te technical note tech

Chemical Analysis of Pump Motor Housing Components from the DC-9 Ramp Fire at Barranquilla, Columbia, in March 1995

Louise C. Speitel

February 1996

DOT/FAA/AR-TN95/92

Document is on file at the Technical Center
Library, Atlantic City International Airport, NJ 08405

U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City International Airport, NJ 08405

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-TN95/92		

4. Title and Subtitle	5. Report Date
CHEMICAL ANALYSIS OF PUMP MOTOR HOUSING COMPONENTS FROM THE DC-9 RAMP FIRE AT BARRANQUILLA, COLUMBIA, IN MARCH 1995	February 1996
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Louise C. Speitel	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Airport and Aircraft Safety Research and Development Division FAA Technical Center Atlantic City International Airport, NJ 08405	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Aviation Administration Office of Aviation Research Washington, D.C. 20591	Technical Note
	14. Sponsoring Agency Code AAR-422

15. Supplementary Notes

16. Abstract

This document describes the methodology for identifying unknown pump motor housing materials suspected of being involved in the propagation of a ramp fire aboard a DC-9 aircraft. The DC-9 was gutted from a fire believed to have originated in the vicinity of this lavatory pump motor. The ramp fire started after power up in Barranquilla, Columbia. The National Transportation Safety Board requested the FAA to identify the pump motor housing components to assist the investigation of the incident.

The flammability of the identified pump motor housing components was reviewed. The acetal copolymer, the principal component, is known to sustain continued combustion in the presence of a small ignition source and may have contributed to the spread of the fire. Acetal polymers may not be an appropriate fire-safe material for this application.

17. Key Words	18. Distribution Statement
Ramp fire, Chemical analysis Aircraft incident, Material identification	Document is on file at the Technical Center Library, Atlantic City International Airport, NJ 08405

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	26	

ACKNOWLEDGMENTS

The author acknowledges Fred Arnold and Theresa Gigante for performing the TGA and DSC analyses of the pump housing components. The assistance of Richard E. Lyon in sharing his knowledge of polymer chemistry is appreciated.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

OBJECTIVES.

An investigation was conducted to identify the composition of the plastic components of the flush motor pump housing suspected of being involved in the propagation of the fire aboard a DC-9 aircraft in Barranquilla, Columbia. The flammability of the identified plastic components was also reviewed to determine if these plastics are appropriate fire-safe materials for this application.

BACKGROUND.

The DC-9 was gutted by a fire while parked at the ramp. The fire was believed to have originated in the vicinity of the lavatory pump motor. The ramp fire started after Auxiliary Power Unit (APU) power up. The National Transportation Safety Board (NTSB) requested that the FAA identify the material in the pump housing components to assist the investigation of the incident.

TEST MATERIALS.

The configuration of the pump components and tank are illustrated in figure 1. Three materials were analyzed from the lavatory pump motor housing. Each of these materials could have served as a fuel source in the ensuing fire.

- A rigid circular flange (6 3/8-in. o.d.) was mounted flush with the top of the tank. The flange was intact. No melting of the flange was observed. A small section appeared to have undergone minimal thermal decomposition. There was some deformation of the surface that was mounted against the bulkhead. Approximately 7 inches of the perimeter of the rigid flange was affected.

- A paper gasket pressed against the rigid circular flange between the top of the tank and the rigid circular flange. Approximately 7 inches of the perimeter of the gasket had thermally decomposed.

- A melted thermoplastic pump motor housing was attached to the rigid circular flange. Only a small melted section of this thermoplastic housing was recovered from the accident scene, and its entire surface was charred.

CHEMICAL ANALYSIS OF SAMPLES AND RESULTS

A spectroscopic method of analysis was used to identify the pump motor housing components. Thermal decomposition analysis provided additional confirmation of the spectroscopic identification.

INSTRUMENTATION.

The equipment, instrumentation, and software utilized in this investigation are listed in table 1. IBM compatible 486, 66 MHz computers with 16 MByte random access memory were utilized for data acquisition and reduction.

TABLE 1. INSTRUMENTATION AND SOFTWARE

Instrument	Software
Carver Hydraulic Press, Model M-3925 with heated platens and digital temperature controller	
Nicolet Model 550 FTIR	OMNIC™ Software for windows, version 1.2.
	OMNIC™ Search, version 1.2.
	Hummel Polymer High Resolution Library, 1995
Perkin Elmer Model 7 DSC	7 Series/ Unix DSC Software Library, version 3.0
Perkin Elmer Model 7 TGA	7 Series/ Unix TGA Software Library, version 3.0

FOURIER TRANSFORM INFRARED ANALYSIS.

Sample films of the rigid flange and melted thermoplastic housing were pressed for Fourier Transform Infrared (FTIR) identification. A Teflon coated polyimide release film was placed under and over the sample to be pressed. The rigid flange was pressed at 35,000 pounds and 216 degrees Celsius. The melted thermoplastic was pressed at 30,000 pounds and 202 degrees Celsius.

The samples were analyzed at a 4.0 cm^{-1} resolution using a Nicolet Model 550 Fourier Transform Infrared Spectrometer. A digital search was conducted of the Expanded Hummel Polymer High Resolution Library, a 2011 spectra library with a resolution of 4 cm^{-1}. The spectra are illustrated in figures 2 and 3 for the pump's rigid flange and melted thermoplastic housing as well as the resins that provided the best match. Excellent matches were obtained for each pump housing component. The rigid flange spectra matched that of Poly(arylene ether-sulfone). Poly(arylene ether-sulfone) is Amoco Chemical's early terminology for their sulfone polymers polyethersulfone, Radel®A and polyphenylsulfone, Radel®R. Kendra Shoulders of Amoco provided FTIR spectra of Radel®A, Radel®R, and Udel®. The spectra of the rigid flange matched that of Udel®, indicating that the rigid flange is polysulfone, and not polyethersulfone or polyphenylsulfone as indicated from the Hummel Polymer Library. To confirm the identification of the rigid flange, a film was pressed of a certified sample of polysulfone, obtained from Aldrich Chemicals. An exact match was obtained by FTIR.

The melted thermoplastic housing spectra matched that of polyoxymethylene (POM), the acetal homopolymer, commonly referred to as polyacetal. Acetal copolymers are known to have infrared spectra which are difficult to distinguish from the homopolymer. There are two different acetal copolymers manufactured in the United States. They are very similar chemically and cannot be distinguished by infrared analysis. Nuclear magnetic resonance spectroscopy (nmr) is used to identify the particular acetal copolymer. The FTIR identification of the resins is illustrated in table 2. Various acetal and sulfone polymers are listed in table 3.

TABLE 2. FTIR IDENTIFICATION OF PUMP MOTOR HOUSING COMPONENTS

Pump Component	FTIR Matched Resin	Chemical Formula
Rigid Flange	Polysulfone	$\left[C_6H_4\text{-}4\text{-}C(CH_3)_2C_6H_4\text{-}4\text{-}OC_6H_4\text{-}4\text{-}SO_2C_6H_4\text{-}4\text{-}O\right]_n$
Melted Housing	Polyoxymethylene	$\left[CH_2O\right]_n$

TABLE 3. ACETAL AND SULFONE POLYMERS

Polymer Name	Chemical Name	Trade Name	United States Producers
Acetal Polymers	Polyoxymethylene (POM)	Delrin®	Dupont
	POM Copolymer	Celcon®	Hoechst Celanese
	POM Copolymer	Ultraform®	BASF
Sulfone Polymers	Polysulfone	Udel®	Amoco
	Polyethersulfone	Radel® A	Amoco
	Polyphenylsulfone	Radel® R	Amoco

<u>THERMAL METHODS OF ANALYSIS</u>.

