

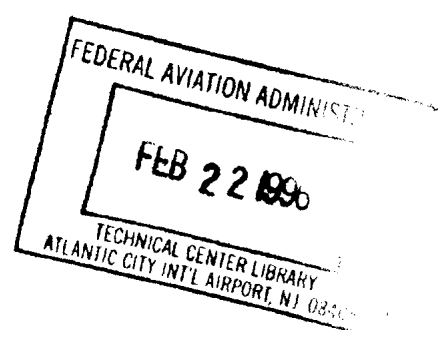
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Chemical Analysis of Pump Motor Housing Components from the DC-9 Ramp Fire at Barranquilla, Columbia, in March 1995

Louise C. Speitel



February 1996

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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.					
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TABLE OF CONTENTS

	Page
INTRODUCTION	
Objectives	
Background	
Test Materials	
CHEMICAL ANALYSIS OF SAMPLES AND RESULTS	2
Instrumentation	2
Fourier Transform Infrared Analysis	2
Thermal Methods of Analysis	3
Differential Scanning Calorimetry	3
Thermal Gravimetric Analysis	4
Flammability of Pump Motor Housing Components	5
SUMMARY OF RESULTS	6
CONCLUSIONS	6
REFERENCES	7
APPENDIX	
Properties and Uses of Sulfone Polymers and Acetal Polymers	

LIST OF ILLUSTRATIONS

Figure		Page
1	Configuration of Pump Components and Tank in Lavatory of DC-9	8
2	Comparison of FTIR Spectra of the Rigid Flange and PolySulfone	9
3	Comparison of FTIR Spectra of the Melted Pump Motor Housing and Polyoxymethylene	10
4	DSC Thermograms for the Rigid Flange in Nitrogen	11
5	DSC Thermogram for the Rigid Flange in Nitrogen Showing the Glass Transition Temperature	12
6	DSC Thermographs for the Melted Pump Motor Housing in Nitrogen	13
7	TGA Thermogram for the Rigid Flange and Polysulfone in Nitrogen	14
8	TGA Thermogram for the Rigid Flange and Polysulfone in Air	15
9	TGA Thermogram for the Melted Pump Motor Housing and Polyoxymethylene in Nitrogen	16
10	TGA Thermogram for the Melted Pump Motor Housing and Polyoxymethylene in Air	17
11	TGA Thermogram for the Paper Gasket in Nitrogen	18
12	TGA Thermogram for the Paper Gasket in Air	19

LIST OF TABLES

Table		Page
	Instrumentation and Software	2
2	FTIR Identification of Pump Motor Housing Components	3
3	Acetal and Sulfone Polymers	3
4	DSC Analysis of Pump Motor Housing Components	4
5	TGA Analysis of Pump Motor Housing Components	5

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.

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	OMNICTM Software for windows, version] .2.
	OMNICTM 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	-fC6H4-4-C(CH3)2C6H4-4-OC6H4-4-SO2C6H4-4-Dtn
Melted Housing	Polyoxymethylene	{CH ₂ O} _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

THERMAL METHODS OF ANALYSIS.

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 Co.MPONENTS

Material	Melting Point Onset (DC)	Peak Melting Point (DC)	Melting Point Range (DC)	Glass Transition Temperature (DC)
Rigid Flange	None	None	None	188
Polysulfone	None	None	None	190 ¹⁴¹
Polyethersulfone	None	None	None	225 ¹⁴²
Polyphenylsulfone	None	None	None	220 ¹⁴³
Melted Pump Housing	159.9	165.5	130-170	
Acetal Homopolymer		175 ¹⁴⁴ - 181, ¹⁴⁵	178-329 ¹⁴⁶	
Acetal Copolymer		165 ¹⁴⁷		

The rigid flange did not melt within the 50 to 400°C temperature range which is consistent with the amorphous, noncrystalline 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

Material	Heated in nitrogen				Heated in air			
	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					502	527	435-653	13
Polysulfone					512	548	420-675	0
Melted Pump Housing					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-O 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, noncrystalline 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 lavatories. Polyetheretherketone or polyaryletherketone, or other high temperature thermoplastics may be more appropriate.

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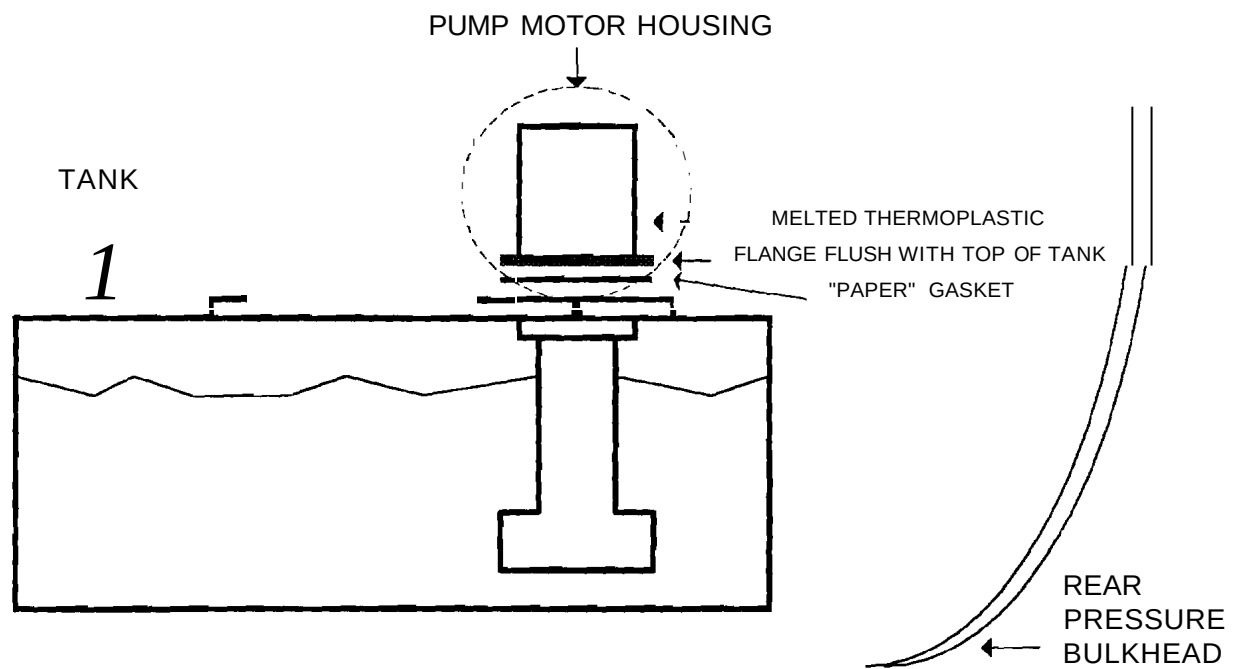


