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AIRCRAFT ELECTRICAL RESEARCH DIVISION
ENGINEERING AND EVALUATION SECTION

11 July 1946

INVESTIGATION OF METHODS FOR IMPROVING THE TEMPERATURE COMPENSATION OF THE ECLIPSE, TYPE 1001 AND 1317 A. C. CARBON PILE VOLTAGE REGULATOR

By A. H. Barauck, Project Engineer

FR-2901

- Report E-2901 -

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To: Chief of the Bureau of Aeronautics
Attn: Technical Information Section

Subj: Investigation of Methods for Improving the Temperature Compensation of the Eclipse, Type 1001 and 1317 A. C. Carbon Pile Voltage Regulator, E-2901, NRL Problem 31E4, by A. H. Barauck, Project Engineer - forwarding of.

Encl: (HW)
(A) Five (5) copies of subject report E-2901, dated 11 July 1946.

1. Enclosure (A) is forwarded herewith.

J B Cochran

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INVESTIGATION OF METHODS FOR IMPROVING THE TEMPERATURE COMPENSATION OF THE ECLIPSE, TYPE 1001 AND 1317 A. C. CARBON PILE VOLTAGE REGULATOR

By A. H. Barauck, Project Engineer

- Report E-2901 -

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ABSTRACT

The initial value of regulated voltage of the Eclipse Type 1001 A.C. carbon pile voltage regulator is very high at low ambient temperatures. Regulation within wide speeds and ambient temperatures is also poor. Studies were made in an effort to correct the temperature compensation of the type 1001 unit by some expedient which would lend itself to application in the field. The method of accomplishing this, as recommended herein, involved the replacement of the bi-metal abutment ring and its backing ring with an aluminum ring having the same dimensions as the combination removed. It was also determined that the aging of a rectifier effects the temperature compensation of a voltage regulator. Several rectifiers were used but none giving optimum performance were obtainable at this time.

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AUTHORIZATION

1. The studies in this report were authorized by BuAer ltr Aer-E-3121-SHH, F36-1(1), Ser. No. 93971 of 5 June 1945 to NRL.

INTRODUCTION

2. The difficulties resulting from poor temperature compensation of the Eclipse Type 1317 A.C. carbon pile regulator have been discussed in reference (b). The Eclipse Type 1001 A.C. Carbon Pile Regulator, covered by this report, is similar to the former unit except for certain physical differences, such as the mounting base, pile housing and location of component parts. The carbon stack in the two units differs in length and disc dimension.

3. Since these regulators require extensive redesign in order to overcome all of their shortcomings, it was not considered feasible to improve temperature compensation to the extent that the resultant voltage variation would be within the limits of reference (c). This development was undertaken with the view of improving the temperature compensation of the regulator sufficiently to make it safe, overcoming the objectionable high voltage which exists at times with the present Eclipse Type 1001 Regulator. It was intended that the resulting conversion be simple so that it could be readily accomplished by Naval personnel.

CONDITIONS OF OPERATION

4. All of the information and observed data presented in this report were obtained when using an Eclipse Type 1001-2-A Regulator. Four regulators were tested: Serial Nos. 9686, 9712, 9728 and 9738; the manufacturer's drawing number was E-106422. The regulators were used to control an Eclipse NEA-5, Type 1097-3-C, A.C.-D.C. Generator, Serial No. 1424, with 9 microfarads compensation. The D.C. voltage was maintained at approximately 27.7 volts with no D.C. load.

5. The change made in the abutment ring was to substitute an aluminum ring for the bi-metal abutment ring and its aluminum backing ring. This aluminum abutment ring was taken from an Eclipse Type 1042 D.C. carbon pile regulator. It had the same working angle at an ambient temperature of 25° ± 5°C., as the original bi-metal ring and a thickness equal to the combined thicknesses of the bi-metal and its backing ring. The dimensions of the ring used are:

Outside diameter	2.195 inches
Inside diameter	1.370 inches
Thickness at outer edge	0.193 inches
Angle of abutment face	4.0 degrees (approx.)