Differential Scanning Calorimetry (DSC) and Thermal Gravimetric Analysis (TGA) were performed on the sample materials to confirm the identification of the pump housing components. The sample heating rate for both techniques was 10 degrees Celsius per minute. Sample weights ranged from 0.3 to 1.5 mg. The DSC was run in nitrogen. The TGA was run with a nitrogen purge of approximately 50 cc/minute. A TGA analysis was also run in air for each of the three pump materials. TGA was also run on certified samples of polysulfone and polyoxymethylene obtained from Aldrich Chemicals.

DIFFERENTIAL SCANNING CALORIMETRY. The DSC thermograms for the plastic housing components are illustrated in figures 4 through 6. The DSC results along with reference data for sulfone and acetal polymers are listed in table 4.

TABLE 4. DSC ANALYSIS OF PUMP MOTOR HOUSING COMPONENTS

Material	Melting Point Onset (°C)	Peak Melting Point (°C)	Melting Point Range (°C)	Glass Transition Temperature (°C)
Rigid Flange	None	None	None	188
Polysulfone	None	None	None	190[1]
Polyethersulfone	None	None	None	225[2]
Polyphenylsulfone	None	None	None	220[3]
Melted Pump Housing	159.9	165.5	130-170	
Acetal Homopolymer		175[5] - 181[4]	178-329[2]	
Acetal Copolymer		165[5]		

The rigid flange did not melt within the 50 to 400°C temperature range which is consistent with the amorphous, noncrystaline structure of sulfone polymers. Its glass transition temperature of 188°C is consistent with the polysulfone.

The melted thermoplastic housing has a lower melting point than acetal homopolymer. The observed melting points are consistent with melting points reported for acetal copolymers.

THERMAL GRAVIMETRIC ANALYSIS. The TGA thermograms for each pump component along with the FTIR matching polymer are illustrated in figures 7 through 10. The TGA curves for the paper gasket are illustrated in figures 11 through 12. The TGA results are listed in table 5. The decomposition temperatures of the melted pump housing are consistent with that of acetal copolymers. The decomposition temperatures of the rigid flange are consistent with polysulfone.

TABLE 5. TGA ANALYSIS OF PUMP MOTOR HOUSING COMPONENTS

	Heated in nitrogen				Heated in air			
Material	Onset (°C)	Peak Weight Loss Temp. (°C)	Weight Loss Temp. Range (°C)	Weight Percent Residue at 700°C	Onset (°C)	Peak Weight Loss Temp. (°C)	Weight Loss Temp. Range (°C)	Weight Percent Residue at 700°C
Rigid Flange	517	536	478-621	42	502	527	435-653	13
Polysulfone	526	544	424-546	33	512	548	420-675	0
Melted Pump Housing	365	398	315-424	0	255	276	242-298	0
POM	322	351	290-404	0	276	277	240-281	0
Gasket		370	150-700	54		505	243-328	40

FLAMMABILITY OF PUMP MOTOR HOUSING COMPONENTS.

All acetal copolymers are flammable and sustain continued combustion when subjected to Underwriters Laboratory's test UL94. An UL94HB rating has been attained for all acetal homopolymers and copolymers. An HB rating indicates that using a Bunsen burner as an ignition source under specified conditions with a horizontally mounted sample, bars 1/2 in. and less ignite and continue to burn after the flame is removed . The burning rate for 1/8- to 1/2-in.-thick bars is less than 1.5 in. per minute. Bars less than 1/8 in. thick burn at less than 3 in. per minute. An HB designation also indicates that the sample stops burning before the 4-in. mark.

Sulfone Polymers do not support combustion when subjected to the UL94 flammability test, will exhibit no flaming, but may drip. The sulfone polymers have a UL94 V-0 flammability rating.

SUMMARY OF RESULTS

1. The FTIR analysis gave an excellent spectral match for the two plastic components of the pump housing. The melted thermoplastic's spectrum matched that of polyoxymethylene, the acetal homopolymer. FTIR does not rule out acetal copolymers. The rigid flange's spectrum matched that of polysulfone.

2. The DSC analysis of the rigid flange confirmed that it is an amorphous, noncrystaline polymer, substantiating the FTIR identification of polysulfone. The glass transition temperature was also consistent with a polysulfone.

3. The DSC and TGA analyses of the melted pump housing was consistent with an acetal copolymer.

4. The TGA analysis of the rigid flange is consistent with a polysulfone.

5. Sulfone polymers are commonly used for pump housings (see appendix).

CONCLUSIONS

1. The melted thermoplastic component of the pump motor housing is an acetal copolymer.

2. The rigid flange of the pump motor housing is polysulfone.

3. Since little of the melted pump motor housing was recovered from the accident scene and most of its surface was charred and since acetal copolymers sustain continued combustion when subjected to test UL94, the acetal copolymer pump motor housing may have contributed to the propagation of the DC-9 ramp fire.

4. Since acetal polymers have low melting points and sustain continued combustion when subjected to a small ignition source, they may not be an appropriate fire-safe material to be used as a pump housing in aircraft lavatorys. Polyetheretherketone or polyaryletherketone, or other high temperature thermoplastics may be more appropriate.

REFERENCES

1. J. Agranoff, Editor, Modern Plastics Encyclopedia 1985-1986, Vol. 62, Number 10A, © 1985 by McGraw-Hill, New York, NY, pp. 90-97.

2. Engineered Materials Handbook, Volume 2, Engineering Plastics, prepared under the direction of the ASM International Handbook Committee, © 1988 by ASM International, Metals Park, Ohio, pp. 145-162.

3. Preliminary Data Radel®R Polyphenylsulfone, Amoco Performance Products, Inc., Bulletin R-F-49978, Alpharetta, GA.

4. J. Brandup, E.H. Immergut, Eds., Polymer Handbook, Second Edition, © 1975, by John Wiley & Sons, Inc., New York, p. III-42.

5. I. Rubin, Ed., Handbook of Plastic Materials and Technology, © 1990 by Wiley Interscience, John Wiley and Sons, Inc., New York, 1990, pp. 11-24.

