

March 17, 1953

J. V. McNULTY

2,632,133

IGNITION MEANS

Filed March 15, 1945

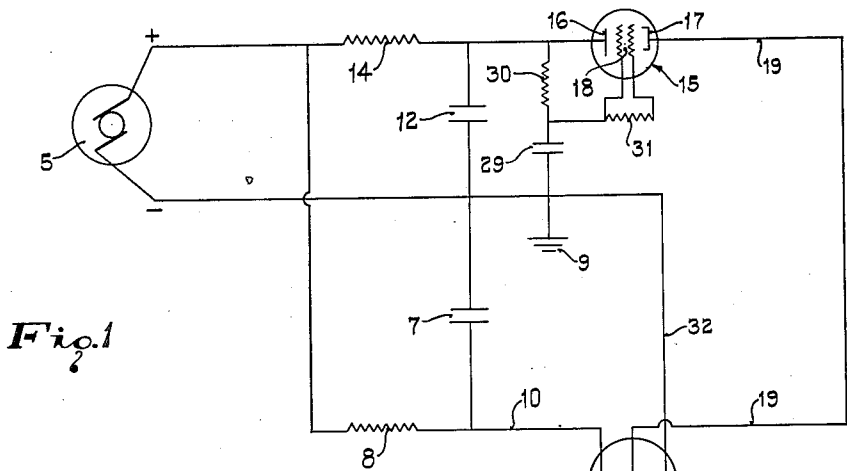


Fig. 1

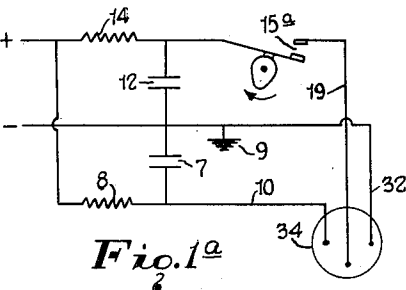


Fig. 1a

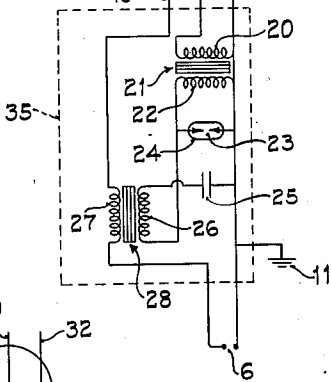


Fig. 2

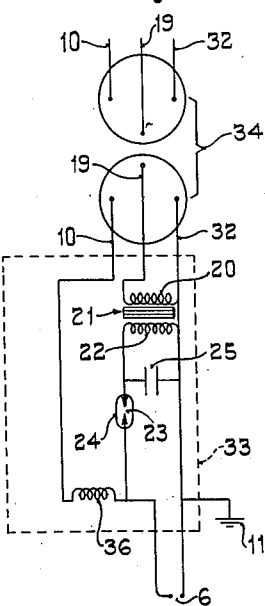


Fig. 3

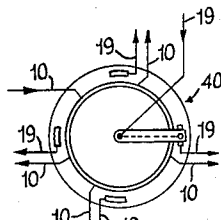
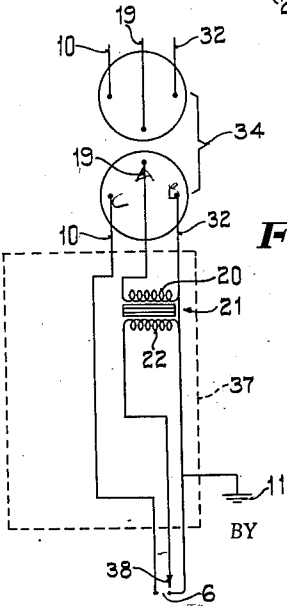


Fig. 4

INVENTOR.  
John V. McNulty  
F. Bascom Smith  
ATTORNEY.

## UNITED STATES PATENT OFFICE

2,632,133

## IGNITION MEANS

John V. McNulty, Binghampton, N. Y., assignor  
to Bendix Aviation Corporation, New York,  
N. Y., a corporation of Delaware

Application March 15, 1945, Serial No. 582,891

18 Claims. (Cl. 315—183)

1

This invention relates to electrical apparatus and more particularly to means for producing sparks between spaced electrodes.

