

Sept. 1, 1942.

A. SENAUKE ET AL

2,294,515

SYNCHRONIZING SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed April 15, 1941

4 Sheets-Sheet 1

Fig. 1.

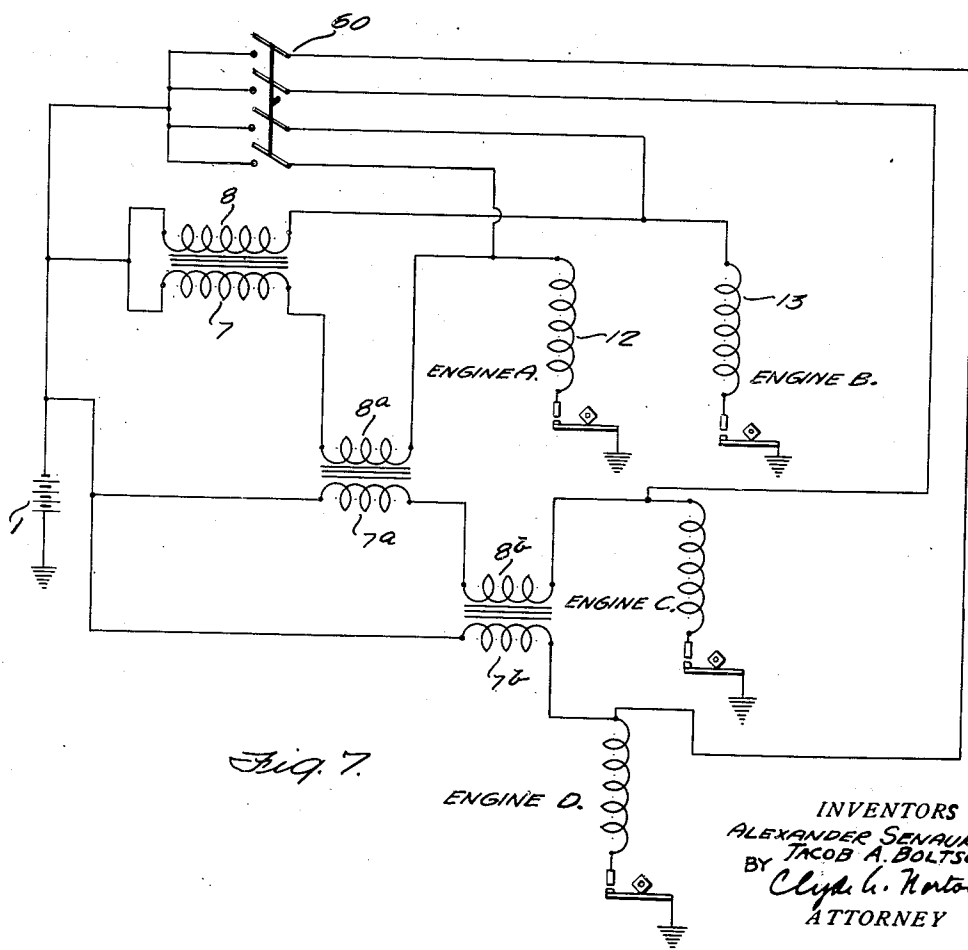
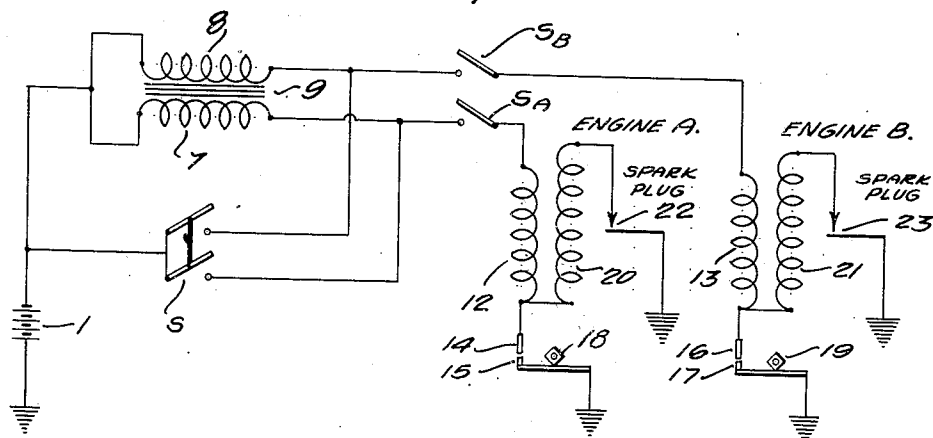


Fig. 7.

INVENTORS
ALEXANDER SENAUKE
JACOB A. BOLTSON
BY
Clyde G. Norton
ATTORNEY

Sept. 1, 1942.