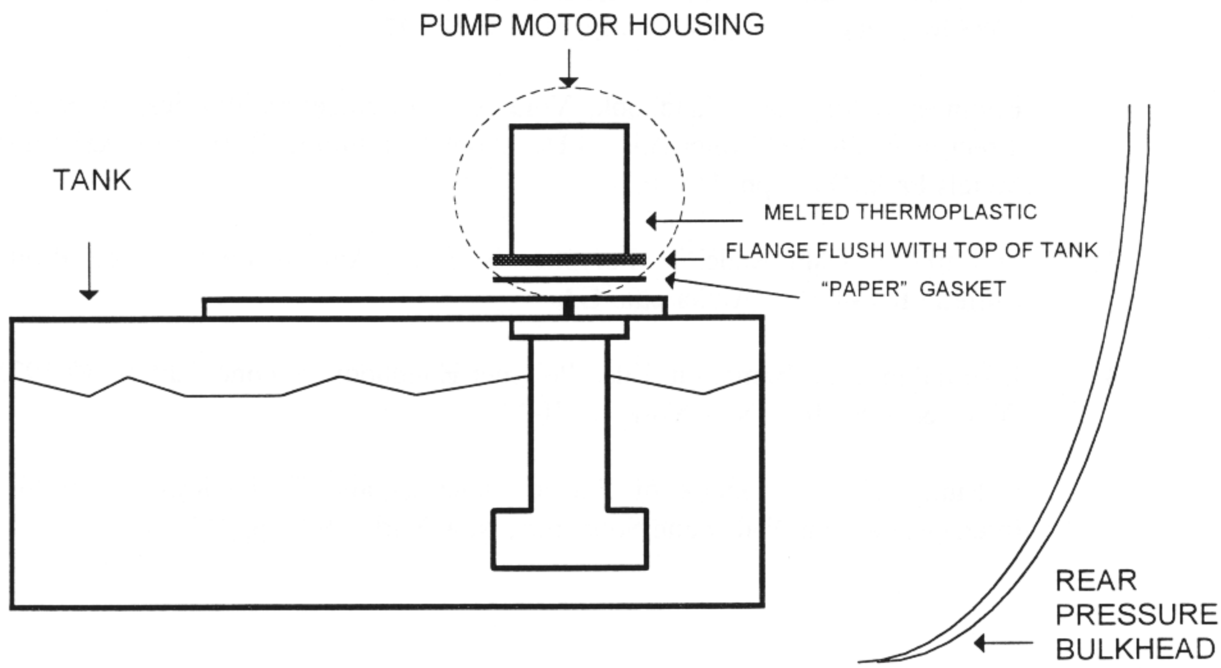

FIGURE 1. CONFIGURATION OF PUMP COMPONENTS AND TANK IN LAVATORY OF DC-9

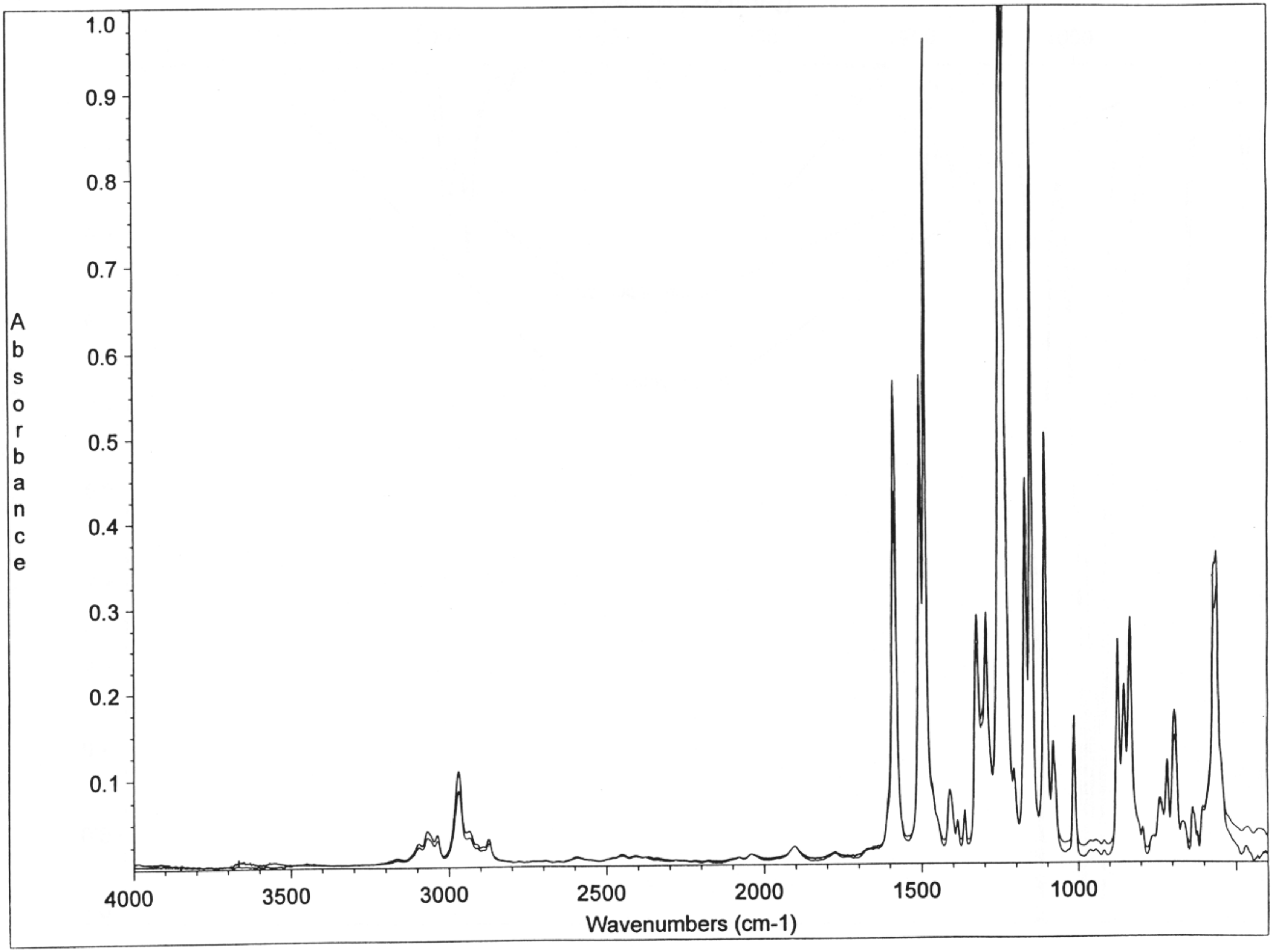

FIGURE 2. COMPARISON OF FTIR SPECTRA OF THE RIGID FLANGE AND POLYSULFONE

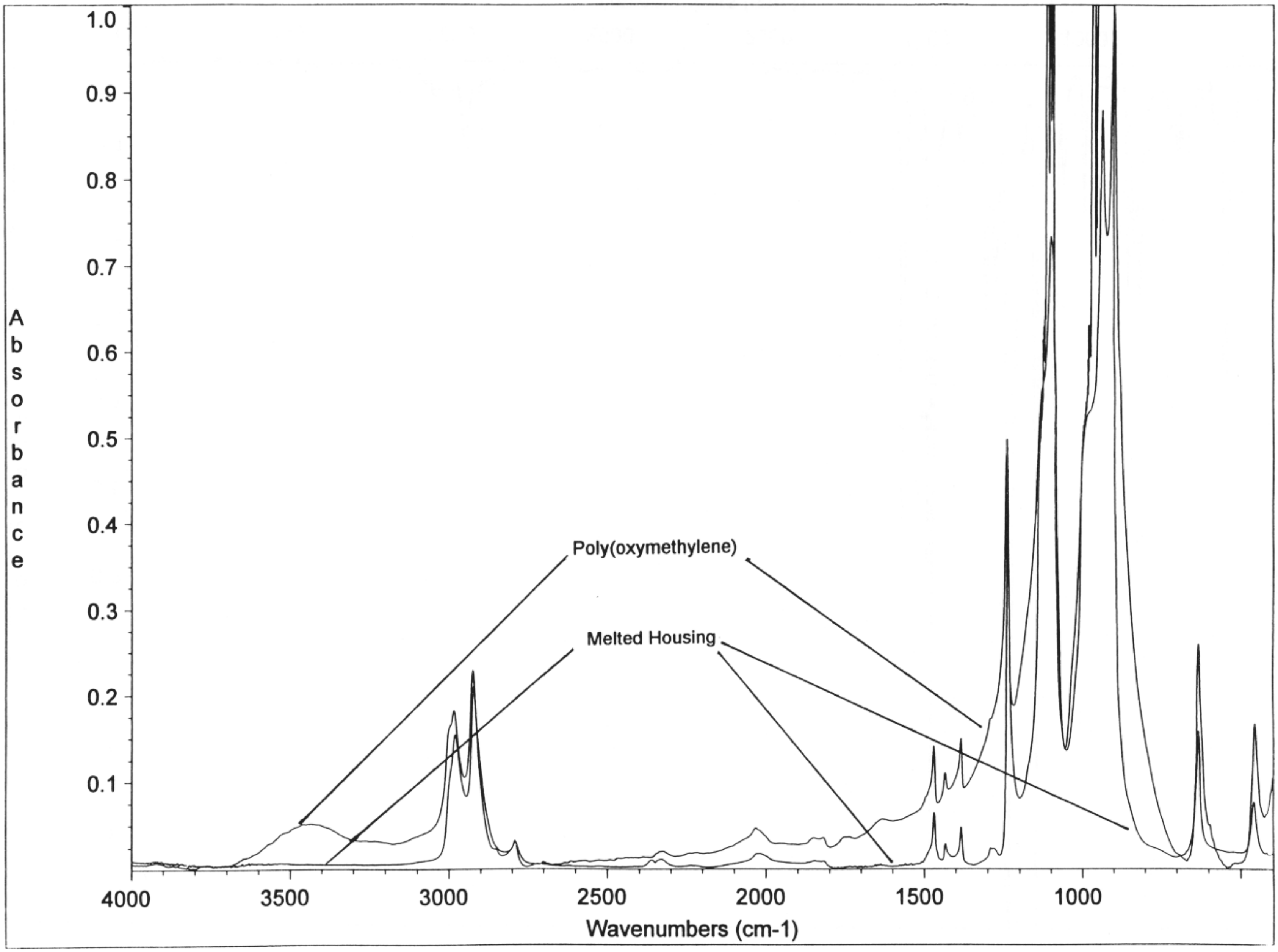

FIGURE 3. COMPARISON OF FTIR SPECTRA OF THE MELTED PUMP MOTOR HOUSING AND POLYOXYMETHYLENE

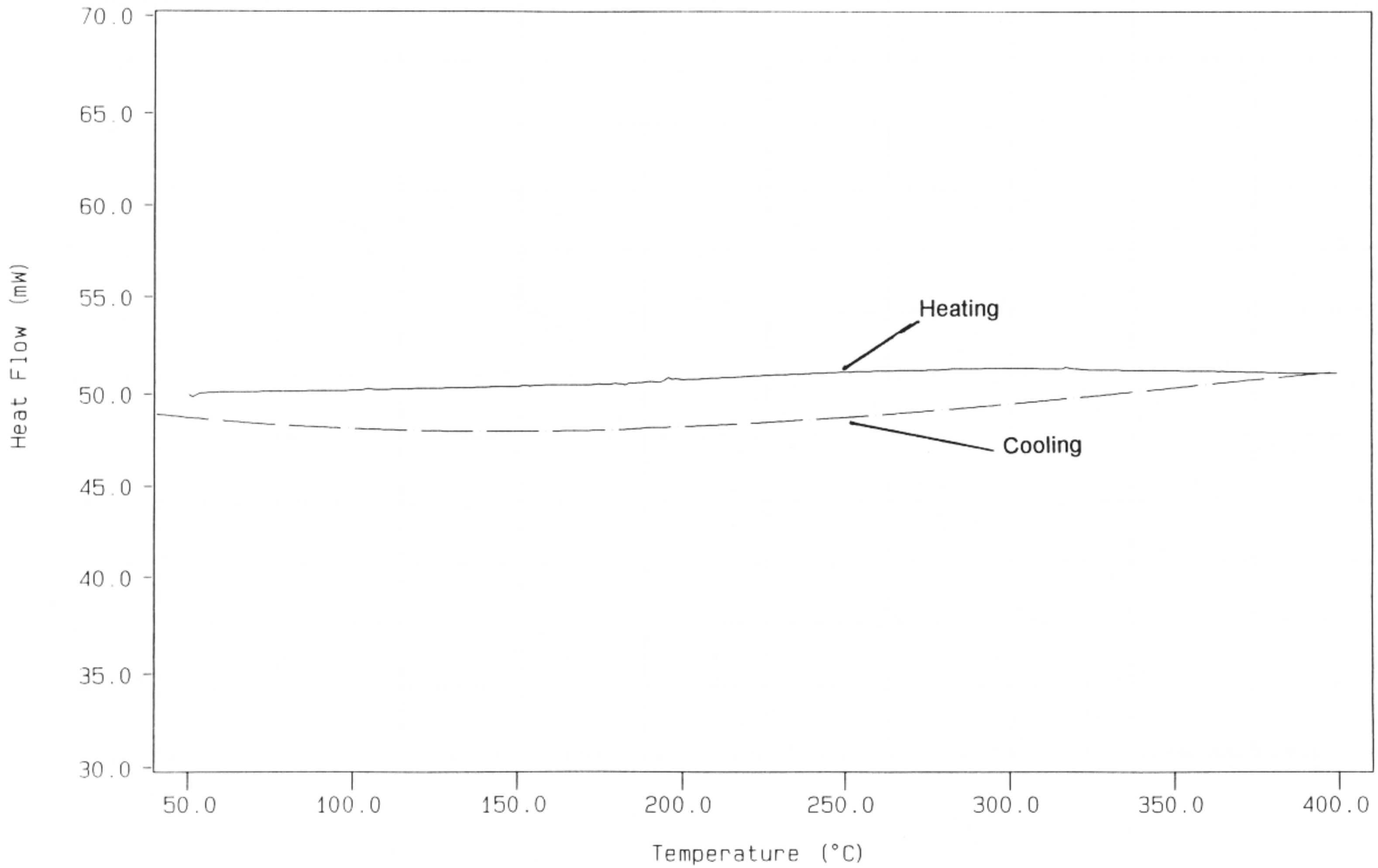

FIGURE 4. DSC THERMOGRAMS FOR THE RIGID FLANGE IN NITROGEN

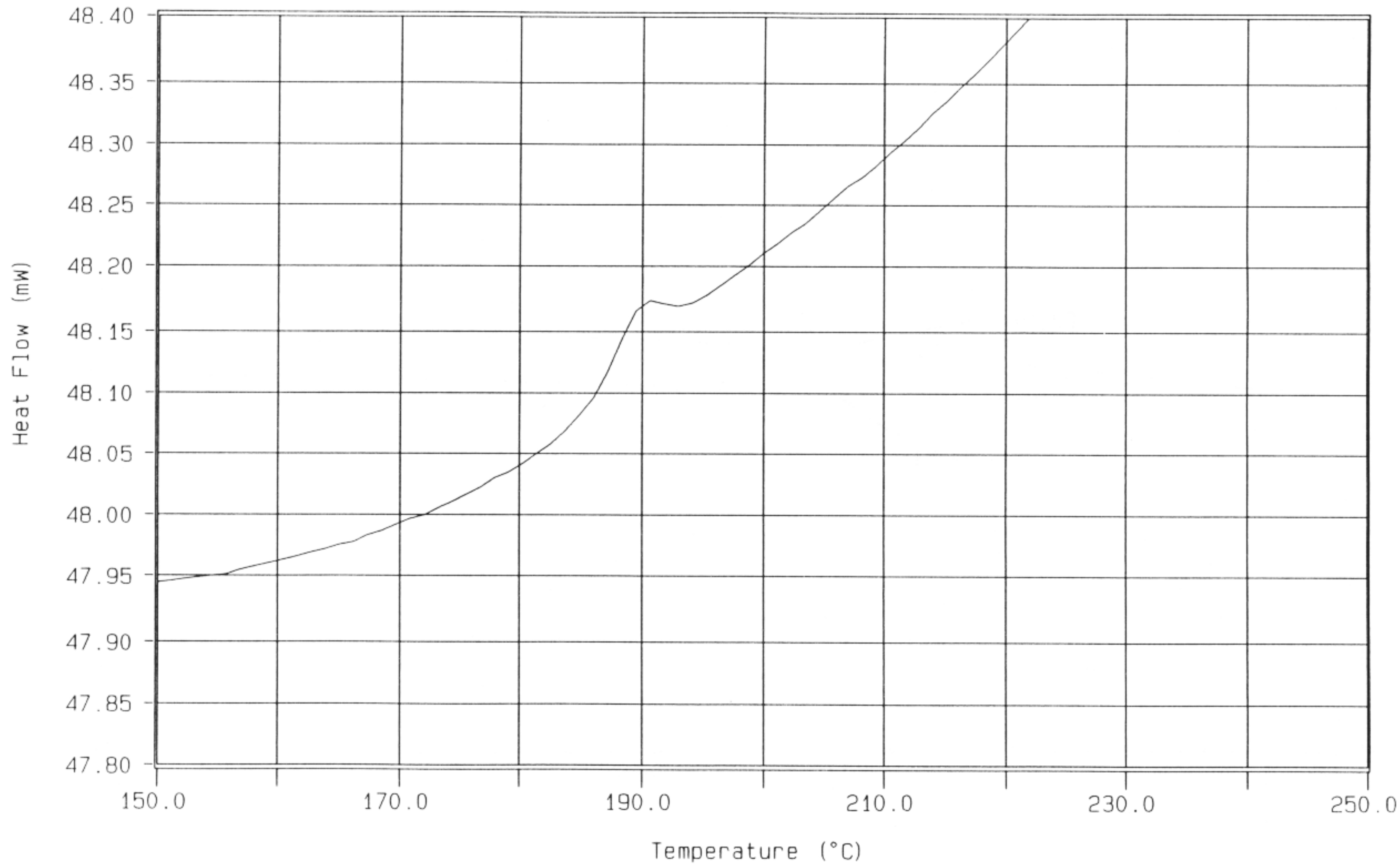

FIGURE 5. DSC THERMOGRAM FOR THE RIGID FLANGE IN NITROGEN SHOWING THE GLASS TRANSITION TEMPERATURE