FIGURE 1. CONFIGURATION OF PUMP COMPONENTS AND TANK IN LAVATORY OF DC-9

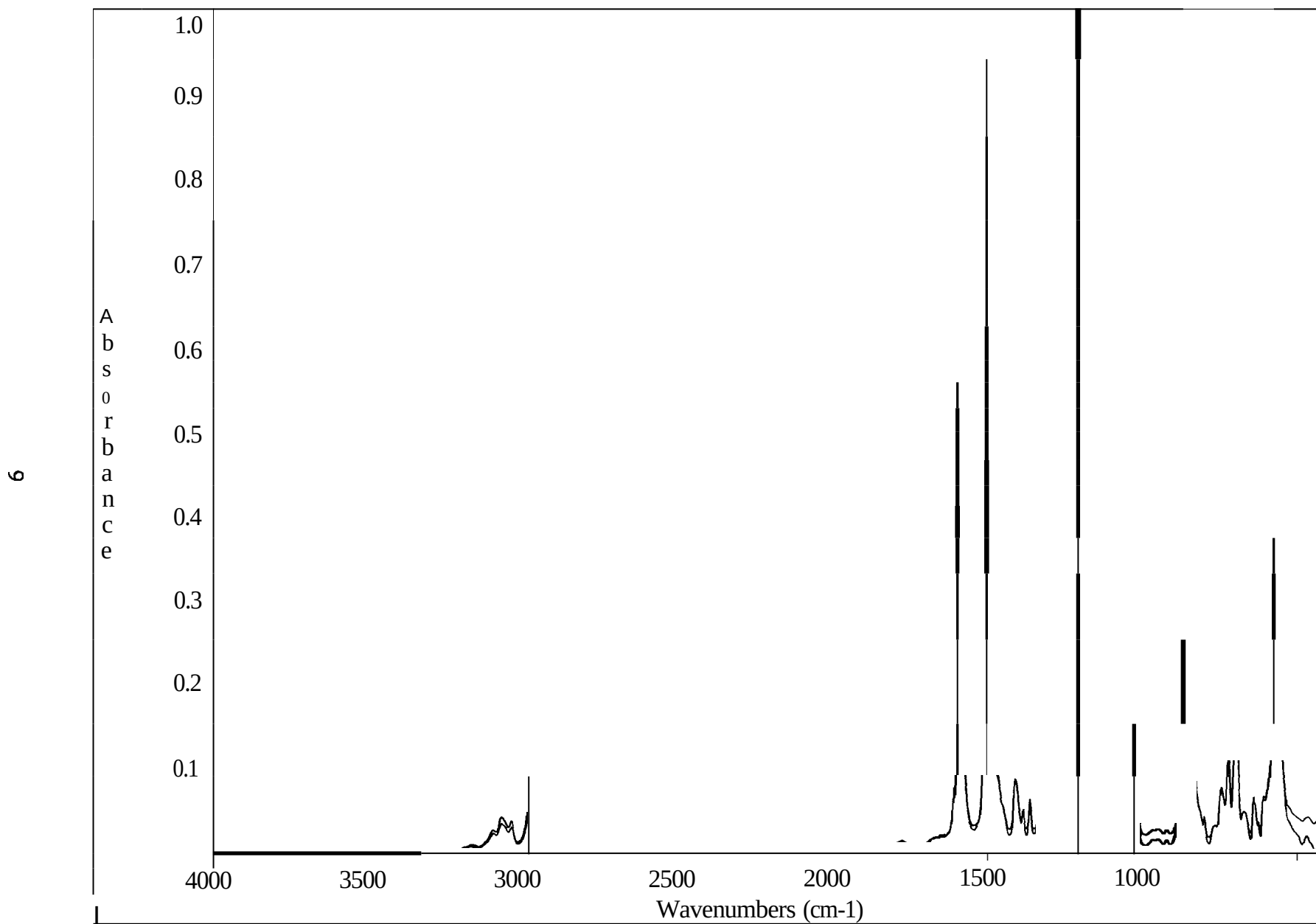


FIGURE 2. COMPARISON OF FTIR SPECTRA OF THE RIGID FLANGE AND POLYSULFONE

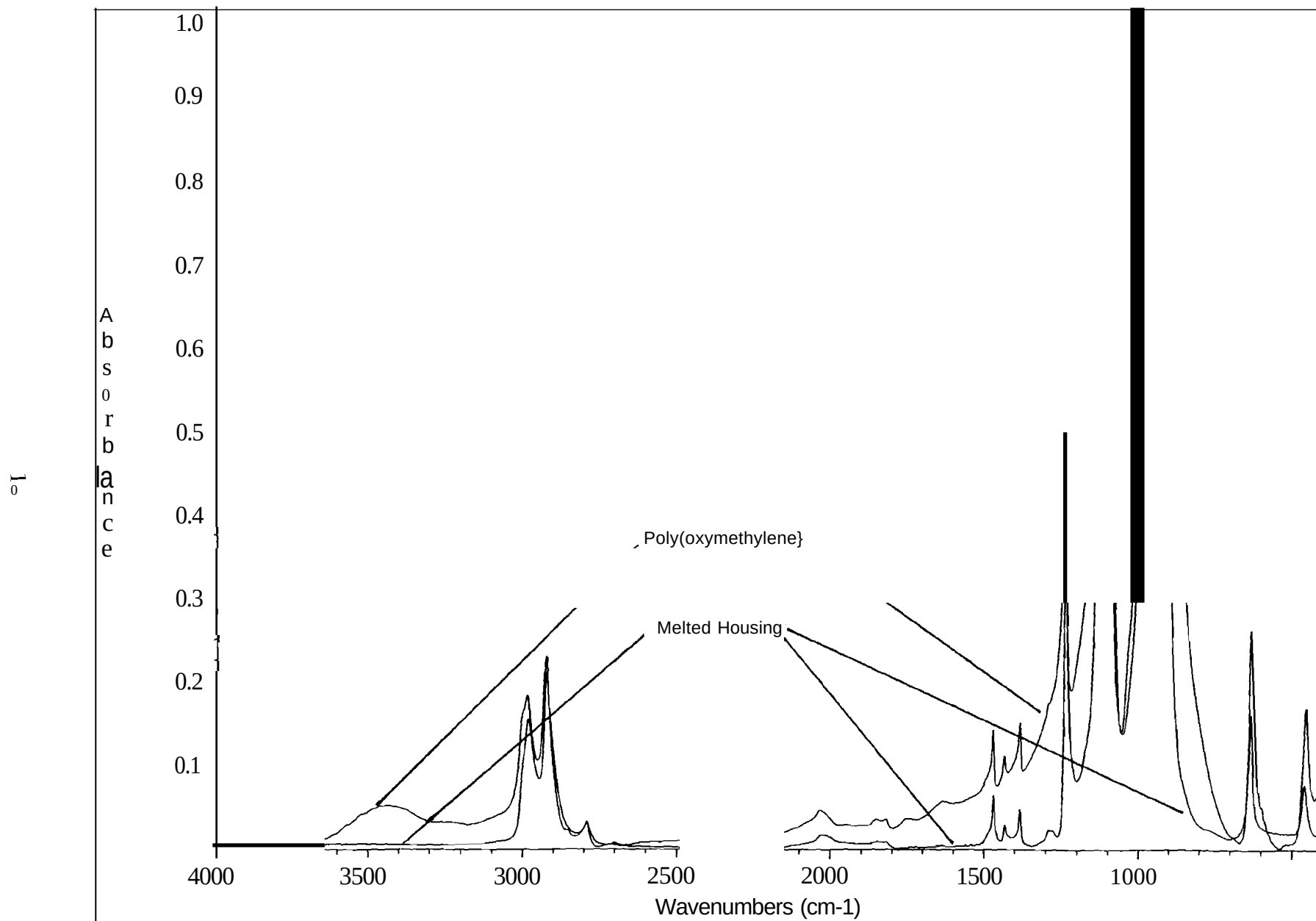


