NATIONAL BUREAU OF STANDARDS REPORT

7040

Electrical Characteristics

of

Static Inverters

For Battery-Operated Fluorescent Seadrome Lights

by

L. Chernoff
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U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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L. Chernoff
R. T. Vaughan

Prepared For

Ship Aeronautics Division
Bureau of Naval Weapons
Department of the Navy
Washington 25, D.C.

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Electrical Characteristics of Static Inverters For Battery-Operated Fluorescent Seadrome Lights

1. Introduction

The type FMF-6B buoy-mounted, 6-watt, fluorescent channel marker light in use at present has as its power source a 90-volt dry battery pack. Its circuit employs a starter switch and ballast resistor. The switch is manipulated by striking a treadle on the pedestal assembly of the light, a procedure usually accomplished from a service boat by a crewman employing a boat hook. When a 6-watt green, fluorescent lamp is used, the intensity is about 27 candles, the lamp current is 110 milliamperes, and the efficacy of the light is about 2.7 candles per watt output from the battery. With a duty cycle of 8 hours per day, the battery pack has a life of about three weeks.

Some changes in the present light are desirable (see NBS Report 5893). These include improved switching, increased efficacy, and longer battery life.

The present method of switching the light has been found to be cumbersome, time-consuming, and costly. The service boat must stop at each buoy, and in rough or choppy water this has resulted in lost and damaged buoys.

A modification was suggested (NBS Report 5781) which allowed the lamp to be turned on or off by a momentary contact between a squirrel-cage antenna on the light assembly and a lightweight rod held by an operator in the service boat.

A transistorized photoelectric switch was considered (see NBS Reports 5889, 5981, 6225). Such a switch would allow the light to be turned on and off by directing a light at the switch. Physical contact, then, need not be made with the light itself and the FMF-6B light could be controlled from about 50 feet away. Since the photoelectric switch is transistorized, however, battery voltages of 12 volts or less would have to be used.

The efficacy of a fluorescent lamp when operated on alternating current will be greater than when operated on direct current. A few a-c types of power supplies were, therefore, considered.

A mechanical vibrator drawing power from a 6-volt lead-acid battery was tested. When used in the FMF-6B light, the green fluorescent lamp had an intensity of about 24 candles and the unit drew about 2 amperes from the battery. The efficacy was about 2.2 candles per watt output from the battery.

Transistorized inverters were then considered. An inverter to be operated with a 12-volt storage battery was obtained on purchase order from one company. The unit was compact and did not require an external ballast or starter since the inverter itself contained a ballast. However, the lamp current was only 30 milliamperes instead of the desired 110 milliamperes and the efficacy was less than 1 candle per watt.

Shortly thereafter a breadboard model of a transistorized inverter was voluntarily submitted by Walter Kidde and Company, Inc. Initial tests were promising with respect to efficacy and battery drain, and a service test quantity of inverters based on this design was purchased by the Naval Air Engineering Facility (Ship Installations).

2. Material Tested

Four static inverters manufactured by Walter Kidde & Company, Inc., Philadelphia 12, Pa. were received from the Naval Air Engineering Facility (Ship Installations) in August 1960. A dimensional diagram of the inverters is presented in Figure 1; Figure 2 is a schematic electrical diagram. The circuit is described by the manufacturer as an "Uchrin-Royer square wave oscillator circuit with reverse diodes across the switching transistors."

The inverters were designed to operate on an input of 12 volts d.c. and to deliver a current of about 150 milliamperes through a 6-watt fluorescent lamp.

3. Tests

3.1 General Procedure

Power for the inverters was obtained from four 6-volt dry batteries (type 2F4) connected in series parallel to give a nominal input voltage of 12 volts. Input current was measured by means of a d-c ammeter and input voltage was measured by means of a d-c voltmeter. Output current was measured by means of a moving iron type a-c milliammeter and root-mean-square output voltage was measured by means of an electrostatic voltmeter. Output wave forms were displayed on a cathode ray oscilloscope from which they were photographed.

3.2 Operating Characteristics

The output of each of the inverters was used in turn to operate each of two type F6T5/G fluorescent lamps. The lamps are 6-watt, green

fluorescent lamps, $8\frac{1}{4}$" in length, with T-5 bulb and miniature bipin bases. The lamps were manufactured by the General Electric Company. The operating circuit employed a starter switch but no external ballast and is shown in Figure 3.

The operating characteristics of the inverters are reported in Table I.

