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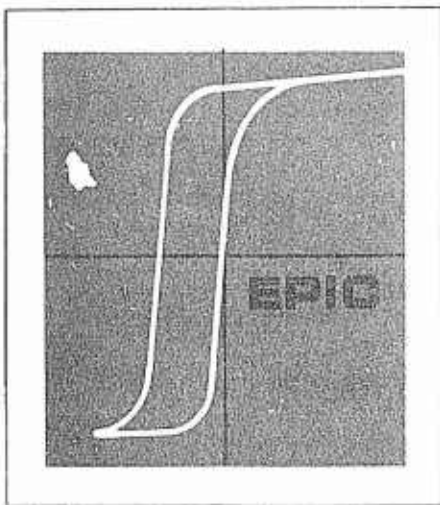
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PYROCERAM

Data Sheets

John T. Milek

DS-130
August 1963



**ELECTRONIC
PROPERTIES
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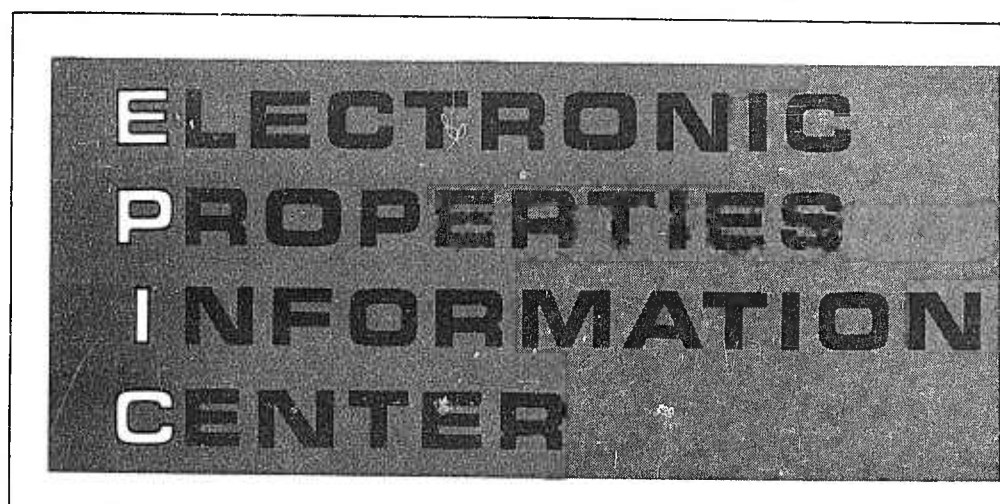
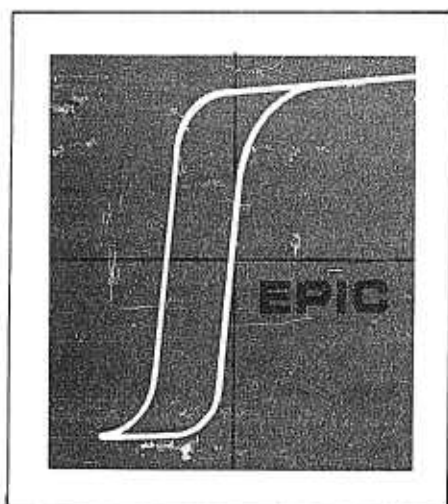
HUGHES AIRCRAFT COMPANY
CULVER CITY, CALIFORNIA

PYROCERAM

Data Sheets

John T. Milek

DS-130
August 1963



HUGHES

HUGHES AIRCRAFT COMPANY
CULVER CITY, CALIFORNIA

FOREWORD

This report was prepared by Hughes Aircraft Company under Contract No. AF 33(616)-8438. The contract was initiated under Project No. 7381, Task No. 738103. The work was administered under the direction of the Directorate of Materials and Processes, Aeronautical Systems Division, with Mr. R.F. Klinger acting as Project Engineer.

Many persons have contributed to the program which this report represents. The author wishes especially to acknowledge the contributions of the following: J.J. Anders, J.W. Atwood, C.L. Blocher, D.L. Grigsby, F.S. Harter, D.H. Johnson, H.T. Johnson, M.S. Neuberger, and E. Schafer.

ABSTRACT

The Electronic Properties Information Center has been established to collect, index and abstract the literature on the electrical and electronic properties of materials and to evaluate and compile the experimental data from that literature. A modified coordinate index to the literature is machine stored and printed for manual use. The Center publishes data sheets, summary reports, thesauri, glossaries, and similar publications as sufficient information is evaluated and compiled. This report consists of the compiled data sheets on Pyroceram.

This report has been reviewed and is approved for publication.



H. Thayne Johnson, Supervisor
Electronic Properties Information Center



John W. Atwood
Project Manager

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INTRODUCTION

In June 1961, a program was initiated under the direction of the Air Force to collect, index and abstract the literature on the electrical and electronic properties of materials and to evaluate and compile the experimental data from that literature. Placed at Hughes Aircraft Company in Culver City, California, the program, now called the Electronic Properties Information Center, was originally intended to cover ten major categories of materials: Semiconductors, Insulators, Ceramics, Ferroelectrics, Metals, Ferrites, Ferromagnetics, Electroluminescent Materials, Thermionic Emitters, and Superconductors.

During the first year, studies were completed on the Semiconductor and Insulator categories; and Ceramics was discontinued as a separate category and subsumed under the other nine. Vocabulary studies have now been completed on all categories, and retrospective documentation is virtually complete for Semiconductors and Insulators. A full index to the literature is maintained; and publications such as data sheets, summary reviews, glossaries, and thesauri are periodically issued. The use of the Center and these publications are available to anyone wishing information within the scope of the Center's objectives. A full list of publications to date appears at the end of this report.

This report contains data sheets on Pyroceram. The data sheets have been compiled direct from the literature. Articles are allowed to accumulate in the system until it is judged that a sufficient number are available on one material for adequate evaluation. The manual

modified coordinate index is then used to retrieve all literature on the material to be compiled. Bibliographies are checked to make sure that valuable and relevant literature is not overlooked. Then the assembled literature is given to the specialist doing the evaluation and compilation.

Evaluation is confined to primary source data except when only secondary citations are available. If equally valid data are available from several sources, all are given. Data are rejected when judged questionable because of faulty or dubious measurements, unknown sample composition, or if more reliable data are available from another source. Selection of data is based upon that which is judged most representative, precise, reliable, and covers the widest range of variables. The addition of new data to a previously evaluated property requires a reappraisal of the reported values. Older data may be deleted if the new data are judged more accurate or representative.

After a thorough analysis and evaluation, the data is compiled into data sheets which present it in its most optimum form. This will be, primarily, but not limited to, curves or tabular form. Where possible, graphs are adapted directly from the original sources. If this is not possible, they are drawn from data compiled from the articles. Where thought important, notes are entered with each graph to help the user.

The references, from which the data are drawn, are shown by

reference number below each graph with the full bibliographic information at the end of the data sheets. The bibliography is referred to and listed in the order of entry into the Center (accession number). This provides a quick cross reference into the index used with the literature.

This compilation deals only with Pyroceram as an Insulator. Non-insulator data will be included in a future revision.