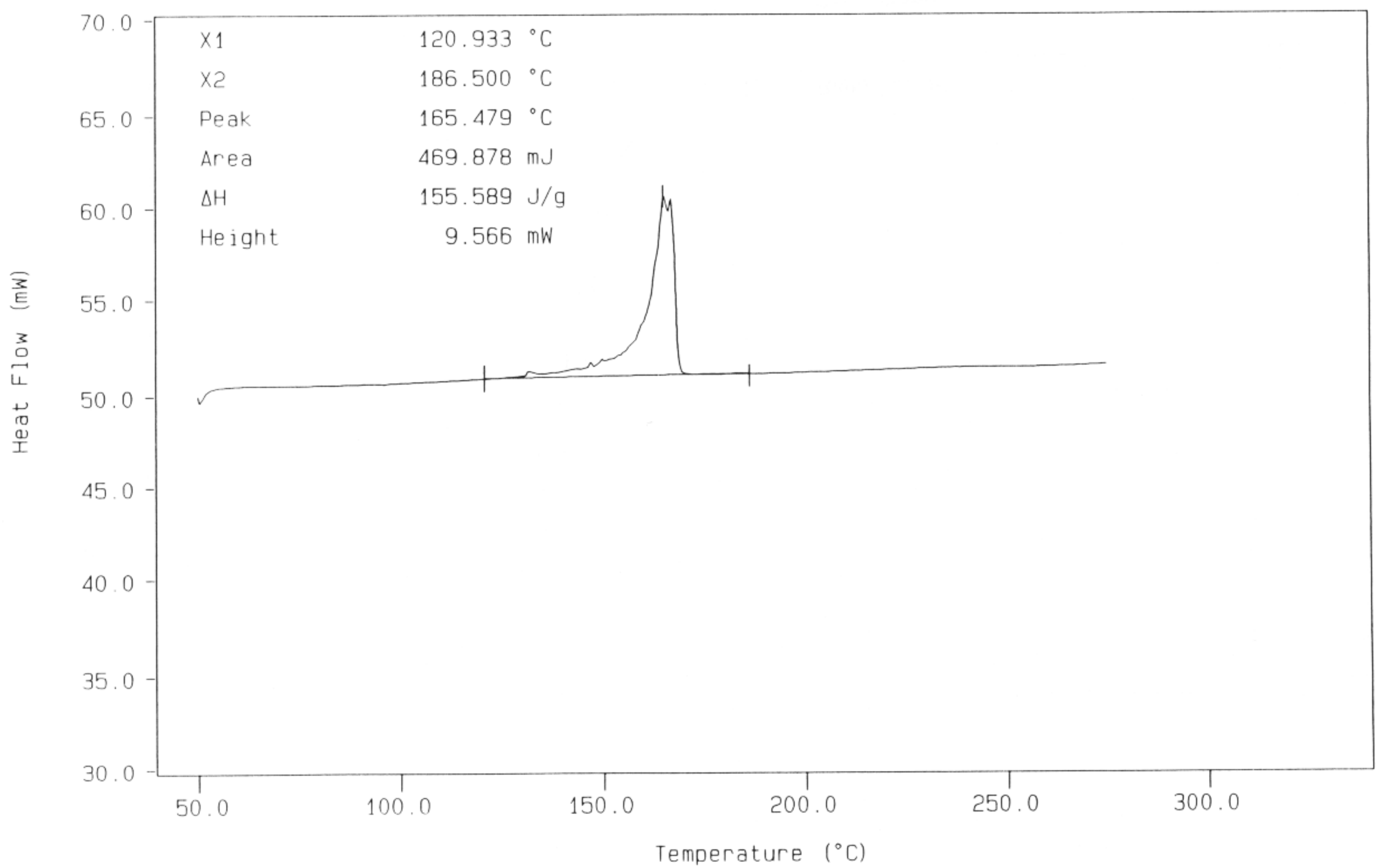

FIGURE 6. DSC THERMOGRAPHS FOR THE MELTED PUMP MOTOR HOUSING IN NITROGEN

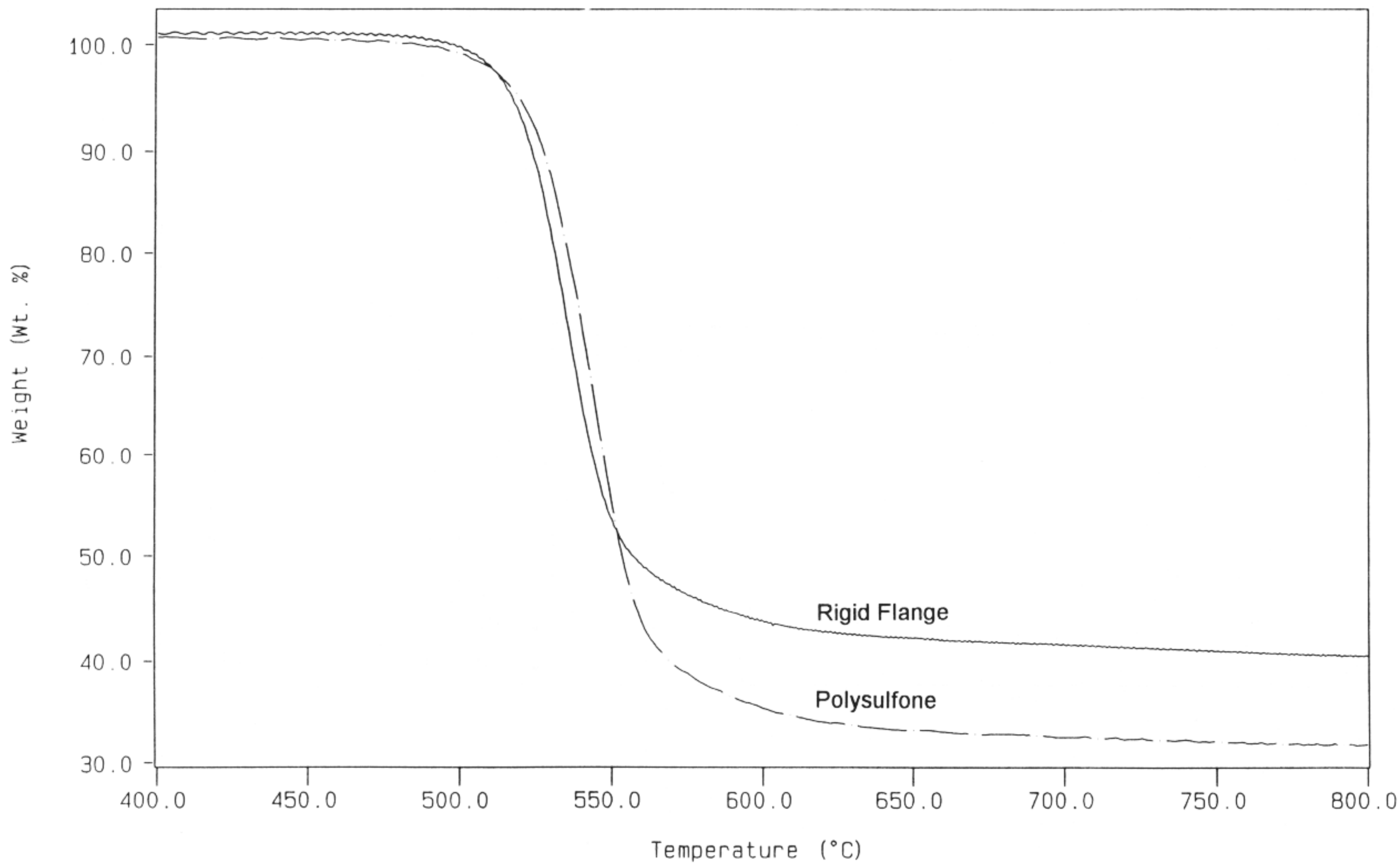

FIGURE 7. TGA THERMOGRAM FOR THE RIGID FLANGE AND POLYSULFONE IN NITROGEN

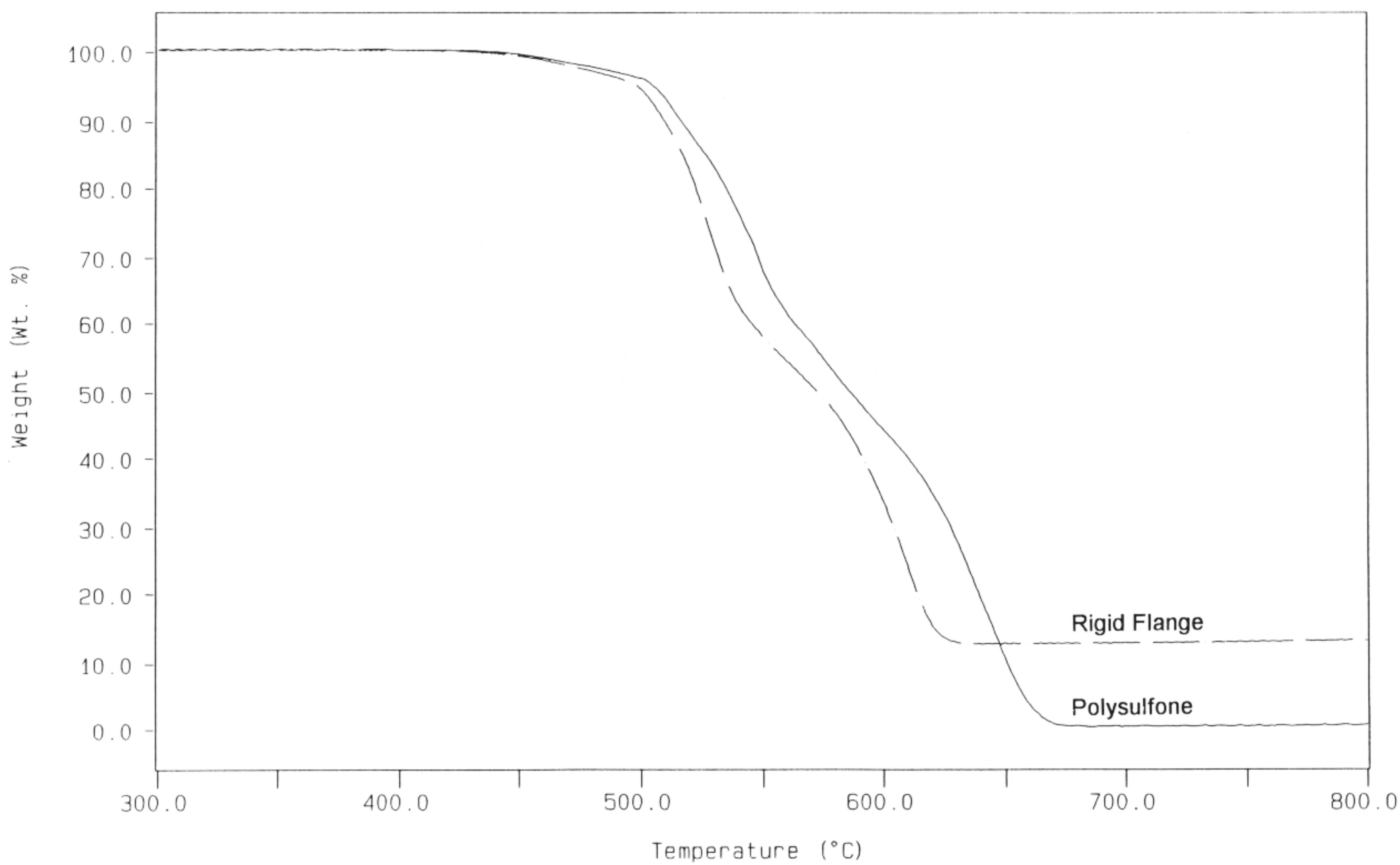

FIGURE 8. TGA THERMOGRAM FOR THE RIGID FLANGE AND POLYSULFONE IN AIR

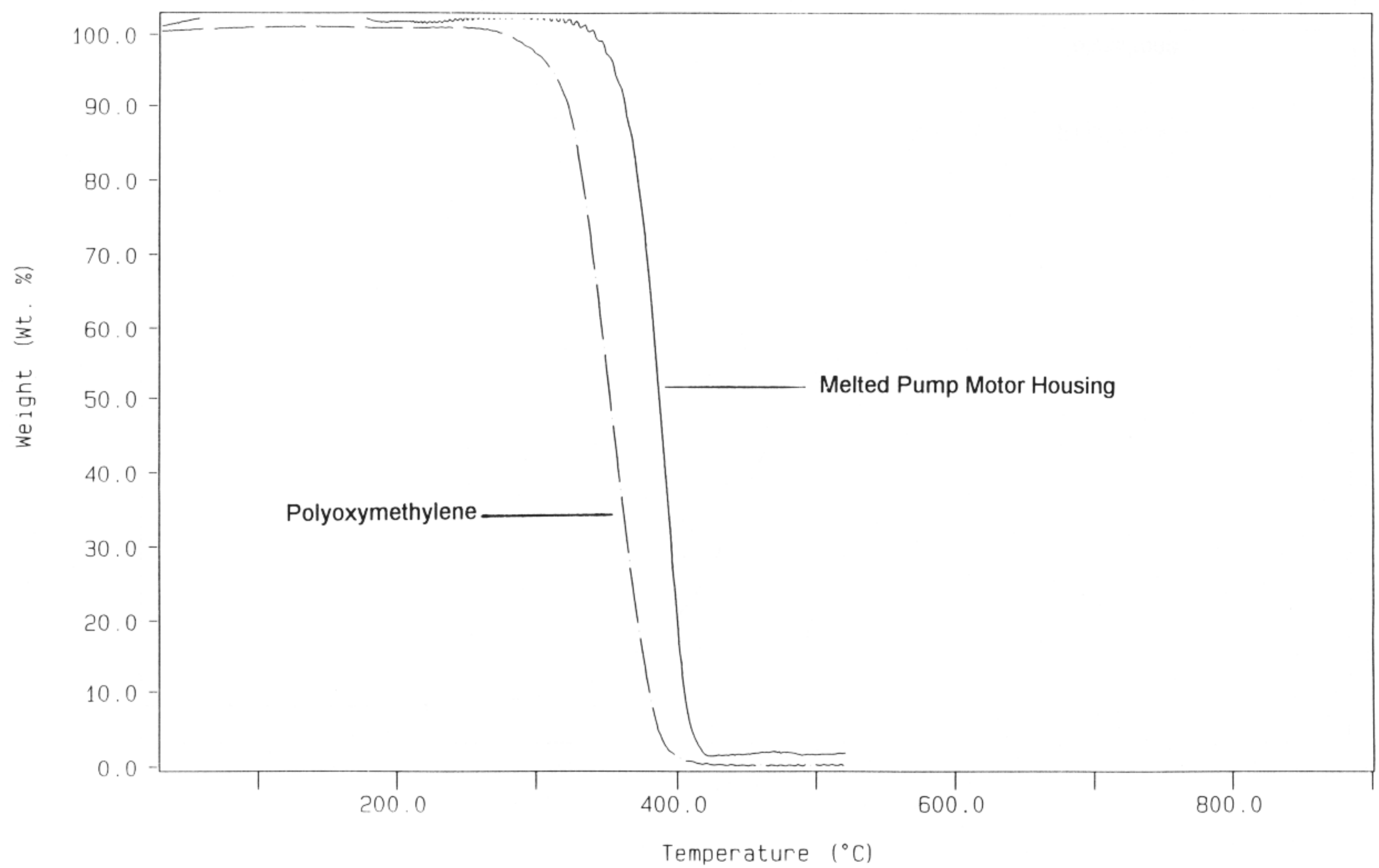

FIGURE 9. TGA THERMOGRAM FOR THE MELTED PUMP MOTOR HOUSING AND POLYOXYMETHYLENE IN NITROGEN

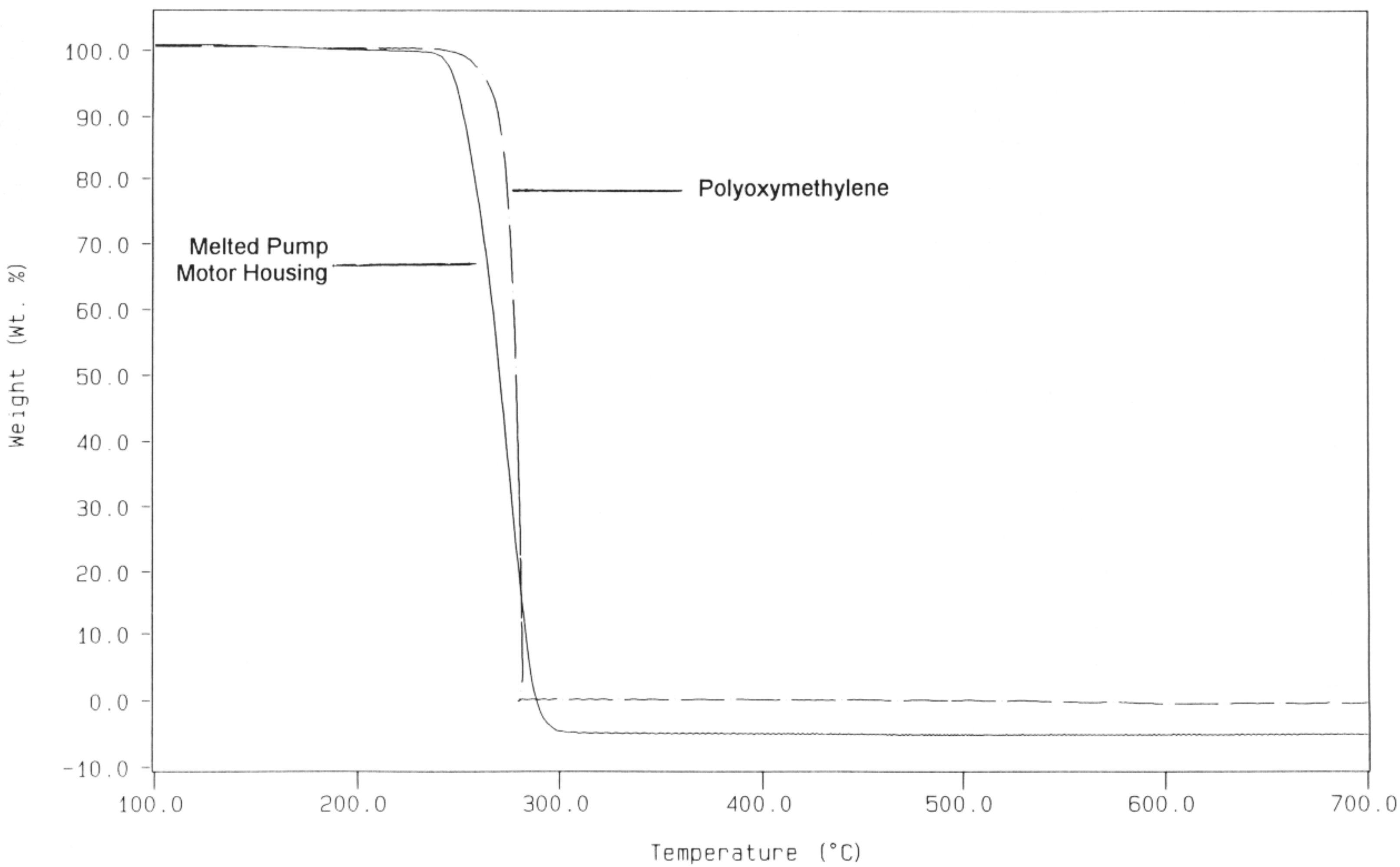