Table I

Inverter Operating Characteristics

Inverter	Input Voltage (Volts)	Input Current (Amperes)	Input Power (Watts)	Output Voltage (Volts)	Output Current (Amperes)	Output Power (Watts)	Efficiency
			With Lamp No. 1				
1	11.4	0.75	8.6	41.0	0.140	5.74	0.67
2	11.4	0.79	9.0	40.0	0.144	5.76	0.64
3	11.2	0.78	8.7	40.0	0.142	5.68	0.65
4	11.2	0.74	8.3	40.0	0.136	5.44	0.66
Average	11.3	0.76	8.6	40.2	0.140	5.66	0.66
			With Lamp No. 2				
1	11.2	0.78	8.7	43.0	0.138	5.93	0.68
2	11.4	0.80	9.1	43.6	0.142	6.19	0.68
3	11.2	0.81	9.1	43.0	0.137	5.89	0.65
4	11.2	0.76	8.5	43.0	0.133	5.72	0.67
Average	11.2	0.79	8.8	43.2	0.138	5.93	0.67

Three of the output waveforms are shown in Figure 4. The average output frequency of the inverters as determined from these three waveforms is 910 cycles per second.

3.3 Operating Characteristics with Shorted Output and With Open Output

The electrical characteristics of inverter number 3 were measured when its output was shorted and when it was open. These characteristics are given in Table II.

Table II

Electrical Characteristics of Inverter

Number 3 with Output Shorted and Open

Circuit Condition	Input Voltage (Volts)	Input Current (Amperes)	Input Power (Watts)	Output Voltage (Volts rms)
Shorted	11.5	0.44	5.1	-
Open	11.5	0.33	3.8	118.2

Figure 5 shows the output waveform of this inverter when it is operating with an open output circuit. After operating with both shorted and open output, this inverter showed no signs of any damage and no change in its operating characteristics.

3.4 Electrical Characteristics as a Function of Input Voltages

Inverter 4 was operated at the regular battery input voltage, with the input voltage increased about 1.5 volts, and with the input voltage decreased about 1.5 volts. Changes in input voltage were accomplished by using an additional 1.5-volt battery.

These measurements are reported in Table III.

Table III

Electrical Characteristics of an Inverter

Operating with Three Different Input Voltages

Unit No. 4 with Lamp No. 1

Input Voltage (Volts)	Input Current (Amperes)	Input Power (Watts)	Output Voltage (Volts)	Output Current (Amperes)	Output Power (Watts)	Output Frequency (Cycles per Second)	Efficiency
9.2	0.62	5.8	41	0.111	4.6	890	0.79
11.2	0.75	8.4	41	0.134	5.5	950	0.65
12.2	0.70	8.5	41	0.148	6.1	980	0.71

Output waveforms at these three different input battery voltages are shown in Figure 6.

3.5 Temperature Range of Peformance

Three of the inverters were subjected to below freezing temperatures to see if there was some lower limit of temperature at which they would operate. All three units stopped operating within the temperature range of 5 to 15 degrees Fahrenheit.

One of the inverters was subjected to temperatures well above the boiling point of water. At 250 degrees Fahrenheit, the inverter still operated satisfactorily. Some of the operating characteristics of inverter number 1 as a function of temperature are presented in Table IV.

Table IV

Operating Characteristics of Inverter Number 1 as a Function of Temperature

Lamp	Temperature (Degrees Fahrenheit)	Input Voltage (Volts)	Input Current (Amperes)	Input Power (Watts)	Output Voltage (Volts)	Output Current (Amperes)	Output Power (Watts)	Efficiency
1	30	11.3	0.75	8.48	41.0	0.137	5.62	0.66
2	30	11.3	0.76	8.60	41.5	0.138	5.73	0.67
1	140	11.5	0.76	8.74	40.0	0.138	5.52	0.63
1	194	11.5	0.80	9.20	40.0	0.134	5.36	0.58
1	240	10.9	0.90	9.81	39.0	0.131	5.11	0.52

3.6 Intensity of 6-Watt Green Fluorescent Lamps when Operated with the Static Inverters

Two of the inverters were used to provide power for each of six 6-watt fluorescent lamps. The lamps were the two used in the tests reported above and four more lamps of the same type.

Each of the lamps in turn was operated with each of two inverters. The lamps were operated until intensity stability had been reached and intensity measurements were then made. These intensity measurements were made using a photoelectric photometer employing a color-corrected photocell at a distance of 10 meters from the lamp with the lamp perpendicular to the photometric axis.