FIGURE 3. COMPARISON OF FTIR SPECTRA OF THE MELTED PUMP MOTOR HOUSING AND POLYOXYMETHYLENE

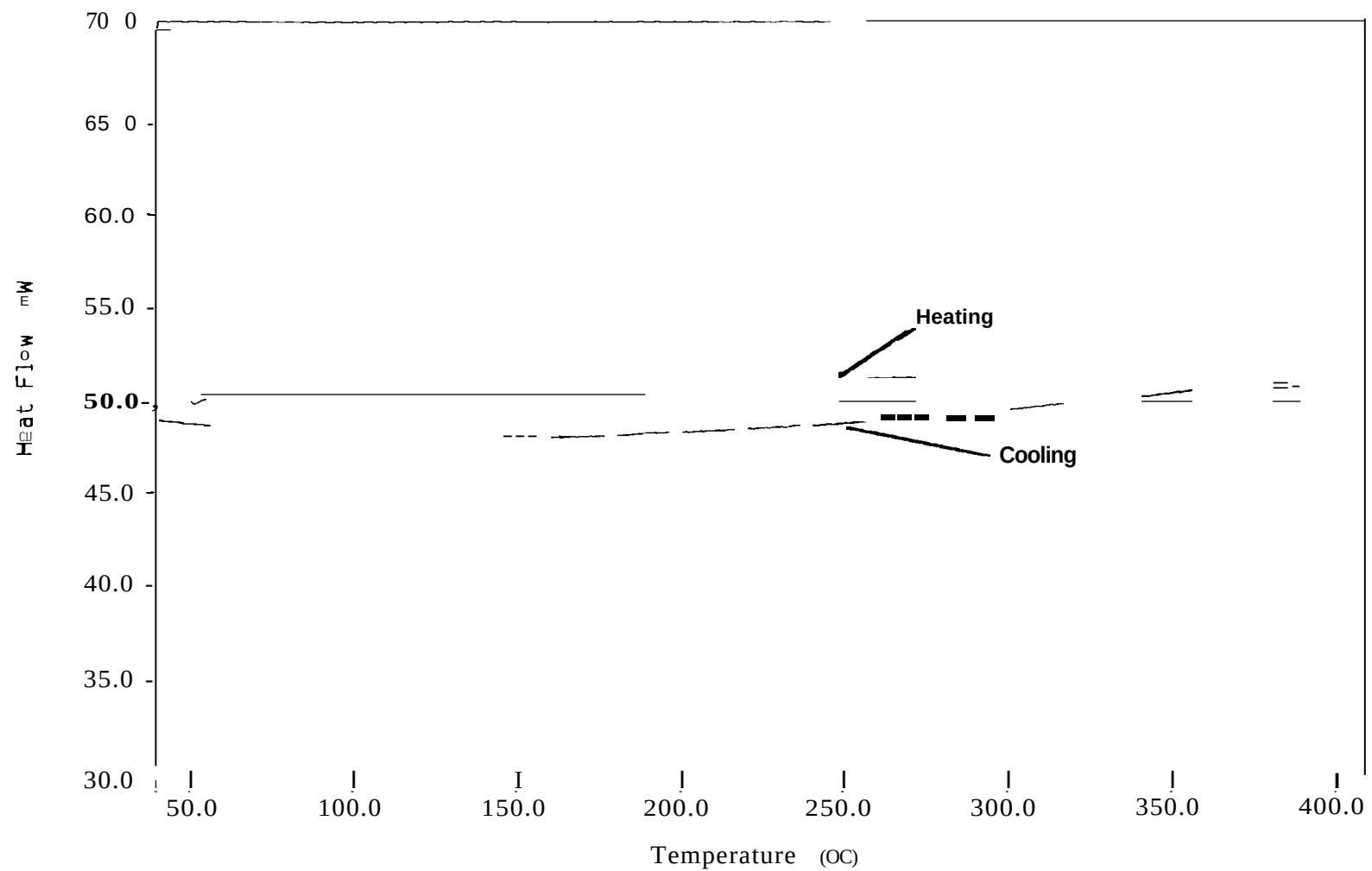


FIGURE 4. DSC THERMOGRAMS FOR THE RIGID FLANGE IN NITROGEN

