - door (white)	Nylon 6,6	0.38
52461468B	Heating and Ventilation, Case, mode with valve inlet and outlet - Housing (black)	Polypropylene	
52461468C	Heating and Ventilation, Case, mode with valve inlet and outlet - seal	PP/PE copolymer	
52461468D	Heating and Ventilation, Case, mode with valve inlet and outlet - seal	PP/PE copolymer	
52464968	Heating and Ventilation, seal, air distributor case		0.04
52465340	Fluid reservoirs, Radiator outlet tank - strucure	Nylon 6/6	0.41
52472378	Heating and Ventilation, valve mode - seal	Polyether urethane	0.22

Table 2: The Amounts of Polymers Used in Cars and Light Trucks Manufactured in the United States and Canada During the First Five Months of 1999[4]

Polymer Type	Amount Used (Million Pounds)	Typical Applications in Vehicles
Polypropylene(PP)	221	HVAC, fan & shroud, battery tray, console, radiator, cowel vent, air duct, instrument panel, package shelf
Polyurethane(PU)	211(RIM & Foam)	Body panel, fender, roof panel, bumbers, headliner, seat, upholstery
Polyvinyl Chloride(PVC)	116	Bumper trim, electrical insulation, boots, bellows, seat cover, steering wheel, floor.
Acrylonitrile/butadiene/ Styrene(ABS) and Blends	97	Bumper beam & trim, console, engine cover, fascia, heat liner, electrical insulation, grille, lamp, instrument panel, door, fender
Polyethylene(PE)	91	Gas tank, bumper, electrical insulation, reservoir, fuel filler pipe
Nylon(Polyamide)PA	89	Fuel system, fuel line, gas cap, canister, head lamp support, brake radiator end tank, engine cover, intake manifold, lamp housing
Polycarbonate(PC)	59	Bumper, electrical, grille, lamp support, lens, lamp, instrument panel
Thermoplastic Polyester (PET/PBT)	39	Body panel, hood, connector, door, fuse junction, HVAC components, fuel rail
Thermoset Polyester (SMC/BMC)	38	Door lift gate, fenders, hood, quarter panels, rear deck spoiler, body panel.
Styrene/Polyphenylene oxide PS/PPO	33	Connector, console, engine air cleaner, instrumental panel
Styrene Maleic Anhydride Polymer(SMA)	23	Console, head liner, instrumental panel
Phenolic	18	Brake system, engine pulley, ash tray, transmission component
Acrylic polymers	18	Emblems, lamp and instrument panel lenses
Polyacetals	12	Pump, fuel filler neck.

Table 3: Filler Identification of Selected Polymeric Parts

Part Number	Brief Description	Inorganic Filler	Percent Inorganic Filler	Percent Organic Residue	Density g/cm^3
10138735	Heating and Ventilation, side window defogger - outlet duct		0.2%	0%	0.80
10153750	Heating and Ventilation, floor air outlet distributor - duct		17.4%	0%	1.04
10208798	Floor drain plug, - structure	Si	3.1%	43%	1.19
10231299	Bumpers, Rear bumper fascia - structure		3.5%	20%	1.04
10243962	Radiator and Engine Cooling, Radiator air upper baffle		0.2%	1%	0.88
10246204A	Body Front End, Cowl air inlet (left) - seal		1.6%	0%	1.14
10246204B	Body Front End, Cowl air inlet (left) - Structure		1.1%	2%	0.89
10269100A	Instrument Panel and Gages, Instrument panel - structure		21.0%	0%	0.96
10269100B	Instrument Panel and Gages, Instrument panel - padding		0.3%	8%	0.06
10269100C	Instrument Panel and Gages, Instrument panel - covering		5.0%	21%	0.89
10269102A	Instrument Panel and Gages, Instrument panel upper trim panel - structure		1.2%	18%	1.18
10269102B	Instrument Panel and Gages, Instrument panel upper trim panel - seals		0.7%	0%	0.04
10269102C	Instrument Panel and Gages, Instrument panel upper trim panel - seal film		1.5%	1%	0.03
10277446A	Heating and Ventilation, Distributer, windshield defroster nozzle - duct		17.6%	2%	1.05
10277446B	Heating and Ventilation, Distributer, windshield defroster nozzle - seal		22.8%	0%	0.04
10277466	Heating and Ventilation, main instrument panel ventilation ducts - ducts and supporting structure		21.0%	0%	1.07
10277772A	Interior trim, Headliner trim finish panel assembly - covering		1.8%	2%	0.09
10277772B	Interior trim, Headliner trim finish panel assembly - interior foam		2.3%	4%	0.03
10277772C	Interior trim, Headliner trim finish panel assembly - structural backing (yellow)		82.0%	3%	0.16
10278015A	Body Front End, Hood insulator - black fiberous structure		3.2%	17%	0.06
10278015B	Body Front End, Hood insulator - insulating fibers		74.8%	15%	0.08
10278989A	Body Rear End, Rear compartment lift window closeout panel assembly - carpet like coating	talc	1.6%	11%	0.27
10278989B	Body Rear End, Rear compartment lift window closeout panel assembly - structure		4.8%	6%	1.14
10282257A	Instrument Panel and Gages, Dash sound barrier - black plastic		31.3%	0%	1.20
10282257B	Instrument Panel and Gages, Dash sound barrier - insulating foam		1.7%	0%	0.05
10284967	Body Front End, Front Fender - structure		21.5%	5%	1.20
10296526	Body Front End, Front wheelhouse panel liner (left) - structure		0.1%	1%	0.88

Table 3: Filler Identification of Selected Polymeric Parts

Part Number	Brief Description	Inorganic Filler	Percent Inorganic Filler	Percent Organic Residue	Density g/cm^3
16215781A	Instrument Panel and Gages, Instrument clust - black housing		0.1%	2%	1.43
16215781B	Instrument Panel and Gages, Instrument clust - white housing		9.6%	11%	1.36
16215781C	Instrument Panel and Gages, Instrument clust - clear housing		0.1%	0%	1.11
16514312	Bumpers, Rear bumper fascia energy absorber - stucture		0.4%	0%	0.99
16524838	Bumpers, Headlamp support panel - structure		46.5%	0%	1.11
16633455	Interior Trim, Quarter inner trim finishing panel		0.8%	14%	0.95
16795366	Seats, Rear seatback cushion - formed foam		0.5%	4%	0.05
16795385A	Seats, Rear seatback back cover - foam		10.6%	0%	1.23
16795385B	Seats, Rear seatback back cover		2.6%	9%	1.17
16795385C	Seats, Rear seatback back cover		1.4%	0%	0.02
22098787	Radiator and Engine Cooling, Engine coolant fan	talc/glass fibers	35.5%	3%	1.44
26024352	Fluid reservoirs, Power steering fluid reservoir	kaolin	33.0%	5%	1.40
52458712	Heating and Ventilation, case heater cover (RR) - structure		38.1%	0%	1.20
52458713	Heating and Ventilation, case air distributor front		38.3%	0%	1.20
52458898	Heating and Ventilation, case, shroud (temp valve)		37.9%	0%	1.17
52458938	Heating and Ventilation, heater front case seal	kaolin	38.4%	1%	0.18
52458941	Heating and Ventilation, heater core shroud seal	kaolin	34.7%	1%	0.21
52458960	Heating and Ventilation, case heater (RR)		39.6%	1%	1.23
52458961A	Heating and Ventilation, heater core tube seal - Dark foam	kaolin	46.2%	7%	0.09
52458961B	Heating and Ventilation, heater core tube seal - Light colored foam	kaolin	38.9%	3%	0.05
52458965	Heating and Ventilation, A/C evaporator and upper blower case - structure	talc	38.1%	0%	1.22
52458972	Heating and Ventilation, A/C evaporator seal	kaolin	36.9%	3%	0.11
52458976	Heating and Ventilation, case aux a/c evaporator and blower lower	kaolin	43.3%	1%	1.71
52461468A	Heating and Ventilation, Case, mode with valve inlet and outlet - door (white)	silica	38.2%	1%	1.48
52461468B	Heating and Ventilation, Case, mode with valve inlet and outlet - Housing (black)		20.7%	1%	1.07
52461468C	Heating and Ventilation, Case, mode with valve inlet and outlet - seal	calcium carbonate	20.9%	1%	1.20
52461468D	Heating and Ventilation, Case, mode with valve inlet and outlet - seal		0.3%	1%	0.86
52464968	Heating and Ventilation, seal, air distributor case		0.7%	1%	0.04

Table 3: Filler Identification of Selected Polymeric Parts

Part Number	Brief Description	Inorganic Filler	Percent Inorganic Filler	Percent Organic Residue	Density g/cm^3
52465340	Fluid reservoirs, Radiator outlet tank - strucure		25.3%	2%	1.18
52472378	Heating and Ventilation, valve mode - seal		19.7%	2%	0.03

Table 4: Thermal Gravimetric Analysis of Selected Polymeric Parts in Nitrogen

Part Number	Part Description	Polymer Identification	Decomposition: Initial		Major		Secondary	
			Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C
10138735	Heating and Ventilation, side window defogger	Ethylene-Vinyl Acetate Copolymer	403	2.73	403	2.73	425	1.42
10153750	Heating and Ventilation, floor air outlet distributor	PP/PE copolymer	354	2.56	354	2.56	378	1.32
10208798	Floor drain plug,	Hydrocarbon Polymer (EPR or EPDM)	295	0.31	459	1.76		
10231299	Bumpers, Rear bumper fascia	Polyurethane - MDI/poly(2-propylene glycol)	266	0.28	363	2.12	309	0.32
10243962	Radiator and Engine Cooling, Radiator air upper baffle	PP/PE copolymer	374	1.63	374	1.63	385	1.53
10246204A	Body Front End, Cowl air inlet (left)		266	0.70	351	5.86		
10246204B	Body Front End, Cowl air inlet (left)	PP/PE copolymer	389	3.82	389	3.82	443	0.21
10269100A	Instrument Panel and Gages, Instrument panel	Polystyrene	371	10.58	371	10.58		
10269100B	Instrument Panel and Gages, Instrument panel	Acrylonitrile butadiene Copolymer	338	0.97	365	2.02	485	0.09
10269100C	Instrument Panel and Gages, Instrument panel	ABS	269	4.16	269	4.16	432	0.86
10269102A	Instrument Panel and Gages, Instrument panel upper trim panel		465	5.86	465	5.86		
10269102B	Instrument Panel and Gages, Instrument panel upper trim panel	Ethylene-Vinyl Acetate Copolymer	271	1.01	333	2.39		
10269102C	Instrument Panel and Gages, Instrument panel upper trim panel		287	0.05	434	9.78		
10277446A	Heating and Ventilation, Distributer, windshield defroster nozzle	PP/PE copolymer	403	1.90	403	1.90	548	0.04
10277446B	Heating and Ventilation, Distributer, windshield defroster nozzle		262	0.81	329	1.97		

