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QUARTERLY REPORT

ON

RECONSTITUTED MICA PAPER FOR CAPACITORS

PERIOD: Third Quarter
1 January through 31 March 1958

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ORDER NO.: 56395-PHILA-57-81

Industrial Mobilization Activity
United States Army Signal Supply Agency
Philadelphia, Pennsylvania.

Micamold

MICAMOLD ELECTRONICS MFG. CORP.

1087 FLUSHING AVENUE, BROOKLYN, NEW YORK.

Manufacturers Code

Mfr A	Spruce Pine Co.
Mfr B	General Electric Co.
Mfr C	Mica Insulator Co.

RECONSTITUTED MICA PAPER

FOR CAPACITORS

Third Quarterly Report
(Period of January 1958 through March 1958)

Object: To evaluate the mechanical and electrical characteristics of reconstituted natural mica paper and to determine the feasibility of employing it as a capacitor dielectric.

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MICAMOLD ELECTRONICS MANUFACTURING CORPORATION

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Abstract:

During this period, tests were continued on uncured specimens of impregnated reconstituted mica paper capacitors. The necessary equipment for curing (heat-pressing) the material was not readied until late in the period.

Voltage strength tests were performed and the results show voltage strengths, at best, only 30% of natural mica capacitors.

Additional temperature coefficient tests were performed on silvered electrode, reconstituted mica paper capacitors with no significant improvements over the foil specimens tested previously.

Insulation resistance tests were performed. The test results show the insulation resistance values of impregnated reconstituted mica paper capacitors to be equivalent to natural mica capacitors.

Purpose:

a. To evaluate the mechanical and electrical characteristics of reconstituted natural mica paper and to determine the feasibility of employing it as a capacitor dielectric.

b. To prepare preproduction samples of reconstituted natural mica paper capacitors for qualification tests in accordance with Military Specification MIL-C-5A covering mica dielectric capacitors.

c. To establish pilot facilities for the production of capacitors employing reconstituted natural mica paper as a dielectric.

d. To produce pilot quantities of capacitors employing reconstituted natural mica as a dielectric.

Discussion:

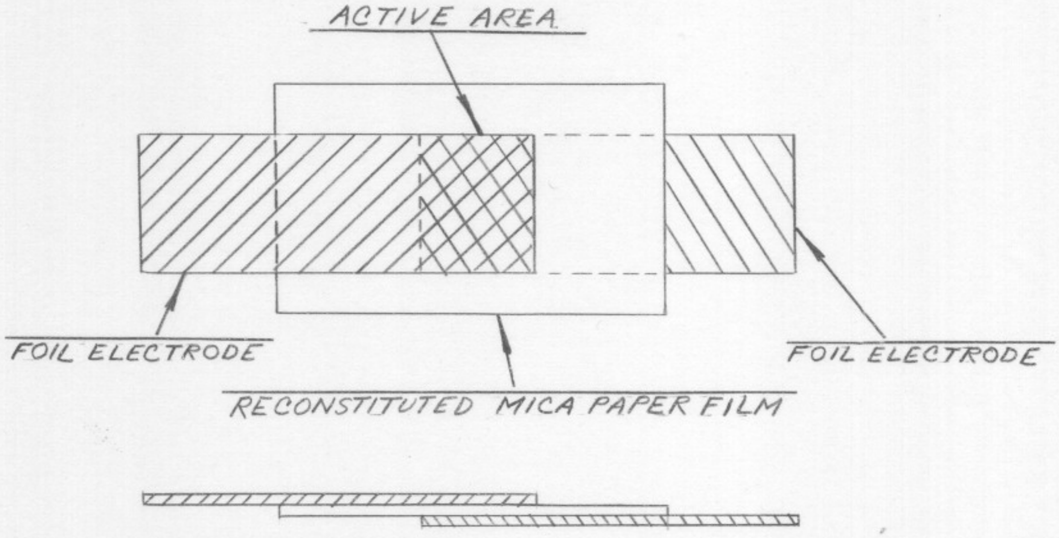
During the previous quarters, considerable mention was made of a "heat-press" cycle to be included in the fabrication of reconstituted mica paper capacitors. It was hoped and expected that the effect of such a step would be to improve the stability, design constant, and other electrical and mechanical features of the capacitor so that they more closely approach the characteristics of natural mica capacitors. Unfortunately this process could not be introduced until very late in this, the third quarter. Therefore, the evaluation of the effects of the "heat-press" cycle must await the next report period.

Engineering evaluations during this quarter were concentrated mostly on reconstituted mica paper capacitors of silvered electrode construction to determine if silvering offers any improvements in stability and Q over the foil constructed capacitors evaluated previously. The evaluation was limited mostly to new materials, and those other materials discussed previously which could reasonably be expected to withstand the firing process without flaking or destructive gassing.

The silvered reconstituted mica paper capacitors were submitted to compression, temperature coefficient, Q, and insulation resistance tests. Voltage strength tests were performed on foil electrode capacitors.

1. Voltage Strength:

a. Except for relatively infrequent instances, receiving type natural mica capacitors covered by Specification MIL-C-5A use a single dielectric film between electrodes. For the higher voltage transmitting mica capacitors, multiple mica films are resorted to. Therefore, voltage tests on reconstituted mica paper specimens were performed on single and double dielectric layers to see what dielectric thicknesses would be required for use in MIL-C-5A capacitors. Also we were interested in determining if the voltage strength is significantly improved due to isolation of any imperfections in the film. The test specimens consisted of cased and uncased single and double film elements of foil construction with a 1/8 square inch active area.



The DC test potentials were increased gradually at a constant rate, across the dielectric until the dielectric punctured. Tests were also conducted on similarly prepared natural mica specimens for comparison purposes.

b. Single Film Specimens:

The voltage tests were conducted on approximately six specimens of each of the various materials listed in Tables 1 and 2. A review of the test results shows the uncured impregnated reconstituted mica paper and untreated mica paper capacitors to be inferior to natural mica with regard to voltage strength. Depending on dielectric thickness, the manufacturer, and the treatment, the voltage strength in volts/mil for a 1/8 square inch area ranged from approximately 700 to 2650 as compared to voltage strengths in excess of 6000 volts/mil for the natural mica specimens.

There does not appear to be any significant difference between the flash voltages of cased and uncased samples. The variations in most instances appear to be random with no assignable causes, nor could any trend be distinguished. The dielectric voltage strength in volts/mil increases with increasing dielectric thickness as evidenced in Figure 1. Another point of interest noted in Figure 1 is the effect of the percentage of resin impregnation on the voltage strength. Optimum dielectric strength is obtained with approximately 1 or 2% resin impregnation. The next quarter will attempt to verify this and to determine if this holds on cured mica paper. It will also be of interest to see if the "heat-press" cycle raises the voltage strength level.