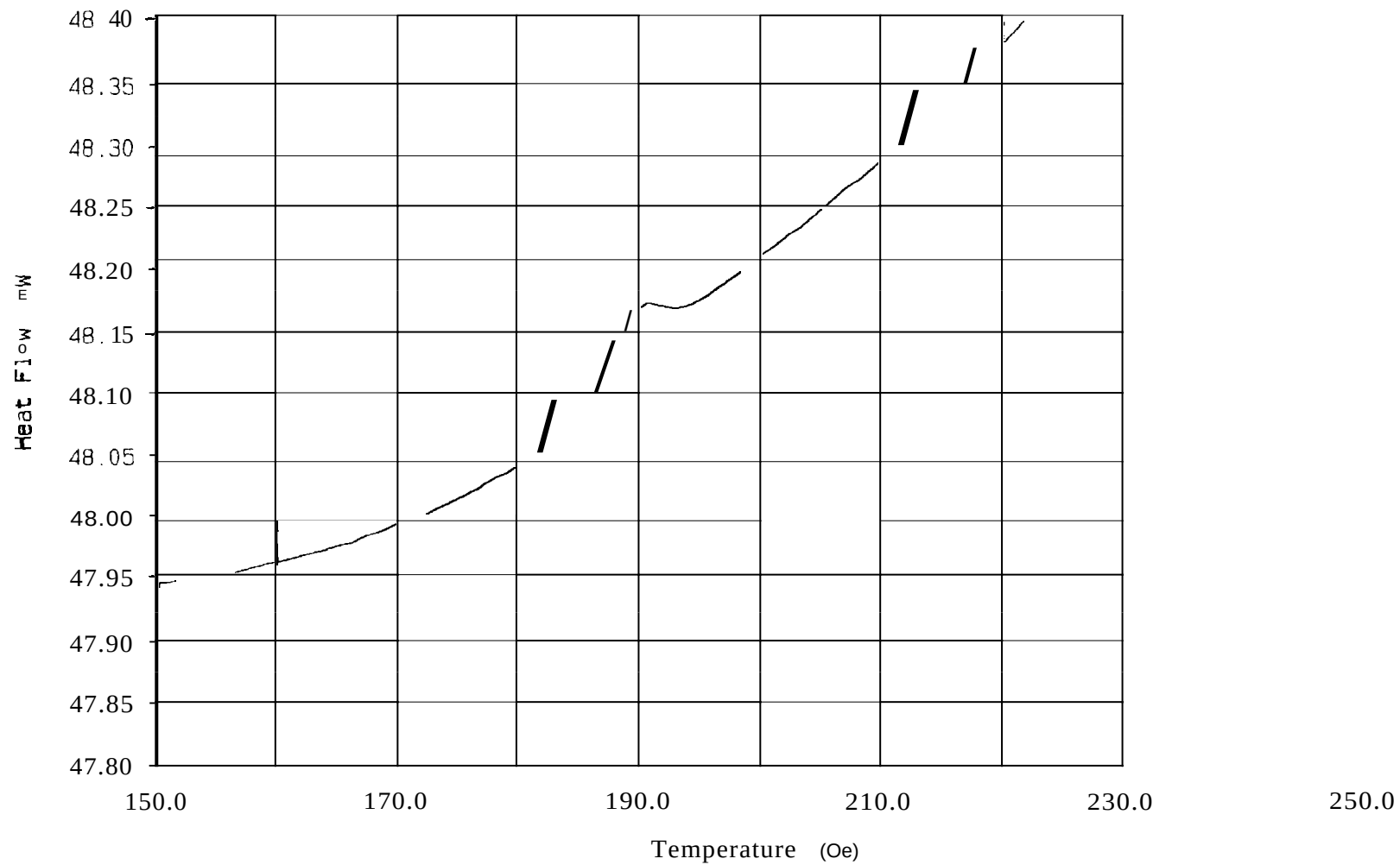


FIGURE 5. DSC THERMOGRAM FOR THE RIGID FLANGE IN NITROGEN SHOWING THE GLASS TRANSITION TEMPERATURE

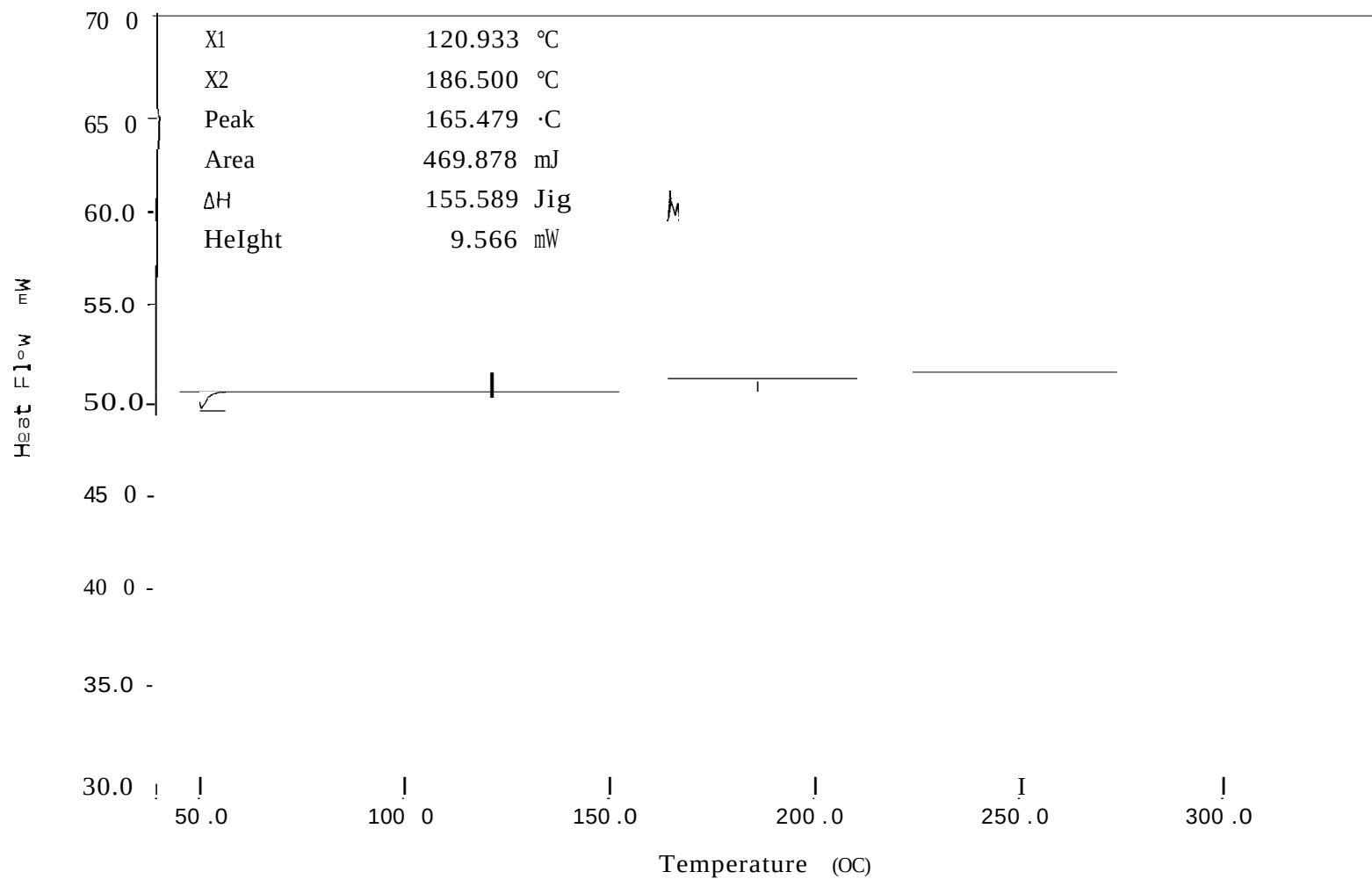