Table 4: Thermal Gravimetric Analysis of Selected Polymeric Parts in Nitrogen

Part Number	Part Description	Polymer Identification	Decomposition: Initial		Major		Secondary	
			Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C
10277466	Heating and Ventilation, main instrument panel ventilation ducts	polypropylene	340	2.59	348	3.14	465	0.06
10277772A	Interior trim, Headliner trim finish panel assembly	Nylon 6	283	0.08	400	5.25	358	0.39
10277772B	Interior trim, Headliner trim finish panel assembly	Polyurethane - TDI/poly(2-propylene glycol)	264	1.48	264	1.48	333	1.13
10277772C	Interior trim, Headliner trim finish panel assembly	Phenolic resins	70	0.01	591	0.03	322	0.03
10278015A	Body Front End, Hood insulator	Nylon 6 and Novalac Binder	320	0.70	369	1.50	445	0.14
10278015B	Body Front End, Hood insulator	Novalac Binder	345	0.02	492	0.04	611	0.03
10278989A	Body Rear End, Rear compartment lift window closeout panel assembly	Nylon 6	331	0.21	389	2.44	687	0.15
10278989B	Body Rear End, Rear compartment lift window closeout panel assembly	polypropylene	321	0.28	433	3.08	350	0.74
10282257A	Instrument Panel and Gages, Dash sound barrier	Polyethylene and Vinyl Acetate copolymer	436	6.55	436	6.55	781	0.11
10282257B	Instrument Panel and Gages, Dash sound barrier	Polyurethane - TDI/poly(2-propylene glycol)	202	0.16	266	1.21	336	0.81
10284967	Body Front End, Front Fender		289	0.52	342	0.79	367	0.71
10296526	Body Front End, Front wheelhouse panel liner (left)	PP/PE copolymer	434	15.77	434	15.77		
16215781A	Instrument Panel and Gages, Instrument clust	ABS	401	10.35	401	10.35	430	0.51
16215781B	Instrument Panel and Gages, Instrument clust	Polystyrene/phenolic resin	407	9.92	407	9.92	477	0.20
16215781C	Instrument Panel and Gages, Instrument clust	Styrene/acrlonitrile copolymer	345	5.43	345	5.43	414	0.13
16514312	Bumpers, Rear bumper fascia energy absorber	Ethylene-Vinyl Acetate Copolymer	360	0.23	405	5.58	421	1.99
16524838	Bumpers, Headlamp support panel	PP/PE Copolymer	369	3.69	369	3.69		

Table 4: Thermal Gravimetric Analysis of Selected Polymeric Parts in Nitrogen

Part Number	Part Description	Polymer Identification	Decomposition: Initial		Major		Secondary	
			Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C
16633455	Interior Trim, Quarter inner trim finishing panel	PP/PE copolymer	416	2.65	416	2.65		
16795366	Seats, Rear seatback cushion	Polyurethane	255	0.60	342	2.63		
16795385A	Seats, Rear seatback back cover	polypropylene	365	2.91	365	3.91	709	0.13
16795385B	Seats, Rear seatback back cover	Polypropylene	342	2.15	342	2.15	398	1.23
16795385C	Seats, Rear seatback back cover	Polyethylene Terephthalate	271	0.90	325	1.93	271	0.90
22098787	Radiator and Engine Cooling, Engine coolant fan	Nylon 6	423	4.40	423	4.40		
26024352	Fluid reservoirs, Power steering fluid reservoir	Nylon 6/6	421	3.20	421	3.20		
52458712	Heating and Ventilation, case heater cover (RR)	polypropylene	447	10.23	447	10.23		
52458713	Heating and Ventilation, case air distributor front	polypropylene	378	1.36	412	1.56		
52458898	Heating and Ventilation, case, shroud (temp valve)	polypropylene	376	1.70	376	1.70	405	1.68
52458938	Heating and Ventilation, heater front case seal	Polyurethane	264	0.11	452	0.30	702	0.48
52458941	Heating and Ventilation, heater core shroud seal	Polyurethane	266	0.12	447	0.57	691	0.22
52458960	Heating and Ventilation, case heater (RR)	polypropylene	436	7.35	436	7.35		
52458961A	Heating and Ventilation, heater core tube seal	Polyurethane	262	0.14	325	0.43	613	0.04
52458961B	Heating and Ventilation, heater core tube seal		251	0.13	459	1.21	291	0.16
52458965	Heating and Ventilation, A/C evaporator and upper blower case	polypropylene	396	1.40	432	2.74		
52458972	Heating and Ventilation, A/C evaporator seal	Polyurethane	291	0.14	434	0.55	698	0.26
52458976	Heating and Ventilation, case aux a/c evaporator and blower lower	Polyurethane	347	1.00	347	1.00	501	0.14

Table 4: Thermal Gravimetric Analysis of Selected Polymeric Parts in Nitrogen

Part Number	Part Description	Polymer Identification	Decomposition: Initial		Major		Secondary	
			Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C
52461468A	Heating and Ventilation, Case, mode with valve inlet and outlet	Nylon 6,6	418	3.12	418	3.12		
52461468B	Heating and Ventilation, Case, mode with valve inlet and outlet	polypropylene	445	13.07	445	13.07		
52461468C	Heating and Ventilation, Case, mode with valve inlet and outlet	PP/PE copolymer		0.41	432	2.95	705	0.68
52461468D	Heating and Ventilation, Case, mode with valve inlet and outlet	PP/PE copolymer	318	0.54	416	2.10		
52464968	Heating and Ventilation, seal, air distributor case		253	0.74	356	1.45	311	0.63
52465340	Fluid reservoirs, Radiator outlet tank	Nylon 6/6	407	7.35	407	7.35	452	0.29
52472378	Heating and Ventilation, valve mode	Polyether urethane	269	0.87	340	3.01		

Table 5: Thermal Gravimetric Analysis of Selected Polymeric Parts in Air

Part Number	Part Description	Polymer Identification	Decomposition: Initial		Major		Secondary	
			Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C
10138735	Heating and Ventilation, side window defogger	Ethylene-Vinyl Acetate Copolymer	280	0.56	407	2.46	443	1.06
10153750	Heating and Ventilation, floor air outlet distributor	PP/PE copolymer	284	0.48	347	2.30	329	1.53
10208798	Floor drain plug,	Hydrocarbon Polymer (EPR or EPDM)	291	0.30	291	0.30	564	4.32
10231299	Bumpers, Rear bumper fascia	Polyurethane - MDI/poly(2-propylene glycol)	240	0.04	311	0.66	528	0.04
10243962	Radiator and Engine Cooling, Radiator air upper baffle	PP/PE copolymer	300	1.26	300	1.26	523	0.19
10246204A	Body Front End, Cowl air inlet (left)		265	2.62	265	2.62	299	0.99
10246204B	Body Front End, Cowl air inlet (left)	PP/PE copolymer	352	5.32	352	5.32	369	1.22
10269100A	Instrument Panel and Gages, Instrument panel	Polystyrene	351	8.08	351	8.08	544	0.12
10269100B	Instrument Panel and Gages, Instrument panel	Acrylonitrile butadiene Copolymer	273	3.87	273	3.87	519	0.57
10269100C	Instrument Panel and Gages, Instrument panel	ABS	262	6.09	262	6.09	608	0.26
10269102A	Instrument Panel and Gages, Instrument panel upper trim panel		271	0.11	356	2.23	432	1.32
10269102B	Instrument Panel and Gages, Instrument panel upper trim panel	Ethylene-Vinyl Acetate Copolymer	253	3.42	253	3.42	275	0.83
10269102C	Instrument Panel and Gages, Instrument panel upper trim panel		276	0.24	378	5.42	429	1.19
10277446A	Heating and Ventilation, Distributer, windshield defroster nozzle	PP/PE copolymer	342	3.67	342	3.67	582	0.08
10277446B	Heating and Ventilation, Distributer, windshield defroster nozzle		266	1.50	313	2.67		

Table 5: Thermal Gravimetric Analysis of Selected Polymeric Parts in Air

Part Number	Part Description	Polymer Identification	Decomposition: Initial Temp. °C	Decomposition: Initial Rate %mass/°C	Major Temp. °C	Major Rate %mass/°C	Secondary Temp. °C	Secondary Rate %mass/°C
10277466	Heating and Ventilation, main instrument panel ventilation ducts	polypropylene	369	0.18	416	2.94	557	0.04
10277772A	Interior trim, Headliner trim finish panel assembly	Nylon 6	277	0.23	405	1.79	396	1.81
10277772B	Interior trim, Headliner trim finish panel assembly	Polyurethane - TDI/poly(2-propylene glycol)	253	3.26	253	3.26	530	0.15
10277772C	Interior trim, Headliner trim finish panel assembly	Phenolic resins	65	0.01	470	0.15	320	0.04
10278015A	Body Front End, Hood insulator	Nylon 6 and Novalac Binder	302	1.27	389	0.67	488	0.46
10278015B	Body Front End, Hood insulator	Novalac Binder	336	0.06	526	0.36		
10278989A	Body Rear End, Rear compartment lift window closeout panel assembly	Nylon 6	385	1.50	405	3.43	483	0.81
10278989B	Body Rear End, Rear compartment lift window closeout panel assembly	polypropylene	313	4.93	313	4.93	462	0.22
10282257A	Instrument Panel and Gages, Dash sound barrier	Polyethylene and Vinyl Acetate copolymer	385	1.36	445	3.50	407	0.84
10282257B	Instrument Panel and Gages, Dash sound barrier	Polyurethane - TDI/poly(2-propylene glycol)	204	0.18	255	4.05	302	0.67
10284967	Body Front End, Front Fender		271	0.53	316	2.70	526	0.37
10296526	Body Front End, Front wheelhouse panel liner (left)	PP/PE copolymer	282	8.19	282	8.19		
16215781A	Instrument Panel and Gages, Instrument clust	ABS	374	5.21	374	5.21	532	1.09
16215781B	Instrument Panel and Gages, Instrument clust	Polystyrene/phenolic resin	398	3.60	398	3.60	485	3.53
16215781C	Instrument Panel and Gages, Instrument clust	Styrene/acrlonitrile copolymer	300	14.85	300	14.85	349	0.27
16514312	Bumpers, Rear bumper fascia energy absorber	Ethylene-Vinyl Acetate Copolymer	356	0.36	427	3.14	494	0.28
16524838	Bumpers, Headlamp support panel	PP/PE Copolymer	336	1.63	336	1.63	490	0.02

