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CASE FILE COPY

SNAP-8 POWER FACTOR CORRECTION ASSEMBLY

By

R. M. Hill

Aerojet-General Corporation
Azusa, California

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA-Lewis Research Center
Contract NAS5-417 and NAS3-13458

Martin J. Saari, Project Manager

DIVISION Power Systems
TM 4936:69-568
DATE 29 July 1969
W.O. 1140-59-1521

TECHNICAL MEMORANDUM

AUTHOR(S): R. M. Hill

TITLE: SNAP-8 Power Factor Correction Assembly Design Review

ABSTRACT

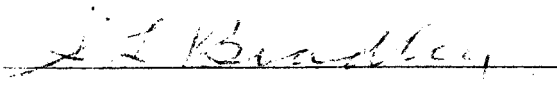
The PFCA has been designed to incorporate changes resulting from stress analysis, technical reviews and a major design review. Complete detail drawings have been made and released for this configuration.

This TM includes the data presented at the Design Review Meeting as modified by the conclusions and action items. This data now forms a part of the permanent design file for the Power Factor Correction Assembly.

KEY WORDS: Power Factor Correction Assembly, PFCA, Design Review

APPROVED:

DEPARTMENT HEAD


S. L. Bradley

NOTE: The information in this document is subject to revision as analysis progresses and additional data are acquired.



AEROJET-GENERAL CORPORATION

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SCOPE OF REVIEW

The scope of this design review includes some background data on the reasons for using capacitors, the selection and design of the capacitors, as well as data relating to the complete package design.

The general packaging concept for all electrical components has been established by other design reviews and has been followed in the design of this assembly.

Two technical reviews and a Major Design Review have been held, with packaging design changes incorporated into the drawings as suggested. The revised design of a prototype Power Factor Correction Assembly is complete and the final drawings have been released. A stress analysis of the current design has been performed. The analysis indicates satisfactory design margins for all the structural components. The stress analysis is included in Appendix K. The thermal analysis (Appendix I) performed before the last technical review is still valid and indicates the temperature rise within the capacitors is small compared to the maximum temperature capability of the parts. Some additional data related to the heat sink temperature and fuse wire temperature calculations have been added to Appendix I.

The design for the PFCA, as represented by the assembly drawing in Figure 1, has been reviewed and approved. The reviews and analysis performed show that the design will meet the requirements outlined by the component specification, AGC-10603, Appendix G.

PROGRAM REVIEW

PURPOSE OF CAPACITOR ASSEMBLY

The purpose of the Power Factor Correction Assembly is to provide a component with sufficient capacitive reactance to balance the inductive loads of the vehicle and the internal electrical loads of the SNAP-8 system. By correcting the power factor to near unity, the alternator will tend to operate at maximum efficiency. The term 'near unity' is used because the curve of efficiency vs power factor is relatively flat in the immediate vicinity of unity pf so small changes in capacitance or power factor of the loads make only minor changes in efficiency.

Figure 2 illustrates the changes in alternator power factor for conditions of no correction and for 40 and 57 KVAR correction with a vehicle load power factor of 0.85 lag. The effect of over compensation resulting from 57 KVAR correction applied with a 1.0 pf vehicle load is also shown. Test data included in Appendix L shows that a leading power factor of 0.9 can be controlled by the electrical system with no problems.

Technical Memorandum, TM 4936:66-410, entitled, "Power Factor Correction Trade-Off Analysis," is included as Appendix A.

SELECTION OF CAPACITOR CIRCUIT

The selection of a capacitor circuit was based on several different considerations. First, the choice of a three-phase wye and delta was considered. For a fixed three-phase KVAR rating (kilovolt amperes reactive) the capacitance for a wye circuit is three times the value for a delta. The voltage rating of each capacitor in a wye is only 58% of the delta voltage. In the types of capacitors being evaluated, however, the minimum practical voltage rating is higher than the delta requirements so this is not an important factor. The size and weight of the capacitors is proportional to the capacitance value and therefore is an important factor in the selection of a delta circuit.

SELECTION OF CAPACITOR TYPE

Next, the selection of a capacitor type was considered. Some factors were decided easily because they contributed to good performance with maximum efficiency. These included the use of film and foil construction as compared to metalized film and extended foil construction as compared to inserted tab. The use of multiple capacitor sections to improve reliability and to minimize the effects of incremental capacitance changes was also decided early in the program. Choice of capacitor dielectric film involved considerable study. The final choice of Kapton was based both on its physical characteristics and on its availability. Data included in Appendix B presents a comparison of Kapton and polycarbonate characteristics. Also included in this Appendix is some correspondence relative to the selection of the dielectric film and a summary of Kapton properties. The terms Kapton, H-film and polyimide all refer to the same material.

The selection of the size of the individual capacitors and the number of them per phase was based on a combination of factors including practical values of capacitance to be manufactured in a single container and reasonable increments of capacitance change to be made by adding or removing capacitors. Ten capacitors per phase was selected with the total of 175 microfarads per phase equally divided. This value of 17.5 microfarad per capacitor was included in the component specification, AGC-10563 (Appendix C).

FUSING AND RELIABILITY

A conceptual design meeting was held to discuss the PFCA package design. Minutes of this meeting are included as Appendix D. One of the action items of this meeting was to determine if fusing the capacitors would increase the reliability of the unit. The results of this analysis were that fusing was required and further analysis was performed to determine the possible advantages of multiple fuses. The reliability analysis is presented as Appendix E.

Further consideration of the capacitor circuit including the fuses resulted in the selection of the circuit shown in the schematic diagram, Figure 1.

This circuit has the advantage that a single fuse per capacitor can protect for both line to line and line to ground faults. A memo stating the effect of this circuit change on increasing reliability is also included in Appendix E.

To minimize the use of low temperature solder and fusible metals and to insure high reliability welded electrical connections, a fuse was designed for use with the PFCA. Fusing current is approximately four times rated current.

CAPACITOR PROCUREMENT

Seventy capacitors have been purchased in accordance with Specification AGC-10563 except that the film material was changed to Kapton. Delivery of 69 units has been accomplished to date. The number of acceptable parts was reduced to this value during the process of acceptance testing. Acceptance testing was performed in accordance with AGC-STD-1338. This standard is included in Appendix F.

Figure 4 is a photograph of one of the capacitors showing details of its external features.

ASSEMBLY OF BREADBOARD PFCA

Thirty of the capacitors have been assembled into a breadboard unit, Figure 5, for testing in the Electrical Component Test Facility (ECTF).

The breadboard unit uses the same capacitors as intended for the prototype. They are mounted on a similar baseplate, set in Dow Corning heat sink compound (Appendix H) to simulate the heat transfer of the prototype unit.

Tests have been initiated with the breadboard operating with the other components of ECTF.

COMPONENT FAILURES

One capacitor failed at approximately 50 hours of operation. The failure has been reported (FR 1279) and is being investigated. The defective capacitor was automatically removed from the circuit by the fuse and ECTF continued to operate with a slight current unbalance until the capacitor and fuse were replaced. The breadboard was returned to operation immediately. This unit has since been operating with 24 capacitor connected. Two units per phase were

disconnected to reduce the capacitive current to allow total system operation at 0.90 lagging pf. This is the value defined for the present ECTF test plan.

A second capacitor failed at approximately 223 hours of operation. Results of the failure were the same as reported above. This failure was reported on FR 1191. The capacitor and fuse were replaced and the assembly was returned to testing. Test time in excess of 2400 hours has now been accumulated with no additional failures.

Analysis of the failures is continuing, but preliminary results indicate that the failures were caused by random type defects that result in "infant mortality" or early failure. This type of defect is common to many types of electronic components where each part is an individual that may contain defective material, may be damaged in handling, processing or testing. The common method of eliminating this type of defect is to perform a "burn-in" test or "accelerated aging" test to intentionally cause failure of these defective pieces. These tests are usually performed at elevated temperature and with higher than rated voltage applied. Test times vary from 50 to 500 hours based on the type of component and experience.

Proposed corrective action for the SNAP-8 capacitors will include in-process burn-in tests at different stages of construction from individual section to complete components. Additional dielectric tests, insulation resistance tests and voltage retention tests will also be performed at each stage of construction to help detect low quality or defective parts before final assembly. As a final precaution, a burn-in test will be included in the formal acceptance test procedure.

The capacitors that have already been fabricated and delivered will be given equivalent burn-in tests to eliminate defective parts before the prototype assembly is fabricated.

DESIGN OF PROTOTYPE PFCA

Specification AGC-10603 was prepared to define the prototype assembly for the PFCA. This specification is included as Appendix G.

The assembly drawing, Figure 1, and complete detail drawings have been prepared for a prototype unit. This design represents the latest configuration

incorporating changes suggested by preliminary stress analysis, two Management Technical Review (MTR) meetings, and a Major Design Review meeting. The minutes of these MTR meetings are contained in Appendix N, and the minutes of the design review meeting in Appendix O.

A stress analysis has been performed on this design configuration. The results show the design to be satisfactory for the mechanical load requirements. The stress calculations are included in Appendix K.

A thermal analysis was also performed. The results are included in Appendix I. The calculations show a temperature rise within the capacitors of approximately 50°F. This was based on the capacitor specification figure of 150°F heat sink temperature. Other thermal calculations show a maximum heat sink interface temperature of 168°F. Considering both sets of calculations, the resulting hot-spot temperature within the capacitors does not exceed approximately 220°F. The solder within the capacitor has the lowest operating temperature capability of all the materials present. The solder temperature limit is approximately 400°F. The large temperature difference between the actual and permissible values and the low temperature gradients within the components contributes to high reliability and long life.

The original reliability analysis performed (Appendix E) provided a reliability figure of 0.99946 as a conservative estimate. The changes that have been made since that time, including change to Kapton film and change in interconnection circuit, are changes that contribute to increased reliability.

PROGRAM STATUS

The assembly drawing, Figure 1, and complete detail drawings have been prepared for a prototype unit. This design is being presented for review.

Testing has been initiated, using the breadboard assembly with ECTF.

Stress, reliability and thermal analyses have been performed with satisfactory conclusions.

Future plans include revision of the design as required as a result of this review. This data package has been revised and updated, and is being released in the form of a Technical Memo to form a part of the design file for this component.

The revised drawings have been released for fabrication of one prototype Power Factor Correction Assembly. After completion, the unit will be tested in ECTF for electrical tests, then will be available to the project for further test assignment.

The specifications and standards defining the components and test requirements for the PFCA will be corrected and revised to include the additional requirements for in-process and burn-in testing.

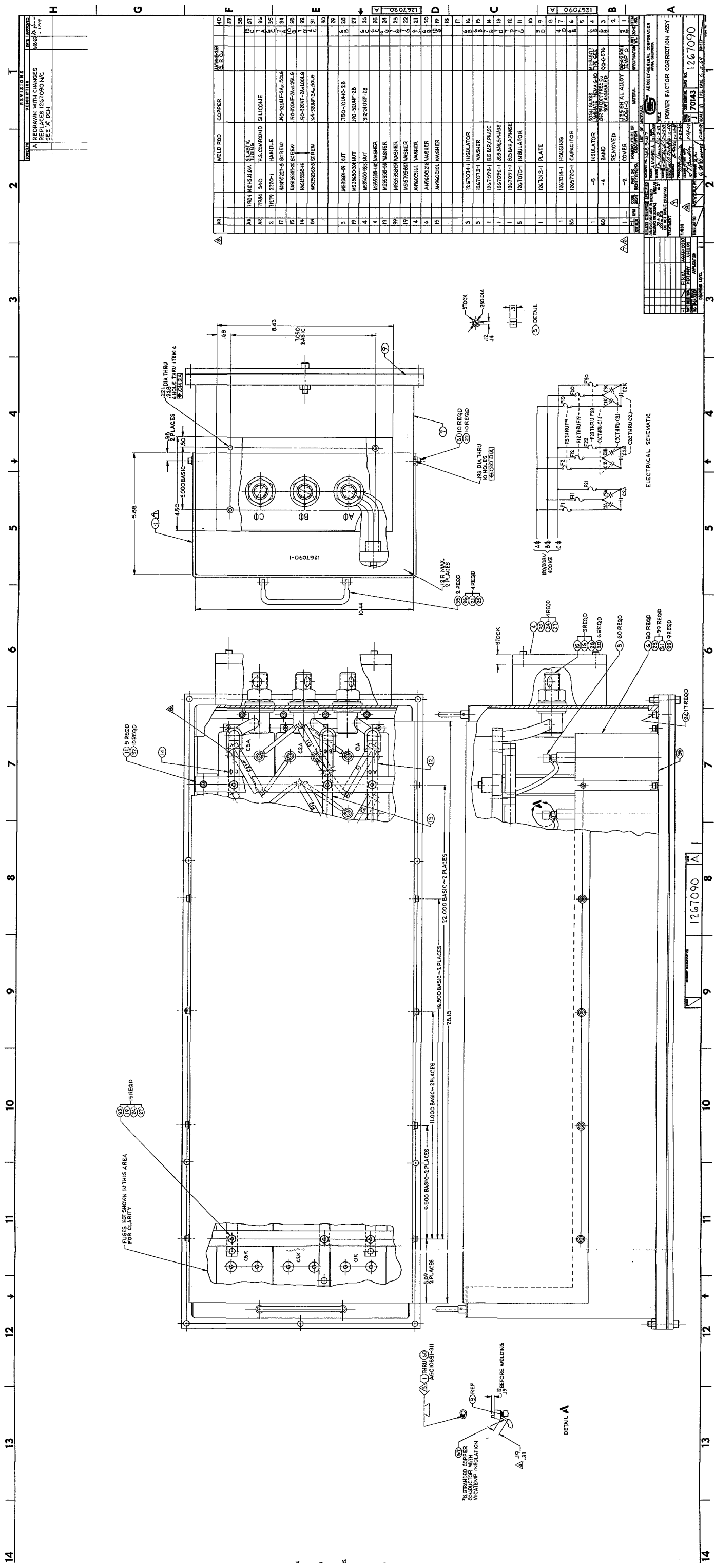


Figure 1

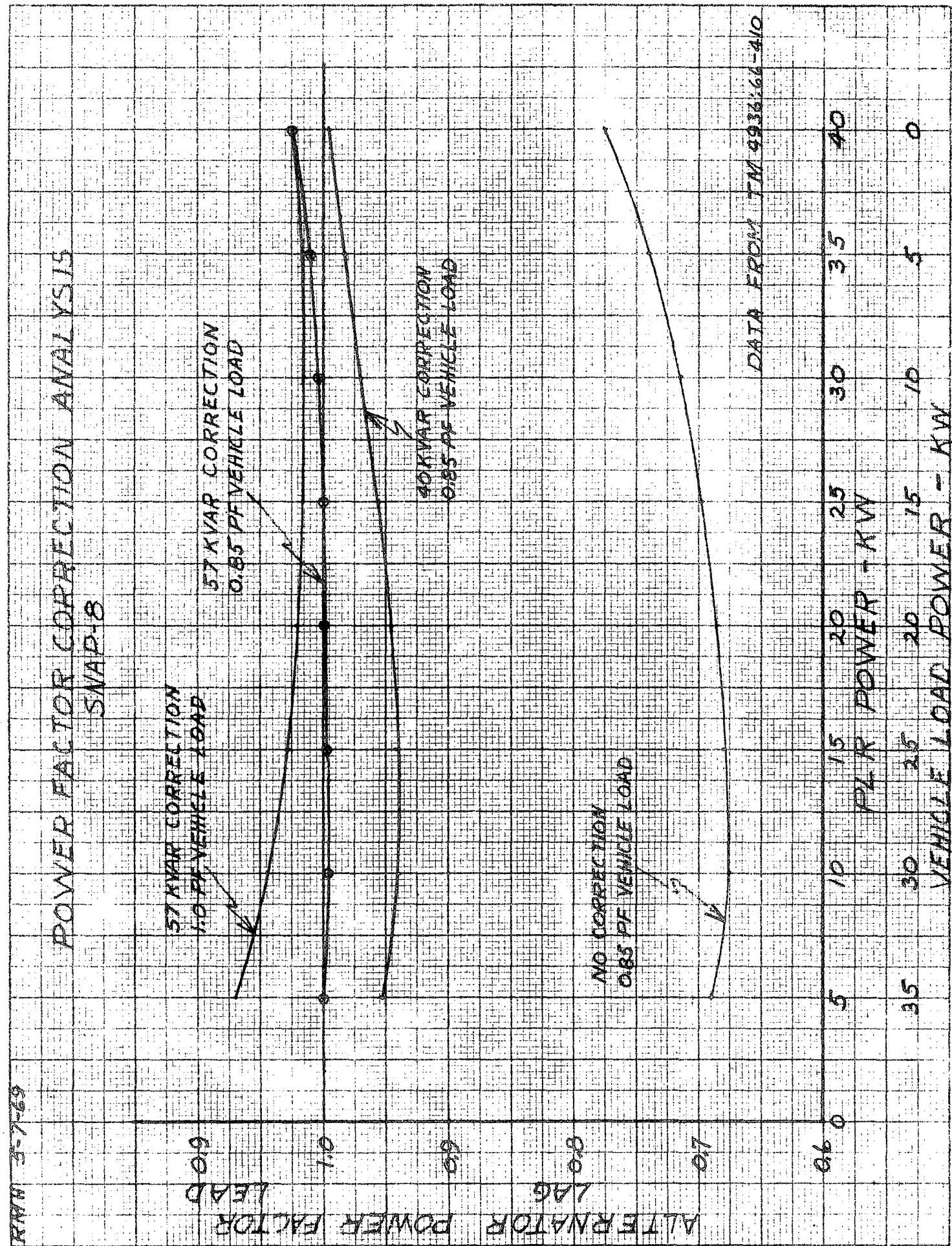
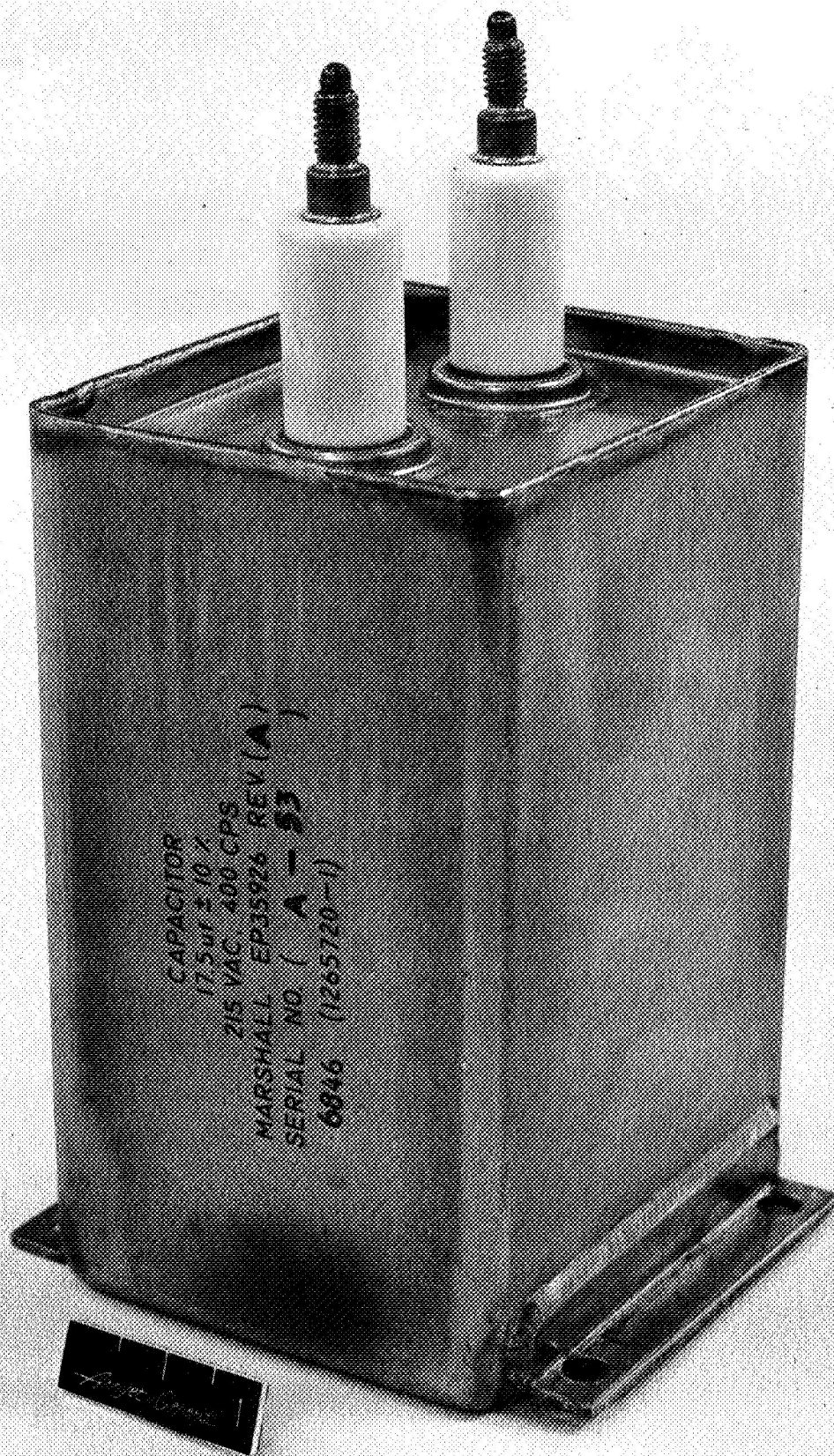


Figure 2



POWER FACTOR CORRECTION CAPACITOR

Figure 3

769-15(N)-1103

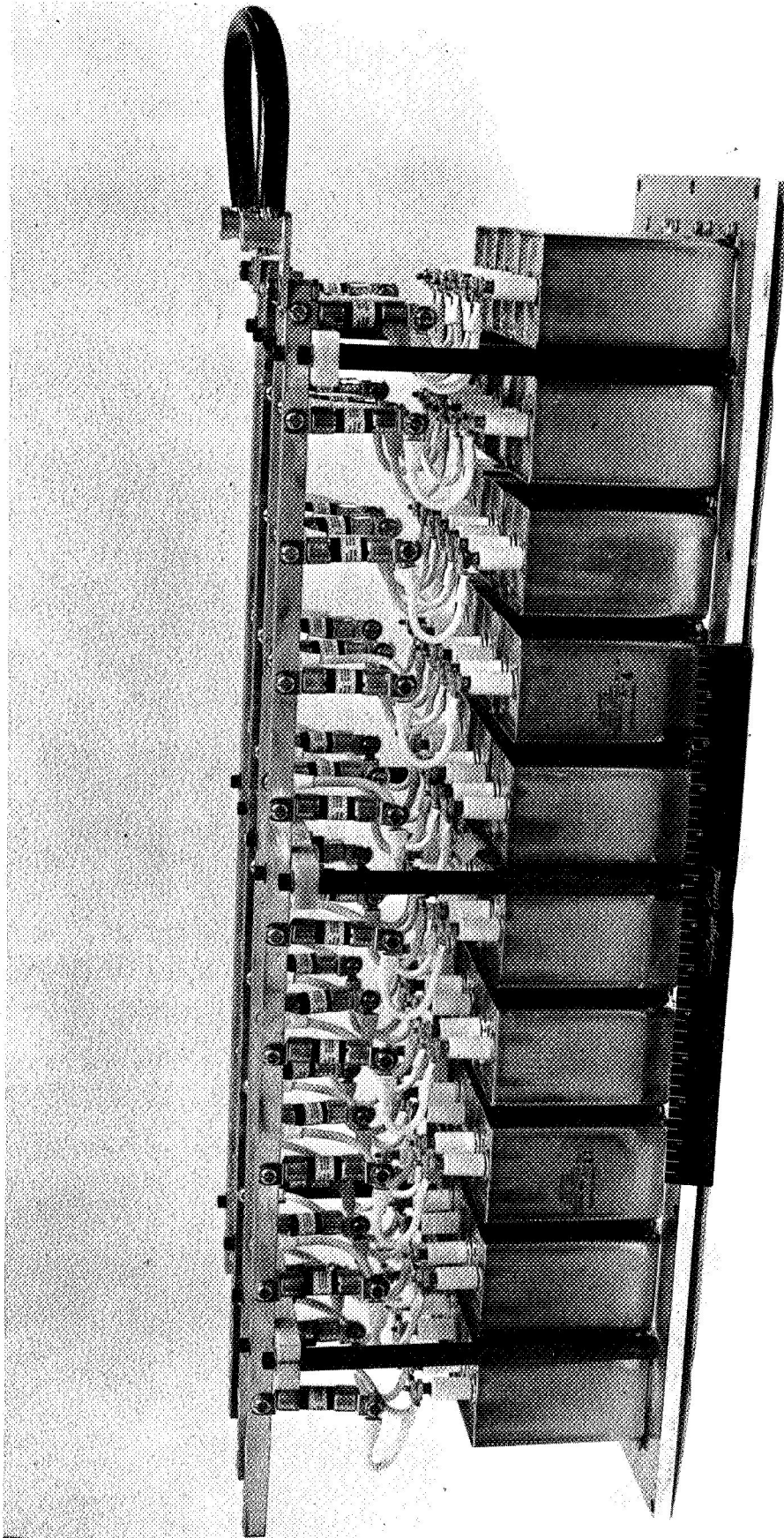


Figure 4

BREADBOARD POWER FACTOR CORRECTION ASSEMBLY

APPENDIX A

TM 4936:66-410

Power Factor Correction Trade-Off Analysis

DIVISION SNAP-8
TM 4936:66-410
DATE 21 June 1966
W.O. 0740-05-2046

TECHNICAL MEMORANDUM

AUTHOR(S): F. N. Collamore
TITLE: Power Factor Correction Trade-Off Analysis

ABSTRACT

The affect of power factor correction on the SNAP-8 system performance and efficiency is shown. The alternator KVA requirements and losses are substantially reduced by the addition of power factor correction capacitors. The effect of the power factor correction capacitors on the Inverter/PMA startup is shown.

APPROVED:

DEPARTMENT HEAD


E. Eber

NOTE: The information in this document is subject to revision as analysis progresses and additional data are acquired.



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PAGES

POWER FACTOR CORRECTION TRADE-OFF ANALYSIS

- I. Introduction
- II. Steady State Analysis
- III. System Startup Analysis
 - PMA Starting
 - 95 Cps Operation
 - 220 Cps Operation
- IV. P.F. Correction Capacitor Design
- V. Development Program Plan and Cost Analysis

I. INTRODUCTION

The SNAP-8 alternator power factor has a significant affect on its losses and consequently on the SNAP-8 system efficiency, as shown on alternator performance curve, Figure 4, the alternator efficiency increases with increasing power factor. At the reference vehicle load condition of 35 kw @ 0.85 PF lag the alternator operating power factor is 0.698 lag. This power factor and resulting efficiency of the alternator is caused by the low power factor parasitic loads on the system. These consist of the PMA's and the speed control system.

A significant improvement in the alternator power factor and efficiency may be accomplished by adding power factor correction to the system. In addition, reduced alternator losses will result in longer alternator life, higher reliability and a lower heat load on the lubricant and cooling system. The values used are typical and do not reflect specific state points such as PCS-G.

II. STEADY STATE ANALYSIS

The loads on the SNAP-8 electrical system consist of the following:

1. Vehicle load
2. PMA power requirements
3. PCS control
4. Speed control system

The reference system vehicle load is 35 kw at 0.85 PF. The PMA requirements are shown on Table 1 and total 14.14 kw at 0.61 PF. The speed control system consists of the parasitic load resistor (PLR) and the saturable reactor used to control the power to the PLR. The speed of the SNAP-8 system

is controlled by controlling the total power on the turbine alternator. The speed control system adjusts the system load to control the turbine alternator speed. Figure 2 shows the speed control power factor vs the power in KW. Figure 3 shows the speed control system reactive power vs KW.

1.2 KW is allowed for PCS controls including saturable reactor losses. The 4.5 KW parasitic load includes 1.5 KW minimum parasitic load resistor power at cutoff plus 3.0 KW for system stabilization.

The SNAP-8 system power factor may be improved either by improving the power factors of the individual components which load the system, or by adding power factor correction capacitors, or by a combination of both. The tabulated data shown on Table 2 shows the effect of power factor correction on the system performance. Data is shown for three values of power factor correction:

1. 18.4 KVAR (Correct the PMA's to 1.0 PF)
2. 40 KVAR (a nominal value)
3. 56.1 KVAR (Correct the alternator to 1.0 PF at REF. load conditions as shown on Table 2).

NOTE: With the alternator PF corrected to 1.0 at reference load condition, the alternator power factor with no vehicle load increases to .98 lead. The alternator electrical system as determined by its excitation system, is expected to be capable of operating stably to 0.92 power factor leading. The improved alternator efficiencies result in lower losses and the power savings shown on Table 2.

III. SYSTEM STARTUP ANALYSIS

The power factor correction capacitors may be connected to the alternator terminals and be applicable only when the alternator is supplying

power to the system. As an alternative, the power factor correction capacitors may be connected in parallel with the NaK PMA's so that they would also be applicable during the startup cycle. This would have the advantage of reducing the reactive load on the inverter during startup cycle. If a 40 KVA power factor correction capacitor was selected, its rating under startup conditions would be:

220 cps	88 volts	9.3 KVA
95 cps	40 volts	1.83 KVA
95 cps	19 volts	.87 KVA

This would change the inverter power requirements as follows:

220 cps 88 volts steady state

Without PF Correction

2370 watts 0.49 PF lag 4830 VA

With PF Correction

2370 watts 0.42 PF lead 5630 VA

95 cps 19 volts steady state

Without PF Correction

345 watts 0.55 PF lag 628 VA

With PF Correction

345 watts 0.7 PF lead 493 VA

95 cps PMA starting

Without PF Correction

785 watts 0.31 PF lag 2520 VA 33.5 volts

NaK PMA starting torque 12.6 in/lb

With PF Correction

1170 watts 0.59 PF lag 1970 Va 40 volts

NaK PMA starting torque 20 in/lb

It can be seen from the above tabulation that the addition of a power factor correction capacitor to the PMA's during starting will have a significant effect on the startup inverter characteristics. If this is taken into account in the inverter specification, it does appear that the addition of the PF correction would be beneficial in that it would result in a smaller inverter or a higher PMA starting capability.

IV. P.F. CORRECTION CAPACITOR DESIGN (Conceptual)

The preliminary power factor correction capacitor design was based on a nominal rating of 40 KVA at 400 cps. Using the capacitors connected line-to-line on 208 volts, a total of 370 MFD are required.

During the preliminary evaluation, the following types of capacitors were considered:

TYPE		PF	MAX. AMB. TEMP.	REL. SIZE
1.	Oil impregnated paper	.005	125°C	3
2.	Mylar film	.008	125°C	1
3.	Teflon film	.0001	200°C	4
4.	Polystyrene film	.0002	85°C	5
5.	Polycarbonate film	.002	125°C	2

Of these types, it appears that the polycarbonate film capacitors offers the best combination of desirable characteristics. For example, it would seem that its lower loss would be more desirable than the smaller size of the Mylar capacitor. Although, the high temperature capability and very low

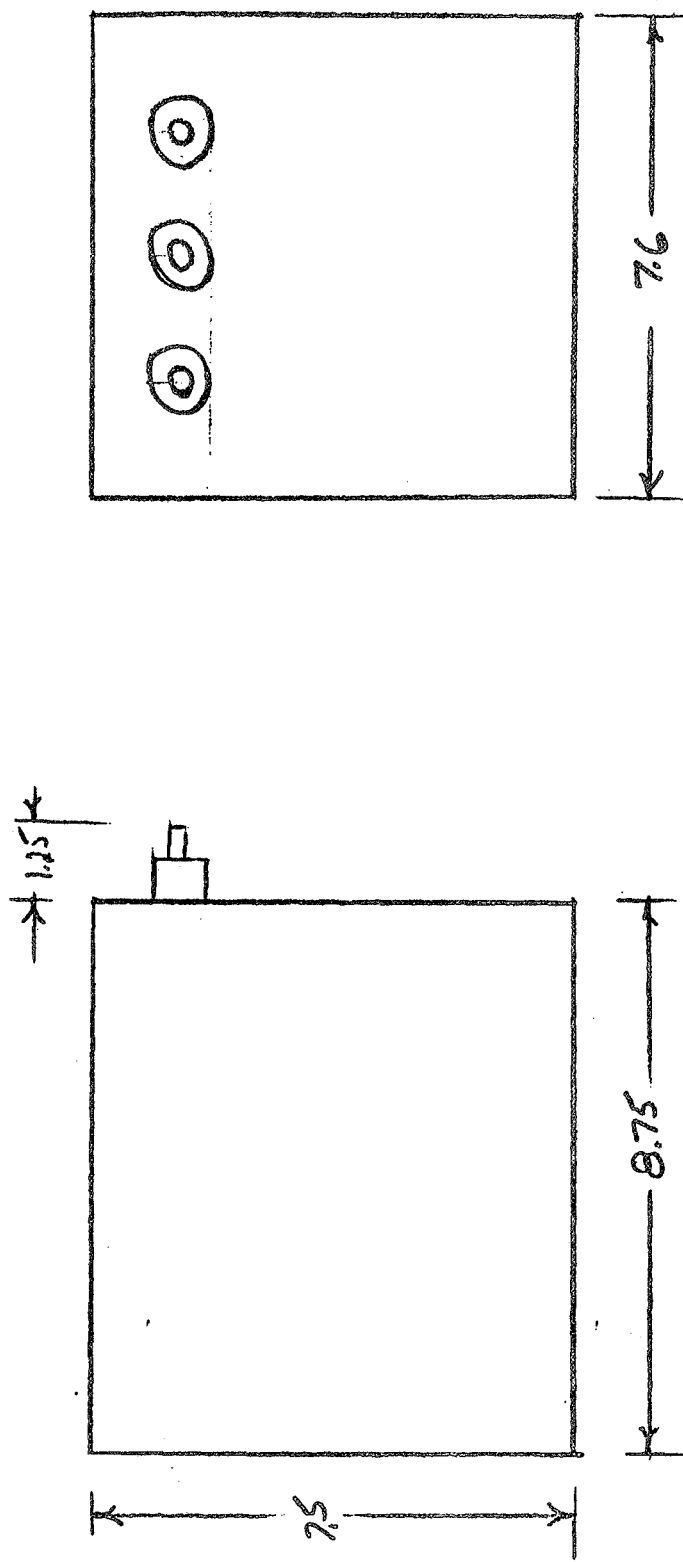
loss of the Teflon capacitor is attractive, its larger size and low radiation tolerance are severe disadvantages.