Lamp 4 was found to have an intensity of only about half the average intensity of the other five lamps. Since this average is in good correlation with previously reported values of intensity for this type of lamp (NBS Test 43A-27/43), it is assumed that lamp number 4 is defective and values for its intensity have not been used.

The results of these intensity measurements are given in Table V.

Table V

Intensity Measurements of 6-Watt Green Fluorescent Lamps Operated with Static Inverter

Unit	Lamp	Input Power to Inverter (Watts)	Lamp Current (Amperes)	Intensity (Candles)	Efficacy (Candles per Watt)
2	1	7.88	0.143	28.5	3.62
2	2	7.94	0.143	32.8	4.13
2	3	8.21	0.138	33.5	4.08
2	5	7.95	0.139	35.0	4.40
2	6	8.06	0.138	34.0	4.22
	Average	8.01	0.140	32.8	4.09
4	1	7.57	0.136	28.0	3.70
4	2	7.49	0.135	32.3	4.31
4	3	7.90	0.133	32.7	4.14
4	5	7.63	0.132	33.8	4.43
4	6	7.74	0.132	33.3	4.30
	Average	7.66	0.134	32.0	4.18

The intensity of a fluorescent lamp will increase as the frequency of the applied voltage increases[1]. During a previous test (NBS Test 43A-27/43) of the same type of lamp used in this test, the lamps were operated from a d-c source. For a given current, the intensity of the lamps operated by the inverters was about 10% higher than the intensity of those run on d.c.

[1]Meyers, G. A., and Strojny, F. M. W., Design of Fluorescent Lamps for High Frequency Service, ILLUMINATING ENGINEERING, Vol. LIV, pp. 65-70 (Jan. 1959).

3.7 Battery Life and Characteristics

Various types of battery packs for the FMF-6B light were considered. Comparison was made among two 12-volt battery types suitable for use with the inverters and two types of 90-volt packs (See Table V). The 90-volt dry pack is of the type in use at present. Of the two 12-volt battery types, the 12-volt dry battery was tested in order to determine if it is advantageous to back-fit the present FMF-6B lights for this battery and an inverter. The number of cells in this battery was chosen so that the volume of the battery would permit use of the present battery container.

In a life test of the 12-volt dry battery, the light was operated about 8 hours a day. After 30 days there was insufficient current to open the starter so that the lamp could operate. It was possible, however, to operate the lamp when the starter was removed from the circuit and a manual starting switch was used. It is estimated that with a suitable starter one to two more weeks of operation could be obtained from the 12-volt dry battery. Results of these comparisons are given in Table VI.

Table VI

Battery Life and Characteristics

Battery Type	Rated Volts per cell	Volts Total	Total Load (Amperes)	Rated Amp-hours	No. of cells req.	Weight (lbs)	Volume (cu.ft)	Length of Cycle (Months)	No. of Cycles Avail.	Total Months of Service	Cost ($)	Battery* cost per thousand Candle-hours ($)	Source of Informatio
Dry	90	90	**	--	4 parallel	45	0.6	0.6	1	0.6	31	8	NBS Test 43A-44/43
Silver-Zinc	1.5	90	**	60	60 series	110	1	2.5	60 to 100	150 to 250	4000	3 to 4	Manufacture
Dry	1.5	12	0.8	--	32 8 series 4 parallel	75	0.8****	1.0***	1	1.0***	47	6.2	Test for th report
Lead-Acid	2	12	0.8	600	6 series	500	4.5	3	20 to 30	60 to 90	150	0.35 to 0.55	Manufacture

* This figure does not include the price of the inverter, nor the cost of recharging the storage batteries.

** Not specified.

*** See discussion of tests in Sec. 3.7.

**** This figure represents the total volume of the separate cells. A single package with an equal capacity could be designed to have a volume of 0.6 cubic foot.

4. Conclusions and Recommendations

These static-inverters appear satisfactory for use in FMF-6B battery-operated fluorescent seadrome lights. Use of these inverters could provide higher intensity, greater efficacy, longer battery life, and reduced cost of operation. A photoelectric switch could easily be employed in lights using these inverters since the battery voltage would be suitable.

The results of these tests indicate that consideration should be given to changing the specification for the FMF-6B light to substitute a power supply employing a 12-volt dry battery and a static inverter for the present 90-volt power pack.

References

1. NBS Report 5893: Report of a Survey of Visual Landing Aids.

2. NBS Report 5781: A Redesign of the Switching Mechanism of the Type FMF-6B Channel Marker Light.

3. NBS Report 5889: Development, Testing, and Evaluation of Visual Landing Aids Consolidated Progress Report for the Period January 1 to March 31, 1958.

