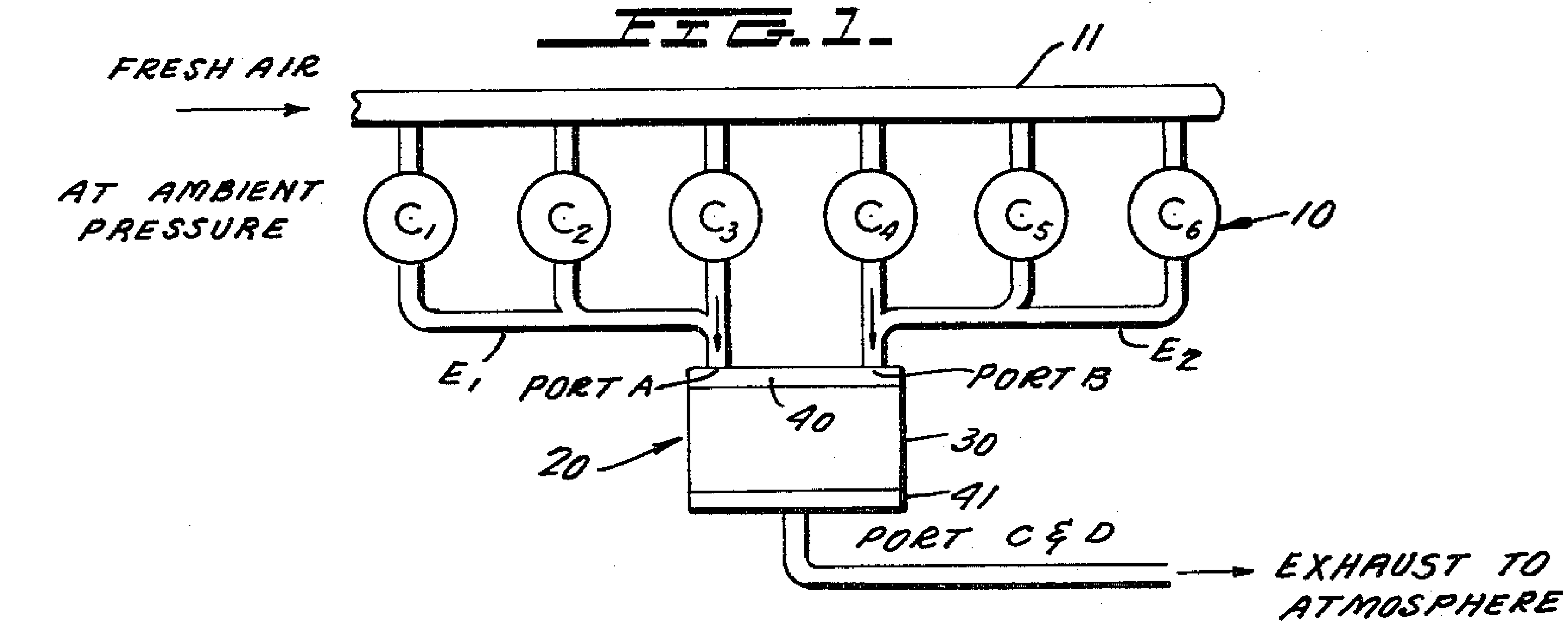
WAVE MACHINE TO INITIATE SCAVENGING OF INTERNAL COMBUSTION

Filed March 20, 1962 4 Sheets-Sheet 1

FIG. 1.



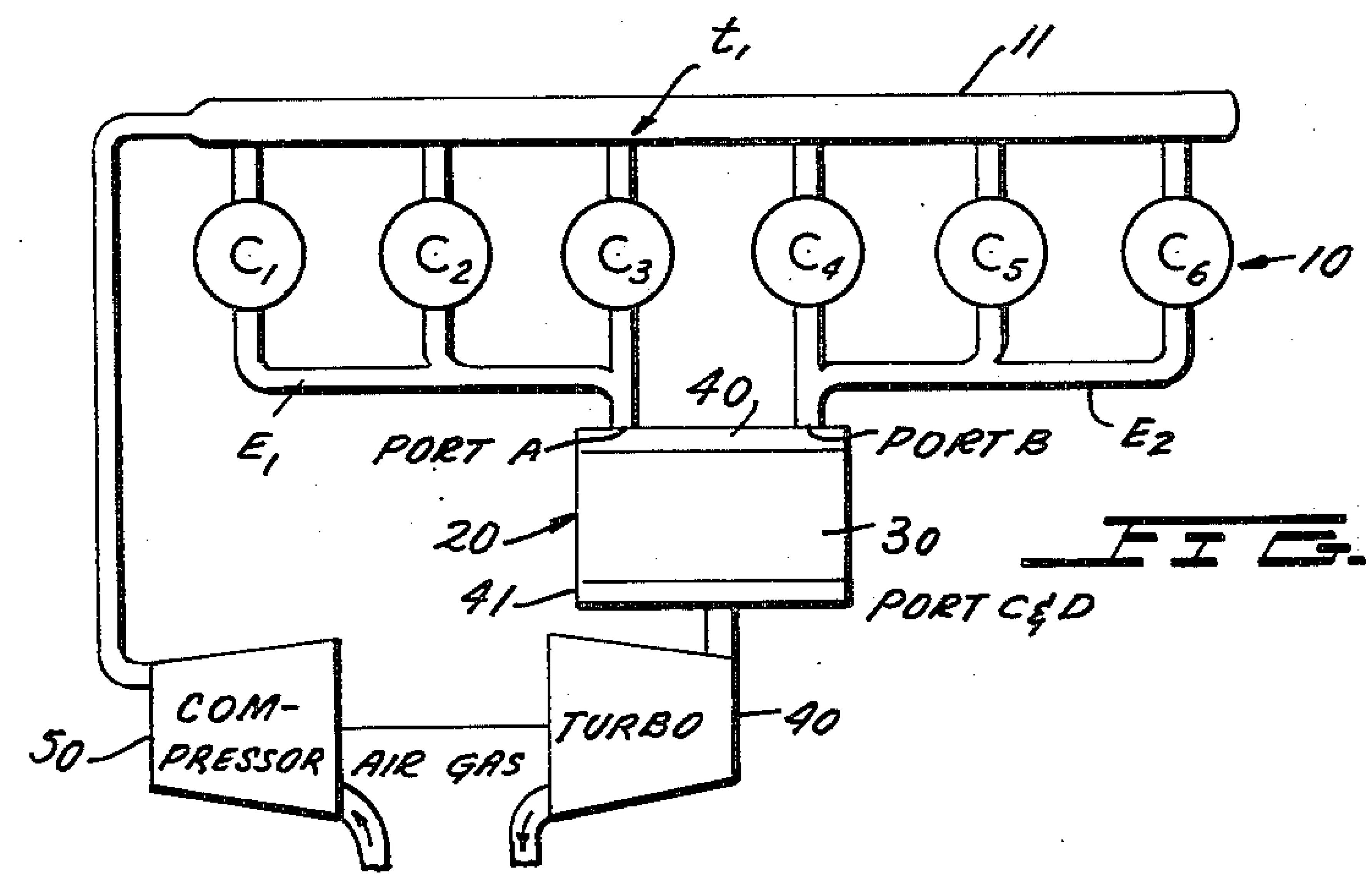


FIG. 3.