MATERIALS DESCRIPTION

Pyroceram is a new family of glass materials developed by Corning Glass Works in the past few years. It is essentially a crystalline material formed from a non-crystalline glass.

A glass batch containing one or more nucleating agents is melted, formed, and cooled. Subsequent heat treatments cause the nucleating agents to form billions of submicroscopic crystallites per cubic millimeter in the pyroceram. The end product, after heat treatment, is a fine grained crystalline material, non-porous and reportedly harder than most ceramics and many metals.

Pyroceram can be formed by conventional glass-forming methods: blowing, drawing, pressing, rolling, and casting.

Corning Glass Works has two types of pyroceram available (commercially) as Code 9606 and 9608.

Present electronic applications include missile nose cones (radomes and conical windows for hypersonic aircraft).

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

MATERIALS CENTRAL

AERONAUTICAL SYSTEMS DIVISION

AIR FORCE SYSTEMS COMMAND

INSULATION MATERIALS

August 1963

PYROCERAM - Corning 889 CA*

Dielectric Constant

Temperature (°C)	Frequency (CPS)	ϵ'
25	60	5.8
25	10^6	5.9
500	10^6	5.8

[Ref. 5633]

Dissipation Factor

Temperature (°C)	Frequency (CPS)	Tan δ
25	60	0.008
25	10^6	0.0008
500	10^6	0.04

[Ref. 5633]

Volume Resistivity

Temperature (°C)	ρ (ohm cm)	Ref.
500	10^{10}	5633

*This glass composition is no longer commercially available.

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

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August 1963

PYROCERAM - Corning 7911*

Dielectric Constant

Temperature (°C)	Frequency (CPS)	ϵ'
25	10^6	3.8
500	10^6	2.9
500	10^{10}	3.75

[Ref. 5633]

Dissipation Factor

Temperature (°C)	Frequency (CPS)	Tan δ
25	10^6	0.0002
25	10^{10}	0.00055
500	10^6	0.12
500	10^{10}	0.0017

[Ref. 5633]

Volume Resistivity

Temperature (°C)	ρ (ohm cm)
500	10^9

[Ref. 5633]

*This glass composition is no longer commercially available.

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ELECTRICAL AND ELECTRONIC PROPERTIES

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August 1963

PYROCERAM - Corning 8605*

Dielectric Constant

Temperature (°C)	Frequency (CPS)	ϵ'	Ref.
25	10^6	6.1	{ 5796 4836
25	10^{10}	6.1	{ 5796 5633
300	10^6	6.3	4836
500	10^{10}	6.1	5633

Dissipation Factor

Temperature (°C)	Frequency (CPS)	Tan δ	Ref.
25	10^6	0.0017	{ 4836 5796
25	10^{10}	0.0002	{ 5633 5796
300	10^6	0.014	4836
500	10^{10}	0.0025	5633

*This glass composition is no longer commercially available.

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

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INSULATION MATERIALS

August 1963

PYROCERAM - Corning 8605

Loss Factor

Temperature (°C)	Frequency (CPS)	ϵ''	Ref.
25	10^6	0.0102	{4836 5796
25	10^{10}	0.0012	5796
300	10^6	0.078	4836

Volume Resistivity

Temperature (°F)	ρ (ohm cm)	Ref.
500	$10^{10.1}$	5796

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ELECTRICAL AND ELECTRONIC PROPERTIES

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INSULATION MATERIALS

August 1963

PYROCERAM - Corning 8606*

Dielectric Constant

Temperature (°C)	Frequency (CPS)	ϵ'	Ref.
25	10^6	5.62	{5796 4836
25	10^{10}	5.53	{5796 5633
300	10^6	5.80	4836
500	10^{10}	5.54	5633

Dissipation Factor

Temperature (°C)	Frequency (CPS)	Tan δ	Ref.
25	10^6	0.0024	{4836 5796
25	10^{10}	0.0003	{5633 5796
300	10^6	0.013	4836
500	10^{10}	0.0018	5633

*This glass composition is now designated Corning 9606.

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ELECTRICAL AND ELECTRONIC PROPERTIES

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INSULATION MATERIALS

August 1963

PYROCLERAM -- Corning 8606

Loss Factor

Temperature (°C)	Frequency (CPS)	Loss Factor	Ref.
25	10^6	0.0134	{ 5796 4836
25	10^{10}	0.0016	5796
300	10^6	0.075	4836

Volume Resistivity

Temperature (°F)	ρ (ohm cm)	Ref.
500	10^{10}	5796

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

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AERONAUTICAL SYSTEMS DIVISION

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INSULATION MATERIALS

August 1963

PYROCERAM - Corning 9605*

Dielectric Constant

Temperature (°C)	Frequency (CPS)	ϵ'	Ref.
25	10^6	6.1	4834 4009
25	10^{10}	6.1	4834 4009
300	10^6	6.3	4834 4009
300	10^{10}	6.1	4834 4009
500	10^{10}	6.1	4834 4009

Dielectric Strength

Room temperature (?) [thickness not stated] 300 volt/mil

[Ref. 4834]

*This glass composition is no longer commercially available.

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

MATERIALS CENTRAL

AERONAUTICAL SYSTEMS DIVISION

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INSULATION MATERIALS

August 1963

PYROCLRAM - Corning 9605

Dissipation Factor

Temperature (°C)	Frequency (CPS)	Tan δ	Ref.
25	10^6	0.0017	4009
25	10^{10}	0.0002	4009
300	10^6	0.014	4009
300	10^{10}	0.0008	4009
500	10^{10}	0.0025	4009

Loss Factor

Temperature (°C)	Frequency (CPS)	Loss Factor	Ref.
25	10^6	0.010	4009
25	10^{10}	0.001	4009
300	10^6	0.078	4009
300	10^{10}	0.005	4009
500	10^{10}	0.015	4009

Volume Resistivity

Temperature (°F)	Resistivity (ohm cm)	Ref.
68-212	10^{13}	4834
480	1.1×10^{10}	4009
660	1.5×10^8	4009

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PYROCERAM - Corning 9606

Dielectric Constant

Temperature (°C)	Frequency (CPS)	ϵ'	Ref.
20	10^6	5.58	{5793 5790
25	10^6	6.78	5788
25	10^6	5.58	{5789 5790
25	10^6	5.62	4009
25	10^{10}	5.45	{5633 5795 5789 5794 5790
25	10^{10}	5.53	4009
300	10^6	5.60	{5795 5789 5790
300	10^6	5.80	4009
300	10^{10}	5.51	{5795 5789 5794 5790
300	10^{10}	5.53	4009
500	10^6	8.80	{5795 5789 5790
500	10^{10}	5.53	{5633 5795 5789 5794 5790
500	10^{10}	5.54	4009

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ELECTRICAL AND ELECTRONIC PROPERTIES