4. NBS Report 5981: Development, Testing, and Evaluation of Visual Landing Aids Consolidated Progress Report for the Period April 1 to June 30, 1958.

5. NBS Report 6225: Development, Testing, and Evaluation of Visual Landing Aids Consolidated Progress Report for the Period July 1 to September 30, 1958.

6. 43A-27/43: Electrical Characteristics of 6-Watt Fluorescent Lamps for Seadrome Buoy Lights.

7. 43A-44/43: Life Test of Type X511 Batteries.

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DIMENSIONAL DIAGRAM
of a
STATIC INVERTER FOR BATTERY-OPERATED
FLUORESCENT SEADROME LIGHTS

Manufactured by
Walter Kidde & Company, Inc.

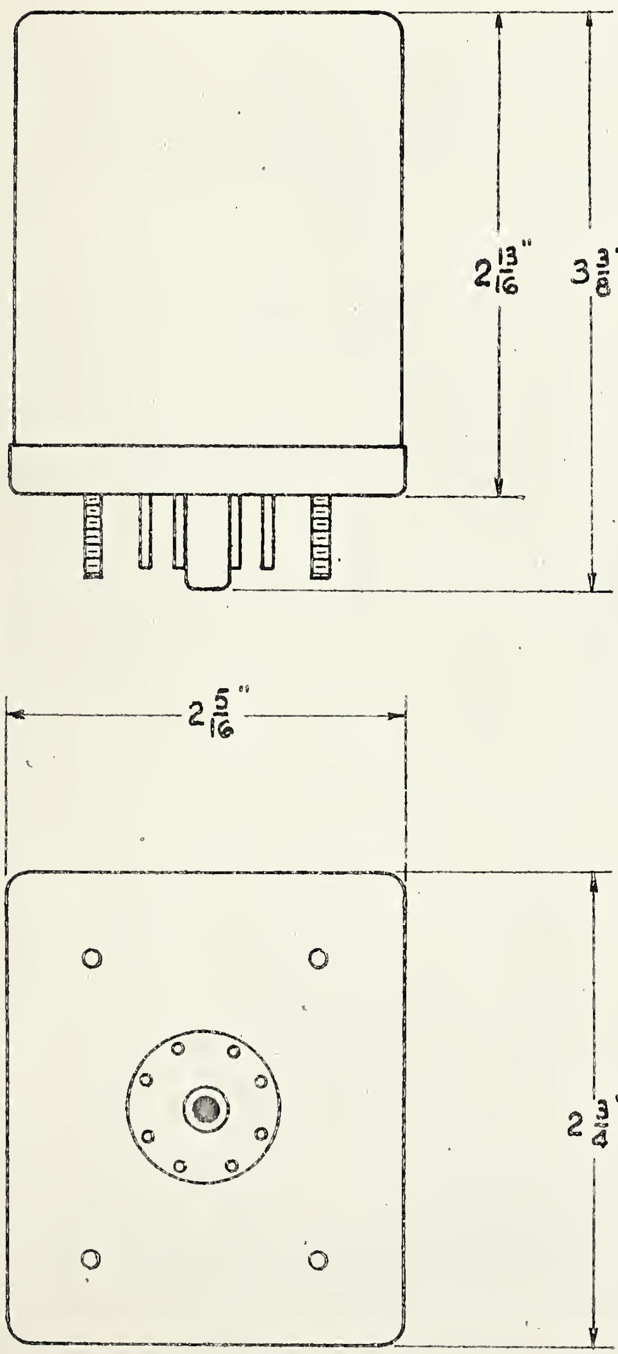


Figure 1

SCHEMATIC DIAGRAM
of a
STATIC INVERTER FOR BATTERY-OPERATED
FLUORESCENT SEADROME LIGHTS

Manufactured by
Walter Kidde & Company, Inc.