Discuss

c. Mfr C submitted a special, high density, untreated, 2 mil mica paper for evaluation primarily to determine if the material lends itself to silvering. This new material was more adaptable to silvering than previously tested untreated mica paper. Also, voltage tests reveal an average voltage strength for this special mica paper of approximately 2500 volts/mil as compared to approximately 1750 volts/mil for Mfr C regular density, 2 mil mica paper. If this is verified through additional testing, then the special grade of mica paper may be a better base for the impregnated films and possibly raise the end-product voltage strength.

d. Double Film Specimens:

Voltage breakdown tests, similar to those performed for single film sections, were performed on double film sections. A principle behind the use of multiple dielectric layers is, as in the case of paper dielectric capacitors, to raise the volts/mil level of the dielectric by statistically reducing the likelihood that conducting particles or other imperfections in the layers will be aligned. A review of the test results summarized in Table 3 reveals that, in general, there is no improvement in the volts/mil level of the double filmed specimens over the single dielectric film capacitors except for the heavily impregnated specimens from Mfr C. Apparently, imperfections in the relatively thick reconstituted mica paper are not as serious as is the case with thin paper dielectric tissues. At this moment, there does not appear to be any advantage of double layers of reconstituted mica paper over a single layer of equal thickness, except possibly, for the heavily impregnated mica paper.

Table 1.- Summary of d.c. voltage breakdown, single layer (uncased)

Mfr	Type	Breakdown in Volts			Breakdown in Volts/mil		
		Av.	Max.	Min.	Av.	Max.	Min.
C	.9 mil, impreg.	1370	1650	1200	810	970	710
C	1.3 mil, impreg.	2120	2500	1600	1000	1180	760
C	1.5 mil, impreg.	2660	3000	2300	1130	1270	970
C	2 mil, impreg.	5220	5500	4500	1610	1700	1390
C	.9 mil, untreated	1450	1600	1300	1610	1780	1450
C	1.3 mil, untreated	2150	2200	2000	1790	1840	1670
C	1.5 mil, untreated	2240	2400	2100	1930	2060	1810
C	2 mil, untreated	3600	4000	3000	1750	2000	1500
C	2 mil, Spec. 0, untreated	4410	5000	3000	2510	2840	2220
C	2 mil, Spec. 1, impreg.	4960	5500	3800	2650	2940	2030
C	2 mil, Spec. 5, impreg.	5000	5500	4500	2490	2740	2240
C	1.3 mil, Spec. 1, impreg.	2630	2900	2400	2010	2210	1830
C	1.3 mil, Spec. 5, impreg.	2430	2500	2300	1800	1850	1710
C	.9 mil, Spec. 1, impreg.	1720	2500	1300	1680	2450	1270
C	.9 mil, Spec. 5, impreg.	1880	2100	1800	1650	1840	1580
B	4 mil, untreated	4520	5000	4000	1350	1500	1200
B	1.5 mil, S-1182, impreg.	1580	1900	1200	1340	1610	1020
B	1.5 mil, S-1250, impreg.	1870	2200	1300	770	910	540
B	2 mil, S-1211, impreg.	3170	3400	2500	1340	1440	1060
A	2 mil, integ., impreg.	2420	3000	1700	730	910	520
A	2 mil, integ., untreated	1740	2100	1400	680	810	540
--	Nat. Mica, $1\frac{1}{4} - 1\frac{1}{2}$ mils	---	---	---	7400	7700	7100
--	Nat. Mica, 1 3/4 - 2 mils	---	---	---	6100	6500	5200

Table 2.- Summary of d.c. voltage breakdown of molded sections (single layer)

Mfr	Type	Breakdown in Volts Av.	Max.	Min.
C	.9 mil, impreg.	1240	1600	1000
C	1.3 mil, impreg.	2840	3500	2500
C	1.5 mil, impreg.	4000	4800	3300
C	2 mil, impreg.	7640	9000	5600
C	.9 mil, untreated	1280	1600	900
C	1.3 mil, untreated	1900	2300	1500
C	1.5 mil, untreated	1880	2200	1600
C	2 mil, untreated	3460	4300	2800
C	2 mil, Spec. 0, untreated	4840	4900	4700
C	2 mil, Spec. 1, impreg.	4680	5000	3400
C	2 mil, Spec. 5, impreg.	4480	5000	3500
C	1.3 mil, Spec. 1, impreg.	2150	2500	1800
C	1.3 mil, Spec. 5, impreg.	2440	2700	1900
C	.9 mil, Spec. 1, impreg.	1860	2500	1300
C	.9 mil, Spec. 5, impreg.	1840	2200	1500
B	4 mil, untreated	5680	6000	5100
B	1.5 mil, S-1182, impreg.	1700	2000	1300
B	1.5 mil, S-1250, impreg.	2140	2400	1800
B	2 mil, S-1211, impreg.	3820	4300	3500
A	2 mil, integ., impreg.	2800	3300	2400
A	2 mil, integ., untreated	2020	2300	1400
--	Nat. Mica, $1\frac{1}{4}$ - $1\frac{1}{2}$ mils	---	---	$>$10000
--	Nat. Mica, 1 3/4 - 2 mils	---	---	10000

Table 3.- Summary of d.c. voltage breakdown, double layer (uncased)

Mfr	Type	Breakdown in Volts			Breakdown in Volts/mil		
		Av.	Max.	Min.	Av.	Max.	Min.
C	.9 mil, impreg.	3380	3800	3000	1410	1590	1250
C	1.5 mil, impreg.	6780	7100	6500	1440	1500	1380
C	2 mil, impreg.	9920	10000	9800	1540	1550	1520
C	.9 mil, untreated	2980	3200	2500	1650	1770	1390
C	1.3 mil, untreated	4160	4800	3700	1730	2000	1540
C	1.5 mil, untreated	4040	4100	3800	1750	1770	1640
C	2 mil, untreated	6500	7000	6000	1590	1720	1470
C	2 mil, Spec. 0, untreated	8300	9000	7000	2360	2560	1990
C	2 mil, Spec. 1, impreg.	*9900	10000	9500	---	---	*>2500
C	2 mil, Spec. 5, impreg.	9760	10000	9000	2430	2490	2230
C	1.3 mil, Spec. 1, impreg.	4720	5500	4100	1800	2100	1560
C	1.3 mil, Spec. 5, impreg.	4880	5100	4800	1810	1890	1780
C	.9 mil, Spec. 1, impreg.	3920	4700	3400	1920	2300	1670
C	.9 mil, Spec. 5, impreg.	3960	4500	3800	1740	1980	1670
B	4 mil, untreated	7140	8000	6000	1070	1200	900
B	1.5 mil, S-1182, impreg.	3660	4000	3200	1550	1720	1360
B	1.5 mil, S-1250, impreg.	4280	4700	3500	880	970	720
B	2 mil, S-1211, impreg.	6600	7000	6000	1400	1480	1270
A	2 mil, integ., impreg.	4820	5800	3700	730	880	560
A	2 mil, integ., untreated	4940	6500	3800	960	1260	740
--	Nat. Mica, $1\frac{1}{4}$ - $1\frac{1}{2}$ mil	*9380	9800	9100	---	---	*>3200
--	Nat. Mica, 1 3/4 - 2 mil	*9820	10000	9500	---	---	*>2500

*Specimens flashed around the safe edge. The dielectric puncture point was not reached.

