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FINAL REPORT

BATTERY CHARGING HANDCRANK GENERATOR, HG-3

Specification No. 58-A1071-A
Dated 8 May 1958

[redacted] W.O. 604)

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Submitted by

[redacted]

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Prepared by: [redacted]

Approved by:

May 6, 1960

Distribution: ARD (Copies #1-#9)
Contracting Officer (Copy #10)

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FINAL REPORT

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PURPOSE

The purpose of this project is to develop a portable battery-charging, handcrank generator consisting of a voltage generator, power regulator, and indicating meter. This device is to enable one man to efficiently and quickly recharge secondary batteries of the nickel-cadmium and lead acid type. The electrical and mechanical design of the unit, designated as the HG-3, shall be especially directed toward the development of a miniaturized product having a high degree of reliability when exposed to rough handling during the field usage. In addition to the above objectives, the performance requirement of Specification No. 58-A1071-A concerning operating life, noise, etc. must be met.

SUMMARY

The subject task calling for the development of a lightweight handcrank generator for battery charging has now been completed. The ten (10) prototype models have been constructed and shipped to the Government technical representative with the related accessories, instruction books, and drawings. This report constitutes the last item of the contract and its acceptance will officially close out the contract.

It is felt that the results of this project have been successful and have justified the expenditure of the time and money allotted. A lightweight, compact handcrank generator has been developed which is inherently self-regulating and of non-critical maintenance-free construction. Its operation is simple, requiring a minimum of instruction, and as a further safeguard, the unit is protected against incorrect operation or connection. Its efficiency is comparatively high, considering the inherent dissipation in high current-low voltage devices, being approximately 60% to 65% over the cranking range.

To aid the operator in determining the state of charge of the battery and the necessary cranking rate, indicating features are provided showing current flow and full-charge condition for the battery. A variety of fastening methods have been provided through the use of webbed straps and a can-opener-type mounting plate.

The past several months, since the submission of Progress

Report No. 8, have been spent in repair and modification of the second prototype model and construction of the eight (8) remaining field models. The modification work on the second model was comparatively minor in nature, being concerned mainly with revision of the crank handle and hub, and the wall mounting fixture, and in no way affected the general system and layout of the generator. The eight field units have been constructed identical to the modified second model and are felt to be in agreement with the Government specifications.

Although the eight models were constructed within the remaining funds, the time required was somewhat longer than was originally expected due mainly to difficulty in obtaining fiberglass cases of high quality workmanship. The cases actually used are definitely below standard but are believed to be the best the manufacturer can or will supply. Since the faults in the case do not particularly compromise the strength or usefulness of the units, agreement was reached with the Government technical representative that they would be acceptable for these eight models. Numerous other minor difficulties plagued the construction of the eight units but none of these were other than what normally would be expected in the construction of handmade samples. The eight units have been tested extensively and duplicate the results obtained with the second prototype sufficiently that they are considered to be acceptable working models.

This Laboratory is now engaged in a production engineering

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study of the HG-3 generator. It is expected that this study by the development of complete and efficient tooling, the use of high quality molded parts, and the substitution in the electronics of more economical components will enable a manufacturer to construct this generator at a much lower cost and with much greater ease than present methods allow.

The HG-3 generator is basically a very simple electro-mechanical transducer, the output characteristics of which are noncritical and straightforward. The majority of the electronic circuitry employed is for intermittent duty only and during normal operation is not in use. Furthermore, since the electronics is basically switching circuitry, it also is reasonably insensitive to varying component parameters. It therefore follows that if the unit can be made of inexpensive material and components, its economical production is almost assured. While the ten (10) units as supplied to the Government are within the specifications and will undoubtedly meet the operating life requirements with comparatively little trouble, they are hand-made samples and were constructed primarily to prove the feasibility of the device. The production engineering study, therefore, is a very necessary and logical follow-up phase for this development contract now being completed and should lead to the overall goal, namely the economical procurement of handcrank generators in production quantities.