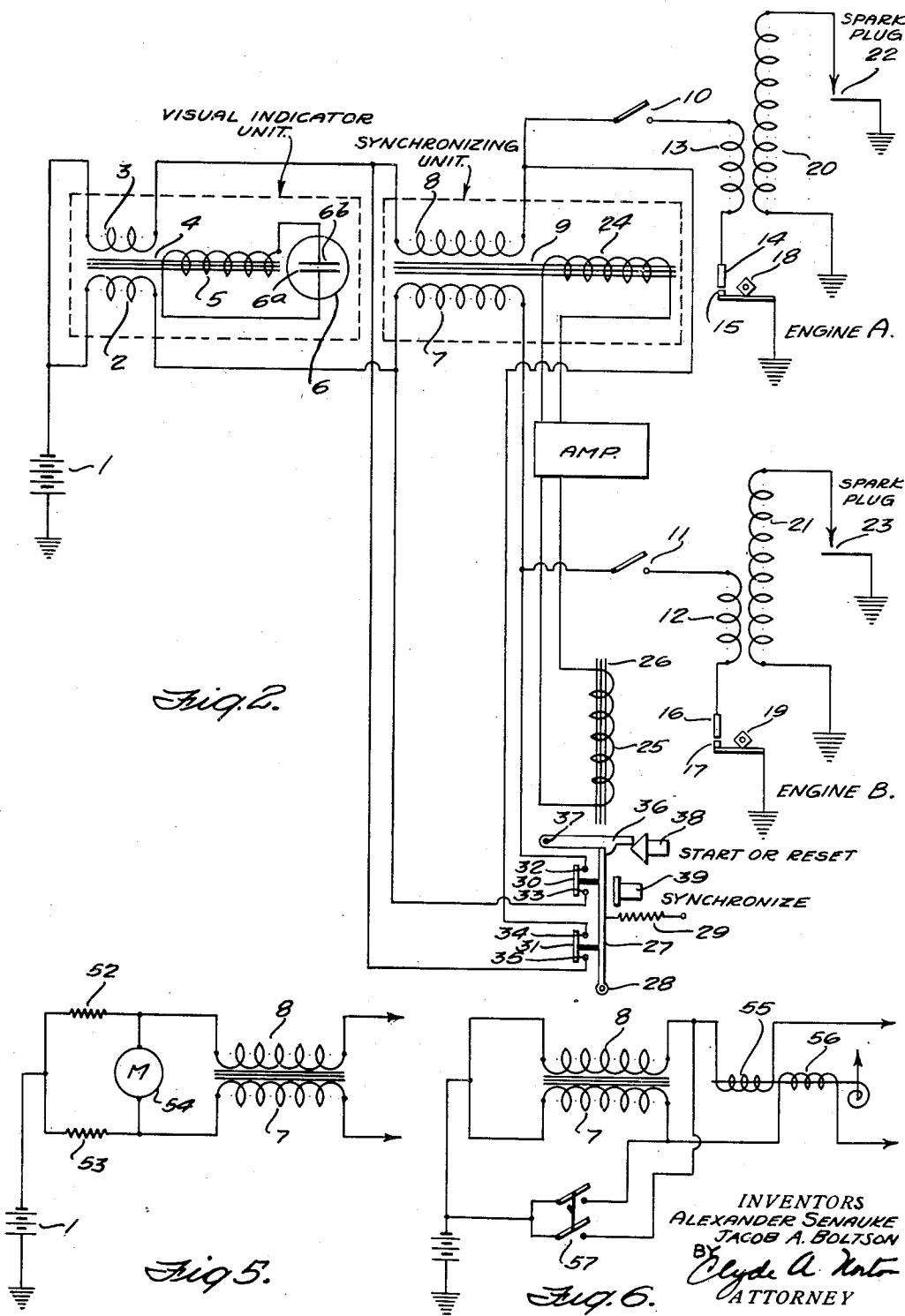
A. SENAUKE ET AL

2,294,515

SYNCHRONIZING SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed April 15, 1941

4 Sheets-Sheet 2



Sept. 1, 1942.

A. SENAUCHE ET AL

2,294,515

SYNCHRONIZING SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed April 15, 1941

4 Sheets-Sheet 3

Fig. 3.

