Dec. 29, 1942. G. B. BANKS 2,306,372

GASOLINE KNOCK RECORDER

Filed March 26, 1940 2 Sheets-Sheet 1

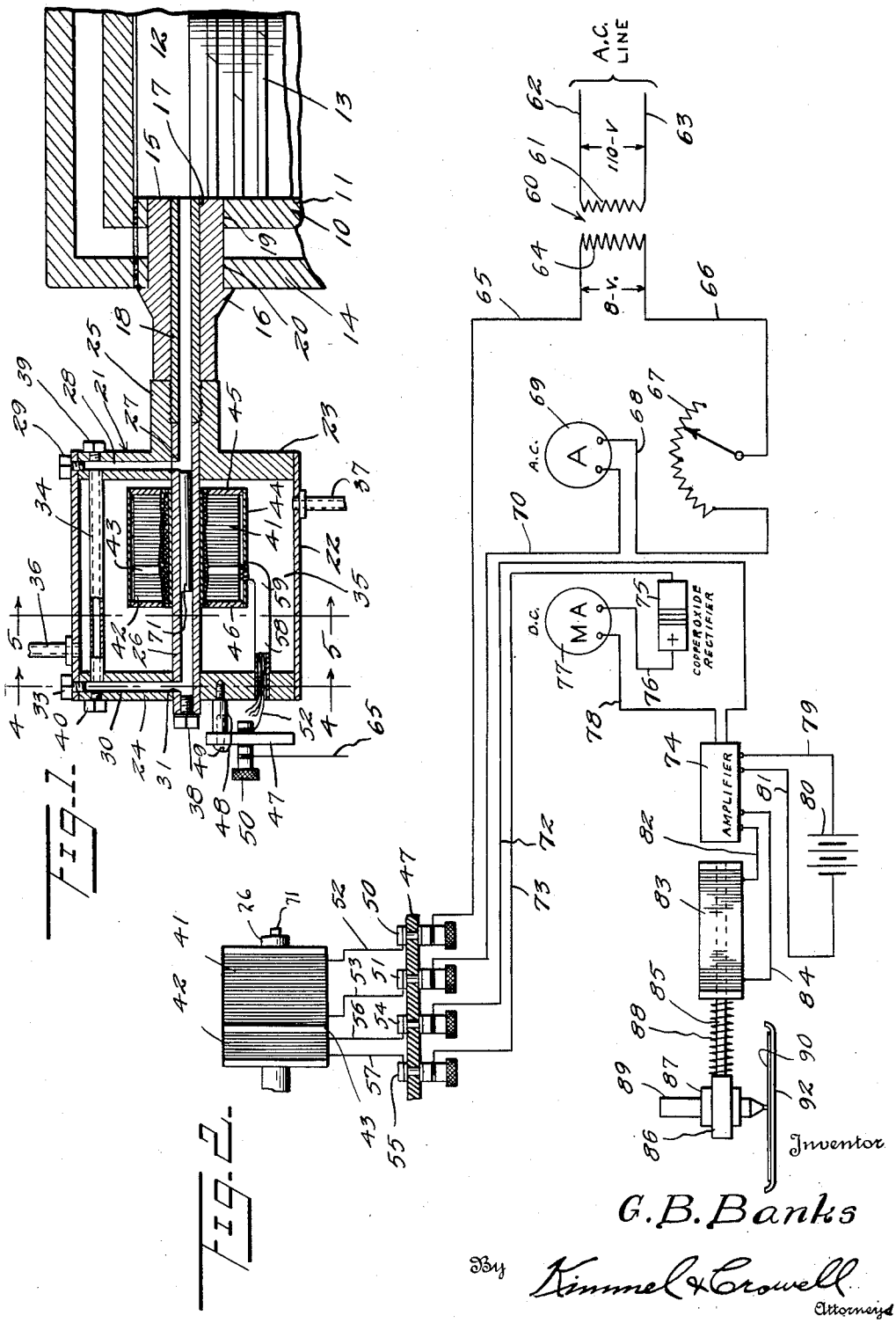


FIG. 1.

FIG. 2.

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GASOLINE KNOCK RECORDER

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Fig. 3.