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DETAILED DISCUSSION

A. Review of Past Work

1. General

In order to obtain a clear understanding of the progressive development of the HG-3 generator, a brief chronological review of the work progress is in order. Details of these phases may be found in previous eight progress reports, together with pertinent drawings and wiring diagrams.

2. Power and Current Regulation

At the inception of the project, it was believed that the development of a subminiature power and current regulator would require the greater share of time and money and, therefore, was undertaken as the initial phase of the development. To attain the specified regulation characteristics, two parallel approaches were studied. The first involved a servo-type regulator in which two silicon-controlled rectifiers, acting as ideal switches, would be triggered by a feedback magnetic amplifier which, in turn, would be controlled by a one ampere sensing element. It was felt that this type of regulator would be non-dissipative in nature because of the characteristics of the silicon-controlled rectifiers and thus be in keeping with the high efficiency requirements of the specification. The second approach involved a more simple network using a series power transistor which would be biased to a one ampere flow rate. While this would be a comparatively inefficient method, it also would be far less complex, less expensive and more compact. However, because of the inherent inefficiency and, also, difficulty in stabilizing the current to one ampere, this alternate approach was soon dropped in favor of the first.

The development of the non-dissipative type regulator was pursued actively during the early phases and was brought to a rather high degree of performance and stability. Its main disadvantage was a high degree of circuit complexity, which would have made the packaging problem more severe. It should be borne in mind, however, that the non-dissipative power regulator developed did result in acceptable regulation over a fairly wide frequency and temperature range and did definitely result in invaluable experience, particularly with respect to advanced solid state switching techniques.

Concurrently with the completion of the development phase for the non-dissipative power regulator, the first prototype generating unit was also completed. Preliminary tests showed that the self-impedance of the generator was considerably higher than expected. In operation, the actual result was a source impedance of sufficient magnitude to make the unit a current generator rather than a conventional voltage generator. Further experimentation showed that the generator's impedance was almost purely inductive and could be adjusted to such a value as to hold the output current into a 12-volt battery at a range of approximately 1.0 to 1.3 amperes over the specified handcranking range. A constant current, non-dissipative generator had been actually developed which eliminated the need for any external regulating means. It was found that the only external components actually needed were a fullwave bridge, a filter condenser and filter choke, and the only other electronics required were for auxiliary (indicating or protective) features. Furthermore, in addition to regulating the current to approximately constant value, independent of speed, the high source inductance of the generator also effectively provided the first leg of the T-filter, thus eliminating a large separate iron core choke which had been found necessary in the earlier investigations.

The above results, of course, eliminated the need to develop a separate power and current regulator and this work phase was halted immediately. The problem of holding the current to 1.0 ampere then became a part of the generator design phase, basically being dependent upon proper choice of magnetic rotor configuration and the number of turns in the windings. In optimizing these parameters, a constant current, one-ampere generator was soon developed and it was further found that in addition to holding a one-ampere rate over the cranking range, the current plateau dropped for battery packs of more than 10 cells, clamping the power output at approximately 15 watts, also a requirement of the specifications. Therefore, all following work was carried out on the basis of employing the inherent self-regulation characteristics of the basic generator unit.

3. The Basic Generator Unit

The initial development of the basic generator unit was governed by three primary factors, namely, a compact, simple and rugged construction, a comparatively low rotor speed because of the noise problem in a high speed ratio, and avoidance of electromechanical commutators because of the disadvantage of brush wear, sparking, noise, etc. These factors indicated the desirability of a simple magneto-type alternator using a permanent magnet rotating field, thereby avoiding the complexity of a separately energized field and distributed stator windings.

Because of the acoustic noise specification of 50 db. maximum, it was felt that the speed step-up mechanism should have as low a ratio as compatible with the cranking speed, and therefore a four-pole rotor was chosen as a suitable compromise, eliminating the high speed required for a two-pole arrangement or the complicated coil configuration required in a six-pole configuration. It has been calculated that in order to avoid a severe filtering and regulation problem, an output frequency from the alternator of 60 cycles for a cranking speed of 60 rpm. would be a minimum figure. This called for a speed ratio of 30:1, which was felt to be feasible through the use of either timing belts or gears.