FIGURE 6. DSC THERMOGRAPHS FOR THE MELTED PUMP MOTOR HOUSING IN NITROGEN

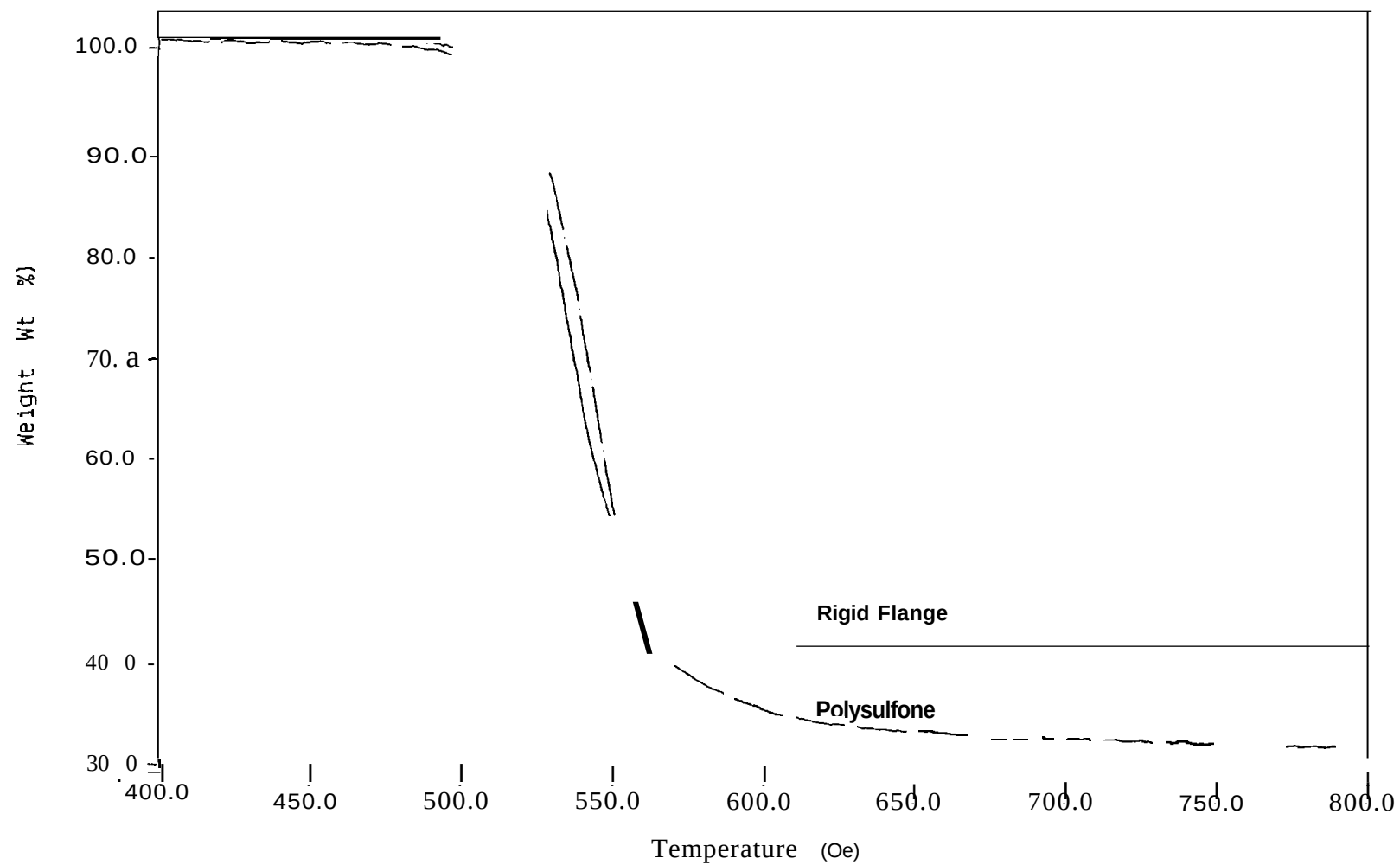


FIGURE 7. TGA THERMOGRAM FOR THE RIGID FLANGE AND POLYSULFONE IN NITROGEN

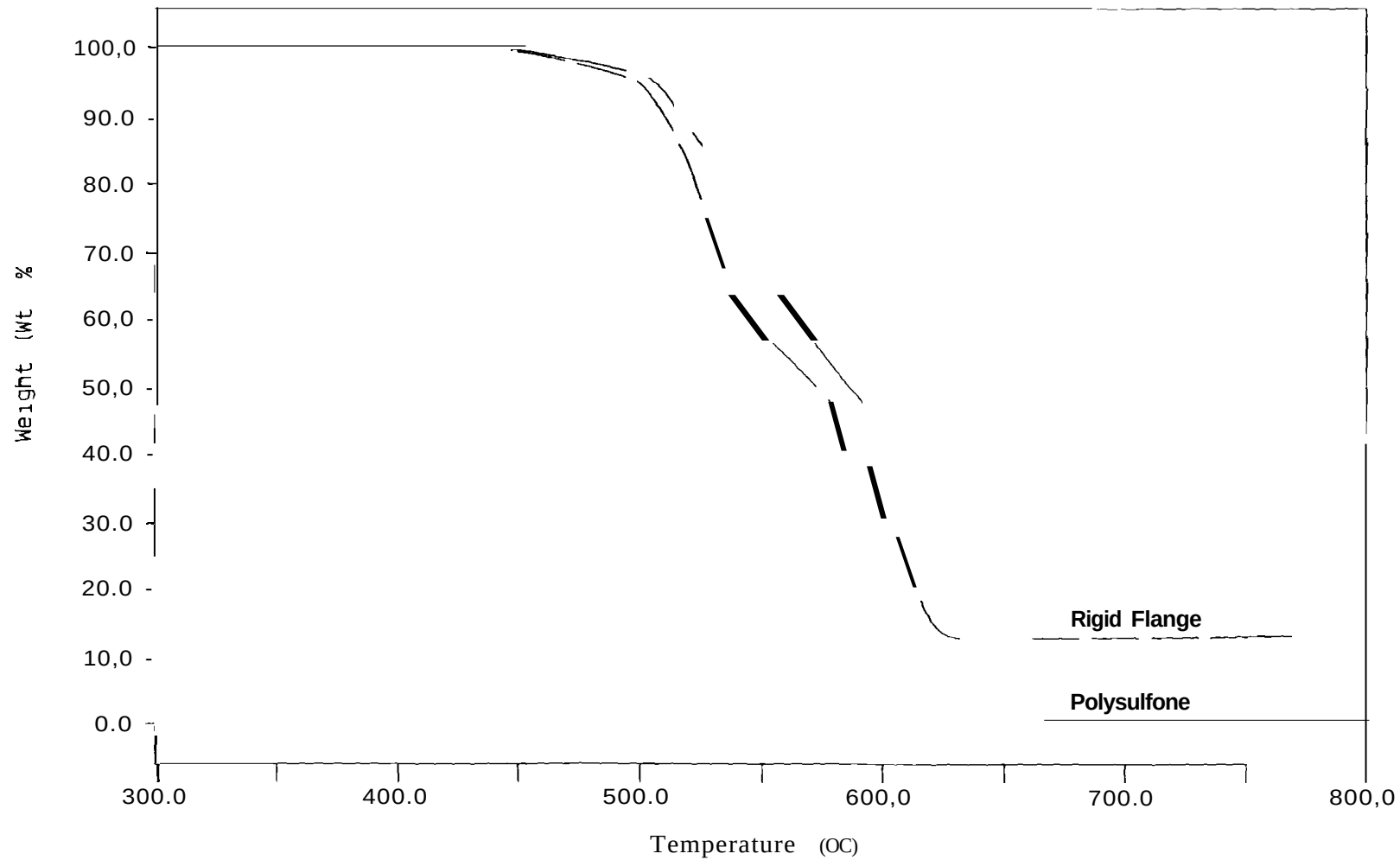