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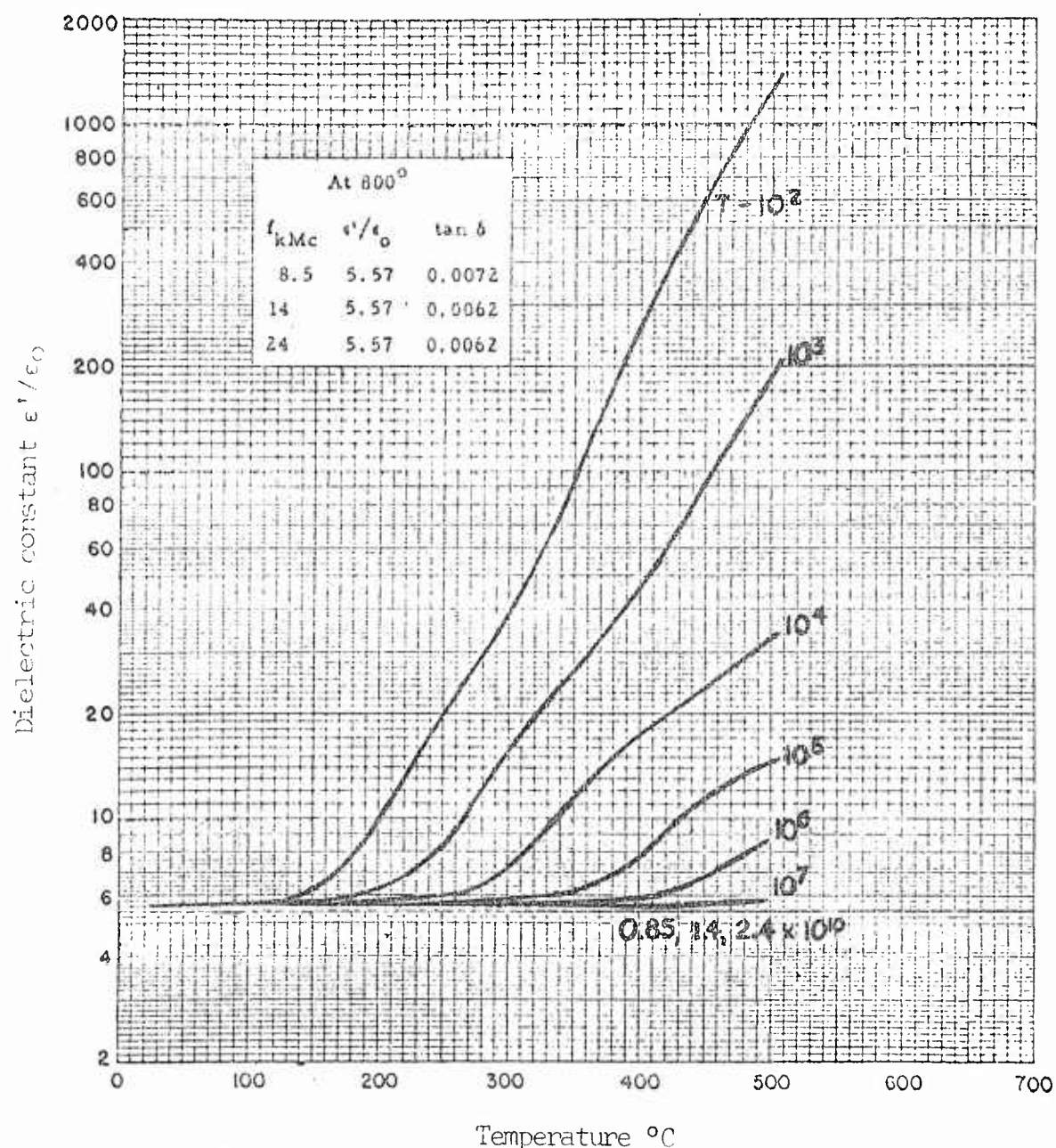
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INSULATION MATERIALS

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PYROCELFAM - Corning 9606

Dielectric Constant



[Ref. 5788].

DATA SHEET

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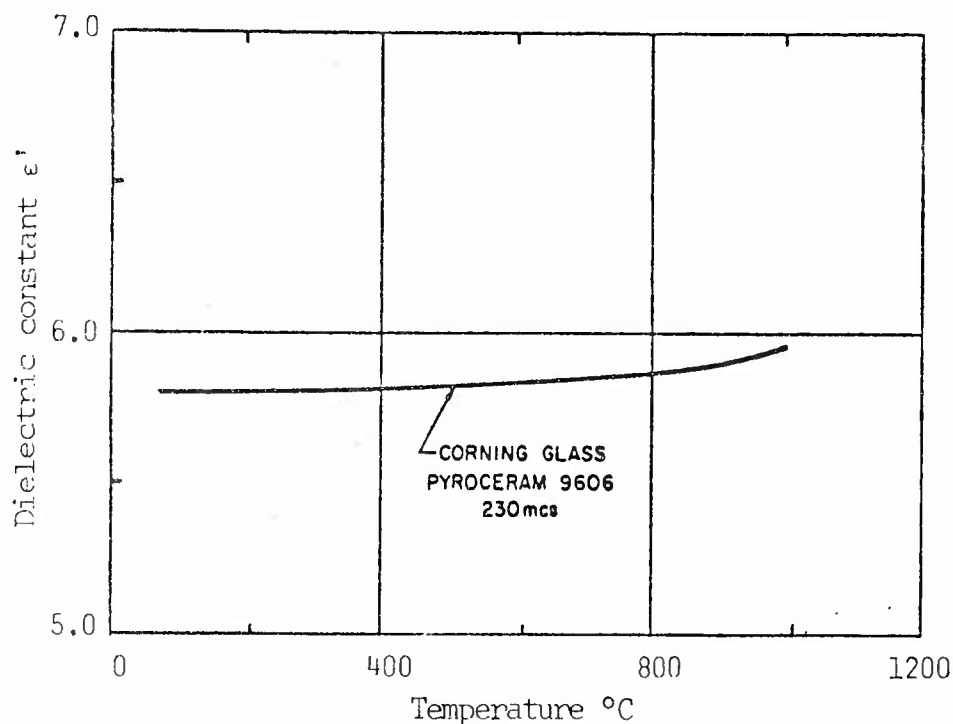
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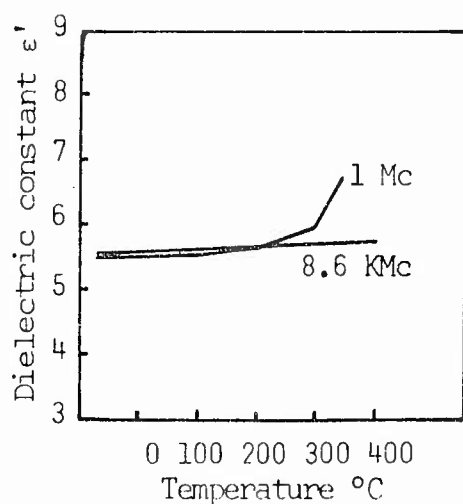
PYROCERAM - Corning 9606

Dielectric Constant



Dielectric constant as a function of temperature.

[Ref. 5742]



Dielectric constant as a function of temperature.