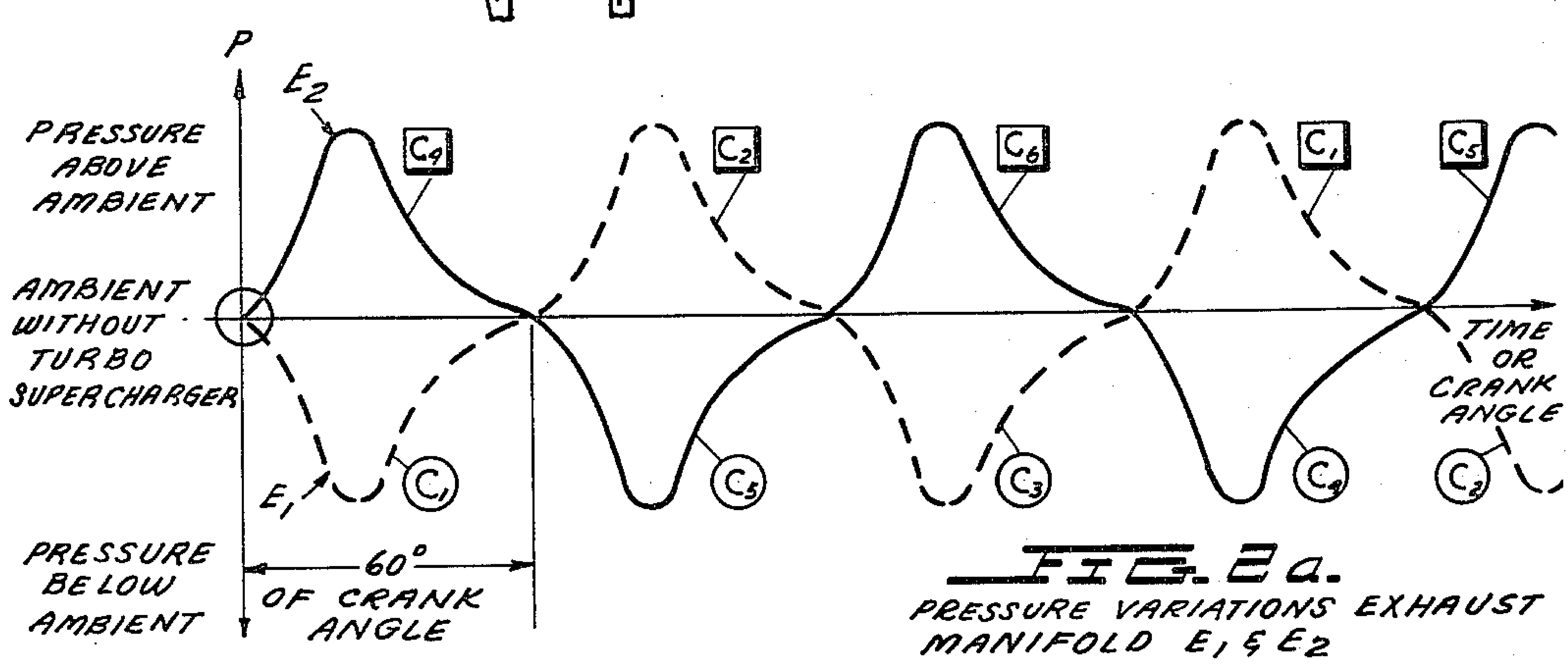


FIG. 2a.
PRESSURE VARIATIONS EXHAUST MANIFOLD E_1 & E_2

	60°	120°	180°	240°	300°	360°
E_1	◯ C_1	□ C_2	◯ C_3	□ C_1	◯ C_2	□ C_3
E_2	□ C_4	◯ C_5	□ C_6	◯ C_4	□ C_5	◯ C_6

FIG. 2b

◯ SCAVENGING
□ BLOW DOWN

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FIG. 6.

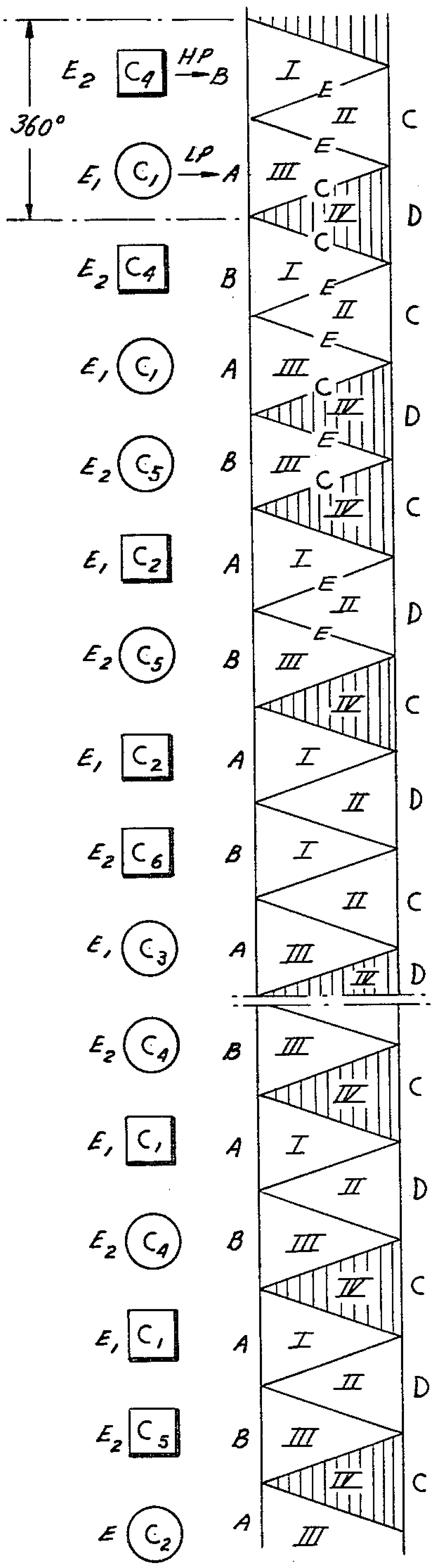

FIG. 4a.

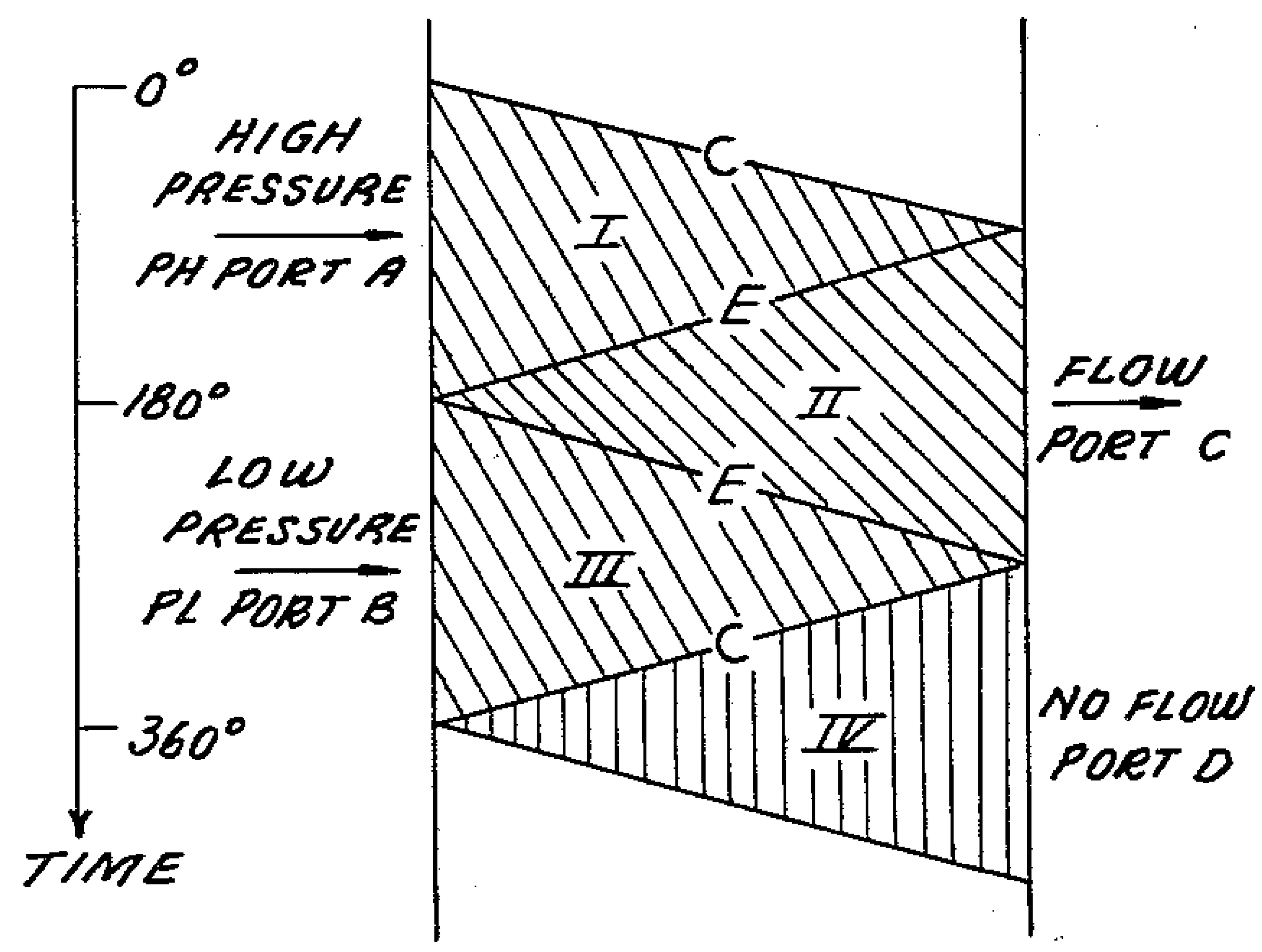

FIG. 4b.