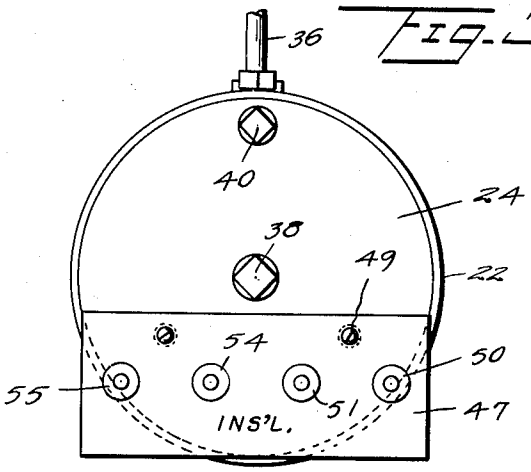


Fig. 5.

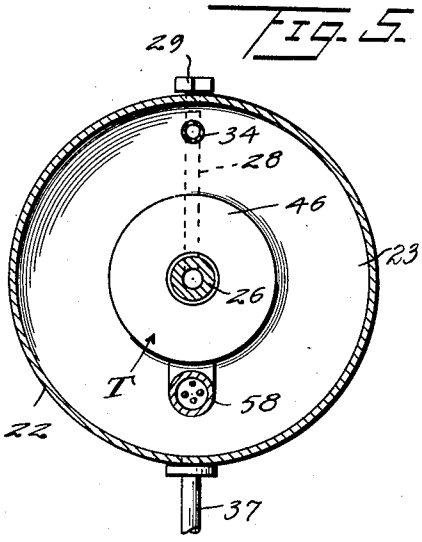


Fig. 4.

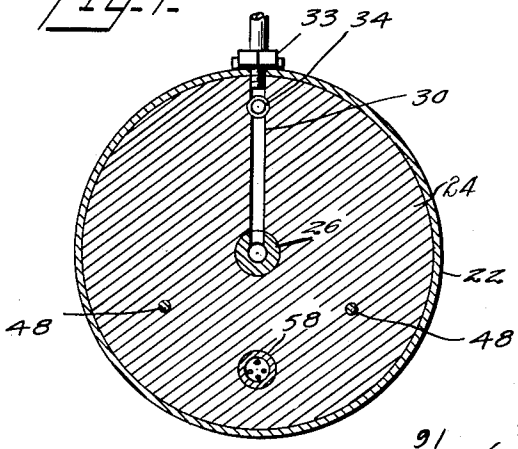
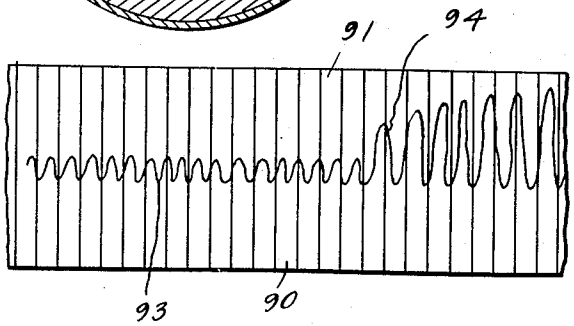


Fig. 6.



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UNITED STATES PATENT OFFICE

2,306,372

GASOLINE KNOCK RECORDER

George B. Banks, New Rochelle, N. Y.

Application March 26, 1940, Serial No. 326,091

4 Claims. (Cl. 177—351)

This invention relates to recording devices and is an improvement over the recording device forming the subject matter of my copending application, Serial No. 270,419 filed April 27, 1939.

An object of this invention is to provide an improved recording device for recording the compression values of combustible fuels and recording the compression formed in the cylinder of an internal combustion engine before and after the combustion of the fuel.

Another object of this invention is to provide a recording device of this character which is adapted to be connected to the cylinder of an internal combustion engine and which is of such a character that the different pressures generated in the combustion chamber of the engine may be accurately and very finely recorded so that the different compressions developed by different combustible fuels may be used as a basis for determining the octane rating of the fuel under test as compared to a fuel having a known octane rating.

A further object of this invention is to provide a recording device of this character which includes the use of electro-magnetic means for generating electric impulses which are communicated to a stylus operator for actuating the operator in accordance with the amount of electric current communicated to the operator.

A still further object of this invention is to provide an improved method of recording compression values in an internal combustion engine cylinder, the method embodying the use of electro-magnetic means actuated by the compression generated in the cylinder of the engine.