In order to have the windings delivering current continuously, it was found advantageous to use a series-connected stator and fullwave bridge rather than a center-tapped winding and two-diode rectifier. For the stator core, 4 mil Orthornol laminations were originally chosen, although this was later changed to 12 mil Silectron material for reasons of economy.

Most of the development work in the generator unit eventually centered about the design of a proper rotor. Initially, Alnico rotors were procured because of their comparatively high flux density. The original breadboard model used a four-pole Alnico rotor and its performance gave the required current output. It was found that as much as 25% of the input power was lost in the rotor due to severe eddy currents. Because of the high premium put on operating efficiency, it was decided to eliminate the Alnico rotor and use instead a rotor constructed of a ceramic permanent magnet material known as Indox 5, manufactured by Indiana Steel Products Company. A number of designs, differing mainly in pole dimensions, were constructed and upon test the efficiency of the rotor was found to be excellent. While the theoretical flux density of this material is considerably lower than Alnico 5, the difference in operating flux density is not as great because the magnets are air stabilized before installation. Furthermore, Indox 5 was found to have at least twice the stability of Alnico and therefore was less sensitive to environmental factors such as heat, vibration, etc.

Having found an acceptable rotor design, it remained a matter of choosing the correct number of turns to obtain the desired current amplitude. It was shortly found by empirical experimentation that a large number of turns would provide a greater voltage at lower speeds but would also result in a larger source inductance, therefore lowering and flattening the current plateau. On the other hand, a smaller number of turns, while not having the regulation nor as large a current delivery at the lower cranking speeds, did result in rather high current delivery at the lower cranking speeds. The final choice, therefore, was a matter of compromise.

The present design uses two series-connected windings of No. 19 Heavy Formvar wire and provides a regulation of approximately 5% into a battery terminal voltage of approximately 13 volts. These figures are for the specified cranking

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range of 60 to 100 rpm. It may be further noted that considerable current delivery is also available at 50 rpm. and that the regulation is maintained through a higher speed range than specified. The speed has been taken up to 140 rpm. with only a slight increase in output current. While the Indox rotor must be fabricated instead of cast, it is still felt that the gain in operating efficiency, in view of the fact that this generator must be manually cranked, justifies this substitution.

4. Rectifier and Filter

Throughout the development the main problem with the rectifying and filtering components has been one of size. Because of the distinct advantage of the generator design of using a single winding output, a fullwave bridge was required for the rectifying element and the choice of the General Electric 1N91 germanium diodes with two in parallel for each leg of the bridge was made quite early in the development. Although 4 silicon diodes would have sufficed for this component, the premium placed on operating efficiency dictated the choice of germanium diodes because of their lower forward voltage drop. Actually, the difference in efficiency between the two is rather small and because of the assembly and size problem in using 8 diodes as opposed to 4, it is believed that future models could justify the use of silicon diodes.

For the filter, it had been planned from the start of the project to use a lowpass "T" filter consisting of two iron core chokes and one large tantalum electrolytic capacitor. When the non-dissipative regulator was being investigated, a breadboard filter was made up in order to feed the D.C. output current to the batteries and it was determined that the first choke in this filter had to be very large due to the large iron area and turns required for effective filtering at 60 cycles. When it was found that the self-inductance of the generator, in addition to regulating the current, also provided an effective input leg for the filter, the large separate choke was quickly eliminated. Sufficient filtering was obtained through the use of a 1200 mfd. electrolytic tantalum capacitor and a small, two-winding choke using an AL-71 Silectron C-core, although several other core materials and capacitors were tried initially. Again, the filter represents somewhat of a compromise in the efficiency parameter since the greater the number of turns in the choke, the smaller the capacitor can be. The values reached above were felt to be justified since it allowed the replacement of a 2500 mfd. capacitor with the considerably smaller 1200 mfd. size. The power loss in the choke is estimated to be approximately 0.3 watts and further optimization would only result in a very slight decrease in this figure.