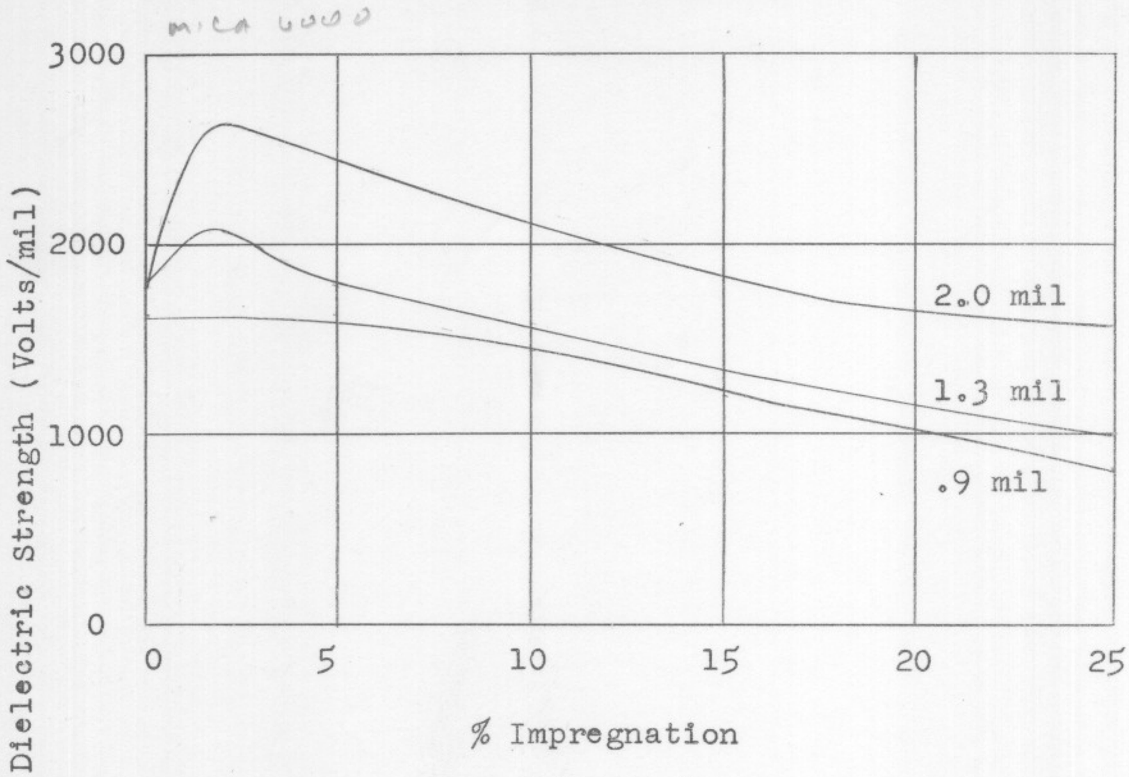


FIGURE 1a

AVERAGE VOLTAGE STRENGTH vs % IMPREGNATION
(single film)

MANUFACTURER: Mfr. C

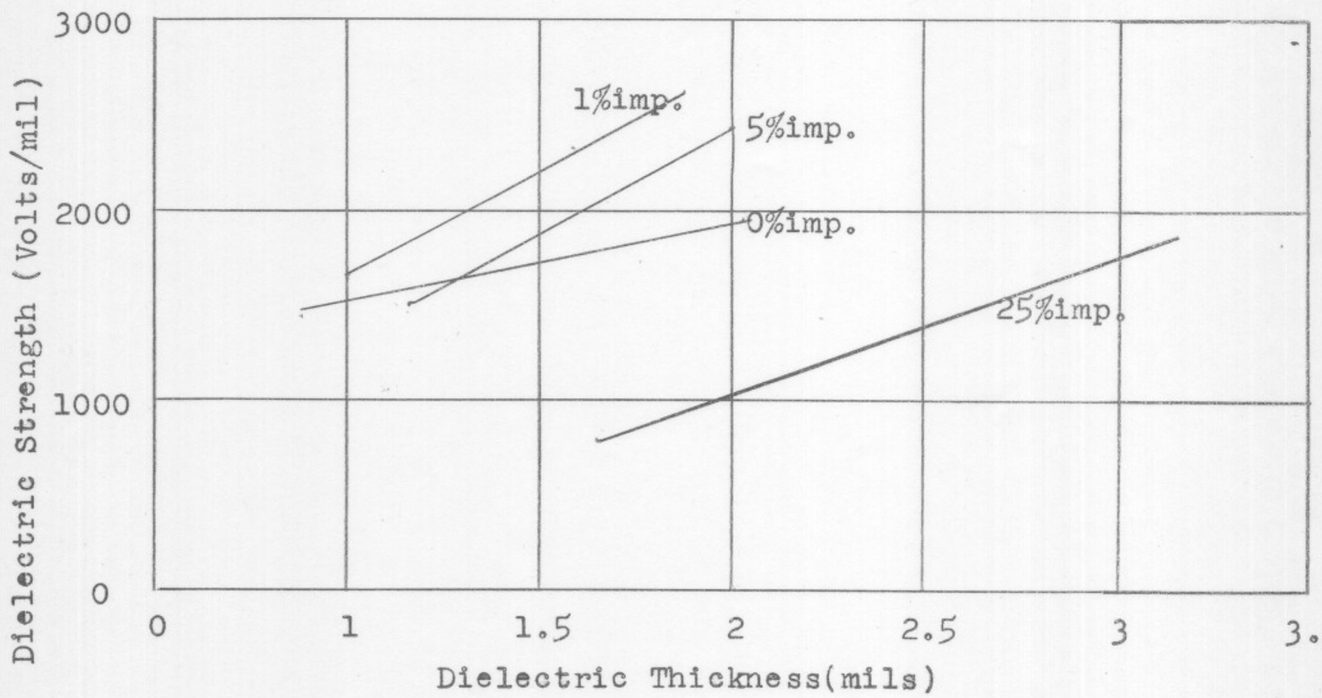


FIGURE 1b

AVERAGE VOLTAGE STRENGTH vs DIELECTRIC THICKNESS
(single film)

MANUFACTURER: Mfr. C

2. Temperature Characteristics:

a. In an attempt to improve upon the characteristics reported last quarter, samples were made with silvered electrodes, as opposed to foil electrode designs tested previously. The types of materials silvered were those which, due to impregnation techniques and mica paper density, were capable of withstanding the severe firing temperatures without excessive flaking and gassing. Such materials are:

Item 1 Mfr C, 2 mil, Special 0, untreated
Item 2 Mfr C, .9 mil, Special 1, treated
Item 3 Mfr C, .9 mil, Special 5, treated
Item 4 Mfr C, 1.3 mil, Special 5, treated
Item 5 Mfr B, S-1250, treated
Item 6 Mfr B, S-1182, treated
Item 7 Mfr A, 2 mil, integrated, treated
Item 8 1 3/4 - 2 mil natural mica

The silvered capacitor sections were encased in MIL-C-5A style CM45 cases. Molding materials of phenolic and alkyd resins were used to determine what effects the molding material and process have on the temperature characteristics. Capacitance values of the samples ranged from approximately 70 uuf for Mfr A to 225 uuf for the others. Mica —?

b. Temperature coefficient and capacitance drift test results did not reveal any significant improvement in stability of silvered capacitors over foil capacitors except for the case of natural mica capacitors. Reference is made to Tables 4, 5, and 6 for a summary of the test results. Table 6 covers foil sections. Some samples exhibit temperature coefficients meeting C and D characteristics of MIL-C-5A, ± 200 ppm/°C and ± 100 ppm/°C, respectively. Such is the case with samples of Mfr C .9 mil Special 5, Mfr B types S-1182 and S-1250, and Mfr C 1.3 mil Special 5, all molded with phenolic resin. However, the erratic results and the relatively poor stability (25°C drift) indicates that additional stabilizing procedures are required. Such procedures may take the form of the "hot-press" cycle plus a final stabilizing temperature cycling.

c. Surprisingly, the alkyd molded units had poor, negative coefficients and excessively high capacitance drifts as compared with phenolic molded sections. This occurred only with the reconstituted mica paper capacitors. There is a difference in the molding temperatures, pressures, and the resin fluidity between the two molding materials. Some conjecture is that gas produced in the uncured mica paper during molding may produce more voids with the more fluid alkyd resin. Such a condition would exhibit large negative coefficients as opposed to stabilized natural mica, silvered sections. Also, it was noted that alkyd molded sections exhibited significantly higher capacitance values which may be indicative of much higher pressures being exerted on the reconstituted mica film. Existence of high stresses on the dielectric would also effect the temperature characteristics in the manner seen and would indicate that additional stabilization is required to relieve the dielectric stresses.

d. Work during the next quarter will be performed on "hot-pressed" sections of foil and silvered electrode construction. Added stabilizing temperature cycles will be attempted to relieve dielectric stresses introduced during molding.

Table 4.- Temp. char. (PPM/°C) at 1 kc, silvered capacitors, CM45

Item	Unit No.	Case Material	Temp. Coefficient (PPM/°C) -55°C	-10°C	65°C	85°C	% Cap. Drift (25°C)
1	1	phenolic	90	30	105	175	.8
Mfr C	2	phenolic	0	145	75	290	.9
2 mil	3	phenolic	-535	-575	0	55	.3
Spec. 0	6	alkyd	10	165	170	210	1.5
	7	alkyd	-510	-455	-775	-650	2.5
	8	alkyd	-480	-535	-595	-425	2.5
2	1	phenolic	-720	-975	-2110	-2760	1.6
Mfr C	2	phenolic	-625	-815	-1665	-1680	1.5
.9 mil	3	phenolic	500	575	185	160	1.0
Spec. 1	5	alkyd	-1300	-1410	-1920	-1680	5.8
	7	alkyd	-825	-950	-995	-800	4.0
	8	alkyd	-825	-1000	-1700	-1595	3.7
3	1	phenolic	50	80	-70	-55	.7
Mfr C	2	phenolic	85	50	20	55	.5
.9 mil	3	phenolic	-40	-50	45	115	.1
Spec. 5	6	alkyd	-50	25	20	35	.4
	7	alkyd	25	90	-80	-90	1.6
	8	alkyd	-160	-190	-230	-245	.4
4	2	phenolic	115	275	145	215	.6
Mfr C	4	phenolic	310	141	60	105	.6
1.3 mil	6	alkyd	-95	0	-280	-230	.1
Spec. 5	7	alkyd	-355	-305	-330	-270	1.1
	8	alkyd	-220	-285	-485	-445	1.0
5	1	phenolic	-190	-185	0	-340	1.2
Mfr B	2	phenolic	140	230	75	356	1.0
1.5 mil	3	phenolic	65	50	-65	55	1.3
S-1250	6	alkyd	35	55	215	260	.5
	7	alkyd	90	150	135	350	.3
	8	alkyd	215	320	215	355	.7
6	1	phenolic	-10	100	90	95	.5
Mfr B	2	phenolic	55	170	170	150	.4
1.5 mil	3	phenolic	-115	-60	-140	-95	.4
S-1182	6	alkyd	-355	-365	-170	-135	1.3
	7	alkyd	-550	-585	-665	-605	2.3
	8	alkyd	-430	-355	-610	-520	1.9
7	2	phenolic	-520	-450	-325	-120	1.2
Mfr A	3	phenolic	60	190	125	55	.8
2 mil	4	phenolic	-450	-600	-405	-485	1.0
integ.	6	alkyd	-610	-695	-395	-380	2.0
	7	alkyd	-480	-525	-535	-690	1.4
	8	alkyd	-725	-865	-760	-865	2.7
8	1	phenolic	60	100	100	120	.3
Nat.	2	phenolic	105	200	45	45	.04
Mica	3	phenolic	110	125	0	45	.1
	5	alkyd	115	135	80	55	.2
	7	alkyd	45	25	45	105	.05
	8	alkyd	80	100	165	90	.2