For the preliminary design polycarbonate capacitors similar to Sprague Electric P/N 260P40593 are used. They are rated 4MFD @ 300 volts and are 1.0 in. diameter and 2.31 in. long. A quantity of 93 units are required for the assembly shown in Figure 1. The power factor correction capacitor assembly is designed for liquid cooling using the lubricant and coolant system fluid. The individual capacitors are hermetically sealed so that the package may be filled with coolant which may be circulated around the individual capacitor units. The total heat loss for a 40 KVA PF correction assembly is 80 watts.

Additional work will be required to make the final capacitor selection. This will include optimizing the unit capacitor voltage and capacitance rating to obtain highest reliability and best packaging configuration. Additional work is required to determine the nuclear radiation capabilities of the various capacitor types. Other capacitor types not considered in this preliminary analysis should be included in the final design analysis. Work is in process by various capacitor manufacturers using Polyimide film which may offer the advantage of both high temperature capability and nuclear radiation resistance.

V. DEVELOPMENT PROGRAM PLAN AND COST ANALYSIS

The development program plan and cost analysis has been prepared and submitted as part of the Continuation Program Plan. It is covered under task w.o. 1041-19.



P.F. CORRECTION CAPACITOR

40 KVA 3PH. 208 VOLTS

400CPS

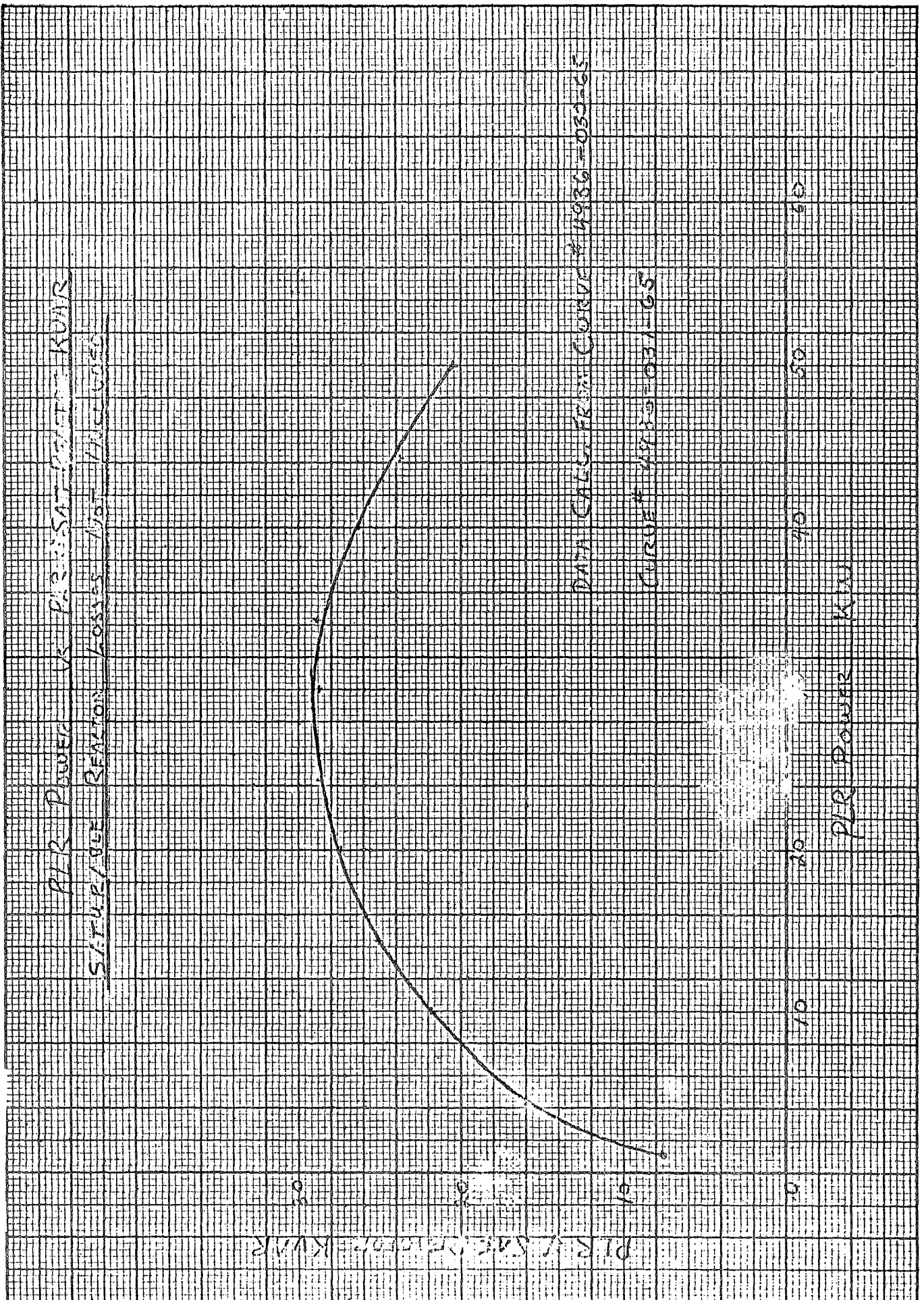
LOSS - 80 WATTS

WT. - 25 LBS.

PLR POWER VS. INPUT POWER FACTOR
SATURABLE REACTOR LOSSES NOT INCLUDED



A666-NF-1126

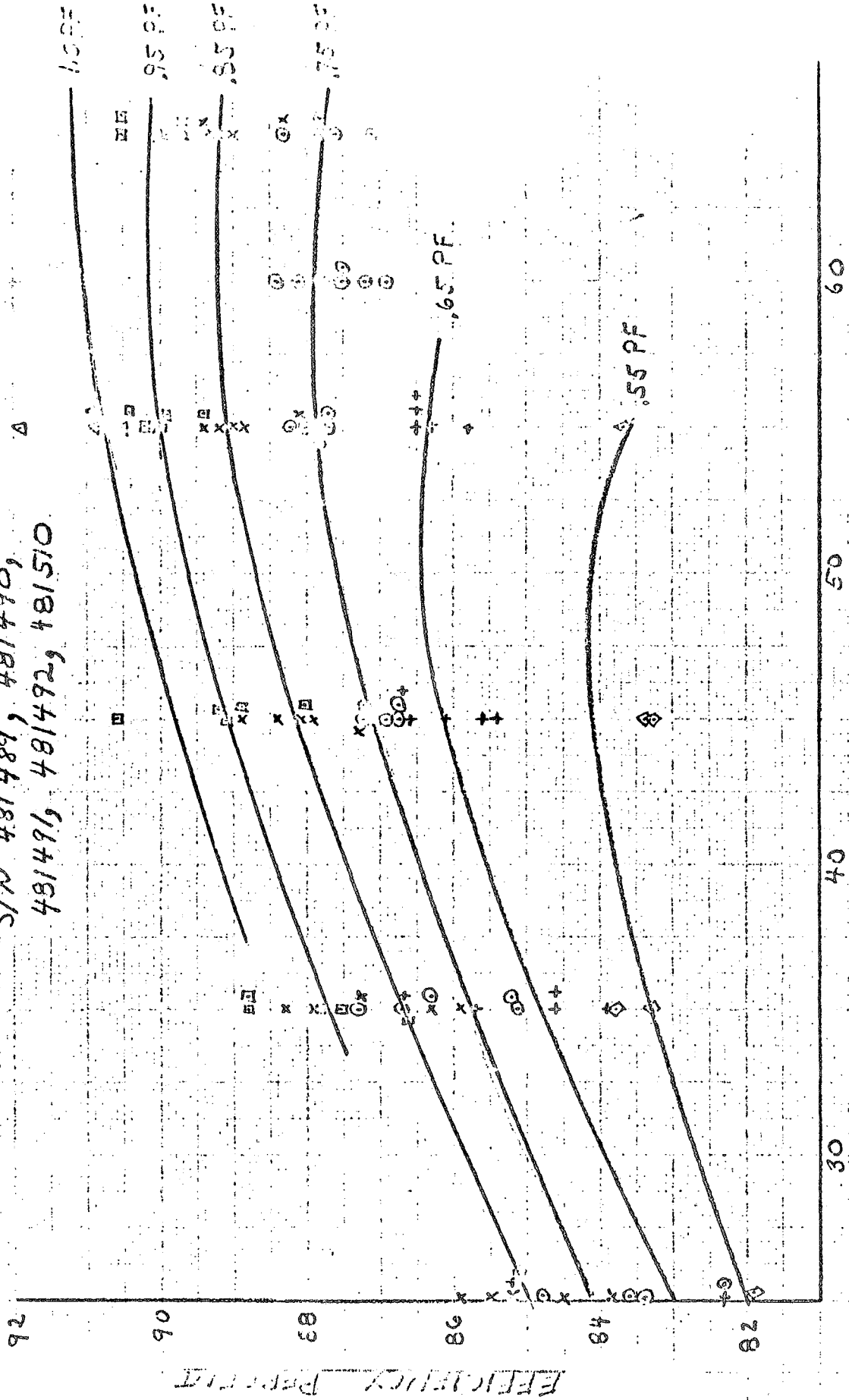


ALTERNATOR PERFORMANCE

AGC PIN 094069

S/N 481489, 481490,

481491, 481492, 481510



PMA POWER REQUIREMENTS

	<u>KW</u>	<u>PF</u>	<u>KVAR</u>	<u>References</u>
Hg PMA	3.53	.77	2.92	4932:65-00062
HRL PMA	4.6	.555	6.9	4932:65-00066
FRI PMA	4.52	.555	6.78	4932:65-00064
L/C PMA	1.49	.638	1.80	4932:65-00076
TOTAL	14.14		18.40	

Overall PF = 0.61

Overall KVA = 23.2

TABLE 1

No Load		35 KW 0.85 PF Load		35 KW 0.85 PF Load PMA's Corrected		35 KW 0.85 PF Load L0 KVA PF Corrected		35 KW 0.85 PF Load 56.1 KVA PF Corrected	
KW	KVAR	KW	KVAR	KW	KVAR	KW	KVAR	KW	KVAR
Vehicle Load	0	0	21.6	35	21.6	35	21.6	35	21.6
PMA Input	14.14	18.4	18.4	14.14	18.4	14.14	18.4	14.14	18.4
PCS Control	1.2			1.2		1.2		1.2	
PIR	39.5	26.7	16.1	4.5	16.1	4.5	16.1	4.5	16.1
TOTAL	54.84	45.1	56.1	54.84	56.1	54.84	56.1	54.84	56.1
PF Correction KVAR	---	---	---	.04	-18.4	.08	-40	.11	-56.1
Alternator Output	54.84	45.1	56.1	54.88	37.7	54.92	16.1	54.95	0
Alternator PF	.773	.698	.824	.96				1.0	
Alternator KVA	70.9	78.6	66.6	57.2				54.95	
Alternator Eff	88.2	87.1	88.8	90.1				90.8	
Alternator Input Power	62.1 KW	62.9	61.9	60.9				60.6	
Alternator PF with Vehicle load = 0	---	.773 lag	.90 lag	.995 lag				.98 lead	
Power Savings KW	---	---	1.0	2.0				2.3	

TABLE 2

APPENDIX B

Film Characteristics

Memo 4936-67-0148, Capacitors for
Power Factor Correction Service

U. S. Government Memorandum, Dated 12-13-66
Subject: Recommendations and Supplementary Information
on
Capacitors for SNAP-8 Applications.

Bulletin H-1A, Summary of Properties - Kapton

FILM CHARACTERISTICS

Electro-Technology -- June 1967

	<u>Polycarbonate</u>	<u>H - Film</u>
dielectric constant	2.8 - 3.1	3.0 - 3.5
dielectric strength, v/mil	2250 - 4250	5600 - 7000
volume resistivity, ohm/cm ³	1×10^{17}	1×10^{18} @ 25°C
surface restivity, ohms	3×10^{13} (80% RH)	1×10^{16} @ 25°C
dissipation factor	0.003 - 0.0095 (1 Mc)	0.002 - 0.003
tensile strength, psi	7500 - 9500	17,000 - 25,000
ultimate elongation, %		70 - 90

Insulation Directory/Encyclopedia -- June/July 1967, pp 247, 252

	<u>Polycarbonate</u>	<u>H - Film</u>
Maximum temperature	270°F	400°C +
Minimum temperature	-150°F	
Dielectric K	IKC-LMC 25°C 2.99-2.93	1 KC 25°C 3.5 1 KC 200°C 3.0
Power factor	" 0.13-1.10	1 KC 25°C 0.3% 1 KC 200°C 0.3%
Dielectric strength	cast 2250 V/mil extruded 1500 V/mil	1 mil 7000V/mil
Volume resistivity (ohm/cm)	cast 4.7×10^{16} extruded 15×10^{16}	25°C 10^{18} 200°C 10^{14}
Area factor (in ² /lb/mil)	23,100	19,440
Specific gravity	1.2	
Tensile yield (psi)	cast 7500-9500 extruded 8000-9500	25°C 25,000 200°C 17,000
Elongation %	cast 95-110 extruded 85-105	25°C 70% 200°C 90%



AEROJET-GENERAL CORPORATION

INTER-OFFICE MEMO

10-907-102 (STOCK NO. J-1-1)

TO: E. Eber

DATE: 30 October 1967
4936-67-0148-SLB:lk

FROM: S. L. Bradley

160-X5736

SUBJECT: Capacitors for Power Factor Correction Service, SNAP-8 Power System

DISTRIBUTION: W. F. Banks, R. Gordon, R. Hill, E. Howard, Originator, 4936 File

When capacitors for power factor correction of the SNAP-8 system were being considered, a number of types were reviewed.

Capacitors utilizing glass, ceramics and mica were not seriously considered because of the huge volume required to obtain the capacitance required. Also, electrolytics were not considered because of high losses and low reliability.

Paper dielectric capacitors were given some consideration because of their long use in power systems for power-factor correction service, however this type was rejected because of excessive losses, large size and susceptibility to radiation damage.

The plastic film type capacitors however offered the best overall characteristics for use in SNAP-8 power factor correction service. Mylar and Teflon film types were considered, but the polycarbonate film and H film types were the ones that offered the most favorable characteristics. Both of these films offer high dielectric constant, high dielectric strength and low dissipation factor. All of these characteristics are better for the H film than for the polycarbonate film. In addition, a capacitor made of H film can operate above 400°F whereas the maximum operating temperature of a polycarbonate film unit is 270°F. Also, the polycarbonate film is only obtainable in Germany, and it is delivered with a great many pin-hole defects.

In spite of these faults, the polycarbonate film capacitor was originally chosen for the units to be used in SNAP-8. This decision was made because, at the time, H film was in an early development stage, and film thin enough for practical capacitors was not obtainable.

However, since that decision was made Dupont "Kapton" H-film in thicknesses of $\frac{1}{2}$ or 1 mil has become available and can be obtained in 12 to 14 days. As a result of this change in conditions, the decision to use polycarbonate film has been reversed, and H film capacitors have been purchased from Marshall Industries. Delivery of the first thirty of the seventy units on order is expected by early December 1967.

S. L. Bradley

Mr. Eber
Capt. Eber
as Division

UNITED STATES GOVERNMENT

Memorandum

NASA-Lewis Research Center
Cleveland, Ohio

TO : SNAP-8 Systems Section
Attention: A. W. Nice

DATE: December 13, 1966

FROM : Electrical Components & Experiment Branch
Power Conditioning Section

SUBJECT: Recommendations and supplementary information on capacitors for SNAP-8 applications

In answer to your request dated November 7, 1966, the following information and recommendations are hereby submitted.

It is understood that the capacitor(s) in question is intended to be used for power factor correction. The capacitor package is to be connected to the SNAP-8 alternator terminals, and should provide a leading reactive load of approximately 40 kvar. It is also understood that reliability is of prime importance and that component development should be kept within the present state-of-the-art.

With the above information and the general SNAP-8 requirements as given in Spec. No. 417-1 as guides, a brief review of readily available capacitor information has been made and is summarized below.

1. Application

- A. In order to provide 40 kvar, a three-phase capacitor bank of approximately 375 microfarads (125 μ F per phase) is needed if line-to-line connection is used (208 volts). If line-to-neutral (120 volts) is used, approximately 1125 microfarads (375 μ F per phase) is needed.
- B. For this application, some of the more important parameters of capacitors are:
 - a. Nuclear radiation tolerance (5×10^{12} NVT) (5×10^7 RAD (c)).
 - b. 400 HZ a-c voltage rating.
 - c. Internal heat dissipation as determined by the capacitor dissipation factor (DF).
 - d. Maximum operating temperature.
 - e. Physical size.
 - f. Failure mode.
 - g. Life (10,000 hr. req'd).
 - h. Reliability.



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2. Capacitor Types

- A. Although capacitors utilizing ceramics and glass dielectric materials have the highest radiation tolerance, they were not considered for this application because of the amount of capacity needed. These devices are normally only made to values of around 0.1 μF and have relatively high dissipation factors of around 0.5 to 2.0 percent. The development necessary to meet the requirements of this application would be prohibitive.
- B. Capacitors utilizing mica dielectric also were not considered for this application. Although their dissipation factor (DF) is low (0.04%), and they should be highly radiation tolerant, their normally small capacitance values would place them in the same class as ceramic and glass types. A type of re-constituted mica exists in a form suitable for higher capacity values, but details of this material are presently unavailable. In either case, a substantial development program would be required to satisfy the needs of this application.
- C. Electrolytic types of capacitors were not considered because of their high dissipation factor (>10%) and susceptibility to radiation damage.
- D. Paper dielectric capacitors are well developed and are commonly used for power factor correction in commercial power systems. Their a-c voltage ratings at 60 HZ are well established. These units usually use an oil, or some other, impregnant to secure the desired qualities. The dissipation factor of these types is around 0.5 to 1.0%, and their upper temperature limit is normally about 120°C. The maximum allowable temperature may vary as determined by the type of impregnant. Under the nuclear radiation of the SNAP-8 application, the commonly used impregnant will evolve gas and perhaps change physically. If the capacitors can be suitably shielded and sealed, the paper types may satisfy this application.
- E. Plastic film capacitors offer a wide variety of types and characteristics. The most promising for this application are the Mylar, Teflon, polycarbonate, and "H-film" (polyimide) types. In general, all of these films tend to evolve gas and show other degradation effects under the nuclear radiation dosages specified for the SNAP-8. The effects are negligible with some films and serious in others.
 - 1) Mylar is one of the most widely used plastic dielectric films for capacitors. Its dissipation factor varies with temperature and has values between 0.3% and 1.3%. It is relatively immune to damage from the nuclear radiation environment of SNAP-8.

Its maximum allowable temperature is 150°C. The reliability of capacitors using this type of dielectric should be well established (MIL-C-27287). However, the largest capacity normally available in a single unit is 10 μ F, and a-c voltage ratings are not well established.

- 2) Teflon as a dielectric film is also in common usage. It has a very low dissipation factor ($\approx 0.05\%$) and a high temperature capability of 250°C. However, it would probably suffer considerable damage under the nuclear radiation of SNAP-8. Shielding would, therefore, be required. Teflon capacitors are generally physically larger than Mylar, or polycarbonate types. Also, presently available Teflon types are normally limited to values less than 10 μ F.
- 3) Polycarbonate as a capacitor dielectric film is a relatively recent development. Its nuclear radiation tolerance is generally the same as Mylar and it should survive the SNAP-8 dosages. Its dissipation factor is low ($\approx 0.1\%$). The maximum allowable temperature is 125°C. The maximum capacity normally available in a single unit is 10 μ F. Unfortunately, the reliability and a-c voltage ratings of this type capacitor have not been established. Work under contract NAS3-7623 is presently under way to help establish the a-c rating and reliability of polycarbonate capacitors.
- 4) H-film as a capacitor dielectric is presently in the early development stages. Film thin enough for practical capacitors is not yet available. This material is very promising because of its high temperature capability (250°C) and reasonable dissipation factor of 0.25%. Its nuclear radiation tolerance should be comparable to that of polycarbonate. Application of this material to the SNAP-8 capacitors would require a prohibitively long development.

3. Mechanical Problems

- A. Gas tends to be evolved from impregnants and plastic films under nuclear radiation. This must be a consideration with hermetically sealed construction. Some type of pressure relief vents may be required to prevent physical distortion or damage.
- B. In the capacitors for this application, internal cooling means must be provided since no effective heat path exists through the capacitor materials. Even the few watts lost in the capacitors with the lowest dissipation factors would probably raise the internal temperatures beyond the allowable maximum.

4. Electrical Problems

- A. The dissipation factor of dielectrics tend to increase as a result of nuclear radiation. Therefore, power losses internal to the capacitors would increase as time passes, in a SNAP-8 power system.
- B. The most common failure mode of the types of capacitors suitable for this application is "shorted."

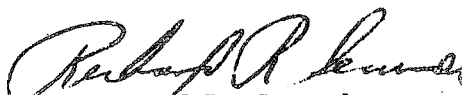
5. Preliminary Recommendations

Since no single capacitor type is ideally suited for this application, a tentative order of preference is given below. This order is based on the application requirements and capacitor characteristics as outlined above.

- A. Oil-impregnated paper type capacitors most probably offer the best chance of success. They are well-established in a-c power factor correction service and much reliability data exists. However, the selection of a radiation resistant oil impregnant or suitable shielding may prove to be a prohibitive problem.
- B. Mylar capacitors are a second choice. Their reliability in d-c applications is well established and they should not be severely effected by the specified radiation. However, they have not found wide usage in a-c applications in sizes required here. The proper a-c derating for long life and reliability has not been established.
- C. Polycarbonate capacitors are the third choice. Although the low dissipation factor and good radiation tolerance of polycarbonate film offers the most promise in this application, much development would be necessary to establish a-c ratings and reliability. This type is considered state-of-the-art or a little beyond. The film itself is only available from one supplier (in Germany).

In general, whichever type is selected, internal cooling means must be provided. Metallic or BeO heat conductors between sections may be sufficient. Some type of pressure relief must be provided to prevent a build-up of internal pressure caused by gases evolved under nuclear radiation.

As a first estimate, and neglecting shielding, the capacitor bank for this application will occupy approximately 1000 to 2000 cubic inches and weigh approximately 100 to 200 pounds.


Richard R. Secunda

SUMMARY OF PROPERTIES

GENERAL

"Kapton"* polyimide film possesses a unique combination of properties previously unavailable among polymeric film materials. The ability of "Kapton" to maintain its excellent physical, electrical and mechanical properties over a wide temperature range has opened new design and application areas to plastic films. "Kapton"* is proving itself especially useful in applications which have high operating temperatures.

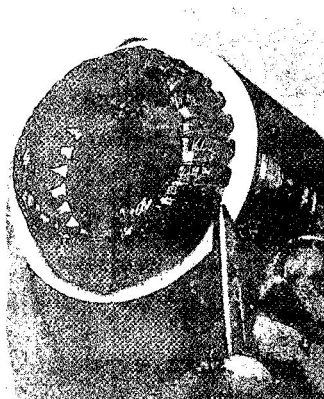
"Kapton" Type H has been used successfully in applications where the temperatures have been as low as -269°C . and as high as 400°C . At room temperature, the properties of "Kapton" and "Mylar"* polyester film are similar. However, as the temperature is increased or decreased the properties of "Kapton" are less affected than those of "Mylar". A flame resistant material, "Kapton" begins to char above 800°C . There is no known organic solvent for the film and it is infusible and does not melt. "Kapton" is synthesized by a polycondensation reaction between an aromatic tetrabasic acid and an aromatic amine.

Adhesives are available for bonding "Kapton"

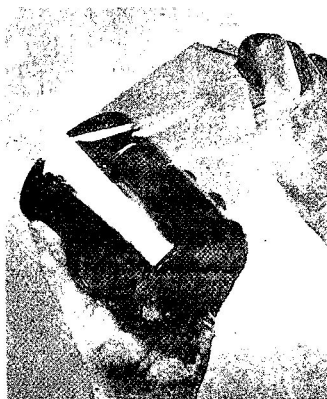
to itself, to metals, to papers of various types and to other films. "Kapton" Type H can also be laminated, metalized, punched, formed or adhesive coated.

Applications for "Kapton" polyimide film include: wire & cable wrap, formed coil wrap, flexible printed circuits, motor slot liners, magnet wire, transformers, capacitors, magnetic and pressure sensitive tapes, and hose and tubing. Many of these applications are based on the fact that the excellent electrical properties of "Kapton," such as dielectric strength and dissipation factor, remain nearly constant over a wide range of temperature and frequency. Others make use of the film's radiation resistance or chemical resistance at elevated temperatures. It is this combination of useful properties at extremes in temperature which make "Kapton" a unique new industrial material.

Because "Kapton" has no melting point, Du Pont combines "Teflon"* FEP-fluorocarbon resin with the polyimide to give a heat-sealable structure for fabrication purposes. This combination is known as "Kapton" Type F and its properties are reviewed in Bulletin F-1. The all polyimide film, "Kapton" Type H, is discussed in this bulletin.



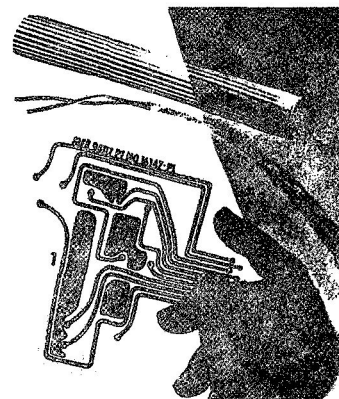
Precision motors use slot liners made of "Kapton" Type H because of the material's toughness and its ability to insulate at higher operating temperatures.



"Kapton" is a transparent gold colored film which can be run on conventional film handling equipment with little if any adjustment.



"Kapton" finds use as layer insulation in transformers. The polyimide insulation permits the design of small units which operate at higher temperatures with no reduction in rating.



Printed circuits and flat cable construction have been made from "Kapton" because of its dimensional stability at high temperature and its solder resistance. "Kapton" is used as a wire wrap where good high temperature insulation and low weight structures are required.

PROPERTIES OF 1 MIL "KAPTON" TYPE H

PROPERTY	TYPICAL VALUES—1 mil film			TEST METHOD
	—195°C	25°C	200°C	
PHYSICAL PROPERTIES				
Ultimate Tensile Strength (MD)	35,000 psi	25,000 psi	17,000 psi	ASTM D-882-64T
Yield Point (MD)		10,000 psi at 3%	6,000 psi at 3%	ASTM D-882-64T
Stress to Produce 5% Elongation (MD)		13,000 psi	8,500 psi	ASTM D-882-64T
Ultimate Elongation (MD)	2%	70%	90%	ASTM D-882-64T
Tensile Modulus (MD)	510,000 psi	430,000 psi	260,000 psi	ASTM D-882-64T
Impact Strength		6 Kg-cm/mil		Du Pont Pneumatic Impact Test
Folding Endurance (MIT)		10,000 cycles		ASTM D-643-43
Tear Strength—Propagating (Elmendorf)		8 gm/mil		ASTM D-1922-61T
Tear Strength—Initial (Graves)		510 gm/mil		ASTM D-1004-61
Tear Strength—Initial (Graves)		1100 lb./in.		ASTM D-1004-61
Bursting Test (Mullen)		75 psi		ASTM D-774-63T
Density		1.42 gm/cc		ASTM D-1505-63T
Coefficient of Friction Kinetic (Film-to-Film)		.42		ASTM D-1894-63
Refractive Index (Becke Line)		1.78		Encyclopaedic Dictionary of Physics, Volume I
Area Factor		135 ft ² /lb./mil		Calculation

PROPERTY	TYPICAL VALUES—1 mil film				TEST CONDITION	TEST METHOD
THERMAL PROPERTIES						
Melting Point	NONE					
Zero Strength Temperature	815°C				20 psi load for 5 seconds	Hot Bar (Du Pont Test)
Cut-through Temperature	435°C				1 mil	Weighted Probe on Heated Film (Du Pont Test)
	525°C				2 - 5 mil	
Coefficient of Thermal Expansion	2.0 x 10 ⁻⁵ in./in./°C				(—) 14°C to 38°C	ASTM D-696-44
Coefficient of Thermal Conductivity	3.72 x 10 ⁻⁴ $\frac{(\text{cal}) (\text{cm})}{(\text{cm}^2) (\text{sec}) (^\circ\text{C})}$				25°C	Model TC-1000
	3.89 x 10 ⁻⁴ "				75°C	Twin Heatmeter
	4.26 x 10 ⁻⁴ "				200°C	Comparative Tester
	4.51 x 10 ⁻⁴ "				300°C	
Flammability	Self-extinguishing					
Heat Sealable	No					
Specific Heat	0.261 cal./gm./°C				40°C	Differential Calorimetry
	250°C	275°C	300°C	400°C		
Shrinkage	0.3%		0.5%	3.5%	30 minutes	ASTM D-1204
Heat Aging (In air)	8 yrs.	1 yr.	3 months	12 hours	Circulating Air Oven	Time to Reach 1% Elongation

"KAPTON" — A USEFUL FILM FROM -269°C to 400°C

PROPERTY	TYPICAL VALUES—1 mil film			TEST CONDITION	TEST METHOD
	% Tensile Retained	% Elongation Retained	% Modulus Retained		
CHEMICAL PROPERTIES					
CHEMICAL RESISTANCE TO:				Days Immersed at Room Temperature	
Benzene	100	82	100	365	
Toluene	94	66	97	365	
Methanol	100	73	140	365	
Acetone	67	62	160	365	
10% Sodium Hydroxide		Degrades		5	
Glacial Acetic Acid	85	62	102	36 days at 110°C	
p-Cresol	100	77	102	22 days at 200°C	
"Arochlor" *	100	53	142	365 days at 200°C	
Transformer Oil	100	100	100	180 days at 150°C	
Water pH = 1	65	30	100	14 days at 100°C	
pH = 4.2	65	30	100	14 days at 100°C	
pH = 7.0	65	30	100	70 days at 100°C	
pH = 8.9	65	20	100	14 days at 100°C	
pH = 10.0	60	10	100	4 days at 100°C	
RADIATION RESISTANCE					
Gamma (Savannah River)	Still Flexible (180° Bend) Retains 50% of Original Elongation			Exposure 4.16 x 10 ⁶ RADS	Westinghouse Fluorescent Sunlamps Ozone Present, Dry Environment Soil Burial
Electron (Van de Graaff)				Exposure 6 x 10 ⁶ RADS	
Neutron plus Gamma (Brookhaven)				Exposure 10 ¹⁰ RADS	
UV	Excellent				
FUNGUS RESISTANCE	Inert			12 months	
MOISTURE ABSORPTION	1.3% 2.9%			50% Relative Humidity at 23.5°C Immersion for 24 hrs. at 23.5°C	Constant Environment Room ASTM D-570-63
HYGROSCOPIC COEFFICIENT OF EXPANSION	2.2 x 10 ⁻⁵ in/in/% Relative Humidity			72°F 20% - 80% Relative Humidity	
PERMEABILITY					
Gas	cc/(100 in ²) (24 hrs.) (atm/mil)			23°C	ASTM D-1434-63
Carbon Dioxide	45				
Hydrogen	250				
Nitrogen	6				
Oxygen	25				
Helium	415				
Water Vapor	gm/(100 in ²) (24 hrs.)/mil				ASTM E-96-63T
	5.4				

PROPERTY	TYPICAL VALUES—1 mil film			TEST CONDITION	TEST METHOD
	-195°C	25°C	200°C		
ELECTRICAL PROPERTIES					
Dielectric Strength (1-mil)	10,800	7,000 volts	5,600 volts	60 cycles	ASTM D-149-64
Dielectric Constant		3.5	3.0	1 kilocycle	ASTM D-150-64T
Dissipation Factor		.003	.002	1 kilocycle	ASTM D-150-64T
Volume Resistivity		10 ¹⁸ ohm-cm	10 ¹⁴ ohm-cm		ASTM D-257-61
Surface Resistivity		10 ¹⁶ ohms		50% Relative Humidity	ASTM D-257-61
Corona Start Voltage (1-mil)		465 volts		50% Relative Humidity	ASTM D-1868-61T
Insulation Resistance		100,000 megohm mids.			Based on 0.05 mfd. wound capacitor using 1-mil H Film

*Monsanto registered trademark

APPENDIX C

Specification AGC-10563A



AEROJET-GENERAL CORPORATION

CODE IDENT. NO. 70143

SPECIFICATION AGC-10563A

CAPACITOR, POWER FACTOR CORRECTION - SNAP-8

SUPERSEDING:					
AGC - 10563		AGC -		AGC -	
DATE 13 January 1967		DATE		DATE	
RELEASES (REPLACE PAGES IN SPECIFICATION WITH LATEST CHANGE BELOW)					
REV LTR	RELEASE DATE	PAGE NUMBERS			PAGE ADDITIONS
		1	2	3	
		4	5	6	
		7	8	9	
	13 Jan 67				

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Authorized for Release:


J. Coff, Manager
Specifications and Standards
Power Systems Division
Von Karman Center

1. SCOPE

1.1 This specification covers the requirements for the performance, design and test of one type of fixed capacitor for use in the power factor correction assembly of the SNAP-8 Power Conversion System.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the latest issue in effect on the date of invitation for bids, shall form a part of this specification to the extent specified herein. In the event of conflict between documents referenced here and other detail content of Sections 3, 4, and 5, the detail requirements of Sections 3, 4, and 5, shall be considered a superseding requirement.