Another object of this invention is to provide an indicating and recording device whereby the sudden rise in pressure due to detonation or "knock" may be clearly indicated and recorded. The method embodies the use of a water cooled "by-pass" so that the pressure developed during normal explosion will be nearly equally effective on both ends of the magnetic core. Any unbalance or excessive movement of the core may be readily checked by adjusting the magnetic pull on the core by means of a suitable rheostat in the circuit of the primary coil. The pressure due to detonation or knock, being of relatively greater pressure and of much less duration than the pressure due to explosion, is dissipated by the cooling effect and the longer travel in the by-pass and is therefore almost entirely effective on one end of the core only. This unbalanced pressure gives the core a considerable movement into the secondary coil and by the increase in transformer action will give a clear indication of the point of detonation or knock.

To the foregoing objects and to others which may hereinafter appear, the invention consists of the novel construction, combination and arrangement of parts as will be more specifically referred to and illustrated in the accompanying drawings wherein are shown embodiments of the invention, but it is to be understood that changes, variations and modifications may be resorted to which fall within the scope of the invention as claimed.

In the drawings:

Figure 1 is a fragmentary vertical section of an internal combustion cylinder and a longitudinal section partly broken away and in detail of a portion of the device embodying this invention.

Figure 2 is a diagrammatic view of the electric circuits and elements embodying this invention.

Figure 3 is a detail end elevation of the attachment for the engine shown in Figure 1.

Figure 4 is a sectional view taken on the line 4—4 of Figure 1.

Figure 5 is a sectional view taken on the line 5—5 of Figure 1.

Figure 6 is a plan view of the recording sheet used with this invention.

Referring to the drawings, numeral 10 designates generally an internal combustion engine provided with a cylinder 11, having a combustion chamber 12 and a piston 13 which is slidable in the cylinder 11. A water jacket 14 engages about the cylinder 11 in the conventional manner and it will be understood that the engine structure 10 is a conventional internal combustion engine and is here shown as one example of an engine with which the hereinafter described invention may be incorporated.

A cylindrical plug 15 is extended through the walls of the water jacket 14 and the cylinder 11 and is provided with a flange 16 which is adapted to engage the exterior of the jacket 14 so as to limit the insertion of the plug 15 within the jacket 14 and the cylinder 11. The plug 15 provided with an axial bore 17 within which a tube 18 is fixedly secured. The plug 15 is adapted to be secured in any suitable manner in the openings 19 and 20 which are formed in the cylinder 11 and the jacket 14, respectively, and the tube 18 is adapted to be fixedly mounted in the bore 17 in any suitable manner. The tube 18 at its outer end projects beyond the outer end of the plug 15 and forms a supporting member for supporting a casing generally designated as 21. The casing 21

comprises a cylindrical jacket 22, an inner head 23 and an outer head 24. The inner head 23 is provided with a bushing or boss 25 which engages about the projecting end of the tube 18 and is adapted to be secured in any suitable manner such as by threads or the like to the projecting end of the tube 18.

A tubular member 26 extends axially through the head 24 and through the head 23, terminating within the bushing or boss 25. The tube 26 is provided with a lateral passage 27 and the head 23 is provided with a radial duct or passage 28 which communicates at one end with the lateral passage 27. The duct 28 is formed by drilling a hole radially of the head 23 and the outer end of the hole is closed by means of a threaded plug 29. The head 24 is provided with a radial duct 30 which communicates with the interior of the tube 26 through a lateral passage 31 formed in the tube 26. A plug 32 is threaded through the jacket or casing 22 into the outer end of the opening or duct 30 so as to close the outer end of this duct.

A connecting tube 34 extends between the two heads 23 and 28 outwardly of the axial tube 26 and is secured at one end in the head 23 and at the opposite end is secured in the head 24 and provides a means establishing communication from the duct 28 to the duct 30.

The jacket or casing 22 provides a water chamber 35, and an intake pipe 36 is connected at one end to the jacket 35 and at the other end to a source of water supply (not shown).