[Ref. 1261]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

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PYROCERAM - Corning 9606

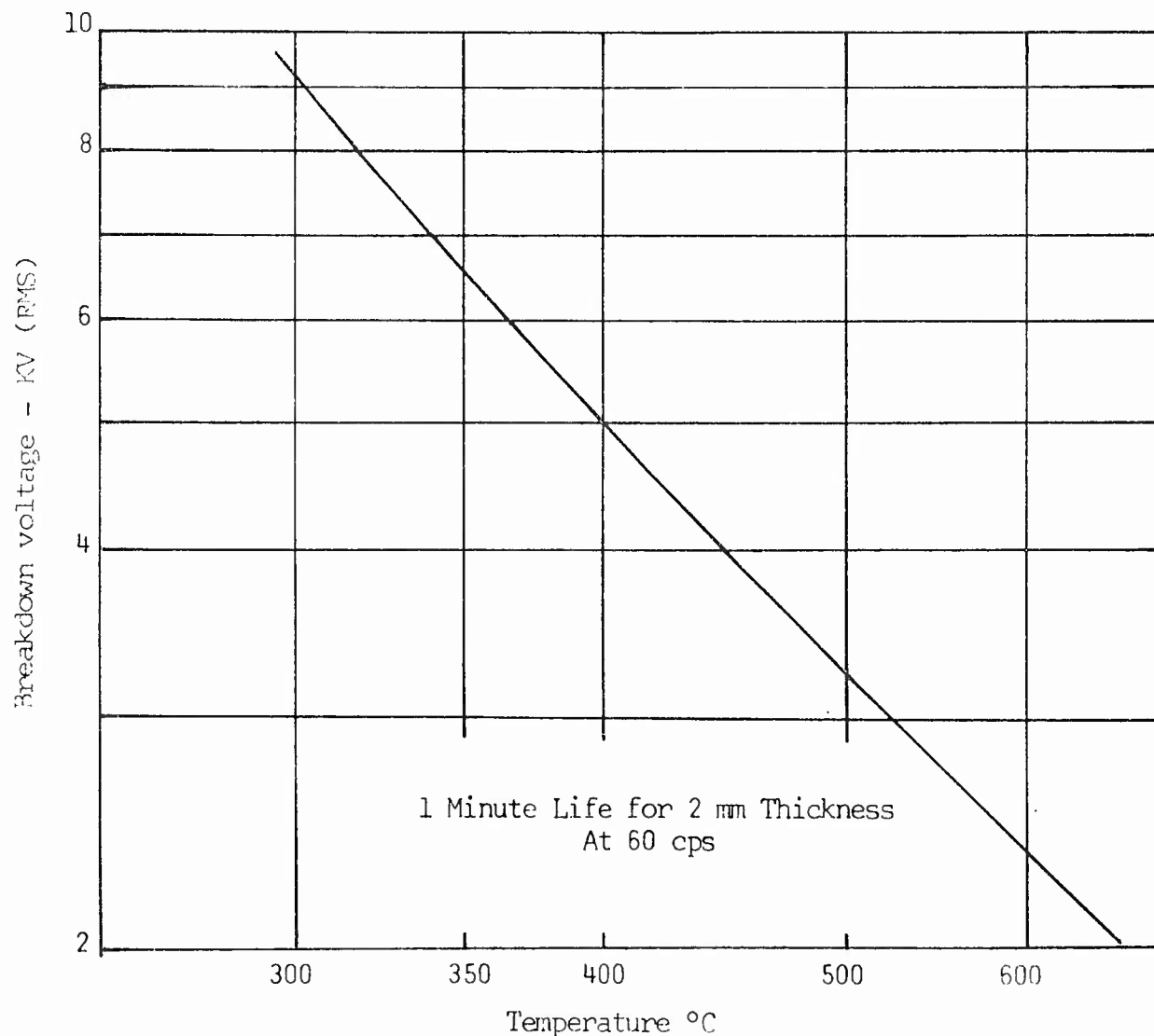
Dielectric Strength

68° F

0.10 inch thick

345 volts/mil

Ref. 5791



Dielectric breakdown as a function of temperature.

[Ref. 5788]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

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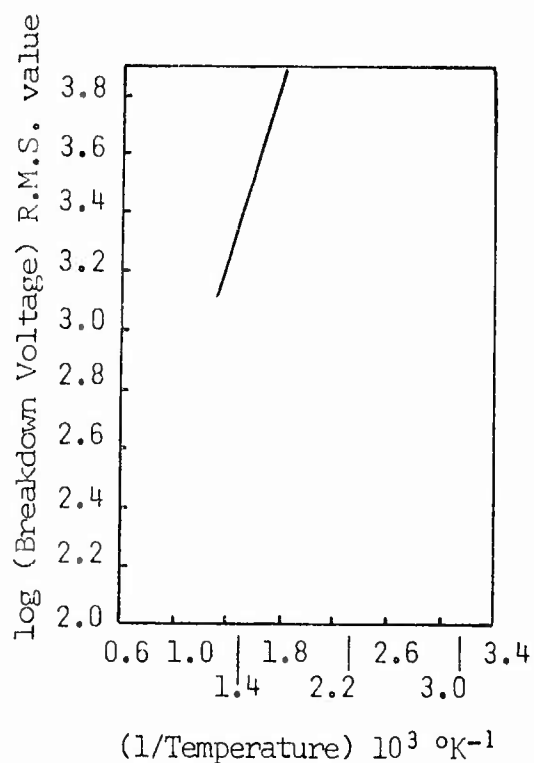
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INSULATION MATERIALS

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PYROCERAM - Corning 9606

Dielectric Strength



Dielectric strength as a function of temperature for Corning 9606. One-minute breakdown for sample thickness of 2 mm at 60 CPS.

[Ref. 1261]

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ELECTRICAL AND ELECTRONIC PROPERTIES