FIGURE 10. TGA THERMOGRAM FOR THE MELTED PUMP MOTOR HOUSING AND POLYOXYMETHYLENE IN AIR

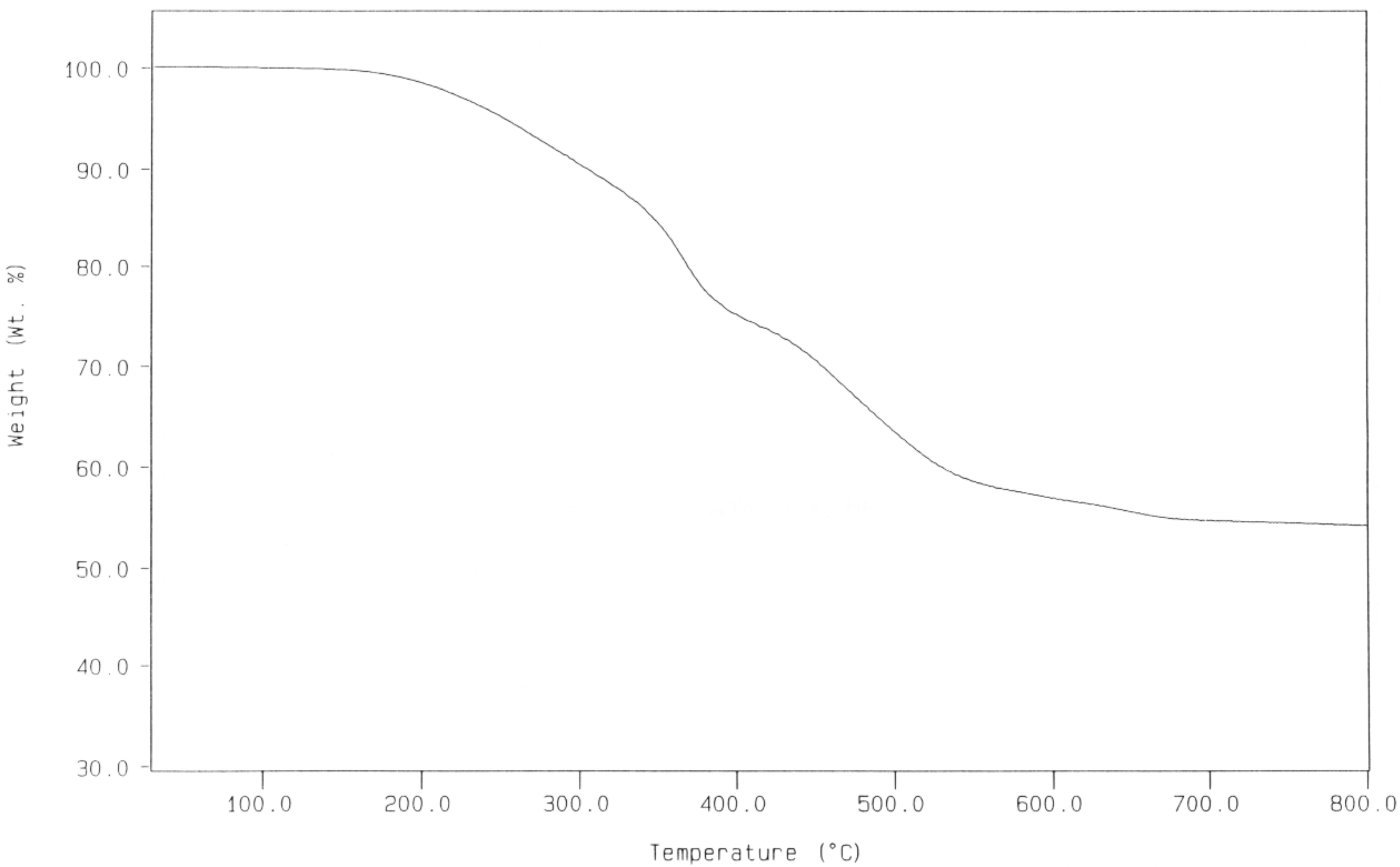

FIGURE 11. TGA THERMOGRAM FOR THE PAPER GASKET IN NITROGEN

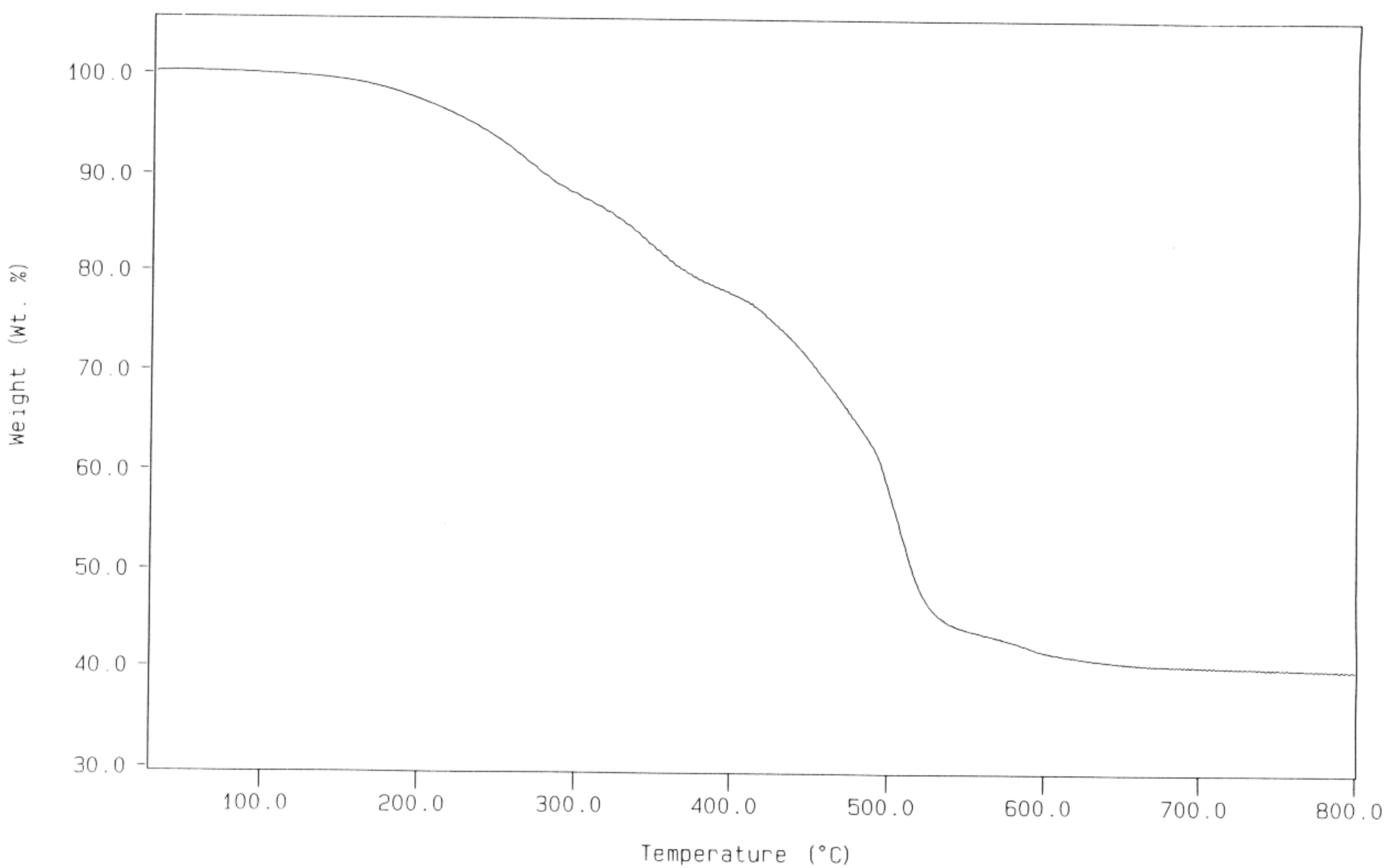

FIGURE 12. TGA THERMOGRAM FOR THE PAPER GASKET IN AIR

APPENDIX

PROPERTIES AND USES OF SULFONE POLYMERS AND ACETAL POLYMERS

Sulfone polymers are high-temperature plastics that offer outstanding thermal resistance, high impact strength, transparency, hydrolytic stability, and ease of processing. They can effectively compete in