United States Patent

Ratcliff

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[54] **GATED POWER SUPPLY FOR SONIC CLEANERS**

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[73] Assignee: **The Bendix Corporation**

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[52] **U.S. Cl.** ....**318/118,** 310/8.1, 323/22 SC

[51] **Int. Cl.** **H01v 9/00**

[58] **Field of Search** ....310/8.1; 318/118; 323/22 SC, 323/38, 16, 19

[56] **References Cited**

UNITED STATES PATENTS

3,283,179	11/1966	Carlisle et al.	323/22 SC
3,271,644	9/1966	McShane	318/118 X
3,121,169	2/1964	Benton	310/8.1 X
3,152,295	10/1964	Schebler	318/118
3,286,158	11/1966	Thatcher	323/22 SC
3,365,654	1/1968	Johnston	323/22 SC
3,374,422	3/1968	Blume	323/22 SC

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[57] **ABSTRACT**

A gated sonic power supply which permits selection of an optimum duty cycle and pulse repetition rate at which sonic energy must be pulsed to produce the most efficient degassing of tap water and/or uniform cavitation of a cleaning fluid. A pulse generator is used to trigger a gate within the sonic generator. The width of the pulse from the pulse generator determines the length of time that the sonic generator output signal is interrupted to give a pulse-modulated power output. The pulse width from the generator is variable to allow for the selection of a modulation width or duty cycle that gives a maximum efficiency of operation. Also, the frequency of the pulse from the pulse generator may be varied to select the optimum pulse repetition rate.