Table 5: Thermal Gravimetric Analysis of Selected Polymeric Parts in Air

Part Number	Part Description	Polymer Identification	Decomposition: Initial		Major		Secondary	
			Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C	Temp. °C	Rate %mass/°C
16633455	Interior Trim, Quarter inner trim finishing panel	PP/PE copolymer	331	2.27	331	2.27	354	2.04
16795366	Seats, Rear seatback cushion	Polyurethane	262	3.35	262	3.35	544	0.35
16795385A	Seats, Rear seatback back cover	polypropylene	284	3.03	284	3.03	687	0.18
16795385B	Seats, Rear seatback back cover	Polypropylene	345	2.20	391	1.94	526	0.66
16795385C	Seats, Rear seatback back cover	Polyethylene Terephthalate	253	3.61	253	3.61	273	1.04
22098787	Radiator and Engine Cooling, Engine coolant fan	Nylon 6	430	3.90	430	3.90	479	0.42
26024352	Fluid reservoirs, Power steering fluid reservoir	Nylon 6/6	425	2.64	425	2.64	535	0.15
52458712	Heating and Ventilation, case heater cover (RR)	polypropylene	298	0.25	351	3.17		
52458713	Heating and Ventilation, case air distributor front	polypropylene	295	0.42	345	2.66		
52458898	Heating and Ventilation, case, shroud (temp valve)	Polypropylene	291	0.51	345	2.79		
52458938	Heating and Ventilation, heater front case seal	Polyurethane	255	0.14	463	0.38	684	0.29
52458941	Heating and Ventilation, heater core shroud seal	Polyurethane	251	0.12	459	0.42	709	0.27
52458960	Heating and Ventilation, case heater (RR)	polypropylene	356	1.36	375	3.20		
52458961A	Heating and Ventilation, heater core tube seal	Polyurethane	269	0.18	483	1.56	615	0.07
52458961B	Heating and Ventilation, heater core tube seal		273	0.45	452	0.44	501	0.32
52458965	Heating and Ventilation, A/C evaporator and upper blower case	polypropylene	295	0.47	347	2.95	333	1.10
52458972	Heating and Ventilation, A/C evaporator seal	Polyurethane	246	0.15	447	0.41	696	0.35
52458976	Heating and Ventilation, case aux a/c evaporator and blower lower	Polyurethane	340	0.62	483	0.63	709	0.04

Table 5: Thermal Gravimetric Analysis of Selected Polymeric Parts in Air

Part Number	Part Description	Polymer Identification	Decomposition: Initial Temp. °C	Decomposition: Initial Rate %mass/°C	Major Temp. °C	Major Rate %mass/°C	Secondary Temp. °C	Secondary Rate %mass/°C
52461468A	Heating and Ventilation, Case, mode with valve inlet and outlet	Nylon 6,6	430	4.07	430	4.07	517	0.33
52461468B	Heating and Ventilation, Case, mode with valve inlet and outlet	polypropylene	293	0.68	342	2.81	335	1.86
52461468C	Heating and Ventilation, Case, mode with valve inlet and outlet	PP/PE copolymer	313	0.37	351	1.05	711	0.86
52461468D	Heating and Ventilation, Case, mode with valve inlet and outlet	PP/PE copolymer	282	1.64	282	1.64	459	0.83
52464968	Heating and Ventilation, seal, air distributor case		251	0.81	289	3.41		
52465340	Fluid reservoirs, Radiator outlet tank	Nylon 6/6	430	5.58	430	5.58	463	0.32
52472378	Heating and Ventilation, valve mode	Polyether urethane	271	1.24	271	1.24	548	0.08

Table 6: Melting Points, Glass Transition Temperatures and Heat of Fusion of Selected Polymeric Parts as Determined by Differential Scanning Calorimetry Conducted in Nitrogen

Part Number	Part Description	Polymer Identification	Melting Point °C	Glass Transition Temperature °C	Heat of Fusion J/g	Thermal Conductivity W/(m-°C) @ 30°C
10138735	Heating and Ventilation, side window defogger - outlet duct	Ethylene-Vinyl Acetate Copolymer	124	-53	125	0.23
10153750	Heating and Ventilation, floor air outlet distributor - duct	PP/PE copolymer	124, 161		90	0.19
10208798	Floor drain plug, - structure	Hydrocarbon Polymer (EPR or EPDM)	Amorphous	13		0.13
10231299	Bumpers, Rear bumper fascia - structure	Polyurethane - MDI/poly(2-propylene glycol)	Amorphous	117		0.14
10243962	Radiator and Engine Cooling, Radiator air upper baffle	PP/PE copolymer	122, 145		21, 58	0.33
10246204A	Body Front End, Cowl air inlet (left) - seal			-50		
10246204B	Body Front End, Cowl air inlet (left) - Structure	PP/PE copolymer	119, 156	24	20, 71	
10269100A	Instrument Panel and Gages, Instrument panel - structure	Polystyrene	Amorphous	123		0.26
10269100B	Instrument Panel and Gages, Instrument panel - padding	Acrylonitrile butadiene Copolymer	Amorphous	108		0.08
10269100C	Instrument Panel and Gages, Instrument panel - covering	ABS	Amorphous	78		0.10
10269102A	Instrument Panel and Gages, Instrument panel upper trim panel - structure		108		147	0.34
10269102B	Instrument Panel and Gages, Instrument panel upper trim panel - seals	Ethylene-Vinyl Acetate Copolymer	109	31	30	0.23
10269102C	Instrument Panel and Gages, Instrument panel upper trim panel - seal film		109		158	
10277446A	Heating and Ventilation, Distributer, windshield defroster nozzle - duct	PP/PE copolymer	124, 161		7, 91	0.19
10277446B	Heating and Ventilation, Distributer, windshield defroster nozzle - seal		49	-39	21	0.13
10277466	Heating and Ventilation, main instrument panel ventilation ducts - ducts and supporting structure	PP/PE copolymer	112, 155	66	6, 73	0.36

Table 6: Melting Points, Glass Transition Temperatures and Heat of Fusion of Selected Polymeric Parts as Determined by Differential Scanning Calorimetry Conducted in Nitrogen

Part Number	Part Description	Polymer Identification	Melting Point °C	Glass Transition Temperature °C	Heat of Fusion J/g	Thermal Conductivity W/(m-°C) @ 30°C
10277772A	Interior trim, Headliner trim finish panel assembly - covering	Nylon 6	220	38	122	0.12
10277772B	Interior trim, Headliner trim finish panel assembly - interior foam	Polyurethane - TDI/poly(2-propylene glycol)	Amorphous	129		0.08
10277772C	Interior trim, Headliner trim finish panel assembly - structural backing (yellow)	Phenolic resins	Amorphous	20		0.28
10278015A	Body Front End, Hood insulator - black fiberous structure	Nylon 6 and Novalac Binder	206	36	8	0.07
10278015B	Body Front End, Hood insulator - insulating fibers	Novalac Binder	Amorphous	36		0.19
10278989A	Body Rear End, Rear compartment lift window closeout panel assembly - carpet like coating	Nylon 6	220		60	0.11
10278989B	Body Rear End, Rear compartment lift window closeout panel assembly - structure	polypropylene	160		24	0.33
10282257A	Instrument Panel and Gages, Dash sound barrier - black plastic	Polyethylene and Vinyl Acetate copolymer	107		87	0.35
10282257B	Instrument Panel and Gages, Dash sound barrier - insulating foam	Polyurethane - TDI/poly(2-propylene glycol)	Amorphous			
10284967	Body Front End, Front Fender - structure		273, 288	80	.48, .71	0.35
10296526	Body Front End, Front wheelhouse panel liner (left) - structure	PP/PE copolymer	123, 164		133	0.24
16215781A	Instrument Panel and Gages, Instrument clust - black housing	ABS	Amorphous	107		0.13
16215781B	Instrument Panel and Gages, Instrument clust - white housing	Polystyrene/phenolic resin	Amorphous	106		0.12
16215781C	Instrument Panel and Gages, Instrument clust - clear housing	Styrene/acrlonitrile copolymer	Amorphous	111		0.09
16514312	Bumpers, Rear bumper fascia energy absorber - stucture	Ethylene-Vinyl Acetate Copolymer	47, 99		22, 107	0.29

Table 6: Melting Points, Glass Transition Temperatures and Heat of Fusion of Selected Polymeric Parts as Determined by Differential Scanning Calorimetry Conducted in Nitrogen

Part Number	Part Description	Polymer Identification	Melting Point °C	Glass Transition Temperature °C	Heat of Fusion J/g	Thermal Conductivity W/(m-°C) @ 30°C
16524838	Bumpers, Headlamp support panel - structure	PP/PE Copolymer	118, 162		6, 64	0.28
16633455	Interior Trim, Quarter inner trim finishing panel	PP/PE copolymer	124, 161		13, 94	0.20
16795366	Seats, Rear seatback cushion - formed foam	Polyurethane	62	-	17	0.07
16795385A	Seats, Rear seatback back cover - foam	polypropylene	159	43	60	0.35
16795385B	Seats, Rear seatback back cover	Polypropylene	166	44	55	0.31
16795385C	Seats, Rear seatback back cover	Polyethylene Terephthalate	252	54	48	0.37
22098787	Radiator and Engine Cooling, Engine coolant fan	Nylon 6	219	40	70	0.35
26024352	Fluid reservoirs, Power steering fluid reservoir	Nylon 6/6	261	35	83	0.31
52458712	Heating and Ventilation, case heater cover (RR) - structure	Polypropylene	159		86	0.37
52458713	Heating and Ventilation, case air distributor front	Polypropylene	162		74	0.33
52458898	Heating and Ventilation, case, shroud (temp valve)	Polypropylene	160		71	0.29
52458938	Heating and Ventilation, heater front case seal	Polyurethane	Amorphous	14, 46		0.12
52458941	Heating and Ventilation, heater core shroud seal	Polyurethane	Amorphous	40		0.12
52458960	Heating and Ventilation, case heater (RR)	Polypropylene	164	13	86	0.29
52458961A	Heating and Ventilation, heater core tube seal - Dark foam	Polyurethane	Amorphous	42		0.17
52458961B	Heating and Ventilation, heater core tube seal - Light colored foam		97		14	
52458965	Heating and Ventilation, A/C evaporator and upper blower case - structure	Polypropylene	159		66	0.39
52458972	Heating and Ventilation, A/C evaporator seal	Polyurethane	Amorphous	31		0.19

Table 6: Melting Points, Glass Transition Temperatures and Heat of Fusion of Selected Polymeric Parts as Determined by Differential Scanning Calorimetry Conducted in Nitrogen

Part Number	Part Description	Polymer Identification	Melting Point °C	Glass Transition Temperature °C	Heat of Fusion J/g	Thermal Conductivity W/(m-°C) @ 30°C
52458976	Heating and Ventilation, case aux a/c evaporator and blower lower	Polyurethane	Amorphous	76, 130.00		0.17
52461468A	Heating and Ventilation, Case, mode with valve inlet and outlet - door (white)	Nylon 6,6	258		50	0.41
52461468B	Heating and Ventilation, Case, mode with valve inlet and outlet - Housing (black)	Polypropylene	162		102	0.11
52461468C	Heating and Ventilation, Case, mode with valve inlet and outlet - seal	PP/PE copolymer	114, 149	-22	1, 14	0.35
52461468D	Heating and Ventilation, Case, mode with valve inlet and outlet - seal	PP/PE copolymer	119, 151	-22	12, 20	0.13
52464968	Heating and Ventilation, seal, air distributor case			65		0.02
52465340	Fluid reservoirs, Radiator outlet tank - strucure	Nylon 6/6	261	102	118	0.39
52472378	Heating and Ventilation, valve mode - seal	Polyether urethane	Amorphous	4		

Table 7: Heat Capacities of Selected Polymeric Parts as Determined by Modulated Differential Scanning Calorimetry Conducted in Nitrogen