An outlet or discharge pipe 37 is connected at one end to the jacket or casing 22 diametrically opposite the inlet 36 and as shown in the drawing the outlet 37 may be disposed closely adjacent the head 23 whereas the inlet 36 may be disposed closely adjacent the head 24. A plug 38 is adapted to be threaded into the outer end of the axial tube 26 as shown in Figure 1 so that if desired, the interior of the duct 26 may be cleaned by removing the plug 34 and in like manner, the ducts 28 and 30 may be cleaned by removing the plugs 29 and 33, respectively.

A removable plug 39 is threaded into the wall or head 23 in alignment with one end of the connecting pipe 34 and a second plug 40 is threaded into the head or wall 24 in alignment with the opposite end of the connecting pipe 34. It will, therefore, be seen that the various ducts or passages may be readily cleaned by removing the several plugs so that the operation of the device will not be impaired by accumulation of carbon or other foreign matter in the several ducts.

A primary coil 41 of a transformer generally designated as T in Figure 5 is disposed about the axial pipe 26 and a secondary coil 42 is disposed about the pipe 26 and is spaced from the primary coil 41 by means of an insulated spacing member 43. The coils 41 and 42 are mounted within a cylindrical housing 44 which is provided with heads 45 and 46 so as to seal the two coils 41 and 42 within the water chamber 35. In this manner the water in the chamber 35 will act as a cooling means not only for the coils 41 and 42 but also for the several ducts hereinbefore described.

An insulated plate 47 is disposed in outwardly spaced relation to the outer head 24, being supported in spaced relation to the head 24 by means of a pair of supporting studs 48 which are threaded into the head 24. The insulated plate 47 is fixed to the two studs 48 by fastening devices 49. The plate 47 is provided with terminals 50 and 51 which are adapted to be connected to the primary coil 41 by means of conductors 52 and 53, respectively. The plate 47 is also provided with a second pair of terminals 54 and 55 which are connected to the secondary coil 42 by conductors 56 and 57, respectively.

The conductors 52, 53, 56 and 57 are extended through the head 24 and preferably the conductors 52, 53, 56 and 57 are extended through a conduit 58 which at one end is mounted in the head 24 and terminates at the outer end of the head 24. The other end of the conduit 58 is provided with an elbow 59 which is connected to the cylindrical casing 44.

A voltage reducing transformer 60 is provided with a transformer coil 61 which is adapted to be connected by conductors 62 and 63 to a source of alternating current supply of conventional voltage such as 110–120 volts and the primary 60 also includes a secondary coil 64 which has one side thereof connected as by a conductor 65 to the terminal 50. The other side of the secondary coil 64 is connected by means of a conductor 66 to a rheostat 67. The rheostat 67 is connected by means of a conductor 68 to an ammeter 69 and the ammeter 69 is connected by a conductor 70 to the terminal 51.

The rheostat 67 is provided for the purpose of transmitting the desired amount of electric current from the secondary 64 to the primary coil 41.

A movable core 71 is slidable within the tube 26, the core 71 being an iron core and preferably the tube 26 is of non-magnetic material and the core 71 is of a substantially greater length than the length of the coil 41 so that the opposite ends of the core 71 will project beyond the ends of the coil 41 as shown in Figure 1. In the initial position of the core 71, the inner end thereof will be in substantial alignment with the outer edge of the lateral passage 27 so that the compression passing through the interior of the tube 18 and the inner portion of the tube 26 will strike the inner end of the core 71 and a portion of the compressed fluid will flow through the lateral passage 27, the duct 28, the pipe 34, the duct 30 and back into the pipe 26 at the opposite end of the core 71. The force of the compressed fluid which may be burned fuel or compressed air, will initially move the core 71 in the direction of the secondary coil 42 so that the electric current in the coil 41 will be transferred to the secondary coil 42, the amount of current transferred from the primary 41 to the secondary 42 being in proportion to the endwise movement of the coil 41 relative to the secondary coil 42.

The electric current transferred from the primary coil 41 to the secondary coil 42 by movement of the core 71 will be transmitted to a recording device through conductors 72 and 73 which are connected at one end thereof to the terminals 54 and 55. The conductor 72 at the opposite end is connected to an electric current amplifying device 74 which is of conventional construction and the conductor 73 at its opposite end is connected to a rectifying device 75 in the form of a copper oxide rectifier which is adapted to change the alternating current to direct current. The rectifier 75 is connected by means of a conductor 76 to a vacuum tube ammeter 77 which will indicate the amount of electric current passing through the rectifier 75 from the secondary 42.