SPECIFICATIONS

Military

MIL-D-1000	Drawings, Engineering, and Associated Lists
MIL-T-5021	Tests, Aircraft and Missile Welding Operators, Qualifications
MIL-C-45662	Calibration System Requirements

STANDARDS

Military

MIL-STD-143	Specifications and Standards, Order of Precedence for the Selection of
MIL-STD-826	Electromagnetic Interference Test Requirements and Test Methods
MS 33586	Metals, Definition of Dissimilar

(A)

Aerojet-General Corporation

AGC-STD-1338	Capacitor, SNAP-8, Quality Conformance of
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(Copies of specifications, standards, drawings, bulletins, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Performance.-3.1.1 Operational requirements.-

3.1.1.1 Rated voltage.- The capacitor shall be rated to operate at 215 volts, root mean square, (vrms) at 395 to 405 Hertz (Hz, cycles per second).

3.1.1.2 Capacitance. - The rated capacitance shall be 17.5 ± 1.75 microfarads (μf).

3.1.1.3 Power dissipation. - The power dissipation of the capacitor, including resistance losses in the terminals, at the rated voltage and frequency, and at the rated temperature (see 3.3.1.3) shall not exceed 5.0 watts.

3.1.2 Operability. -

3.1.2.1 Reliability. - It shall be a design objective to attain a reliability of 99.99 percent for 10,000 hours of continuous rated operation in the natural and induced environments specified.

3.1.2.2 Maintainability. - The capacitor shall be designed so as not to require routine maintenance, repair, or service during its operating life.

3.1.2.3 Useful life. -

3.1.2.3.1 Operating life. - The capacitor shall be capable of continuous operation for 10,000 hours, unattended under the environmental conditions specified herein. There shall be no degradation in performance below the requirements specified in paragraph 3.1.1.

3.1.2.3.2 Shelf life. - The capacitor shall have a shelf life of two years without requiring processing when protected and packaged per Section 5 and thereafter be capable of meeting the operating life requirements of this specification.

3.1.2.4 Natural environment. - The capacitor shall operate in a natural environment of any of the following:

- (a) Air or sulphur hexafluoride (SF_6) at approximately 14.7 pounds per square inch, absolute (psia) and 125°F to 200°F .
- (b) Room ambient conditions for testing, with a relative humidity up to 95 percent.

3.1.2.5 Transportability. - Not applicable

3.1.2.6 Human performance. - Not applicable.

3.1.2.7 Safety. - Not applicable.

3.1.2.8 Induced environment. - The capacitor shall be designed to withstand the following induced environment.

3.1.2.8.1 Shock. - The capacitor, non-operating, shall be capable of withstanding 20 g shocks along three mutually perpendicular axes. Three shocks shall be made in each direction (six shocks) along each axis (a total of 18 shocks). The wave shape of the input pulse shall be half-sine pulse for 10 milliseconds duration.

3.1.2.8.2 Vibration. - The capacitor, non-operating, shall be capable of withstanding random noise vibration over a frequency interval of 20 to 2000 Hz for five minutes in each of three mutually perpendicular axes with the acceleration density as follows:

- (a) 20 to 200 Hz: increasing at 2 decibels (db) per octave.
- (b) 200 to 700 Hz: at $0.64 \text{ g}^2/\text{Hz}$.
- (c) 700 to 900 Hz: decreasing at 17.5 db per octave.
- (d) 900 to 2000 Hz: at $0.15 \text{ g}^2/\text{Hz}$.

3.1.2.8.3 Acceleration.- The capacitor, non-operating, shall be capable of withstanding 6 g steady acceleration in either direction along any axis.

3.1.2.8.4 Combined loadings.- The capacitor shall be capable of withstanding the combined loading of shock (see 3.1.2.8.1), vibration (see 3.1.2.8.2), and acceleration (see 3.1.2.8.3).

3.1.2.8.5 Operation.- During operation, the capacitor shall be able to withstand the following environments without malfunction or damage:

- (a) Shocks of 3 g on each of three mutually perpendicular axes with the wave forms of a half-sine pulse for 8 milliseconds duration.
- (b) Vibrations of 0.25 g peak over a frequency range of 5 to 2000 Hz for 5 minutes.
- (c) Steady acceleration of 3.5 g in either direction along any axis.
- (d) Total integrated nuclear radiation, including direct, scattered, and secondary radiation as follows:
 - (1) Fast neutrons: 10^{11} nvt, integrated dose for 10,000 hours.
 - (2) Gammas: 10^6 rads (c), integrated dose for 10,000 hours.

3.2 Interface requirements.- The envelope and mounting dimensions of the housings and the location and kind of nameplates shall be at the discretion of the manufacturer within the limitations specified herein. The manufacturer shall submit all necessary interface documents, to AGC for coordination prior to fabrication of the capacitor (see 3.4.1).

3.2.1 Mounting.- The capacitor shall be designed to mount with threaded fasteners onto a heat sink maintained at 150°F and to transfer to that heat sink the internally generated heat.

3.2.2 Terminals.- The terminals shall be on the side of the housing opposite to the mounting surface.

3.3 Design and construction.-

3.3.1 General design features.-

3.3.1.1 Construction.- The capacitor shall be of metal foil with a polycarbonate plastic film dielectric.

(A) 3.3.1.2 Enclosure.- The enclosures of the capacitors shall be hermetically sealed by welding to prevent leakage in excess of that specified in 3.3.1.6. The enclosure shall be able to withstand a minimum differential pressure of 15 psi in either direction.

3.3.1.3 Rated temperature.- The capacitor shall be capable of operating throughout its operating life with a continuous temperature environment of 125°F to 200°F. The capacitor shall be capable of storage, nonoperating, with a continuous temperature environment of +20°F to +120°F.

3.3.1.4 Dielectric Strength: The capacitor shall be capable of withstanding a potential of 650 volts dc, minimum, applied between the capacitor terminals, for a period of 24 hours at 200°F without breakdown, and with a steady-state current flow not in excess of 1 microampere.

(A) 3.3.1.5 Dielectric Strength, Insulation.- With both plates of the capacitor connected together, and with all metallic parts of the case connected together, the capacitor shall withstand a minimum potential of 2150 volts dc applied between the case and the capacitor plates at 200°F. The potential shall be applied for a minimum period of one minute after the steady state current is reached. No sudden breakdown, arc-over, or steady state current flow in excess of one microampere shall be permitted.

3.3.1.6 Leakage.- The maximum leakage rate of the enclosure shall not exceed the equivalent of 1×10^{-7} standard cc/second of helium as measured with a mass spectrometer.

3.3.2 Selection of specifications and standards.- Specifications and Standards for necessary commodities and services not specified herein shall be selected according to MIL-STD-143. Where, in the best interests of the Aerojet-General Corporation, it is necessary to control the design selections of products, materials, and processes not described by available specifications, a specification or standard shall be prepared and submitted to the Aerojet-General Corporation for review prior to its use.

3.3.3 Materials, parts and processes.- Parts, materials, and processes used in the unit shall be selected by the supplier and shall be adequate for the application. In the selection of parts and material, those known to be significantly radiation-sensitive or subject to harmful deterioration in a vacuum shall be avoided. Preference shall be given to parts and materials readily available, particularly to those which have been qualified in accordance with specifications and standards issued by the Department of Defense or industry associations. All parts and materials selected by the supplier shall be subject to review and approval by AGC as to their suitability for use. Approval of any part, material or process shall not be construed as assurance of acceptance by AGC of any finished units.

3.3.3.1 Terminals.- The terminals shall be of sufficient size to efficiently and continuously conduct the rated load current without an appreciable temperature rise in the terminals. Design of the terminals shall permit external copper connections to be made to the capacitor by inert gas welding (with use of heat sink on the terminal, if necessary).

3.3.3.2 Welding. - Unless otherwise specified, all welding shall be performed by operators who are currently qualified to the requirements of MIL-T-5021.

3.3.4 Standard and commercial parts. - Military and industry standard parts shall be used where they suit the purpose and shall be identified on the drawings by their military or industry (NAS etc.) standard part number. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., shall not be used if they are replaceable by standard parts (MS, MIL, JAN, AN) without alteration. In the event there are no suitable corresponding standard parts, commercial parts may be used provided they conform to the requirements of this specification.

3.3.5 Moisture and Fungus Resistance. - Materials shall be selected for resistance to deterioration due to humidity, water absorption, or the growth of fungus; or shall be coated or treated to prevent deterioration.

3.3.6 Corrosion of metal parts. - Materials shall be of a corrosion-resistant type or suitably processed to resist corrosion. The use of dissimilar metals as defined in Standard MS33586 shall be avoided. Where contact between dissimilar metals is unavoidable, they shall be suitably protected against electrolytic corrosion. The protection shall be of a type that offers a low-impedance path to radio-frequency currents.

3.3.7 Interchangeability and replaceability. - All parts having the same manufacturer's part number shall be directly and completely interchangeable with respect to installation and performance and be adequately serialized to provide for the use of matched or fitter subassemblies. Changes in part numbers shall be governed by the requirements of Specification MIL-D-1000.

3.3.8 Workmanship. - The workmanship and finish shall be of a sufficiently high grade to assure satisfactory operation consistent with the requirements of this specification. The standards of workmanship exhibited in any approved unit, subject to any corrective action stated in the notice of approval, shall define the requirements of workmanship insofar as those not specifically covered by applicable specifications.

(A) 3.3.9 Electromagnetic interference. - The capacitor shall be designed to meet the acceptance criteria for Conducted Susceptability, Induction Field Radiated Susceptability, and Radiated Interference of MIL-STD-826.

(A) 3.3.10 Identification and Marking. - Each capacitor shall be permanently identified by a method compatible with the service environment with, as a minimum, the following information as applicable:

- (a) Part Name
- (b) Supplier's part number and drawing revision letter
- (c) Supplier's name or trademark designation
- (d) Date of manufacture
- (e) Supplier's model, serial, and AGC assigned serial numbers

- Note: (1) The supplier's part number shall be the number of the contractor's assembly drawing which includes sub-assembly ordering data.
- (2) The supplier's name or trademark shall not be in letters larger than any other letters.

3.4 Documentation requirements.- At the time specified in the contract (see 6.2), the supplier shall submit the documents, data, and material, described in the following subparagraphs. All documents will be subject to review and approval by the Aerojet-General Corporation for technical adequacy, completeness, and legibility. The format and method of presentation of these documents may be the usual practice when such practice is adequate to satisfy the specified requirements.

3.4.1 Engineering Documents.- The manufacturer shall submit the following documents for approval prior to fabrication of the capacitors.

- (a) Assembly and detail drawings per MIL-D-1000, category F, Form 2.
- (b) Material and part specifications or standards.
- (c) Design analysis and test data to demonstrate compliance with the design criteria of 3.1.1 and 3.3.1.
- (d) Design analysis of environmental stresses of 3.1.2.8.
- (e) Design analysis to demonstrate effect of all manufacturing process on reliability (especially the making of electrical connections).
- (f) Special manufacturing, processing, and cleaning procedures.
- (g) Acceptance test procedure.

3.4.2 Quality Assurance Documents.- The supplier shall submit a "Build-up and Assembly" log with each unit or lot submitted. As a minimum, these logs shall contain the following data:

- (A) (a) Configuration status and traceability of functionally significant materials and articles to their fabrication lot and purchased material lot.
- (b) Records of final inspections and acceptance tests.
- (c) List of nonconformances pertaining to the subject assembly.
- (d) Variables data considered essential by AGC.

3.4.3 Change control.- The supplier shall make no changes in drawings, specifications or processing techniques after approval of such documents by the Aerojet-General Corporation.

4. QUALITY ASSURANCE PROVISIONS

4.1 Supplier's responsibility.-

4.1.1 Inspection.- Unless otherwise specified, the supplier is responsible for the performance of all inspection requirements as specified herein, and may utilize any inspection facilities acceptable to the procuring activity.

4.1.2 Test report.- The supplier shall submit an acceptance test report on each unit or lot submitted. The report shall include completed data sheets indicating each test performed, actual test values observed and evidence of quality control acceptance.

4.1.3 Test conditions.- Unless otherwise specified herein, all tests required by this specification shall be made at local test site ambient conditions. All test instrumentation shall bear visual evidence of current calibration in accordance with the calibration system requirements of MIL-C-45662.

(A) 4.2 Classification of inspections.- Inspections to be performed on the unit shall be classified as inprocess inspection (see 4.3) and Quality Conformance Inspection (see 4.4).

4.3 Inprocess inspection.- Inprocess inspection shall include, as a minimum, inspection of welded joints and electrical connections.

(A) 4.4 Quality Conformance Inspection.- Quality Conformance Inspection for each unit shall be in accordance with AGC-STD-1338.

5. PREPARATION FOR DELIVERY

5.1 Preservation, packaging and packing.- The methods of preservation, packaging and packing of the unit shall be determined by the supplier so as to provide cleanliness and mechanical protection and be compatible with the method of transportation selected by the supplier. Damage to a unit due to improper packaging shall be cause for rejection.

5.2 Marking for shipment.- Each shipping container will be marked with, as a minimum, the following information in letters one-inch high (when deemed possible by the container size):

- (A) (a) Part name
- (b) Supplier's part number
- (c) Serial number
- (d) NASA contract number
- (e) Date of final assembly
- (f) Purchase order number
- (g) Supplier's name
- (h) SNAP-8

6. NOTES

6.1 Intended use.- The capacitor covered by this specification is intended for use in an electrical-power generation system which may be used in conjunction with space operations.

6.2 Ordering data.- Procurement documents should specify the following:

- (a) Title, number, and revision letter of this specification.
- (b) Dates and delivery instructions for submittal of documentation.
- (c) Serialization instructions (see 3.3.10).
- (d) Variables data required (see 3.4.2).

APPENDIX D

Memo 4901:67-1059

Conceptual Design Meeting
of the
POWER FACTOR CORRECTION CAPACITOR PACKAGE



INTER-OFFICE MEMO

10-007-102

TO: Distribution

DATE: 26 July 1967
4901-67-1059: CGB:vsh

FROM: C. G. Boone

SUBJECT: Conceptual Design Meeting of the Power Factor Correction Capacitor Package

DISTRIBUTION: PSD Department and Section Heads, RGordon, RMill

A Conceptual Design meeting of the capacitor package was held July 7. The pertinent factors brought out are as follows:

1. The capacitor package provides a net gain of approximately 2.5 kw in system output. The major gain is in providing an improved alternator efficiency which outweighs the heat losses of the capacitor package.
2. The capacitors also provide a reduced load requirement for the inverter when battery inverter power to the pumps is connected to the capacitors.
3. The heat losses in the capacitors amount to approximately 150 watts maximum.
4. The losses in the capacitor essentially double the load on the low temperature (140°F) heat rejection system.
5. The capacitor assembly is composed of a package of capacitor modules with each module containing eight to twelve capacitors. There are ten modules per phase, and the wiring is parallel. The overall capacitor assembly is hermetically sealed and bolted to the bottom surface of the heat sink within the LCA. The rating of the capacitor package is 57 KVAR.
6. The heat loss of the capacitors results in a radiator requirement of approximately 75 sq ft.

The following action items resulted from this meeting:

1. Reliability is to study the effects on overall system reliability of having the power factor capacitors included in the system. It is recognized that much data is available on various types of capacitors but little, if any, will be available for the polycarbonate-type of capacitors.
2. The Electrical Section is to work with the Reliability Section in determining whether fusing within the capacitor package would provide additional reliability.


C. G. Boone
Chief Engineer
Power Systems Division

APPENDIX E

Memo 4925:67-0161

Reliability Analysis of Power Factor Correction Assembly

Memo 4925-69-0080

Reliability Reevaluation of Power Factor Correction Assembly



AEROJET-GENERAL CORPORATION

INTER-OFFICE MEMO

16-007-102 (STOCK NO. 2-1)

TO: R. M. Hill

DATE: 3 August 1967
4925:67:0161:BLA:dmp

FROM: B. L. Amstatter

SUBJECT: Reliability Analysis of Power Factor Correction Assembly

DISTRIBUTION: W. F. Banks, C. G. Boone, S. L. Bradley, E. Eber, R. Gordon, G.G. Takach

An analysis was performed to determine the comparative reliabilities of the power factor correction assembly using either a single fuse for each capacitor or a pair of fuses for each. It was assumed that all electrical connections would be welded. The study also assumed that the capacitors were polycarbonate, were operated at 95°C, were rated at >600 volts DC, and were operated at 60% of rated power.

It was further assumed that the loss of three capacitors out of the ten in one phase would not result in a detrimental condition. The evaluation used the worst-case-analysis method. Failure was assumed to be in the 'open' mode since shorting of a capacitor would result in a blown fuse. Failure of a fuse to open when required was considered negligible since current through a shorted capacitor would be several times higher than the fuse rating. Operation without fusing was not considered because shorting of one capacitor would result in shorting of the entire phase.*

Results showed that, although use of redundant fuses would provide additional protection against an inadvertent open, a single fuse for each capacitor was sufficient to provide required reliability.

Overall Reliability with single fuse per capacitor = .99946**

Overall Reliability with two fuses per capacitor = .99988**

B. L. Amstatter

B. L. Amstatter, Head
Reliability Section
Power Systems Division

* The reliability of an unfused power factor correction assembly is only .74. This is based on single unit reliability of .99 in the 'shorting' mode (which is optimistic) and on the assumption that a short does not clear itself but shorts the entire phase.

** Conservative estimates

3 August 1967
4925:67:0161FAILURE RATE DATA

Failure rate data for capacitors, fuses and welds were obtained from applicable, industry-accepted sources. Among these were Avco, Hughes, THW(STL), and WPAFB. The data were evaluated for environmental and derating considerations, and the following results were obtained and utilized in the calculations.

<u>Component</u>	<u>Environment</u>	<u>Failure Rate Per 1000 Hours (%)</u>	<u>Failure Probability 10,000 Hours</u>
Capacitor*	95°C; 60% rated power, greater than 600V rating	.20%	0.02
Fuse	--	.05%	0.005
Weld	--	.003%	0.0003 ea.
Total for each capacitor-fuse set (1 fuse only) Reliability figure used (conservative value)			0.026** .97
Total for each capacitor fuse set (2 fuses in redundancy) Reliability figure used			0.02*** .98

Notes:

1. Reliability of 2 fuses in parallel = $1 - (.005)^2 = .9999+$
2. Failure mode of fuse was considered to be inadvertent open.
3. Shorting of capacitor results in open because of fuse; therefore entire capacitor failure rate applies to open failure.

* Based on data for polystyrene capacitors

** Includes three (3) welds per set

*** Includes four (4) welds per set

DETAIL CALCULATIONS

Probability that one capacitor-fuse set does not fail = R

Probability that one capacitor-fuse set fails = Q (=1-R)

Probability of no failures in one leg = R^{10} (A)

Probability of one failure in one leg = $10 \times R^9 \times Q$ (B)

Probability of two failures in one leg = $45 \times R^8 \times Q^2$ (C)

Probability of three failures in one leg = $120 \times R^7 \times Q^3$ (D)

Probability of not more than three failures in one phase =
(A) + (B) + (C) + (D) (E)

Probability for three phases (worst case)** = $(E)^3$ (F)

	<u>R = .97</u>	<u>R = .98</u>
(A)	.73740	.81705
(B)	.22806	.16676
(C)	.03174	.01532
(D)	<u>.00262</u>	<u>.00083</u>
Total per phase (E)	.99982	.99996
Total for 3 phases (F)**	.99946	.99988

* Coefficients of terms are taken from Binomial expansion

** Probability of more than three failures occurring in same phase,
resulting in worst case imbalance is extremely remote (<.0002 with
single fuse; <.00006 with 2 fuses)

INTEROFFICE MEMO



AEROJET-GENERAL CORPORATION

TO: R. M. Hill ✓

DATE 29 April 1969
4925-69-0080:BLA:mlg

FROM: B. L. Amstadter

SUBJECT: Reliability Reevaluation of Power Factor Correction Assembly

COPIES TO: W. F. Banks, S. L. Bradley, R. Gordon, L. P. Lopez, G. McRoberts, R. W. Marshall
 G. G. Takach, W. Weleff, W. L. Snapp (Cleveland)
 NASA-LeRC: G. M. Thur
 NASA-Hq: P. R. Miller

REFERENCE: (a) Memo 4925-67-0161 dtd 3 August 1967, B. L. Amstadter to R. M. Hill,
 Subject: Reliability Analysis of Power Factor Correction Assembly

The latest configuration of the power factor correction assembly (delta connection with a fuse at each node) has been evaluated. While the probability of a worst case imbalance in the assembly is increased over the previous configuration, two advantages more than compensate for this increase and result in an overall improvement in system reliability. First, the new configuration prevents a short between one phase and ground and thereby increases the system reliability if there is a grounded neutral. Second, when one capacitor shorts and the corresponding fuse opens, the overall result is a very slight phase angle change of the alternator current and a very slight increase in current in all three alternator phases. The alternator currents remain approximately equal even though the P.F.C.A. currents are somewhat unbalanced. Since the original reliability of the P.F.C.A. was well above its requirement, it was considered unnecessary to recalculate this value (which will be higher than before).

B. L. Amstadter, Supervisor
 Reliability
 MSO

APPENDIX F

AGC-STD-1338



AEROJET-GENERAL CORPORATION

CODE IDENT. NO. 70143

AGC-STD-1338

CAPACITOR, SNAP-8, QUALITY CONFORMANCE INSPECTION OF

SUPERSEDING:							
AGC - DATE			AGC - DATE			AGC - DATE	
RELEASES (REPLACE PAGES IN STANDARD WITH LATEST CHANGE BELOW)							
REV LTR	RELEASE DATE	1	2	3	4	5	6
	26 May 67						
							PAGE ADDITIONS

Authorized for Release:

[Signature]
J. Coff, Manager
Specifications and Standards
Power Systems Division
Von Karman Center

1. SCOPE

1.1 This standard covers the Quality Conformance Inspection requirements of the SNAP-8 power-factor correction Capacitor procured in accordance with AGC-10563.

2. APPLICABLE DOCUMENTS

2.1 Department of Defense (DOD) document.- The following document forms a part of this standard to the extent specified herein. Unless otherwise specified, the issue in effect on the date of inspection shall apply.

SPECIFICATION

Military

MIL-C-45662

Calibration System Requirements

2.2 Aerojet-General Corporation (AGC) documents.- The following documents form a part of this standard to the extent specified herein. Unless otherwise specified, the issue in effect on the date of inspection shall apply.

SPECIFICATION

AGC-10563

Capacitor, Power Factor Correction - SNAP-8

STANDARD

AGC-STD-1283

Method 11

Leak Testing, Helium, Hermetically Sealed Enclosures

3. DEFINITIONS

3.1 There are no unusual terms used in this standard.

4. GENERAL REQUIREMENTS

4.1 Test equipment.- Data monitoring instrumentation and test equipment shall be within its current calibration period. The following items of equipment, or an equivalent approved by the cognizant engineer, are required to test the capacitor in accordance with this procedure:

- (a) Power supply, 400 Hertz (Hz); 215 vac range
- (b) Capacitance bridge
- (c) Oven, 200°F, capacity, with temperature controls
- (d) Power supply(s), 650 and 2150 vdc range
- (e) Microampere (μa) meter, 0 to 3 μa range
- (f) Heat sink - 150°F continuous operating temperature
- (g) External impedance (see Figures 2a and 2b)

4.2 Quality assurance provisions.- Unless otherwise specified, the quality assurance provisions are identified in two areas of responsibility.

4.2.1 Quality Control responsibility.- Quality control shall be responsible to verify the following by affixing an inspector's stamp on the data record.

(a) Use of the applicable equipment or approved equivalent (see 4.1).

(b) Current calibration date of the equipment used (see 4.3).

4.2.2 Shop or Laboratory supervisors responsibility.- In the shop or laboratory, the supervisor shall be responsible to verify by affixing his signature on the data record, that the requirements herein have been complied with by a qualified technician and the data recorded is accurate and complete.

4.3 Calibration of test equipment.- The calibration system for data monitoring equipment shall meet the requirements of MIL-C-45662.

4.4 Test data.- During the tests, data shall be recorded on a reproducible copy of the Test Data Record shown as Figure 1 and shall meet the acceptance limits specified. Copies may be obtained from the Power Systems Specification and Standard Department. A copy of the completed record shall be sent to the Power Systems Quality Engineering Department upon completion of the tests.

4.5 Inspection sequence.- Examinations and tests shall be performed in accordance with Table I.

Table I. Operation Sequence

Operation	Description	Reference Paragraph
1	Examination	5.1
2	Capacitance	5.2
3	Dielectric strength	5.3
4	Hermetic seal	5.4
5	AC Voltage Test	5.5

5. DETAILED REQUIREMENTS

5.1 Examination.- Each capacitor shall be examined and measured for the following criteria. All specified information shall be entered on the Test Data Record.

(a) Envelope and mounting dimensions in accordance with the applicable drawings.

- (b) Identification marking in accordance with AGC-10563
- (c) Electrical terminal and hermetic seal condition (bent, corroded, cracked, or otherwise indicating damage)
- (d) Workmanship and cleanliness

5.2 Capacitance.-- The capacitance of each capacitor shall be measured as follows:

- (a) Connect the 400 Hz power supply (4.1a) to the capacitance bridge (4.1b) as shown in the manufacturers operating procedure.
- (b) Measure and record the capacitance, dissipation factor and test frequency on the data record.

5.3 Dielectric strength.-- Measure the current flow through the dielectric and the insulation as follows:

- (a) Install the capacitor in a temperature controlled oven (4.1c) and bring electrical connections out of oven.
- (b) Raise the oven temperature to $200^{\circ} \pm 10^{\circ}\text{F}$ and let the capacitor stabilize at temperature (60 minutes, minimum).
- (c) Connect the dc power supply (4.1d) and the external impedance as shown in Figure 2a to provide 650 vdc across the capacitor terminals.
- (d) Apply the 650 +10, -0 vdc potential and monitor the current flow for one minute, minimum.
- (e) Record the maximum current (3.4 on the data record).
- (f) Connect the power supply and the external impedance as shown in Figure 2b to provide 2150 vdc between the terminals and the capacitor case.
- (g) Apply the 2150 +25, -0 vdc potential and monitor the current flow for one minute, minimum.
- (h) Record the maximum current (3.5 on the data record).

5.4 Hermetic seal.-- The capacitor housing shall be leak tested in accordance with AGC-STD-1283, Method 11, and the leakage rate shall be recorded on the data record.

5.5 AC Voltage test.- The capacitor shall be tested for degradation resulting from an applied alternating current as follows:

- (a) Install the capacitor on a temperature controlled heat sink (4.1f) and place in the oven.
- (b) Connect the power supply (4.1a) to supply 405 Hz, 215 vac, rms, across the capacitor.
- (c) Raise the oven temperature to $200 \pm 10^{\circ}\text{F}$ and maintain the heat sink at $150^{\circ} \pm 7^{\circ}\text{F}$ and let the capacitor stabilize at temperature (60 minutes, minimum).
- (d) Apply 215 ± 1 vac at 405 ± 1 Hz for 4 hours, minimum. Monitor the test continuously for evidence of failure.
- (e) After the capacitor has cooled to room temperature, repeat the test in 5.2 and record the capacitance, dissipation factor, and frequency (3.7, 3.8, and 3.9 on the data record).
- (f) A capacitance, or dissipation factor value, outside the specified limits, or a shift in the capacitance value greater than 2 percent of the value recorded as 3.1, shall be cause for rejection.

AGC-STD-1338

CAPACITOR, SNAP-8

TEST DATA RECORD

Part No. _____ Ser. No. _____ Date _____

Test Performed by _____ Cognizant Engineer _____

Record

Reference

1. Test equipment:

4.2.1

Description and (Type Model)	Serial or Inventory No.	Calibration Date	Notes	Insp. Stamp

2. Examination:

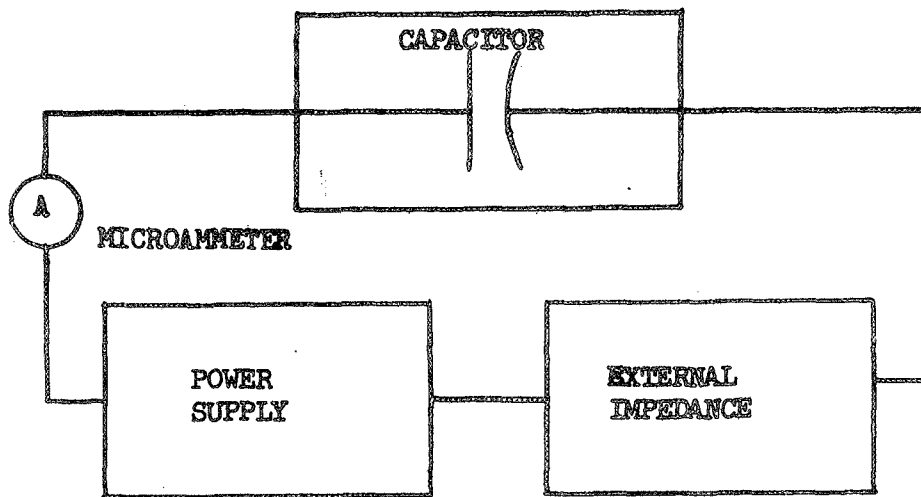
5.1

Acc Acceptance Tag No. _____

3. Tests:

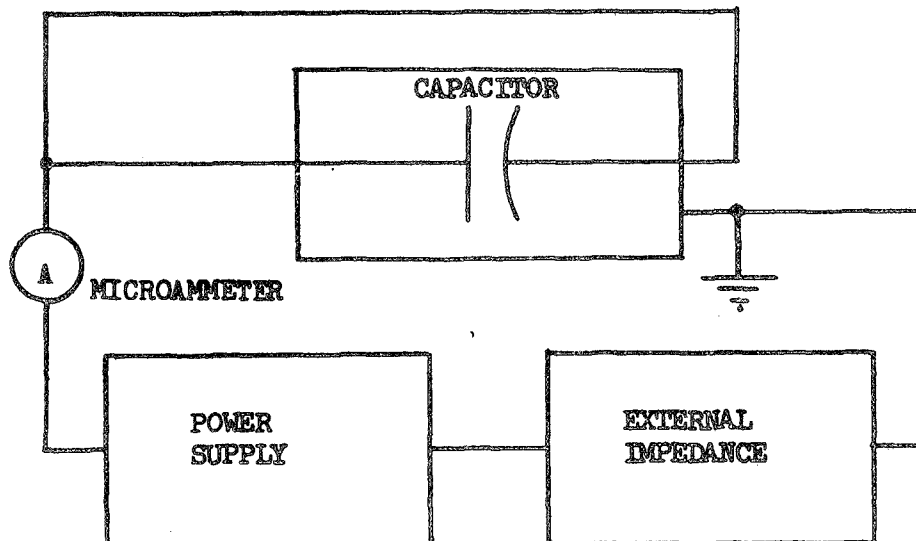
Item	Test Reading	Acceptable Limits	
3.1 Capacitance (μf)		15.75 to 19.25	5.2
3.2 Dissipation factor		0.0025 maximum	5.2
3.3 Frequency (Hz)		395 to 405	5.2
3.4 Current flow, dielectric (μA)		1.0 maximum	5.3(e)
3.5 Current flow, insulation (μA)		1.0 maximum	5.3(h)
3.6 Leakage rate (sec/sec)		1×10^{-7} maximum	5.4
3.7 Capacitance (μf)		(see 5.5 f)	5.5
3.8 Dissipation factor		(see 5.5 f)	5.5
3.9 Frequency (Hz)		395 to 405	5.5

Figure 1. Test Data Record



Note: The sum of the internal impedance of the power supply and the external impedance shall be 0.8 to 1.0 megohm.

