Oct. 18, 1966 M. C. BAUM ETAL 3,280,369

XENON ARC INFRARED POWER SYSTEM

Filed Jan. 20, 1964 2 Sheets-Sheet 1

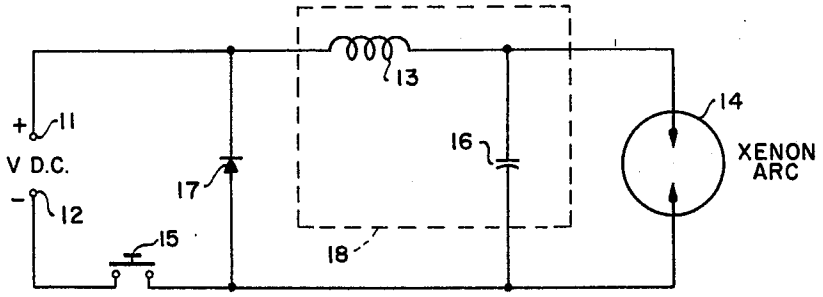


FIG. 1.

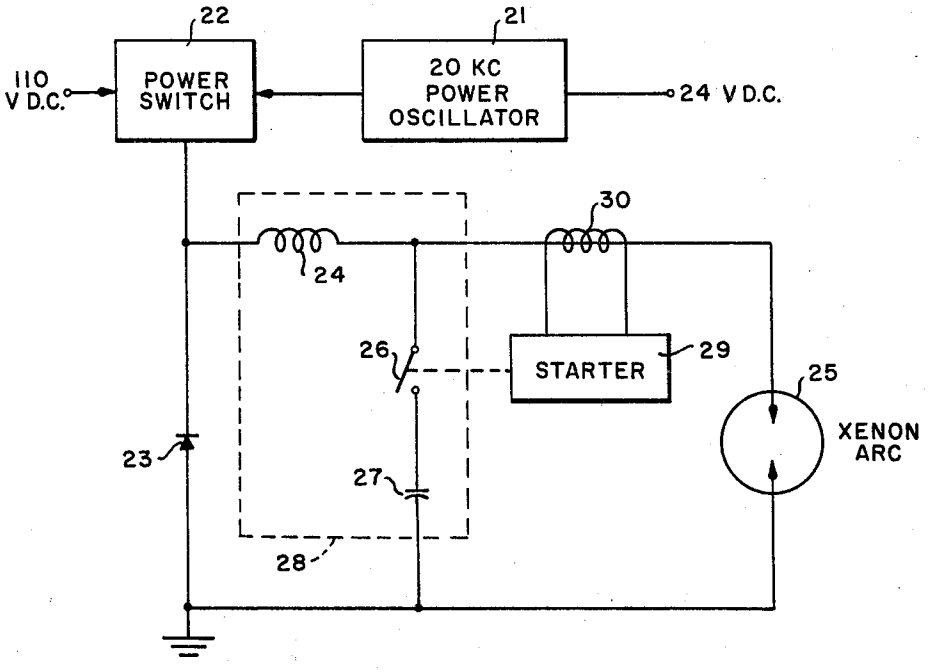


FIG. 2.