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5. Indicating Features

The original specifications called for voltage and current indication requiring a multipurpose miniature meter with a selector switch. It was soon realized that such a device would be impractical because of space considerations, and therefore a subordinate investigation was required.

The problem of indicating current was solved fairly early with the procurement of a subminiature milliammeter made by Marion Electrical Instruments Company. By reading the voltage across a 0.5 ohm resistor in the output lead, and placing a germanium diode in series with the meter, the current range was shifted from zero to 1.0 amperes to 0.5 to 1.0 amperes. As such, the operator is given a reasonably good indication, since in the extreme left position of the needle, the current is at half value and in the extreme right, is at the full one ampere value.

The problem of indicating output voltage was found to be far more severe since the voltage charging characteristics of Nicad batteries generally have a very slow rise and, furthermore, are dependent upon ambient temperature. Only a high precision voltmeter could be used to give a state-of-charge type of information and even this would only be accurate at room temperature if no compensating means were included. Obviously, a new approach was required and the result was the development of the circuit now employed, which is basically a transistor-driven incandescent lamp triggered on by a Zener diode-resistor network. The charging characteristics of Nicad batteries were found to experience a comparatively sharp rise at a point where the batteries reached 90% to 100% fully charged. By designing the Zener diode-resistor network to have a firing voltage approximately at this point, the turning on of the lamp indicates to the operator that his batteries are at a state-of-charge of approximately 80% to 100%. Because of ambient temperature conditions and differences between various types and capacities of nickel-cadmium batteries, this indicating point represents a compromise and the final setting will probably be dictated by field experience more than any other factor. The circuit can be adjusted for different "fully charged" values. Therefore, for a given battery configuration and approximately known temperature conditions, it can probably be modified for a setting very close to 100%. Even without modification, it should serve as a valuable indicator after a brief period of familiarization in field usage.

6. Protective Features

The HG-3 electrical system, as originally conceived, consisted of an alternator, fullwave bridge, filter and indicating means. With correct connection and usage, no electrical trouble was envisioned. However, because of its possible use by untrained personnel in the field, several protective features were requested during the development to guard against the possibilities of operating into an open load circuit (such as the clip lead falling off the battery terminal during operation), or incorrect battery connection to the generator (due, possibly, to indistinct polarity markings on the battery). Without protective features, the first condition due to the sudden loss of armature reaction in the generator can result in very high output voltage which, of course, can cause failure in the filter capacitor, transistor and Zener diodes. The second condition, by inspection of the wiring diagram, can result in a severe short circuit current through the rectifier diodes, burning them out.

To provide protection against an open circuit condition, it was first decided to employ a heavy duty Zener diode which would simply clamp the output voltage at a rate sufficiently above the battery terminal voltage so as not to bother normal operation, but sufficiently low to protect the critical components. Except for cost, this solution seemed quite simple and was incorporated in one of the early models. The later request, however, for a circuit to protect against incorrect polarity, lead to the development of a transistor-driven relay circuit employing a red indicating light and further investigation showed that by proper circuit arrangement, both features could be supplied using the same components and thereby eliminating the high power Zener diode. The present circuit was the result of this experimentation and operates, in general, in the following manner.

In the event of an open load circuit, a Zener diode-resistor network in the base of a low power transistor recognizes the increase in output voltage, turning on the transistor and energizing the relay. The relay, in turn, closes in a 5 ohm load across the generator which then delivers approximately 1.2 amperes into this load. This low voltage is sufficient to hold the relay in and therefore the circuit is protected until the crank stops. In the case of reverse battery connection, the relay is energized through a diode and simply opens up the path to the remainder of the generator electronics, protecting the bridge elements and filter condenser from high current surges. In this condition, the red indicator light is immediately energized, indicating the incorrect connection to the operator. Lamp indication is not necessary in the case of an open load condition since the sudden decrease in manual input power (because the output power will have dropped from 12 to 15 watts down to 5 or 6 watts) is definitely noticeable and therefore the condition is brought to the operator's attention.