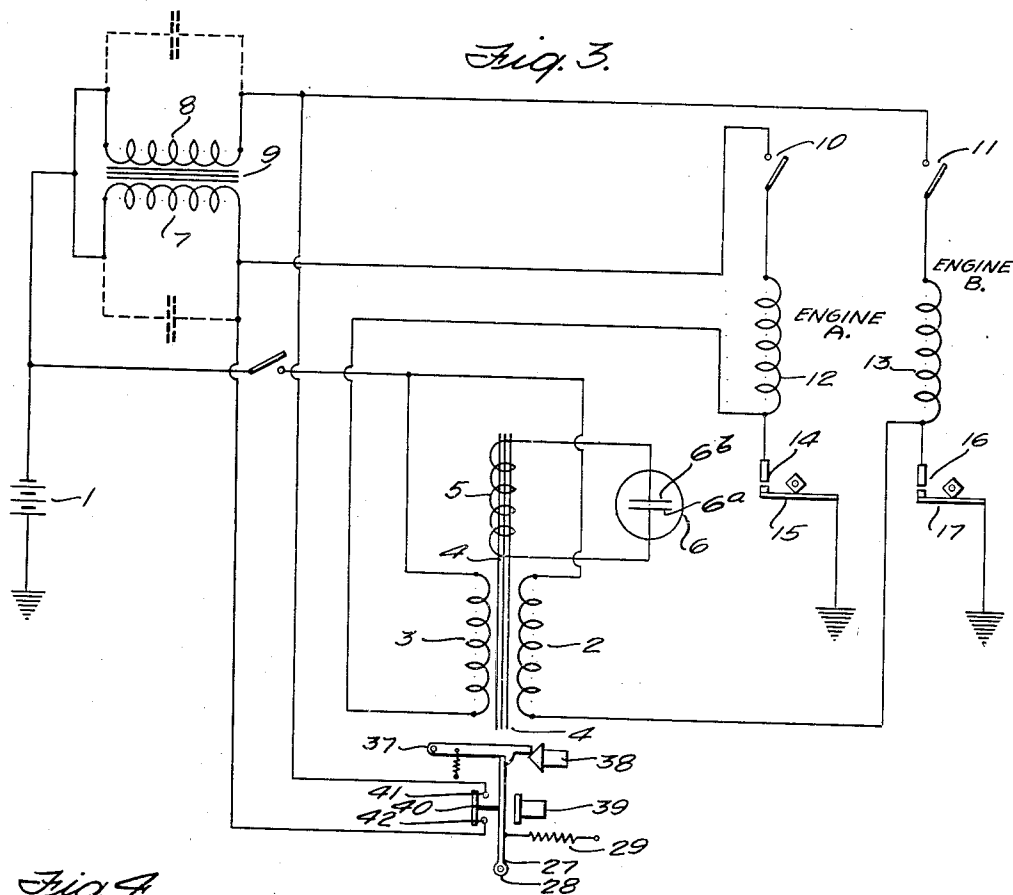
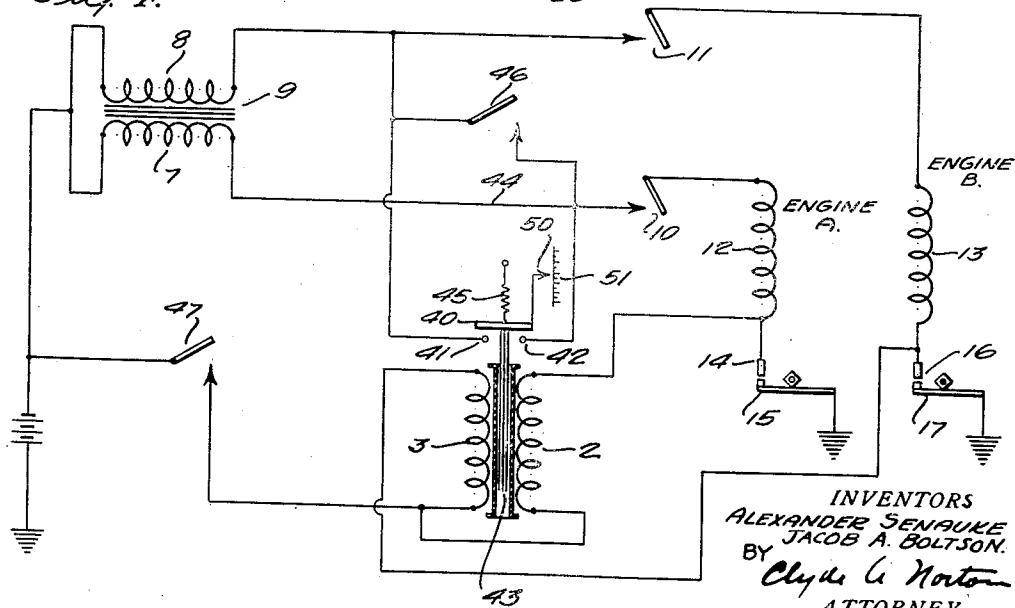


Fig. 4.



INVENTORS
ALEXANDER SENAUCHE
JACOB A. BOLTON.
BY
Clyde G. Norton
ATTORNEY

Sept. 1, 1942.