INVENTORS
MATTHEW C. BAUM
JOSEPH LaRUSSA
BY
Dow D. Doty
ATTYS

Oct. 18, 1966 M. C. BAUM ETAL 3,280,369

XENON ARC INFRARED POWER SYSTEM

Filed Jan. 20, 1964 2 Sheets-Sheet 2

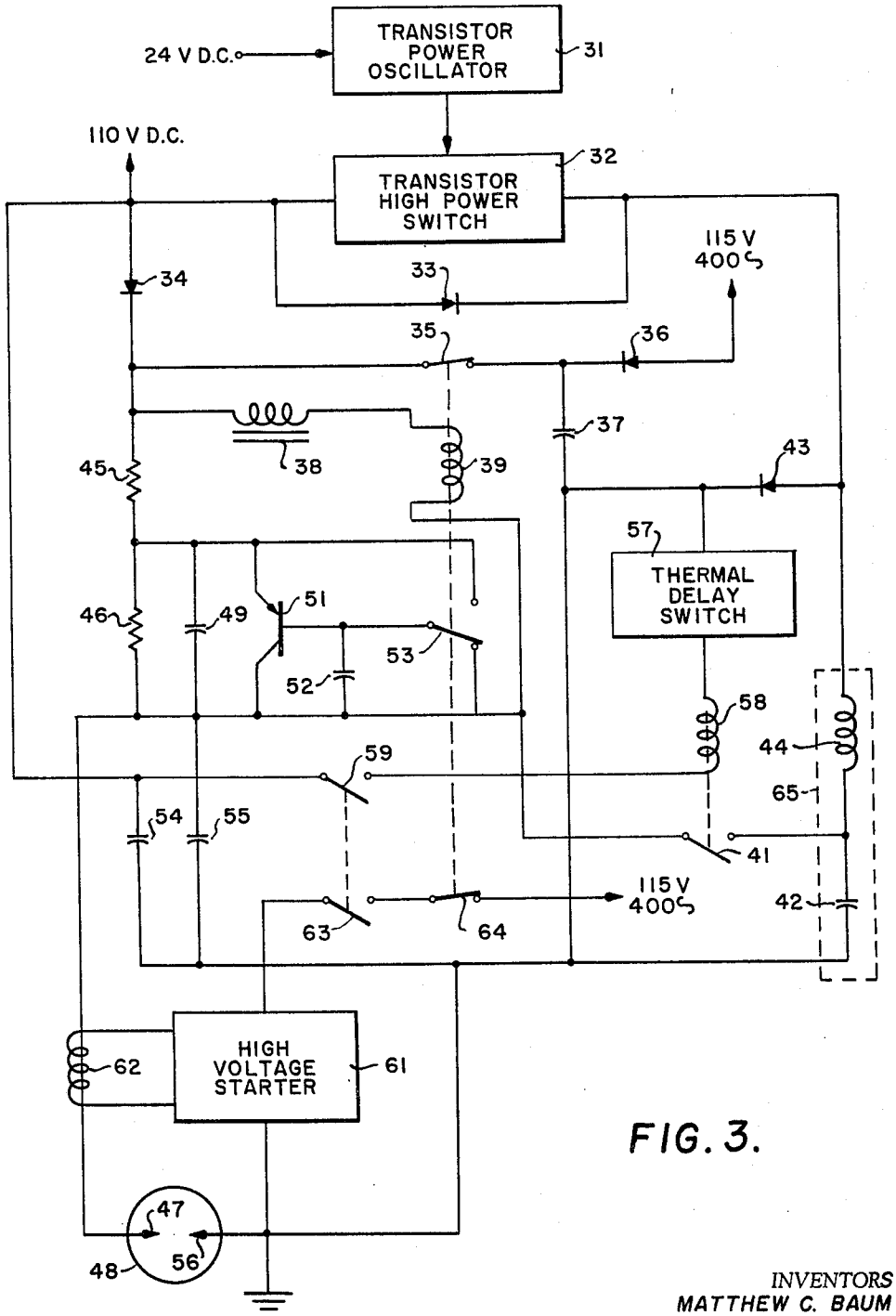


FIG. 3.

INVENTORS
MATTHEW C. BAUM
JOSEPH LaRUSSA

BY

Dow D. Doty ATTYS.

United States Patent Office 3,280,369
Patented Oct. 18, 1966

3,280,369

XENON ARC INFRARED POWER SYSTEM

Matthew C. Baum, New York, and Joseph La Russa, Yonkers, N.Y., assignors, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

Filed Jan. 20, 1964, Ser. No. 339,041
5 Claims. (Cl. 315—243)

The present invention relates generally to radiant energy generating systems and in particular is a starter and power supply system for energizing a xenon arc infrared lamp.

In order to obtain stable operation of xenon arc lamps, it is necessary to regulate the current through the lamp, rather than the voltage across it. This is due to the fact that at low currents the lamp exhibits a negative resistance while for currents in the normal operating range they have a dynamic resistance close to zero.