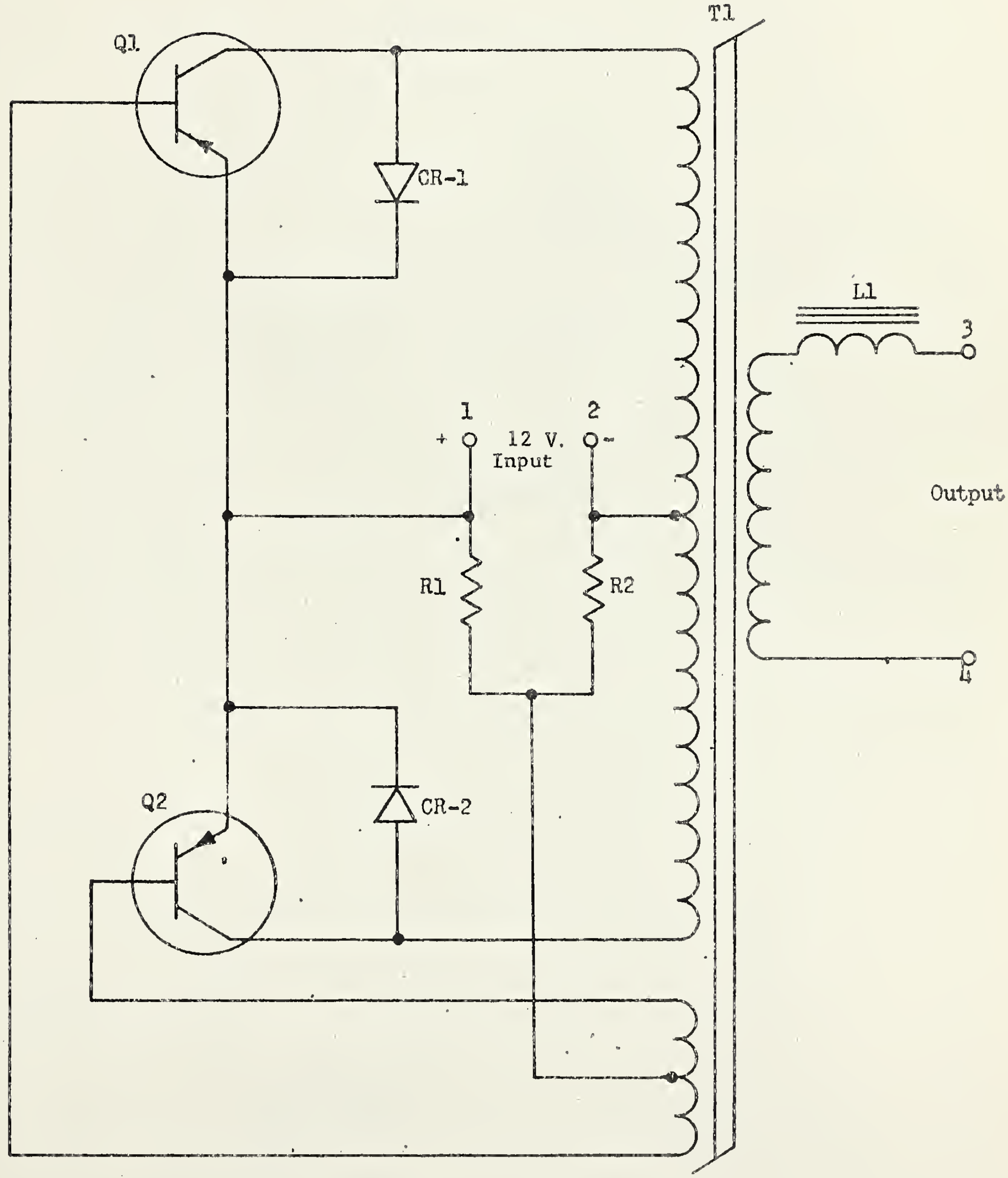


Figure 2

CIRCUIT DIAGRAM
of a
Static Inverter
Operating in a
Battery-Operated Fluorescent Seadrome Light