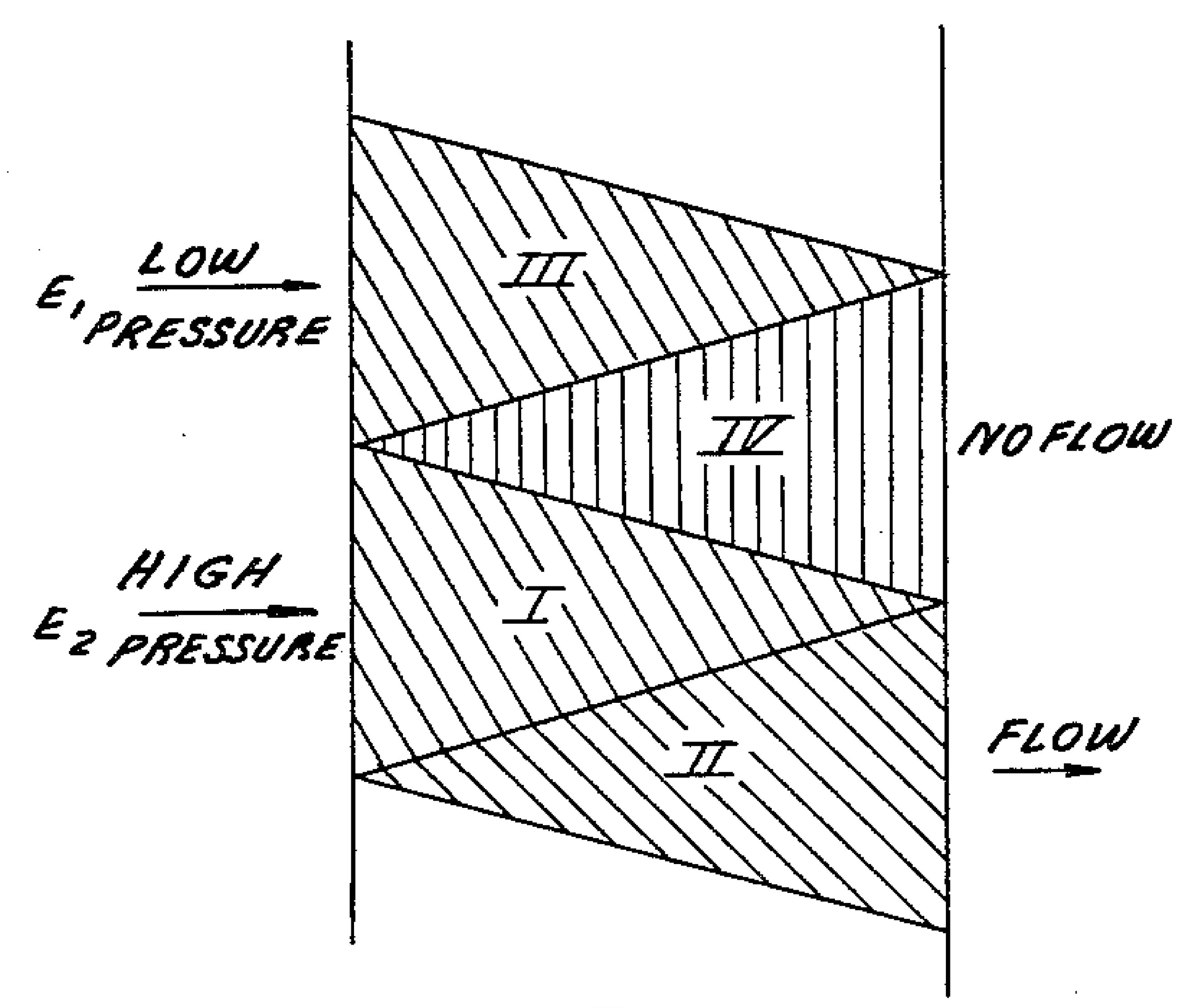

FIG. 4c.

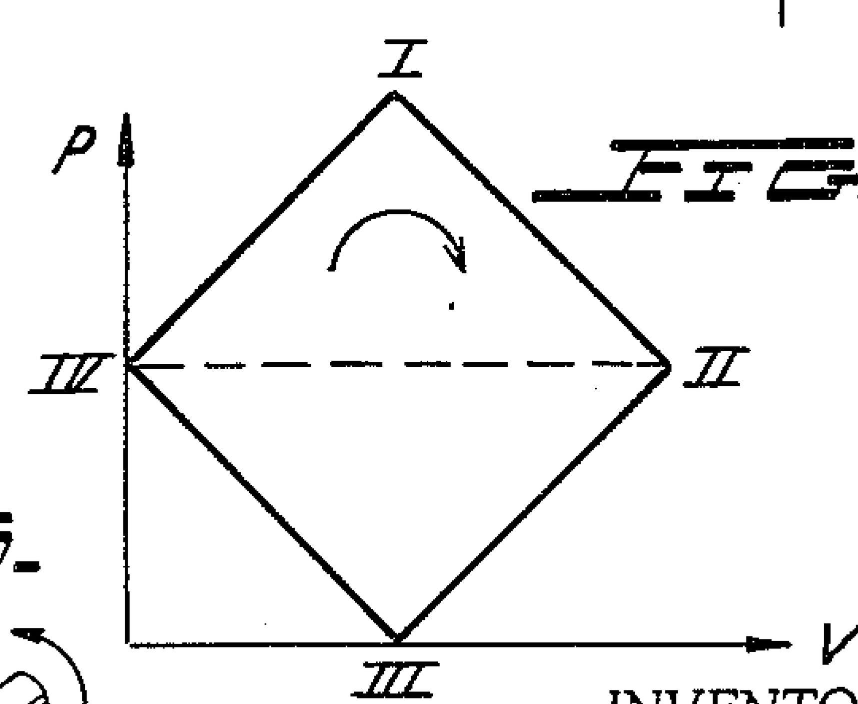

FIG. 5.

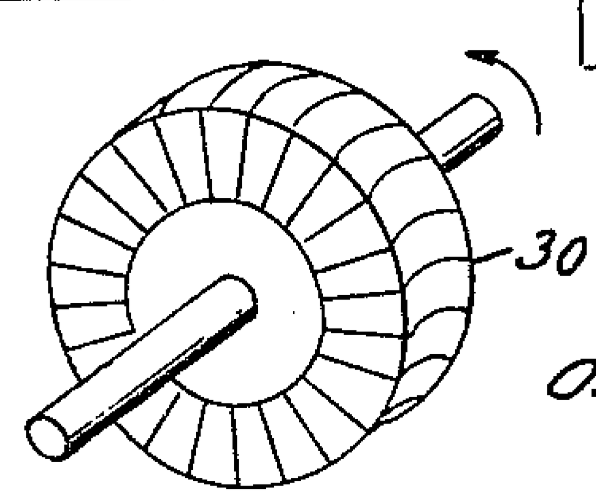

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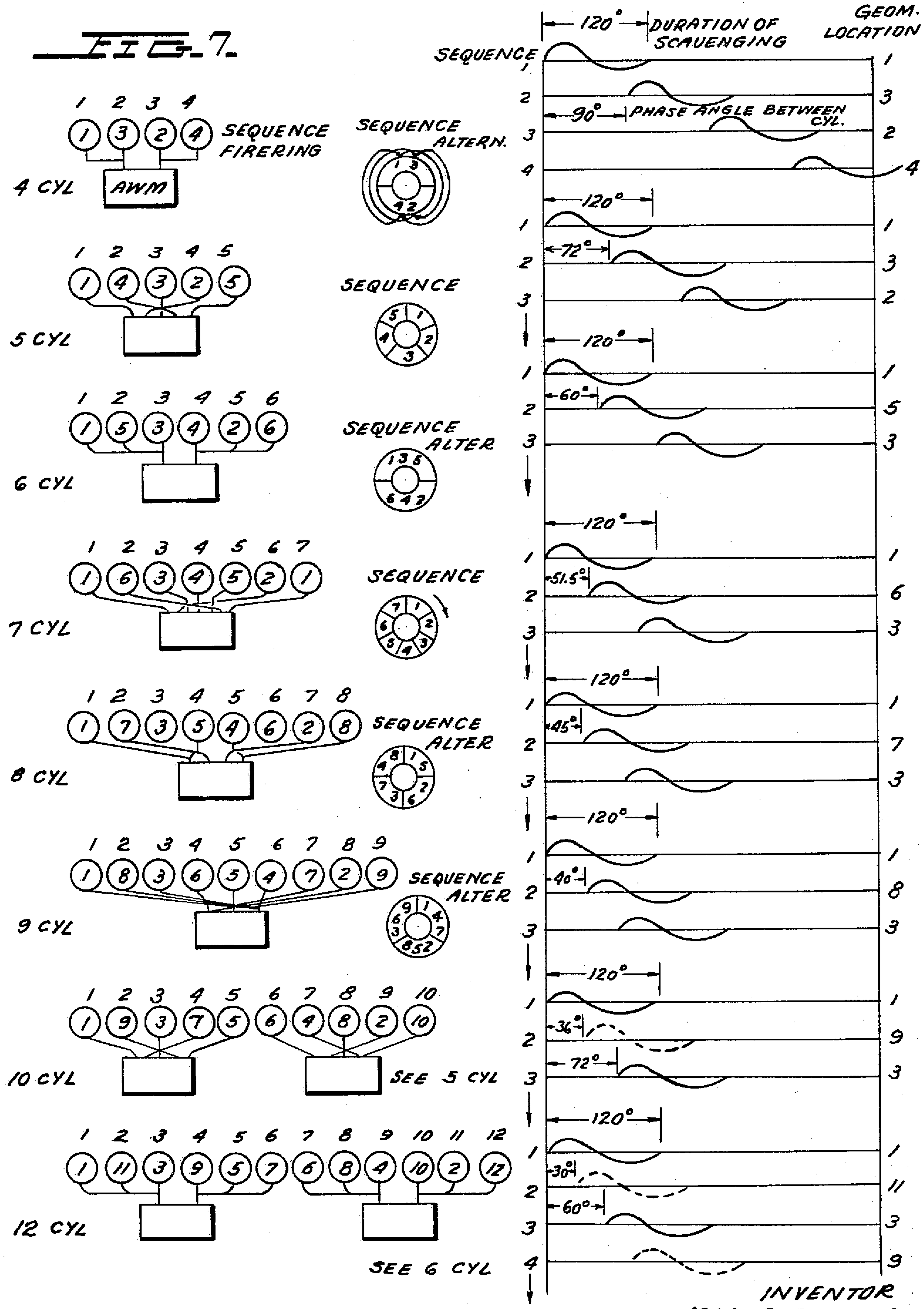
FIG. 7