Figure 2a. Block Diagram - Dielectric Strength Test



Note: The sum of the internal impedance of the power supply and the external impedance shall be 20.0 to 21.5 megohms

Figure 2b. Block Diagram - Insulation Resistance Test

Return this Form to Procuring Activity.

Document Preparing Activity:

AEROJET-GENERAL CORPORATION

Plant: Azusa

Address: 1100 W. Hollyvale St., Azusa

Organization: Engineering Services Dept.

DOCUMENT ANALYSIS SHEET

INSTRUCTIONS

This sheet may be completed by any activity involved in the use of this document. This sheet is for the express purpose of obtaining information relative to use of this document in order to insure that suitable products can be procured, manufactured, inspected, or tested, with a minimum amount of delay and at the least cost. This Form and comments should be returned at any time its response is warranted. This Form may not be used to stipulate exceptions to this document taken in response to a request for quotation, nor may it be used to request waiver of requirements when performing under a contract invoking this document.

DOCUMENT TITLE: Capacitor, SNAP-8, Quality Conformance Inspection of

DOCUMENT NUMBER: AGC-STD-1338

REVISION:

1. HAS ANY PART OF THE DOCUMENT CREATED PROBLEMS OR REQUIRED INTERPRETATIONS?

A. GIVE PARAGRAPH NUMBER AND WORDING.

B. RECOMMENDATIONS TO ALLEVIATE PROBLEM. (Include Attachments, If Applicable).

2. COMMENTS ON ANY REQUIREMENT, QUALITY ASSURANCE PROVISION, PACKAGING, CONTINUITY OF PROCEDURE, ETC., (Which appear to be too stringent or unnecessary, or incorrect).

3. IS THIS DOCUMENT EXCESSIVELY RESTRICTIVE?
IF ANSWER IS YES, IN WHAT WAY?

_____ YES

_____ NO

4. REMARKS: (Quality of Document, Clarity, Continuity, etc.)

SUBMITTED BY: (Name and Address to which further inquiry regarding comments should be directed).

DATE:

APPENDIX G

Specification AGC-10603

POWER FACTOR CORRECTION ASSEMBLY, PROTOTYPE



AEROJET-GENERAL CORPORATION

CODE IDENT. NO. 70143

SPECIFICATION AGC- 10603

PART I

POWER FACTOR CORRECTION ASSEMBLY, PROTOTYPE

SUPERSEDING:												
AGC - DATE		AGC - DATE		AGC - DATE								
RELEASES (REPLACE PAGES IN SPECIFICATION WITH LATEST CHANGE BELOW)												
REV LTR	RELEASE DATE	PAGE NUMBERS				PAGE ADDITIONS						
	22 Jul 68	1	1	2	3	4	5	6	7	8	9	

Authorized for Release:


J. Coff, Supervisor
Specifications and Standards
Mechanical Systems Operations
Electronics Division
Azusa Facility

1. SCOPE

1.1 This specification covers the requirements for the performance, design, and design approval testing of a Power Factor Correction Assembly for use in the electrical power system of the SNAP-8 Power Conversion System (PCS). Part II of this specification will specify the exact configuration information including the detail design and quality conformance inspections.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the latest issue in effect on the date of invitation for bids, shall form a part of this document to the extent specified herein. In the event of conflict between the documents referenced here and other detail content of Section 3, 4, and 5, the detail requirements of Section 3, 4, and 5 shall be considered a superseding requirement.

NASA DOCUMENTS

NPC 200-2

Quality Program Provisions for Space Systems Contractors

SPECIFICATIONS

Military

MIL-D-1000

Drawings, Engineering, and Associated Lists

MIL-T-5021

Tests, Aircraft and Missile Welding Operators, Qualifications

MIL-I-6866

Inspection, Penetrant Method of

MIL-S-7742

Screws Threads, Standard, Optimum Selected Series, General Specification for

Aerojet-General Corporation

AGC-10331

Electrical Connections, Inert-Arc Welding of, Procedure for

AGC-10507

Environmental Design Criteria and Test Levels, SNAP-8 Components

AGC-10563

Capacitor, Power Factor Correction, SNAP-8

AGC-13860

Radiographic Quality Levels Fusion Weldments

STANDARDS

Military

MIL-STD-143

Specifications and Standards, Order of Precedence for the Selection of

MIL-STD-453

Inspection Radiographic

MS33540

Safety Wiring, General Practices for

MS33586

Metals, Definition of Dissimilar

DRAWING

Aerojet-General Corporation

*

Low Temperature Control Assembly

(Copies of documents required by contractors in connection with specific procurement functions should be obtained as indicated in the Department of Defense Index of Specifications and Standards or as specified by the Contracting Officer.)

3. REQUIREMENTS

3.1 Performance. - The power factor correction assembly, hereafter called "The PFCA", shall meet the requirements herein under the conditions specified.

3.1.1 Operational requirements. -

3.1.1.1 Nominal electrical ratings. - The PFCA nominal electrical ratings shall be in accordance with Table I.

Table I. Nominal Electrical Ratings

Characteristic	Rate Value
(a) Rated voltage (rms) line-to-line	215
(b) Rated frequency (Hz)	400 $\pm$ 5
(c) Nominal capacity (KVAR)	*
(d) Nominal capacitance per phase (microfarads)	175
(e) Max. power dissipation (watts/phase)	50

3.1.1.2 Balanced circuit. - The PFCA shall be constructed with a three phase delta connected circuit. Each bank of capacitors shall be matched and balanced between phases within 5 percent.

3.1.1.3 Capacitors. - The PFCA capacitors shall be in accordance with AGC-10563.

* To be added at a later date.

3.1.2 Operability.-

3.1.2.1 Reliability.- It shall be a design objective to attain a reliability of 99.99 percent for 10,000 hours of continuous rated operation in the natural and induced environments specified herein.

3.1.2.2 Maintainability.- The PFCA shall not require routine maintenance, repair, or servicing during its operating life.

3.1.2.3 Useful life.-

3.1.2.3.1 Operating life.- The PFCA shall be capable of continuous operation for 40,000 hours, unattended, under the environmental conditions specified herein. There shall be no degradation in performance below the minimum requirements specified in Table I.

3.1.2.3.2 Shelf life.- The PFCA shall have a shelf life of two years without requiring other processing when protected and packaged per Section 5 and thereafter be capable of meeting the operating life requirements of this specification.

3.1.2.4 Natural terrestrial and space environment.- The PFCA shall be capable of withstanding the following natural terrestrial environments and the natural environments in space as specified in AGC-10507 and subsequently meet the requirements of 3.1.1.1:

- (a) Humidity
- (b) Salt fog
- (c) Temperature
- (d) Explosive atmosphere
- (e) Magnetic field

3.1.2.5 Transportability.- To be added, if required,

3.1.2.6 Human performance.- Not applicable.

3.1.2.7 Safety.- Not applicable.

3.1.2.8 Induced environment.- The PFCA shall be capable of withstanding all the induced environments specified in AGC-10507 prior to or during operation, as applicable, and thereafter meet the requirements of 3.1.1.1.

3.2 Interface requirements.- The PFCA shall be designed for mounting in the low temperature controls assembly (LCA) which will contain an actively-cooled heat sink. The envelope and mounting dimensions of the housing and the location of the electrical terminals shall be at the discretion of the supplier, subject to approval by the AGC Components engineering section.

3.3 Design and construction.-

3.3.1 General design features.-

3.3.1.1 Construction.- Simplicity of construction to attain the specified degree of reliability shall be a prime consideration in the manufacture of the PFCA.

3.3.1.2 PFCA housing.- *

3.3.1.3 Rated temperature.- The PFCA shall be capable of operating throughout its service life with a continuous temperature environment of 150° to 200°F. For periods of 5 to 10 hours the PFCA will be required to operate at temperatures between 20°F and 150°F.

3.3.1.4 Heat transfer.- The mechanical design of the PFCA housing shall be such as to transfer the heat load through the mounting base of the housing.

3.3.1.5 Dielectric strength.- The PFCA shall be capable of withstanding a dielectric test voltage of 1000 volts, 400 Hz (rms) applied between all terminals and the PFCA housing for one minute at sea-level pressure.

3.3.1.6 Insulation resistance.- The insulation resistance of the PFCA shall be measured between all mutually isolated terminals at a potential of 500 vdc with a megohm bridge. The resistance shall be at least 100 megohms at a temperature of 150°F.

3.3.2 Selection of specifications and standards.- Specifications and standards not specified herein shall be selected in accordance with MIL-STD-143. Where no applicable specification exists, or if existing control documents are not adequate to provide the degree of control necessary for all special processes and materials, a specification or standard shall be prepared.

3.3.3 Materials, parts and processes.- Parts, materials and processes used in the PFCA shall be selected by the supplier and shall be adequate for the application. In the selection of parts and material, those known to be significantly radiation-sensitive or subject to harmful deterioration in a vacuum shall be avoided. Preference shall be given to parts and materials readily available, particularly to those which have been qualified in accordance with specifications and standards issued by the Department of Defense or industry associations. All parts and materials selected by the supplier shall be subject to review and approval by AGC as to their suitability for use. Approval of any part, material, or process shall not be construed as assurance of acceptance by AGC of any finished PFCA.

* The PFCA housing construction and design criteria will be specified at a later date.

3.3.3.1 Terminals. - The terminals shall be of sufficient size to efficiently and continuously conduct the rated load current without an appreciable temperature rise in the terminals. The terminals shall be permanently and legibly marked in accordance with the assembly drawing.

3.3.3.2 Threads. - Screw threads shall be in accordance with Specification MIL-S-7742.

3.3.3.3 Safety wiring. - Accidental loosening of screw, screw parts, and other connections shall be prevented by safety wiring, staking or other approved methods. Safety wiring shall be in accordance with Standard MS33540.

3.3.3.4 Electrical connections. - *

3.3.3.5 Welding. - All welding shall be performed in accordance with an AGC approved welding specification. The welding operator shall be certified in accordance with MIL-T-5021, Class A. Welds shall be inspected for surface and internal defects. The weld quality level shall be in accordance with AGC-13860, Class 2.

3.3.4 Standard and commercial parts. - Military and industry standard parts shall be used where they suit the purpose and shall be identified on the drawings by their military or industry (NAS etc.) standard part number. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., shall not be used if they are replaceable by standard parts (MS, MIL, JAN, AN) without alteration. In the event there are no suitable corresponding standard parts, commercial parts may be used provided they conform to the requirements of this specification.

3.3.5 Moisture and fungus resistance. - Materials shall be selected for resistance to deterioration due to humidity, water absorption, or the growth of fungus; or shall be coated or treated to prevent deterioration.

3.3.6 Corrosion of metal parts. - Materials shall be of a corrosion-resistant type or suitably processed to resist corrosion. The use of dissimilar metals as defined in Standard MS33586 shall be avoided. Where contact between dissimilar metals is unavoidable, they shall be suitably protected against electrolytic corrosion. The protection shall be of a type that offers a low-impedance path to radio-frequency currents.

3.3.7 Interchangeability and replaceability. - All parts having the same manufacturer's part number shall be directly and completely interchangeable with respect to installation and performance and be adequately serialized to provide for the use of matched or fitted subassemblies. Changes in part numbers shall be governed by the requirements of Specification MIL-D-1000.

3.3.8 Workmanship. - The workmanship shall be of a sufficiently high grade to assure satisfactory operation consistent with the requirements of this specification and AGC-10331. The standards of workmanship exhibited in any approved PPCA, subject to any corrective action stated in the notice of approval, shall define the requirements of workmanship insofar as those not specifically covered by applicable specifications.

* Internal and external electrical connection requirements will be specified at a later date.

3.3.9 Electromagnetic interference.- The PFCA design shall be in accordance with the electromagnetic interference requirements of AGC-10507.

3.3.10 Identification and marking.- Each PFCA shall be permanently identified by a method compatible with the service environment with, as a minimum, the following information as applicable:

- (a) Part name
- (b) Supplier's name or trademark designation. The supplier's name or trademark shall not be in letters larger than any other letters.
- (c) Date of manufacture.
- (d) NASA Contract No. (NAS 5-417).
- (e) Interface connections.
- (f) AGC drawing number, dash number, revision letter, and serial number.

3.4 Documentation requirements.- At the time specified in the contract (see 6.2), the supplier shall submit the documents, data, and material, described in the following subparagraphs. All documents will be subject to review and approval by Aerojet-General Corporation for technical adequacy, completeness, and legibility. The format and method of presentation of these documents may be the supplier's usual practice when such practice is adequate to satisfy the specified requirements.

3.4.1 Engineering documents.- The following documents shall be submitted to and approved by the AGC Components engineering group prior to fabrication of the unit.

- (a) Assembly and detail drawings per MIL-D-1000, Category F, Form 2.
- (b) Design analysis and test data to demonstrate compliance with the design criteria of 3.1.1 and 3.3.1.
- (c) Design analysis of environmental stresses of 3.1.2.8.
- (d) Special manufacturing, processing, and cleaning procedures.
- (e) Quality conformance inspection procedure.
- (f) In-process and quality conformance inspection records.
- (g) Welder qualification records per MIL-T-5021.

3.4.2 Quality Assurance Documents.- The supplier shall submit a Buildup and Assembly log with each unit submitted. As a minimum, these logs shall contain the following data:

- (a) Configuration status and traceability of functionally significant materials and articles to their fabrication lot and purchased material lot.

- (b) Records of Quality Conformance Inspections in accordance with 4.3. The records shall include completed data sheets for each test performed, actual test values observed and evidence of quality control acceptance. Records of In-process Inspections shall be available for review by the Aerojet-General Corporation. As a minimum, the Quality Conformance Inspection data sheets shall contain the following:

- (1) Name of unit.
- (2) Part and serial number of unit tested.
- (3) This specification number, revision letter, and applicable paragraph number.
- (4) Date of completion of inspection.
- (5) Description of each examination and test performed, measuring and test equipment used, and actual values observed.
- (6) Stamp of supplier's inspector.

- (c) List of nonconformances pertaining to the subject assembly.

- (d) Variables data considered essential by AGC which will be specified with the approval of the engineering documents.

3.4.3 Change control. - The supplier shall make no changes in AGC approved drawings, specifications, or processing techniques without written approval of the Aerojet-General Corporation.

4. QUALITY ASSURANCE PROVISIONS

4.1 Supplier's responsibility. -

4.1.1 Quality program provisions. - The supplier shall maintain quality program policies, objectives, and procedures in accordance with the intent of NPC 200-2 to the extent that it is applicable for controlling the design, procurement, fabrication, and testing of the unit. Unless otherwise specified, the supplier shall be responsible for the performance of all inspection requirements specified herein except for the design approval test which will be conducted at AGC.

4.1.2 Classification of inspections. - Inspections to be performed on the units shall be classified as In-process Inspections (see 4.2) Quality Conformance Inspection (see 4.3), and Design Approval tests (see 4.4).

4.2 In-process inspection. - In-process inspection shall include the following as minimum requirement:

- (a) Welds, other than electrical connections, shall be penetrant inspected in accordance with MIL-I-6866, Type II, Method B, and X-rayed in accordance with MIL-STD-453.
- (b) Electrical connections and electrical wiring shall be inspected in accordance with AGC-10331.

4.3 Quality conformance inspection.- The Quality Conformance Inspection program shall be as specified in Part II of this specification and shall include, as a minimum, the following:

- (a) Visual inspection for conformance to the applicable drawings and standards of workmanship.
- (b) Balanced circuits test.
- (c) Rated load test.
- (d) Dielectric strength.
- (e) Insulation resistance.

4.4 Design approval test.- The PFCA design approval test which will be applicable to hardware supplied in accordance with this Specification shall consist of the following:

- (a) Quality Conformance Inspection (see 4.3).
- (b) A test equivalent to 2500 hours of PFCA operation at the performance levels specified in 3.1.1.
- (c) A post-test disassembly and inspection that reveals no indication of impending failure or performance degradation that would prevent the unit from completing its operating life requirements.
- (d) The unit that successfully undergoes design approval testing shall not be delivered for installation in the PCS-G. The unit that is tested should be completely representative of the units that are delivered.

5. PREPARATION FOR DELIVERY

5.1 Preservation, packaging and packing.- The methods of preservation, packaging and packing of the unit shall be determined by the supplier so as to provide physical and mechanical protection and be compatible with the method of transportation selected by the supplier. Damage to a unit due to improper packaging shall be cause for rejection.

5.2 Marking for shipment.- Each shipping container shall be marked with, as a minimum, the following information in letters one-inch high (when deemed possible by the container size):

- (a) Part name
- (b) Specification number and revision letter
- (c) Part number and revision letter
- (d) Serial number
- (e) NASA contract number
- (f) Purchase order number
- (g) Supplier's name

6. NOTES

6.1 Intended use.- The PFCA covered by this specification is intended for use in an electrical-power generation system which may be used in conjunction with space operations.

6.2 Ordering data.- Procurement documents should specify the following:

- (a) Title, number, and revision letter of this specification.
- (b) Dates and delivery instructions for submittal of documentation.
- (c) Serialization instructions.

APPENDIX H

DOW CORNING 340 Silicone Heat Sink Compound

Information about

Electronic Materials

DOW CORNING 340 Silicone Heat Sink Compound

Dow Corning® 340 silicone heat sink compound is a grease-like silicone material, heavily filled with heat-conductive metal oxides. This combination of base and fillers produces a material with higher thermal conductivity than previously available silicone heat sink compounds. The low bleed properties of this improved compound assure lasting protection for heat sink coupling.

Dow Corning 340 silicone heat sink compound is applied to the base and mounting studs of transistors and diodes. This silicone compound will not dry out, harden, or melt even after long term exposure to temperatures up to 200 C. It maintains a positive heat sink seal that improves heat transfer from the device to the heat sink or chassis, thereby increasing overall efficiency of the device.

SPECIFICATIONS

These values are Dow Corning quality control standards.

Consistency

Penetration, worked and measured within one minute

after working (ASTM D 217) 250-320

Bleed, percent maximum after 24 hours at 200 C 0.5

Evaporation, percent maximum after 24 hours at 200 C 1.0

Specific Gravity, minimum 2.3

TYPICAL PROPERTIES

These values are not intended for use in preparing specifications.

Color White, opaque

Consistency

Penetration, worked and measured within one minute

after working (ASTM D 217) 260

Bleed, percent after 24 hours at 200 C 0.0

Evaporation, percent after 24 hours at 200 C 0.5

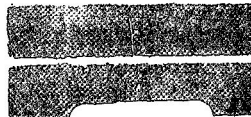
Specific Gravity 2.45

Thermal Conductivity, K Factor, cal. cm² / °C / sec. / cm0010

NOTE: This data sheet obsoletes all previously issued data sheets on Dow Corning 340 silicone heat sink compound.

(Continued on next page)

The information and data contained herein are based on information we believe reliable. You should thoroughly test any application, and independently conduct satisfactory performance before commercialization. Suggestions of tests should not be taken as instructions to achieve any particular result.



QUANTITY 6400

DATE APRIL 1964

ELECTRONIC PRODUCTS DIVISION
DOW CORNING CORPORATION
MIDLAND, MICHIGAN 48666
MATERIALS SECTION

APPENDIX I

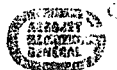
Memo 4942-69-0026

Thermal Analysis of PFCA

Heatsink #1 Thermal Calculations

PFCA Fuse Wire Thermal Calculations

INTEROFFICE MEMO



AXELSON-GENERAL CORPORATION

TO: R. M. Hill

DATE 27 February 1969
4942-59-0025:DEK:el

FROM: D. E. Knittle

Bldg 160 X-6008

SUBJECT: Thermal Analysis of the Power Factor
Correction Assembly for the SNAP-8 System

COPIES TO: WFBanks, SLBradley, RGGeimer, LP Lopez, RWMarshall
WLSnapp (Cleveland)

NASA-LeRC: ERFurman, HGHurrell, AWNice, MJSaari, GMThur

NASA-Hq.: PRMiller (RNP)

NAVPLANTREP/NASA-COR: JDGentry

- Enclosure: (1) Thermal Analysis of the Power Factor Correction Assembly for the SNAP-8 System
(2) Thermal Network Power Factor Correction Assembly for the SNAP-8 System
(3) Thermal Parameters

This memorandum deals with a thermal analysis of the most important portion of the Power Factor Correction Assembly for the SNAP-8 system. The digital computer code TAP was used to predict the steady state temperature distribution through a one-sixth section of one Power Factor Correction Assembly Capacitor during normal operation. The nodal network used in the analysis is given in Enclosure (2) and the values of the thermal parameters used are given in Enclosure (3). This analysis assumed that there is no net heat exchange between capacitor cans, that the system is in a hard space vacuum, and that the capacitor stack is surrounded by five layers of the kapton electrical insulation. In addition, the assembly was assumed to have been mounted on a cold plate (infinite sink) maintained at 150°F.

The steady state temperature distribution predicted in this analysis is presented in Enclosure (1). The highest temperature predicted was 200°F. It can easily be seen from the analysis that the heat generated in the capacitors is carried along by the aluminum wrappings to the copper end strips. The copper end strips carry the heat to the bottom of the can where it is transferred across the kapton layers to the capacitor housing. The heat is then transmitted by the housing to the cold plate.

D. E. Knittle
PCS-G Group
Power Systems Department

Approved:

L. P. Lopez, Head
PCS-G Group
Power Systems Department

QUADRILLE WORK SHEET



AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

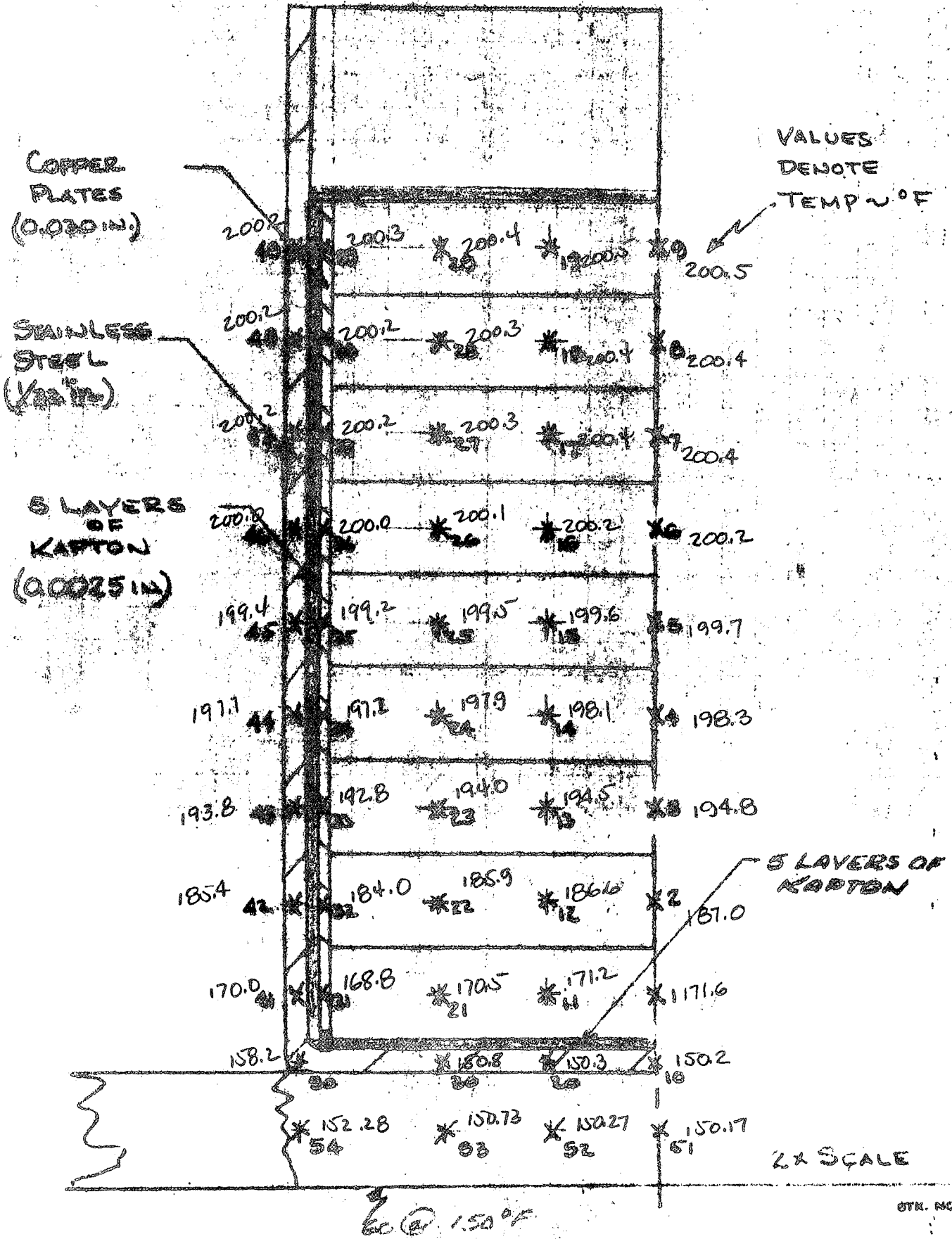
Enclosure (4942-39-002)

PAGE _____ OF _____ PAGES

DATE _____

WORK ORDER _____

THERMAL ANALYSIS OF THE
SUBJECT RF. CORR. ASS'Y - SNAP B BY D KNITTLE





AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

Enclosure (2)
4942-69-0026

QUADRILLE WORK SHEET

THERMAL NETWORK

P.F. CORR. ASSY SNIP B

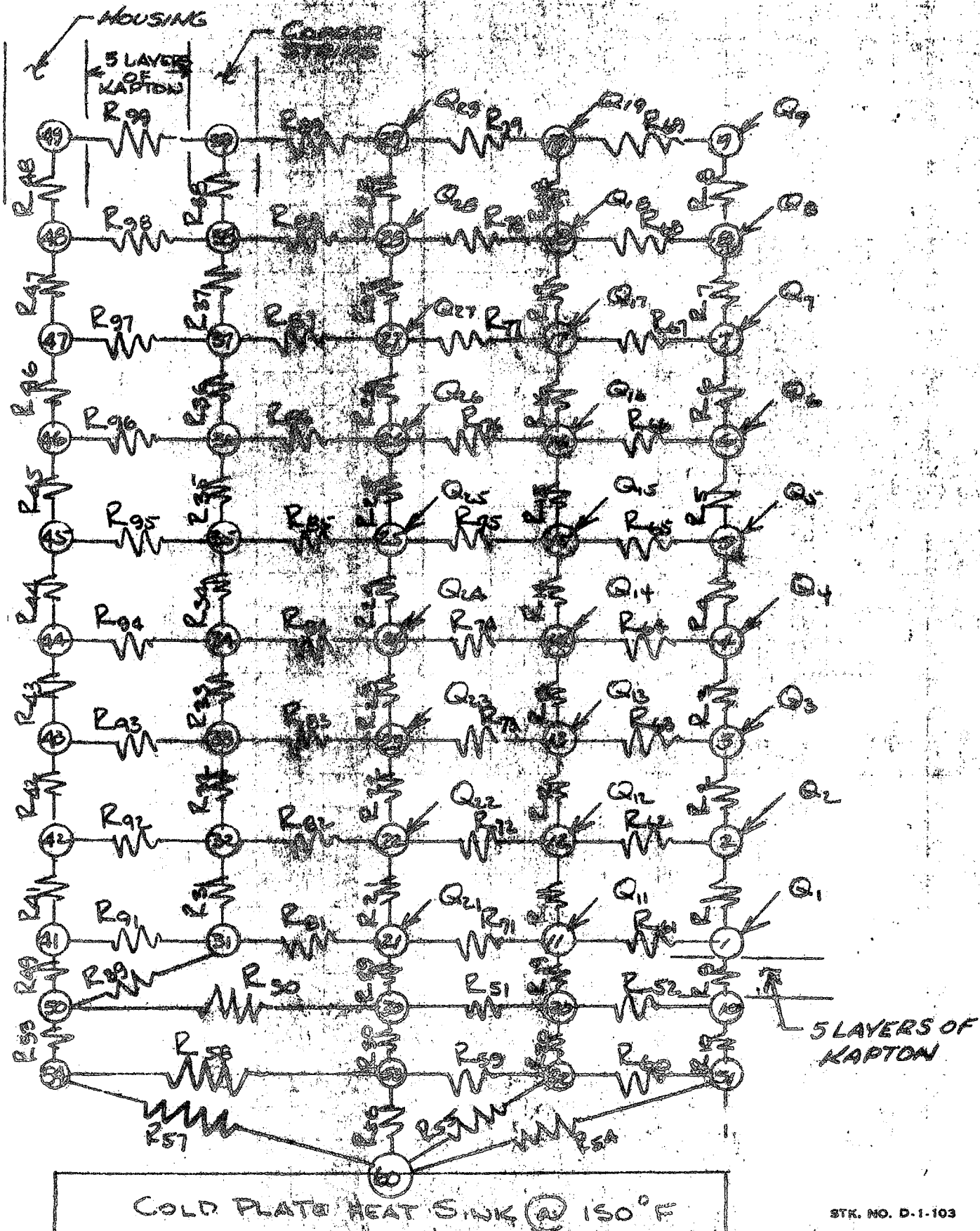
D. KNITTLE

SUBJECT

PAGE _____ OF _____ PAGES

DATE _____

WORK ORDER _____





AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

Enclosure (3)
4942-69-0026

QUADRILLE WORK SHEET

PAGE _____ OF _____ PAGES

DATE _____

SUBJECT THERMAL PARAMETERS

BY QUADRILLE

WORK ORDER _____

THERMAL CONDUCTIVITIES

MAT'L
KAPTON
COPPER
ALUMINUM
STAINLESS STEEL

$K \sim \text{BTU/HR-IN-}^{\circ}\text{F}$
 3.09×10^{-3}
18.1
9.9
2692

HEAT INPUTS

$$Q_1 - Q_2 = 0.059 \text{ BTU/HR.}$$

$$Q_{11} - Q_{12} = 0.118$$

$$Q_{41} - Q_{42} = 0.14$$

RESISTORS

$R_1 - R_2 = 1.40 \text{ HR-}^{\circ}\text{F/STU}$
 $R_9 = 70$
 $R_{10} = 0.23$
 $R_{11} - R_{12} = 70$
 $R_{19} = 35$
 $R_{20} = 0.115$
 $R_{21} - R_{22} = 186$
 $R_{29} = 93$
 $R_{30} = 0.115$
 $R_{31} - R_{32} = 0.86$
 $R_{39} = 0.43$
 $R_{41} - R_{42} = 21.6$
 $R_{49} = 10.8$
 $R_{50} - R_{52} = 24.7$
 $R_{53} = 0.23$
 $R_{54} = 0.15$
 $R_{55} - R_{56} = 0.075$
 $R_{57} = 0.17$
 $R_{58} - R_{60} = 0.123$
 $R_{61} - R_{69} = 0.231$
 $R_{71} - R_{79} = 0.231$
 $R_{81} - R_{89} = 0.377$
 $R_{91} - R_{99} = 1.18$

thermal analysis - heat sink

temp #1

10-temp #1

$$W = 200 \text{ \# / hr}$$

$$t_{in} = 140^\circ \text{F}$$

$$\rho = .207 \text{ \# / \# of}$$

$$\mu = 56 \text{ \# / ft hr}$$

$$K_{140} = .0804 \text{ B / hr of ft}$$

$$\gamma_{140} = 72.1 \text{ \# / ft}^3$$

$$\text{Area of cross-section} = 1.25 \times .25 = .312 \text{ in}^2$$

$$P = 3.00 \text{ in (since only one side of h.s. is used, only use } 1/2 \text{ the perimeter or 1.5 inches)}$$

$$L = 233.1 \text{ in} = 19.425 \text{ ft}$$

$$\text{Area of surface} = 233.1 \times 1.5 = 349.65 \text{ in}^2 = 2.428 \text{ ft}^2$$

$$d_e = \frac{4A}{P} = \frac{4(.312)}{3} = .416 \text{ in} = .035 \text{ ft}$$

$$W = 260W = 887 \text{ B / hr}$$

$$V = \frac{W}{\rho \gamma} = \frac{200(144)}{.207(72.1)} = 1280 \text{ ft}^3 / \text{hr}$$

$$R = \frac{V d_e \gamma}{\mu} = \frac{1280(.035)(72.1)}{56} = 57 \therefore \text{flow is laminar}$$

$$h_c = \frac{2.53K}{d_e} \left[\frac{W C_p}{K L} \right]^{1/4} = \frac{2.53(.0804)}{.035} \left[\frac{200(.207)}{.0804(19.425)} \right]^{1/4} = 5.81(3.4)^{1/4} = 5.81(3.4) = 19.754 \text{ B / hr of ft}^2$$

$$\Delta t_f = \frac{Q}{h_c A_s} = \frac{887}{19.754(2.428)} = 18.5^\circ \text{F}$$

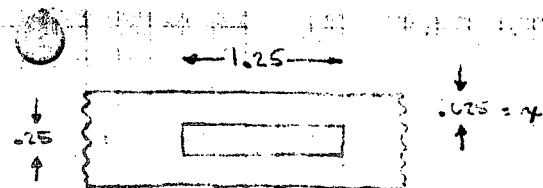
film temp rise

$$\Delta t_{in-out} = \frac{Q}{W C_p} = \frac{887}{200(.207)} = 14.4^\circ \text{F}$$

Liquid temp rise

$$\Delta t_{matl} = \frac{Q L}{K A_s} = \frac{887(.625)}{8(2.428)(12)} = 2.4^\circ \text{F}$$

Rise through SST



$$K_{316 \text{ SST}} = 8 \text{ B / hr of ft}$$

$$t_{outlet} = t_{in} + \Delta t_{in-out} = 140 + 14.4 = 154.4^\circ \text{F}$$

$$t_{\text{heat sink surface}} = t_{in} + \Delta t_f + \Delta t_{matl} + \Delta t_{in-out}/2 = 140 + 18.5 + 2.4 + 7.2 = 168.1^\circ \text{F}$$

$$t_{avg} = (t_{in} + t_{out})/2 = (140 + 154.4)/2 = 147.2^\circ \text{F}$$

Thermal Analysis
Lo Temp #1

7-15-69

Thermal Calculations PFCA Fuse Wire

Copper wire diameter #20AWG 0.03196 inch

Wire resistance #20AWG 0.010 $\frac{\text{ohms}}{\text{ft}}$

Copper thermal conductivity, k 2700 $\frac{\text{BTU in}}{\text{ft}^2 \text{ hr. } ^\circ\text{F}}$

Assume no heat loss except by conduction

Assume total heat generated at center of wire

Assume uniform temperature gradient in wire

Load impedance

$$X_c = \frac{1}{2\pi f C} = \frac{1}{6.28 \times 400 \times 17.5 \times 10^{-6}} = 22.8 \Omega$$

$$Z \cong X_c$$

Fuse Current

$$I = \sqrt{\frac{E}{Z}} = \sqrt{\frac{208}{22.8}} = 15.8 \text{ amperes}$$

Wire Resistance

$$R = \frac{0.010 \times 2}{12} = 0.00167 \text{ ohms}$$

Power dissipated

$$P = I^2 R = (15.8)^2 \times 0.00167 = 0.415 \text{ Watts}$$

$$0.415 \text{ W} \times 0.65692 \frac{\text{BTU}}{\text{min W}} \times 60 \frac{\text{min}}{\text{hr}} = 1.418 \frac{\text{BTU}}{\text{hr.}}$$

Area of wire

$$A = \frac{\pi D^2}{4} = \frac{\pi \times (0.03196)^2}{4} \times \frac{1}{144} = 5.55 \times 10^{-6} \text{ ft}^2$$

Temperature Gradient

$$\Delta T = \frac{P \ell}{A k} = \frac{1.418 \times 1}{2 \times 5.55 \times 10^{-6} \times 2700} = 47.3^\circ \text{F}$$

Assume 180°F ambient temperature

$$180 + 47.3 = 227.3^\circ \text{F Hot spot temp.}$$

Copper melting temperature 1980°F .