FIGURE 8. TGA THERMOGRAM FOR THE RIGID FLANGE AND POLYSULFONE IN AIR

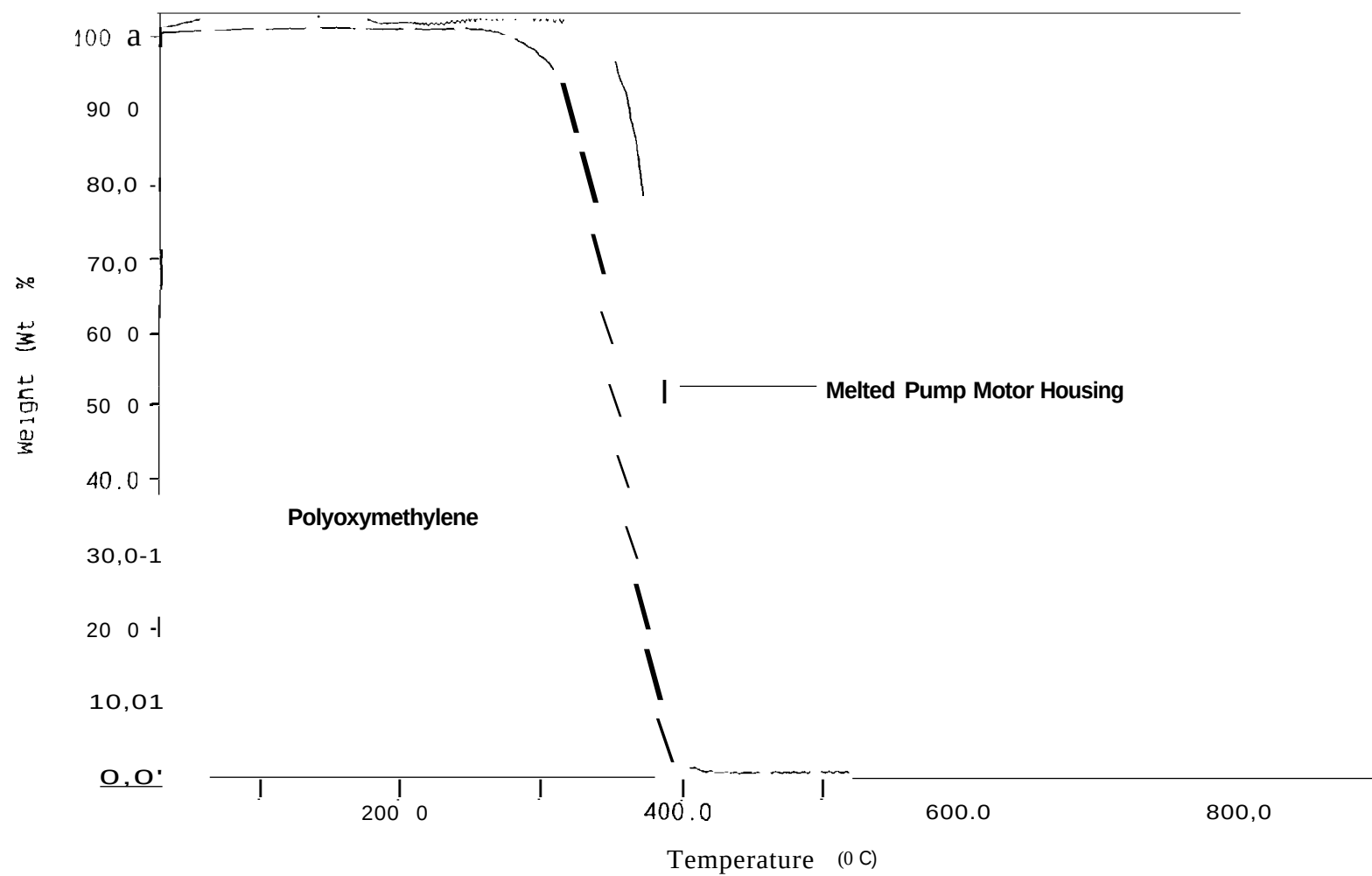


FIGURE 9. TGA THERMOGRAM FOR THE MELTED PUMP MOTOR HOUSING AND POLYOXYMETHYLENE IN NITROGEN