Part Number	Polymer Identification	Inorganic Filler	Heat Capacity J/(g K) -40 °C	-20 °C	0 °C	20 °C	40 °C	60 °C	80 °C	100 °C	200 °C
10138735	Ethylene-Vinyl Acetate Copolymer		1.325	1.412	1.527	1.664	1.827	2.053	2.379	3.027	2.463
10153750	PP/PE copolymer		1.454	1.539	1.650	1.757	1.867	2.030	2.198	2.388	2.614
10208798	Hydrocarbon Polymer (EPR or EPDM)	Si	1.313	1.425	1.543	1.621	1.609	1.660	1.720	1.777	2.051
10231299	Polyurethane - MDI/poly(2-propylene glycol)		1.295	1.371	1.442	1.513	1.576	1.642	1.749	1.991	0.219
10243962	PP/PE copolymer		1.559	1.660	1.777	1.870	2.013	2.216	2.439	2.795	2.693
10246204A			2.046	2.261	2.300	2.340	2.400	2.460	2.520	2.620	2.850
10246204B	PP/PE copolymer		1.563	1.660	1.780	1.880	2.020	2.250	2.450	2.750	2.820
10269100A	Polystyrene		0.890	0.942	1.009	1.066	1.128	1.197	1.264	1.329	1.706
10269100B	Acrylonitrile butadiene Copolymer		1.503	1.581	1.662	1.734	1.809	1.891	1.965	2.032	2.300
10269100C	ABS		1.058	1.154	1.261	1.362	1.462	1.560	1.665	1.750	1.938
10269102A			1.430	1.568	1.751	1.885	2.120	2.481	2.891	5.303	2.404
10269102B	Ethylene-Vinyl Acetate Copolymer		1.457	1.552	1.585	1.625	1.676	1.722	1.776	1.833	2.101
10269102C			0.856	0.996	1.150	1.290	1.513	1.855	2.662	4.855	1.854
10277446A	PP/PE copolymer		0.312	0.353	0.432	0.512	0.593	0.705	0.843	1.024	1.164
10277446B			0.147	0.323	0.408	0.456	0.478	0.496	0.522	0.552	0.702
10277466	polypropylene		1.268	1.360	1.480	1.590	1.752	1.800	1.950	2.033	2.310
10277772A	Nylon 6		1.303	1.383	1.496	1.600	1.727	1.860	1.963	2.080	3.049
10277772B	Polyurethane - TDI/poly(2-propylene glycol)		1.620	1.701	1.771	1.822	1.876	1.962	1.981	2.054	2.353
10277772C	Phenolic resins		1.060	1.087	1.127	1.164	1.206	1.247	1.238	1.311	1.420
10278015A	Nylon 6 and Novalac Binder		1.116	1.144	1.210	1.300	1.370	1.446	1.512	1.586	2.244
10278015B	Novalac Binder		0.921	0.954	0.988	1.017	1.054	1.085	1.118	1.143	1.231
10278989A	Nylon 6	talc	0.979	1.031	1.101	1.185	1.267	1.344	1.408	1.500	2.133
10278989B	polypropylene		0.869	0.923	1.003	1.078	1.150	1.231	1.315	1.402	1.663
10282257A	Polyethylene and Vinyl Acetate copolymer		1.270	1.380	1.497	1.578	1.734	2.066	2.481	4.016	2.048
10282257B	Polyurethane - TDI/poly(2-propylene glycol)		2.063	2.131	2.193	2.238	2.292	2.351	2.403	2.445	2.706
10284967			1.203	1.291	1.380	1.452	1.535	1.616	1.697	1.747	2.002
10296526	PP/PE copolymer		1.434	1.545	1.654	1.756	1.893	2.072	2.266	2.528	2.703
16215781A	ABS		1.288	1.346	1.419	1.482	1.558	1.663	1.771	1.931	2.415
16215781B	Polystyrene/phenolic resin		1.122	1.191	1.271	1.329	1.392	1.471	1.551	1.646	2.054
16215781C	Styrene/acrlonitrile copolymer		1.076	1.131	1.199	1.255	1.319	1.393	1.481	1.619	2.014
16514312	Ethylene-Vinyl Acetate Copolymer		1.535	1.747	1.951	2.098	2.434	3.031	4.046	7.921	2.665
16524838	PP/PE Copolymer		1.363	1.426	1.502	1.583	1.683	1.782	1.893	2.028	2.177

Table 7: Heat Capacities of Selected Polymeric Parts as Determined by Modulated Differential Scanning Calorimetry Conducted in Nitrogen

Part Number	Polymer Identification	Inorganic Filler	Heat Capacity J/(g K) -40 °C	-20 °C	0 °C	20 °C	40 °C	60 °C	80 °C	100 °C	200 °C
16633455	PP/PE copolymer		1.504	1.594	1.705	1.796	1.919	2.062	2.223	2.426	2.539
16795366	Polyurethane		1.688	1.759	1.853	1.916	2.002	2.081	2.138	2.204	2.596
16795385A	polypropylene		1.175	1.257	1.360	1.445	1.544	1.654	1.786	1.886	2.219
16795385B	Polypropylene		1.036	1.109	1.165	1.216	1.257	1.336	1.412	1.498	1.965
16795385C	Polyethylene Terephthalate		1.444	1.493	1.541	1.596	1.644	1.690	1.737	1.785	2.099
22098787	Nylon 6	talc/glass fibers	0.902	0.963	1.038	1.121	1.255	1.376	1.483	1.551	2.718
26024352	Nylon 6/6	kaolin	0.996	1.056	1.133	1.212	1.351	1.488	1.585	1.686	2.141
52458712	polypropylene		1.294	1.369	1.462	1.553	1.656	1.776	1.902	2.043	2.263
52458713	polypropylene		1.091	1.158	1.263	1.365	1.446	1.552	1.667	1.805	1.999
52458898	polypropylene		1.042	1.108	1.196	1.278	1.364	1.468	1.582	1.705	1.954
52458938	Polyurethane	kaolin	1.176	1.261	1.339	1.416	1.468	1.519	1.564	1.590	1.782
52458941	Polyurethane	kaolin	1.344	1.414	1.474	1.533	1.607	1.659	1.721	1.772	1.882
52458960	polypropylene		0.930	0.980	1.050	1.150	1.200	1.310	1.410	1.530	1.690
52458961A	Polyurethane	kaolin	1.148	1.263	1.304	1.362	1.413	1.446	1.497	1.541	1.638
52458961B		kaolin	1.815	1.919	2.031	2.064	2.152	2.239	2.488	2.883	2.515
52458965	polypropylene	talc	1.028	1.089	1.178	1.254	1.337	1.434	1.540	1.665	1.857
52458972	Polyurethane	kaolin	1.212	1.259	1.340	1.424	1.477	1.478	1.513	1.557	1.712
52458976	Polyurethane	kaolin	1.296	1.342	1.403	1.467	1.541	1.612	1.740	1.798	2.021
52461468A	Nylon 6,6	silica	0.844	0.896	0.964	1.036	1.138	1.255	1.360	1.440	1.912
52461468B	polypropylene		1.292	1.361	1.461	1.560	1.667	1.787	1.921	2.092	2.283
52461468C	PP/PE copolymer	calcium carbonate	1.562	1.641	1.659	1.663	1.717	1.795	1.889	1.987	2.156
52461468D	PP/PE copolymer		1.714	1.837	1.868	1.878	1.935	2.042	2.186	2.358	2.576
52464968			1.265	1.366	1.618	1.810	1.908	2.077	2.132	2.422	1.624
52465340	Nylon 6/6		1.115	1.170	1.250	1.313	1.437	1.585	1.705	1.812	2.274
52472378	Polyether urethane		2.062	2.237	2.341	2.395	2.449	2.501	2.561	2.609	2.799

Figure 1: Schematic Diagram Showing the Location of Components in the Camaro. (A) Front View.

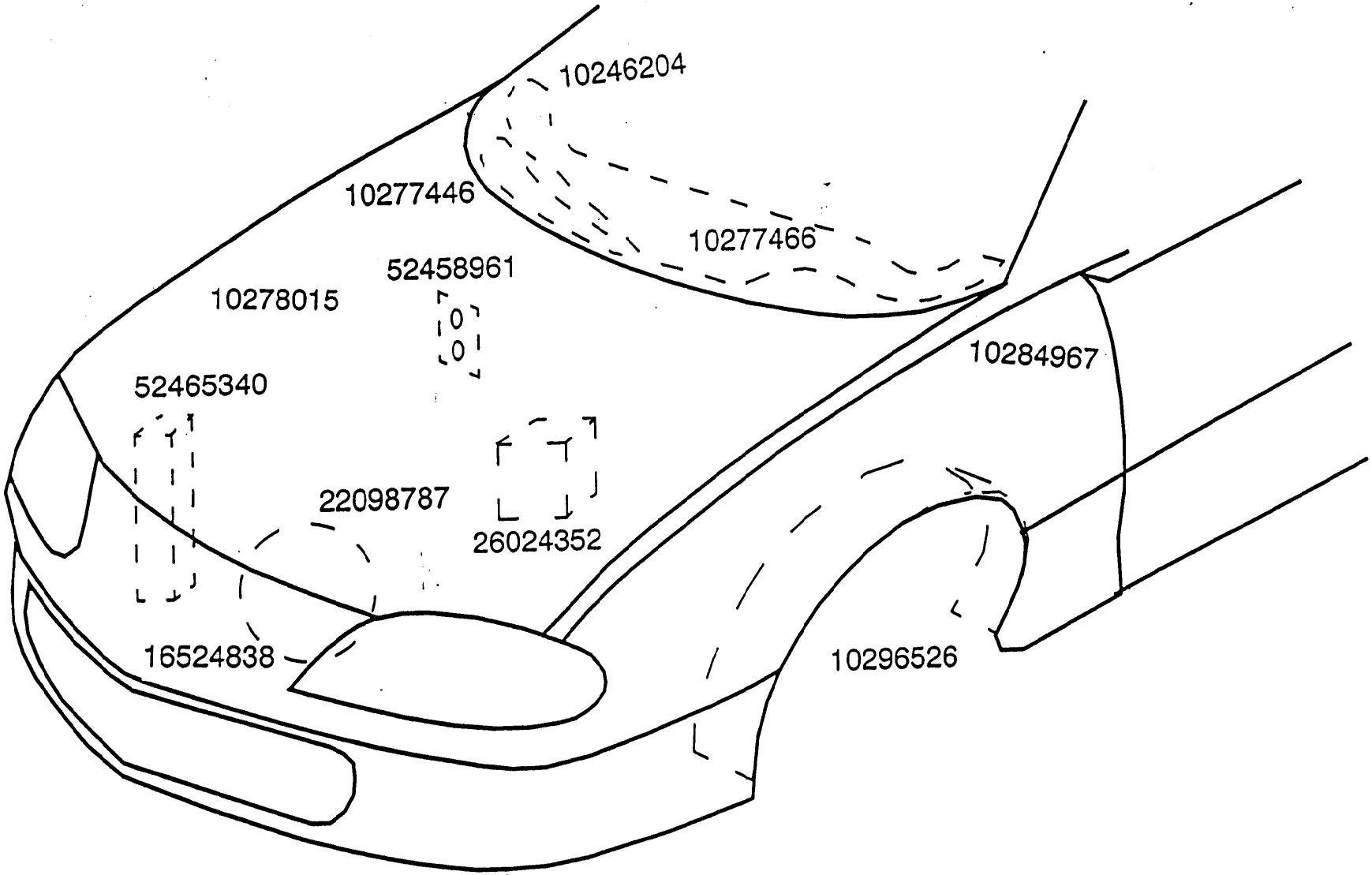

Figure 1: Schematic Diagram Showing the Location of Components in the Camaro. (B) Top View of Engine Compartment.