One of the objects of the present invention is to provide novel means for producing sparks of greater potency than is feasible in ignition circuits of the type now in use.

Another object of the invention is to provide novel electrical spark producing means adapted for use in igniting the charge of a direct expansion or jet propulsion type of engine for starting the same.

Still another object is to provide reliable and efficient ignition means for starting engines of the above-mentioned type at all altitudes and under all conditions of operation in aircraft or the like.

A further object is to provide simple and durable apparatus for producing a shower of high energy sparks across the electrodes of a spark gap.

A still further object is to provide a novel method for producing high energy sparks across the electrodes of a spark gap such as in an igniter for a combustible medium in an engine or the like.

The foregoing objects and novel features of the invention will more fully appear from the following detail description when the same is read in connection with the accompanying drawings. It is to be expressly understood, however, that the drawings are for the purpose of illustration only and are not intended to define the limits of the invention, reference for this latter purpose being had primarily to the appended claims.

In the drawings, wherein like reference characters refer to like parts throughout the several views,

Fig. 1 is a schematic diagram illustrating one form of electrical circuit embodying the present invention;

Fig. 1a is a detail schematic diagram showing a modification of a portion of the circuit of Fig. 1;

Figs. 2 and 3 are schematic diagrams illustrating modifications of a portion of the circuit illustrated in Fig. 1; and,

Fig. 4 is a detail schematic diagram illustrating the use of a distributor in the circuits of Figs. 1 to 3.

The embodiment of the invention illustrated in Fig. 1, by way of example, includes a relatively low voltage source of direct electrical current, such as direct current generator 5. The

2

latter may be replaced by a dynamotor, a vibrator, an alternating current generator with suitable rectifying means or any other suitable direct current source. In order to permit high altitude operation with a minimum of radio shielding and flashover difficulties, the source 5 should be adapted to deliver direct current at a voltage of about 350 volts. This voltage has been found satisfactory in tests but the same may be varied between wide limits in the same and different installations depending upon the results desired.

In order to produce a high frequency discharge across the electrodes of a spark gap 6 and to insure better operation when said gap is fouled by carbon deposits or the like, a large capacity condenser 7 is connected across the terminals of source 5 in the electrical sense indicated in the drawings and with a resistance 8 interposed between one terminal of the condenser and the positive terminal of said source. The other terminal of the condenser which is connected to the negative terminal of generator 5 may also be connected to ground as at 9. The high potential terminal of condenser 7 is connected to one terminal of spark gap 6 by means of a lead 10 and the other terminal of said gap is connected to ground as at 11. It will be understood, of course, that wherever ground connections are employed as a return path for the flow of electrical current, a wire connection such as lead 32 may also be used. For a purpose to more fully appear hereafter, the secondary winding 27 of a high frequency step-up transformer coil 28 is connected in lead 10 between condenser 7 and spark gap 6.

By reason of the low voltage of the charge on condenser 7, the latter is normally unable to discharge across spark gap 6. Accordingly, means are provided for breaking down the resistance of said gap to thereby permit condenser 7 to discharge and create a spark having relatively great energy. In the form shown in Fig. 1, said means includes a condenser 12 connected across the terminals of generator 5 and a resistance 14 which is connected between said condenser and the positive terminal of the generator. The discharging of condenser 12 may be controlled in any suitable manner such as by means of the mechanically operated contactor 15a or the like but preferably the same is discharged through a gaseous tube discharge device 15, a tube known commercially as a strobotron type 631PI being suitable for this purpose. As shown, said discharge device includes an

anode 16, a cathode 17 and a grid 18 interposed therebetween, a two-element grid being shown by way of example.

The high potential side of condenser 12 is connected to anode 16 and cathode 17 is connected by means of a lead 19 to the primary winding of a high-frequency step-up transformer 21. The secondary winding 22 of said transformer has a spark gap 23 connected across the same, said gap being sealed in a gas tight container 24. Also connected across secondary winding 22 and in parallel with gap 23 are a condenser 25 and a primary winding 26 of the high frequency transformer 28, said condenser and winding 26 being connected in series with each other.