6. In order to form a comparison between the operation of the regulators as received and after they had been modified and adjusted, regulation runs were made at ambient temperatures of -55, +25 and +71 degrees Centigrade, both before and after regulator warm-up. The runs made prior to warm-up are referred to as "cold" runs while those made after the 30 minute warm-up period (pile dissipating approximately 30 watts) are called "hot" runs. For the "cold" runs, all data for the three speeds were taken as quickly as possible after the start of operations.

7. Another comparison of the temperature characteristics of the original and the modified regulators was made by placing the regulators in an ambient temperature of -55°C. for a period of at least 4 hours, then removing it to an ambient of +25° ± 5°C. and immediately connecting it to control an NEA-5 generator rotating at 6,000 R.P.M. A steady load (not shocked) of 5.0 amperes was applied so that the pile was dissipating approximately 30 watts. Readings of voltage and time were taken until the voltage stabilized. This procedure was repeated except that the regulator was allowed to saturate in ambient temperatures of +71°C. and +25° ± 5°C.

EFFECT OF CHANGING ABUTMENT RINGS

8. Although four regulators were tested, the data of only one, Serial No. 9712, are shown since the regulator was considered to be typical. The results of the regulation runs and the voltage versus operating time studies are presented in Tables I and II, respectively.

9. The results of the regulation tests indicate that a variation of 20 volts exists between extremes of ambient temperature. speed and load when a bi-metal ring is used while a **variation of 18.3 volts** exists under the same operating conditions but with an aluminum ring. The extremes are circled in Table I. Just as significant as this voltage variation is the initial voltage at a low ambient temperature. It will be noted (see Table I) that the initial voltage is 127.5 volts and 108.0 volts for the bi-metal ring and aluminum ring, respectively. In some of the regulators equipped with the bi-metal ring, this initial voltage was as high as 175 volts. It is thought to be more desirable to have a low initial voltage in view of the deletrious effect of high voltage on electronic gear.

10. The results of the time versus volts test indicate that a regulator equipped with an aluminum ring is not as susceptible to temperature changes as one with the bi-metal ring. (see Table II). This is evident from the fact that after operating for 5 minutes in an ambient temperature of approximately +25°C. (subsequent to being conditioned at -55°C.) the voltage of

the regulator with the bi-metal ring decreased 8.4 volts while there was only a change (increase) of 1.9 volts when the aluminum ring was used.

EFFECT OF RECTIFIERS ON TEMPERATURE COMPENSATION

11. An investigation was conducted in an attempt to discover the reason for differences in regulation when different rectifiers were used. The Laboratory has attempted to acquire rectifiers with improved temperature characteristics but such rectifiers are not currently available.

12. The rectifier which was used in the Type 1317 Regulator and reported in reference (b) was substituted in the Type 1001 regulator, Serial No. 9712. The latter regulator was equipped with an aluminum ring. Regulation runs at ambient temperatures of -55°C., +25°C. and +71°C. were conducted. The results of these tests are presented in Table III.

13. The original rectifier (from the Type 1001 Regulator, Serial No. 9712) was then subjected to an aging test which consisted of placing it in an ambient temperature of +71°C. for 14 days while 50 volts A.C. was impressed upon it with a resistive load of 200 milliamperes. The effect of rectifier aging on voltage regulation is shown in Table IV.

14. It will be noted that while a variation of 18.3 volts exists in Table I (regulator equipped with original rectifier, unaged), a 15.5 volt variation is evident in Table III (regulator equipped with rectifier used in Type 1317 regulator and known to have aged). In Table IV (regulator equipped with original rectifier which was given accelerated aging), the voltage variation was decreased from 18.3 volts to 16.8 volts. Also the initial voltage at -55°C. has been increased from 108.0 to 111.5 volts. The raising of the A.C. voltage is to be expected since the decrease in D.C. output voltage resulting from aging of a rectifier causes the carbon pile resistance to decrease. Hence, the regulated A.C. voltage increases.