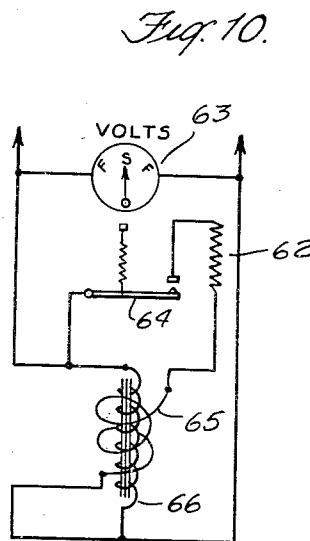
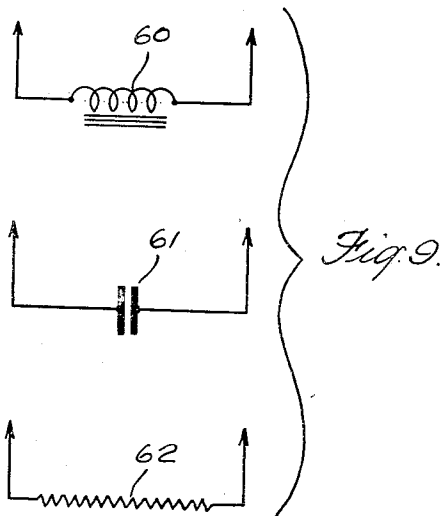
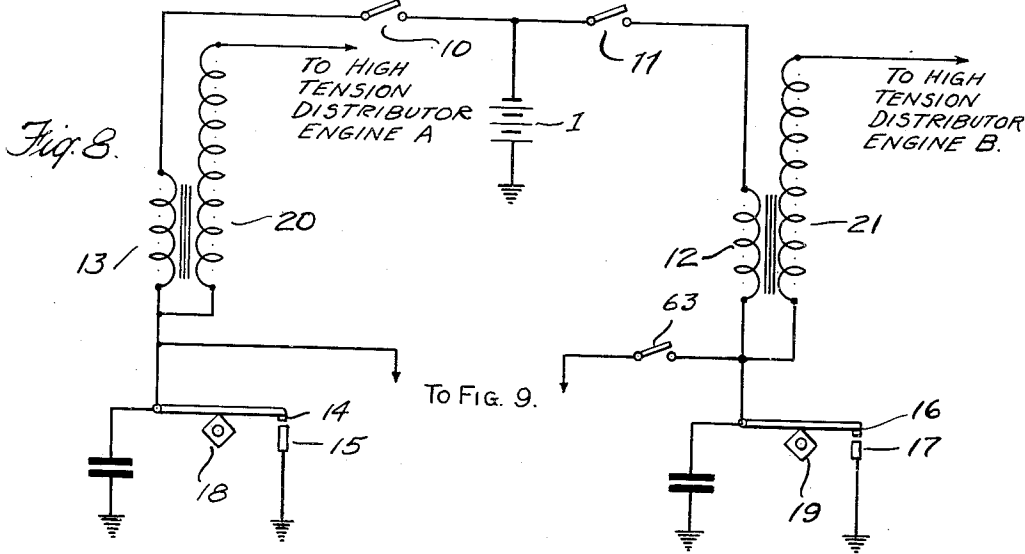
A. SENAUCHE ET AL

2,294,515

SYNCHRONIZING SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed April 15, 1941

4 Sheets-Sheet 4



BY

INVENTORS
ALEXANDER SENAUCHE
JACOB A. BOLTSON
Clyde A. Norton
ATTORNEY

UNITED STATES PATENT OFFICE

2,294,515

SYNCHRONIZING SYSTEM FOR INTERNAL COMBUSTION ENGINES

Alexander Senauke and Jacob A. Boltson,
New York, N. Y.

Application April 15, 1941, Serial No. 388,640

17 Claims. (Cl. 60—97)

This invention relates to apparatus for synchronizing internal combustion engines of the type having electrical ignition.

In accordance with this invention, we provide simple electrical means by which, when two or more such engines have been brought to approximately the same speed, they may be caused to lock into synchronism, and to maintain synchronism for all normal variations of load, or other variations which might tend to cause them to go out of synchronism.

Also, we may provide an electrical indicator to show the operating conditions, i. e., synchronism or lack of it, and we may also provide automatic or manual means to render the synchronizing system inoperative, under conditions which might make the same necessary, such, for example, as failure of one or more motors.

Among the objects of our invention may be mentioned:

To provide a system of the class described which is completely electrical, and which does not require any connection to the manifolds of the engines to be controlled;

To provide a system of the class described which may be easily, quickly and inexpensively installed on existing engines;

To provide a system of the class described which will furnish a visual indication of the operation of the system at all times.

To provide a system of the class described which may be cut in or out manually, if desired, or which will automatically cut itself out in case conditions make it undesirable to attempt to maintain synchronism, or which will automatically synchronize the engines when they are running close to the same speed, and will automatically cut itself out when conditions produce too great a difference in speed between the engines.

To provide a system which will automatically protect either engine against the possibility of misfiring at a time when it might damage the engine, as has been known to happen with systems of the prior art.

Still other objects and advantages of our invention will be apparent from the specification.

In this application we have particularly pointed out and distinctly claimed the part, improvement or combination which we claim as our invention or discovery and we have explained the principles thereof and the best mode in which we have contemplated applying those principles, so as to distinguish our invention from other inventions.

In the drawings:

Fig. 1 is a circuit diagram of a simple form of our invention;

Fig. 2 is a circuit diagram of another form of system in accordance with our invention employing automatic switching and synchronizing indication;

Fig. 3 is a circuit diagram of another form of system in accordance with our invention;

Fig. 4 is a circuit diagram of still another form of system in accordance with our invention;

Figs. 5 and 6 are circuit diagrams illustrating the use of alternative forms of synchronism indicators in accordance with our invention;

Fig. 7 is a circuit diagram of our system as applied to synchronize more than two engines, and

Figs. 8, 9, and 10 are circuit diagrams of a still further modification of our invention.

In the various figures, like reference numbers indicate like parts.

Referring now more particularly to Fig. 1, in accordance with our invention, we may insert in the primary side of the ignition circuit of each of the engines to be controlled a coil which we term a synchronizing coil, having an inductance sufficient to impair the ignition when the inductance of the coil is effective. The value of inductance of such coil is not critical, and in general, it may be of the order of three or four times that of the spark coil as seen from the primary side, but in any one system, the inductance of each of the coils should be substantially the same, the system may employ a common battery for the engines, as indicated.