Discharge tube 15 is normally non-conductive with respect to the charge on condenser 12 and means are accordingly provided for rendering the same conductive and, hence, for permitting said condenser to discharge. Said means in the form shown comprises a condenser 29 and a resistance 30 connected in series with each other and in parallel with condenser 12 across the terminals of generator 5, resistance 30 being connected between condenser 29 and the positive terminal of the source of electrical energy. The high potential or positive side of condenser 29 is connected to one end of a resistor 31 which connects the terminals of the elements of the two-element grid 18 of tube 15. If a single element grid is employed, the resistance 31 may be eliminated.

In the operation of the above-described circuit condensers 7, 12 and 29 will be simultaneously charged by generator 5 or other suitable source through resistances 8, 14 and 30, respectively. As soon as condenser 29 has been charged to the grid glow potential of tube 15, a discharge takes place between grid 18 and cathode 17. The establishment of a glow in tube 15 in this manner renders said tube conductive to the charge on condenser 12 and the latter accordingly discharges through said tube and primary winding 20 of transformer 21. The sudden discharge of condenser 12 through primary winding 20 induces current flow at a higher voltage in secondary winding 22, thereby charging condenser 25. When the latter has been charged to the sparkover voltage of spark gap 23 the same discharges across said gap through primary winding 26 of transformer 28. The discharge of condenser 25 through winding 26 induces a sufficiently high potential across secondary winding 27 to cause igniter gap 6 to break down, that is, to create a flow of current between the electrodes of said gap. When the resistance of gap 6 has thus been reduced, condenser 7 is enabled to discharge across the same, thereby creating a spark having a large amount of energy, said energy being that which is stored in condenser 7 during each cycle of operation.

When the several condensers have been discharged in the above manner, tube 15 once again becomes non-conductive and the cycle is repeated in rapid succession. The frequency of this cycle or sparking rate of the circuit is determined by the product of the resistance 30 and the capacity of condenser 29. These elements may accordingly be varied to produce the desired frequency or sparking rate. The time constants for condensers 7 and 12 are also determined by the products of their respective capacities and resistances 8 and 14, respectively. These elements of the circuit are accordingly so chosen that condensers

7 and 12 will assume a sufficient charge for accomplishing the desired results when the system is working at the highest desired sparking rate while at the same time preventing sustained flow of current through discharge tube 15 and across spark gap 6.

In one satisfactorily operable circuit which embodied a strobtron tube of the character mentioned above and which was capable of a sparking rate of approximately 150 sparks per second at spark gap 6, the electrical values and structural data of the various elements were as follows: The capacities of condensers 7, 12, 25 and 29 were 5 mfd., 1 mfd., 250 mmfd., and .005 mfd., respectively, and the resistances of resistors 8, 14, 30 and 31 were 1000 ohms, 7000 ohms, 10 megohms, and 10,000 ohms, respectively. The output voltage of the source 5 was approximately 350 volts and the spark-over voltage of spark gap 23 was approximately 3 kilovolts. The primary windings of transformers 21 and 28 consisted of twenty-five turns of No. 22 copper wire and three turns of No. 20 copper wire, respectively, and the secondary windings of said transformers consisted of 1800 turns of No. 40 copper wire and 34 turns of No. 20 copper wire, respectively. Each of these transformers was wound on a tube  $\frac{3}{8}$  inch by  $1\frac{1}{2}$  inch, having a powdered iron core. The electrodes of gap 6 were spaced about .085 inch apart.

It will be understood, of course, that the above electrical values and structural data are mentioned by way of example only and not by way of limitation. All or any of these values and data may be varied between rather wide limits in the same and different installations.

In order to reduce the radio shielding requirements and, hence, the weight of the above-described system, the high voltage elements thereof may be grouped together and enclosed in a single metallic casing. In Fig. 1, such a casing is diagrammatically illustrated at 35 by dotted lines. The unit thus shielded may, for convenience of installation, replacement, repair or the like, be detachably electrically connected to the remainder or low voltage portion of the circuit by any suitable means, such as a plug and socket connector 34 which is also diagrammatically illustrated. A three-terminal connector 34 is shown, but lead 32 and, hence, the detachable connection therefor may be eliminated if the installation permits of the use of a ground return.