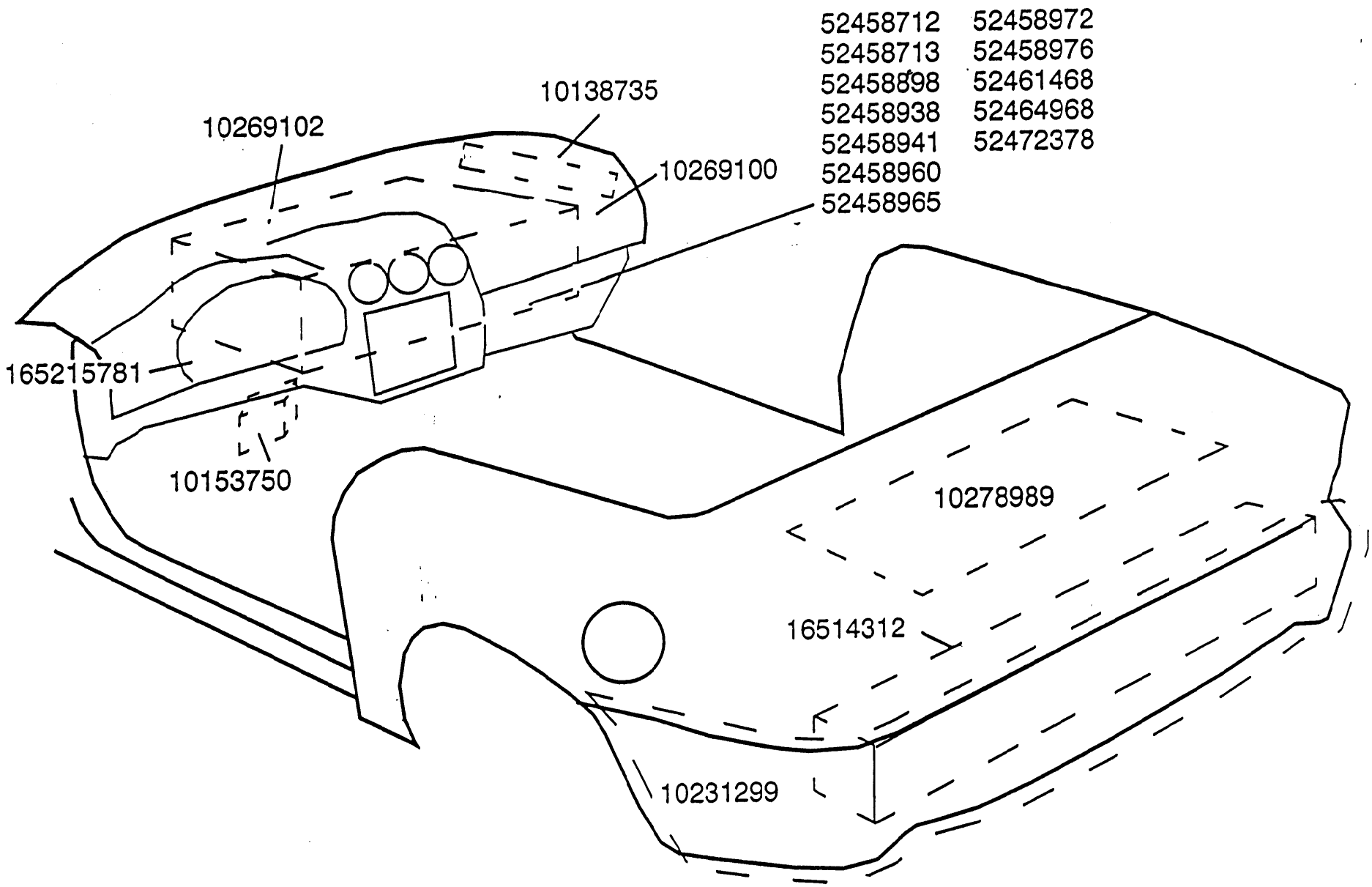

Figure 1: Schematic Diagram Showing the Location of Components in the Camaro. (C) Side View.

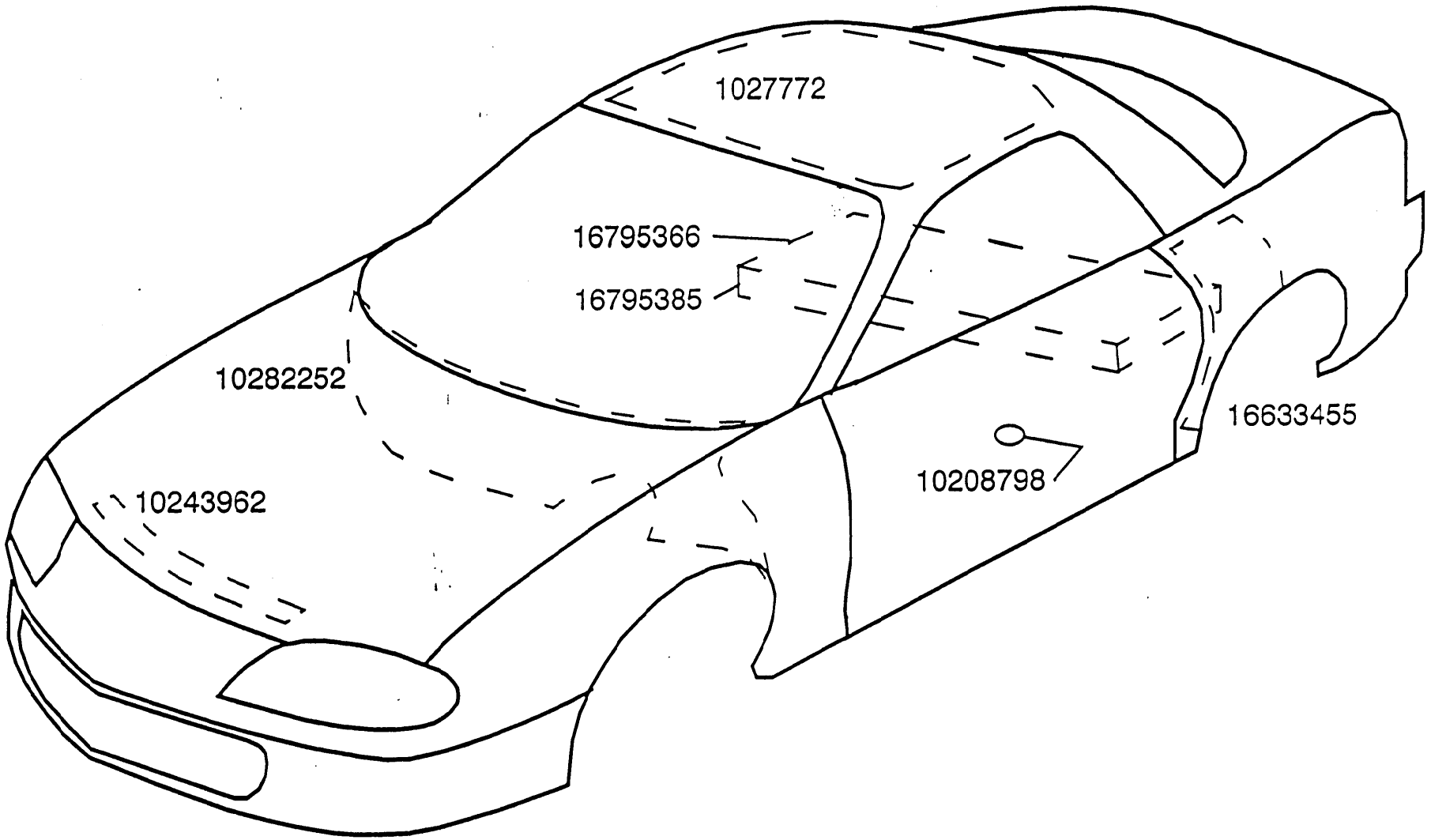

Figure 2: High Resolution Thermal Gravimetric Analysis of Polypropylene
Part # 10278989B Conducted in Nitrogen.

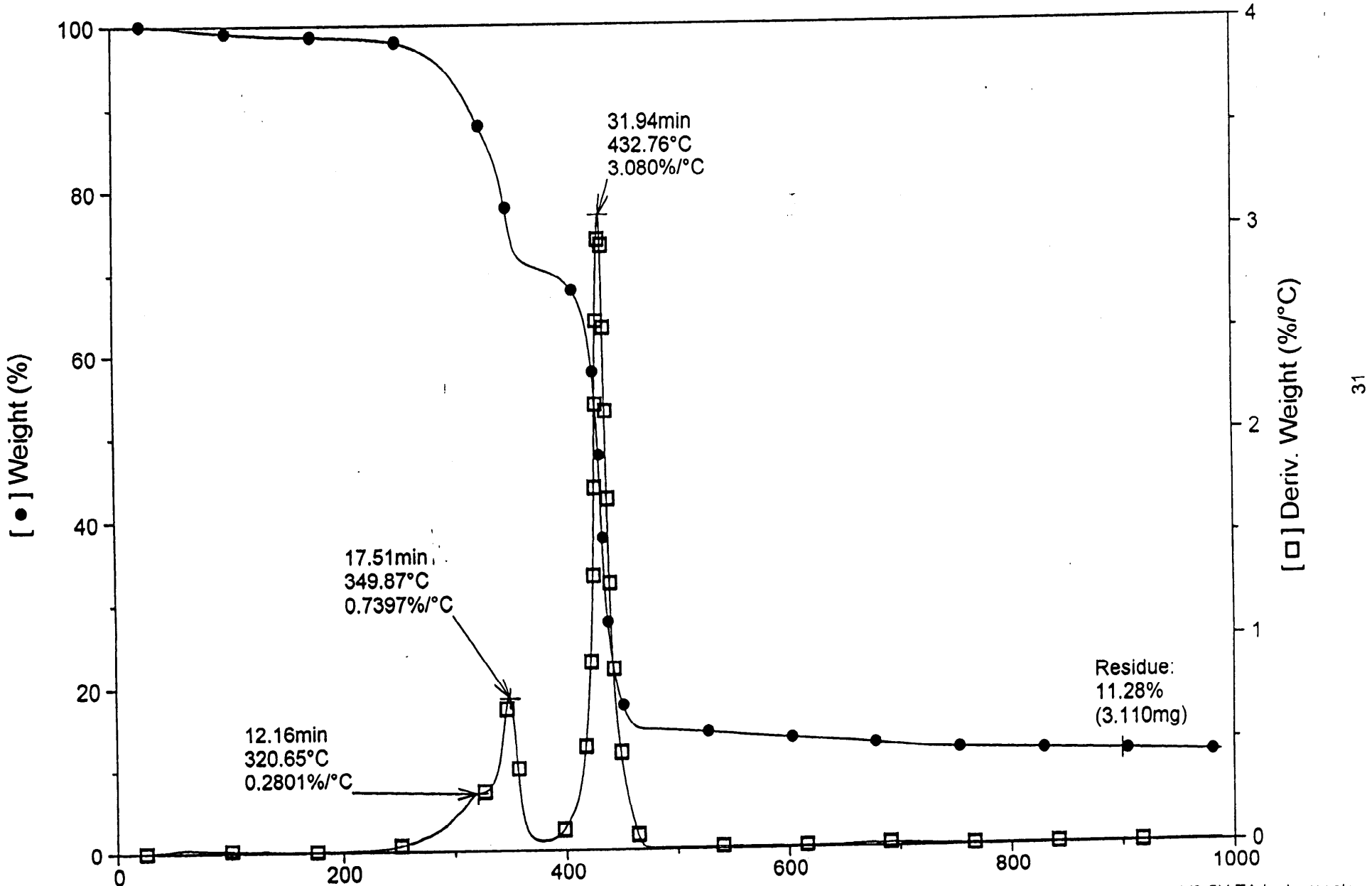

Figure 3: High Resolution Thermal Gravimetric Analysis of Polypropylene
Part # 10278989B Conducted in Air.