We may then couple the two synchronizing coils tightly together in such a manner as to buck, or oppose each other, that is to say, so that the magnetic flux produced by each coil neutralizes that produced by the other. This may be done by winding both coils in the same direction and reversely connecting the two coils, or by winding in opposite directions and similarly connecting them, as will be understood by those skilled in the art.

This is shown in Fig. 1, in which 7 is the synchronizing coil for engine A, and 8 the synchronizing coil for engine B. The coils may be mounted on a core 9 of magnetic material if desired, which core may be open or closed.

The coil 7 may be connected in series with the primary coil 12 of engine A, and breaker points 14 and 15, operated by cam 18, which energizes secondary coil 20 to apply firing voltage to spark plug 22.

Similarly, coil 8 may be connected in series with primary coil 13 of engine B, and breaker points 16 and 17 operated by cam 19, which energizes secondary coil 21 to apply firing voltage to spark plug 23.

For simplicity we have shown only one spark plug for each engine, but it will be understood that this is only for convenience of illustration, as the system may be applied to engines having four, six or more cylinders.

If these synchronizing coils are cut out of circuit as by switch S, and the individual ignition circuits of the engines closed at switches S_A and S_B, and the engines brought manually to approximately the same speed, and then the coils put into circuit by opening switch S, it will be found that the engines will fall into synchronism, and effectively lock themselves in, and will maintain synchronism for all normal variations of load or fuel feed tending to carry the engines out of synchronism. Under these conditions, the inductance of the synchronizing coils falls to a very low effective value, because the ignition currents flowing in each synchronizing coil are in phase and produce opposing flux, and each engine receives substantially the same ignition it would have if the synchronizing coils were not in circuit.

If now a condition arises which tends to cause one engine to slow down, this will be evidenced by a departure of the ignition impulses from phase coincidence, and the synchronizing coils will begin to be effective in reducing the ignition currents in both engines. This causes the faster engine to slow down until it has fallen into step with the slower, after which both may slightly increase their speed, remaining in synchronism.

It might be supposed that this impairment of the ignition of both engines would reduce the speed of the slower engine just as much as that of the faster engine, so that there would be no tendency of the engines to go back into synchronism, but repeated tests of our system have conclusively demonstrated that the system acts as described, and will maintain synchronism for all reasonable variations in conditions which would otherwise cause changes in speed of one engine or the other. The theoretical explanation of this phenomenon is not entirely clear, but there is no question of the fact, and we state the fact, without attempting to explain it theoretically.

Referring now more particularly to Fig. 2, 1 represents the common source of ignition currents for engines A and B, which source may be the usual battery, grounded on one side, and connected on the other side to the common terminals of coils 2 and 3. Coils 2 and 3 preferably have an inductance relatively low with respect to that of the synchronizing coils 7 and 8, but, like those coils, are so poled that that flux produced by coil 2 is equal and opposite to that produced by coil 3 when the engines are in synchronism.

Coils 2 and 3 may be wound on a core 4 of magnetic material, and another coil 5 may be provided on the same core, having its terminals connected to indicator lamp 6, which may be a gas discharge lamp such as a neon tube having electrodes 6a and 6b. The number of turns of coils 2, 3, and 5 may be so chosen that any departure from synchronism of the engines produces a voltage in coil 5 sufficient to light the lamp 6.

The synchronizing coils 7 and 8 may be mounted on a second core 9 of magnetic material, this

core being preferably closed, and an additional winding 24 may also be mounted on this core. Synchronizing coil 7 may have one terminal connected to one terminal of coil 2, and its other terminal connected through ignition switch 11 to the ignition primary coil 12, which is connected through breaker points 16 and 17 to ground, in the well known manner, and the breaker points may be operated by the timer 19 as usual.

The secondary of the ignition circuit is shown diagrammatically as including coil 21 grounded on one side and connected to spark plug 23 of engine B. It will be understood that the engine may and ordinarily will have more than one cylinder, but for simplicity we have shown only one.

The circuit for engine A is similar to that already described, synchronizing coil 8 being connected to coil 3, on one side, and on the other through ignition switch 10, ignition primary coil 13, and breaker points 14 and 15 to ground. Ignition secondary coil 20 may be connected between ground and spark plug 22.

Control of the system may be had through relay 25 connected to coil 24, either directly, or through an amplifier of any suitable type, in case coil 24 does not deliver enough power to operate relay 25. Relay core 25 may control trip arm 36 pivoted at 37. Trip arm 36 may in turn control switch 27, which may be pivoted at 28 and may carry contacts 30 and 31, for connecting terminals 32 and 33 and 34 and 35 respectively, and the said terminals may be connected to opposite terminals of the synchronizing coils 7 and 8 respectively.

As will be seen, when switch 27 closes, synchronizing coils 7 and 8 are short-circuited, but when said switch is in the position shown, the said coils are in circuit. Trip arm 36 may be spring or gravity-biased to hold switch 27 against closure, but when relay 25 is energized, is moved sufficiently to release switch 27, which will then be closed. A pair of manual push buttons 38 and 39 may be provided, the former for operating the trip arm 36, and the latter for switch 27.