In the arc lamp power supplies of the prior art, several methods of current control have been employed which are satisfactory for some purposes. For alternating current power supplies, a reactive ballast is placed in series with the xenon lamp, while for direct current power supplies, a resistive ballast is used. For some applications, the direct current operation is most feasible, since the lamp is actually capable of following an alternating current but the resulting envelope modulation is sometimes objectionable. Unfortunately, most of the commercially available prior art ballasts are particularly undesirable because of their size, weight, and, especially, because of their inefficiency. For example, in a typical commercial unit used to regulate a 900 watt xenon arc, the resistive ballast measured 26 by 16 inches and weighed 27 pounds. Furthermore, it dissipated 2400 watts of power—a considerable amount, considering the 900 watts of useful output obtained therefrom. In addition, because the xenon arc lamp required approximately 30,000 volts in the radio frequency range to break down the arc, a typical commercially available unit that will produce such voltage weighs approximately 16 pounds, occupies a relatively large volume, and requires about 20 to 30 seconds to start the arc.

The instant invention overcomes most of the foregoing disadvantages because it is comparatively small in size, light in weight, and highly efficient as a result of uniquely interconnected and interacting solid-state elements being employed therein.

For the purpose of making an exemplary comparison between the subject invention and the prior art devices the following table lists the relative operational values thereof:

Operational Parameter	Subject Invention	Prior art Devices
Power Input	1,200 watts	3,300 watts.
Power Output	900 watts	900 watts.
Efficiency	75%	27.3%.
Starting time	200–500 milliseconds	20–30 sec.
Power supply wt	4 lbs., 4 oz	27 lbs.
Starter wt	2 lbs., 5 oz	16 lbs.
Total wt	9 lbs., 9 oz	43 lbs.

The aforementioned values are, of course, only typical and merely represent the relative merits of the subject invention versus the prior art power supply and starting devices for a 900 watt xenon arc lamp; however, it should be understood that although other relative values would be indicated for xenon arc lamps having other power input requirements, the relative merits therebetween would be substantially similar, with the devices made as a result of using the teachings and concepts of this invention probably falling into a superior category for most practical purposes.

It is, therefore, an object of this invention to provide an improved xenon arc power supply.

Another object of this invention is to provide an improved method and means for starting an xenon arc lamp.

Still another object of this invention is to provide a more efficient method and means for starting and powering an xenon arc lamp.

A further object of this invention is to provide an xenon arc powering system that is relatively small in size and light in weight.

A further object of this invention is to provide a method and means of producing a flashing xenon arc containing infrared radiant energy as well as visible radiant energy that may be expediently used in buoys or other mounting devices to facilitate navigation of boats, ships, aircraft, landcraft, or any other appropriate vehicles.

Another object of this invention is to provide a more reliable method and means for starting and powering a xenon arc.

Still another object of this invention is to provide a xenon arc starting and powering system that is easily and economically manufactured, maintained, and operated.

Other objects and many of the attendant advantages will be readily appreciated as the subject invention becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying figures of the drawing wherein:

FIG. 1 is a schematic diagram of the basic circuit of the subject invention;

FIG. 2 is a combined schematic and block diagram of a more sophisticated version of the basic form of the subject invention; and

FIG. 3 is a detailed schematic and block representation of the subject invention.

Referring now to FIG. 1, there is shown a direct current voltage input at a pair of terminals **11** and **12**. Connected in series with said terminals **11** and **12** are a reactive ballast and current regulating inductance **13**, a xenon arc lamp **14**, and a switch **15**. Connected in parallel with xenon arc lamp **14** is a capacitor **16**, and connected between terminal **11** and the junction of lamp **14** and switch **15** is a diode **17**. The aforementioned inductance **13**-capacitor **16** combination, of course, constitutes a reactive low pass filter **18**, and the entire basic circuit acts as a "direct current transformer" circuit.

The embodiment of FIG. 2 depicts a twenty kilocycle per second power oscillator **21**, preferably of the transistorized circuitry type, which has the input thereto connected to a 24 volt direct current supply and the output thereof coupled to a power switch **22**, likewise preferably of the transistorized circuitry type. A 110 volt direct current supply is also coupled to power switch **22**. Of course, the aforesaid oscillator and switch are well known and conventional, per se, so it is deemed unnecessary to further define the detailed circuitry thereof at this time.