15. In reference (d) the effect of ambient temperature on rectifier characteristics is discussed. One effect is the change in efficiency, viz., at an ambient temperature of +63°C. the efficiency increased 10 per cent over that at +24°C. while at -50°C. it was 7 per cent lower than normal. Another effect is that the load rating of the cells decreases rapidly with an increase in ambient temperature. The process of increasing cell resistance known as aging is accelerated at high ambient temperatures. However, the aging curve is a function of specific conditions and cannot be readily predicted. Clark, in reference (f), states that aging takes place within the first 10,000 hours at

full rated continuous load. After this time a constant output value results. The author further states that the maximum safe plate temperature should not exceed +75°C. However, Richards, in reference (e), states that +85°C. is a safe maximum limit. It is quite evident from the results presented in this report that these rectifier characteristics bear a direct relationship to the behavior of a voltage regulator.

CONCLUSIONS

16. The temperature compensation of the Eclipse 1001 A.C. carbon pile voltage regulator was improved by replacing the bi-metal abutment ring with an aluminum ring having the same dimensions. The following characteristics were noted as a result of this modification:

(a) At extremely low temperatures, the initial voltage was low though within the minimum limit of most electronic gear.

(b) The regulation over extreme ambient temperature, speed and load ranges is improved.

(c) The effect of rectifier aging is to aid the temperature compensation of the modified regulator equipped with the aluminum abutment ring.

RECOMMENDATIONS

17. It is recommended that all Eclipse Type 1001 A.C. carbon pile regulators now in service and those contemplated for future use be modified by replacing the bi-metal abutment ring and its auxiliary ring with an aluminum ring, the dimensions of which are given herein.

18. Although the characteristics of rectifiers have a definite influence on regulator behavior, this influence is not considered to be the major change needed. It is felt, rather, that this type of voltage regulator should be improved in all its component parts.

REFERENCES

(a) BuAer ltr to NRL Aer-E-3121-SHH, F36-1(1), Serial No. 93971, dated 5 June 1945.

(b) NRL Interim Report, E-2737, dated 7 January 1946.

(c) BuAer Specification for Airborne Regulators Nav-Aer M-615 of 1 June 1945.

(d) "Characteristics and Applications of the General Electric Company Selenium Rectifier Cells" by E. A. Harty. AIEE Technical Paper 43-124 of June 1943.

(e) "Characteristics and Applications of the Selenium Rectifier" by W. H. Richards. Journal of IEE Vol. 8, Part II, 1941.

(f) "Selenium Rectifiers" by Carole Clark. Product Engineering. March 1942.

TABLE I

REGULATION RUNS

Conditions: All tests conducted at indicated ambient temperature. "Hot" indicates that unit was warmed up for 30 minutes in indicated ambient temperature.

REGULATION RUNS AT VARIOUS AMBIENT TEMPERATURES

		REGULATED VOLTS							
		BI-METAL RING				ALUMINUM RING			
	Gen.	Cold		Hot		Cold		Hot	
Temp. °C.	Speed R.P.M.	No. Load	Full Load	No Load	Full Load	No Load	Full Load	No Load	Full Load
-55	4,500	127.5	119.4	112.5	111.3	108.0	107.8	113.2	110.9
	6,000	125.4	113.9	114.0	111.0	109.0	106.0	112.5	110.0
	8,000	123.0	109.6	115.0	109.8	109.1	102.8	113.0	106.0
+25	4,500	117.5	114.1	113.7	111.9	112.0	110.0	116.2	113.5
	6,000	116.9	113.1	114.2	111.2	111.9	109.0	117.0	113.0
	8,000	119.0	111.5	115.7	109.0	112.1	105.0	117.5	108.0
+71	4,500	113.8	111.0	112.3	110.0	115.2	113.0	120.2	117.9
	6,000	112.9	110.4	112.9	109.6	115.9	112.5	120.3	117.1
	8,000	113.9	107.8	113.9	107.5	115.5	107.5	121.1	112.2

TABLE II

Regulated Voltage as a Function of Operating Time

Conditions: After being in the indicated ambient temperature for at least 4 hours, the regulator was removed to an ambient temperature of +25° ± 5°C. and immediately made to control the NEA-5 generator at such speed (6,000 R.P.M.) and load (5.0 amperes) as to make the pile dissipate 30 ± 5 watts.