Table 5.- Temp. Char. (PPM/°C) at 10 kc, silvered capacitors, CM45

Item	Unit No.	Case Material	Temp. Coefficient (PPM/°C)				% Cap. Drift (25°C)
			-55°C	-10°C	65°C	85°C	
1 Mfr C 2 mil Spec. 0	1	phenolic	25	-180	-265	70	.8
	2	phenolic	-40	0	0	225	.8
	3	phenolic	-520	-670	-105	-35	.5
	6	alkyd	-35	0	100	100	1.5
	7	alkyd	-510	-595	-920	-790	2.2
	8	alkyd	-525	-715	-860	-715	2.7
2 Mfr C .9 mil Spec. 1	1	phenolic	-750	-1045	-2340	-2940	1.7
	2	phenolic	-705	-945	-1630	-1755	1.4
	3	phenolic	450	425	110	85	1.1
	5	alkyd	-1285	-1605	-2500	-1905	5.5
	7	alkyd	-830	-1040	-1290	-960	3.7
	8	alkyd	-865	-1080	-1670	-1655	4.0
3 Mfr C .9 mil Spec. 5	1	phenolic	-35	-140	-30	-55	.4
	2	phenolic	70	-60	10	0	.3
	3	phenolic	-50	-160	-10	15	.2
	6	alkyd	-95	-150	-60	-75	.9
	7	alkyd	-70	-135	-80	-130	1.7
	8	alkyd	-195	-295	-165	-340	1.0
4 Mfr C 1.3 mil Spec. 5	2	phenolic	0	35	80	75	.6
	4	phenolic	-70	-70	60	75	.4
	6	alkyd	-165	-195	-280	-240	.3
	7	alkyd	-405	-505	-460	-380	1.0
	8	alkyd	-290	-440	-580	-535	.9
5 Mfr B S-1250	1	phenolic	-215	-310	-325	-200	.9
	2	phenolic	40	0	25	50	.3
	3	phenolic	-40	-150	-130	0	.6
	6	alkyd	-170	-305	-25	-30	1.1
	7	alkyd	-145	-280	45	30	1.3
	8	alkyd	-100	-300	90	90	1.5
6 Mfr B S-1182	1	phenolic	-55	-20	15	35	.9
	2	phenolic	20	45	130	135	.7
	3	phenolic	-135	-140	-140	-95	.6
	6	alkyd	-435	-565	-235	-190	1.7
	7	alkyd	-640	-750	-745	-620	3.1
	8	alkyd	-525	-505	-615	-545	2.4
7 Mfr A 2 mil impreg.	2	phenolic	-675	-960	-365	-290	1.2
	3	phenolic	-40	-430	40	-30	1.7
	4	phenolic	-555	-1080	-455	-550	.8
	6	alkyd	-765	-1415	-620	-585	4.5
	7	alkyd	-705	-1340	-745	-885	2.7
	8	alkyd	-790	-1360	-960	-1000	1.8
8 Nat. Mica	1	phenolic	30	10	30	45	.09
	2	phenolic	40	40	45	30	.04
	3	phenolic	40	40	35	35	.09
	5	alkyd	75	40	60	70	.09
	7	alkyd	40	0	35	45	.3
	8	alkyd	80	50	20	45	.2

Table 6.- Temp. characteristics of foil capacitors, phenolic case

Item	Unit No.	Temp. coefficient (PPM/°C), 10 kc				% Cap. Drift (25°C)
		-55°C	10°C	65°C	85°C	
Mfr C .9 mil impreg.	3J	10	70	100	210	.7
	6J	0	-25	95	380	1.6
	1J	5	55	85	290	1.2
	4J	-10	25	40	135	.3
	5J	-15	35	25	170	.6
Natural Mica	7C	-300	-345	-625	-630	.4
	8C	-210	-245	-610	-435	.5
	10C	-35	-30	-220	-115	.7
	6C	-190	-25	-275	15	2.1
	5C	-135	-105	-160	50	1.3
Mfr A 2 mil impreg.	5N	-180	-110	-610	-490	1.0
	6N	-200	-100	-425	-465	.5
	4N	-185	-130	-655	-645	.8
	8N	-135	-100	-415	-275	.8
	13N	-165	-120	-810	-595	.8
Mfr A 2 mil untreated	6E	-200	-195	-1280	-1080	1.2
	8E	-210	-220	-1200	-1240	6.5
	9E	-220	-250	-1220	-1130	2.1
	5E	-195	-235	-795	-775	.9
	7E	-245	-260	-1280	-1210	2.1
	4E	-225	-230	-1240	-1260	2.0

3. Q Measurements:

a. Last quarter, Q measurements were made on foil constructed sections. During this quarter, Q measurements were made on silvered electrode sections, cased and uncased, to determine if silvered electrodes possibly through more intimate contact with the dielectric, will raise the Q of reconstituted mica paper capacitors. Also, the effects of molding materials on the Q were investigated.

b. For a summary of the test results see Tables 7 and 8. A review of the Q measurements on the silvered sections reveals, on the whole, a poorer Q than comparable foil sections reported upon previously. This is especially true of the heavily impregnated mica paper capacitors where the Q of molded sections ran as low as 115. The Q values of unimpregnated and lightly impregnated mica paper capacitors of Mfr C, on the other hand, ranged from about 800 to 2300. The poor and erratic Q values for heavily impregnated mica paper capacitors are attributed to flaking off or poor bonding of the silvered electrodes to the dielectric. Where the dielectric was specially treated, as in the case of the "Special" series of Mfr C, and where "Silvering" was compatible, higher Q values were attained. However, except for "Spec. 1" items of Mfr C, the Q values were considerably lower than the average of approximately 1600 for the silvered natural mica capacitors. Using only the "Spec. 1" series reconstituted mica paper capacitors as a basis, it appears that a realistic Q limit, at this time, of silvered sections is 600.

c. It is difficult to evaluate the effects of the molding material on Q. In some instances, as in the heavily impregnated and untreated mica paper of Mfr C, the Q values were lowered considerably after molding. This appears true for natural mica capacitors also. However, the opposite is the case for the "Spec." series of Mfr C.

Table 7.- Average Q, silvered, CM45 style, phenolic case, reconstituted mica capacitors

Item	Uncased Sections			Molded Sections		
	Av.	Max.	Min.	Av.	Max.	Min.
Mfr C, .9 mil, impreg.	385	465	310	117	119	115
Mfr C, 1.5 mil, impreg.	475	535	335	145	180	120
Mfr C, .9 mil, untreated	1150	1430	910	875	1110	740
Mfr C, 1.3 mil, untreated	1110	1370	750	900	1250	630
Mfr C, 1.5 mil, untreated	820	1080	695	665	795	610
Mfr C, 2 mil, untreated	1100	1310	930	625	820	450
Mfr B, 4 mil, untreated	810	1010	535	345	570	135
Mfr B, 1 mil, S-1182	900	1295	515	830	885	765
Mfr B, 2 mil, S-1211	600	700	490	780	835	750
Mfr B, 1 mil, S-1250	270	320	215	425	595	335
Mfr A, 2 mil, impreg.	665	700	625	690	750	630
Mfr C, 2 mil, Spec. 0	305	365	235	905	1070	580
Mfr C, .9 mil, Spec. 1	1560	1710	1280	2330	2280	1660
Mfr C, 1.3 mil, Spec. 1	1130	1300	960	1560	1750	1130
Mfr C, 2 mil, Spec. 1	395	505	310	1300	1720	980
Mfr C, .9 mil, Spec. 5	525	590	470	655	815	600
Mfr C, 1.3 mil, Spec. 5	685	720	630	665	735	595
Mfr C, 2 mil, Spec. 5	685	830	420	360	390	280
Nat. Mica, 1¼ - 1½ mil	1820	2100	1440	1570	1680	1360
Nat. Mica, 1 3/4 - 2 mil	1820	1980	1550	1750	2090	1360

Table 8.- Average Q, silvered, CM45 style, alkyd case, reconstituted mica capacitor