The ammeter 77 is connected by means of a conductor 78 to the amplifier member 74. The amplifier 74 is connected by means of a conductor 79 to one side of a source of electric current sup-

ply which may be in the form of a battery or other source of direct current supply and the other side of the current supply source 80 is connected by a conductor 81 to the amplifier 74. The output side of the amplifier 74 is connected by means of a conductor 82 to one end of a solenoid coil 83. The opposite end of the solenoid coil 83 is connected by a conductor 84 to the amplifier 74.

A solenoid core 85 is slidable within the coil 83 and the outer end of the core 85 is provided with a non-magnetic head 86 through which a stylus holder 87 extends. A spring 88 is disposed about the core 85 and at one end bears against the outer end of the coil 83 and at the opposite end bears against the non-magnetic head 86 so as to constantly urge the core 85 outwardly with respect to the coil 83. A stylus 89 is mounted in the holder 87 and is adapted to engage the adjacent surface of a recording sheet 90 which is provided with a plurality of transversely extended parallel lines 91. The recording sheet 90 is mounted in a sheet holder or support 92 which is adapted to be moved relative to the stylus 89. The operating means for moving the support 92 may be any conventional operating means and as an example of an operating means therefor reference is had to my copending application, Serial No. 270,419.

In the use and operation of this recording device, a fuel of known octane rating is used as a combustible fuel in the engine 10 and the pressures generated in the combustion chamber 12 will effect movement of the magnetic core 71. When the explosion or combustion of the fuel initially occurs, this high pressure will first effect movement of the core 71 and at the same time a portion of the burned gases will flow from the duct 28 through the connecting tube 34 and the duct 30 to the tube 26 at the outer end of the core 71. In this manner the gases which engage the outer end of the core 71 will act to prevent excessive movement of the core 71 and will serve as a balancing means for the core. However, the pipe 34 is extended through the water chamber 35 so that this pipe is cooled by the water in the chamber 35 and the hot gases passing through the pipe 35 and also through the duct 30 and in the outer portion of the pipe 26 will be cooled by the water in the chamber 34.

In this manner the pressure of the gases on the outer end of the core 71 will be reduced from the pressure of the gases which initially engage the inner end of the core. At the time the engine 10 is started, the rheostat 67 is adjusted so as to provide for the desired amount of current passing to the primary 41. The amount of current passing to the primary 41 is adjusted to such a degree that there will be an effective transfer of electric current from the primary 41 to the secondary 42 as the core 71 is shifted endwise in the direction of the secondary 42. The impulses transferred from the primary 41 to the secondary 42 are then communicated through the conductors 72 and 73 to the amplifier 74.

The current transferred from the secondary 42 to the amplifier 74 is increased to a degree sufficient to energize the solenoid coil 83 in order to effect movement of the core 85. Where fuel of a known octane rating is used, the movement of the core 88 will cause the stylus 89 to form an indication 93 on the record sheet 90. After the known octane rating fuel has operated the engine 10 for a predetermined period, an unknown octane rating fuel is used to operate the engine 10 and where the unknown octane rating fuel has a higher rating than the known octane rating fuel, the stylus 89 will make an indication 94 on the record sheet 90 which is of a greater length than the indication 93. The rating of the unknown octane rating fuel can then be readily computed by the difference between the indication 93 and the indication 94.

In an auto engine whose top speed is 3600 R. P. M., and of the four cycle type, we have a cylinder firing once every other revolution so even at top speed we would never have more than thirty detonations per second. Detonation is not induced by engine speed, but by the volume charge of fuel ignited. Assume that 3600 R. P. M. of the engine produces maximum car speed of 100 miles per hour. But a motor does not knock at top speed, detonation occurs when we have a large charge of fuel ignited in the cylinder when the car is going about 20 miles per hour, that is, when the car is laboring up a hill or knock occurs only when the motor is delivering full horse power. If 3600 R. P. M. corresponds to 100 miles per hour, then 20 miles per hour represents

$$\frac{3600}{5}$$

equals 720 R. P. M. and the maximum detonation frequency would be

$$\frac{720}{3600}\times 30$$

equals 6 cycles per second. The 60 cycle commercial frequency corresponds to 120 alternations per second. The solenoids of the Ruddell oscillograph respond to frequencies of about 1000 cycles per second. Hence, there is no question as to the magnetic field of my solenoid system responding to a frequency of 6 cycles per second.