high-performance applications with metals, glass, and ceramics. This family of polymers has superior resistance to steam and boiling water.[1] Sulfone polymers have similar mechanical properties at room temperature. Uses include circuit boards, connectors, lamp housings, motor parts, and pump housings.[2]

Acetal polymers are highly crystalline. They have high strength, hardness, toughness, and resistance to creep and fatigue, high abrasion and frictional resistance, and good dimensional and chemical resistance. Acetal polymers can lose strength and toughness after long term exposure to hot environments. Homopolymers resist deterioration for up to 1 1/2 years at 180°F (82°C) in air, while the copolymers may be used continuously at temperatures up to 220°F (104°C) in air. Acetal polymers are used as replacements for metal parts in plumbing (ballcocks, showerheads, fittings, valves), automotive (window support brackets, handles, steering column), consumer products (telephone components, lawn sprinklers, zippers), and machinery components (mechanical couplings and pump impellers).[3,4]

REFERENCES

1. Engineered Materials Handbook, Volume 2, Engineering Plastics, prepared under the direction of the ASM International Handbook Committee, © 1988 by ASM International, Metals Park, Ohio, pp. 145-162.

2. J. Agranoff, Editor, Modern Plastics Encyclopedia 1985-1986, Vol. 62, Number 10A, © 1985 by McGraw-Hill, New York, NY, pp. 90-97.

3. I. Rubin, Ed., Handbook of Plastic Materials and Technology, © 1990 by Wiley Interscience, John Wiley and Sons, Inc., New York, 1990, pp. 11-24.

4. G. Odian, Principles of Polymerization, 2nd Edition, © 1981 by John Wiley & Sons, Inc., New York, pp. 408-409.