Item	Uncased Sections			Molded Sections		
	Av.	Max.	Min.	Av.	Max.	Min.
Mfr C, .9 mil, impreg.	360	465	290	160	165	155
Mfr C, 1.5 mil, impreg.	445	510	400	230	245	200
Mfr C, .9 mil, untreated	1090	1290	930	---	---	---
Mfr C, 1.3 mil, untreated	1165	1390	1040	575	690	510
Mfr C, 1.5 mil, untreated	990	1270	720	565	610	530
Mfr C, 2 mil, untreated	1200	1750	1040	425	560	340
Mfr B, 4 mil, untreated	920	1110	800	185	245	160
Mfr B, 1 mil, S-1182	485	530	460	515	565	470
Mfr B, 2 mil, S-1211	660	730	590	520	570	470
Mfr B, 1 mil, S-1250	275	290	265	280	300	265
Mfr A, 2 mil, impreg.	680	745	610	575	720	500
Mfr C, 2 mil, Spec. 0	335	425	230	600	735	505
Mfr C, .9 mil, Spec. 1	1095	1190	930	1075	1170	985
Mfr C, 1.3 mil, Spec. 1	1100	1200	930	1380	1740	1050
Mfr C, 2 mil, Spec. 1	440	530	330	720	810	630
Mfr C, .9 mil, Spec. 5	540	660	420	525	560	485
Mfr C, 1.3 mil, Spec. 5	815	1030	550	605	710	545
Mfr C, 2 mil, Spec. 5	645	735	525	370	470	300
Nat. Mica, 1 3/4 - 2 mil	1650	1970	1430	1780	1860	1630
Nat. Mica, $1\frac{1}{4}$ - $1\frac{1}{2}$ mil	1530	1720	1170	1240	1310	1160

4. Insulation Resistance:

a. During this quarter, insulation resistance measurements were made on uncured reconstituted mica paper capacitors and compared with the insulation resistance values of natural mica capacitors. Measurements were made, with 100 vdc applied, on silvered and foil electrode sections, both cased and uncased. Specification MIL-C-5A requires only a 25°C measurement with a 7500 megohm minimum. For evaluation purposes, however, insulation resistance measurements were made from 25°C through 125°C, and in some instances up to 140°C.

b. For a summary of the test results, see Tables 9 and 10. At first, measurements were made on sections molded in a phenolic resin. This material is ordinarily used only for applications up to 85°C. The test results reveal insulation resistance values exceeding 80000 megohms at 25°C for the reconstituted as well as natural mica capacitors. At 85°C, the samples ranged, in general, approximately from 10000 to greater than 80000 megohms. At 125°C, all capacitors, including the natural mica, had average insulation resistances in the order of approximately 5000 megohms.

c. As mentioned above, the phenolic cases are used only up to 85°C. This limitation is due in part, to the increased conductivity of the case at high temperatures. To compare the actual insulation resistance characteristics of natural and reconstituted mica capacitors, uncased capacitor sections were fabricated and tested over the temperature range of 25° to 140°C. The sampling consisted of representative specimens of natural mica, uncured impregnated mica paper, unimpregnated mica paper, and cured impregnated mica paper. Over this temperature excursion, the insulation resistance of all specimens exceeded 80000 megohms. It appears, therefore, that for operating temperatures up to 140 C, the insulation resistance values of natural and reconstituted mica are equivalent. An additional test was performed to observe the moisture absorbtion of reconstituted mica paper. The specimens were allowed to stand at room conditions after the heat run. Periodic measurements revealed a rapid degradation of insulation resistance of the untreated reconstituted mica paper. The impregnated reconstituted mica paper and natural mica capacitors were not affected by normal laboratory humidity conditions over a 21 hour period (see Table 11).

Table 9.- Insulation resistance of CM45 style, phenolic molded samples (megohms)

	25°C			85°C			125°C		
Item	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
Mfr C, .9 mil, impreg.	--	--	>80K	--	>80K	20K	9K	15K	4K
Mfr C, 1.3 mil, impreg.	--	--	↑	--	>80K	25K	19K	40K	2K
Mfr C, 1.5 mil, impreg.	--	--		--	>80K	21K	13K	18K	3K
Mfr C, 2 mil, impreg.	--	--		--	>80K	60K	7K	5K	13K
Mfr C, .9 mil, untreated	--	--		36K	60K	9K	8K	18K	1K
Mfr C, 1.3 mil, untreated	--	--		33K	70K	1K	4K	10K	1K
Mfr C, 1.5 mil, untreated	--	--		25K	45K	12K	8K	17K	2K
Mfr B, 1 mil, S-1182	--	--		--	>80K	40K	6K	23K	2K
Mfr B, 2 mil, S-1211	--	--		--	>80K	55K	23K	70K	4K
Mfr B, 1 mil, S-1250	--	--		--	>80K	2K	4K	8K	1K
Mfr A, 2 mil, untreated	--	--		--	>80K	10K	18K	30K	4K
Mfr A, 2 mil, impreg.	--	--	↓	--	--	>80K	24K	70K	7K
Nat. Mica, 1 3/4 - 2 mil	--	--	>80K	--	--	>80K	7K	26K	1K

Table 10.- Insulation resistance of CM30 style, phenolic molded samples (megohms)

Item	25°C			85°C			125°C		
	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
Mfr C, .9 mil, impreg.	--	--	>80K	31K	35K	25K	3K	3K	3K
Mfr C, 1.3 mil, impreg.	--	--	↑	45K	60K	13K	3K	5K	2K
Mfr C, 1.5 mil, impreg.	--	--		36K	60K	15K	7K	16K	4K
Mfr C, 2 mil, impreg.	--	--		47K	60K	40K	6K	9K	5K
Mfr C, .9 mil, untreated	--	--		54K	70K	40K	12K	20K	6K
Mfr C, 1.3 mil, untreated	--	--		55K	60K	50K	6K	8K	5K
Mfr C, 1.5 mil, untreated	--	--		60K	70K	50K	3K	4K	2K
Mfr C, 2 mil, untreated	--	--		28K	55K	6K	6K	9K	1K
Mfr B, 4 mil, untreated	--	--		10K	28K	4K	6K	7K	1K
Mfr B, 1 mil, S-1182	--	--		49K	70K	35K	10K	12K	8K
Mfr B, 2 mil, S-1211	--	--		44K	60K	25K	5K	10K	3K
Mfr B, 1 mil, S-1250	--	--		--	80K	40K	9K	12K	4K
Mfr A, 2 mil, untreated	--	--		--	80K	35K	8K	10K	5K
Mfr A, 2 mil, impreg.	--	--		51K	70K	35K	8K	11K	3K
Nat. Mica, 1 - $1\frac{1}{4}$ mil	--	--		54K	60K	35K	10K	14K	9K
Nat. Mica, $1\frac{1}{4}$ - $1\frac{1}{2}$ mil	--	--	↓	--	>80K	50K	11K	18K	6K
Nat. Mica, 1 3/4 - 2 mil	--	--	>80K	--	>80K	60K	5K	14K	3K