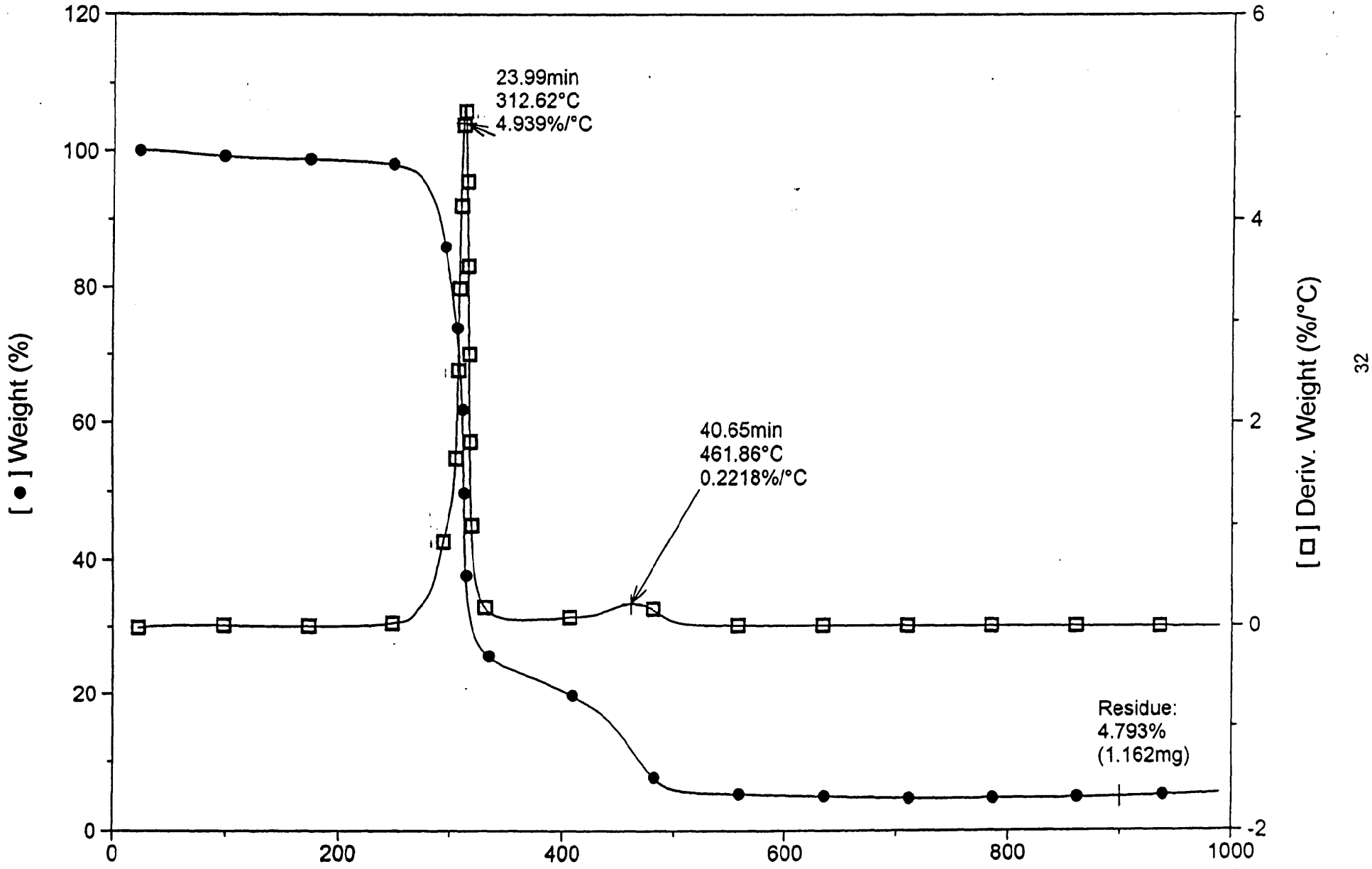

Figure 4: High Resolution Thermal Gravimetric Analysis of Nylon
Part # 10277772A Conducted in Nitrogen.

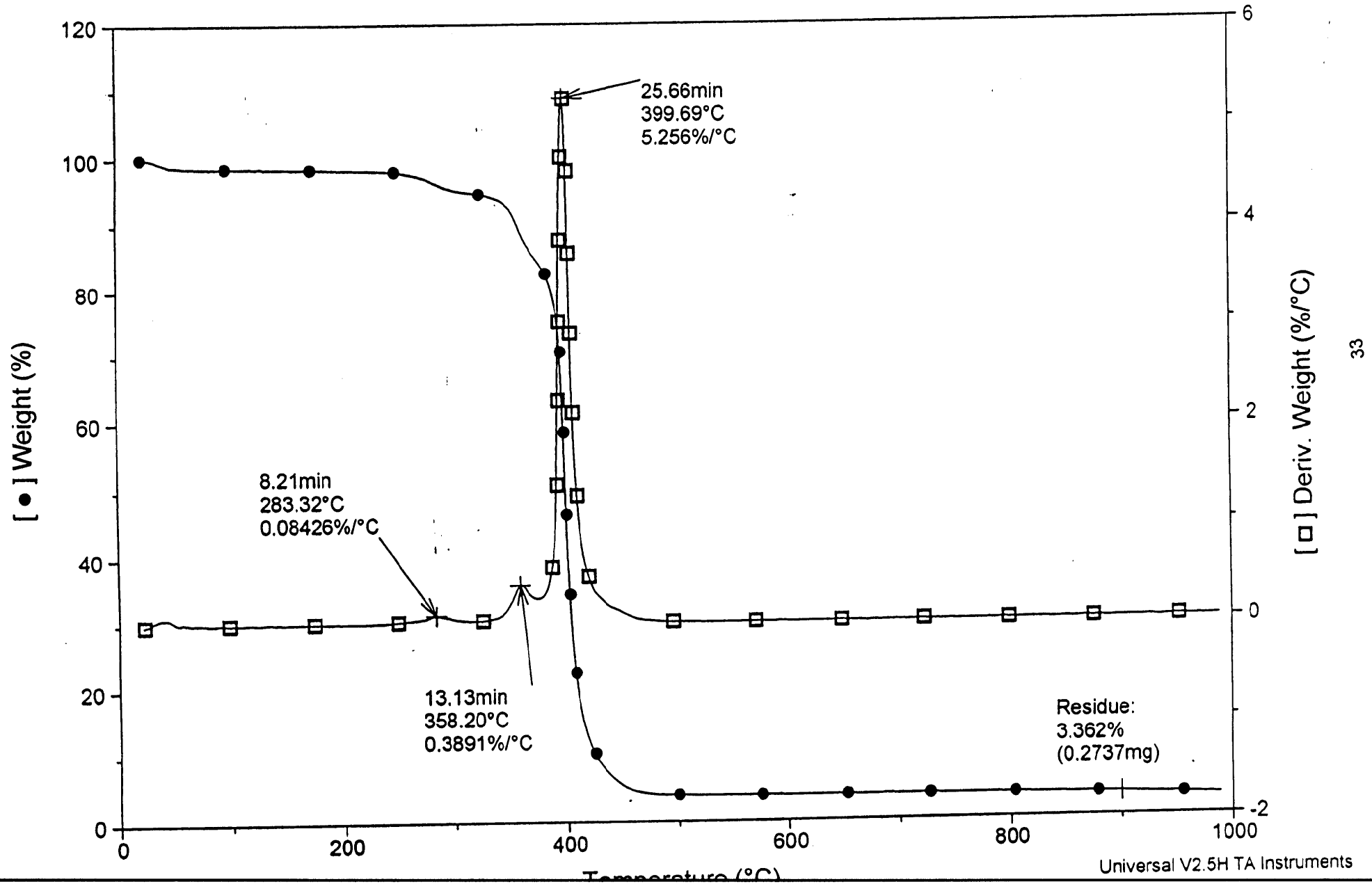

Figure 5: High Resolution Thermal Gravimetric Analysis of Nylon
Part # 10277772A Conducted in Air.