Conclusion: Hot spot temperature is well within the safe temperature range for copper wire.

APPENDIX J

Marshall Industries Design Data

EP 35926

CONFIGURATION CONTROL ITEM

CAPACITOR DESIGN SPECIFICATION

MARSHALL INDUSTRIES
CAPACITOR DIVISION



17.5 UF ± 10 %: 215 VAC 400 CPS

P/N

EP35926

A

REV.

AEROJET-GENERAL

CUSTOMER PART/INS. NO.

AGC10563 1265720

PREPARED BY: 5/18/67

A. ENRIQUEZ

CHECKED

5/11/67

OUTLINE/ ASSEMBLY

EP CONSTRUCTION STYLE:

KAPTON CAN

APPROVED: 5/18/67

P. R.

ISSUED

5/11/67

DELIMITATION, DIMENSIONS AND NOTES

SMT. 2

STAMP WITH BLACK EPOXY INK # 408-001-004.
AND COAT ENTIRE STAMP WITH ONE COAT
OF VARNISH PART NO. 849-001-001

REVISION RECORD

LTR	CHANGE	DATE	BY
A	1. 17.5 UF ± 10% 2. 215 VAC, 400 CPS 3. MARSHALL EP35926 Rev () 4. SERIAL NO. () 5. (1265720-1) 6. (CODE) - INK STAMP - *	5-5-67	RE REL

MARKING INFORMATION

CAPACITOR
17.5 UF ± 10 %
215 VAC, 400 CPS
MARSHALL EP35926 Rev ()
SERIAL NO. ()
(1265720-1)
(CODE) - INK STAMP - *

BILL OF MATERIALS

QTY/ CAP	PART NO./ PURCH SPEC (REV.)	DESCRIPTION
27	3W35926	SECTION (MATCH 27 SECTIONS TO 17.5 ± 10%)
1/2	864U013-018	LEADS WIRE #18 N-1 (Per MIL-STD-1276)
1	1173-001-192	CAN
1	1508-002-201	LID
2	1803-001-018	TERMINAL
AIR	160-001-308	TAB, TINNED COPPER
AIR	1449-001-004	INSULATION, KAPTON
AIR	722A005-6XX	SLEEVING
AIR	740-001-002	ALUMINUM WELD SOLDER
AIR	619-001-003	RESIN
AIR	619-002-001	HARDENER
2	1719-001-109	DRIVE SCREW
AIR	821-001-XXX	TAPE MYLAR

MANUFACTURING PROCEDURES

SHOP ORDER TRAVELER NO. SP35926
ASSEMBLY TOP DRAWING NO. 11535926
TEST PROCEDURE NO. PODTEST
LABORATORIES
PROCEDURE 7137

SECTION 8 FINAL TEST SPEC

CAP (MIN): IR(T-T):
CAP (MAX): IR(T-C):
DF (MAX): V(T-T):
V(T-C):

SMT 1 4 3

TESTING

SECTION TEST

CAP (MIN): 15.75 μ F } 27 SECTIONS MATCHED
CAP (MAX): 19.25 μ F }
D.F (MAX): .25% @ 400 CPS, 93°C (.30% @ 1000 CPS, 25°C)
IR (T-T): 11K MEG @ 93°C (APPROX 100K MEG @ 25°C 2 MINUTE TEST @ 500 VDC)
V (T-T): 1200 VDC
DF (MAX): .65% @ 10K, 25°C

SUB ASSEMBLY TEST

COMPLETE PACK
BEFORE ASSEMBLY IN CAN: 1000 VDC

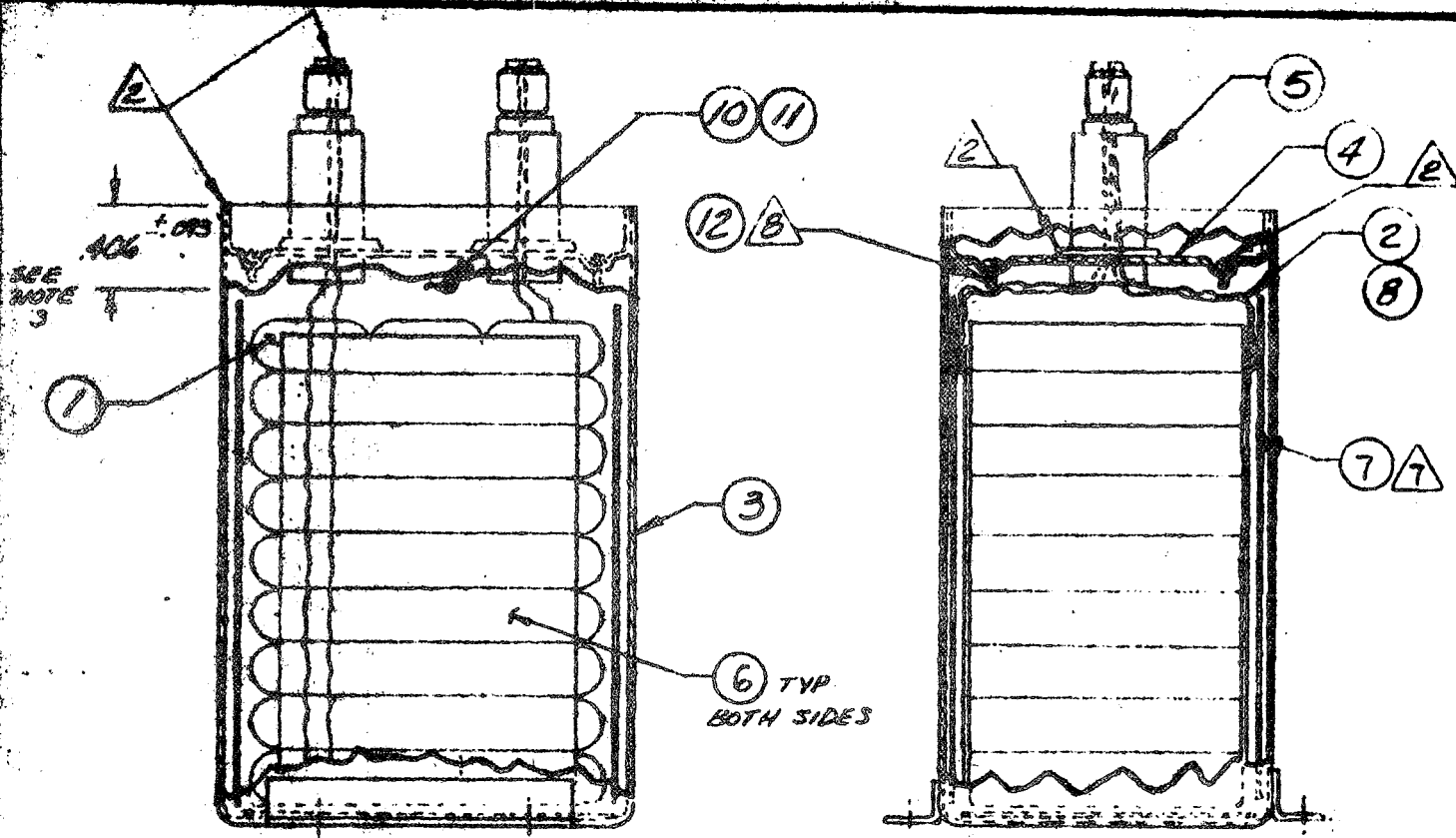
FINAL TEST (PACK IN CAN)

CAP (MIN): 15.750 μ F
CAP (MAX): 19.250 μ F
D.F (MAX): .25% @ 400 CPS, 93°C
*IR (T-T): 400 MEG @ 93°C (2 MINUTE TEST @ 500 VDC)
IR (T-C): 10K MEG
V (T-T): 800 VDC
V (T-C): 2150 VDC

* FOR LONG TERM TEST, IR TO BE 650 MEG MIN @ 93°C

APPROVAL: R.C. ALLEN 11/3/67

REV A	MARSHALL INDUSTRIES CAPACITOR DIVISION		CODE IDENT NO.		
			99515	A	EP35920
SCALE <i>1X</i>			<i>A. ENRIQUEZ</i>	7/19/67	SH 5 OF 3



NOTES: 1) MATERIAL SECTIONS TO 17.5 MS $\pm 10\%$

2) ALL FASTENING AND JOINING TO BE BY WELDING EXCEPT TABS MAY BE SOLDERED TO CAPACITOR SECTIONS. ALL WELDING IS TO BE DONE BY OPERATORS WHO ARE CURRENTLY QUALIFIED TO THE REQUIREMENTS OF MIL-T-5021. WELDED CONNECTIONS TO INCLUDE TERM. TO LID, LEADS TO TERM. LID TO CAN AND SEALING OF FILL HOLES.

3) PREPARE LID FOR VIBRATION USING ITEM 7. BEFORE ASSEMBLING LID TO CAN, FILL CAN WITH FILLING COMPOUND ITEMS 10 AND 11 TO WITHIN .406 $\pm$.093 INCHES OF TOP OF CAN. THEN ASSEMBLE LID SNUGLY AND EVENLY INTO CAN BEFORE CURING EPOXY.

4) SWEDGE BOTH ENDS OF EACH SECTIONS 100%.

5) SOLDER TAB ON EACH SECTION FOR 100% COVERAGE WHEN CONNECTING SECTIONS IN PARALLEL.

6) HIGH FREQUENCY (10K) OF TEST REQUIRED 100% TO ASSURE UNIFORM TAB TO SECTION CONNECTION. (ITEM 12 OF SOT35926)

7) INSULATE CAPACITOR PACK FROM CAN BY USING 3 LAYERS MIN. OF ITEM 7 (3 MILS KAPTON)

8) ASSEMBLE DRIVE SCREWS INTO LID AND WELD FAST BEFORE ASSEMBLING LID TO CAN.

9. AFTER TERMINAL HOUS HAVE BEEN WELDED CLOSED, CAN IS TO BE ALKALINE CLEANED, HCL PICKLED, FOLLOWED BY NITRIC ACID BATH TO REMOVE WELDING RESIDUE. (SUGGESTED SOURCE: SPECIFIC PLATING CO., L.A.)

10) CIRCLES INDICATE ITEMS "CALLED OUT" FROM PAGE 1 OF EP35926.

MARSHALL
INDUSTRIES



CAPACITOR DIVISION

CODE IDENT NO.

99515

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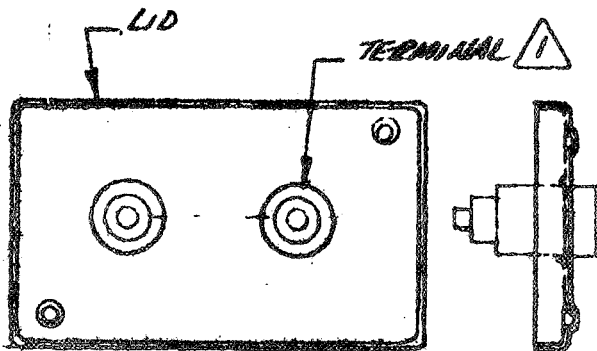
MS35926

SCALE $\frac{1}{4}$

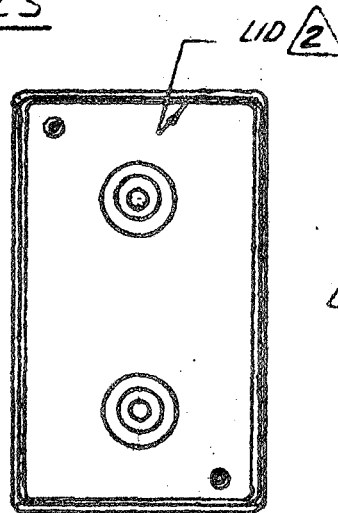
A. ENRIQUEZ 5/19/67

SH 1 OF 2

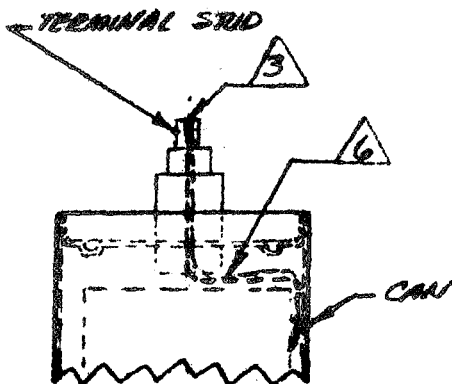
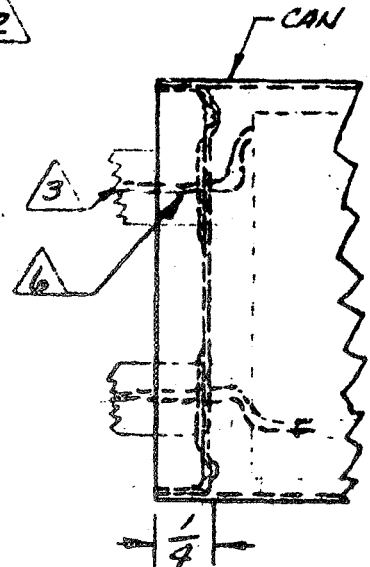
WELDING DETAILS



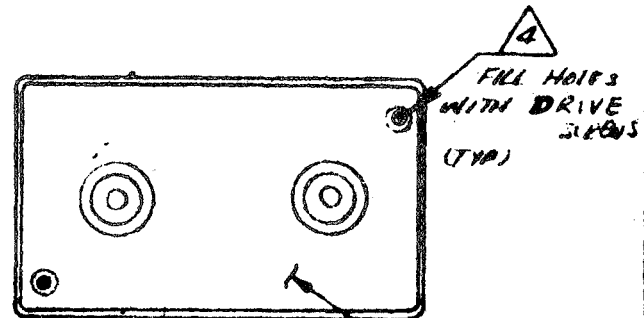
TERMINAL TO LID



LID TO CAN



LEADS TO TERMINALS



FILL HOLE SEALING LID SURFACE

- NOTES:
- 1 WELD (HELIARC) ALL AROUND BY APPLYING HEAT TO STAINLESS STEEL LID RATHER THAN TERMINAL FLANGE.
 - 2 WELD (HELIARC) ALL AROUND. USE CAUTION TO PREVENT EXCESS HEATING OF CAN AT PLACES OTHER THAN AT SEAM. USE HEAT SINK IF NECESSARY. TEMPERATURE SHOULD BE LIMITED TO 130°C ON CAN SURFACE AT ANY POINT BELOW 1/4" FROM THE TOP OF CAN. DO NOT GRIND OR POLISH THE FINISHED WELDED SEAM.
 - 3 WHEN ASSEMBLING LID TO CAN, FEED NICKEL WIRES UP THROUGH TERMINALS. AFTER LID HAS BEEN WELDED TO CAN, WELD NICKEL LEADS TO TERMINAL STUDS. NOTE THAT TWO (2) WIRES GO TO EACH TERMINAL.
 - 4 FILL HOLES ARE SEALED WITH STAINLESS STEEL SCREWS. LID IN PLACE. (2 PLACES) BEFORE ASSEMBLING LID TO CAN.
 - 5) ALL WELDING TO BE DONE ONLY BY AN APPROVED QUALIFIED WELDING OPERATORS MUST BE QUALIFIED TO MIL-1-5071.
 - 6 INSULATE WIRES WITH SLEEVING (ITEM No 8). SLEEVING TO ENTER INTO BARREL OF TERMINAL.

MARSHALL
INDUSTRIES



CAPACITOR DIVISION

CODE IDENT NO.

99515

A

M5359-6

SCALE 1/4"

A. ENRIQUEZ 11/9/67

SH 2 OF 2

APPENDIX K

Memo 4927-69-0016

Stress Analysis for the Power Factor Correction Assembly

SA-E-176

SA-E-177

SA-E-178

SA-E-179

INTEROFFICE MEMO



AERONAUTICAL CORPORATION

TO: S. L. Bradley

DATE 28 April 1969

4927-69-0016:WW:mlg

FROM: W. Weleff

SUBJECT: Stress Analysis for the Power Factor Correction Assembly

COPIES TO: W. F. Banks, R. M. Hill, L. P. Lopez, R. W. Marshall, G. McRoberts

ENCLOSURES: (1) Analysis SA-E-177, File No. SS-1090-02 dated 24 April 1969
(addressee only)
(2) Analysis SA-E-178, File No. SS-1090-02 dated 8 April 1969
(addressee only)

The objective of this analysis was to investigate the structural adequacy of the Power Factor Correction Assembly components. Static as well as dynamic loads were included in this analysis. The requirements contained in the "Environmental Design Criteria and Test Levels for SNAP-8 Components" (AGC Specification 10507-A) were used as a basis for determination of the imposed loads on this assembly. Although the induced loads are affected by the stiffness of the mounting brackets and attachments to the PCS-G structure and the launch vehicle, the induced vibration and shock environment was assumed at the attachment interface of the Power Factor Correction Assembly. The acceleration, vibration and shock loading requirements are contained in Paragraphs 3.4.1, 3.4.2, and 3.4.4 of the above specification and are assumed to be applied simultaneously.

The vibration excitation of the assembly during launch in accordance with the above specification is between 5 and 2000 cycles per second at a peak acceleration of 24 g. The shock load is 20 g's in any direction with a pulse in the form of a half sine wave of 10 milliseconds duration.

The acceleration loads are 6 g's in the axial direction and in the direction of the gravity vector, 3 g's in the opposite direction, and 2 g's in the transverse direction. The effects of the static loads and temperature distribution are insignificant. Analysis was made for the insulator bar, the buss bar and the fuses (Enclosures 1 and 2). The stresses of these members for these loading conditions are well within the yield strength of the corresponding materials. The resultant safety margins are all positive. The assembly is considered structurally adequate to resist the induced loads and release of the drawings for fabrication is accepted.

W. Weleff, Supervisor
Stress and Dynamics Group
M.S.O.

3-20-69

SUMMARY OF ANALYSIS

Project SNAP-8 Component Electrical
Part Power Factor Correction Assy. Drawing No. 1267090
Subject _____
Reference(s) _____
Engineer J. J. Plese App'd W. Weleff

Distribution:

S. L. BradleyR. M. HillFile: SS 1090-02OBJECTIVE:

Evaluate adequacy of the design for static and dynamic loads.

ASSUMPTIONS:

Requirements of SNAP-8 for flight condition. AGC-Specification 10507-A - Environmental design criteria and test levels. SNAP-8 components.

REFERENCES (Analysis Methods):

See last page of analysis.

RESULTS & CONCLUSIONS:

1. Stresses in the centrally located insulator bar are too high due to the combined loads of vibration, shock, and 2g acceleration.
2. Safety factor on end terminal is low.

RECOMMENDATIONS & COMMENTS:

1. Need design change by adding at least one additional insulator bar, and
2. Eliminate high stress concentration areas by increasing radii at sharp corners.

4-24-69

SUMMARY OF ANALYSIS

Project SNAP-8 Electrical

Power Factor Correction Assy. 1267090

S. L. Bradley

R. M. Hill

as of (date)

WW

W. A. Claff

1090-02

Evaluate the structural adequacy of the assembly for static and dynamic loads.

ANALYSIS

Requirements for the SNAP-8 correspond to the AGC specification 10507-A environmental design criteria and test level for SNAP-8 components.

REFERENCES (Analysis Methods):

Dwg. No. 1267013-15; 62-64; 69-74. See also last page of the analysis.

RESULTS AND CONCLUSIONS:

The stresses in the components comprising this assembly are below the yield strength of the corresponding materials. As a result positive margins of safety are obtained for all components of the Power Factor Correction Assembly.

RECOMMENDATIONS - COMMENTS:

Drawings will be released for management technical review and fabrication.



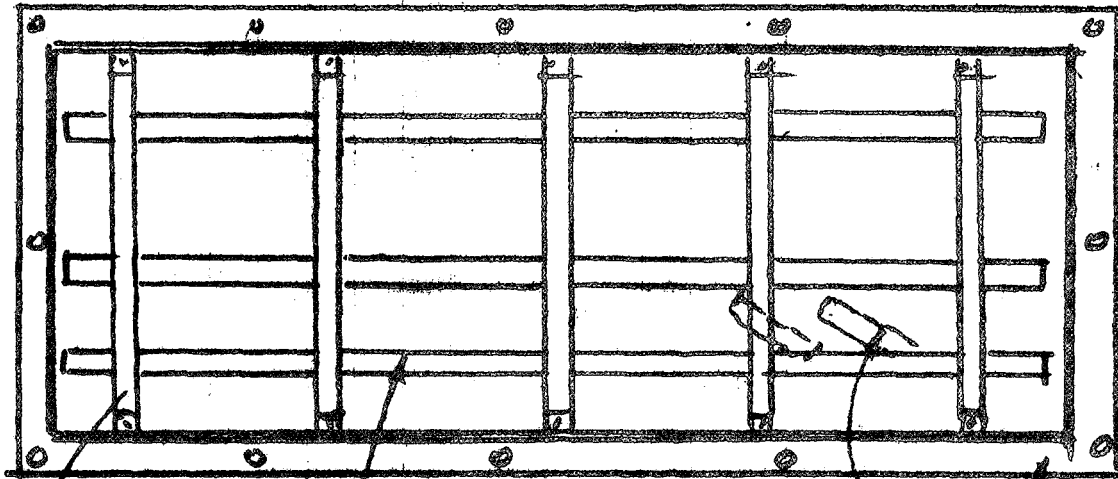
AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

QUADRILLE WORK SHEET

PAGE 1 OF 10 PAGESDATE 3-31-69SUBJECT Power Factor Corr. Ass'y BY W.W.

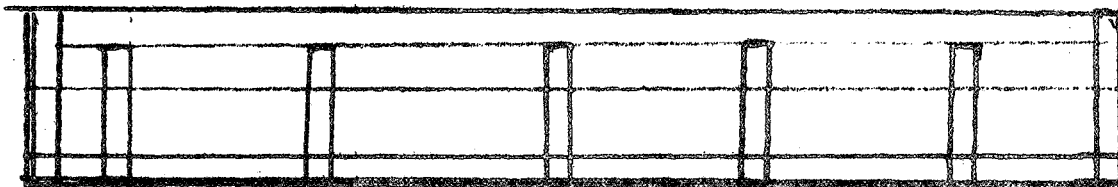
WORK ORDER _____

PLAN



BUS BAR
INSULATOR BAR
FUSE CONTAINER BOX
(10 PSI BUS BAR)

ELEVATION



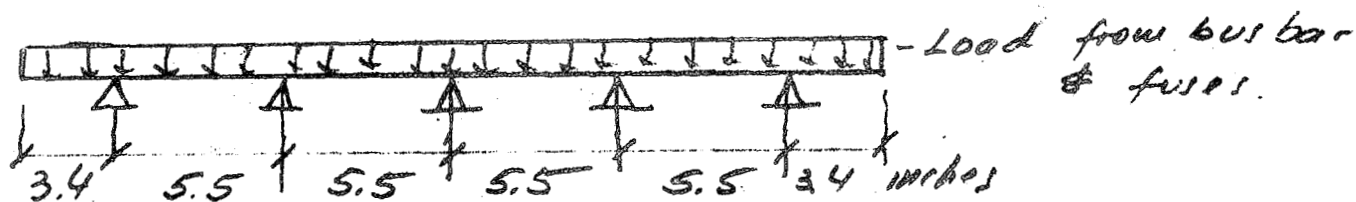
SYSTEM CONFIGURATION

K-5

SUBJECT Power Factor Corred. Assembly. w/wWORK ORDER

A Analysis of the Bus Bar.

a) Geometry



Loads: a) Assumed 10 fuses per bus bar
 $= 10 \times W_1 = 10 \times 0.173 = 1.73 \text{ lbs.}$

$$W_1 = \frac{W_1}{\text{Length of bar}} = \frac{1.73}{28.8} = 0.06 \text{ #/in}$$

W_1 - weight of a fuse: 0.173 lbs.
 obtained by J. Mamola (Dpt. 4936)
 per Drawing No 1267060. See also Drawing
 SA-E-178. (Fiber glass housing with metal
 plugs)

b). Weight of bus bar

$$W_2 = (\text{Volume} \times \text{Density}) = a \times b \times l \times \gamma$$

$$= 0.5 \times 0.5 \times 28.8 \times 0.325 = 2.34 \text{ lbs}$$

$$a = 0.5 \text{ in.}$$

$$b = 0.5 \text{ in.}$$

$$l = 28.8 \text{ inch.}$$

$$\gamma = 0.325 \text{ lb/in}^3 \text{ for copper}$$

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CORPORATION
AZUSA, CALIFORNIAPAGE 3 OF PAGESDATE 4-11-69SUBJECT Power Factor Corr. Factor BY W. WWORK ORDER

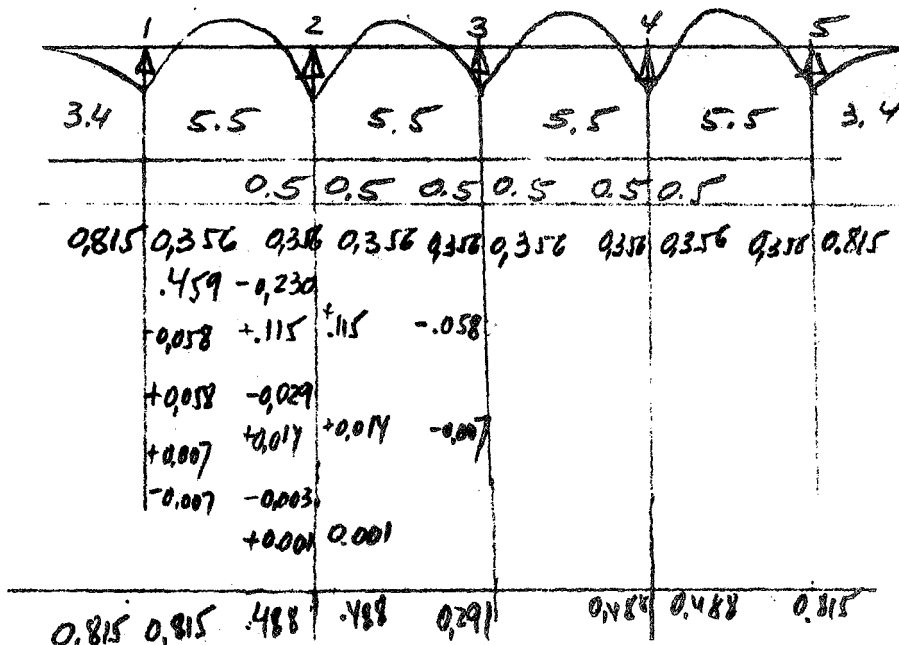
Load per unit length

$$W_2 = \frac{W_2}{L} = \frac{2.34}{28.8} = 0.081 \text{ lbs/in}$$

Total weight per unit length

$$W = W_1 + W_2 = 0.060 + 0.081 = 0.141 \text{ lbs/in}$$

c) Moment diagram:



Fixed End Moment:

a) From cantilever

$$M_1 = \frac{W a^2}{2} = \frac{0.141 \times 3.4^2}{2} = 0.815 \text{ in lbs.}$$

$$M_{21} = M_{12} = M_{23} = M_{32} = M_{34} = M_{43} = M_{45} = M_{54} = \frac{W l^2}{12} = \frac{0.141 \times 5.5^2}{12} = 0.356 \text{ in lbs.}$$

d Deflections:

(1). At the cantilevering end

$$\delta_{(1)} = \frac{W X^3}{8 E I} = \frac{0.141 \times 3.4^3}{8 \times 17 \times 10^6 \times 5.24 \times 10^{-3}} = 7.77 \times 10^{-6} \text{ in}$$

$$E = 17 \times 10^6 \text{ psi}$$

$$I = \frac{b h^3}{12} = \frac{0.5 \times 0.5^3}{12} = 0.00524 \text{ in}^4 = 5.24 \times 10^{-3} \text{ in}^4$$

SUBJECT Power Factor Corr. Factors BY W. W.