Table 11.- Insulation resistance of uncased specimens at 25°C (megohms)

Item	Unit No.	25°C meas. after drying at 65°C	Insul. Resistance after standing: 1 hr	2 hr	3 hr	5 hr	21hr
cured, impreg.	1	>80K	>80K	>80K	>80K	>80K	>80K
" "	2	↑	↕	↕	↕	↕	↕
" "	3						
" "	4		>80K	>80K	>80K	>80K	80K
unimpregnated	7		3.5K	5.5K	3K	2.5K	2K
"	8		3.5K	3K	2K	1.5K	1.4K
"	9		50K	40K	40K	40K	30K
uncured, impreg.	13		>80K	>80K	>80K	>80K	>80K
" "	14		↑	↑	↑	↑	↑
" "	15						
" "	16						
Natural Mica	19						
" "	20						
" "	21	↓	↓	↓	↓	↓	↓
" "	20	>80K	>80K	>80K	>80K	>80K	>80K

5. Compressibility:

a. Previously, compressibility tests were made noting the mechanical effects of simulated molding pressures on natural and reconstituted mica dielectrics. During this quarter, the dielectric films were silvered and the capacitance measured as a function of compression over the range of 0 to 2500 psi.

b. As was predicted by the previous compression test results, natural mica section were very stable, capacitance-wise, with changes less than 1% noted over the test pressure range. On the other hand, the reconstituted mica paper sections experienced increases as high as 90% in capacitance while under compression with permanent increases of 12%. In general, the capacitance increases experienced with these silvered specimens were less than with foil constructed samples tested previously.

c. The following list of representative compression test specimens includes new materials received during the third quarter:

Item
1 natural mica, $1\frac{1}{4}$ - $1\frac{1}{2}$ mil, single film
2 natural mica, 1 3/4 - 2 mil, single film
3 Mfr C, .9 mil, Special 5, impreg. single film
4 Mfr C, 1.3 mil, " " " " "
5 Mfr C, .9 mil Special 11, " " "
6 Mfr C, 1.3 mil " " " " "
7 Mfr B, 1 mil, S-1250, single film
8 Mfr B, 1 mil, S-1182, single film

Item
9 Mfr B, 2 mil, S-1211, double film
10 Mfr B, 2 mil, S-1211, single film
11 Mfr A, 2 mil, integrated, impreg. single film
12 Mfr A, 2 mil, integrated, impreg. double film

Table 12 summarized the compression test results. In the next quarter, a sampling will be made on cured specimens. It is expected that capacitance stability for the reconstituted mica paper will be improved and approach that of natural mica.

Table 12.- Percent increase of capacitance with pressure

Item	Pressure - lbs/in²						
	0 (uuf)	500	1000	1500	2000	2500	0
1	285	.5%	.5%	.7%	.7%	.7%	0%
2	224	0%	0%	0%	0%	0%	0%
3	219	4%	6%	9%	11%	13%	2%
4	138	11%	15%	19%	23%	26%	5%
5	122	14%	22%	29%	35%	40%	3%
6	123	16%	24%	31%	35%	40%	4%
7	103	5%	11%	14%	16%	21%	3%
8	124	17%	32%	41%	49%	55%	12%
9	97	40%	56%	70%	77%	85%	7%
10	47	47%	59%	72%	81%	89%	8%
11	55	13%	20%	25%	29%	33%	6%
12	111	14%	22%	29%	33%	39%	4%

6. General:

Some of the new materials received during this period were reconstituted mica paper from Mfr C with different percentages of resin impregnation. As noted under paragraph 1 of this discussion, optimum voltage strength appears to be reached with a minimum amount of impregnation, namely 1%. A review of the data for the relationship of dissipation factor and dielectric constant as functions of the impregnation yields interesting observations. Reference to Figure 2 indicates a relatively rapid rise in dielectric constant between 1% and 6% impregnation with a gradually diminishing rise above 6%. The minimum dissipation factor, at 100 kc, is sharply shown in Figure 3 to fall within 1% and 2% impregnation. For capacitor purposes, it appears at this moment, that the volume efficiency of reconstituted mica paper capacitors may have to be compromised in order to raise the voltage strength and Q levels closer to that of natural mica.