3 Claims, 2 Drawing Figures

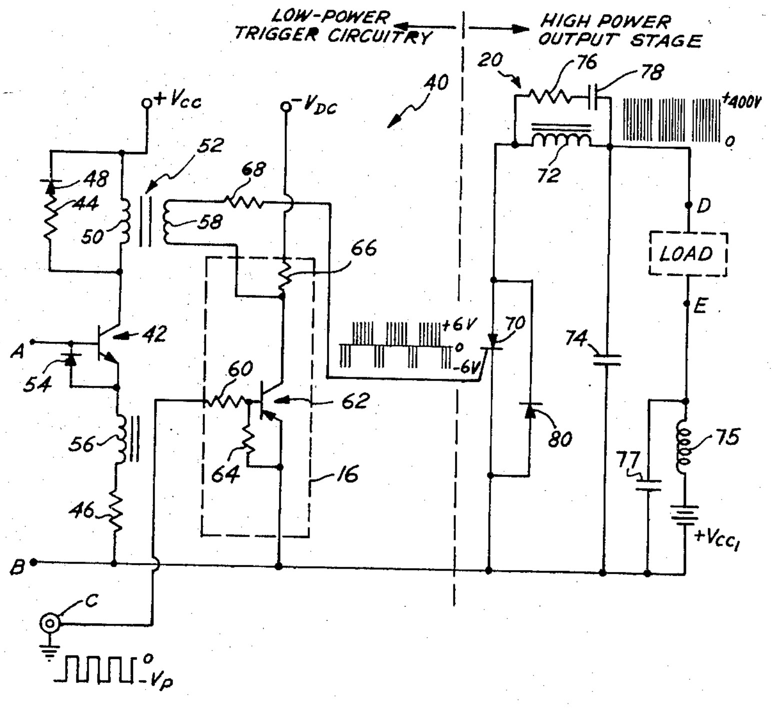


Fig. 1

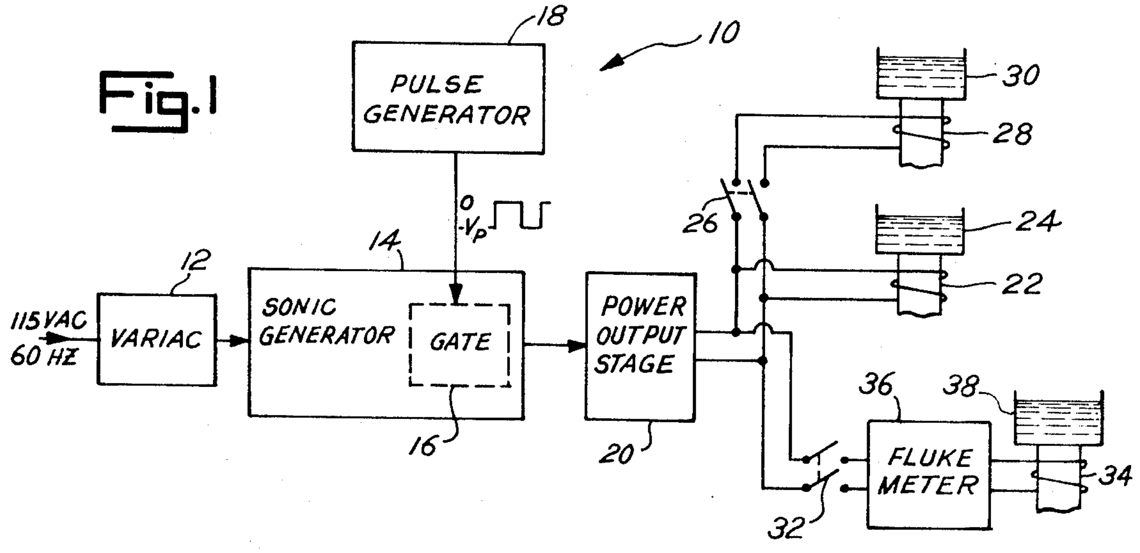
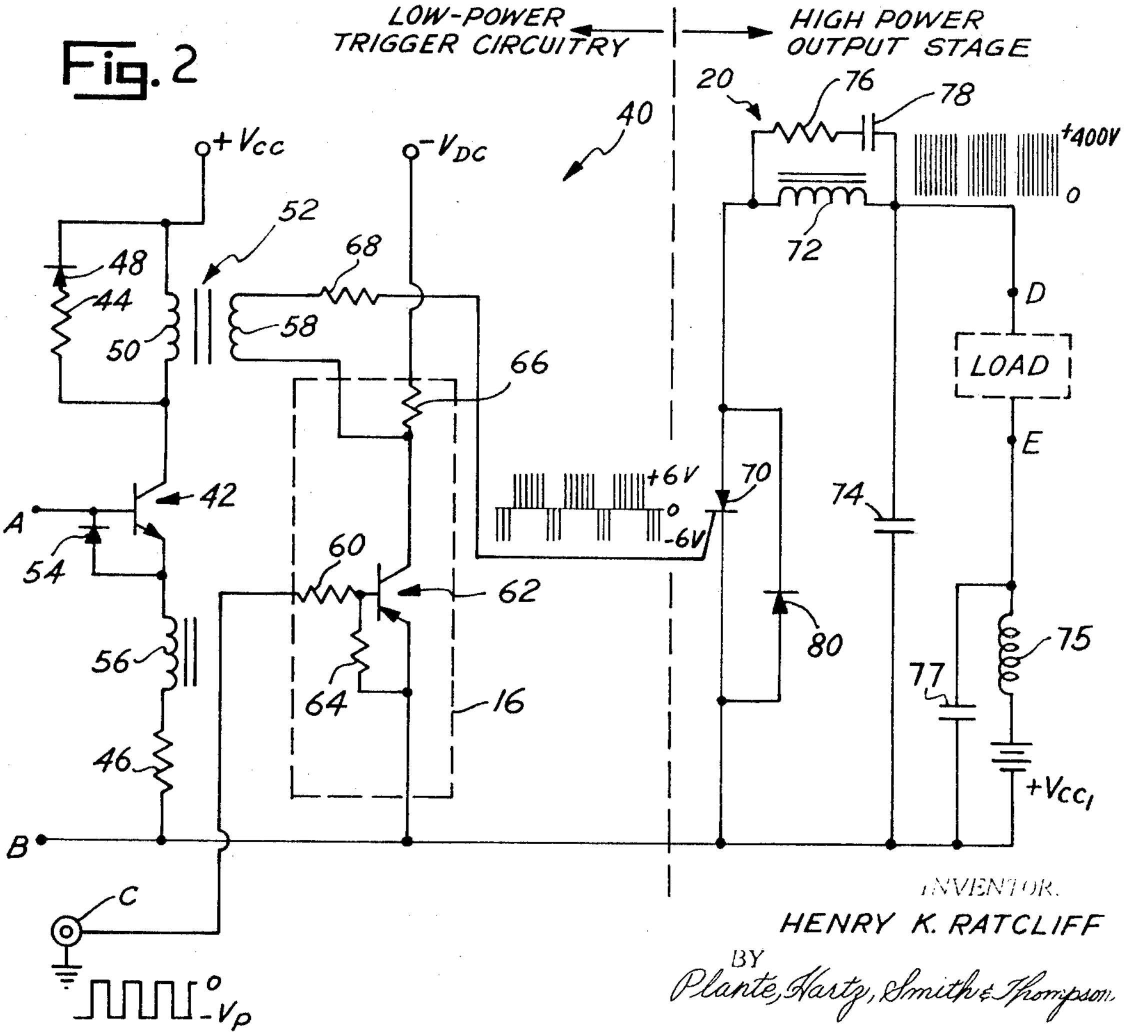