In Fig. 2 there is illustrated a modified high voltage unit 33 which may be employed in lieu of unit 35 of Fig. 1. These two units are alike except that an inductance coil 36 in lead 10 is substituted for high frequency transformer 28 and the gaps 6 and 23 are connected in series across condenser 25. When the other elements have the values mentioned above inductance 36 may consist of about thirty turns of No. 20 copper wire wound on a core like that mentioned above for coils 21 and 28 and the sparkover voltage of sealed gap 23 should be on the order of 14 kilovolts. Also, the spark-over voltage of igniter gap 6 should be somewhat higher in this embodiment than in the embodiment of Fig. 1. The operation of the unit illustrated in Fig. 2 is substantially the same as that described above for Fig. 1, except that the igniter gap 6 is electrically broken down by a direct discharge from condenser 25, said discharge being blocked, so to speak, from the remainder of the circuit by inductance coil 36.

A still more simplified high tension unit 37

5

which may be satisfactorily used in some applications in conjunction with the low tension supply and control portion of the above circuit is illustrated in Fig. 3. In this unit, lead 10 from condenser 7 is connected directly to a terminal of igniter gap 6 and the high potential end of secondary winding 22 is connected directly to an auxiliary electrode 38 which is mounted in spark gap relation with one of the electrodes of igniter gap 6. In this embodiment, whenever a sufficient potential is developed across secondary winding 22 in the manner set out above, a discharge from auxiliary electrode 38 to one of the main electrodes of igniter gap 6 will occur, thereby ionizing the space between the main electrodes and, hence, permitting condenser 7 to discharge across the latter to produce the desired high energy spark for igniting a combustible charge or the like.

In some installations it may be possible and practical to connect winding 22 directly across the electrodes of gap 6 for initiating current flow between said electrodes and thereby further simplify the circuit.

There is thus provided a novel method and means for producing sparks possessing a relatively great amount of electrical energy which may be reliably employed for long periods of operation to ignite the combustible charge of an engine under all conditions of operation at all altitudes attainable by modern aircraft. The novel circuit provided is extremely simple, both in construction and operation, and may be inexpensively manufactured and installed.

Although only a limited number of embodiments of the invention are illustrated and described in detail, it is to be expressly understood that the same is not limited thereto. For example, by providing a suitable distributor of any well known type, such as distributor 40 shown in Fig. 4, sparks may be produced in predetermined succession at a series of spark gaps corresponding to igniter gap 6. If it is desired to produce these sparks at predetermined intervals or in accurately timed relation to one another, suitable means such as a cam operated contactor 15a may be employed in conjunction with discharge tube 15 for accurately timing the discharges from condenser 12. It will also be clear that the invention may be used for purposes other than igniting the combustible charges in direct expansion engines or engines of other types. Various other changes may also be made in the design and arrangement of the parts illustrated as well as in the suggested electrical values thereof without departing from the spirit and scope of the invention, as the same will now be understood by those skilled in the art. For a definition of the limits of the invention, reference is had primarily to the appended claims.

What is claimed is:

1. In apparatus of the class described, a source of uni-directional electrical energy, a storage condenser of relatively high capacity and a resistor connected in series across the terminals of said source, an igniter spark gap having the electrodes thereof connected in series with the secondary winding of a high frequency transformer coil across the terminals of said condenser, said source being adapted to charge said condenser to a voltage below the spark-over voltage of said gap, and means for reducing the electrical resistance of said gap to enable said condenser to discharge, said means including a second condenser connected in series with a resistor across said source, a gaseous tube discharge device connected

6

in series with the primary winding of a second high frequency transformer coil across said second condenser, said tube being normally non-conductive to the charge on said second condenser, a second spark gap connected across the secondary winding of said second transformer, a third condenser connected in series with the primary winding of said first transformer across the terminals of said second spark gap, and means for rendering said discharge tube conductive to the charge on said second condenser comprising a resistance and a fourth condenser connected in series across the terminals of said second condenser and means connecting the high potential side of said fourth condenser to the grid of said discharge tube.