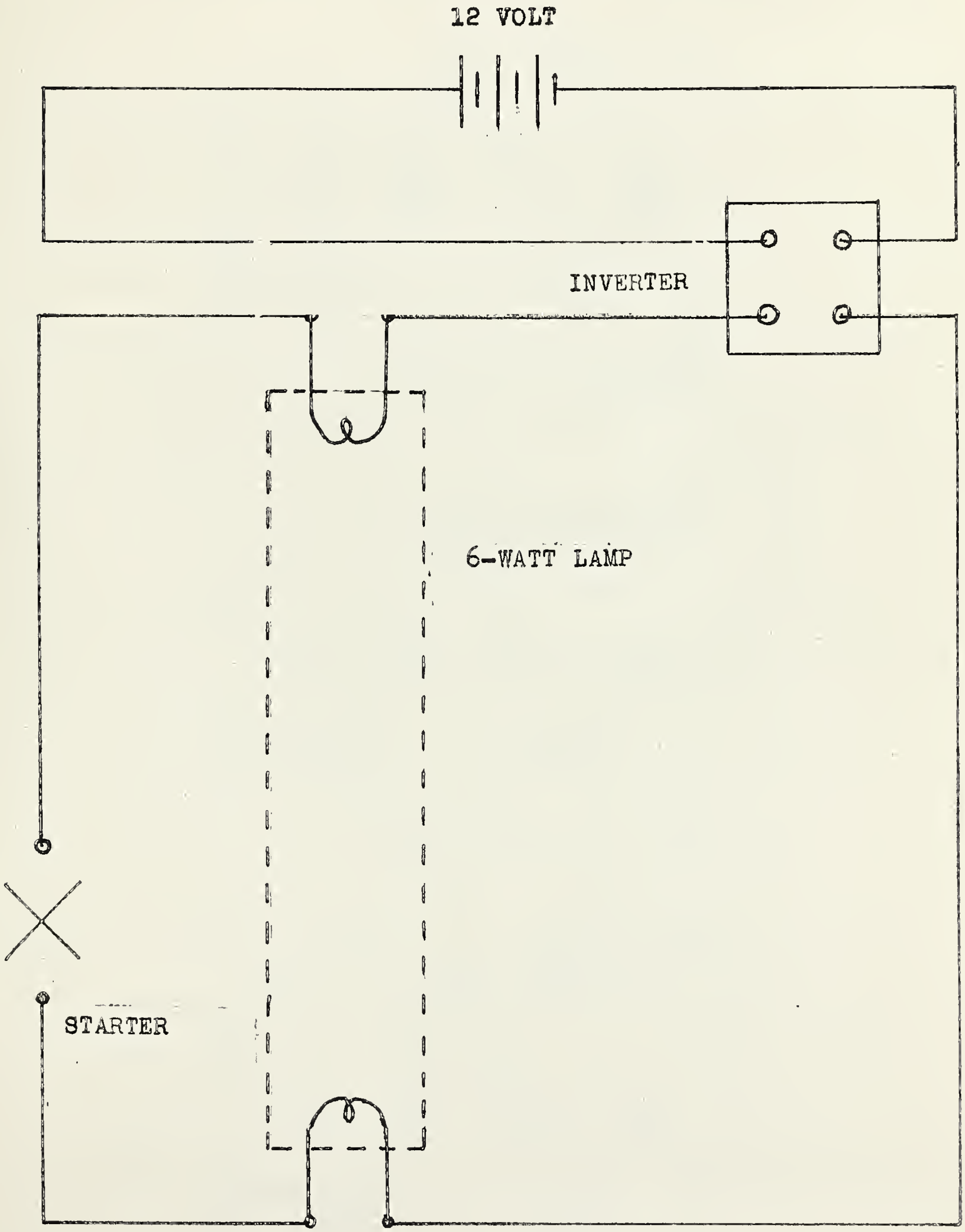
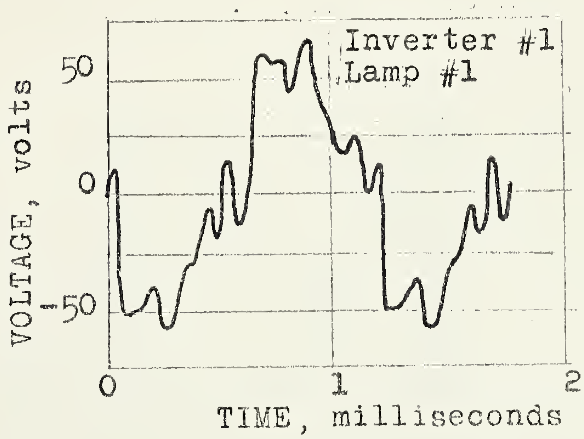
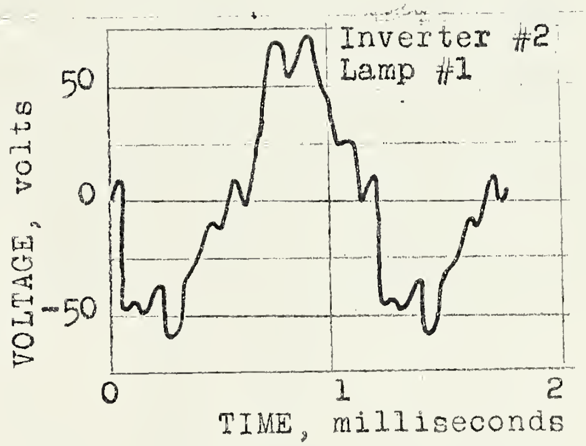