(2) Midspan

$$\delta_2 = \frac{5WL^4}{384EI} - \frac{3}{48} \frac{M_L}{EI} - \frac{3}{48} \frac{M_R}{EI} =$$

$$= \frac{5(0.141) 5.5^4}{384 \cdot 17 \times 10^6 \cdot 5.24 \times 10^{-3}} - \frac{3}{48} \frac{(0.488 + 0.291)}{17 \times 10^6 \cdot 5.24 \times 10^{-3}} =$$

$$= 1.89 \times 10^{-5} - 4.6 \times 10^{-5} = -2.71 \times 10^{-5} \text{ in.}$$

e). Natural frequencies

1. For the cantilevering end

$$f_{N1} = \frac{1}{2\pi} \sqrt{\frac{g}{\delta_1}} = \frac{1}{2 \times 3.14} \sqrt{\frac{386}{7.77 \times 10^{-6}}} = \frac{19.7 \times 10^3}{6.28 \times 2.79} =$$

$$= 1125 \text{ cps.}$$

2 For the midspan of the beam

$$f_{N2} = \frac{1}{2\pi} \sqrt{\frac{g}{\delta_2}} = \frac{1}{2 \times 3.14} \sqrt{\frac{386}{2.71 \times 10^{-6}}} = \frac{19.7 \times 10^3}{6.28 \times 1.65} =$$

$$= 1905 \text{ cps.}$$

f. Magnification factors, Assuming 15% damping.

$$\frac{f}{f_{N1}} = \frac{2000}{1125} = 1.78$$

$$\frac{f}{f_{N2}} = \frac{2000}{1905} = 1.05$$

Frequency range from
240 - 2000 cps for 24g.Magnification factor $R = 3.3$

g) Stresses.

For 24g input to the system
Combined load input

~~Aerojet-General~~

QUADRILLE WORK SHEET

CORPORATION
AZUSA, CALIFORNIAPAGE 5 OF _____ PAGES

DATE _____

SUBJECT Power Factor Cor. Factor BY W.W

WORK ORDER _____

Due to vibration	$24 \times 33 = 79.4g$
Due to shock (Ref -)	$20g = 20.0g$
Lateral acceleration	$2g = 2.0g$
Total	$\frac{79.4}{+} \frac{20.0}{+} \frac{2.0}{+} = 101.4g$

Moment at cantilevering end:

$$M_E = 0.815 \times 101.4 = 82.5 \text{ in-lbs.}$$

$$f_b = \frac{82.5 \times 6}{0.5 \times 0.5^2} = 3960 \text{ psi.} < 32000 \text{ psi.}$$

$$f_s = \frac{\text{Shear load at support}}{\text{Area}} = \frac{0.141 \times 3.4 \times 101.4}{0.5 \times 0.5}$$

$$= 195 \text{ psi} < 17600 \text{ psi.}$$

Allowable materials properties

Copper per QQ-C-502 spec, hard + temper

$$F_{TU} = 40000 \text{ psi. Ultimate Tensile Strength}$$

$$F_{TY} = 0.80 \times F_{TU} = 32000 \text{ psi. (Assumed) Yield,}$$

$$F_S = 0.55 F_{TY} = 17600 \text{ psi. (Assumed) Shear -}$$

For safety factors see page 9.

QUADRILLE WORK SHEET

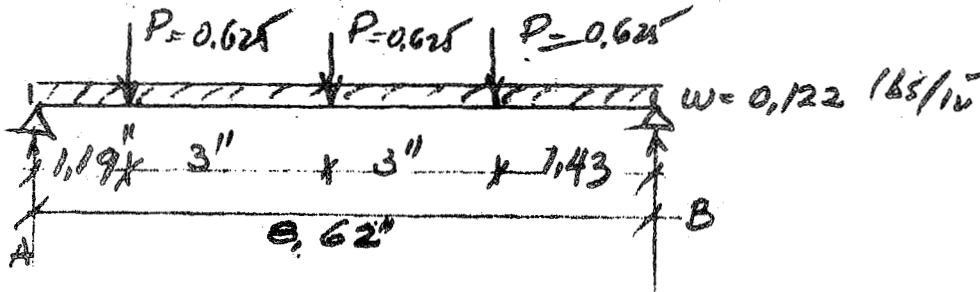
CORPORATION
AZUSA, CALIFORNIAPAGE 6 OF _____ PAGES

DATE _____

WORK ORDER _____

SUBJECT Power Factor Cond Assembly BY U.WB. Insulator Bar.

Five bars spaced 5.5 inches apart

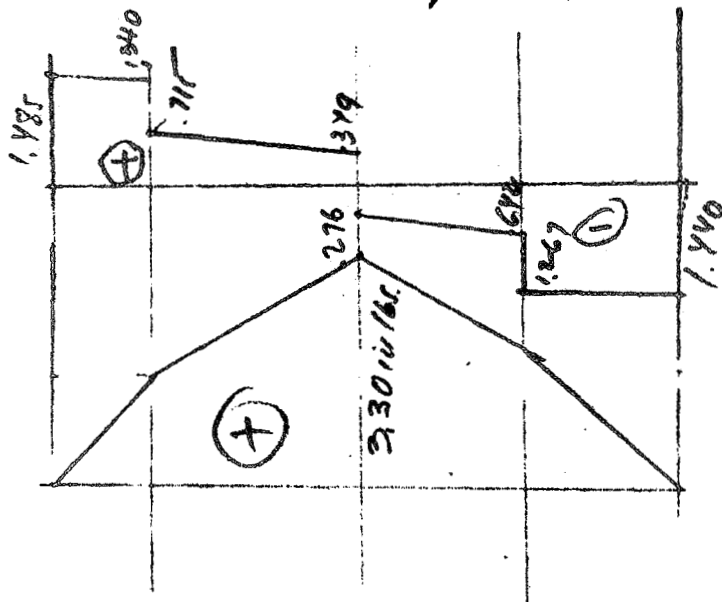


a) Loads: Concentrated load and reactions from the Bus Bar.

$$P = 0.141 \times (3.4 + \frac{5.5}{2}) = 0.625 \text{ lbs.}$$

w - Weight of insulator bar. 0.5, 0.75 Doril glas laminate H-17511

$$W = 0.5 \times 0.75 \times 0.325 = 0.122 \text{ lbs/in}$$



Reactions

$$A = 0.122 \times \frac{8.62}{2} + \frac{0.625(1.43 + 4.43 + 7.43)}{8.62}$$

$$= 0.525 + 0.96 = 1.485 \text{ lbs.}$$

$$B = 0.525 + (3 \times 0.625 - 0.96)$$

$$= 0.525 + 0.915 = 1.440 \text{ lbs.}$$

$$\text{max } M = 1.485 \times 4.19 - 0.625 \times 3 - 0.122 \times \frac{4.19^2}{2}$$

$$= 6.25 - 1.88 - 1.07 = 3.30 \text{ lb-in}$$

b). Moment and shear diagrams.

QUADRILLE WORK SHEET

CORPORATION
AZUSA, CALIFORNIAPAGE 7 OF PAGESDATE SUBJECT Power Factor Corr. An'y BY W.W.WORK ORDER

c). Deflection

$$\delta = \delta_1 + \delta_2 + \delta_3 + \delta_4$$

 δ_1 - deflection at midspan due to uniform load δ_2 - " " due to $P_1 = 0.625$ lbs δ_3 - " " $P_2 = 0.625$ lbs δ_4 - " " $P_3 = 0.625$ lbs.

$$\delta_1 = \frac{5 w l^4}{384 EI} = \frac{5 \cdot 0.122 \cdot (8.62)^4}{384 \times 2.2 \times 10^6 \times 1.76 \times 10^{-2}} = 2.29 \times 10^{-4} \text{ in}$$

$$E = 2.2 \times 10^6 \text{ psi.}$$

cross plys.  0.75 Glas laminate
Nemo G-10

$$I = \frac{b h^3}{12} = \frac{0.5 \times 0.75^3}{12} = 1.76 \times 10^{-2}$$

$$\delta_2 = \frac{P a_1}{12 EI} \left(2 l b_1 - b_1^2 - \frac{l^2}{4} \right) = \frac{0.625 \cdot 1.19}{12 \times 2.2 \times 10^6 \times 1.76 \times 10^{-2}} \left(2 \cdot 8.62 \cdot 7.43 - 7.43^2 - 4.31^2 \right) = \frac{0.744 (118.0 - 55.1 - 18.6)}{46.4 \times 10^4} = 7.1 \times 10^{-5} \text{ in}$$

$$\delta_3 = \frac{P a_2}{12 EI} \left(2 l b_2 - b_2^2 - \frac{l^2}{4} \right) = \frac{0.625 \cdot 4.19}{12 \times 2.2 \times 10^6 \times 1.76 \times 10^{-2}} \left(2 \cdot 8.62 \cdot 4.43 - 4.43^2 - 4.31^2 \right) = \frac{2.62 (79.7 - 19.6 - 18.6)}{46.4 \times 10^4} = 2.18 \times 10^{-4} \text{ in}$$

$$\delta_4 = \frac{P b_3}{12 EI} \left(l^2 - b^2 - \frac{l^2}{4} \right) = \frac{0.625 \cdot 1.43 (8.62^2 - 1.43^2 - 4.31^2)}{12 \times 2.2 \times 10^6 \times 1.76 \times 10^{-2}} = \frac{0.894 (74.4 - 2.04 - 18.6)}{46.4 \times 10^4} = 1.03 \times 10^{-4} \text{ in}$$

$$\delta = \sum \delta = 2.29 \times 10^{-4} + 0.71 \times 10^{-5} + 2.18 \times 10^{-4} + 1.03 \times 10^{-4} = 6.21 \times 10^{-4} \text{ in}$$

SUBJECT Power Factor Cor. An'ly BY W.W.

d) Natural frequency

$$f_N = \frac{1}{2\pi} \sqrt{\frac{g}{\delta}} = \frac{1}{2 \times 3.14} \sqrt{\frac{386}{6.21 \times 10^{-4}}} = \frac{19.7 \times 10^2}{6.28 \times 2.5} = 125.8 \text{ cps.}$$

e) Magnification factor 15% damping.

$$\frac{f}{f_N} = \frac{2000}{125.8} = 14.8 \quad \text{for } \frac{f}{f_N} = 1.0$$

$$R = 3.30$$

f). Stresses.

For 24g input to the system (see spec)	
Combined load input	$24 \times 3.3 = 79.2g$
Shock load	$20g = 20.0g$
Lateral acceleration	$2g = 2.0g$
total	$\frac{79.2g}{+} \frac{20.0g}{+} \frac{2.0g}{+} = 101.4g$

$$\text{max } M = 101.4 \times 3.30 = 333 \text{ in. lbs}$$

$$f_b = \frac{333 \times 6}{0.5 \times 0.75^2} = \frac{1996}{0.281} \geq 7100 \text{ psi} < 40000 \text{ psi.}$$

g). Materials properties (Catalog Syntone Corp)

Tensile Strength $F_t = 40000 \text{ psi.}$ Flexural Strength $F_b = 50000 \text{ psi. Long.}$
40000 psi. Cross ply.Compressive Strength $F_c = 60000 \text{ psi. Long.}$
35000 psi. Cross.Modulus of Elasticity $E = 2.7 \times 10^6 \text{ psi. Long.}$

SUBJECT Power Factor Cor. Assy. w.w BY w.wModulus of Elasticity $E = 2.2 \times 10^6 \text{ psi. cross p's.}$

h/. Fatigue

$$\begin{aligned} \text{Maximum cycles} &= 2000 \times 60 \times 5 \text{ minutes} \\ &= 600000 \text{ cycles} \end{aligned}$$

Assume fatigue strength = 50% of tensile
for 10^6 cycles
 $= 20000 \text{ psi.} > 7100 \text{ psi.}$

C. Safety factors:

1) Buss bar

$$\begin{aligned} F.S. &= \frac{\text{Allowable}}{\text{fcalc} \times \text{correction factor}} = \frac{32000 \times 0.80}{3960 \times 1.5} \\ &= 4.3 \end{aligned}$$

2) Insulator bar

$$F.S. = \frac{40000 \times 0.8}{7100 \times 1.5} = 3.01$$

~~Aerojet-General~~

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DATE _____

SUBJECT Power Core Factor BY W.W.

WORK ORDER _____

References:

1. Structural design criteria SNAP-8
AGC-10650.
2. Environmental design criteria and
test levels - SNAP-8, AGC-10507-A.
3. Mechanical Vibrations. W.T. Thompson
4. Formulas for stress and strain.
Roark, R.L.

8 April 1969

SUMMARY OF ANALYSIS

Project SNAP-8 Department Electrical
 Power Factor Cor. Assy. 1267061
 Fuse Housing DCN-1
 J. Mamola

S. L. Bradley

R. M. Hill

W. Welleff

W. Welleff

1090-03

Check adequacy of the new fuse housing design.

Epoxy laminates (replacing ceramic housing)

RE ANALYSIS (Analysis Methods):

See attachment. Materials properties supplied by Mamola.

CONCLUSIONS:

Fuse housing is satisfactory to resist the imposed dynamic load requirements specified in AGC-10507-A.

RE REVISIONS AND COMMENTS:

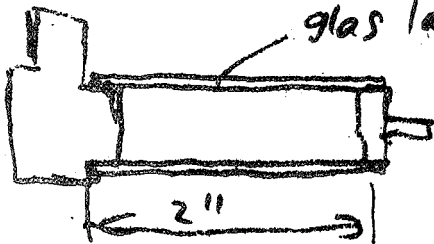
Sign off the drawing.

Aerojet-General

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AZUSA, CALIFORNIAPAGE 1 OF 1 PAGESDATE 4-8-69SUBJECT Fuel HousingBY W.W.

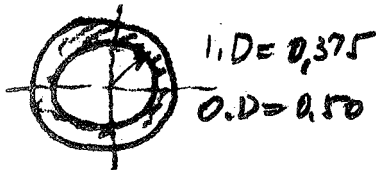
WORK ORDER _____

Material changed from ceramic to epoxy
glas laminates. Grade G-10 (Syntane Corp)Weight $W = 0.173 \text{ lbs}$

Assume 100 g.

$$P = 0.173 \times 100 = 17.3 \text{ lbs}$$

$$\text{Moment} = 17.3 \times \frac{2.0}{2.0} = 17.3 \text{ in lbs}$$



$$S = \frac{\pi (d_1^4 - d_2^4)}{32 d_1} = \frac{3.14 (0.5^4 - 0.375^4)}{32 \times 0.5} = 0.0084 \text{ in}^3$$

$$\sigma = \frac{M}{S} = \frac{17.3}{0.0084} = 2060 \text{ psi} < 50000 \text{ psi}$$

Materials properties.

Tensile Strength = 40000 psi Longit.
35000 Cross pl.

Flexural Strength 50000 Long.
40000 Cross pl.

Compressive Strength 60000 Long.
35000 Cross.

Modulus of Elasticity 2.7×10^6 Long.
 2.2×10^6 Cross.

Reference. Catalog: SYNTANE Corp.

Technical Plastics

Local office 518-W- Garfield Ave Glendale
Tel. 213- Chapman-51093.

Dept. 4927

ANALYSIS NO. SA- E-179

DATE 5-20-69

SUMMARY OF ANALYSIS

Project SNAP-8 Component Electrical

Part Power Factor Correction Assy. Drawing No. 1267061

Subject Fuse-Element

Reference(s) J. Mamola

Engineer O. Cano

Approved

W. W. Claff

Distribution:

S. L. Bradley

R. M. Hill

File: SS 1090-03

OBJECTIVE:

Check structural integrity of fuse element.

ASSUMPTIONS:

Wire diameter $\approx .125"$

Material allowances > 700 psi tension

$f_n < 100$ cps

REFERENCES (Analysis Methods):

RESULTS AND CONCLUSIONS:

Element is satisfactory.

RECOMMENDATIONS AND COMMENTS:

None - sign off drawing.



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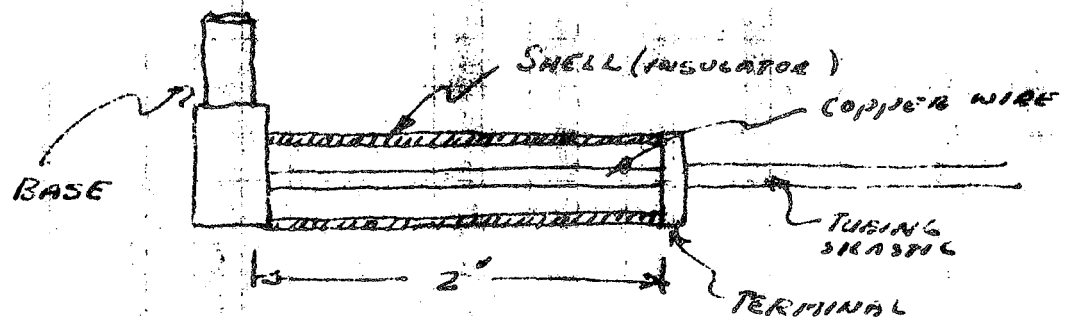
DATE 17 May 67

SUBJECT FUSE - POWER FACTOR CORRECTION ASSEMBLY BY O.A. LAND

WORK ORDER _____

DWG No. 1267060

CRITERIA:



DIMENSIONS:

BETWEEN SUPPORTS = 2"

ASSEMBLY HELD @ BASE AS CANTILEVER

WIRE HELD @ ENDS -

ENVIRONMENTAL:

VIBRATION: 20 - 2000 cps (G^2/cps levels per AGC10563)

SHOCK: 20g - $\frac{1}{2}$ cycle sine - 10 milliseconds duration

ANALYSES:

COPPER WIRE IS INSTALLED WITHIN THE INSULATOR ENCLOSURE UNDER NOMINAL TENSION. VIBRATORY RESPONSE IS PRIMARILY IN THE FORM OF A MULTIDEGREE OF FREEDOM BEAM OR LIGHT WIRE WHICH ESSENTIALLY RESISTS DEFORMATION IN THE FORM OF A TENSION LOAD ALONG THE WIRE.



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AZUSA, CALIFORNIA

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SUBJECT _____ BY _____ WORK ORDER _____

SINCE MAXIMUM ENERGY RESULTS DURING THE PRIMARY MODES, ASSUMED RESPONSES AT THE FUNDAMENTAL FREQUENCY CAN BE CONSIDERED CONSERVATIVE IF A HIGHER FREQUENCY IS SELECTED:

$$\ddot{x} = \sqrt{f g^2} = \sqrt{100 (.69)}$$

$$g = 8 \text{ g's (response)}$$

$$\text{WEIGHT OF WIRE} \approx \frac{\pi (.125)^2 (.3)(2)}{2} = .006 \text{ \#}$$

$$A_{\text{SECTION}} \approx .01 \text{ in}^2$$

T = APPROXIMATION OF TENSILE LOAD ASSUMING WIRE DEFLECTS A MAXIMUM DEFLECTION ALLOWED WITHIN THE SHELL OF .1"

$$T = \frac{(.3)(2)}{2(.1)} = 3 \text{ \#} = \text{TENSION DEVELOPED IN WIRE}$$

$$\sigma_T = \frac{3}{.01} = 600 \text{ PSI STRESS NO PROBLEM}$$

APPENDIX L

Memo 4936-69-0024

Leading Power Factor Test
on System Operating in ECTF

Hill

INTEROFFICE MEMO



AEROJET-GENERAL CORPORATION

TO: W. F. Banks

DATE 10 March 1969
4936-69-0024:SLB:vc

FROM: S. L. Bradley

Bldg. 160A - 5736

SUBJECT: Leading Power Factor Test on System Operating in ECIF

COPIES TO: BL Amstadter, B Breindel, EG Brittain, FN Collamore, RM Hill,
LP Lopez, RW Marshall, CG Neitsch, JR Pope, NE Waldschmidt
NASA, LeRC: Mr. A. W. Nice

Enclosure: (1) Leading Power Factor Load Test

A leading power factor load test has been conducted on the SNAP-8 alternator and regulator system in the Electrical Component Test Facility. The power factor was changed from .90 lag to .90 lead at a steady real load of 60 kilowatts.

The maximum average-of-three-phases voltage change was 1.3 volts or approximately 1%. This result demonstrates that the Voltage Regulator-Exciter is well compensated and will probably operate satisfactorily at leading power factor loads of .85 or lower.

The leading power factor load was limited by the capacitor assembly available, so it was not possible to test at a power factor beyond .90 at this time. At some future time when a larger capacitor load is available another point or two beyond .90 lead will be taken.

S L Bradley

S. L. Bradley
Electrical Components Group
Power Systems Department

SPS-
Section I
Sheet 1

L-3

APPENDIX M

Design Review Checklist

Failure Modes and Effects Analysis

PSD DESIGN REVIEW CHECK LIST

Page 2 of 12

SUBJECT NAME: <u>Power Factor Correction Assembly</u>		YES	NO	N/A	REFERENCE DOCUMENT
<u>P/N</u>					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>General</u>				
1.	Is the basic design objective clearly defined?	X			AGC-10603
2.	Are the performance parameters and output requirements definitive and not subject to misinterpretation?	X			AGC-10603
3.	Are performance tolerances delineated?	X			AGC-10603 AGC-10563
4.	Are failure criteria delineated?	X			AGC-10603 AGC-10563
5.	Were alternate designs considered in selecting the present design?	X			MTR Feb 1969
6.	Were redundancy needs analyzed and results used in the design?	X			4925:67:0161
7.	Were simplification techniques applied?	X			Change in circuit 1267015 rather than double fuses Page M-14
8.	Was a failure modes and effects analysis made?	X			
9.	Have adequate safety margins been incorporated for each important failure mode?	X			75 amp fuses 10 parallel capacitors
10.	If item has a limited life, is it so designated?			X	
11.	Have maintainability requirements been considered?	X			AGC-10603
12.	Have previous test data and failure reports been reviewed and results used in the design?	X			ECTF Test Data FR 1191, FR 1279
13.	Is the method of component identification specified? (The method of marking and location must be compatible with use-environment.)	X			AGC 10563 1267090
14.	If documentation of inspection findings is required, are the characteristics to be observed and their frequency and method of inspection defined?	X			AGC-10603 AGC-10563 AGC-STD-1338
15.	If operational or functional acceptance testing is required, are the parameters, mode of testing, and equipment defined?	X			AGC-STD-1338 AGC-10603

PSD DESIGN REVIEW CHECK LIST

Page 3 of 12

SUBJECT NAME: Power Factor Correction Assembly

YES NO N/A REFERENCE DOCUMENT

P/NDESIGN ENGINEER: DATEItem No.General

- | | | | | | |
|-----|---|---|--|---|--|
| 16. | Are required special inspection equipments, tools, and gages defined? | | | X | |
| 17. | Has a procurement plan for this material been established? | X | | | OP119653 Pre-release of other material |
| 18. | Have qualified and preferred parts been used where applicable? | X | | | 1267090 MS, NAS, AI Std parts |
| 19. | Is the design notebook and file up to date and ready for audit? | X | | | TM 4936:69- 568 Preliminary |
| 20. | Have provisions been made for preservation, packaging, handling, storage, and shipping? | X | | | AGC-10603 |
| 21. | Were trade-off studies made and utilized in selecting the design? | X | | | TM 4936-66-410 |
| 22. | Does the design minimize the probability of human errors during installation, checkout, and operation, such as reversed connections, parts installed backward, no lubrication during startup, etc.? | X | | | 1267090 |
| 23. | Does the design make appropriate use of "fail-safe" devices or techniques? | X | | | 4925:67:0161 |
| 24. | Does the design comply with all applicable specifications? | X | | | AGC-10603
AGC-10563 |
| 25. | Were the action items from the previous Design Review carried out? | X | | | 4901:69-1038 |
| 26. | Is the design compatible with the requirements of the end item? | X | | | AGC-10603 |

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4925:66:107

PSD DESIGN REVIEW CHECK LIST

Page 4 of 12

SUBJECT NAME: <u>Power Factor Correction Assembly</u>		YES	NO	N/A	REFERENCE DOCUMENTS
<u>P/N</u>					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Mechanical</u>				
1.	Has a stress analysis been made?	X			SA-E- 177
2.	Have areas of high stress concentrations such as sharp corners, radii, and re-entrant angles been eliminated?	X			SA-E-176
3.	Has a thermal analysis been made?	X			4942-69-0026
4.	Is thermal expansion likely to have adverse effects on dimensions and tolerances?		X		
5.	Has a tolerance analysis been made to verify proper fitting of parts under extremes of tolerance buildup?	X			AGC-10603 Matched Cap.
6.	Did the tolerance analysis consider operating loads and temperatures?	X			Floating inserts for mounting
7.	Were static, dynamic and magnetic balances and their tolerances considered?			X	
8.	Has a wearout analysis for all rubbing and rolling parts been made?			X	
9.	Have the installation torques and tolerances of all fasteners and their stress effects been evaluated?	X			1267090
10.	Is the inspectability of the component assured? (Are the true positioning and contour requirements designed to enable inspection of part?)	X			1267090
11.	Has the mechanical compatibility with the complete system been verified?	X			1266950
12.	Does mechanical design reflect simplest method, from manufacturing view, to meet needed parameters?	X			1267090
13.	Were environmental effects (including those of nuclear radiation) considered along with safety requirements during design?	X			AGC-10603 AGC-10507

PSD DESIGN REVIEW CHECK LIST

Page 5 of 12

SUBJECT NAME: <u>Power Factor Correction Assembly</u>		YES	NO	N/A	REFERENCE DOCUMENT
<u>P/N</u>					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Electrical</u>				
1.	Are the design essentials adequately defined, including performance, longevity, and repetitive operation requirements?	X			AGC-10603 AGC-10563
2.	Is the design compatible with the life cycle conditions to which the equipment will be exposed?	X			AGC-10603
3.	Have the stability and drift requirements and the effects of environments on these characteristics been considered?	X			AGC-10603 AGC-10563
4.	Was a simplification study made and applied?	X			1267015
5.	Is redundancy employed where beneficial; are possible side effects taken into consideration?	X			4925:67-0161
6.	Were reliability characteristics considered and documented in parts and materials selection?	X			4925:67-0161
7.	Are the part tolerances consistent with design requirements?	X			AGC-10563 1267090
8.	Was adequate derating employed, including sufficient margin for transients and other excessive stresses?	X			AGC-10563
9.	Can the parts operation result in undesirable conditions of temperature, voltage, current, or RFI for other parts or assemblies? If so, was this info used in the design?			X	4936:69:0024 Preliminary EMI Tests
10.	Are the dielectric breakdown and insulation resistance properties adequate for the most severe environments?	X			AGC-10563 AGC-STD-1338
11.	Is hermetic sealing employed where beneficial?	X			AGC-10563
12.	Are type of connections employed reliable?	X			AGC-10331

PSD DESIGN REVIEW CHECK LIST

Page 6 of 12

SUBJECT NAME: <u>Power Factor Correction Assembly</u>		YES	NO	N/A	REFERENCE DOCUMENTS
<u>P/N</u>					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Electrical</u>				
13.	Have all applicable specifications been called out?	X			AGC-10603 AGC-10563
14.	Have the preferred parts lists (JPL Specification No. 20061C and CSFC-PPL-1) been used?			X	
15.	Has expected hot spot temperatures been determined and considered?	X			4942-69-0026
16.	Has effect of component operation on primary power wave form been considered?	X			Will tend to improve it.
17.	Has nuclear radiation environment effects been considered?	X			AGC-10563 AGC-10507
NOTE: The following electrical characteristics should be considered: inductance, capacitance, resistance, sensitivity, leakage, insulation, shielding; distortion, gain, phase, attenuation; slope, harmonics, eddy currents; time, spikes, peaks, contact resistance, contact rating, torque, wire size					

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SUBJECT NAME: <u>Power Factor Correction Assembly</u>		YES	NO	N/A	REFERENCE DOCUMENT
<u>P/N</u>					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Materials</u>				
1.	Are all materials adequately identified by MIL, Fed, AGC, or comparable specifications?*	X			1267090 AGC-10563 AGC-10603
2.	Is the source of supply specified for qualified/preferred materials?	X			1265720
3.	Are the strength characteristics of the materials including tensile, compressive, shear, yield, bending, creep, and fatigue satisfactory for intended use?	X			Stress Analysis SA-E-177
4.	Is each material employed within limits defined by its endurance limit curve?	X			Stress Analysis SA-E-177
5.	Have adequate safety margins been used to provide protection from failure due to corrosion, vibration, shock, fatigue, and other stress factors?	X			Stress Analysis SA-E-177
6.	Are the hardness, ductility, and other characteristics suitable for both the manufacturing processes and application?	X			
7.	Will the material characteristics be significantly changed by exposure to environments, particularly radiation?		X		4936-67-0148 Appendix B
8.	Are the special inspection and test processes compatible with the parts and materials?	X			AGC-STD-1338
9.	Are the thermal expansion characteristics suitable for the intended use?	X			4942:69:0026 Thermal Analysis
10.	Will the materials be compatible with mating parts, fluids, and gases and not act as catalytic agents?	X			
11.	Does each material have suitable electrical and magnetic properties for its application?	X			AGC-10563 AGC-10603
* The order of precedence for specifications must meet MIL-STD-143 requirements.					

4925:66:107
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PSD DESIGN REVIEW CHECK LIST

Page 8 of 12

SUBJECT NAME: <u>Power Factor Correction Assembly</u>		YES	NO	N/A	REFERENCE DOCUMENTS
<u>P/N</u>					
DESIGN ENGINEER: <u> </u> DATE <u> </u>					
<u>Item No.</u>	<u>Materials</u>				
12.	Have adequate metallurgical controls been imposed to assure that each material conforms to its specification?	X			AGC-10563 AGC-10603
13.	Are all tolerances specified and are they compatible with the materials and required manufacturing methods?	X			1267090
14.	If mechanical, metallurgical, and/or chemical testing is required, are the necessary samples, coupons, or test bars defined, and test methods established?			X	

PSD DESIGN REVIEW CHECK LIST

Page 9 of 12

SUBJECT NAME: <u>Power Factor Correction Assembly</u>		YES	NO	N/A	REFERENCE DOCUMENTS
<u>P/N</u>					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Manufacturing Processes</u>				
1.	Are the specified fabrication methods suited to the design and materials?	X			1267090
2.	Are the process capabilities consistent with component requirements?	X			1267090
3.	Is heat treating, stress relief, nitriting, flame hardening, or other special process required?		X		
4.	Will processing and assembly affect the dimensions?		X		
5.	Are process specifications and tolerances designated?	X			1267090
6.	Are requirements after processing and assembly specified?	X			AGC-10603
7.	Have joining methods (welding, brazing, soldering, fastening) been selected to minimize effect on tolerances and part variations?	X			1267090 AGC-10603
8.	Are special inspection and test processes such as radiograph, helium leak test, and penetrant dye check required?	X			AGC-10563
9.	If so, are acceptance criteria specified?	X			AGC-10563
10.	Has the most suitable cleaning method been specified?	X			AGC-10603
11.	Is a protective coating required?	X			1267090
12.	If so, will protective coating affect mating parts?		X		
13.	Are special assembly requirements such as sligment, torque, lock wiring, static balancing, or dynamic balancing defined and documented?	X			1267090
14.	Is there an assembly instruction or specification?	X			1267090

PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: <u>Power Factor Correction Assembly</u>		YES	NO	N/A	REFERENCE DOCUMENTS
<u>P/N</u>					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Manufacturing Processes</u>				
15.	Are the clean room environmental characteristics defined (such as maximum particle size, count, temperature, flow rate, etc.)?			X	
16.	Are there special packaging, handling, or storage requirements?	X			AGC-10603
17.	Are the special process operator and equipment qualification requirements specified?	X			AGC-10603
18.	Are the surface finish, waviness, and lay adequately defined?	X			1267090
19.	Are workmanship acceptance standards defined?	X			AGC-10603
20.	Are the applicable workmanship specifications referenced?	X			AGC-10603
21.	Is a Build-up and Assembly Log required?	X			AGC-10603

PSD DESIGN REVIEW CHECK LIST

Page 11 of 12

SUBJECT NAME: <u>Power Factor Correction Assembly</u>		YES	NO	N/A	REFERENCE DOCUMENTS
<u>P/N</u>					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Environment</u>				
1.	Have the environmental exposures, levels, and durations been fully determined?	X			AGC-10507 AGC-10603
2.	Have the environmental effects on component performance, longevity, and reliability been evaluated?	X			AGC-10507 Appendix B
3.	Does operation of the component generate environments which are detrimental to the component or to other assemblies or subsystems?			X	
4.	Can the component withstand external and self-generated environments without employment of isolation devices?	X			AGC-10603 AGC-10563
5.	Is adequate protection from environments specified in detail where required?	X			AGC-10603 AGC-10563
6.	Were the relationships between environments and modes of failure considered in the failure mode and effects analysis?	X			FMEA Page M-14
NOTE: The following environments should be considered: heat, cold, thermal shock, high pressure, vacuum, pressure shock, humidity; vibration, acoustic noise, acceleration, shock, RFI-radiated, RFI- conducted, RFI-susceptibility; explosive atmosphere, solar radiation, nuclear radiation, salt atmosphere, fungus, meteoroids, zero-gravity, sand, dust, wind.					