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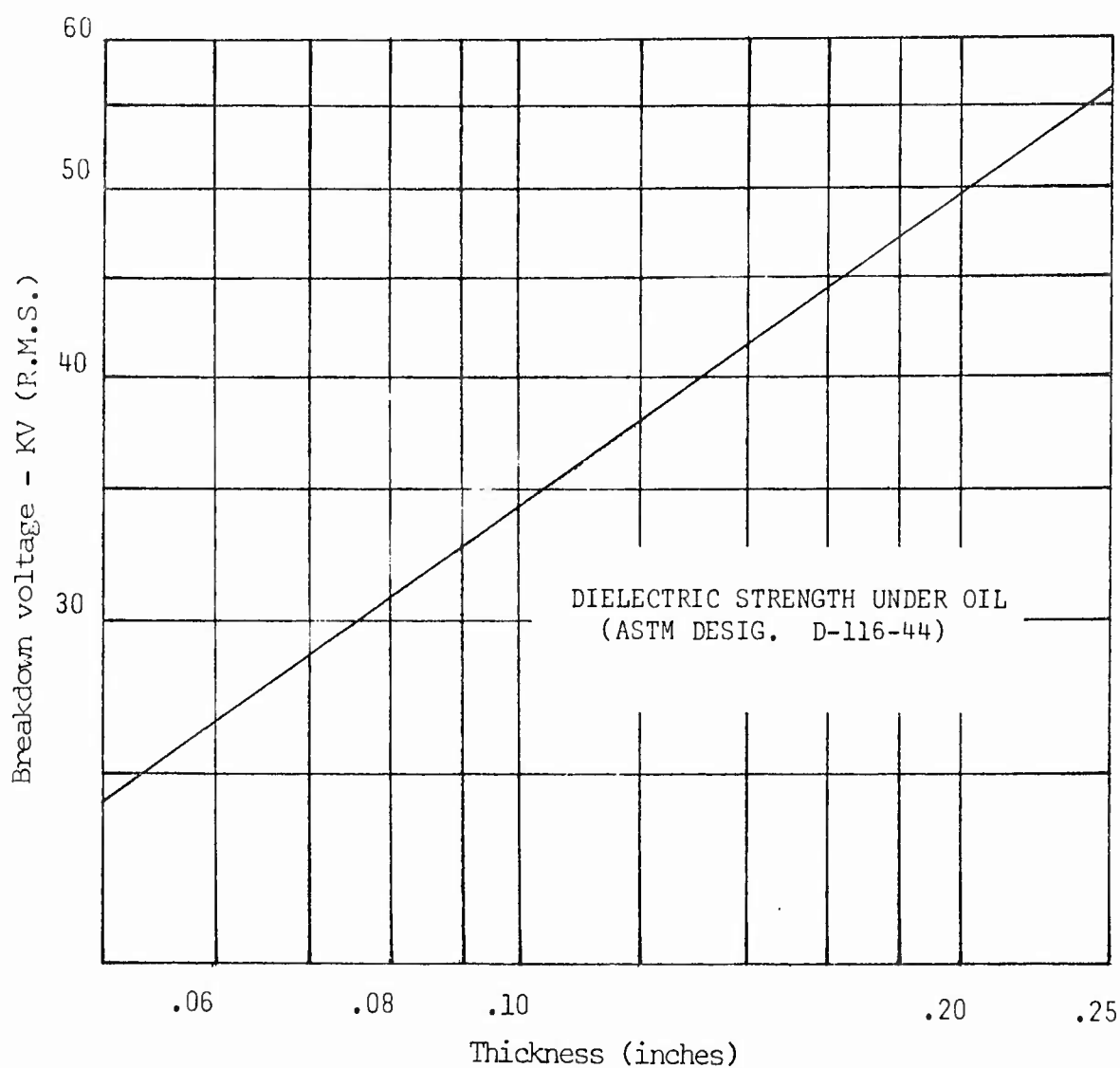
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INSULATION MATERIALS

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PYROCERAM - Corning 9606

Dielectric Strength



Dielectric strength as a function of thickness at 60 CPS.

[Ref. 5788]

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PYROCEFRAM - Corning 9606

Dissipation Factor

Temperature (°C)	Frequency (CPS)	Tan δ	Ref.
25	100	0.020	5791
25	10^6	0.0030	5788
25	10^6	0.0015	{5790
			{5789
25	10^6	0.0024	{5790
			{5789
25	10^{10}	0.00033	{5633
			{5794
			{5789
			{4009
25	10^{10}	0.00083	5790
300	10^6	0.0154	{5790
			{5789
300	10^6	0.013	4009
300	10^{10}	0.00075	{5794
			{5790
			{5789
300	10^{10}	0.0006	4009
500	8.5×10^9	0.0015	5791
500	10^{10}	0.00152	{5633
			{5794
			{5790
			{5789
500	10^{10}	0.0018	4009

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ELECTRICAL AND ELECTRONIC PROPERTIES

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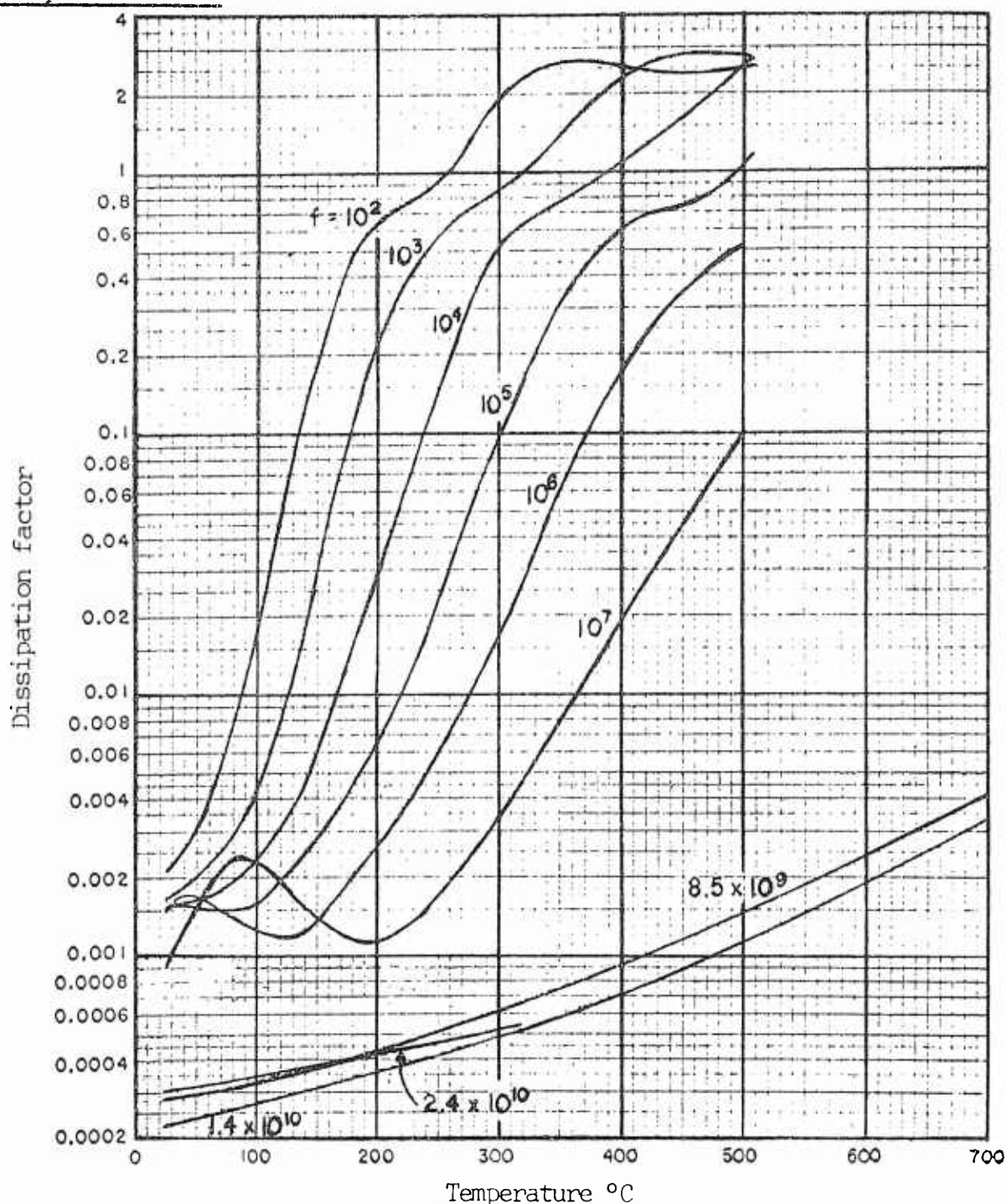
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INSULATION MATERIALS

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PYROCERAM - Corning 9606

Dissipation Factor



Dissipation factor as a function of temperature at various frequencies.