Figure 3

OUTPUT VOLTAGE WAVEFORMS
of a
STATIC INVERTER FOR BATTERY-OPERATED
FLUORESCENT SEADROME LIGHTS
Manufactured by
Walter Kidde & Company, Inc.
Operating a Six-watt Fluorescent Lamp





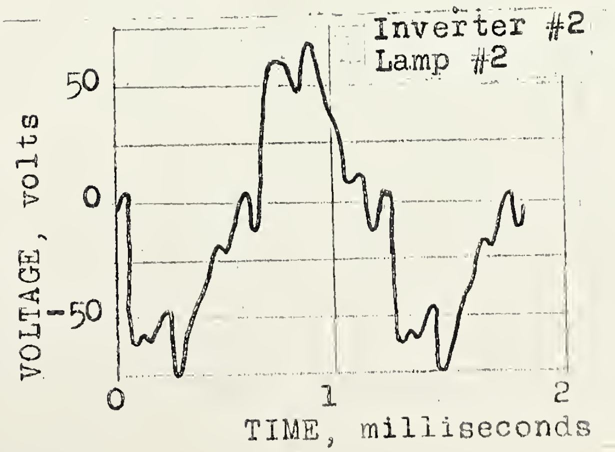


Figure 4

OUTPUT VOLTAGE WAVEFORM
of a
STATIC INVERTER FOR BATTERY-OPERATED
FLUORESCENT SEADROME LIGHTS
Manufactured by
Walter Kidde & Company, Inc.