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WAVE MACHINE TO INITIATE SCAVENGING OF INTERNAL COMBUSTION

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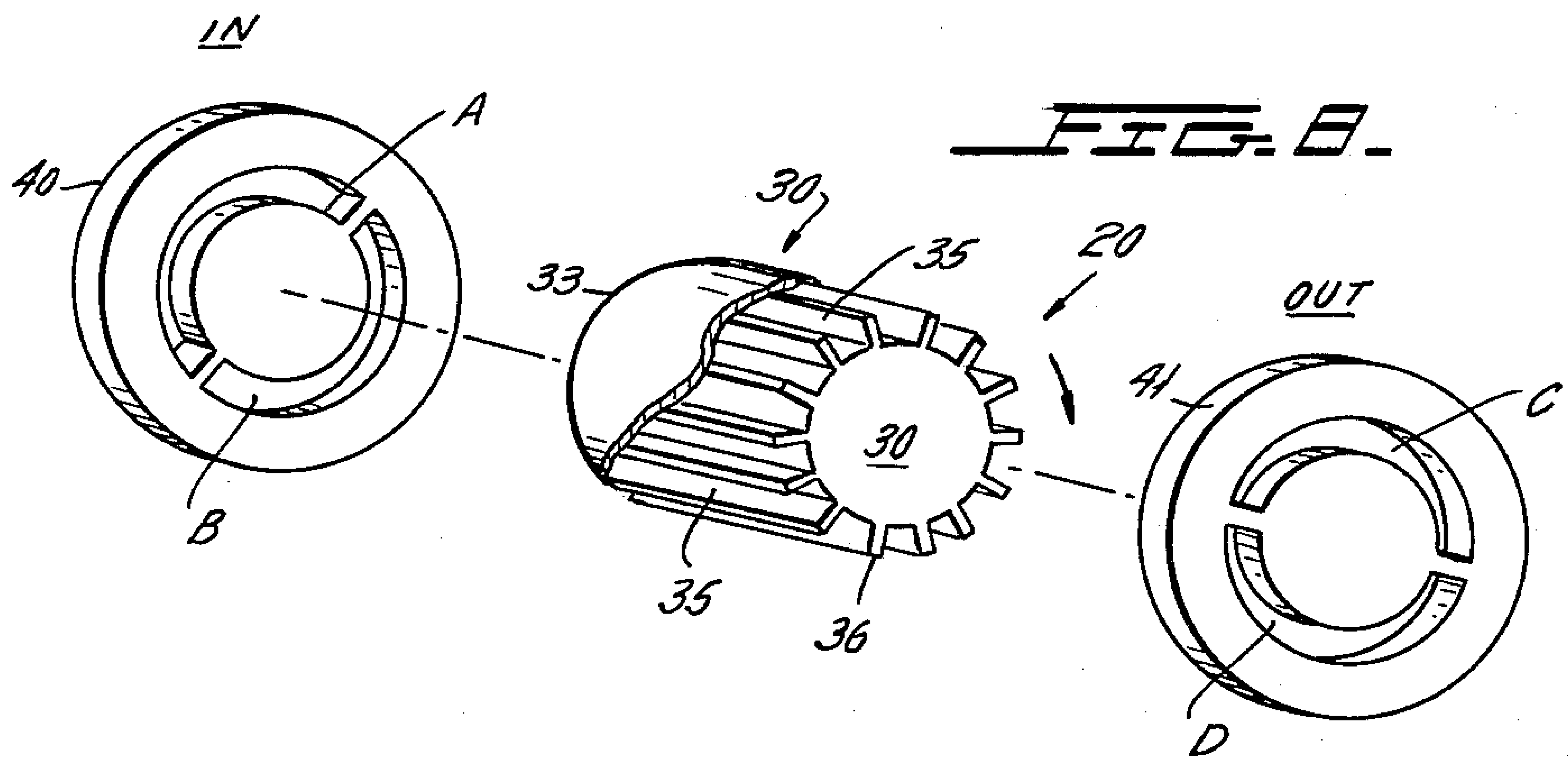


FIG. 8

FIG. 10

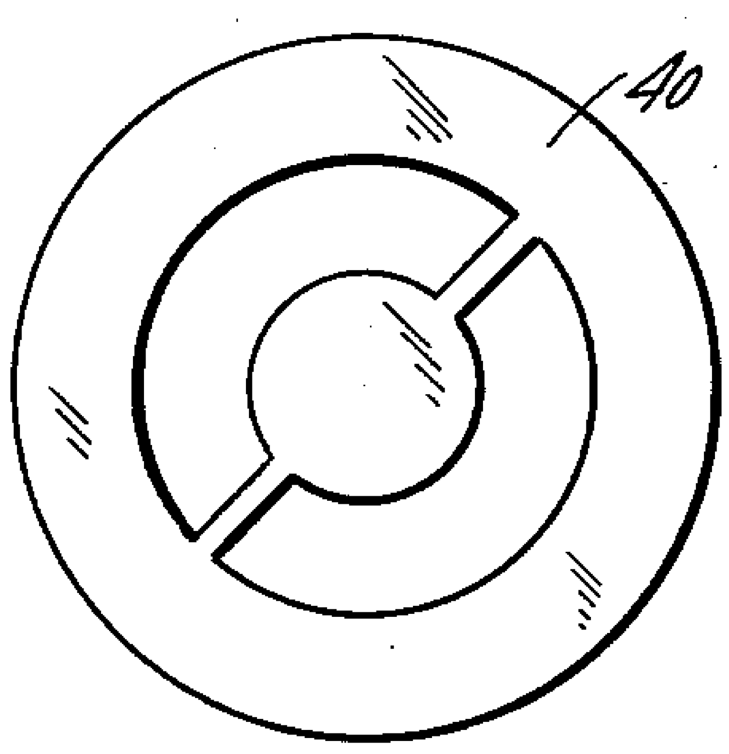


FIG. 11

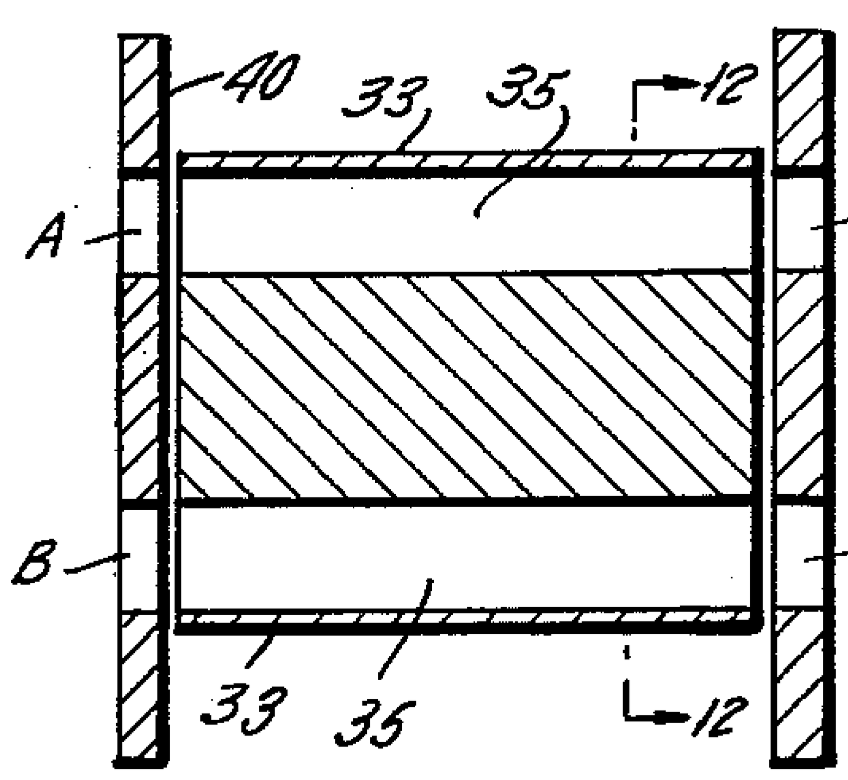
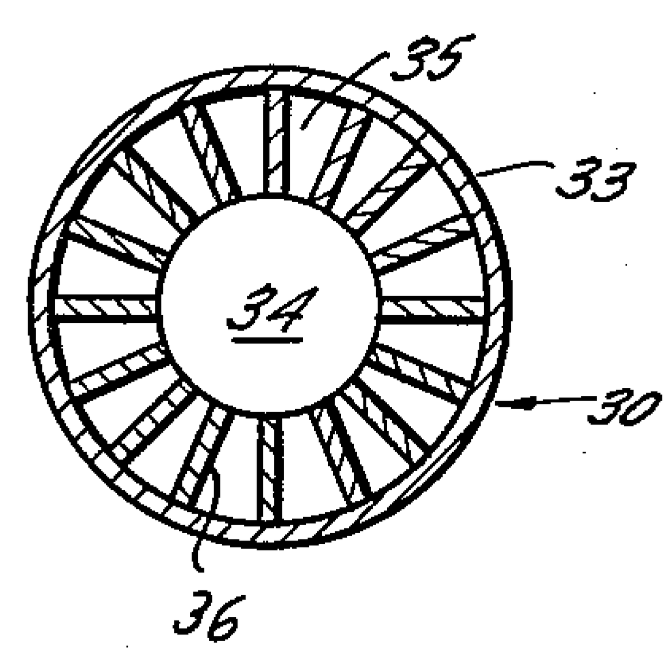