The operation of the system will now be described. Push button 38 will first be depressed, permitting switch 27 to close, short-circuiting the synchronizing coils. Both engines may now be started, and brought to approximately the same speed. The lamp 6 will now flash for each ignition impulse of each engine, but as the engines approach synchronism the frequency and intensity of the flashes will diminish. When the flashes indicate that the engines are sufficiently close in speed to be synchronized, push button 39 may be pushed, throwing coils 7 and 8 into circuit, and trip arm 36 will engage switch arm 27, holding it in open position.

At this time, if the engines have been brought sufficiently close together in speed, they will lock into step and continue in step. If not, lamp 6 will be observed to continue to flash and relay 25 will be energized, releasing switch 27 to closing position, and cutting out coils 7 and 8. The operator may then re-adjust the engine speeds and repeat the operation.

Referring now to Fig. 3, we have shown another form of system according to our invention. While the fundamentals of the circuit of Fig. 3 are the same as those of Fig. 2, there are certain specific differences. In this instance, coils 2 and 3, instead of being in series with coils 7 and 8, are in parallel with the entire primary

side of the ignition circuits. For example, coil 3 may have one terminal connected to the ungrounded side of battery 1 and its other terminal connected to the low potential side of the ignition primary coil 12, and similarly, coil 2 may have one terminal connected to the ungrounded side of battery 1 and its other terminal connected to the low potential side of ignition primary coil 13.

When the coils 2 and 3 are so connected, they should have in themselves, or in series with them, sufficient inductance or resistance to prevent them from acting as a low resistance shunt around the ignition primary and synchronizing coils. In this instance, we may omit the relay 25 and operate the trip arm 36 from core 4. Another difference in this figure is that switch arm 27 carries only one contact 40, to connect the two terminals 41 and 42, which are connected to the low potential sides of coils 8 and 7 respectively.

The operation of this form of our system is essentially the same as before. When the engines are in synchronism, the inductance of coils 7 and 8 is effectively small, and both engines receive normal ignition. Under these conditions, the currents in coils 2 and 3 are equal and oppose each other, so that no substantial flux is generated in core 4, lamp 6 is not lighted, and switch 27 is held open. Should the engines be thrown so far out of step that they cannot continue in synchronism, an effective flux is set up in coil 4, causing the lamp 6 to flash, actuating trip arm 36, permitting switch 27 to close. Closure of this switch connects coils 7 and 8 in parallel, so that the ignition current of each engine flows equally through both coils in parallel, and each engine receives substantially normal ignition, and may be run independently.

Referring now more particularly to Fig. 4, it will be seen that this circuit is the same as that of Fig. 3, except for the provision of the switch 46 for connecting the coils 7 and 8 in parallel, and the omission of coil 5 and lamp 6. Also, it will be noted that switch contact 40 may be mounted on a core 43 of magnetic material arranged to move into and out of the field of coils 2 and 3 against the action of spring 45 biasing the switch to open position. In this instance, push buttons 38 and 39 and trip arm 36 may be omitted.

For independent operation, switch 46 may be closed, connecting coils 7 and 8 in parallel, and switch 47 may be opened. For synchronized operation, 46 will be opened and 47 closed. Should the engines depart too far from synchronization, the current flowing through coils 2 and 3 will draw core 43 into the coils and contact 40 will connect terminals 41 and 42, thus putting coils 7 and 8 in parallel and permitting independent operation. Should the speeds approach each other sufficiently, the flux in core 43 decreases and spring 45 opens the switch, synchronizing the speeds. In this instance, the core 43 may carry or drive a pointer 50 moving over a scale 51 indicating the degree of departure from synchronization.

Departure from synchronization may be indicated in other ways. For example, as shown in Fig. 5, resistances 52 and 53 may be inserted in series between coils 8 and 7 and battery 1, and meter 54 may be connected across the ends of these resistances. At synchronism, the meter will show no reading. As the system starts to go out of synchronism, the meter will be ob-

served to fluctuate, and generally the greater the departure from synchronism, the greater and more frequent the fluctuations will be.

In this connection, it may be noted that the synchronism indicators herein disclosed may be employed even though the synchronizing coils are not. For instance, it may be desired to operate the system manually, and to know when the engines are in synchronism, or how far they are out.

Still another way of indicating synchronization is shown in Fig. 6, in which meter coils 55 and 56 are shown as inserted in series between coils 8 and 7 and their respective ignition primary coils. The indicator may be a moving iron vane carrying a pointer, and coils 55 and 56 may be so arranged with respect to this vane that for synchronism, the flux produced by coil 55 is equal and opposite to that produced by coil 56, and the meter is unaffected. Departure of the system from synchronization destroys this neutralization of the field and causes fluctuation of the meter pointer.

In this instance we have shown the manual switch 57 which may be closed to short-circuit coils 7 and 8 to provide for manual operation.