[Ref. 5788]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

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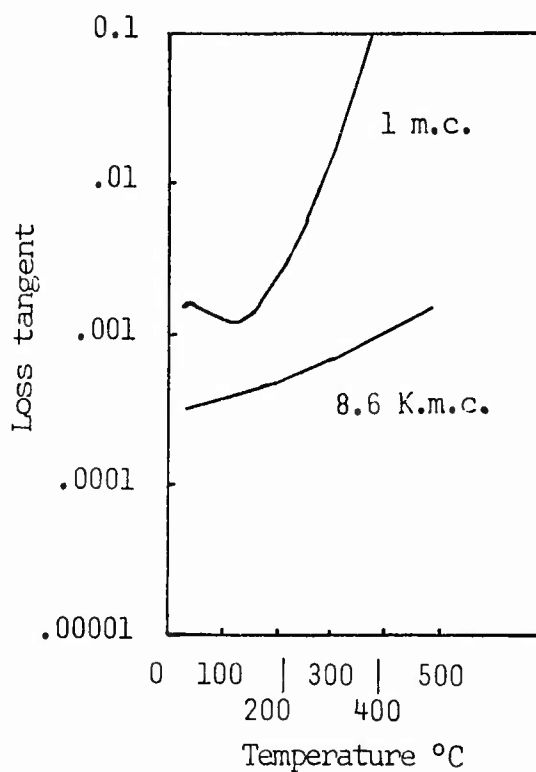
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INSULATION MATERIALS

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PYROCERAM - Corning 9606

Dissipation Factor



Loss tangent as a function of temperature for Corning 9606 at two frequencies.

[Ref. 1261]

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ELECTRICAL AND ELECTRONIC PROPERTIES

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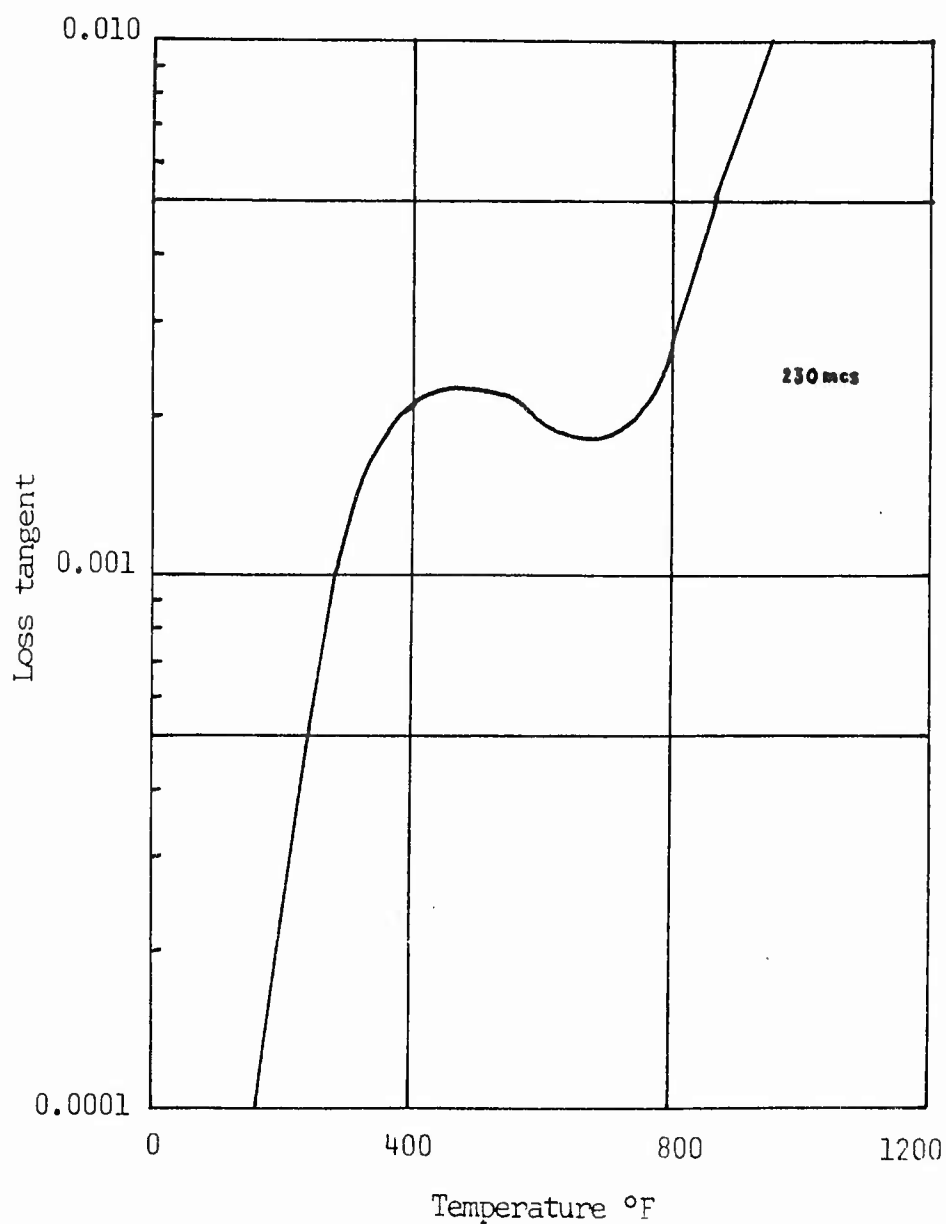
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PYROCERAM - Corning 9606

Dissipation Factor



Loss tangent as a function of temperature for Corning 9606.

[Ref. 5742]

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ELECTRICAL AND ELECTRONIC PROPERTIES

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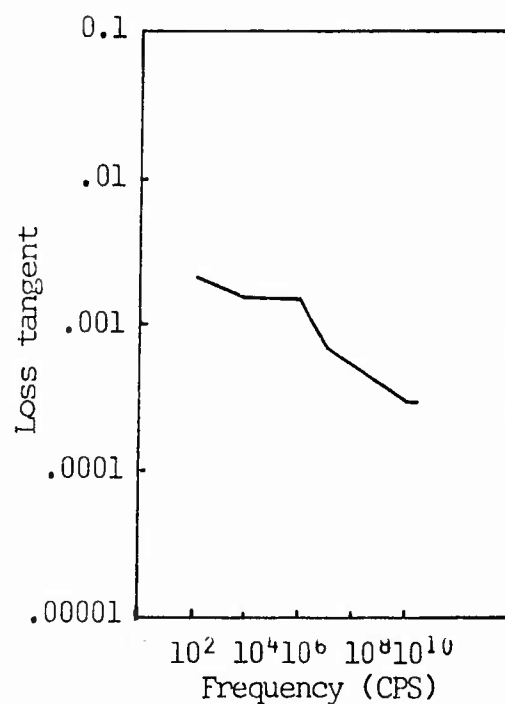
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INSULATION MATERIALS

August 1963

PYROCERAM - Corning 9606

Dissipation Factor



Loss tangent as a function of frequency at room temperature.