The output of power switch **22** is coupled through a diode **23** to ground, and a series connected current regulating ballast inductance **24** and xenon arc lamp **25** is connected in parallel with the aforementioned diode **23**. Also, a series connected switch **26** and capacitor **27** are parallel connected with the aforesaid xenon arc lamp **25**, and when switch **26** is closed, the combination thereof with inductance **24** and capacitor **27** form a low-pass filter **28**. A starter **29** is transformer coupled to one of the electrical leads to xenon arc lamp **25** by means of a winding **30** which timely supplies sufficient current to break down the xenon arc. Starter **29** and switch **26** are so connected that closure of switch **26** actuates starter **29** to simultaneously produce said break down current.

The other preferred, detailed embodiment of the subject invention is illustrated in FIG. 3 as having a transistor power oscillator **31** coupled to the input of a transistor high power switch **32**. Oscillator **31** and switch **32** have respectively applied thereto a 24 volt direct current supply and a 110 volt direct current supply. Connected across transistor high power switch **32** is a diode **33**. Another diode **34** is connected between the 110 volt D.C. input of switch **32** and a relay switch **35**, with switch **35** also being connected through another diode **36** to a 115 volt, 400 cycle supply and through a capacitor **37** to ground. Diode **34** is also connected through an inductance **38**, a relay solenoid **39**, another relay switch **41**, and a capacitor **42** to ground. The output of transistor high power switch **32** is coupled through a diode **43** to ground and through an inductance **44** to the non-grounded side of said capacitor **42**.

A pair of series connected resistors **45** and **46** are connected to one of the electrodes **47** of a xenon arc lamp **48**, with the other electrode of lamp **48** being connected to ground. Connected in parallel with resistor **46** is a capacitor **49** and the emitter and collector elements of a PNP transistor **51**, with the collector thereof also coupled to electrode **47** of xenon arc **48**. The base of said transistor **51** is coupled through a capacitor **52** to the junction of resistor **46** and electrode **47** and to the movable arm of a relay switch **53**. Switch **53** is a single throw-double pole switch with the stationary contacts thereof respectively connected to the aforesaid emitter and collector elements of transistor **51**. The electrical junction of solenoid **39** and switch **41** is coupled to electrode **47** of xenon arc lamp **48**.

A capacitor **54** is connected between the 110 volt D.C. input of transistor high power switch **32** and ground, and another capacitor **55** is connected between electrode **47** and ground. The other electrode **56** of xenon arc lamp **48** is likewise connected to ground to complete the circuit thereto.

A thermal delay switch **57**, of the type which closes as a result of being exposed to some given temperature for a predetermined time period, is connected through a relay solenoid **58** and a switch **59** to the aforesaid 110 volt D.C. input to switch **32**. To complete the circuit, thermal delay switch **57** is also connected to ground. Of course, as shown, solenoid **58** and switch **41** are both parts of a relay with the former adapted for timely opening and closing the latter.

A conventional high voltage starter **61** is transformer coupled by a winding **62** to the electrical lead connected to electrode **47** of xenon arc lamp **48** for timely supplying a predetermined high RF voltage thereto. To effect this, said starter **61** is connected between ground and a start switch **63**, which is ordinarily closed manually by a human operator to start the device constituting this invention operating in its normal manner. Another switch **64** interconnects switch **63** and a 115 volt, 400 cycle power supply.

At this time, it should be noted that the aforesaid switches **35**, **53**, and **64** are the switch portions of a relay. They are ganged together for simultaneous operation thereof by the aforesaid solenoid **39**, and in this particular case, they are normally closed as shown in FIG. 3 and are actuated to the respective opposite conditions only when solenoid **39** is in an energized condition.

Briefly, the operation of the various preferred embodiments of the subject invention is as follows:

Considering first the most basic circuit shown in FIG. 1, it can readily be seen that when switch **15** is closed, the current flows across xenon arc **14** and through inductance **13** while charging capacitor **16**. Then, opening switch **15** turns off the supply current and the magnetic field originally created by inductance **13** in a direction opposing the original current flow begins to collapse. As said field collapses, it induces a voltage in inductance **13** in the direction that will continue to maintain the original current flow through the coil thereof. Thus, the reversed voltage polarity across inductance **13** presents the same electrical condition to xenon arc **14** as when it drew its current directly from the direct current voltage supply.