2. In apparatus of the class described, a source of uni-directional energy, a first condenser connected in series with a resistor across the terminals of said source, a first spark gap connected in series with an inductance across the terminals of said condenser, said source being adapted to charge said condenser to a voltage which is less than the spark-over voltage of said gap, a second condenser connected in series with a second resistor across the terminals of said source, said resistors being connected to the high potential sides of said condensers respectively, a gaseous tube discharge device connected in series with the primary winding of a high frequency step-up transformer coil across said second condenser, said tube being normally non-conductive to the charge on said second condenser, a third condenser connected across the ends of the secondary winding of said coil, a second spark gap connected in series with said third condenser across the terminals of said first spark gap, a fourth condenser connected in series with a resistor across the terminals of said second condenser, and means connecting the high potential side of said fourth condenser to the grid of said discharge tube for rendering said tube conductive to the charge on said second condenser when said fourth condenser is charged a predetermined amount.

3. In apparatus of the class described, a source of unidirectional electrical energy, a first condenser connected in series with a resistor across the terminals of said source, a spark gap connected across the terminals of said condenser, said source being adapted to charge said condenser to a voltage less than the spark-over voltage of said gap, a second condenser connected in series with a resistor across the terminals of said source and adapted to be charged thereby, a gaseous tube discharge device and the primary winding of a high frequency step-up transformer coil connected in series across the terminals of said second condenser, said tube being normally non-conductive to the charge on said second condenser, a third condenser connected in series with a resistor across the terminals of said second condenser, means connecting the high potential side of said third condenser to the grid of said discharge tube to render said tube conductive to the charge on said second condenser when said third condenser is charged to a predetermined voltage, and an auxiliary electrode in spark gap relation with one of the main electrodes of said spark gap, the secondary winding of said transformer coil having opposite ends thereof connected to said auxiliary electrode and said main electrode in spark gap relation therewith.

4. In apparatus of the class described, a spark

gap, a condenser connected to discharge across the electrodes of said gap, a source of uni-directional electrical energy for charging said condenser to a voltage below the spark-over voltage of said gap, and control means for intermittently rendering said gap conductive to the charges on said condenser, said control means including a high frequency transformer coil having the secondary winding thereof connected in series with said gap and means for creating successive impulses of current through the primary winding of said transformer.

5. In apparatus of the class described, a spark gap comprising a pair of spaced electrodes, a condenser connected to discharge across said electrodes, a source of electrical energy adapted to charge said condenser to a voltage below the spark-over voltage of said gap, and control means for rendering said gap conductive to charges on said condenser, said control means including a transformer having the secondary winding thereof connected in series with said gap, and means for creating successive impulses of current at a voltage higher than said spark-over voltage through said secondary winding, said last-named means including a second condenser adapted to be charged by said source and means for controlling successive discharges from said second condenser.

6. In apparatus of the class described, a spark gap comprising a pair of spaced electrodes, a condenser connected to discharge across said electrodes, a source of electrical energy adapted to charge said condenser to a voltage below the spark-over voltage of said gap, and control means for rendering said gap conductive to charges on said condenser, said control means including a transformer having the secondary winding thereof connected in series with said gap, and means for creating successive impulses of current at a voltage higher than said spark-over voltage through said secondary winding, said last-named means including a second condenser adapted to be charged by said source, a discharge device through which said second condenser is connected to discharge and means for periodically rendering said discharge device conductive to successive charges on said second condenser.

7. In apparatus of the class described, a spark gap, a condenser connected to discharge across the electrodes of said gap, a source of electrical energy adapted to charge said condenser to a voltage below the spark-over voltage of said gap, and means for intermittently rendering said gap conductive to the charges on said condenser, said means including a high frequency transformer, a second condenser connected across the secondary winding of said transformer, a second spark gap connected in series with said second condenser across the terminals of said first spark gap, and means for creating successive impulses of current in the primary winding of said transformer.