[Ref. 1261]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

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PYROCERAM - Corning 9606

Loss Factor

Temperature °C	Frequency (CPS)	Loss Factor	Ref.
20	10^6	0.0084	5793
25	10^6	0.014	4009
25	10^6	0.009	{5789 5790
25	10^{10}	0.002	{4009 5789 5790 5794
300	10^6	0.075	4009
300	10^6	0.086	{5789 5790
300	10^{10}	0.004	{5789 5790 5794
300	10^{10}	0.003	4009
500	10^{10}	0.008	{5789 5790 5794
500	10^{10}	0.010	4009

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PYROCERAM - Corning 9606

Volume Resistivity

Temperature °C	Resistivity (ohm-cm)	Ref.
250	1.1×10^8	5788
250	10^{10}	{ 4009 5789 5790 5791 5793
350	1.4×10^8	{ 4009 5789 5790 5791 5793

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

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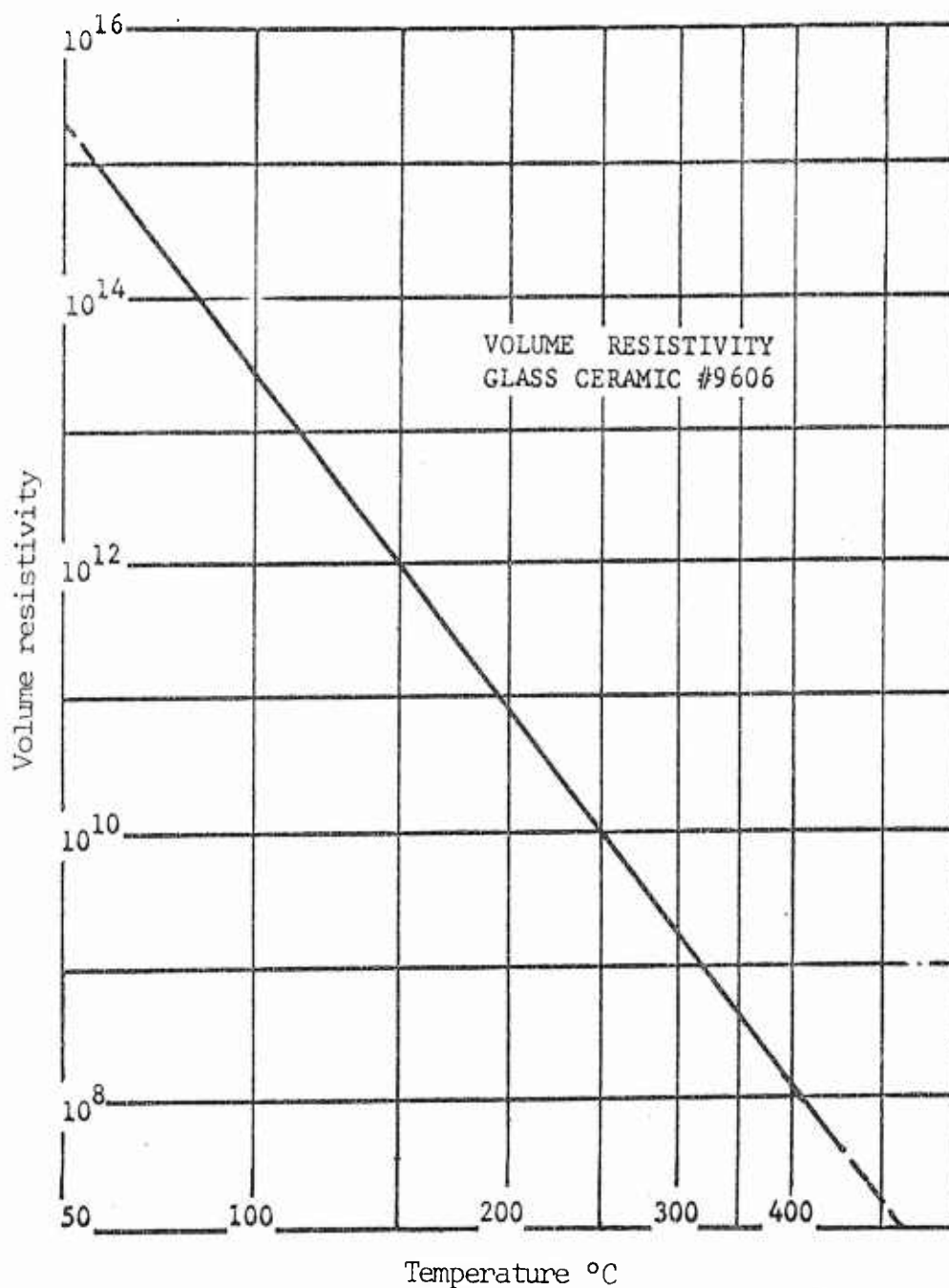
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INSULATION MATERIALS

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PYROCERAM - Corning 9606

Volume Resistivity



Resistivity as a function of temperature for Corning 9606.

[Ref. 5788]

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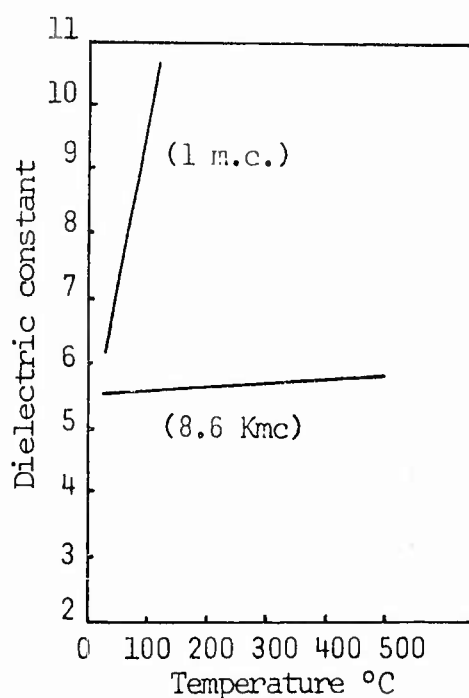
INSULATION MATERIALS

August 1963

PYROCERAM - Corning 9608

Dielectric Constant

Temperature (°C)	Frequency (CPS)	ϵ'	Ref.
25	10^2	7.13	5791
25	10^6	6.78	{ 5789 5791 5788 5793 5790 5795
25	10^{10}	6.54	{ 5789 5791 5795
300	10^{10}	6.65	{ 5789 5791 5795
500	10^{10}	6.78	{ 5789 5791 5795



Dielectric constant as a function of temperature for Corning 9608 at two frequencies.