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PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: <u>Power Factor Correction Assembly</u>		YES	NO	N/A	REFERENCE DOCUMENTS
<u>P/N</u>					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Instrumentation</u>				
1.	Have accuracy and precision requirements been specified for performance parameters?			X	
2.	Have provisions been made for instrumentation to meet these requirements?			X	
3.	Have sensor installation requirements, including hermetic sealing and removal or replacement, been considered?			X	
4.	Will the insertion of sensors affect the operation of the component?			X	
5.	Is adequate instrumentation available for anticipated operating conditions?	X			Instrumentation is all external to assembly
6.	Is an instrumentation development program necessary?		X		
7.	Are written calibration instructions available for the calibration of data gathering equipment?			X	
8.	Has an adequate and reliable instrumentation wiring system been defined?			X	

4925:66:107

POWER SYSTEMS DIVISION
FAILURE MODES AND EFFECTS ANALYSIS

DESCRIPTION OF FUNCTION:

PART NO. 1267090
PART NAME Power Factor Correction Assembly
LOOP ITEM NO.

PAGE 1 OF
DATE 3/31/69
INITIAL REVISION ☐

1 FAILURE MODE	2 FAILURE CAUSE	3 EFFECT ON SNAP-8		4	PROBABILITY OF OCCURRENCE*		6 REMARKS AND RECOMMENDATIONS
		COMPONENT	SYSTEM		5	CRITICALITY OF FAILURE**	
Shorted Capacitor (Terminal to Terminal)	Dielectric Breakdown	Minor	Minor	Low*	Minor		* Two occurrences but burn-in will eliminate early failures of this type. Fuses disconnect line to line or line to ground short circuits.
Shorted Capacitor (Terminal to can)	Insulation Breakdown Shorted Terminal	Minor	Minor	Low	Minor		
Open Fuse	Mechanical Defect	Minor	Minor	Low	Minor		Slight current unbalance (10% PFCA unbalance, smaller system current unbalance).
Open circuit in wiring	Mechanical Defect	Minor	Minor	Low	Minor		
Short Circuit - wiring to ground	Mechanical Defect	Minor to Critical	Minor to Critical	Low	Minor to Critical		Effect would depend on location of short and on system wiring (neutral grounded or floating, etc.) Bus bars with wide spacing and rigid mounting designed to minimize chance of failure. All other wiring fused.

* HIGH - Two or more occurrences of failure mode in ~~burn-in~~ testing.
MODerate - One recorded occurrence.
LOW - No recorded occurrences.

** CRITICAL - Failure which aborts the test in progress or creates an intolerable safety hazard.
MAJOR - A failure or performance degradation in excess of tolerance limits.
MINOR - Failures other than critical or major which have no significant effect on the ability of the ~~machine~~ ^{system} to perform its primary function.

POWER SYSTEM DIVISION
FAILURE MODES AND EFFECTS ANALYSIS

PART NO. 1267090 PAGE 2 OF 6
 PART NAME Power Factor Correction Assembly DATE 3/31/69
 LOOP ITEM NO. INITIAL EX REVISION 0

DESCRIPTION OF FUNCTION:

1 FAILURE MODE	2 FAILURE CAUSE	3 EFFECT ON SNAP-8		4	PROBABILITY OF OCCURRENCE*		6 REMARKS AND RECOMMENDATIONS
		COMPONENT	SYSTEM		5	CRITICALITY OF FAILURE**	
Open Capacitor	Mechanical Defect	Minor	Minor	Low	Minor		Same effect as open fuse or open in wiring
Shorted Fuse	Mechanical Defect	Minor	Minor	Low	Minor		No effect without other failures.

* HIGH - Two or more occurrences of failure mode in ~~testing~~ testing.
 MODerate - One recorded occurrence.
 LOW - No recorded occurrences.

** CRITICAL - Failure which aborts the test in progress or creates an intolerable safety hazard.
 MAJOR - A failure or performance degradation in excess of tolerance limits.
 MINOR - Failures other than critical or major which have no significant effect on the ability of the ~~function~~ **system** to perform its primary function.

APPENDIX N

Memo 4901-69-1038

3 March MTR of PFCA

Memo 4901-69-1073

18 April MTR of PFCA

INTEROFFICE MEMO



AEROJET-GENERAL CORPORATION

TO: Distribution

DATE 13 March 1969
4901-69-1038:RWM:vsh

FROM: R. W. Marshall, Jr.

SUBJECT: 3 March MTR of Power Factor Correction Assembly

COPIES TO: BLAmstadter, WFBanks, SLBradley, HDerow, RGordon, CHawk,
RMHill, LPLopez, BTMacaulay, GMMcRoberts, WWeleff, WLSnapp

Reference: (a) TM 4936:69: Preliminary, "SNAP-8 Power Factor Correction
Assembly, Management Technical Review, February, 1969"

The Electrical Group reviewed the information set forth in the preliminary TM, Reference (a). An extensive discussion of the configuration (see Figure 1) ensued. The configuration, with some changes that are set forth below, was deemed acceptable.

Mr. Plesse discussed the stress analysis that is currently underway. He stated that under vibratory loads the main lateral insulators were overstressed, but that additional support for them could be provided. The recommendations in this area are set forth below.

Thermal analysis on the capacitors is currently underway.

George Anderson has recommended, and the Electrical Group is looking into, changing the main enclosure to a can that fits over the assembly and fastens to the base. This will facilitate assembly and inspection. In this I heartily concur, having had sad personal experience with the difficulties of assembling and inspecting electronic components down in the bottom of a can.

ACTION ITEMS

1. A failure mode and affects analysis shall be performed and its results made a part of this TM.
2. The use of an inverted can as the main enclosure shall be analyzed and the tradeoff with the current design shall be presented at the next MTR.
3. The stress analysis shall be completed and any changes dictated by this analysis shall be factored into the design. This analysis will be included as part of the final TM.
4. The heat transfer analysis will be completed and the results presented at the next MTR. It shall be made part of this TM.
5. Another MTR shall be scheduled prior to the design review.

R. W. Marshall, Jr.
Technical Assistant to Manager
Engine Systems Department



TO: Distribution

DATE 24 April 1969
4901:69:1073:RMM:vsh:ph

FROM: R. W. Marshall, Jr.

SUBJECT: 18 April Pre-Design Review MTR of Power Factor Correction Assembly

COPIES TO: BLAmstadter, WFBanks, SLBradley, WDDaniels, HDerow, RGordon, CHawk,
RHill, AHKreeger, LPopez, BTMacaulay, GMRoberts, WWeloff, WLSnapp
NASA, LeRC: G. M. Thur
NASA, Hq.: P. R. MillerREFERENCE: (a) TM 4936-69-CO3 Preliminary, SNAP-8 Power Factor Correction Assembly
MTR, dtd April, 1969

The design review package (Reference (a)) that has been prepared by the Electrical Group was reviewed at this MTR. The package, as presented, was approved with the following exceptions, which should be corrected or completed prior to the design review:

1. The remarks, under the "Remarks and Recommendations" column of the Failure Modes and Effects Analysis for the first item listed (shorted capacitor), should be revised to state what actually occurs. As stated, it is incorrect since the affected capacitor is not isolated from this circuit.
2. The Reliability Analysis, as represented by a copy of Mr. Amstadter's letter, Appendix E, shall be revised since the circuit on which this analysis is based is not the one currently in use. The new analysis shall be included in the final package presented to the Design Review Board.
3. The screws that bolt the housing to the heat sink will be relocated to provide easier assembly. The referenced screws are on the lead outlet end of the housing.
4. A statement regarding the reliable operating temperature for the solder in the capacitors shall be included in the design review package. This statement should reflect the fact that this temperature is not exceeded and that an adequate margin exists under any of the expected operating conditions of this subsystem.
5. Paragraph 3. 3. 1. 4 of Specification AGC-1063, Power Factor Correction Assembly, Prototype is inadequate in that it does not define the temperature interface of the heat sink for this assembly. Since the Electrical Group is responsible for the design and construction of the electrical packaging, they will define this parameter and relay this information to Mr. Coff and the Systems Group, so that the specification can be corrected.

24 April 1969

6. Having defined the interface temperature (6, above) a paragraph shall be included in the design review package stating that the thermal requirements imposed on this system are met, and with adequate margin, under all operating conditions.

7. The stress analysis currently underway will be completed prior to the design review. If the analysis results in a change to the current design, these changes shall be incorporated in the Power Factor Correction Assembly prior to holding the design review.

R. W. Marshall, Jr.

R. W. Marshall, Jr.
Technical Assistant to Manager
Power Systems Department

APPENDIX O

Memo 5001:69:0124

Minutes of the Major Design Review
of the Power Factor Correction Assembly



SECRET-GENERAL CONFERENCE

INTER-OFFICE MEMO

(0-007-102 (STOCK NO. J 1-1))

TO: Distribution

DATE: 3 June 1969

5001:69:0124:RWM:mrs

FROM: R. Gordon

SUBJECT: Minutes of the Major Design Review of the Power Factor
Correction Assembly

DISTRIBUTION: *B.L.Amstatter, W.F.Banks, *B.L.Bradley, W.D.Daniels, H.Derow,
*R.Gordon, *C.Hawk, *R.M.Hill, A.H.Kraeger, L.P.Lopez, *R.W.Marshall, Jr. (2)
G.M.McRoberts, J.R.Pope, G.G.Takach, *W.Weleff, File
AGC-Cleveland: W. Snapp
NASA, LARC: *A.W.Nice, M.J.Seari, G.M.Thur
NASA, Hq.: P.R.Miller

*Attendees

Reference: (a) SNAP-8 Power Factor Correction Assembly Design Review,
4936:69:0035 Preliminary
(b) Memo: 4901:69:1073 to Distribution from R. W. Marshall, Jr.,
Subject: 18 April Pre-Design Review MTR of Power Factor Correction
Assembly.

The major design review of the Power Factor Correction Assembly (PFCA) was held on Tuesday 20 May 1969. The Electrical Group presented the material in the design package (Reference (a)) which was approved for fabrication except for the action items noted below:

1. The fuse development program including the testing shall be published as a separate TM.
2. The equilibrium temperature of the fuse, under the worst case normal (non-fault) condition, shall be calculated. The results of this analysis shall be included as part of Ref. (a) released as a TM.
3. The vibration response and the resultant stresses in the fuse wire, and the interconnecting wiring shall be calculated and made part of the published TM (Ref. a).
4. If the results of 2 and 3 are unsatisfactory, design changes shall be made to rectify these deficiencies, and they shall be submitted for review.
5. The center mounting holes of the capacitors shall be offset to prevent misassembly.
6. Lifting handles shall be installed on this assembly.
7. Protective covers for storage and shipment for the power terminals shall be added.

DISCUSSION

The fuse that will be used in this assembly has been developed at Aerojet as the result of a study that indicated that commercially available fuses would not meet the SNAP-8 requirements. A test program covering various AGC designs has been executed and the present fuse selected as best meeting the SNAP-8 needs has features not tested. The information developed under this program has not been published. The thermal equilibrium conditions of the fuse under worst case normal (non-fault) conditions has not been calculated, nor has the vibration response and the resultant stress in the fuse wire been calculated.

The mounting brackets used to bolt the capacitors to the heat sink are not symmetrical and could be mismounted during assembly. This can be prevented by offsetting the center mounting bolt hole.

Lifting handles should be added to the assembly which weighs approximately 86 lb. Also, removable covers should be provided to protect the insulated power terminals during storage, handling and transportation.

All action items from the PFCA MTR (Ref. (b)) except Items 5 and 6, which relate to the overall thermal design, have been completed. Since no work is being done on the packaging, including the heat sink design, these items must remain open.

The Design Review Board has serious reservations regarding the efficacy of the means of transferring the generated heat from the PFCA to the heat sink. The present design calls for bolting the 28" x 10" PCFA base plate to the heat sink with bolts located around its perimeter. Heat is transferred to the heat sink by direct contact. Two problems arise: First, the difficulty in fabricating and maintaining, due to material instability, sufficient flatness in the two plates to assure adequate contact; and secondly, the tendency toward thermal instability of the system caused by the plate bowing away from the heat sink as it heats up. As the plate bows, the heat transfer coefficient decreases, which causes further heating of the plate, and in turn more bowing. Compensating for this is the relatively small amount of heat that must be transferred to the heat sink. The Board recommends that Program Management undertake a test with the PCFA mounted on an active heat sink at environmental temperatures and in a hard vacuum.

Robert Gordon

Robert Gordon, Manager
Mechanical Systems Operation

DIVISION Power Systems
TM 4968:70-618
DATE 5 March 1970
W.O. 1475-78-2000

TECHNICAL MEMORANDUM

AUTHOR(S): R. M. Hill

TITLE: SNAP-8 Power Factor Capacitor Development Program

ABSTRACT

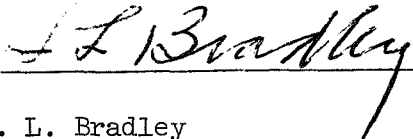
A summary report of the development program for power factor correction capacitors is presented. It includes the preliminary considerations for selection, the testing, failure investigations and conclusions reached. Recommendations are made for completion of the present program.

KEY WORDS: Power factor correction, capacitor, corona, Kapton, PFCA

SNAP-8 DATA CENTRAL FILE

APPROVED:

DEPARTMENT HEAD


S. L. Bradley

NOTE: The information in this document is subject to revision as analysis progresses and additional data are acquired.



AEROJET-GENERAL CORPORATION

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SNAP-8 POWER FACTOR CAPACITOR DEVELOPMENT PROGRAM

I. INTRODUCTION

The development of components for power factor correction of the SNAP-8 power system has progressed from the early concepts to the completion of the first prototype assembly. The purpose of this report is to summarize the development program in a way that will allow a review of the major factors leading to the design of the prototype equipment and the additional conclusions and recommendations reached as a result of the program.

The information leading to the decision to incorporate pf correction will not be discussed in detail, but can be summarized by saying the decision was reached because the efficiency of the alternator could be substantially increased by correcting the system power factor. (Reference TM 4936:66-410).

The decision was made to correct the alternator pf to unity. This value makes the exact pf less critical and allows for considerable variation without greatly affecting the performance of the system.

II. CAPACITOR SELECTION

Determination of the kilovolt-ampere reactive (KVAR) rating of the capacitors was made by the decision to correct the alternator pf to unity under normal system load conditions. Available load data resulted in a KVAR rating of 57. The capacitance per phase is calculated to be 175 microfarads (μf) for a delta connected three phase circuit with 120/208 volts rms applied or 525 μf for a wye connected circuit. The capacitors in the delta circuit require a line-to-line voltage rating while those in a wye need only line-to-neutral voltage rating.

Additional capacitor rating information was derived from the SNAP-8 environmental specifications and previously established packaging concepts for SNAP-8 use. This type of data is defined directly. The choice is in selecting components and materials most suitable to meet the requirements. Included are the operating temperature maximum of 200°F, heat sink temperature of 150°F, shock, vibration, acceleration and combined mechanical loads. Also included were resistance to nuclear radiation of 1×10^{11} nvt fast neutrons and 10^6 rads (c), both integrated doses for 10,000 hour life, the life requirement of 10,000 hours, hermetic sealing of components by welding, the provision for welded electrical connections and the mounting on and heat transfer to a liquid cooled heat sink.

The specification of a capacitor to best meet all these requirements has several more variations where choices are involved. Two of the most important choices are the selection of the dielectric material and the choice of the basic construction techniques combining the dielectric and conductive elements into a complete capacitor.

Glass, ceramic and mica have desirable characteristics of high temperature rating, dielectric strength and radiation resistance. They were eliminated from further consideration, however, because of their large relative size and relatively high losses. Electrolytic capacitors also were rejected early in the process because of their high losses, low radiation tolerance and questionable long life reliability. Impregnated paper and plastic films were the most promising. Impregnated paper was given careful consideration because of the extensive experience available from 60 Hz power factor correction use by commercial power systems. Many impregnating materials were investigated. In every case out-gassing and degradation from nuclear radiation were a problem.

The plastic films given serious consideration were polyethylene terephthalate (Mylar), polytetrafluoroethylene (Teflon), polystyrene, polycarbonate and polyimide (Kapton). The characteristics of these materials are similar enough that each of them could be seriously considered for use. The choice was based on the best combination of features. The two films selected as best were polyimide and polycarbonate. Polyimide has the best characteristics, but at the time of release of specification AGC-10563 polyimide film thin enough for practical capacitor manufacture was not readily available. Experience with its use was based on a few sample quantities. Polycarbonate film was available from only one source, Farbenfabriken Bayer AG in Germany. It had been available long enough and in sufficient quantity that considerable capacitor manufacturing experience had been gained.

Details of the basic capacitor construction were selected to minimize the electrical losses and the impedance. These included the selection of film and foil as compared to metalized film and the use of extended foil construction rather than inserted tab. Other fabrication details were determined on the basis of mechanical interface, environmental requirements and general SNAP-8 packaging requirements.

The capacitance value of the individual packaged parts was based on an evaluation of practical manufacturing processes, allowable loss of capacitance or phase unbalance caused by single component failure. Ten capacitors per phase was selected with the total of 175 microfarads per phase equally divided.

III. CAPACITOR PROCUREMENT

Capacitor procurement was initiated using specification AGC-10563 to define the performance and design requirements. AGC-STD-1338 defines the Quality Conformance Inspection or acceptance test requirements. An Advance Quotation Request was sent to sixteen capacitor manufacturers. Quotations and comments were received from Southern Electronics in Burbank, California, and Marshall Industries in Monrovia, California. No reply or "no bid" was received from the other companies. A second AQR was sent to these two companies with the A revision of specification AGC-10563. On the basis of the proposals received, Marshall Industries was selected to provide the capacitors. At about the same time, Marshall also submitted an alternate proposal to supply capacitors made with Kapton film. They proposed to meet our performance requirements with capacitors estimated to be 23.3 cubic inches and 2.5 pounds compared to 76.5 cubic inches and 5 pounds for the polycarbonate capacitors. Separate inquiries to Dupont confirmed that opening of a new commercial production facility had almost eliminated the problems in obtaining 1/2 and 1 mil thick Kapton film. Deliveries were estimated to be 12 to 14 days. The film thickness for the capacitor is 1/2 mil.

A purchase order was issued for the procurement of 70 capacitors to meet our specification requirements using Kapton for the dielectric.

The original capacitor designed by Marshall used 10 individual sections in parallel, matched to provide the total capacitance. Tests of the first parts fabricated revealed mechanical defects in the Kapton film occurring at fairly regular intervals along the length of the film. The capacitor was redesigned to reduce the size of the individual sections so that fewer sections would

contain the defects and so the amount of material lost with each defective section would be reduced. The new design contained 27 sections packaged in 3 rows of 9. All the sections are in parallel.

The cause of the defects was found to be in the film winding and slitting equipment. Dupont made corrections to eliminate the defects in the film and none have been found since that time. The original defective material was returned to Dupont for replacement. The modified capacitor design was kept as the final design.

Figure 1 shows the configuration of the capacitor package. The seal weld around the top of the stainless steel can and lid is clearly shown. The terminal welds can also be seen at the base and top of the ceramic insulated terminals.

Figure 2 shows the side view of two of the capacitors to illustrate the overlap of the mounting brackets. This design minimizes the mounting area required for each part.

These two photographs illustrate the external mechanical features of the capacitor design.

After the design of the capacitors had become firm, Aerojet Source Control Drawing, 1265720, was issued to maintain control over the design details and to establish an Aerojet part number.

IV. CAPACITOR TESTING

The acceptance testing of the capacitors is not completely documented. By assigning serial numbers after satisfactory completion of the tests, the data on those that fail becomes difficult to use. This system, as specified in the Aerojet purchase order, was changed but not before some data was lost.

Each of the 69 capacitors delivered has passed the tests in AGC-STD-1338 as modified by the test procedure Rototest Laboratories Report 7137. (Rototest later became a part of Ogden Technology Laboratories - the report number remained the same.) Results of these tests indicate that they are all necessary since some rejections occurred for each test. Some parts were repairable while others were completely eliminated. Changing of the helium leak test method and an expansion of the AC voltage test to include burn-in testing can bring the acceptance test procedures up to present requirements.

The first tests performed after the capacitors were delivered to Aerojet-General Corporation were informal re-tests to determine the repeatability of the capacitance and dissipation measurements using different instruments. These tests showed excellent repeatability where actual test values had been recorded. Some of the first parts delivered had dissipation factor so low that they were recorded as 0 rather than actual measured values.

Performance tests were started using capacitors assembled in the breadboard Power Factor Correction Assembly shown in Figure 3. This breadboard was connected into the Electrical Component Test Facility (ECTF) for ambient temperature tests with nominal electrical parameters. At first, 21 capacitors were included in the test.

Failure of capacitor S/N A-63 occurred after approximately 45 hours of testing. The capacitor shorted and blew the protective fuse to isolate itself, as the test continued.

A second failure, S/N A-3, occurred after approximately 223 hours of testing. The effect of the failure was the same as the first. In both cases, the failure was detected by measuring the capacitor line current and detecting an unbalance between phases. System performance was not adversely affected by the failures.

An extensive failure investigation was performed on both failed capacitors. The investigation of S/N A-63 was performed at Aerojet with representation of Marshall Industries assisting. Acceptance test data was reviewed to look for variations from nominal values. No significant differences were found. A visual examination was performed, resistance measurements were made and after removal of the can X-ray examination was performed. Finally, the capacitors were disassembled section by section to isolate the defective parts. Figure 4 shows the package after removal from the can with all loose insulation removed. Figure 5 is a part of the defective section showing the area of failure. A similar investigation was performed on S/N A-3 at Marshall Industries with Aerojet representatives present.

The conclusions reached were that the failures were from random type defects rather than from deficiencies in design or material characteristics. As a check on the dielectric strength of the capacitors, each of them was subjected to a test voltage of 650 volts dc for one hour with no indication of failure. Previous testing at this voltage had been limited to 1 minute duration. A burn-in test was recommended as a means of detecting other failures before the parts are put into service.

All of the capacitors not installed in the breadboard assembly were subjected to a 1 week test (168 hours) at a temperature of 170°F with a voltage of 230 volts applied at a frequency of 410 Hz. One capacitor, S/N A-49, failed at 147 hours. Because this failure occurred so close to the end of the test, the test was extended two additional weeks to bring the total time to 500 hours.

The temperature was increased to 185°F for the additional time. During the remainder of this test 4 more capacitors failed. They were S/N A-61, A-36, A-71, and A-53. In each case the failures occurred at night or over a weekend when the test was unattended. The power supply that was used for these tests exhibited increasing periods of instability during these tests. Attempts to obtain a good record of the voltage variation during these periods of oscillation were not very successful. One short section of chart is shown in Figure 6.

Discovery of the power supply instability and the lack of a consistent pattern in the time to failure indicated a possible failure mode different than had been anticipated. Disassembly and examination of the failed parts indicated that the failures were due to corona.

A special test program was initiated to investigate the measurement and effects of corona upon the capacitor materials. As a start, small scraps of the capacitor film and foil were used to produce visible corona in a vacuum chamber and at atmospheric pressure. An RF spectrum analyzer was used to detect the start of corona. It was found that broadband noise centered around 1.5 MHz was indicated on the scope of the spectrum analyzer when corona was present. The noise signal could be picked up with either a vertical rod antenna or a current probe on the current carrying conductor. It was also noted during these tests that with adequate heat dissipation the capacitor materials could operate with corona present for long periods of time with no apparent degradation or damage. In cases where heat dissipation was restricted, the parts would operate for some periods of time and then the Kapton film would fail in a sudden flash leaving only black ash.

Using the spectrum analyzer to detect the start of corona, several sections removed from failed capacitors were tested. The start of corona could be detected

at as low as 290 volts rms at 400 Hz in some sections and it had started in all sections tested at 320 volts rms. In several cases corona could be sustained at 320 volts for several minutes without causing failure of the section. In other cases, failure occurred within the first few minutes. Visual examination of the failed sections showed the same types of failure observed in the failed parts from the burn-in tests. During the time these tests were being performed, the breadboard PFCA was modified by the addition of electric heaters and vermiculite insulation so that testing could be performed at expected operating temperature. An automatic controller maintains the base plate temperature at 170°F.

The next step in the program was to test a larger number of samples under controlled conditions in order to determine the effects of ambient temperature and applied voltage. All available sections from the six failed capacitors were collected and labeled with the original capacitor serial number and a sample number. These parts were divided into four groups with the same number of parts from each capacitor in each group. A total of 112 sections were put into 4 groups of 28 each. All discolored, slightly damaged or otherwise doubtful sections were put in the first 2 groups and listed with a description of their defects. The worst group was tested first at a temperature of 145°F. The voltage was applied to each group of parts at 210, 230, 250, and then at 10 volt increments. Each voltage level was maintained for $2\frac{1}{2}$ hours unless a failure occurred within the last half hour. If failures occurred, the voltage level was maintained until 1/2 hour had elapsed without an additional failure. The other three groups were tested in the same way except the temperatures were maintained at 170°F, 185°F and 200°F. Each test continued until at least 80% of the parts had failed.

One of the doubtful sections failed at 145°F as the voltage was being increased to 210 volts. The only other failure that appeared to be out of line was in the 170°F group. It failed as the voltage was being increased from 210 to 230 volts. 96 of the 99 sample sections that failed broke down between 300 volts and 320 volts. The cumulative failures are plotted in Figure 7. There is no apparent correlation with temperature in the range of 145°F to 200°F. The test data sheets are included as Appendix A.

The performance and life testing in ECTF have been continuing. The total operating time is now 6900 hours with 2100 hours at 170°F base temperature.

One capacitor failure occurred when a load connection burned off. The resulting load unbalance resulted in a large unmeasured voltage unbalance. The failure of S/N A-5 is attributed directly to the application of excessive voltage.

The completed prototype PFCA with the covers removed and with them installed are shown in Figures 8 and 9.

V. CONCLUSIONS

After reviewing the complete development program for the power factor correction capacitors the following conclusions have been reached:

1. The failures of S/N A-63 and S/N A-3 were caused by random type defects. These defects could have been detected by a properly performed burn-in test.

2. The main failure mechanism of the capacitors is a corona discharge within a capacitor section causing local heating. Degradation of the dielectric film results from excessive local heating causing carbonization of the film and electrical breakdown. This process appears to take place very rapidly, once it starts, with no gradual or partial degradation that can be detected. The film degradation temperature of approximately 1500°F does not appear to be influenced by ambient temperature in the range of 145°F to 200°F.

3. The failures of S/N A-49, S/N A-61, S/N A-36, S/N A-71 and S/N A-53 were probably all caused by local heating from corona discharge started by the uncontrolled application of excessive voltage from the unstable power supply.

4. The failure of S/N A-5 was caused by local heating from corona discharge started by the application of excessive voltage resulting from the severe load unbalance when one phase of the load circuit burned open.

5. The choice of Kapton film for the capacitor dielectric was the best choice. All of the Kapton characteristics are superior to the characteristics of other available films. Since corona discharge does not depend upon the materials, but rather on the geometry of the metallic conductors and the air gaps, the failures resulting from corona could have been more frequent and more severe with a film with lower temperature capabilities.

6. The basic design and construction of the capacitors is satisfactory for SNAP-8 use.

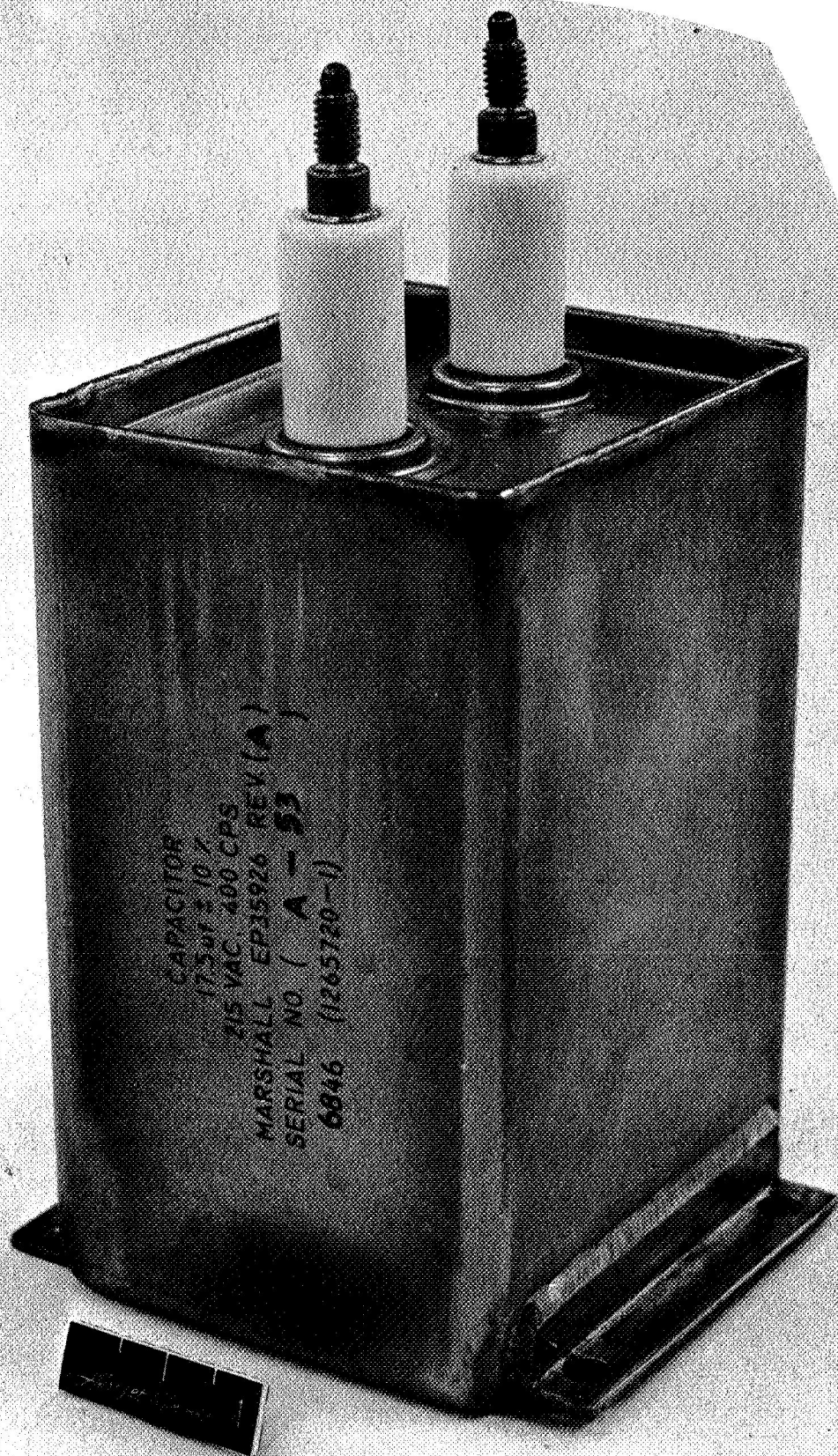
7. The voltage margin between the normal maximum value of SNAP-8 PCS output of 218 volts and the minimum measured corona start voltage of 290 volts is sufficient for high reliability performance of the PFCA.

VI. RECOMMENDATIONS

The following recommendations are made to close the present phase of development and to prepare for the future program.

