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H. A. KIRSHNER ET AL
SELF CONTROLLED MEANS OF OBTAINING A PRESCHEDULED
PRESSURE-TIME RELATIONSHIP

3,066,486

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2 Sheets-Sheet 1

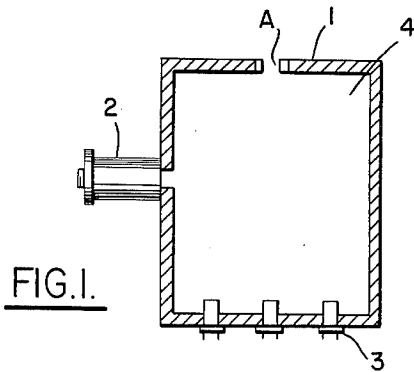


FIG. 1.

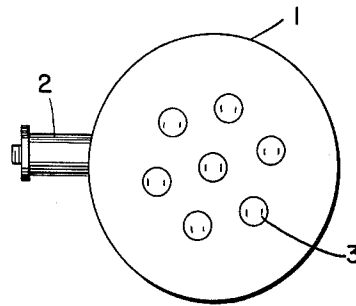


FIG. 2.

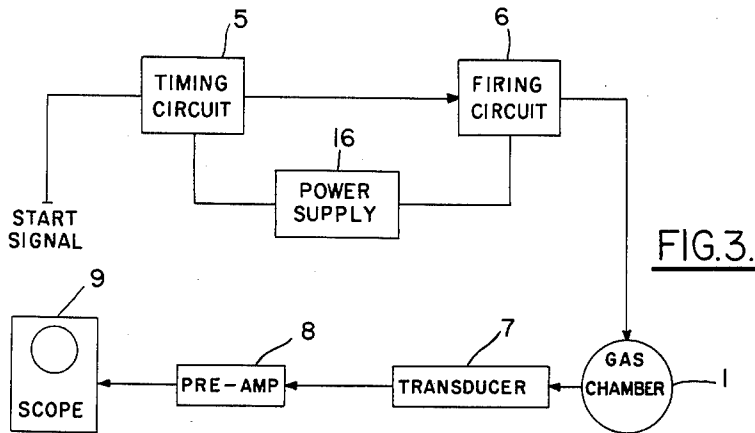


FIG. 3.

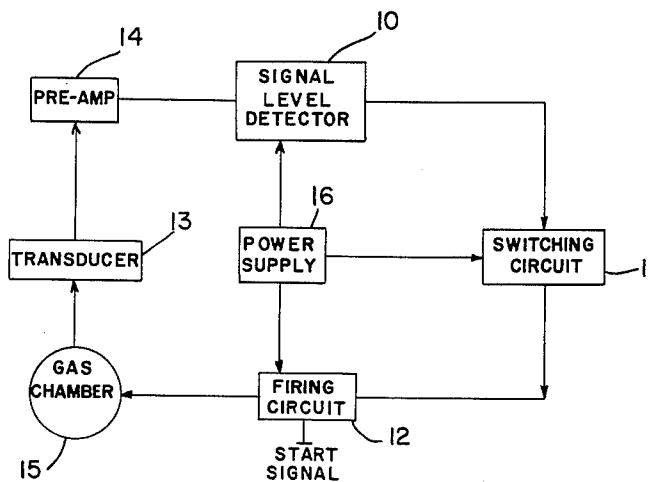


FIG. 4.

INVENTORS,
HOWARD A. KIRSHNER
MARTIN S. SILVERSTEIN
BY

W. E. Zibodeau, a. J. Dupont & H. R. Johns

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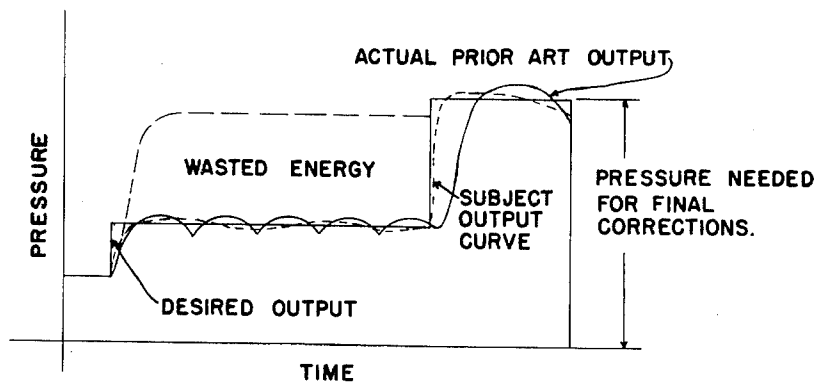


FIG. 5.