Operation of these circuits is considered quite positive and relatively trouble-free. They have the

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advantage of being free from component failure for a very long period of time due to the very minor operating duty imposed upon them. Assuming the generator is always operated correctly, this circuitry will actually never be energized and, therefore, should contribute to a comparatively trouble-free operating life for the generator.

7. Mechanical Drive System

After establishment of the generator rotor speed, investigation was started to determine a suitable speed step-up mechanism for the 30:1 ratio required. In view of the low acoustical noise requirement, it was felt that a timing belt arrangement would be desirable and provide considerably quieter operation than a gear train. Such a drive was included in the first model submitted to the Government and, although it provided a very low noise figure, the mechanical stresses were such that a severe cogging action was noted after a short operating period due to excessive wear of the timing belt. As a compromise correction to maintain quiet operation, the first stage of the transmission was changed to gears and this hybrid system was substituted in the first model. At the same time an investigation was made into the use of a complete gear transmission using nylon drive gears and stainless steel pinions. It was found that the completely geared transmission did not result in as severe a noise problem as expected and a change to this type of drive was made because of the increased efficiency and the considerably reduced mechanical complexity. This gear train has now been standardized in the present models and with the use of a proper lubricant, found to operate quite well and will, undoubtedly, furnish the 1000 hours operating life required in the specification without trouble. The noise output is approximately 56 db.; because these specifications represent design goals rather than absolute requirements, this figure has been accepted by the Government authorities. The 6" crank provided with the generator was the result of considerable study into the associated human engineering factors in which it was determined that this dimension resulted in comfortable cranking action.

8. Packaging and Mounting

The original development phases of this generator were based on the use of a die cast aluminum case, chosen primarily because of the weight limitation and its resistance to shock, vibration and wear. Unfortunately, the first prototype models showed that the use of aluminum was extremely detrimental to the efficiency because of the eddy currents resulting from the inherently loose magnetic circuit of the magneto-type generator unit. Since stainless steel having high resistivity was prohibitive from both an expense and weight standpoint, it was decided to design a case of non-metallic material. For reasons of expediency, a molded fiberglass case was procured. This design has resulted in an extremely strong structure, although it is somewhat expensive to manufacture. A definite economy can undoubtedly be made in future production by going to a molded case using some compound such as nylon, Delrin, etc. It was not economically feasible during the development to engage in this particular type of fabrication because of the rather expensive mold costs and the requirement for only ten units.

The specifications originally called for mounting facilities such that the generator could be fastened securely to a table, a table leg, a post, tree, etc., or a person's knee. Experimentation over the course of the project has proved fairly conclusively that fastening to the human knee would result in excessive operator fatigue and therefore is unrealistic. All models have been made with facilities for fastening to posts or trees by the incorporation of rings for webbed straps on the sides of the generator case. During the course of the project, a further request was made by the Government to have the generator contain a wall mounting fixture in the same fashion as the ordinary can opener. This has been done by providing a separate back plate which can be wood-screwed to a wall and putting slides on the back of the

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generator such that it can be slid into the back plate securely and cranked in a vertical position. By providing slots for webbed straps in this back plate, the facility for mounting to a flat table is also offered. For this type of mounting, the back plate is strapped to a table and the generator is cranked in the horizontal plane. For a simple and rapid mounting means, it has also been found that the generator can be fastened by securing the back plate to a table top by means of double-sided adhesive tape, again cranking horizontally. The tape must be changed each time but the use of straps is avoided.

B. <u>Work Progress Since Report No. 8</u>

Since submission of Progress Report No. 8 the second prototype model of the generator was modified in line with the Government's evaluation report, dated November 27, 1959, and resubmitted to the Technical Representative in early December, 1959, following a conference with Government engineers on December 4, 1959. These modifications consisted, mainly, of revisions of the main hub and crank assembly in order to prevent the crank from scraping against the generator case during operation, and a revision of the wall mounting back plate assembly to provide a more compact arrangement.