REGULATED VOLTS

	-55°C.		+71°C.		+25°C.	
Minutes	Bi-Met. Ring	Alum. Ring	Bi-Met. Ring	Alum. Ring	Bi-Met. Ring	Alum. Ring
0*	122.0*	108.2*	114.0*	114.5*	120.0*	111.5*
0	121.0	107.0	112.0	114.0	119.0	111.2
2	116.0	107.1	113.1	115.3	121.2	112.2
5	112.6	107.7	111.8	115.5	119.9	112.3
7	112.0	108.9	111.0	115.9	118.5	112.7
10	111.9	111.5	110.2	116.1	117.5	113.0
15	112.3	112.0	109.5	116.5	116.3	113.8
20	112.8	114.4	109.3	117.0	116.2	114.5
25	112.7	115.6	109.1	117.1	115.9	115.0
30	112.3	116.9	109.1	117.1	115.5	115.5
35	112.2	117.8	109.1	117.2	115.2	116.0
40		118.1	110.1	117.2	115.1	116.2
45		119.0		117.3	115.0	116.5
50		119.1			115.0	116.8
55		119.5			114.6	116.9
60		119.8				117.0
65						
70						
	↓	↓	↓	↓	↓	↓
Load Shocked	112.7	120.1	110.1	117.2	115.1	117.7

Note: * No Load

TABLE III

REGULATION RUNS WITH SUBSTITUTE RECTIFIER

Conditions: These tests are similar to the tests shown in Table I for the aluminum abutment ring except the original rectifier was replaced by the rectifier taken from the regulator reported in reference (a).

REGULATION RUNS AT VARIOUS AMBIENT TEMPERATURES

REGULATED VOLTS

		Aluminum Ring and Substitute Rectifier			
		Cold		Hot	
Temp. °C.	Gen. Speed R.P.M.	No Load	Full Load	No Load	Full Load
-55	4,500	117.0	114.9	118.0	116.1
	6,000	117.5	113.0	118.1	115.0
	8,000	118.0	108.0	119.0	111.0
+25	45,000	117.1	115.1	118.9	117.1
	6,000	117.2	114.3	119.5	116.8
	8,000	118.0	110.0	120.0	111.9
+71	4,500	118.2	116.0	122.3	120.2
	6,000	118.5	115.0	123.0	119.5
	8,000	119.0	109.0	123.5	114.0

TABLE IV

REGULATION RUNS WITH ORIGINAL RECTIFIER WHICH HAD BEEN AGED

Conditions: These tests are similar to those shown in Table I for the aluminum abutment ring except that the original rectifier was aged in the manner reported herein (See paragraph 13).

REGULATION RUNS AT VARIOUS AMBIENT TEMPERATURES

		REGULATED VOLTS			
		Aluminum Ring and Aged Rectifier			
		Cold		Hot	
Temp. °C.	Gen. Speed R.P.M.	No Load	Full Load	No Load	Full Load
-55	4,500	111.5	110.0	114.0	112.5
	6,000	111.6	108.1	114.0	111.0
	8,000	111.1	104.0	114.0	107.0
+25	4,500	113.0	111.5	117.5	115.3
	6,000	113.0	110.5	118.0	114.6
	8,000	113.5	106.8	118.1	110.0
+71	4,500	117.0	114.3	119.8	117.2
	6,000	116.5	113.5	120.0	116.5
	8,000	117.2	109.0	120.8	111.0

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