[Ref. 1261]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

MATERIALS CENTRAL

AERONAUTICAL SYSTEMS DIVISION

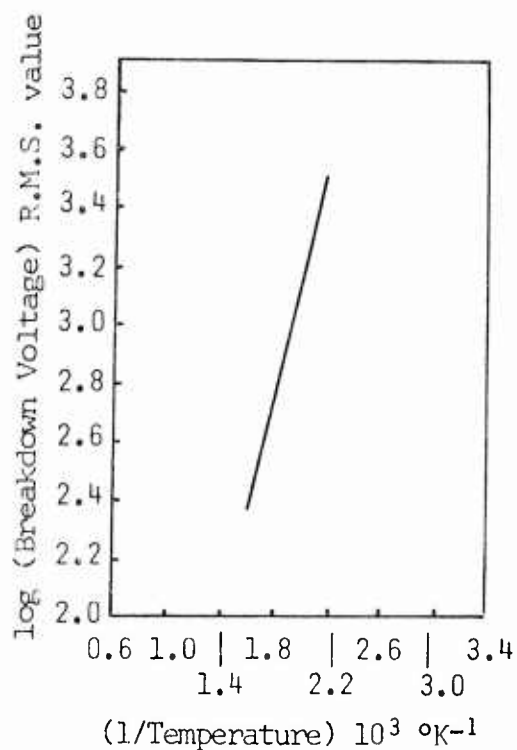
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INSULATION MATERIALS

August 1963

PYROCERAM - Corning 9608

Dielectric Strength



Dielectric strength as a function of temperature for Corning 9608. One-minute breakdown for sample thickness of 2 mm at 60 CPS.

[Ref. 1261]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

MATERIALS CENTRAL

AERONAUTICAL SYSTEMS DIVISION

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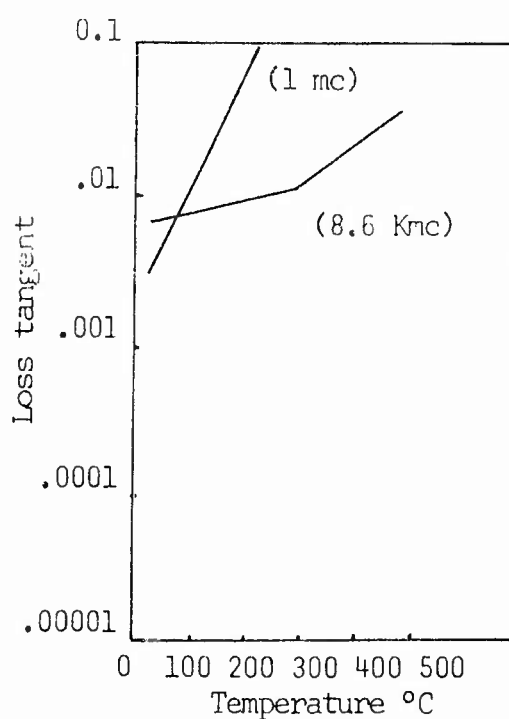
INSULATION MATERIALS

August 1963

PYROCERAM - Corning 9608

Dissipation Factor

Temperature (°C)	Frequency (CPS)	Tan δ	Ref.
25	10^2	0.020	5789
25	10^6	0.0030	5788 5789 5790
25	10^{10}	0.0068	5789 5791
300	10^{10}	0.0115	5789 5791
500	10^{10}	0.040	5789 5791



Loss tangent as a function of temperature for Corning 9808 at two frequencies.

[Ref. 1261]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

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AERONAUTICAL SYSTEMS DIVISION

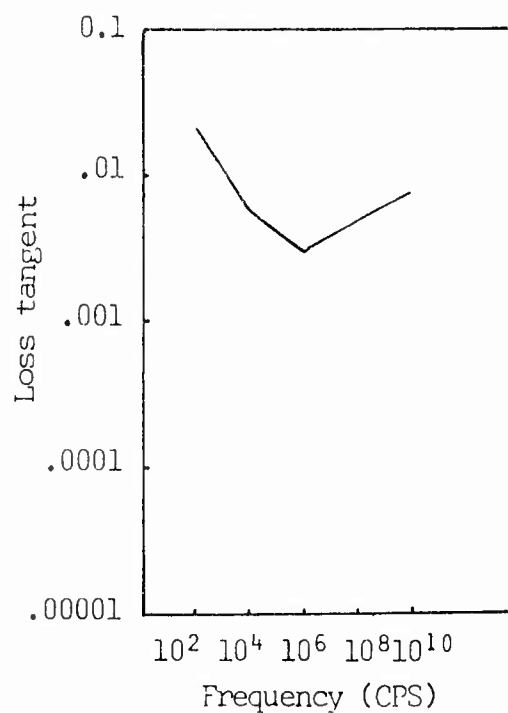
AIR FORCE SYSTEMS COMMAND

INSULATION MATERIALS

August 1963

PYROCLERAM - Corning 9608

Dissipation Factor



Loss tangent as a function of frequency for Corning 9808
at room temperature.

[Ref. 1261]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

MATERIALS CENTRAL

AERONAUTICAL SYSTEMS DIVISION

AIR FORCE SYSTEMS COMMAND

INSULATION MATERIALS

August 1963

PYROCERAM - Corning 9608

Loss Factor

Temperature (°C)	Frequency (CPS)	Loss Factor	Ref.
25	10^6	0.020	5789, 5791, 5793
25	10^{10}	0.045	5789, 5791
300	10^{10}	0.077	5789, 5791
500	10^{10}	0.27	5789, 5791

Volume Resistivity

Temperature (°C)

Resistivity (ohm-cm)

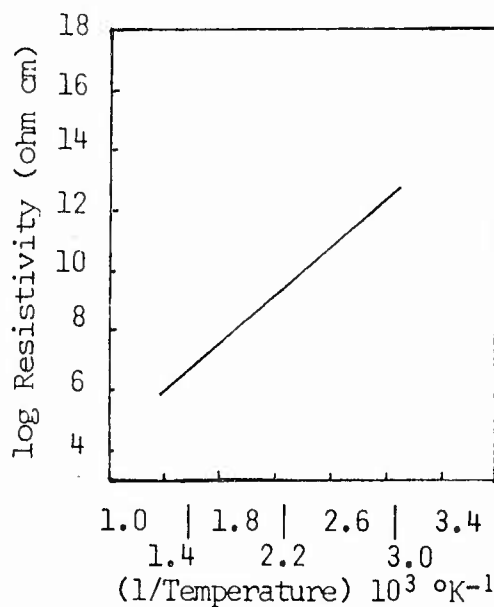
250°

1.1×10^8

350

1.6×10^6

[Ref. 5788, 5789, 5791, 5790, 5793]



Relation between d-c resistivity
and temperature for Corning 9608.

[Ref. 1261]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

MATERIALS CENTRAL

AERONAUTICAL SYSTEMS DIVISION

AIR FORCE SYSTEMS COMMAND

INSULATION MATERIALS

August 1963

PYROCERAM - Unknown Code Designation

Dielectric Constant

Temperature (°C)	Frequency (CPS)	ϵ'	Ref.
25 (?)	10^6	5.5 to 6.3	4835

Dissipation Factor

Temperature (°C)	Frequency (CPS)	Tan δ	Ref.
25 (?)	10^6	0.0017-0.013	4835

Loss Factor

Temperature (°C)	Frequency (CPS)	Loss Factor	Ref.
25 (?)	10^6	0.01-0.07	4835

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