A minor change was also made in the "full charged" indicator circuitry in that the compensating thermistor was

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eliminated and a straight resistive network substituted. This was done after agreement with the Government engineers that temperature compensation for this circuit was of questionable value due to the varying characteristics of different Nicad batteries, and was further complicated by the inherent build-up of heat inside the generator case due to normal dissipation, this build-up being entirely variable depending on the amount of cranking time. In other words, since there is no way to pre-program the compensating circuit for the large number of combinations of conditions that could exist in practice, it is rather pointless to include the thermistor which is an additional item of expense and, also, somewhat fragile. Therefore, the fully charged circuit indications are valid only at room temperature $\pm 30^{\circ}$ F. Above and below these temperatures the operator should keep a log of the amount of the charge delivered to the battery. This, actually, is a very simple matter since, the HG-3 being a one-ampere generator, he need only multiply by the time he has cranked to determine the amount of ampere-hours delivered to the battery.

At the time the changes on the second prototype model were firmed up, this Laboratory also received approval to construct the eight (8) additional models in line with revised Model No. 2. The majority of the work from that time to the present date has been given to this task. Although there have been some minor difficulties in building these eight models, the "bugs" encountered have been, in actuality, nothing more than would normally be expected in the construction of hand-made models following the development of a prototype. The only major trouble encountered has been in the procurement of fiber glass cases of good quality workmanship. This has not been accomplished and the cases supplied for the eight models have been accepted only because they apparently are the best that the supplier can provide and are the result of a second complete run, the first having been rejected by this Laboratory. Therefore, these cases are actually not considered acceptable workmanship by the Laboratory and are only being sent for reasons of expediency and, also, because future models will undoubtedly use a different molding material and process. It should be noted, however, that the cases are believed sufficiently satisfactory for field use and experimentation and since this is their primary purpose, should not present any particular problem to the Government.

After fabrication, the eight models were given a complete electrical and mechanical checkout. The performance results are shown in Figure 2 which indicates a fairly close grouping, particularly when it is borne in mind that the electrical parts were taken from stock without any parametric selection. Figure 1 shows the final electrical schematic.

The experience gained in the construction of these eight units has been very valuable to the Laboratory since it has pointed out various areas in which improvement from a quantity production standpoint can be made to facilitate easier assembly and parts fabrication. This information has been of tremendous help in carrying out the production engineering study and it is considered actually fortunate that the construction of the eight generators was delayed such that the two projects ran concurrently in that it allowed the personnel concerned with the production engineering study to observe the generator being fabricated and note the deficiencies in the assembly procedures.

During this past report period the 30 instruction books were made up in line with the corrections requested on the original draft submitted to Washington last month. The necessary sets of drawings have also been sent to the Government giving the manufacturing details of the various parts and assemblies comprising the HG-3. This final engineering report, then, constitutes the last deliverable item in the contract and its submission will officially close the project.

SUGGESTIONS FOR IMPROVEMENT IN FUTURE MODELS

This Laboratory feels that the present design of the HG-3 fulfills the design goals of the specifications and will meet the operating requirements outlined therein. The main areas for improvement are those concerned with ease and economy of production. It has been estimated that an expenditure of approximately $30,000 for tools would result in efficient production methods for this generator. Obviously, such an expenditure could not be justified in the development contract just completed. It is not meant to imply that the unit cannot be manufactured under present methods, since submission of the eight units shows that this can be done. This is, however, a comparatively expensive procedure and, as such, is not recommended for quantity production. The issuing of the production engineering contract is expected to result in a much less expensive unit through the fabrication of tools which will allow economical parts production in large quantity, and should be completely justified by making available a low cost, compact handcrank generator for battery charging.

The only area which this Laboratory feels is worth future investigation is the feature of indicating the fully-charged condition of the battery. Because this indicator is only accurate over a limited temperature range and may be misleading for certain types of Nicads now under development (since development in this field is in a constant state of advancement), it is questionable as to just how valuable this feature will be in field usage.