Inverter #3 With Its Output Leads Open

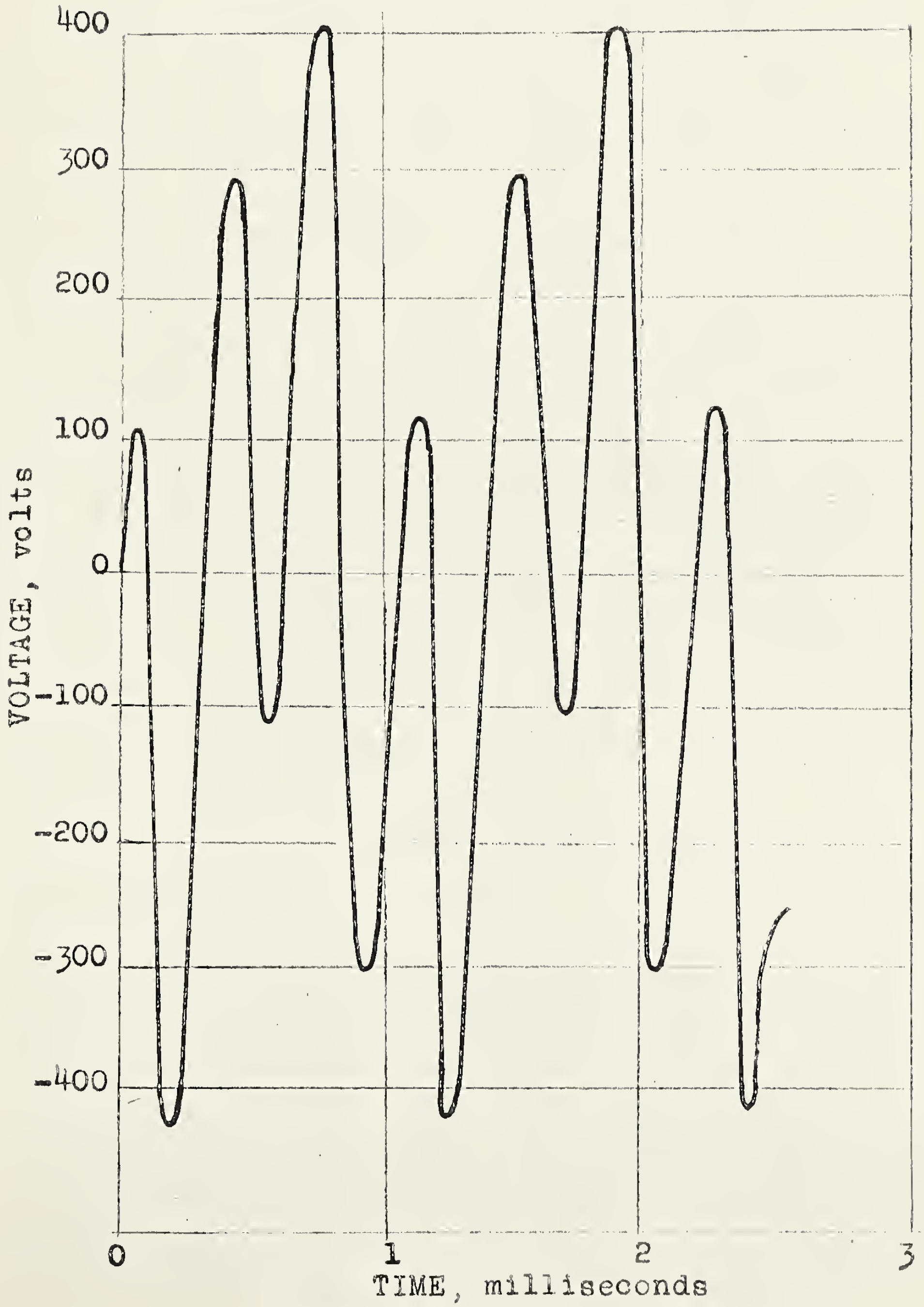
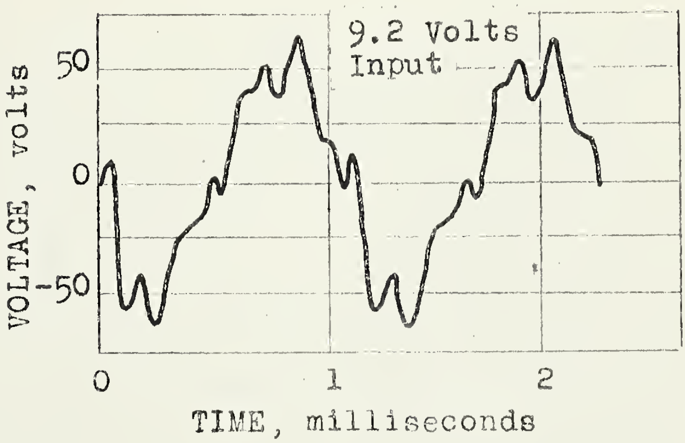
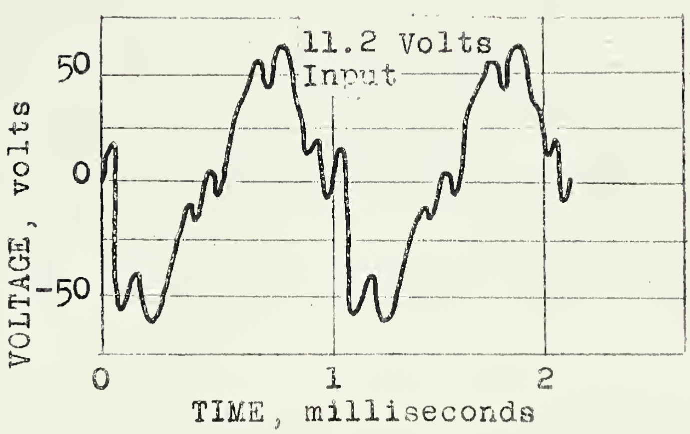


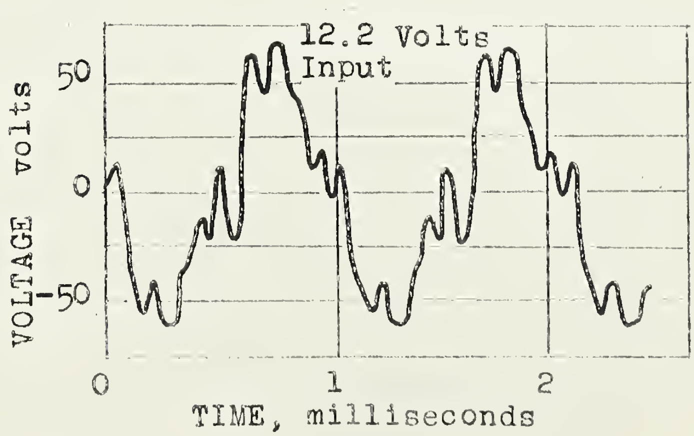
Figure 5

OUTPUT VOLTAGE WAVEFORMS
of a
STATIC INVERTER FOR BATTERY-OPERATED
FLUORESCENT SEADROME LIGHTS
Manufactured by
Walter Kidde & Company, Inc.
Operating a Six-watt Fluorescent Lamp

Inverter #4, Lamp#1
With Three Different Input Battery Voltages







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* Office of Weights and Measures.

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