FIG. 12



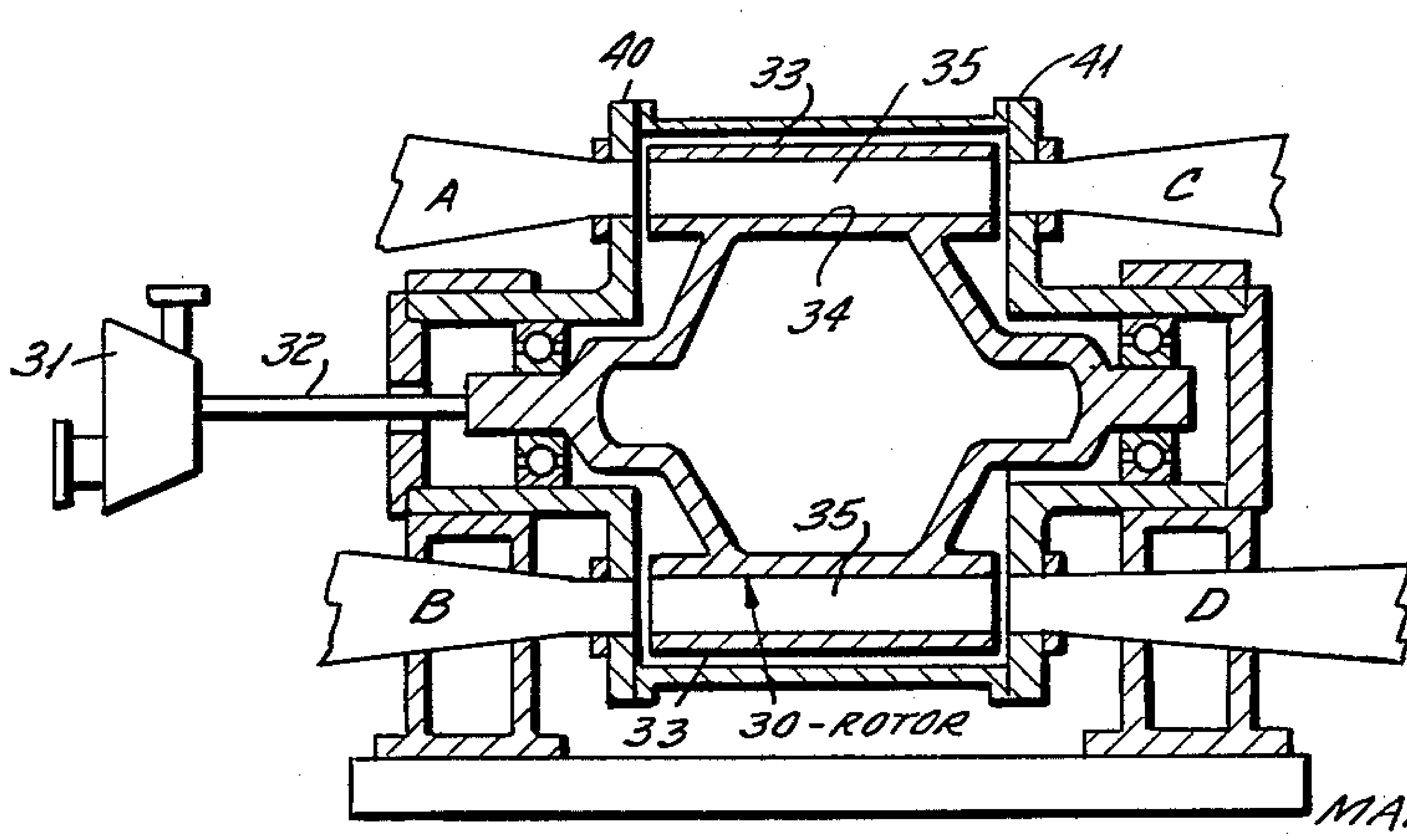


FIG. 9

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United States Patent Office

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3,180,077
WAVE MACHINE TO INITIATE SCAVENGING OF INTERNAL COMBUSTION

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Filed Mar. 20, 1962, Ser. No. 181,083
8 Claims. (Cl. 60—13)

My invention relates to the combination of a wave machine and internal combustion engine and, more particularly, is directed to a novel arrangement whereby the wave machine provides the necessary differential of pressure across the cylinders of a reciprocating engine to thereby initiate scavenging operation of the cylinders at the correct time.

My novel arrangement provides a common intake manifold for all of the cylinders of the reciprocating engine but has multiple subdivided exhaust manifolds to combine undivided cylinders of the reciprocating engine connected in such a manner as to obtain the best scavenging effect. The wave machine has accordingly a suitable number of inlet ports each inlet port being operatively connected to each of the exhaust manifolds. With this novel arrangement a particular wave machine utilizes the blow-down energy of one cylinder of one group in order to initiate the scavenging of a cylinder of another group.

Aerodynamic wave machines have been used as superchargers for reciprocating engines and particular examples and constructions of same are disclosed and described in U.S. Patent 2,957,304 issued October 25, 1960, to Max Berchtold entitled "Aerodynamic Wave Machine Used as a Supercharger for Reciprocating Engines" and assigned to the assignee of the instant invention.

It is the essence of the aforementioned U.S. Patent 2,957,304 to utilize the blow-down energy of a first cylinder to thereby provide input energy for the wave machine, which wave machine in turn provides an increase in pressure which, in turn, aids the scavenging of the same or another cylinder depending on the manifold arrangement. Although this arrangement has been found to be extremely desirable in numerous applications, it has nevertheless been found that under certain operating conditions, as for example in low load operation, the timing of the wave machine may be disturbed so that the output of the wave machine may not supply sufficient clean air to the reciprocating engine. It is possible that the compressed air at the pickup port of the wave machine is contaminated by some of the exhaust gasses from the reciprocating engine. It is noted that even at other operating conditions there is always some degree of contamination of the high pressure output air at the pickup port of the wave machine.

In an internal combustion engine considerable amount of energy is lost as kinetic energy in the exhaust gases. At the time the expansion stroke of the piston has been completed the pressure in the cylinder is considerably higher than the ambient pressure. It is difficult to build turbines capable to extract this energy effectively. In order to support the scavenging, particularly at low load, the amount of this energy is small; therefore high utilization is essential to maintain desirable operating conditions without any other scavenging pumps or blowers driven from the engine. The various means such as piston pumps, Roots-blowers, turbo-blowers, etc. driven by the internal combustion engine, which have to be used to assure proper functioning of the engine under all load conditions, reduce the engine efficiency and are for this reason undesirable elements.

Today most large 2-cycle diesel-engines utilize turbo-superchargers to increase the power output. In longitudinal scavenged engines the turbo-supercharger is capable to provide sufficient air-pressure to assure scavenging under all load conditions. Suitable exhaust manifolds between the cylinders and the turbine are essential. Furthermore it is possible to advance the exhaust valve opening time at low load in order to increase the available exhaust energy furnished to the turbine. This engine type, which requires exhaust valves and the mechanical complications for changing the valve timing is undesirable.

To further improve the scavenging conditions different designs of pulse converters have been proposed between the engine cylinder and the exhaust gas turbine intake. These are based on the principle of the jet pump, which utilizes the momentum exchange between gas streams of different speed. Even though these pumps are inefficient these devices have shown some gains.