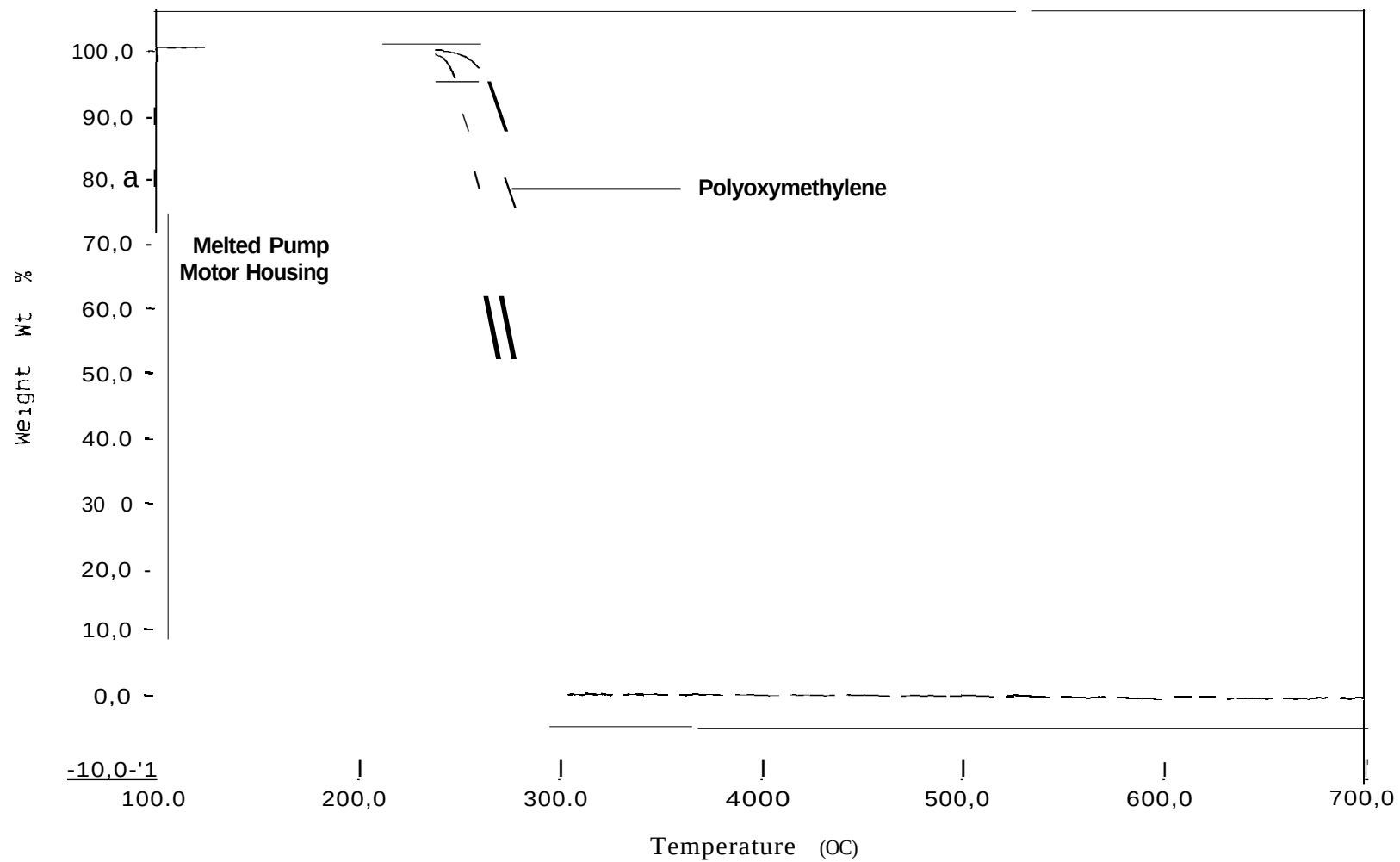


FIGURE 10, TGA THERMOGRAM FOR THE MELTED PUMP MOTOR HOUSING AND POLYOXYMETHYLENE IN AIR

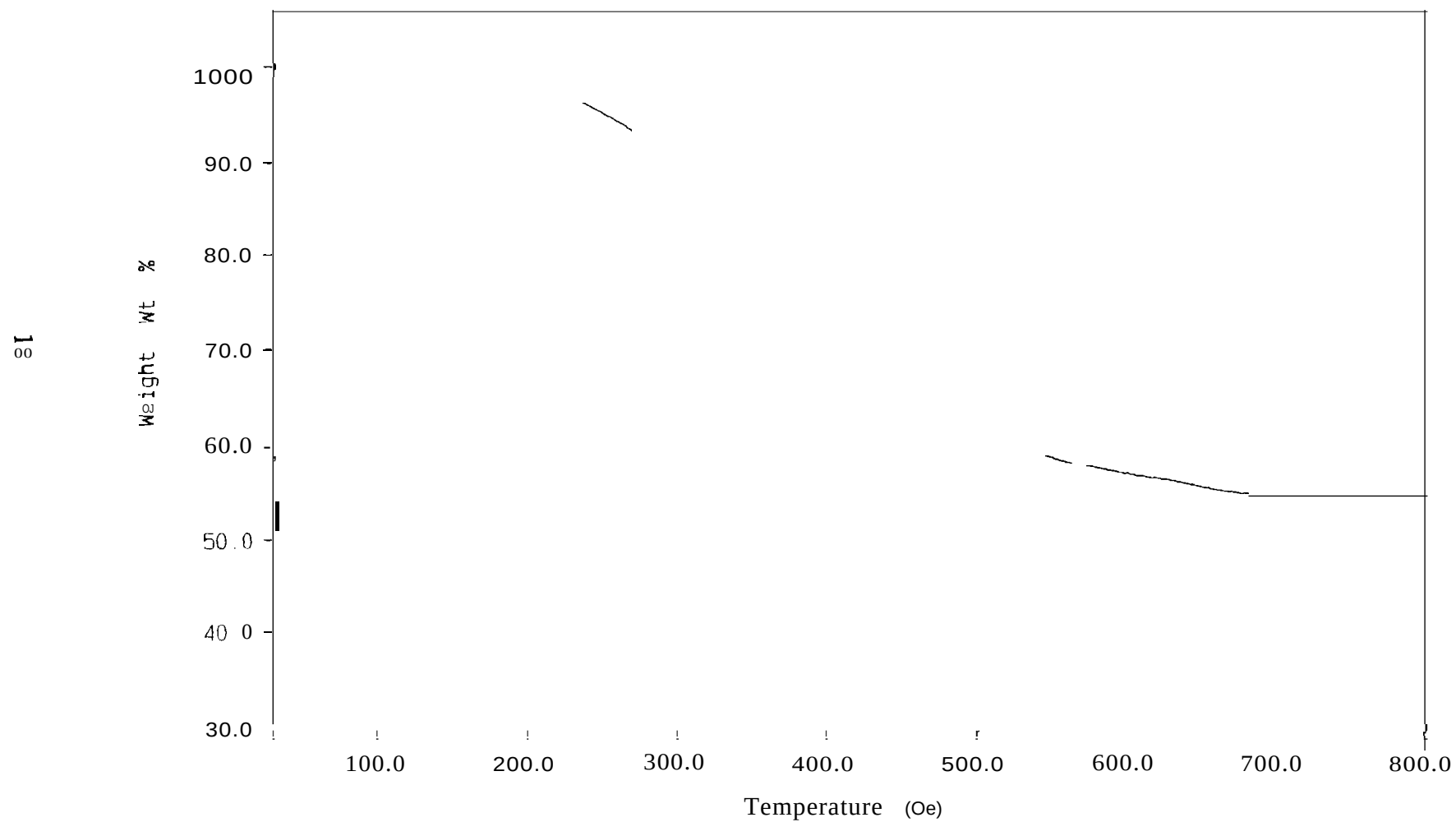


FIGURE II. TGA THERMOGRAM FOR THE PAPER GASKET IN NITROGEN