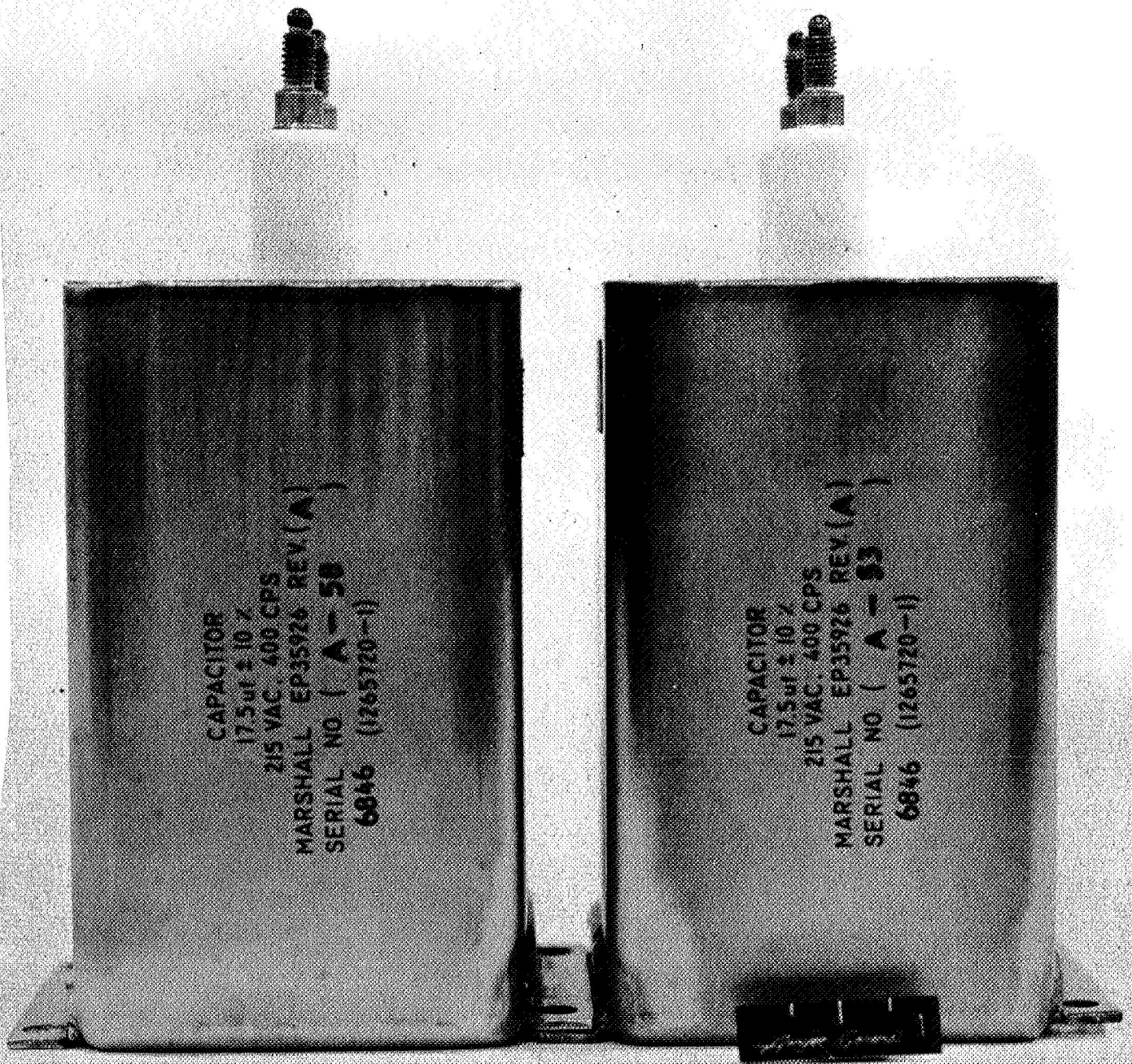
1. Revise the capacitor specification to specify Kapton film for the dielectric material.
2. Revise the specification to include extended foil construction as a requirement.
3. Revise the specification to include the Source Control Drawing, 1265720.
4. Revise the specification to require serial numbers assigned as soon as possible in the assembly process so that all in-process and acceptance testing will be identified with the parts.
5. Revise the acceptance test procedure to include a helium leak test procedure more compatible with the type of package being tested. This procedure can be similar to the Rototest procedure.
6. Revise the acceptance test procedure to change the AC voltage test to a burn-in test using 270 volts rms, 400 Hz as maximum test voltage. Test time of 168 hours and test temperature of 170°F to 200°F.
7. Revise the acceptance test procedure to add a warning note to discharge the capacitors after testing. Specify that the capacitors be discharged through a resistance of 1000 ohms or higher and not to short circuit a charged capacitor.
8. It is recommended that the specification be revised to reduce the capacitance tolerance range. This is not necessary, but the way the capacitors are fabricated from multiple sections it is an easy change to accomplish and should not affect the packaging or the price. A change of from $\pm 10\%$ to $\pm 5\%$ can easily be made.

169-684



POWER FACTOR CORRECTION CAPACITOR

Figure 1



POWER FACTOR CORRECTION CAPACITORS

Figure 2

169-686

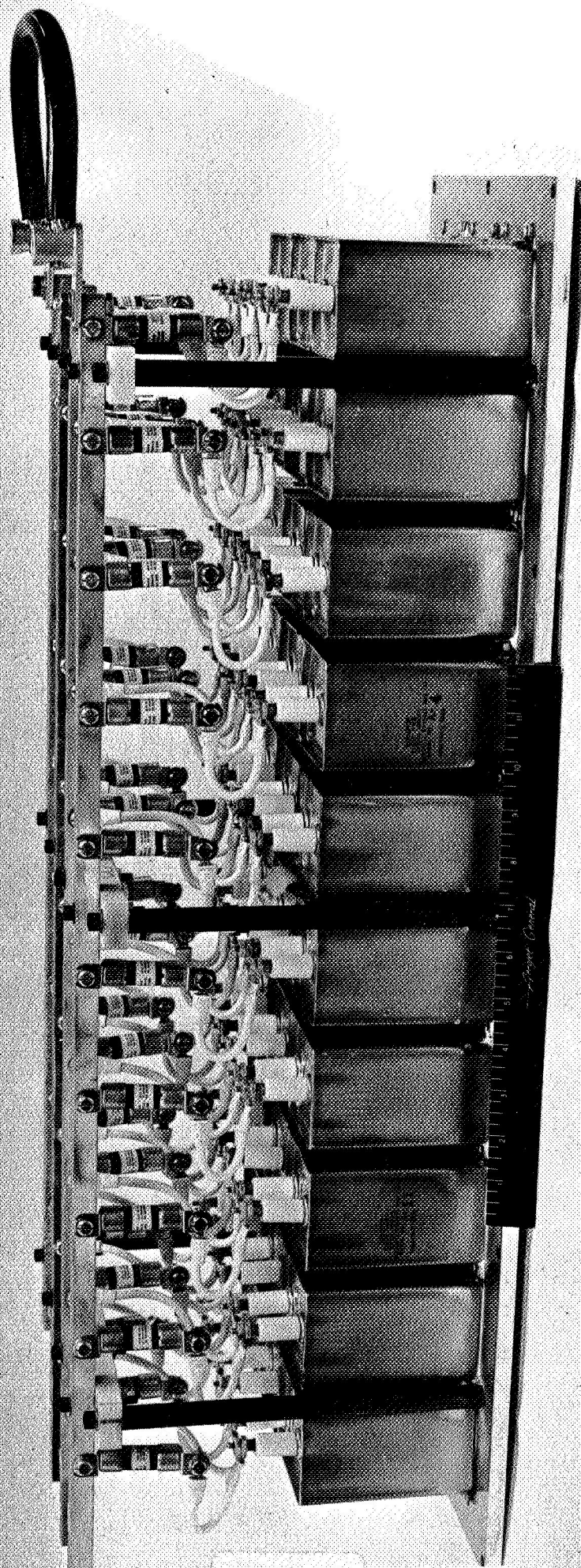
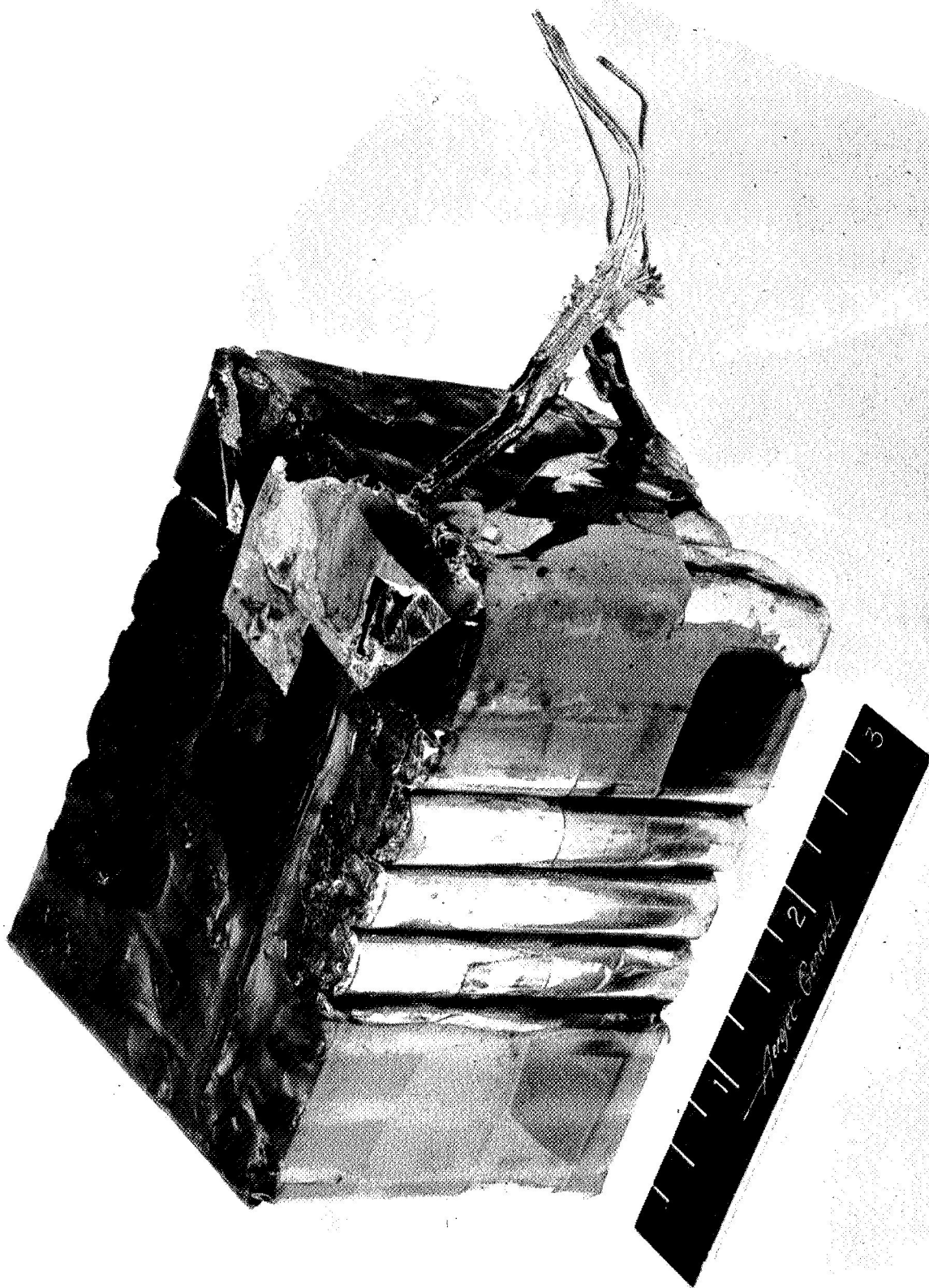


Figure 3

POWER FACTOR CORRECTION ASSEMBLY



SHORTED CAPACITOR, SERIAL NO. A63

Figure 4

27-335



cm 1 2 3 4 5 6

SPECIMEN _____ DATE _____

Figure 5

SHORTED CAPACITOR SECTION, SERIAL NO. A63

CAPACITOR BURN-IN TESTS

RECORD OF UNSTABLE POWERSUPPLY OUTPUT

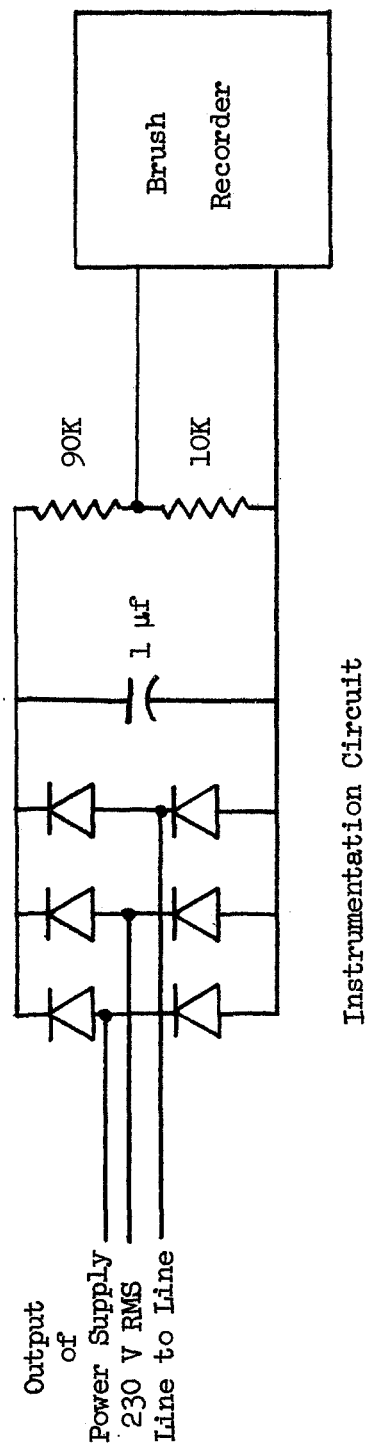
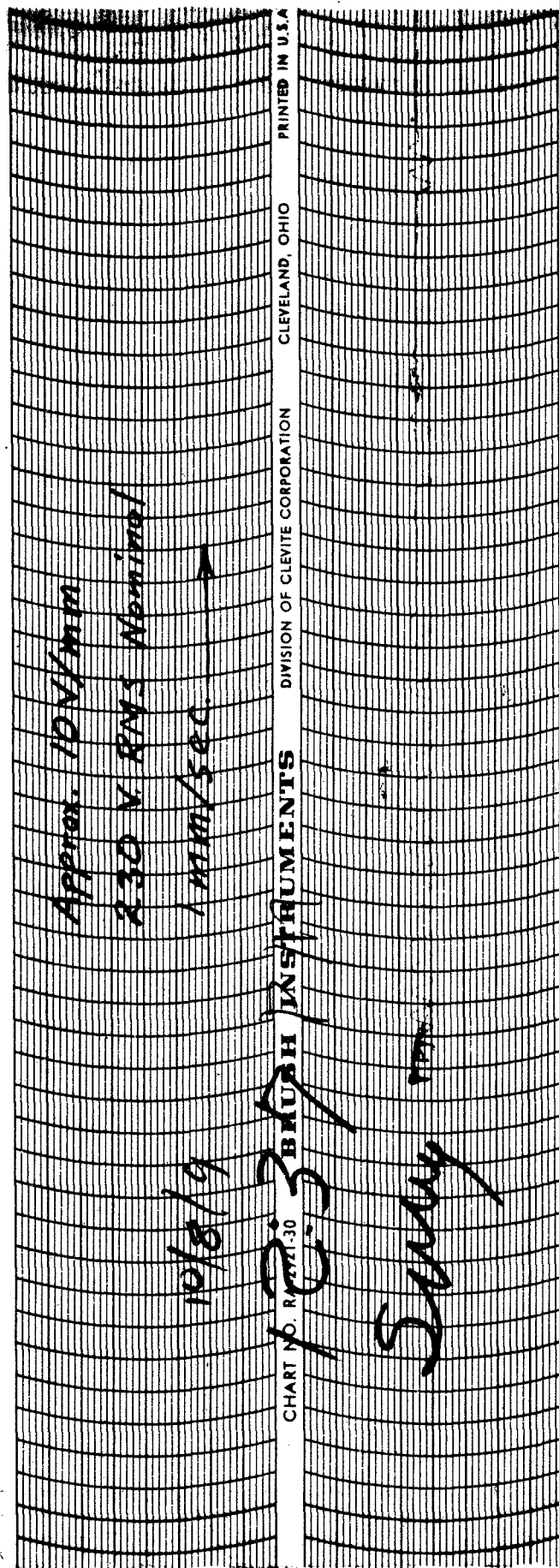


Figure 6

CAPACITOR SECTION TESTS

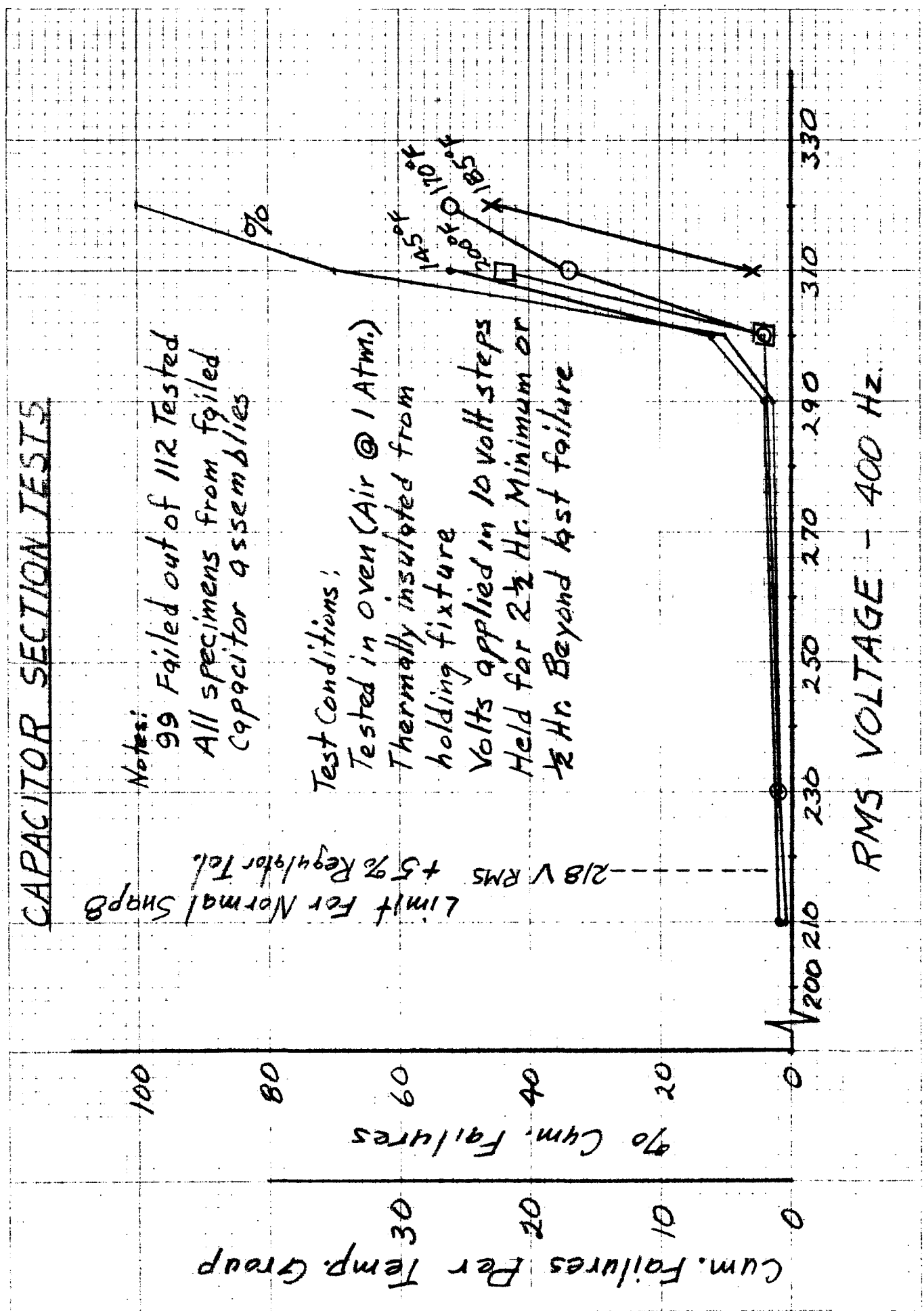
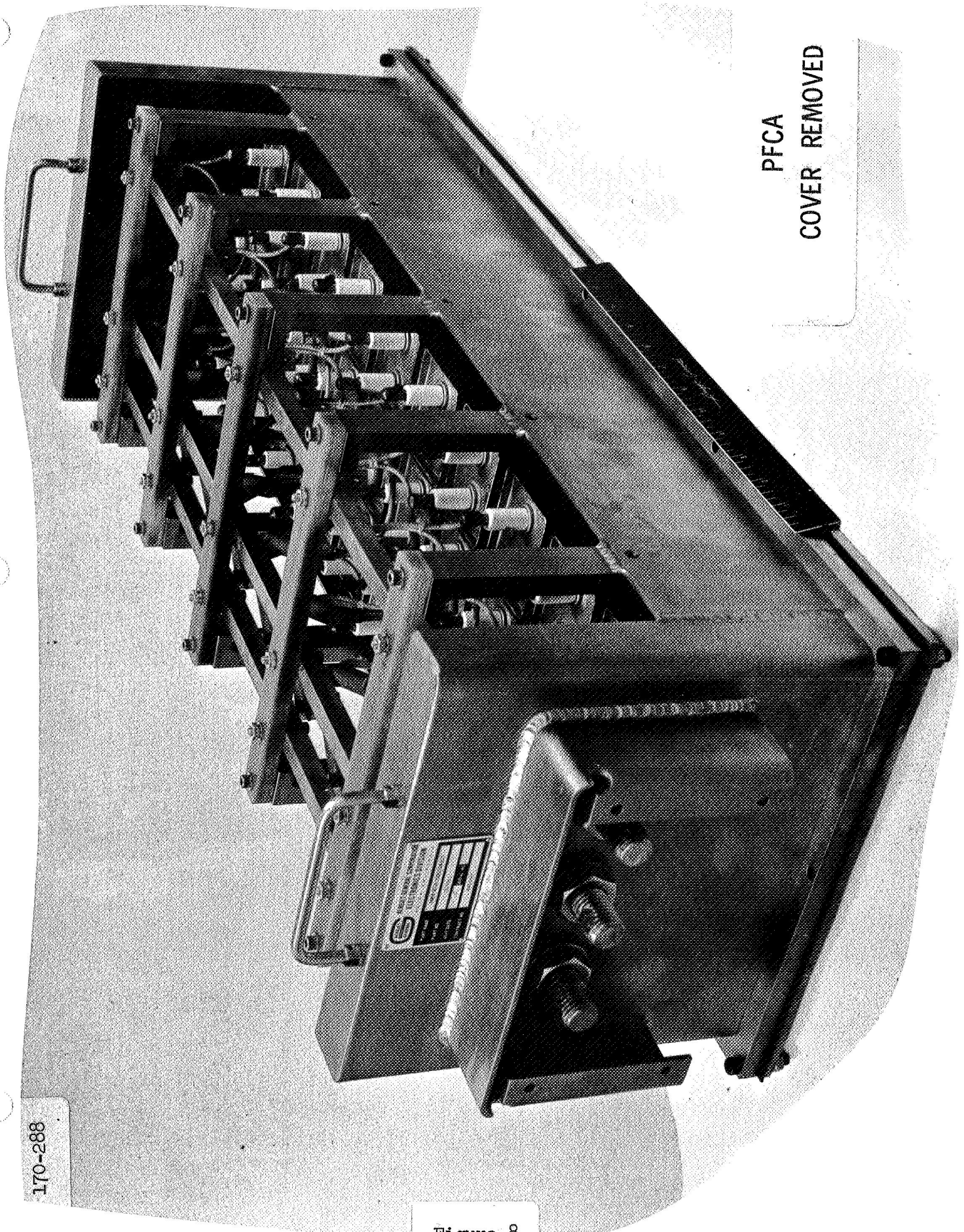


Figure 7

PFCA
COVER REMOVED

170-288

Figure 8



POWER FACTOR
CORRECTION ASSEMBLY



170-287

Figure 9

APPENDIX A

Capacitor Section Test Data

145°F Group-
1

Pos.	S/N	Out at.
1	53-16	3 1/2 Hr @ 310V
2	53-17	1 Hr @ 300V
3	53-18	3 1/2 @ 310V
4	53-19	3 @ 310V
5	53-20	1 1/4 @ 310V
6	36-13	4 @ 310V
7	36-14	2 1/2 @ 310V
8	36-15	2 1/4 @ 310V
9	36-16	
10	71-16	1 @ 310V
11	71-17	1/2 @ 310V
12	71-18	1 @ 310V
13	71-19	4 3/4 @ 310V
14	71-20	3 @ 310V
15	63-13	3/4 @ 310V
16	63-14	0 @ 210V
17	63-15	3 1/4 @ 300V
18	63-16	1 1/2 @ 310V
19	49-16	2 1/2 @ 300V
20	49-17	1 3/4 @ 310V
21	49-18	1/2 @ 310V
22	49-19	3/4 @ 290V
23	49-20 (TC)	3 @ 300V
24	61-16	
25	61-17	4 1/2 @ 310V
26	61-18	4 3/4 @ 310V
27	61-19	5 @ 310V
28	61-20	3 3/4 @ 310V

5/N	210	230	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400
1																		
2																		
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36																		
37																		
38																		

53-16	1
53-17	2
53-18	3
53-19	4
53-20	5
36-13	6
86-14	7
36-15	8
36-16	9
94-16	10
71-17	11
71-18	12
71-19	13
71-20	14
63-13	15
63-14	16
63-15	17
63-16	18
49-16	19
49-17	20
49-18	21
49-19	22
49-20	23
61-16	24
61-17	25
61-18	26
61-19	27
61-20	28

Inf @ 3 1/4
Top 1 1/4

2 1/2 2 1/2

Instrumentation

821957 THE NOISEM = SCHULT
62582 143 NEWSTEN = STROV
62582 143 NEWSTEN = STROV
62582 143 NEWSTEN = STROV

170°

GROUP

2

POS	S/N	OUT at
1	53-11	4 @ 320
2	53-12	2 1/2 @ 320
3	53-13	5 1/2 x @ 310
4	53-14	4 3/4 @ 310
5	53-15	1 hr @ 320
6	36-9	4 1/2 @ 310
7	36-10	2 3/4 @ 310
8	36-11	5 1/4 @ 310
9	36-12	4 1/4 @ 310
10	71-11	OK
11	71-12	5 1/2 @ 310
12	71-13	4 3/4 @ 310
13	71-14	Ø hr @ 230 V
14	71-15	4 3/4 @ 310
15	63-9	3 3/4 @ 310 V
16	63-10	6 HR @ 310 V
17	63-11	2 1/2 hr @ 320 V
18	63-12	OK
19	49-11	1 1/4 HR @ 300 V
20	49-12	4 1/4 HR @ 320 V
21	49-13	3 1/4 @ 320
22	49-14	2 HR @ 310
*23	49-15	1 1/4 HR @ 310
24	61-11	1 1/4 HR @ 320
25	61-12	1 1/2 hr @ 320
26	61-13	4 1/4 @ 310
27	61-14	3 1/4 HR @ 310
28	61-15	2 HR @ 320

185°

GROUP 3

Pos	S/N	
1	53-6	2 1/4 ms @ 320
2	53-7	2 1/4 @ 320
3	53-8	1 1/2 @ 320
4	53-9	1 m @ 320
5	53-10	3 3/4 @ 320
6	36-5	1 1/2 @ 310
7	36-6	1 m @ 320
8	36-7	1 1/2 @ 320
9	36-8	3 1/4 @ 320
10	71-6	OK
11	71-7	OK
12	71-8	OK
13	71-9	2 1/2 @ 320
14	71-10	2 1/2 @ 320
15	63-5	1 1/4 m @ 320V
16	63-6	3 1/2 @ 320
17	63-7	OK
18	63-8	2 m @ 320
19	49-6	1 3/4 @ 320
20	49-7	OK
21	49-8	2 3/4 @ 320
22	49-9	1 HR @ 310
23	49-10 (te)	3 1/4 @ 320
24	61-6	1 1/4 @ 320
25	61-7	2 1/2 @ 320
26	61-8	1 1/4 @ 310
27	61-9	3/4 @ 320
28	61-10	3 @ 320

GROUP 3

TEMP 185°

POS	5/1V	210	230	250	260	270	280	290	300	310	320
1	53-6	✓	✓	✓	✓	✓	✓	✓	✓	✓	2 1/4
2	53-7	✓	✓	✓	✓	✓	✓	✓	✓	✓	2 1/4
3	53-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	1 1/2
4	53-9	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 3/4
5	53-10	✓	✓	✓	✓	✓	✓	✓	✓	✓	1 1/2
6	36-5	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 3/4
7	36-6	✓	✓	✓	✓	✓	✓	✓	✓	✓	1 1/2
8	36-7	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 1/4
9	36-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	OK
10	71-6	✓	✓	✓	✓	✓	✓	✓	✓	✓	OK
11	71-7	✓	✓	✓	✓	✓	✓	✓	✓	✓	OK
12	71-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	2 1/2
13	71-9	✓	✓	✓	✓	✓	✓	✓	✓	✓	2 1/2
14	71-10	✓	✓	✓	✓	✓	✓	✓	✓	✓	1/4
15	63-5	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 1/2
16	63-6	✓	✓	✓	✓	✓	✓	✓	✓	✓	OK
17	63-7	✓	✓	✓	✓	✓	✓	✓	✓	✓	2
18	63-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	1 3/4
19	49-6	✓	✓	✓	✓	✓	✓	✓	✓	✓	OK
20	49-7	✓	✓	✓	✓	✓	✓	✓	✓	✓	2 3/4
21	49-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	1 HR
22	49-9	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 1/4
23	TC 49-10	✓	✓	✓	✓	✓	✓	✓	✓	✓	1 1/4
24	61-6	✓	✓	✓	✓	✓	✓	✓	✓	✓	2 1/2
25	61-7	✓	✓	✓	✓	✓	✓	✓	✓	✓	3/4
26	61-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	3
27	61-9	✓	✓	✓	✓	✓	✓	✓	✓	✓	
28	61-10	✓	✓	✓	✓	✓	✓	✓	✓	✓	

*

Instrumentation
OVEN = STATMAN # 98579
VOLTS = WESTON #311-23067 (SEA)
AMPS = WESTON #311-23068

Temp 200°F Group 4

Pos

1	63-1	3 1/2 HR @ 310
2	63-2	3 1/4 HRS @ 310V
3	63-3	2 1/2 HRS @ 310V
4	63-4	2 3/4 HRS @ 310V
5	49-1	4:00 200V 12/3/69 3 HR @ 300V
6	49-2	11:45 310V 12/4/69 1 1/2 HR @ 310V
7	49-3	3 1/4 HR @ 310V
8	49-4	4 1/4 HR @ 310V
9	49-5	1 1/2 HRS @ 310V
10	61-1	3:15 300V 12/3/69 2 1/4 HR @ 300V
11	61-2	4 1/4 HR @ 310V
12	61-3	
13	61-4	5 HR @ 310V
14	61-5	
15	53-1	
16	53-2	3 3/4 HRS @ 310V
17	53-3	4 1/2 HR @ 310V
18	53-4	3 1/4 HRS @ 310V
19	53-5	1 1/2 HRS @ 310V
20	36-1	4 1/4 HR @ 310V
21	36-2	4 1/2 HR @ 310V
22	36-3	
23	36-4	4 1/2 HR @ 310V
24	71-1	2 3/4 HRS @ 310V
25	71-2	12:30 310V 12/4/69 2 1/4 HRS @ 310V
26	71-3	
27	71-4	10:45 310V 12/4/69 1/2 HR @ 310V
28	71-5	5 1/4 HR @ 310V

GROUP 4

TEMP 200°F

POS	S/N	210	230	250	260	270	280	290	300	310	
1	63-1	✓	✓	✓	✓	✓	✓	✓	✓	✓	1 1/2 HR
2	63-2	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 1/4 HR
3	63-3	✓	✓	✓	✓	✓	✓	✓	✓	✓	2 1/4 Hrs
4	63-4	✓	✓	✓	✓	✓	✓	✓	✓	✓	2 3/4 HRS
5	49-1	✓	✓	✓	✓	✓	✓	✓	✓	✓	1 1/2 HR
6	49-2	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 1/2 HR
7	49-3	✓	✓	✓	✓	✓	✓	✓	✓	✓	4 1/4 HR
8	49-4	✓	✓	✓	✓	✓	✓	✓	✓	✓	1 1/2 HR
9	49-5	✓	✓	✓	✓	✓	✓	✓	✓	✓	4 1/4 HR
10	61-1	✓	✓	✓	✓	✓	✓	✓	✓	✓	5 HR
11	61-2	✓	✓	✓	✓	✓	✓	✓	✓	✓	
12	61-3	✓	✓	✓	✓	✓	✓	✓	✓	✓	
13	61-4	✓	✓	✓	✓	✓	✓	✓	✓	✓	
14	61-5	✓	✓	✓	✓	✓	✓	✓	✓	✓	
15	53-1	✓	✓	✓	✓	✓	✓	✓	✓	✓	
16	53-2	✓	✓	✓	✓	✓	✓	✓	✓	✓	
17	53-3	✓	✓	✓	✓	✓	✓	✓	✓	✓	
18	53-4	✓	✓	✓	✓	✓	✓	✓	✓	✓	
19	53-5	✓	✓	✓	✓	✓	✓	✓	✓	✓	
20	36-1	✓	✓	✓	✓	✓	✓	✓	✓	✓	
21	36-2	✓	✓	✓	✓	✓	✓	✓	✓	✓	
22	36-3	✓	✓	✓	✓	✓	✓	✓	✓	✓	
23	36-4 (TC)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
24	71-1	✓	✓	✓	✓	✓	✓	✓	✓	✓	
25	71-2	✓	✓	✓	✓	✓	✓	✓	✓	✓	
26	71-3	✓	✓	✓	✓	✓	✓	✓	✓	✓	
27	71-4	✓	✓	✓	✓	✓	✓	✓	✓	✓	
28	71-5	✓	✓	✓	✓	✓	✓	✓	✓	✓	

1 1/2 Hrs
3 Hrs