As a result of such current flow and the polarity thereof, diode **17** conducts to complete the circuit, keeping the xenon arc going until such time as the energy stored in the form of a magnetic field in inductance **13** is dissipated sufficiently to decrease the current flow to the extent that the xenon arc will be cut off. Of course, closing switch **15** again at the proper time will prevent such cutoff, since xenon arc lamp **14** effectively experiences a substantially constant supply of regulated direct current which is smoothed by capacitor **16**. Should it be desired that xenon arc lamp operate intermittently, the closing and opening of switch **15** at the proper frequency will cause this condition to be effected.

In the device of FIG. 2, power switch **22** performs the same switching operation as manually operated switch **15** did in the more basic device shown in FIG. 1. Moreover, the oscillator **21** causes switch **22** to be switched at an optimum rate. Because the power dissipated by a switching transistor occurs primarily due to the power expended in accomplishing the transition from a fully off condition to a fully on conducting state, it should be obvious that the transition time therebetween must be as short as possible in order to obtain optimum efficiency. Therefore, it is necessary for the oscillator driving said power switch to have a rise time that in short as possible. In this case, a 20 kilocycle per secod oscillator with a rise time of the order of 0.5 microsecond was selected because it is unusually stable in its operation and produces a relatively clean wave form over a wide range of load. Hence, the oscilator-power switch arrangement allows the power switch to transfer thirty amperes of current from a 110 volt D.C. power source in approximately twenty-five microseconds with rise and fall times of the order of three-tenths microseconds. A starter switch **26** and an RF high voltage booster starter circuit **29** have been added in addition to the aforesaid oscillator and power switch in order to refine the overall operation and make it more automatic as a result of improved current regulation. Otherwise, the device of FIG. 2 functions in the same way as the device of FIG. 1 to force regulated D.C. current through xenon arc lamp **25**. Again, it should be noted that capacitor **27** (like the aforementioned capacitor **16**) smooths the current flow and substantially removes switching frequency components therefrom.

It is apparently noteworthy that if switch **26** is a good switch and diode **23** likewise acts like a good switch and if inductance **24** and capacitance **27** are high-Q components, then all the electrical energy entering from the line must flow through the arc. Since, in this embodiment, the xenon arc maintains a substantially constant voltage drop of approximately 32 volts across its electrodes while the line potential is 110 volts, the current in the line should be approximately $32/110$ of the current that flows in the arc. This gives the circuit the property of acting as a "D.C. Transformer." That this type of D.C. operation, with an equivalent reactive ballast for current regulation, results in unusually high power efficiency in the subject system, has been verified by experimentation.

The operation of the embodiment of FIG. 3 is generally similar to that of the devices of FIGS. 1 and 2. However, some detailed refinements have been incorporated therein which improve the operation thereof.

Not only do new xenon arc lamps exhibit variations in breakdown potential but these characteristic change for any given lamp due to electrode wear, lamp aging, and the like; consequently, it is often difficult to strike an arc with just a standard starter. Hence, the combination of elements in the device of FIG. 3 has been found to be very satisfactory, in that they facilitate automatic lamp starting

with ususual reliability. The specific sequence of operation thereof is as follows:

With the contacts of switches **35**, **53**, and **64** in their normally closed position as shown, transistor **51** is forward biased and acts as a diode, shorting resistor **46**. Capacitor **37** is charged to the peak line voltage of the 400 cycle input by means of diode **36** to provide a potential of approximately 170 volts at the anode electrode of the xenon arc, and when starter button switch **63** is closed, RF high voltage starter **61** creates an ionized path across the xenon lamp electrodes and approximately 50 ampers flow through the lamp. Choke **38** delays the "pull-in" current through relay solenoid **39** for some milliseconds, and this delay is sufficient to insure establishment of the xenon lamp arc. After said delay occurs, solenoid **39** becomes fully energized and opens switches **35** and **64** and positions switch **53** in its other closed position, thereby disconnecting capacitor **37**, disconnecting the power to RF high voltage starter **61**, and applying a reverse bias to transistor **51**, respectively. This reverse bias then causes transistor **51** to limit the current through lamp **48** to approximately four amperes. After several minutes have elapsed and xenon arc lamp **48** is warm from running on four amperes, thermal delay switch **57** (or any other delay type switch operated by any preferred appropriate parameter) closes, causing switch **41** to be closed and the balance of the current required for rated power operation to be supplied to lamp **48**. Of course, once switch **41** is closed, inductance **44** and capacitance **42** constitute a low pass filter **65**. Switch **35** is opened to prevent the charge on capacitor **37** from reaching the transistor power switch **32**, while diodes **33** and **34** limit the voltage for the protection of said power switch.