The instant invention proposes the use of the wave machine described in U.S. application Serial No. 655,441 filed April 26, 1957, now U.S. Patent No. 3,145,909, entitled "Pressure Transformer" to F. J. Gardiner and assigned to the assignee of the instant invention, with some modifications and suitable exhaust manifolds to scavenge 2-cycle engines. The cylinders of a multi-cylinder engine can be grouped with common exhaust manifolds in such a manner that the blow-down phase of one cylinder does not coincide with the scavenging phase of another cylinder in the same group. A cylinder of the other group however is in its scavenging phase. The proposed "Driver wave machine" utilizes the blow-down energy of a cylinder in one group to create a suction effect to one of the cylinders in the other group. The Driver described in aforementioned U.S. application Serial No. 655,441 is capable to convert the temporary pressure rise directly into a temporary vacuum, since inertia effects in wave machines are practically non-existing for the relatively slow pressure fluctuations as they appear in exhaust pipes of internal combustion engines. The proposed scavenging arrangement for 2-cycle engines can also be used in conjunction with a turbo-supercharger. In the later case the turbo-supercharger raises essentially the pressure level for the engine whereas the wave machine creates the conditions for scavenging.

It is a primary object of my invention to provide an arrangement whereby the wave machine is utilized merely to initiate scavenging but does not supply any of the scavenging air for the reciprocating engine. To this end the wave machine is utilized only for the purpose of creating the necessary pressure differential across a cylinder of the reciprocating engine by lowering the exhaust manifold pressure rather than by raising the intake manifold pressure.

Thus an object of my invention is to provide a combination of a wave machine and two-cycle multi-cylinder internal combustion engine wherein the combustion engine has split exhaust manifolds in order to enable the blow-down energy from one cylinder to create the necessary drop in pressure to initiate scavenging in another cylinder.

Still another object of my invention is to provide a wave machine that operates as a pressure transformer with several inlet ports each connected to an exhaust manifold leading to one or more cylinders.

Another object is to provide a novel combination of a reciprocating engine and a wave machine whereby the wave machine serves primarily to initiate scavenging of the wave machine and the timing of the reciprocating engine automatically controls the operation of the wave machine so scavenging is initiated for the proper cylinder always at the correct time.

These and other objects of my invention will be apparent from the following description when taken in connection with the drawings in which:

FIGURE 1 is a schematic illustration of an example such as a six-cylinder reciprocating engine connected to a wave machine by way of a first and second exhaust manifold.

FIGURE 2(*a*) is a graphic illustration of pressure against time for FIG. 1 illustrating the conditions existing in the first and second manifold E_1 and E_2 and has superimposed thereon an illustration of which cylinder causes the condition illustrated.

FIGURE 2(*b*) is a chart showing the conditions existing within the first and second manifold of a six-cylinder engine of FIG. 1 for various degrees of rotation of the reciprocating engine.

FIGURE 3 is a diagrammatic view similar to FIGURE 1 but shows the manner in which the exhaust gas from the wave machine can be utilized to drive the turbine compressor unit required for supercharging the reciprocating engine.

FIGURE 4(*a*) is an illustration of the conditions existing within the rotor of the wave machine when there is blow-down energy provided from one of the cylinders in the first exhaust manifold and when one of the cylinders connected to the second exhaust manifold requires scavenging.

FIGURE 4(*b*) is an illustration of the conditions existing within the rotor of the wave machine similar to FIGURE 4(*a*) but illustrates the conditions when there is blowdown energy from one of the cylinders connected to the second exhaust manifold and when one of the cylinders connected to the first exhaust manifold requires scavenging.

FIGURE 4(*c*) is a state diagram of pressure vs. velocity for the rotor conditions of FIGURES 4(*a*) and 4(*b*).

FIGURE 5 is a perspective view of one form of a rotor that can be used in connection with the embodiments of FIGURES 1 and 3 and shown in the pictorial representation of FIGURES 4(*a*) and 4(*b*) in which the rotor has curved channels for superimposing turbine action.

FIGURE 6 is a view of the condition existing within the rotor and is similar to FIGURES 4(*a*) and 4(*b*) which show a plurality of 360° turns of the rotor and the manner in which the conditions continuously change depending on energy received from the cylinders as well as the requirements of the cylinders for scavenging.

FIGURE 7 is a schematic representation for **4**, **5**, **6**, **7**, **8**, **9**, **10**, and **12** cylinder engines illustrating arrangement of common exhaust manifold connections to the wave machine, the sequence of operation, and a diagrammatic illustration of pressure fluctuations.

FIGURE 8 is a schematic perspective view showing the pressure transformer of aforementioned application Serial No. 655,441; the rotor thereof containing a plurality of cells and also illustrating the dual input and output ports in the stator discs which are positioned on either end of the rotor.

FIGURE 9 is a schematic cross-sectional view showing the rotational mounting of the rotor and the stationary mounting of the stator discs containing the input and output ports.

FIGURE 10 is an end view of a stator disc containing two ports.

FIGURE 11 is a cross-sectional logitudinal section taken through the rotor and stationary disc.

FIGURE 12 is a cross-sectional view taken along the line **12—12** of the rotor of FIGURE 11 and shows the blades, hub and shroud of the rotor.

Although my invention can be applied to any multi-cylinder, two-cycle engine, I have chosen to describe the details of my invention in connection with a six-cylinder engine as set forth in FIGURES 1–6. Specifically referring to FIGURES 1 and 3 the instant invention contemplates a system whereby the cylinders C_1, C_2, C_3, and a second group C_4, C_5, C_6. Both groups are operatively connected to a common intake manifold **11** and the first and second group of cylinders are operatively connected respectively to a first and second exhaust manifold E_1,

E_2. The first and second exhaust manifolds E_1, E_2 are operatively connected respectively to a first and second inlet port A, B of the wave machine **20**. Wave machine **20** is constructed in the exemplary manner shown in FIGURES 8–12, and operates to provide a pressure differential between certain ones of its ports, as is more fully discussed in aforementioned application Serial No. 655,441. Hence, wave machine **20** operates as a pressure transformer to achieve the advantageous objectives of the instant invention. The rotor **30** is driven at high speed rotation about its axis by any suitable means, such as turbine **31**, which is connected to the rotor **30** by shaft **32**. The rotor **30** has a hub **34** and an outer shell or shroud **33**. A plurality of vanes **36** extend from the hub **34** to the shroud **33**, and are permanently secured thereto in any desirable manner, such as brazing.

The space between the vanes **36** forms a plurality of cells or channels **35** through which the fluid will flow. The cells or channels **35** may extend parallel to the longitudinal axis of the rotor **30**, as shown in FIGURES 8–12, or the vanes **36** may be constructed and positioned so that the resulting cells **33** wind helically on the rotor **30**, as shown in FIGURE 5.

The stator discs or plates **40** and **41** are placed on opposite sides of the rotor **30** in the closest possible proximity thereto consistent with high speed requirements in the rotor to obtain the best possible fluid seal. Input stator disc **40** contains dual input ports A, B, while output stator disc **40** similarly contains output ports C, D. The stator discs or plates **40** and **41** are rigidly mounted on the base **50**, and the rotation of the rotor **30** by the turbine **31** causes the plurality of cells **35** to rotate past the input and output ports A, B and C, D respectively.

In either group of engine cylinders at any one instant there will always be a cylinder that is either providing blow-down energy or requires scavenging. This condition will constantly alternate so that the following may be the sequence of operation with respect to time:

60°, cylinder C_1, to be scavenged, cylinder C_4, supplies blow-down energy
120°, cylinder C_2, supplies blow-down energy, cylinder C_5, to be scavenged
180°, cylinder C_3, to be scavenged, cylinder C_6, supplies blow-down energy
240°, cylinder C_1, supplies blow-down energy, cylinder C_4, to be scavenged
300°, cylinder C_2, to be scavenged, cylinder C_5, supplies blow-down energy
360°, cylinder C_3, supplies blow-down energy, cylinder C_6, to be scavenged.

Thus, at the two inlet ports A, B of the wave machine **20**, one of the two inlet ports receives a supply of hot exhaust gas under pressure from the reciprocating engine **10** and the remaining inlet port has a reduction of pressure. At any one instant of time there would be a cylinder in one of the two exhaust manifolds that requires scavenging and, simultaneously, there will be a cylinder in the other of the exhaust manifolds that is supplying blown-down energy.

The operation of the wave machine **20**, therefore, is such that there is a reduction in the pressure in one of the exhaust manifolds containing a cylinder that should be scavenged. This reduction in pressure creates a pressure differential between the fresh air intake and the exhaust manifold, such that the pressure drop permits scavenging of the cylinder by the fresh air whereby the air has not passed through the wave machine.

It must be noted that, in order to achieve the aforementioned results, the cycle of operation of the wave machine **20** is different from the cycles heretofore known. That is, the function and purpose of any one port of the wave machine is constantly and continuously changing to be either a high pressure or low pressure port. Even in the heretofore known pressure transfomer of aforementioned copending U.S. application Serial No. 655,441, this condition has not existed. However, as aforementioned, the ports of the wave machine are alternately connected in time to a cylinder that is providing blow-down energy and thence to a cylinder that requires scavenging so that the reversal of pressure of the various ports is automatically provided for the wave machine 20 by the inherent timing of the reciprocating engine 10. Furthermore, this continuous reversal of pressure is the result of the pulsating exhaust conditions of the reciprocating engine 10. Any cylinder going through the compression and expansion strokes does not contribute any flow into the exhaust manifold.