The commercial frequency produces a magnetic force in the coil which holds the core in place until detonation occurs in sufficient magnitude to cause the core to break away from the magnetic stop. This magnetic stop principle holds the core in place until detonation pressure occurs, exclusive of any pressure oscillations ahead of detonation wave. I am not concerned with the frequency of the variations of the pressure wave, excepting only the pressure wave due to detonation.

In the actual operation of this knock recorder, the point at which "pinking" or knock occurred was clearly shown in relation to the dynamometer load on the test engine. Under test conditions, I find that the best engine speed to be 600 R. P. M. Therefore, the frequency set up by detonation is considerably slower than the commercial frequency supply of 60 cycles per second. When operating this meter, the action I have observed is as follows:

The plunger core 71 is forced more or less out of the primary coil 41 into the secondary coil 42, but because of the by-pass 34 pressure the plunger core 71 is balanced by normal explosion pressure and assumes a more or less stationary position and while in this position the plunger core 71, being magnetized by the current in the primary coil 41, does set up by transformer action a current in the secondary coil 42. This has been shown by the milliammeter in that circuit. While the by-pass 34 provides a counter pressure against the thrust of normal explosion pressures and prevents violent and rapid movement of the plunger core 71, causing it to "float" with a very little movement, when detonation occurs however, the much greater and rapid pressure thrusts the

plunger core 71 outward and further into the secondary coil 42 thereby increasing the transformer action and consequent increase of current in the secondary coil 42, as has been shown by the milliammeter in that circuit. The movement of the plunger core 71 is much greater when subject to detonation pressures, because of the action of the by-pass 34 which prevents more or less any balancing effect on the plunger 71 by reason of the longer travel and cooling of this very short high pressure wave. This pulsating current passed through a conventional type of rectifier and thence through a conventional type of amplifier energizes the stylus coil 83. There is very little movement of the stylus 86 under normal explosion pressure with a decided increase of movement at the instant detonation occurs. The point at which detonation occurs is determined by reading the dynamometer load when detonation is indicated.

The normal explosion pressure obeys "Pascal's law" in that this pressure is transmitted so as to act uniformly on all surfaces inside the engine cylinder, hence it acts on the meter core or piston as well. When detonation occurs the force acting on the cylinder end of the core is increased because of the direct impact of the detonation wave. This higher pressure of detonation does not follow "Pascal's law" but is due to the detonation wave moving in a path which depends upon the mechanics of the combustion process. The detonation phenomena then occurs as a wave of pressure which impacts upon the core and is superimposed upon and adds to the otherwise normal pressure due to normal combustion.

Detonation occurs when the combustion wave is so fast that the unburned remainder of the fuel charge is heated and rapidly compressed to reach a temperature high enough to cause autoignition before the normal combustion process or flame front can reach this unburned portion of the fuel charge.

Under normal combustion pressure, the gas pressure is conveyed through the by-pass so that it can act upon the back end of the core. Hence under normal combustion conditions there is a differential force acting at the back or outer end of the core to keep the core tight against the magnetic stop. A slight time lag occurs from the time the direct pressure is applied at the front or engine end and the restoring force is effective at the outer end of the core, due to the length of the by-pass. However, all the time the fuel charge is being compressed, the force differential is increasing so that the back force at the outer end plus the holding force of the magnet is more than enough to offset any increase in force at the front end due to compression of the fuel. Then when normal combustion begins and the pressure rises faster, but still at a definite rate, the differential force also increases at the same rate but at a phase angle that slightly lags the increase in combustion pressure increase. Thus, at all time during compression or normal combustion due to the fact that Pascal's law holds and the time lag through the by-pass is very small, the force opposing any movement of the core holds it in contact with the magnetic stop. This differential force is very important. It is increasing all the time that the engine piston moves up through the compression stroke so that when the sudden pressure increase comes at the beginning of combustion, the differential force can still hold the core against the magnetic stop. This differential force continues to increase as combustion progresses so that even when the maximum pressure of normal combustion is reached, the core is still held tightly against the magnetic stop.

However, as long as only normal combustion obtains, the variable differential force combined with the solenoid force and the magnetic stop is sufficient to prevent any motion of the core so that the core is held against the magnetic stop.