INVENTOR.
HOWARD A. KIRSHNER
MARTIN S. SILVERSTEIN

BY

W. E. Thibodeau, A. J. Dupont & H. R. Johns
ATTORNEYS:

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3,066,486

**SELF CONTROLLED MEANS OF OBTAINING A
PRESCHEDULED PRESSURE-TIME RELATION-
SHIP**

Howard A. Kirshner, 8 Fallenrock Road, Levittown, Pa.,
and Martin S. Silverstein, 1414 Park Blvd., Camden,
N.J.

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1 Claim. (Cl. 60—39.13)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment of any royalty thereon.

This invention relates to pre-scheduling and automatically controlling gas pressure-time relationships with respect to ammunition and missile propellants and has as an object to provide a simple and flexible means for producing a controlled, predetermined gas pressure-time output which is not dependent upon burning rate, as with solid propellant, nor rate of feed of liquid fuel.

Some of the main difficulties of the prior art, which imposes severe restrictions on propellant systems, are: The pressure-time output of a propellant system depends upon burning rate or pumping rate for solid and liquid propellants respectively. The burning rate of solid propellant is dependent upon the configuration—or exposed area, and composition. The configuration in turn, is limited by casting, extruding, machining and tensile strength. Then, once a solid propellant is ignited, either all the gas generated is utilized or the excess exhausted—there can be no stopping once the propellant is ignited. In addition, the rate of gas evolution varies with the temperature, so that the performance at -65° F. almost always differs from the performance at $+165^{\circ}$ F. Similar difficulties are encountered with liquid fuels: pumping is limited by starts, stops, orifice sizes—cannot change an orifice size once pumping has commenced, nozzles clog and valves jam.

This invention has overcome the foregoing disadvantages. Our system utilizes a plurality of solid propellant increments rather than one or two large charges. The incremental charges are separately loaded in capsules so that they may be separately ignited. Thus, the pressure-time output of our system is only dependent upon the rate and combination of ignition of the capsules, and not of the overall propellant charge. The system can be pre-scheduled to fire capsules in any desired sequence (even to the extent of having a sustained period without firing, then resuming firing of the capsules—stopping and resuming fire without losing valuable energy in the form of exhaust) or as an automatic feedback system. Also, by firing more or less capsules, constant pressure may be maintained regardless of ambient temperatures.

The principle involved in our invention may best be understood by reference to a simplified system shown in the drawings, in which:

FIG. 1 shows a top view of a simplified system;

FIG. 2 shows an end view of this system;

FIG. 3 is a diagrammatic representation of a pre-scheduled system;

FIG. 4 is a diagrammatic representation of an automatic feed back system for maintaining constant pressure, and

FIG. 5 shows pressure plotted against time for a desired relationship having two pressure levels.

FIGURES 1 and 2 of the drawings illustrate a simple seven capsule system in which a pressure cylinder 1 is provided with seven propellant loaded capsules 3 having their exhaust end facing into the chamber 4. A pressure sensitive device 2 is mounted on the cylinder side wall, and is used for obtaining the pressure in the chamber during charge establishments and also for feeding back pressure data in the automatic feedback system shown in

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FIG. 4. In practice, this would take the form of a transducer, converting—say pressure, to voltage.

A firing cycle is established in much the same manner as a propellant-ignition system in conventional gun systems. That is, a propellant is selected which is believed to best suit the needs (for rapid or slow ignition, or combination of the two). A preliminary firing cycle is put into the scheduling circuit 5 by presetting the circuit using a punch card or tape, etc.; activating a starting signal by means of a switch and feeding current from a power supply 16 to the firing circuit 6 causing electrical impulses to be sent to the capsules, thereby electrically igniting the propellant and creating a pressure which is then converted by the transducer 7 into a voltage, fed thru a pre-amplifier 8 into an oscilloscope 9 and photographed to obtain a permanent record of the pressure-time trace. The procedure is repeated, changing the propellant, if necessary, until a firing cycle is achieved which yields the desired pressure-time output. Thus, a firing cycle can be developed, amounting to synthesizing a pressure-time curve by breaking it down into its component parts. Propellant, number of capsules, capsule capacity as well as firing order may be varied to vary the output.