Our system is not limited to the synchronization of only two engines, as will be understood. In the case of a three engine system, engines A and B may be tied together as already described. Engine C may then be tied to either engine A or engine B. In the case of four engines, engines A and B may be tied together, engines C and D may be tied together, and engine C may be tied to engine B or A. This is diagrammatically illustrated in Fig. 7, in which coils 8 and 7 synchronize engines A and B, coils 8a and 7a synchronize engines A and C, and coils 8b and 7b synchronize engines C and D.

Switch 60 which may be a four pole single throw switch, may be used to short-circuit all the synchronizing coils to permit independent operation. Any of the synchronizing indicator arrangements shown and described herein may be employed, if desired, as well as any of the automatic arrangements for rendering the synchronizing coils ineffective on departure of the system from synchronism.

Referring now more particularly to Figs. 8, 9 and 10, in this instance we may dispense with the coils 7 and 8 by providing an impedance connected into the ignition circuits of the engine to be synchronized. This impedance may be substantially inductive as indicated by 60, Fig. 9, substantially capacitive as indicated by condenser 61, or substantially resistive as indicated by resistance 62. The element which may be used may be chosen to suit particular operating conditions as will be explained.

In Fig. 8 as before, the engines may have a common battery 1 (although this is not essential), individual switches 10 and 11 and ignition primary coils 12 and 13 and secondary coils 20 and 21. The synchronizing impedance may be connected as indicated by the arrows between the breaker sides of the primary windings 12 and 13 through synchronizing switch 63.

Assuming that the engines are running in synchronism, the two circuits will be in balance. There will be no potential difference between the terminals of the synchronizing elements 60, 61 or 62, and no tendency for cross currents to flow, even though switch 63 is closed.

Should engine B, however, tend to increase in speed and thus to pull out of synchronism,

it is apparent that the breaker points 16 and 17 will open slightly in advance of points 14 and 15 of engine A. The opening of points 16 and 17 will not break the ignition circuit of engine B because it will be seen that current may still flow through ignition coil primary of engine B, even though points 16 and 17 have opened, the circuit being from battery 1 through primary 12, through synchronizing switch 63, elements 60, 61 or 62, through breaker points 14 and 15 of engine A to ground and thus back to the battery 1.

Thus it will be seen that the circuit is not effectively completely opened until both sets of breaker points have opened and this retards the spark on the faster engine. There is no possibility of misfiring either engine, for example on the compression stroke, because in each engine the breaker points are open only during a relatively small angle of the firing stroke, and, as already stated, neither engine can be fired unless both sets of breaker points are open. Since each engine continues to time its own breaker operation, even under synchronized operation, its breaker points will be closed at all times when misfiring could cause damage, and therefore there can be no spark under such conditions.

We have so far referred to the impedances 60, 61 and 62, but it is to be understood that the system will operate without the use of an impedance; that is, by connecting the arrows of Fig. 8 directly together to provide a straight zero resistance connection between the breaker sides of the two primaries. In general it is not advantageous to operate this way, because the breaker points of the slower running engine will then carry the ignition load for both engines, and it may be found that excessive pitting or burning of the points will occur.

However, it will be understood that operating in this manner gives the greatest amount of what may be termed synchronizing effort, whereas an increase in the value of the impedances 60, 61 or 62 reduces the amount of synchronizing effort, but simultaneously prevents excessive pitting or burning of the contacts. The best value of the synchronizing impedance may be determined by trial for any particular condition. In general, it may be stated that if resistance 62 is employed, its maximum value will be of the order of 10 to 20 ohms. If inductance 60 is employed, its maximum value will be of the order of 500 millihenries, and if condenser 61 is employed, its minimum value may be of the order of 10 mmf. It may be noted here that the use of a resistance as the synchronizing element gives a synchronizing effort which is independent of the speed of the engines, the use of a capacity gives a synchronizing effort which is greater the higher the speed, and the use of an inductance gives a synchronizing effort which decreases with increase in speed.

Referring now to Fig. 10, we have indicated an automatic switch for opening and synchronizing circuit automatically in case the tendency of the engines to separate becomes too great. In this instance, the relay 64 may be provided in series with the synchronizing impedance and this relay may be spring biased to closed position. It may be provided with two windings, the first being a low impedance or current winding 65, to aid in opening the synchronizing circuit, and the second being a high impedance or voltage winding 66, to hold the synchronizing impedance out of circuit until synchronism is obtained. Both windings operate in a manner to open the

switch 64. In addition, as an indicator we may employ a zero center voltmeter connected across the synchronizing impedance and the relay 64. As will be understood, when the engines are operating in synchronism, both circuits will be in balance and there will be no potential differences across the synchronizing impedance and no current flowing therethrough. If conditions cause the two engines to tend to operate at widely different speeds, the potential difference across the synchronizing impedance and the current flow through it will become relatively high and the relay 64 will open.

While we have shown and described certain preferred embodiments of our invention, it will be understood that modifications and changes may be made without departing from the spirit and scope of our invention, as will be clear to those skilled in the art.

We claim:

1. A system for synchronizing internal combustion engines having electrical ignition, comprising, in combination, an inductance in the primary ignition circuit of each engine, each of said inductances having a value sufficient to impair the ignition of its engine, said inductances being coupled together in such a manner as to substantially reduce the effective inductance of each other when said engines are running in synchronism.