In a two-stroke engine 10, the sequence of any one cylinder is as follows: The piston moves up to compress the air contained therein, there is ignition of the air-fuel mixture and, thus, the piston is driven downwardly during the expansion portion of the stroke and energy is taken from the reciprocating engine 10. After about 70 to 80% of the stroke the exhaust ports (valves or ports in the cylinder wall) are opened up to release some of the hot gas contained within the cylinder. This is the blow-down portion of the stroke. Before the piston reaches the lowermost portion of its stroke, the pressure of the gas within the cylinder is nearly equal to the pressure of the gas in the exhaust manifold. At this time the scavenging ports open. Scavenging is completed when the scavenging ports close.

It should be noted that the wave machine having, as for instance on six-cylinder engines, ports A and B that are alternately high and low pressure ports is comparable to a pressure transformer rather than a pressure exchanger. Thus, the basic cycle of operation will bear greater similarity to that of aforementioned U.S. application Serial No. 655,441 rather than that of U.S. Patent 2,970,745 issued February 7, 1961, to M. Berchtold entitled "Wave Engine" and assigned to the assignee of the instant invention or aforementioned U.S. Patent 2,957,304. For this reason, the instant invention is clearly distinguishable from that disclosed and claimed in aforementioned U.S. Patent 2,957,304 wherein the reciprocating engine is super-charged by a wave machine which operates as a pressure exchanger rather than a pressure transformer and, furthermore, is so connected to the reciprocating engine that it pushes air through the cylinders during scavenging rather than sucking air out of the cylinders during scavenging.

In the embodiment of FIGURE 1 an arrangement is shown whereby the gas outlet ports C and D are exhausted to the atmosphere and thus, this embodiment is solely for the purpose of assisting scavenging and does not super-charge the reciprocating engine. During low load or no load operation of the reciprocating engine, the magnitude of exhaust gasses from the reciprocating engine cylinders is extremely low. Thus, in effect, the pressure input to the pressure transformer 20 at state I is low. Therefore, the second pressure will only be slightly below ambient pressure resulting in a small pressure differential. As a result, the degree of scavenging will be less. This means that the device has a self-governing feature resulting in a larger degree of scavenging during the higher load of the reciprocating engine where it is needed and a reduced scavenging during low load of the reciprocating engine where it is not needed. The same variation of the scavenging exists with the embodiment shown in FIGURE 3 since the degree of scavenging will depend on the magnitude of the blow-down pressure emanating from the reciprocating engine cylinders.

As heretofore noted, the embodiment shown in FIGURE 1 is exclusively for the purpose of assisting scavenging and does not supercharge the reciprocating engine 10. However, the embodiment of FIGURE 3 not only assists scavenging but also permits super-charging of the reciprocating engine 10. That is, the output of the compressor

50 is at a pressure level above ambient pressure and thus the pressure at the intake manifold 11 is at the same pressure at the intake manifold 11 is at the same pressure as the output of the compressor. It should be noted, however, that the differential in pressure across the reciprocating engine cylinders in the embodiment of FIGURE 3 is substantially the same as the differential in pressure across the cylinders in the embodiment of FIGURE 1. Thus, the same degree of scavenging exists in both the embodiments of FIGURE 1 and FIGURE 3 but the embodiment of FIGURE 3 also permits super-charging.

In the event the reciprocating engine 10 is operated at its optimum power output, it is possible that there would be an excess pressure created at the compressor 50 of FIGURE 3. This surplus pressure applied to the cylinders will now create an increased pressure difference across the cylinders, to thereby further aid in the scavenging operation at the very time when the best scavenging is desirable.

In the prior art, there is illustrated an arrangement in U.S. Patent 2,828,103 issued March 25, 1958, to M. Berchtold entitled "Non-Steady Flow Turbine" and U.S. Patent 2,867,981 issued January 13, 1959, to M. Berchtold entitled "Aerodynamic Wave Machine Functioning as a Compressor and Turbine," both of which are assigned to the assignee of the instant application, wherein the configuration of the blades can be utilized to obtain shaft power from a wave machine. Thus, by placing the pressure transformer in axial alignment with the compressor and by utilizing the principles taught in aforementioned U.S. Patents 2,828,103 and 2,867,981, it is possible to not only (1) assist in the scavenging, and (2) provide super-charging, but also (3) to utilize the excess energy of the pressure transformer to drive the compressor. That is, within any one cycle of operation of the drive pressure transformer, the device not only creates the necessary pressure differential across the cylinder, but also produces sufficient excess energy so that a turbine action therein will drive the compressor.

In the embodiment of FIGURE 1 the wave machine 20 has a continuous cycle of operation such as illustrated in FIGURE 6. Throughout the drawings, a representation of any one of the six cylinders "C" in a condition of providing blow-down energy is illustrated by placing a "C" with a subscript of the specific cylinder both in a square, whereas the condition for a cylinder requiring scavenging is illustrated by the letter "C" with a subscript of the specific cylinder both placed in a circle. Therefore, the illustration of FIGURES 2(*a*) and 2(*b*) taken in connection with FIGURES 1 and 4 shows the continuous change of pressure existing in the first and second exhaust manifold E_1 and E_2 respectively and FIGURE 6 shows a moving picture of the continuous modification of the conditions within the rotor as the reciprocating engine goes through its complete cycle of operation for all cylinders.

As previously noted, cylinders C_1, C_2 and C_3 are joined to the common exhaust manifold E_1 and the second group of cylinders C_4, C_5 and C_6 are joined to a second common exhaust manifold E_2. Both the manifolds E_1 and E_2 are connected to the wave machine 20 with the exhaust manifold E_1 connected to the inlet port A and the exhaust manifold E_2 connected to the inlet port B.

In the illustration of FIGURES 1 and 3, it is assumed that the reciprocating engine has six cylinders and thus there would be an angle of 60° and a scavenging period of approximately 60°. Thus at any time only one cylinder of one group will be providing blow-down energy and one cylinder of the other group will require scavenging. Thus, if blow-down takes place in one manifold, scavenging occurs in the other manifold. As illustrated in FIGURE 2(*a*), if there is a high pressure in manifold E_1, there is a low pressure in manifold E_2 and thus suction will permit scavenging. On the other hand, when the pressure is high in E_2, scavenging is required in the manifold E_1 and the necessary suction is available for scavenging one of the cylinders in the first group. Thus, FIGURE 2(*a*) represents the approximate pressure fluctuations as a function of time for a crank angle of 120° with the dotted line representing the pressure fluctuations in the first exhaust manifold E_1 and the solid line representing the pressure fluctuations in the second exhaust manifold E_2. The mean pressure is equal to the ambient pressure.

In the embodiment of FIGURE 3 the exhaust gasses of the wave machine **20** emanating alternately from ports C and D are utilized to drive the turbine **40** which, in turn, drives the compressor **50**. It is noted that the wave machine **20** can be used as a direct drive for the compressor by providing the wave machine with short helical rotor channels. Alternately, the rotor could have curved channels as illustrated in FIGURE 5. In this case, the turbine action is superimposed on the wave action in a similar manner as that described in aforementioned U.S. Patents 2,867,981 and 2,828,103. This turbine has the effect of creating a suction for the purpose of initiating the necessary scavenging of the reciprocating engine and also provides the necessary shaft power to drive the compressor. The effect of the curved channels can be increased by a larger angle of attack of the gas on the blades.

Particularly for the propulsion of larger ships 2-cycles internal combustion engines with 4, 5, 6, 7, 8, 9, 10 and 12 cylinders are being used. The presently proposed system to utilize the blow-down energy in an Aerodynamic Wave machine to induce scavenging can be used on all existing engine configurations.

In each particular case there is an arrangement best suited. The present specification should be considered as an example showing the principle of operation. FIGURE 7 illustrates connections and conditions for other multi-cylinder engines and the following is a description for each case. In order to simplify the description the engine cylinders are numbered in the firing order and not as usual in the order of geometrical arrangement. The description applies to in-line-engines, which means that the crank-angle between the consecutively firing cylinders is always 360° divided by the number of cylinders. It is understood, although not illustrated, that all cylinders have a common intake manifold as previously described in connection with FIGURES 1 to 6.

4-cylinder engine

Number **1** and **3** cylinder have common exhaust manifold connecting to one aerodynamic wave machine intake port. Accordingly, the cylinders **2** and **4** are connecting to another areodynamic wave machine intake port. The blow-down period in one intake port is essentially simultaneous with the scavenging period in the other intake port. Since the crank-angle is in this case 90° between cylinders, the blow-down period begins only at a time when the scavenging is well under way. The time for the blow-down period is about 30° whereas the scavenging is about 90°. A diagrammatic presentation of the pressure fluctuation is shown at the right of FIGURE 7. It is therefore necessary to support scavenging in the first part by other means. Fortunately it is possible to utilize the rarefaction wave following the blow-down pressure wave to induce the scavenging. Tuned exhaust pipes to support scavenging are well-known. It is possible that one manifold leads to several working intake ports in the areodynamic wave machine similarly to the present arrangement in the supercharger where 2 cycles are used per revolution.