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This investigation, however, can only be made by the Government since they alone know just what type of batteries will be used and under what conditions they will be charged. It is recommended, therefore, that the Government engineers keep a close check on the field application of the eight models to see just how practical this particular indicating feature is in practice. Needless to say, if it turns out to be unnecessary or impractical, its elimination will save a definite amount of space and cost in future production.

There are several changes which could be effected in the generator electronics which would reduce the cost and alleviate the packaging problem considerably. These are, however, in the province of the production engineering study and, as such, will be the subject of future conferences with the Government engineers. To the best of our knowledge there are no recognized deficiencies in the present generator, the fully-charged circuit being mentioned only in the interest of practicality rather than from the point of an unstable or troublesome circuit design.

The only other area possibly worthy of investigation by the Government in the use of their field models is the general area of mounting features. The generator at low cranking speed takes a considerable amount of input torque and it is again questionable whether any strapping is sufficient to hold the unit securely, particularly in the case of a table mounting. Our experience has shown that the really only secure mounting methods are that of strapping to a rather sizable post or tree, wall mounting and horizontal mounting by wood-screwing the back plate to a table. This whole question, however, is best solved by field experience.

EXPENDITURES

As of April 1, 1960, a total of $72,194.69 has been spent on the contract.

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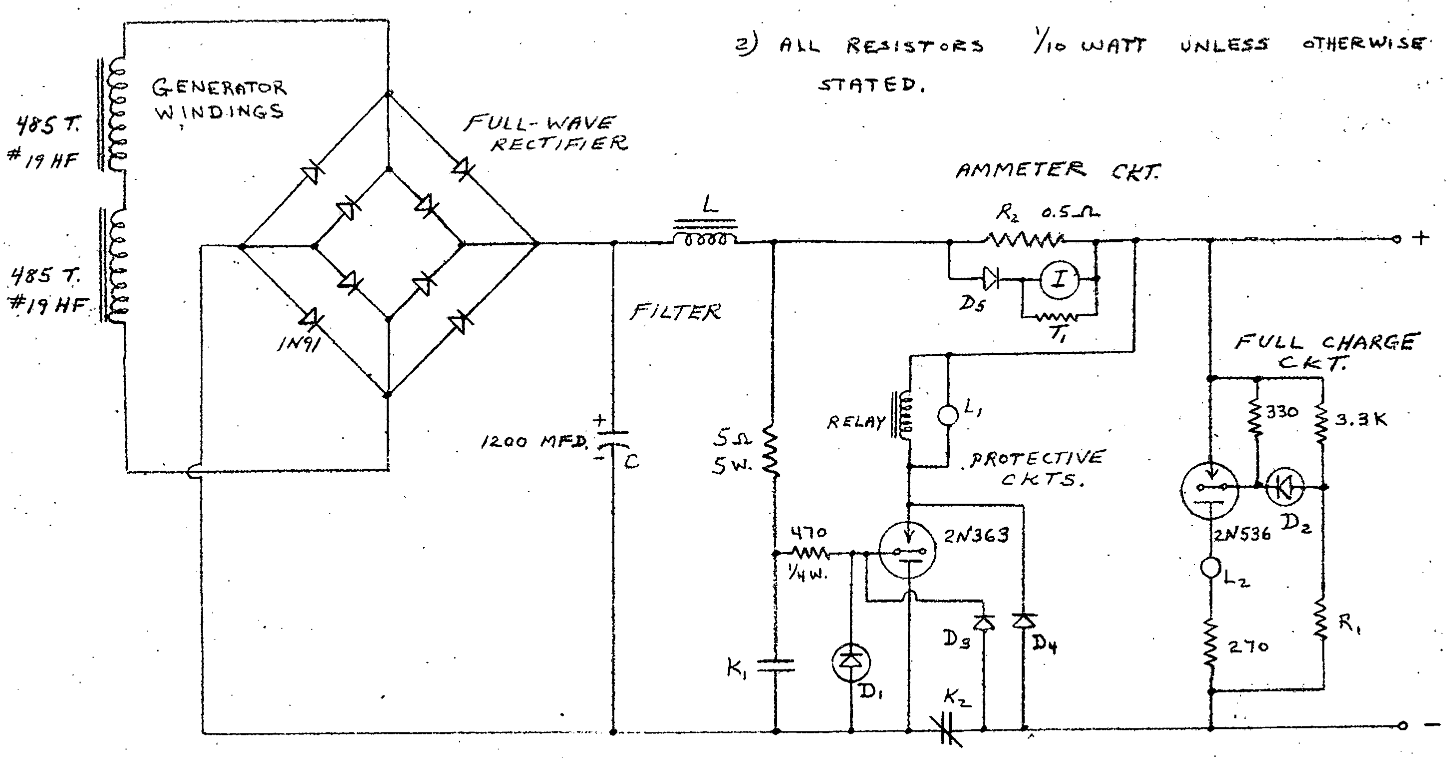
SHEET NO. ____ OF ____
JOB NO. W.O. 604