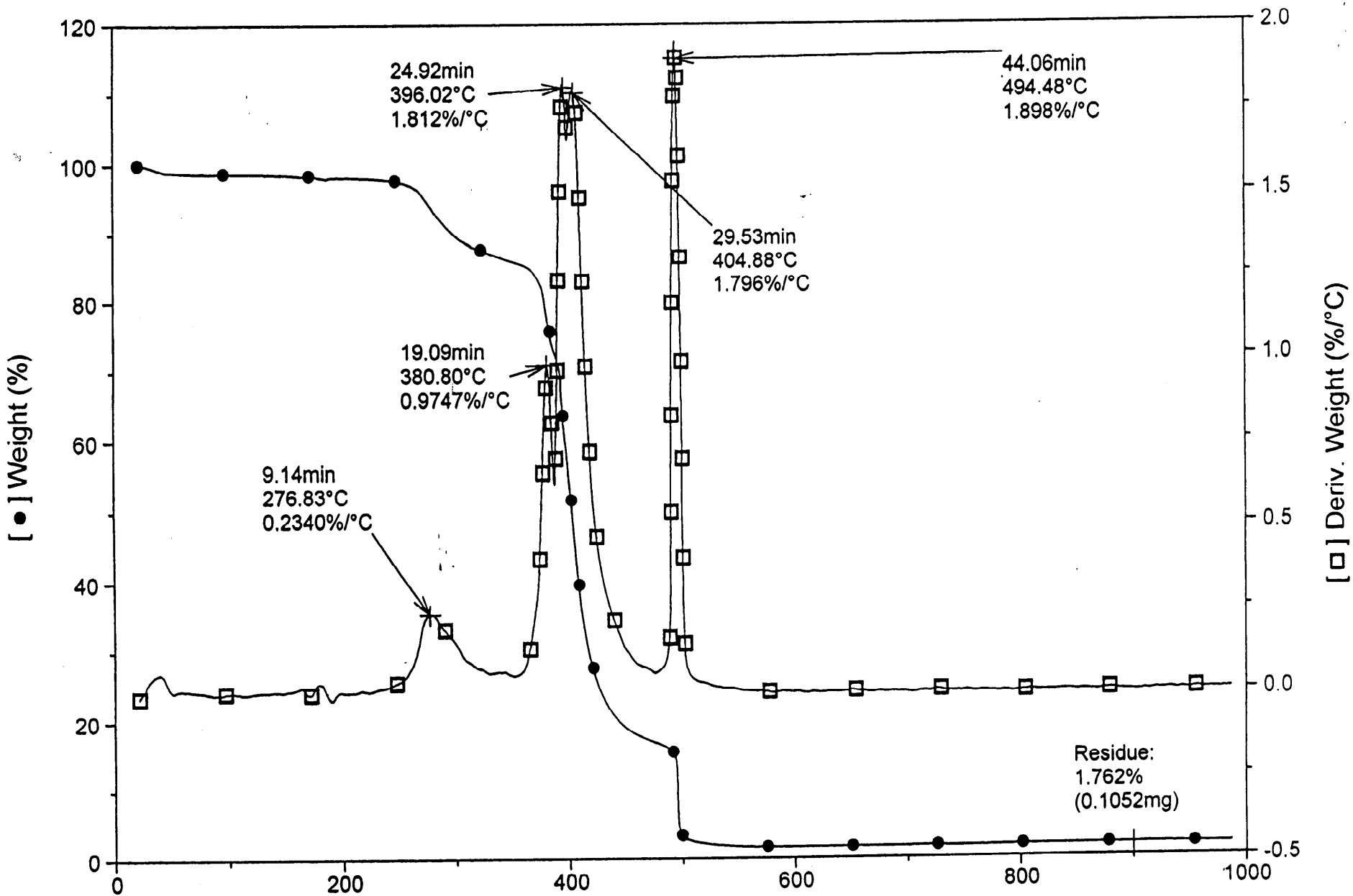

Figure 6: High Resolution Thermal Gravimetric Analysis of Phenolic Resins
Part # 10277772C Conducted in Air.

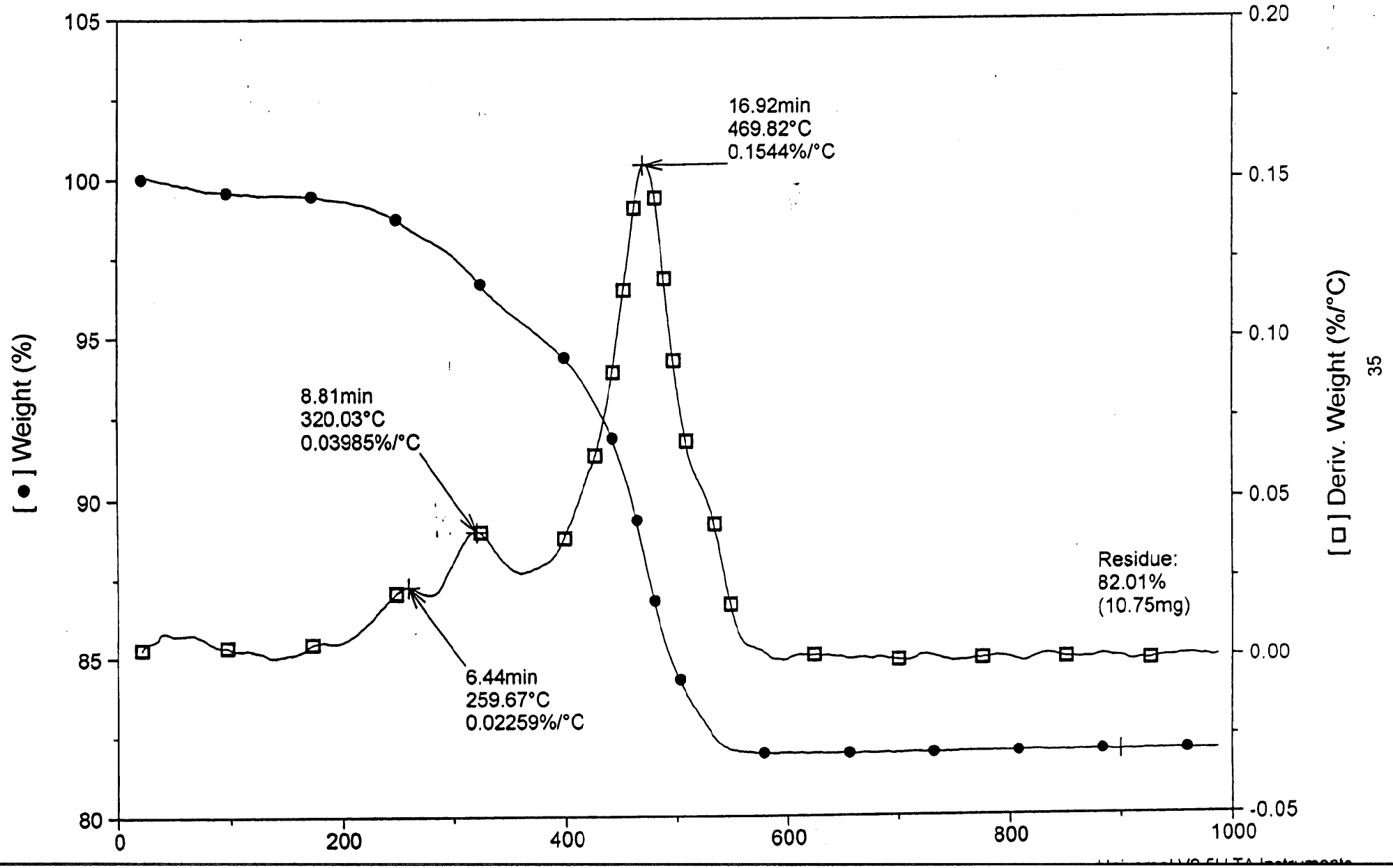

Figure 7: High Resolution Thermal Gravimetric Analysis of Phenolic Resins
Part # 10277772C Conducted in Nitrogen.

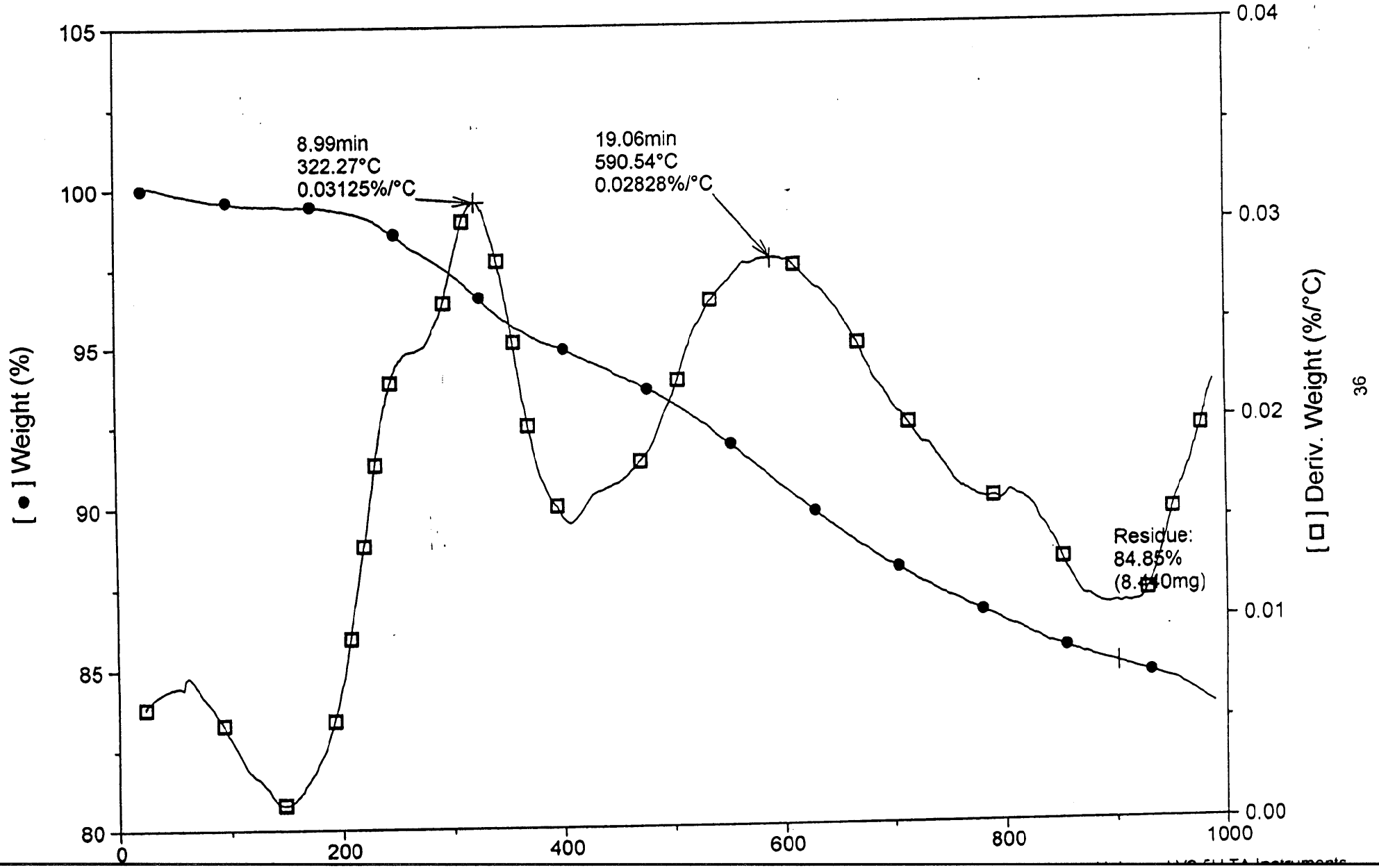

Figure 8: High Resolution Thermal Gravimetric Analysis of Ethylene Vinyl Acetate Foam Part # 10269102B Conducted in Air.