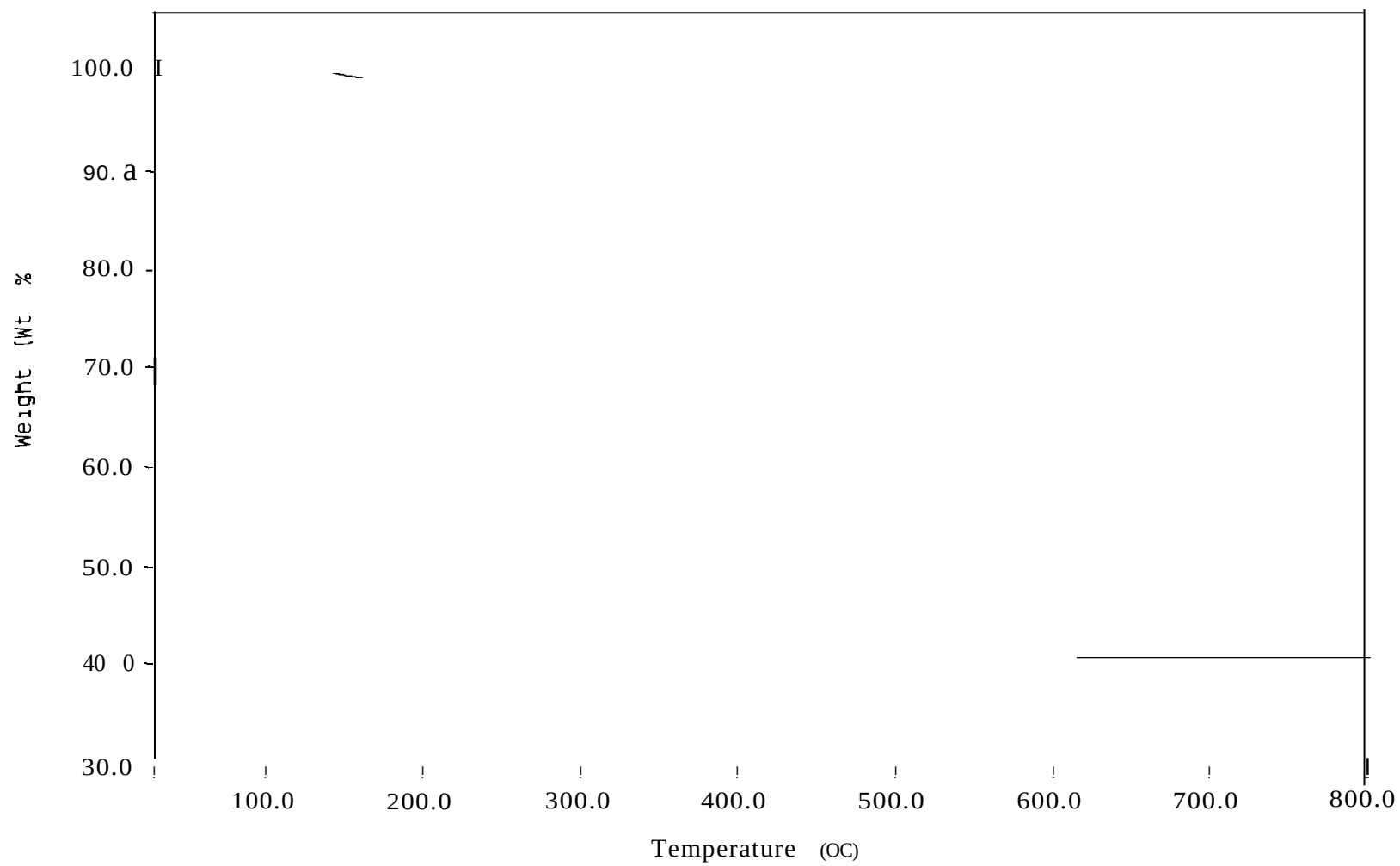


FIGURE 12. TGA THERMOGRAM FOR THE PAPER GASKET IN AIR

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]

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