2. A system for synchronizing internal combustion engines having electrical ignition, comprising, in combination, an inductance in the primary ignition circuit of each engine, each of said inductances being substantially equal in value and having a value sufficient to impair the ignition of its engine, and said inductances being coupled together in opposition to each other, whereby they substantially neutralize each other when said engines are running in synchronism.

3. A system for synchronizing internal combustion engines having electrical ignition, comprising, in combination, an inductance in the primary ignition circuit of each engine, each of said inductances being substantially equal in value and having a value greater than that of the primary of the spark coil, said inductances being coupled together in opposition to each other, whereby they substantially reduce the effective inductance of each other when said engines are running in synchronism.

4. A system for synchronizing internal combustion engines having electrical ignition, comprising, in combination, an inductance in the primary ignition circuit of each engine, each of said inductances having a value sufficient to impair the ignition of its engine, said inductances being coupled together in such a manner as to substantially reduce the effective inductance of each other when said engines are running in synchronism, and means for rendering said inductances ineffective.

5. A system for synchronizing internal combustion engines having electrical ignition, comprising, in combination, an inductance in the primary ignition circuit of each engine, each of said inductances having a value sufficient to impair the ignition of its engine, said inductances being coupled together in such a manner as to substantially reduce the effective inductance of each other when said engines are running in synchronism, and means responsive to a predetermined departure of said engines from synchronism for rendering said inductances ineffective.

6. A system for synchronizing internal combustion engines having electrical ignition, comprising, in combination, an inductance in the primary ignition circuit of each engine, each of said inductances having a value sufficient to impair the ignition of its engine, said inductances being coupled together in such a manner as to substantially reduce the effective inductance of each other when said engines are running in synchronism, means for rendering said inductances ineffective, and electrical means responsive to flow of current in the ignition circuit of each engine for indicating synchronism or departure therefrom.

7. A system for synchronizing internal combustion engines having electrical ignition, comprising, in combination, an inductance in the primary ignition circuit of each engine, each of said inductances having a value sufficient to impair the ignition of its engine, said inductances being coupled together in such a manner as to substantially reduce the effective inductance of each other when said engines are running in synchronism, means responsive to predetermined departure of said engines from synchronism for rendering said inductances ineffective, and electrical means responsive to flow of current in the ignition circuit for indicating synchronism or departure therefrom.

8. A system for synchronizing internal combustion engines having electrical ignition, comprising, in combination, an inductance in the primary ignition circuit of each engine, each of said inductances having a value sufficient to impair the ignition of its engine, said inductances being coupled together in such a manner as to substantially reduce the effective inductance of each other when said engines are running in synchronism, switching means for rendering said inductances ineffective, and means responsive to departure of said engines from synchronism by a predetermined amount, for operating said switching means to render said inductances ineffective.

9. A synchronism indicating system for internal combustion engines having electrical ignition, comprising, in combination, an impedance in the ignition circuit of each of the engines of the system and so arranged as to balance the effect of each other when said engines are in synchronism, and means for providing an indication and responsive to the net effect of said impedances.

10. A synchronism indicating system for internal combustion engines having electrical ignition, comprising, in combination, an inductance in the ignition circuit of each engine and so

arranged as to balance the effect of each other when said engines are in synchronism, and an indicator responsive to the state of balance or unbalance of said impedances.

11. A synchronism indicating system for internal combustion engines having electrical ignition, comprising, in combination, an inductance in the ignition circuit of each engine, said inductances being so arranged that the flux produced due to ignition current in each opposes and balances when said engines are synchronized, and a visual indicator responsive to net flux produced by said inductances.

12. A system for synchronizing a plurality of internal combustion engines having electrical ignition, comprising, in combination, a plurality of engines, each having an interrupter in series with an ignition coil, of means for connecting said interrupters in parallel with each other, whereby neither engine may be fired until both interrupters have opened.

13. A system for synchronizing a plurality of internal combustion engines having electrical ignition, comprising in combination, a plurality of engines, each having an interrupter in series with an ignition coil, of means for connecting said interrupters in parallel with each other, said means including an impedance for reducing the cross-current which would otherwise flow in such connecting means.

14. A system for synchronizing a plurality of internal combustion engines having electrical ignition, comprising, in combination, a plurality of engines, each having an interrupter in series with an ignition coil, of a circuit connecting said interrupters in parallel, manual means for opening and closing said circuit, and an impedance in said circuit.

15. The combination claimed in claim 14, in which said impedance has different effective values for different engine speeds.

16. The combination claimed in claim 14 with means responsive to predetermined tendency out of synchronism for opening said circuit.

17. In a system for synchronizing internal combustion engines having electrical ignition, in combination, a plurality of engines each having its own ignition circuit comprising a primary coil and an interrupter connected in series for both synchronous and non-synchronous operation, and means for coupling said ignition circuits together electrically for synchronized operation, while maintaining each interrupter in series with the primary coil of its own respective engine for synchronized operation.

ALEXANDER SENAUE.
JACOB A. BOLTON.