When the high pressure wave of detonation occurs, the pressure of the detonation wave impacts upon the front end of the core with such force that the differential force is exceeded and the core snaps away from the magnetic stop. This is because the time lag is greater than the life of the detonation pressure wave. It is important to note that once the core has left the magnetic stop, the magnetic holding force is reduced and continues to decrease as long as the core moves away from the stop.

The fundamental principle of this meter depends upon the fact that the detonation pressure is short-lived, that it is a wave pressure, that it acts on the front surface of the core but is not transmitted through the by-pass to act on the back of the core.

The sudden high detonation pressure exists but for a short time and the core is moved back to contact with the magnetic stop when the detonation force at the front of the core drops to a value less than the differential force due to normal combustion pressure plus the magnetic force due to the solenoid.

This meter then differentiates between normal explosion pressures and detonation wave pressures, in that the core does not move until detonation occurs.

With a recording device of this character, the fuel to be tested is run through the engine 10 and its knock point is registered on the recording sheet 90. The knock point of the fuel under test can be readily varied by blending the desired grade of fuel therewith so that the blended fuel will have the same octane rating as a known octane rating fuel. This recording device has been placed under actual test and has proved that the causes of detonation occur considerably before the detonation or knock becomes audible. This recording device also indicates the knock intensity so that various fuels may be compared as to the time in the movement of the piston 13 at which the knock occurs and the degree of such knock.

Furthermore, by providing a device of this kind wherein the generator for the stylus operator is connected to the stylus operator by means of wires which are properly insulated, the vibrations of the generator caused through its direct connection with the engine cylinder will not be communicated to the stylus operator as is the case where the stylus operator is supported from the actuator therefor.

Through use of the water chamber 35, the heat of the burned gases passing through the duct 28, tube 34, duct 30 and the outer portion of the tube 26 may be finely regulated and the water in the chamber 35 may be maintained at any desired temperature in order to effect the desired dissipation of the pressures of the burned gases on the outer end of the plunger or movable core 71.

What I claim is:

1. A pressure recording apparatus comprising a tubular member connected at one end to a source of variable fluid pressure supply, primary and secondary transformer coils about a portion

of said member, a core slidable in said member and normally held substantially entirely within the magnetic field of said primary coil, movement of said core in the direction of said secondary coil transferring electric energy from said primary coil to said secondary coil, and a reduced diameter by-pass duct connected to said tubular member at opposite ends of said core for by-passing a quantity of fluid pressure to the end of the core adjacent said secondary coil whereby to cushion the movement of said core in one direction.

2. A pressure recording apparatus comprising a tubular member connected at one end to a source of variable fluid pressure supply, primary and secondary transformer coils about a portion of said member, a core slidable in said member and normally held substantially entirely within the magnetic field of said primary coil, movement of said core in the direction of said secondary coil transferring electric energy from said primary coil to said secondary coil, ducts connected to said tubular member communicating the fluid pressure to opposite ends of said core, and means for reducing the temperature of the fluid in said ducts to thereby reduce the fluid pressure on said core at the end thereof adjacent said secondary coil whereby to provide a cushioning means for movement of said core in one direction.

3. A pressure recording apparatus comprising a tubular member connected at one end to a source of variable fluid pressure supply, primary and secondary transformer coils about a portion of said member, a core slidable in said member and normally held substantially entirely within the magnetic field of said primary coil, movement of said core in the direction of said secondary coil transferring electric energy from said primary coil to said secondary coil, a casing about said tubular member and said coils, ducts carried by said casing communicating with said tubular member on opposite ends of said core, means circulating a cooling medium through said casing to thereby cool the fluid in said ducts and reduce the pressure of said fluid on one end of said core.

4. A detonation recording apparatus for an internal combustion engine comprising a pressure actuated movable member, tubular means connected to the engine cylinder and communicating with opposite ends of said member equalizing the pressure on opposite sides thereof under normal compression pressures, electro-magnetic means operatively associated with said member, a second electro-magnetic means operatively associated with said member and said first electro-magnetic means, unbalancing of the pressure on one end of said member under detonation pressure effecting movement of said member in one direction to thereby effect a transfer of electric energy from said first to said second electro-magnetic means.

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