5-cylinder engine

Each cylinder has its own individual exhaust pipe leading to a single (or more) intake stator port. There is no common manifold in this case. The blow-down energy of a particular cylinder creates the suction effect for the cylinder running ahead with a crank-angle difference of 72°. In this case the blow-down and suction periods are nearly simultaneous. The pressure zone rotates from one intake port to the next with the same number of revolutions per minute as the engine. The low-pressure zone is running behind with a phase angle of 72°. This arrangement however has the disadvantage of a low rotor utilization since there is no flow in the rotor for 3 out of 5 time intervals. However it will assure sufficient scavenging since the suction period always follows the blow-down period immediately. If the rotor is brought up to speed during start up, scavenging will be assured. This will be an important feature for all configurations.

7-cylinder engine

This arrangement is identical to the 5-cylinder engine arrangement; inasmuch as each cylinder has its individual exhaust pipe leading to its own intake stator port.

8-cylinder engine

Two separate areodynamic wave machines will be used, one for each 4-cylinders, having 90° crank-angles. This makes it the identical case as described above. An alternate hood-up with a single aerodynamic wave machine having 4 intake ports combining cylinders 1–5, 2–6, 3–7, 4–8 (as shown in FIGURE 7) is also possible.

9-cylinder engine

Groups of 3 cylinders have a common manifold leading to one intake stator port of the areodynamic wave machine. According to the firing order, cylinder numbers 1–4–7, 2–5–8, 3–6–9 are from the 3 groups. Each group has one intake stator port. It is also possible to have pairs of simultaneous working cycles. In this case, each manifold is connected to two intake stator ports. The pressure zone rotates in this case 3 times for each revolution for the engine.

10-cylinder engine

Two separate areodynamic wave machines with each having five individual exhaust pipes and intake stator ports. The arrangement is identical to the case described for 5-cylinders. An alternate hook-up with a single aerodynamic wave machine having 5 intake ports combining cylinders 1–6, 2–7, 3–8, 4–9, and 5–10 can also be used.

12-cylinder engine

Two separate areodynamic wave machines are used, each one connected to 6 cylinders. This case is identical to the detailed description in the specification.

Thus, in essence, I have provided a novel arrangement utilizing non-steady flow effects to initiate scavenging of the cylinders of an internal combustion engine. Due to the direct exchange of energy, there is a minimum of losses. Thus, even at low load, a small amount of available exhaust energy is sufficient to initiate the small degree of scavenging that would be required on this load.

The arrangement described in the aforementioned U.S. Patents 2,970,746 and 2,957,304 requires that the ambient air be compressed by the exhaust gasses in the rotor and, thus, the air will be heated due to contact with the rotor and also will be partially contaminated due to the mixing at the intervals between the cold air and the hot gas. These undesirable characteristics are completely eliminated in my novel combination of a pressure exchanger and a reciproating engine having split exhaust manifolds.

Furthermore, with my present arrangement a differential in pressure across the cylinders initiates the scavenging. Thus scavenging by a vacuum on the exhaust side of the cylinder requires little energy since the remaining gas quantity in the cylinder is less with a lower pressure.

Although I have described preferred embodiments of my novel invention, many variations and modifications will now be obvious to those skilled in the art, and I prefer therefore to be limited not by the specific disclosure herein but only by the appended claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. A wave machine to initiate the scavenging of a reciprocating engine, said reciprocating engine having a first and second group of cylinders, said first group of cylinders being connected to a first exhaust manifold; said second group of cylinders being connected to a second exhaust manifold; said wave machine comprised of a rotor in a housing, said housing having a first and a second inlet port on one side thereof; said housing also having a first and a second exhaust port on the other side thereof; said rotor including passage therethrough, interconnecting said inlet and exhaust ports; means for rotating said rotor; said first exhaust manifold being operatively connected to said first inlet port; said second exhaust manifold being operatively connected to said second inlet port; said wave machine first and second ports providing a pressure differential effective to alternately lower the exhaust pressure of said first and second exhaust manifolds.

2. A wave machine to initiate the scavenging of a reciprocating engine, said reciprocating engine having a first and second group of cylinders; said first group of cylinders being connected to a first exhaust manifold; said second group of cylinders being connected to a second exhaust manifold; said wave machine comprised of a rotor in a housing, said housing having a first and a second inlet port on one side thereof; said housing also having a first and a second exhaust port on the other side thereof; said rotor including passages therethrough, interconnecting said inlet and exhaust ports; means for rotating said rotor; said first exhaust manifold being operatively connected to said first inlet port; said second exhaust manifold being operatively connected to said second inlet port; said wave machine first and second ports providing a pressure differential effective to alternately lower the exhaust pressure of said first and second exhaust manifolds; said rotor having at least one outlet port on the other side thereof.

3. A combination of a wave machine and a reciprocating engine; said reciprocating engine having a first and second group of cylinders, a common intake manifold and a first and second exhaust manifold; said common intake manifold being operatively connected to both said first and second group of cylinders; said first group of cylinders being operatively connected to said first exhaust manifold; said second group of cylinders being operatively connected to said second exhaust manifold; said wave machine being a pressure transformer having a rotor in a housing, said housing having a first and a second inlet port on one side thereof; said housing also having a first and a second exhaust port on the other side thereof; said rotor including passages therethrough, interconnecting said inlet and exhaust ports; means for rotating said rotor; said first exhaust manifold being operatively connected to said first inlet port and said second exhaust manifold being operatively connected to said second inlet port; said wave machine first and second ports providing a pressure differential effective to alternately lower the exhaust pressure of said first and second exhaust manifolds.

4. A wave machine to initiate the scavenging of a two-cycle reciprocating engine, said wave machine having a rotor in a housing, said housing having a first and a second inlet port on one side thereof; said housing also having a first and a second exhaust port on the other side thereof; said rotor including passages therethrough, interconnecting said inlet and exhaust ports; means for rotating said rotor; said two-cycle reciprocating engine having a first and second group of cylinders; said first group of cylinders being selectively connected to said first inlet port; said second group of cylinders being selectively connected to said second inlet port.

5. A wave machine to initiate the scavenging of a two-cycle reciprocating engine, said wave machine having a rotor in a housing, said housing having a first and a second inlet port on one side thereof; said housing also having a first and a second exhaust port on the other side thereof; said rotor including passages therethrough, interconnecting said inlet and exhaust ports; means for rotating said rotor; said two-cycle reciprocating engine having a first and second group of cylinders; said first group of cylinders being selectively connected to said first inlet port; said second group of cylinders being selectively connected to said second inlet port; said first and second group of cylinders each comprising cylinders which alternate between supplying blow-down energy to said inlet ports and require low pressure for scavenging.

6. A wave machine to initiate the scavenging of a two-cycle reciprocating engine, said wave machine having a rotor in a housing, said housing having a first and a second inlet port on one side thereof; said housing also having a first and a second exhaust port on the other side thereof; said rotor including passages therethrough, interconnecting said inlet and exhaust ports; means for rotating said rotor; said two-cycle reciprocating engine having a first and second group of cylinders; said first group of cylinders being selectively connected to said first inlet port; said second group of cylinders being selectively connected to said second inlet port, each cylinder of said first and second group of cylinders supplying blow-down energy directly to said inlet ports.

7. A wave machine to initiate the scavenging of a two-cycle reciprocating engine, said wave machine having a rotor in a housing, said housing having a first and a second inlet port on one side thereof; said housing also having a first and a second exhaust port on the other side thereof; said rotor including passages therethrough, interconnecting said inlet and exhaust ports; means for rotating said rotor; said two-cycle reciprocating engine having a first and second group of cylinders; said first group of cylinders being selectively connected to said first inlet port; said second group of cylinders being selectively connected to said second inlet port; said first and second inlet ports alternately receiving blow-down energy from the cylinders of said two-cycle reciprocating engine and thereby having a high pressure field; said first and second inlet ports alternately connected to a cylinder requiring scavenging and having a low pressure field.

8. A wave machine to initiate the scavenging of a two-cycle reciprocating engine, said wave machine having a rotor in a housing, said housing having a first and a second inlet port on one side thereof; said housing also having a first and a second exhaust port on the other side thereof; said rotor including passages therethrough, interconnecting said inlet and exhaust ports; means for rotating said rotor; said two-cycle reciprocating engine having a first and second group of cylinders; said first group of cylinders being selectively connected to said first inlet port; said second group of cylinders being selectively connected to said second inlet port; said first inlet port having alternate high and low pressure fields; said second inlet port having alternate high and low pressure fields; said first and second outlet port being alternately ports for no flow of fluid and exhaust of fluid from said wave machine.

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