SUBJECT HG-3 HANDCRANK GENERATOR - SCHEMATIC
Figure #1

BY HN DATE 2/11/60
CHKD. BY ____ DATE ____

NOTES 1) R_1 SELECTED TO MATCH D_1, 800 – 1100 Ω.

2) ALL RESISTORS 1/10 WATT UNLESS OTHERWISE STATED.



CHOKE, L
150 T. #20 HF
CORE: ARNOLD ENGRG. CO.
AL-71
GAP: .003"

DIODES
D_1 – 1N1315, E_Z = 11.5 V.
D_2 – 1N1316, E_Z = 16.5 V.
D_3, D_4 – 1N677
D_5 – DR435

AMMETER
HCM 7/16
0 – 1.0 MA.
MARION ELEC.

RELAY
G.E. #3S2791G200A5

LAMPS
L_1, L_2 – G.E. #344

THERMISTOR
T_1 – KEYSTONE CARBON #L4504-10-73R

BY HN DATE 4/1/66
CHKD. BY ____ DATE ____
SUBJECT HG-3 HAND CRANK GENERATOR
SHEET NO. ____ OF ____
JOB NO. 604

UNIT NO.	SHORT-CIRCUIT CURRENT AMPS.-60RPM	RIPPLE FACTOR AT 60 RPM.	"REST" DRAIN MA.	"FULL CHARGE" SETTING VOLTS	OUTPUT CURRENT AMPS.						
					BATTERY VOLTS	CRANKING RATE RPM					
						50	60	70	80	100	120
513	1.13	1.32	3.4	14.7	13.3	.94	1.01	1.04	1.05	1.07	1.08
					14.7	.87	.95	1.00	1.02	1.05	1.07
514	1.14	1.32	3.1	14.6	13.3	.94	1.02	1.06	1.08	1.09	1.11
					14.8	.87	.97	1.01	1.04	1.06	1.07
515	1.16	1.35	3.0	14.7	13.2	.98	1.04	1.07	1.08	1.11	1.12
					14.7	.91	.99	1.03	1.06	1.08	1.10
516	1.11	1.20	3.2	14.6	13.3	.93	.99	1.02	1.04	1.06	1.07
					14.8	.85	.94	.99	1.01	1.03	1.05
517	1.12	1.30	3.3	14.7	13.2	.94	1.00	1.02	1.05	1.07	1.08
					14.7	.87	.95	.99	1.02	1.05	1.06
518	1.18	1.50	3.4	14.6	13.3	.96	1.05	1.08	1.10	1.12	1.15
					14.7	.90	1.0	1.05	1.07	1.08	1.11
519	1.10	1.50	3.2	14.6	13.2	.91	.98	1.02	1.03	1.05	1.07
					14.7	.83	.94	.98	1.00	1.02	1.04
520	1.17	1.40	3.3	14.7	13.2	.99	1.05	1.08	1.70	1.12	1.14
					14.7	.93	1.01	1.05	1.07	1.10	1.11

PERFORMANCE CHARACTERISTICS AND TEST DATA FOR HG-3 FIELD MODELS.

FIG. 2