Once the arc is running normally within lamp **48**, both infrared and visible radiant energy are generated thereby which may advantageously be used for many purposes, including those mentioned above.

Obviously, many modifications and other embodiments of the subject invention will readily come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing description in accompaniment with the associated drawing. Therefore, it is to be understood that the invention is not to be limited thereto and that said modification and embodiments are intended to be included within the scope of the appended claims.

What is claimed is:

1. Means for starting and powering an electric arc within a gaseous medium comprising in combination:

a gaseous medium capable of being ionized;

a pair of electrodes disposed within said gaseous medium;

a capacitor connected across said pair of electrodes;

an inductor connected to one of said pair of electrodes;

a diode connected in series with said inductor, with said series connected inductor and diode connected in parallel with the aforesaid capacitor;

a pair of electrical terminals adapted for receiving a direct current voltage, with one terminal thereof coupled to the junction of said diode and said inductor; and

a switch means interconnecting the other terminal of said pair of electrical terminals and the other electrode of said pair of electrodes.

2. A xenon arc infrared lamp starting and power system comprising in combination,

an oscillator,

a power switch coupled to the output of said oscillator,

a ground,

a diode having a cathode and an anode with the cathode thereof connected to the output of said power switch and the anode thereof connected to said ground,

an inductance having a pair of electrical terminals with one of the terminals thereof coupled to the output of said power switch,

a xenon arc lamp connected between the other electrical terminal of said inductance and said ground,

a switch having a movable contact and a stationary contact with the movable contact thereof connected to the junction of said inductance and xenon arc lamp, and

a capacitor connected between the stationary contact of said switch and said ground.

3. The invention according to claim **2** further characterized by a starter means connected for activation by said switch and for timely supplying radio frequency energy to said xenon arc lamp when said switch is closed.

4. A xenon arc starting and powering system comprising in combination:

a xenon arc lamp;

means effectively connected to said xenon arc lamp for initially striking an electric arc thereacross;

means connected to said initial arc striking means and said xenon arc lamp for limiting the current therethrough for a predetermined warm-up period after said arc has been struck, said current limiting means including a resistor connected in series with said xenon arc lamp, a capacitor connected in parallel with said resistor, a transistor connected in parallel with said resistor with said transistor being timely biased to be non-conductive and timely biased to be conductive for shorting out said resistor, and means for biasing said transistor to be non-conductive during the aforesaid warm-up period and conductive during the period said xenon arc lamp is operating at rated power; and

means connected to said arc striking and current limiting means for supplying a substantially regulated current at rated operational power to said xenon arc lamp at the termination of the aforesaid warm-up period.

5. The invention according to claim **4** further characterized by means connected to said transistor biasing means for effecting a predetermined delay period between the biasing of said transistor in a non-conductive state and a conductive state.

References Cited by the Examiner

UNITED STATES PATENTS

2,916,671	12/1959	Retzer	315—176
2,944,191	7/1960	Kapteyn	315—241
2,993,144	7/1961	Grabner et al.	315—183
3,004,191	10/1961	Umbarger	315—241
3,011,094	11/1961	Kapteyn	315—183
3,017,538	1/1962	Sakaki	315—241
3,066,243	11/1962	Mutschler	315—241 X
3,163,755	12/1964	Kotz et al.	315—241 X
3,165,668	1/1965	Harpley	315—290 X

JOHN W. HUCKERT, *Primary Examiner.*

MAYNARD WILBUR, *Examiner.*

J. D. CRAIG, *Assistant Examiner.*