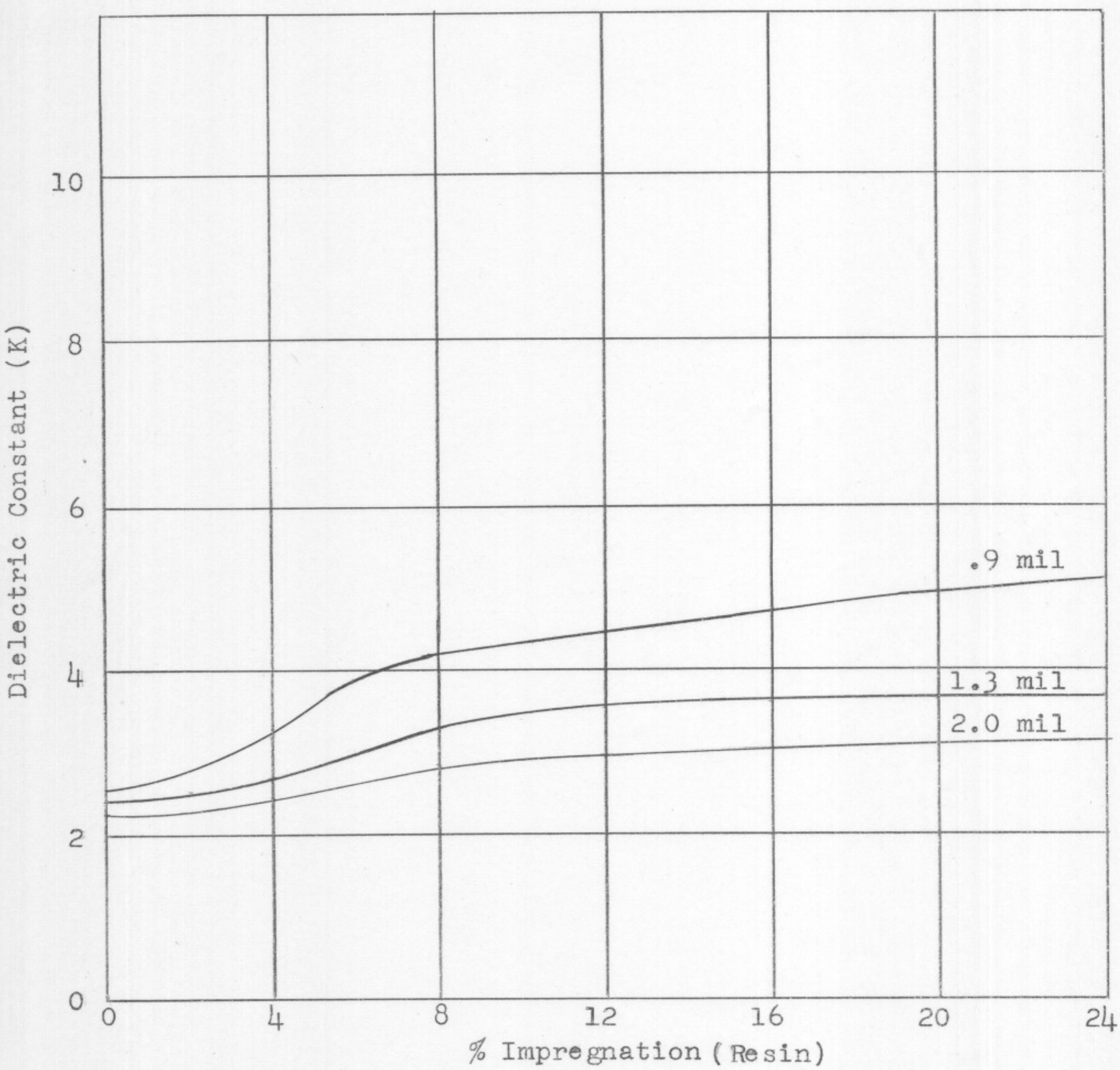


FIGURE 2

AVERAGE DIELECTRIC CONSTANT vs % IMPREGNATION

Manufacturer: Mfr. C (silvered electrodes)

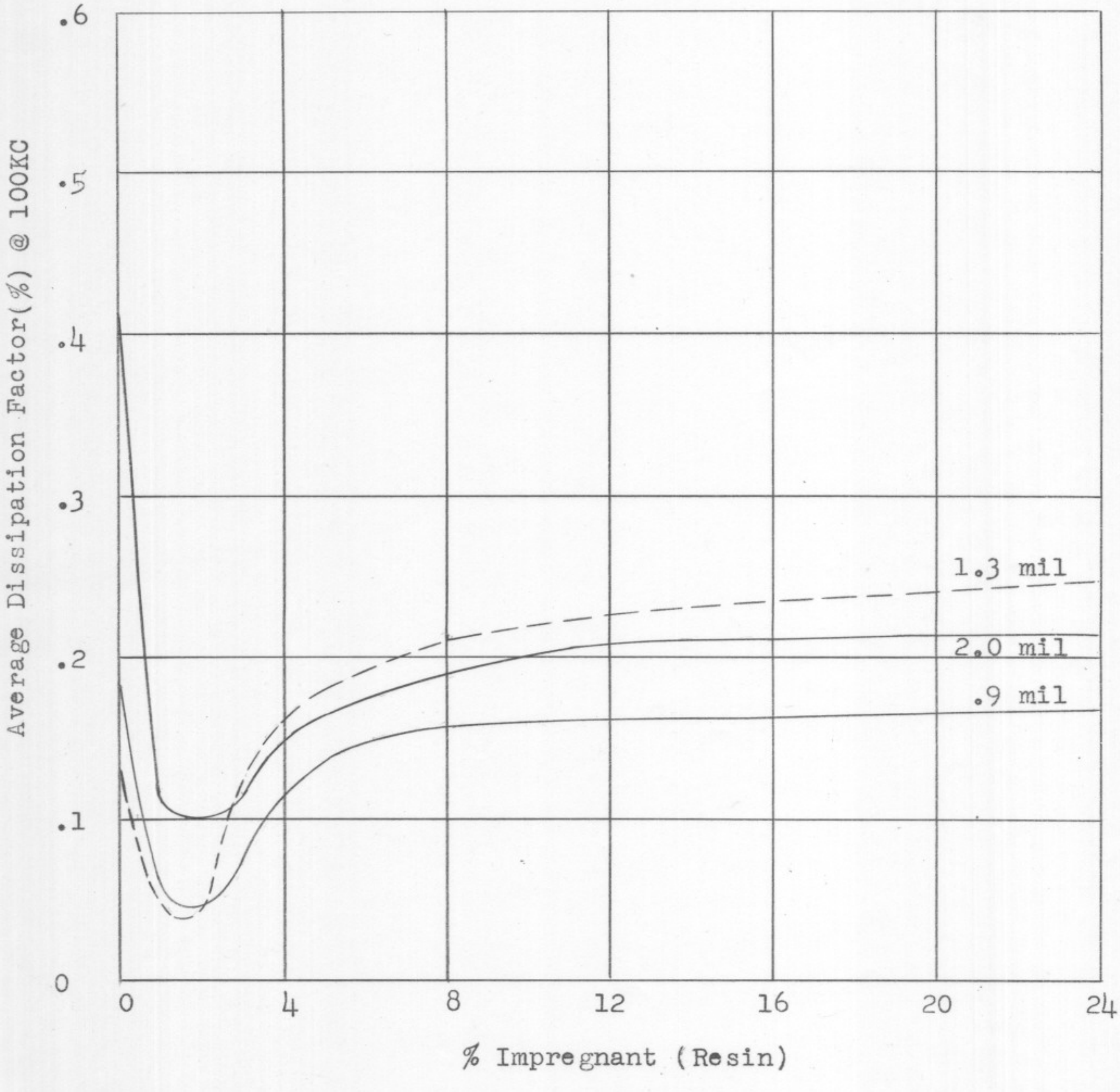


FIGURE 3

AVERAGE DISSIPATION FACTOR vs % IMPREGNATION

Manufacturer: Mfr. C (Silvered electrodes)

2500
2.3
7500
5000
5750.0
VOLTS

MICA INSULATOR CO
STATES 6500 VOLT
DIELECTRIC STRENGTH
CAN BE OBTAINED
FOR A 2.3 MIL
THICKNESS

Conclusions:

a. The average voltage strength of uncured reconstituted mica paper capacitors, at best, is about 2500 volts/mil. This is approximately 30% of the strength exhibited by the natural mica capacitors.

b. Silvered electrodes did not materially improve the temperature coefficient of reconstituted mica paper capacitors. Although C and D characteristics were attained in a few instances, the large capacitance drifts show that additional stabilizing procedures are required.

c. Silvered electrodes did not raise the Q level of reconstituted mica paper capacitors. If anything, the Q was lower than foil electrode capacitors. It appears as if the optimum Q is attained using between 1% and 2% resin impregnated mica paper. A realistic Q limit for silvered electrode capacitors appears to be approximately 600 as compared to 1300 in MIL-C-5A.

d. The insulation resistance values of impregnated mica paper capacitors for MIL-C-5A use appears equal to that of natural mica sections.

Future Work:

Work during the next quarter will be concentrated on determining the effectiveness of the special curing cycle in improving the stability, Q, and voltage strength of reconstituted mica paper capacitors.

Identification of Personnel:

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