8. In apparatus of the class described, a spark gap comprising spaced electrodes, a condenser connected to discharge across the electrodes of said gap, an inductance connected between the high potential side of said condenser and one of said electrodes, a source of electrical energy adapted to charge said condenser to a voltage below the spark-over voltage of said gap, and means for rendering said gap conductive to the charge on said condenser, said means including a step-up transformer, means for periodically energizing said transformer, a second condenser connected across the secondary

winding of said transformer, and a second spark gap connected in series with said second condenser across the terminals of said first spark gap.

9. In apparatus of the class described, a spark gap comprising a pair of spaced main electrodes, a condenser connected to discharge across said electrodes, a source of electrical energy adapted to charge said condenser to a voltage below a spark voltage of said gap, and means for periodically rendering said gap conductive to the charges on said condenser, said means including a high frequency transformer having primary and secondary windings, an auxiliary electrode in spark gap relation with one of said main electrodes, and means connecting said auxiliary electrode and said one of said main electrodes across said secondary winding.

10. The method which includes the steps of simultaneously charging three condensers to voltages below the spark-over voltage of a spark gap, utilizing the charge on the first of said condensers for controlling the discharging of the second of said condensers, stepping up the voltage of the discharge of said second condenser, applying said stepped up voltage across the electrodes of said spark gap to reduce the electrical resistance thereof, and then discharging the third of said condensers across said gap.

11. In an ignition system for an internal combustion engine, in combination, a source of direct current, a condenser charged by said source, a transformer, means for discharging said condenser through said transformer, a second condenser charged by said transformer, a second transformer, a spark gap for discharging said second condenser through said second transformer, and a spark plug having an electrode connected to the second transformer.

12. In an ignition system for an internal combustion engine, in combination, a source of direct current, a resistor, a condenser charged by said source through said resistor, a transformer, contactor means for discharging said condenser through said transformer, a second condenser charged by said transformer, a second transformer, a spark gap for discharging said second condenser through said second transformer, and a spark plug having an electrode connected to the second transformer.

13. In an ignition system for an internal combustion engine, in combination, a source of direct current, a condenser charged by said source, a transformer having a primary winding and a secondary winding, means for discharging said condenser through said primary winding, a second condenser charged by said secondary winding, a second transformer having a primary winding and a secondary winding, a spark gap for discharging said second condenser through the primary winding of said second transformer, and a spark plug having an electrode connected to the secondary winding of the second transformer.

14. In a high frequency ignition system comprising a capacitance, high frequency transformer and spark gap adapted to furnish energy to a spark plug, an auxiliary energy booster circuit adapted to supply additional energy to the discharge of the high frequency circuit, said booster circuit comprising a condenser and impedance, and switch means for connecting and disconnecting said booster circuit to said high frequency circuit.

15. In an ignition system for an internal com-

bustion engine, a combination as defined in claim 11, wherein the means for discharging the first-named condenser includes a distributor.

16. In an ignition system for an internal combustion engine, a combination as defined in claim 12, wherein the contactor means is a distributor. 5

17. In an ignition system for an internal combustion engine, a combination as defined in claim 13, wherein the means for discharging the first-named condenser includes a distributor. 10

18. In a high frequency ignition system comprising a capacitance, high frequency transformer and spark gap adapted to furnish energy to a spark plug, an auxiliary energy booster circuit adapted to increase the energy supplied the spark plug, said booster circuit comprising a condenser serially connected with the secondary of the transformer of the high frequency circuit, and switch means for connecting said 20

booster circuit to said high frequency circuit whereby said booster circuit will supply additional energy to the discharge of the high frequency circuit.

JOHN V. McNULTY.

#### REFERENCES CITED

The following references are of record in the file of this patent:

#### UNITED STATES PATENTS

| Number    | Name            | Date          |
|-----------|-----------------|---------------|
| 1,459,252 | Plumm -----     | June 19, 1923 |
| 1,745,830 | Bethenod -----  | Feb. 4, 1930  |
| 1,955,520 | Vawter -----    | Apr. 17, 1934 |
| 2,009,125 | Smithsen -----  | July 23, 1935 |
| 2,071,958 | Watrous -----   | Feb. 23, 1937 |
| 2,175,900 | Knight -----    | Oct. 10, 1939 |
| 2,203,784 | Holthouse ----- | June 11, 1940 |
| 2,409,202 | Francis -----   | Oct. 15, 1946 |