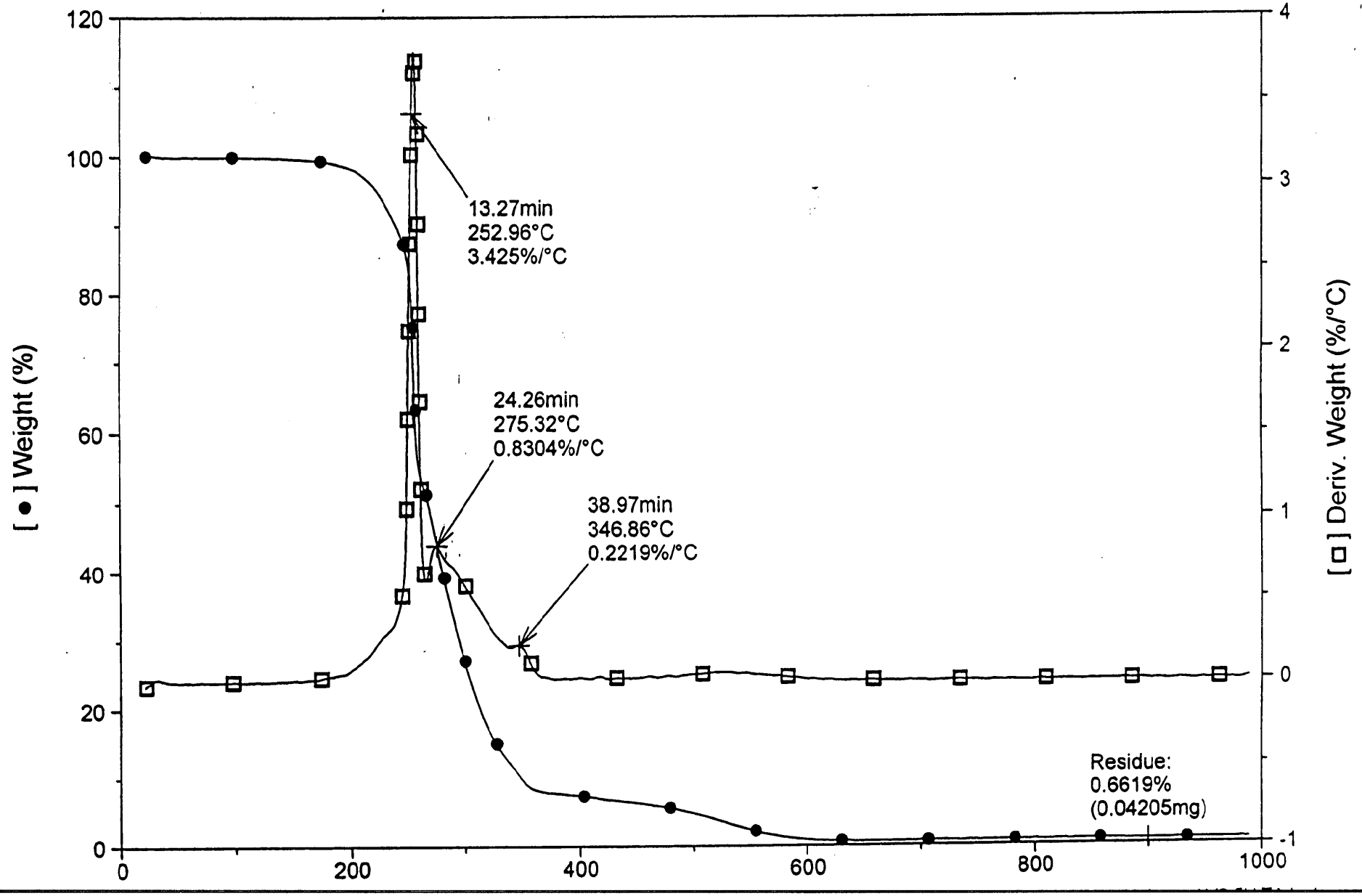

Figure 9: MDSC Charts for Nylon 6 Part # 22098787 Taken from Camaro Coolant Fan Showing Overall Heat Flow, Reversible and Non-reversible Heat Flow.

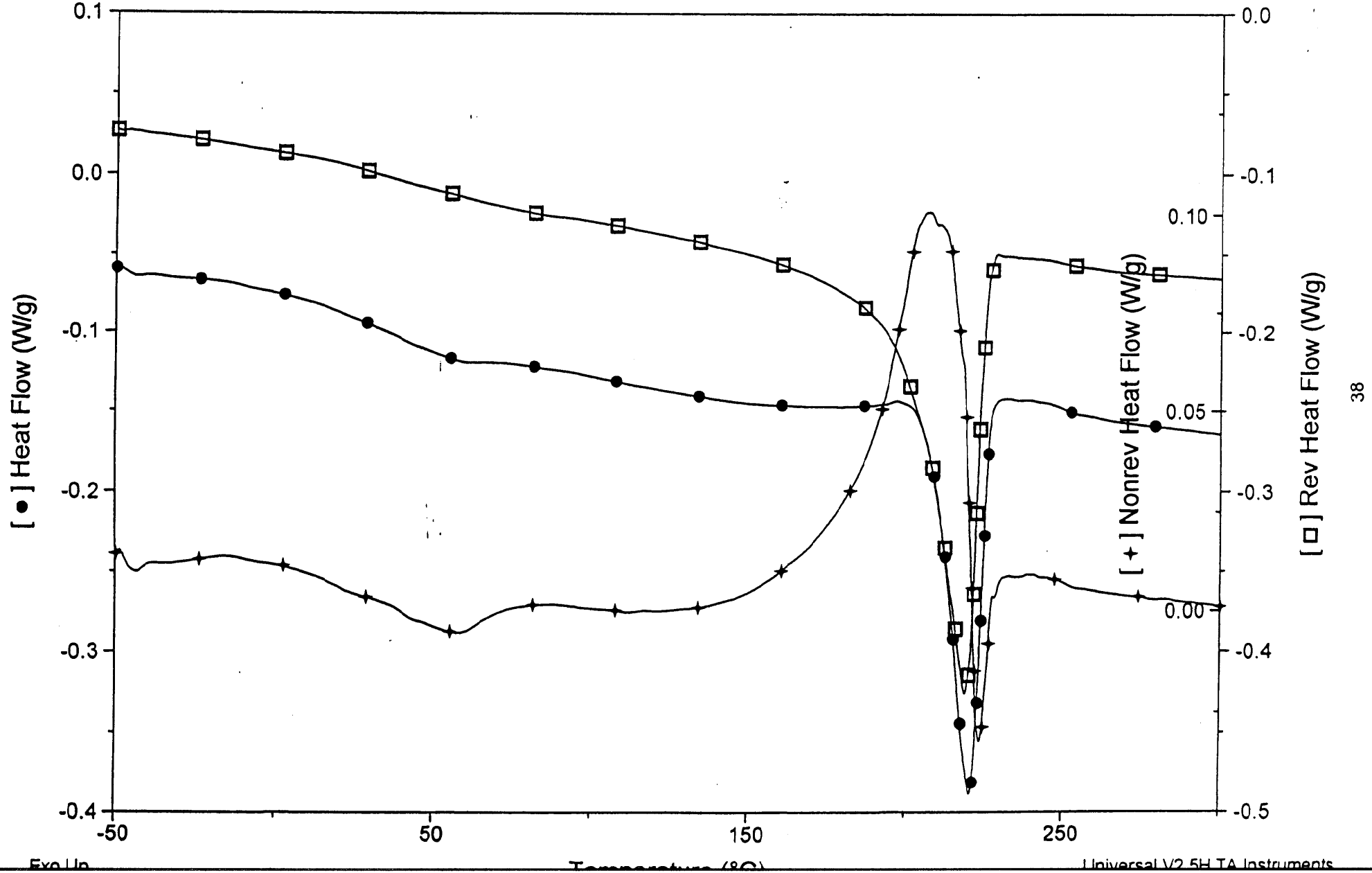

Figure 10: MDSC Chart for Nylon 6 Part # 22098787 Taken from Camaro Engine Coolant Fan Showing Glass Transition Temperature, Heat of Fusion, and Melting Point.

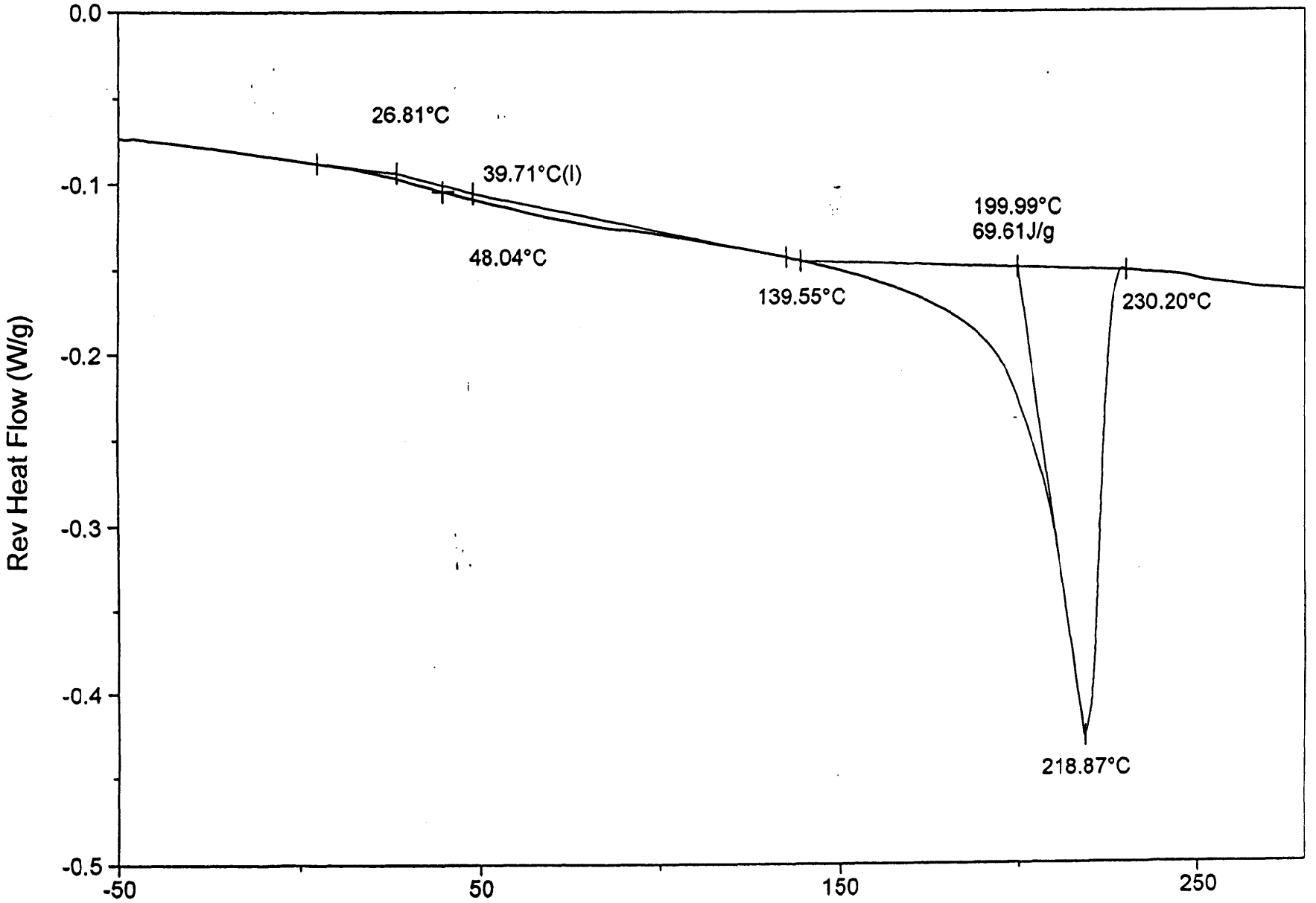

Figure 11: MDSC Chart for Nylon 6 Part # 22098787 Taken from Camaro Engine Coolant Fan Showing Heat Capacity versus Temperature.