In practice, the system may be initiated as in a gun or rocket or missile, and the timing or firing sequence may be by pyrotechnic, electronic, primer cord (or propellant ignition line), or mechanical means.

The greatest potential may be realized from this process in the field of auxiliary power units in guided missiles. Generally constant pressure is desired since the auxiliary power units may be called upon to power a turbine for the manufacture of electrical power for the missile. A constant pressure is also generally required during most of the missile flight, for powering the directional controls via a pneumatic or hydraulic system, whereas near the end of the trajectory a pressure increase is usually required for final ballistic corrections. (See FIGURE 5.) A prior practice has required a solid propellant charge to be ignited with a peak pressure equal to the pressure requirements for final corrections and the excess pressure being exhausted until needed. Thus, weight is taken up with the propellant which produces gas which is not used. In addition, there must be a series of pressure build ups and discharges, even at the lower pressure, requiring exhaust valve operation.

Liquid propellants present the problem of complex pumping systems, clogging of the nozzles and jamming of valves.

Our method can readily be adapted to auxiliary power units by having a starting signal initiate a capsule, or plurality of capsules, to generate a pressure in a gas chamber 15, having a transducer 13, such as a piezo gage, convert the pressure to a voltage, in combination with a preamplifier 14 amplifying the voltage, thereafter sending the amplified voltage to a signal level detector 10, which then sends a signal to a switching circuit 11 activating a firing circuit 12 thereby firing an additional one or plurality of capsules, to raise the pressure or keep it at a predetermined level. Of course, a transducer may be used in the system which does not require an amplifier. An orifice or outlet A shown in FIG. 1 leads to the turbine, vane, or whatever load is being regulated. The time between capsule firings is only dependent upon the sensitivity of the signal level detector, and can be adjusted to secure as smooth or flat an output curve as desired. The capsules are fired in response to a pressure sensitive device, and the system is not sensitive to environmental effects, e.g. a low environmental temperature will cause any given capsule to produce a lower pressure thereby causing the pressure sensitive device to call for more pressure, resulting in the firing of additional capsules.

The output of our system would appear as shown in

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FIGURE 5 as a dotted line. The second pressure level can be obtained by raising the voltage level in the signal level detector after a predetermined time, thus causing additional capsules to be ignited. This may be accomplished by two signal level detectors each responsive to a different predetermined signal voltage or two transducers each sensitive at different pressure levels.

In our testing of the process for obtaining the desired pressure-time output, we used a resistance capacitor charging circuit for our timing circuit; a condenser discharge for the firing circuit; a variation of the Schmidt trigger circuit for the signal level detector and a piezo gage for the transducer. Either A.C. or D.C. current may be used as the power source.

The automatic feed-back system is used to illustrate how a normally varying load can be held substantially constant. Although we have demonstrated a pressure control system, it may be seen that any parameter that can be converted to a voltage signal, may be controlled by this system. We have demonstrated a pressure sensitive transducer to control pressure level, but a transducer sensitive to rate of change of pressure or rate of change of rate of change of pressure could be used and that parameter could then be controlled.

We claim:

A combination for obtaining a predetermined pressure-time output at ambient temperatures ranging from about -65° F. to about $+165^{\circ}$ F., said combination being independent of propellant burning rates in said temperature range, said combination comprising: a chamber in which

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said pressure is generated, a plurality of pressure generating capsules located in said chamber, each of said capsules containing a solid propellant capable of generating a pressure at a given level, pressure sensing means in said chamber for converting said pressure to a voltage, voltage amplifying means connected to said pressure sensing means, a signal level detector for receiving said voltage from said voltage amplifying means, a switching circuit operatively connected with said plurality of capsules and said signal level detector, whereby said signal level detector provides a signal to the switching circuit for firing capsules to produce a predetermined pressure, firing additional capsules in response to a voltage from said pressure sensing means when the pressure in said chamber falls below a predetermined level, and continues to provide signals to said switching circuit until a predetermined pressure-time output is completed.

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