Fig. 2



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GATED POWER SUPPLY FOR SONIC CLEANERS

BACKGROUND OF THE INVENTION

This invention relates to U.S. Pat. application Ser. No. 45,163, filed on June 10, 1970, having the same inventor and assignee as the present application.

For many years better cleaning performance has been obtained when high-frequency electrical energy that is applied to sonic transducers is pulsed at low frequencies. To achieve this result of better cleaning performance, it has been the usual practice to take advantage of AC line frequency. Circuits have been designed that pulse the sonic energy at 60 cycles or 120 cycles per second with the cycles being in synchronization with the AC line frequency. Other systems have been designed that use a commutator to switch the high-frequency energy to a number of transducers. If just one of these transducers is considered, it would appear that it is being pulsed, but not necessarily at the AC line frequency. In fact, the pulse repetition rate depends upon the speed at which the commutator is rotated, and the duty cycle depends upon the number of transducers in the system. However, no system has been disclosed that allows the selection of the optimum pulse repetition frequency and duty cycle of the electrical energy applied to the individual transducers for maximum efficiency of operation and uniform cavitation. By the proper selection of the correct pulse repetition frequency and duty cycles of the sonic energy, a more efficient mode of operation for each individual transducer can be utilized. By utilizing the proper mode of operation, the power requirements of the sonic cleaner can be greatly reduced.

SUMMARY OF THE INVENTION

It is an object of this invention to minimize the high-frequency power needed to irradiate a large area and to obtain a more uniform cavitation.

It is a further object of this invention to minimize the high-frequency power needed for sonic cleaning by using a multiple frequency power supply to pulse modulate the high-frequency power supplied to the transducers at various resonance frequencies, thereby allowing the selection of the most efficient frequency.

It is an even further object of this invention to achieve the required uniform cavitation for maximum efficiency by using a single transducer and a given resonant frequency and duty cycle, the resonant frequency and duty cycle being determined in an independent test setup.

It is a still further object of this invention to modify an existing sonic cleaner by gating the control signal to the power output stage to produce a pulse modulated output, the frequency and duration of the pulse being variable.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a pictorial block diagram of a variable gated sonic cleaner.

FIG. **2** is a circuit schematic of a portion of the sonic generator and the power output stage shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, the control portion of the pulse modulated sonic generator is represented generally by reference numeral **10**. A variac **12** is used to vary the magnitude of 115 volt AC line voltage to the desired energy level. The output of the variac **12** is fed into sonic generator **14**. Within the sonic generator **14**, the line voltage from the variac is converted into DC voltages and a sonic control signal. Also, within the sonic generator **14** is a gate **16** that is operated by a pulse generator **18**. Only when the pulse generator **18** is at a given voltage level will the gate circuit **16** allow the sonic generator **14** to transfer a sonic control frequency to a power output stage **20**. By varying the width of the voltage from pulse generator **18**, the length of time that gate **16** will allow a sonic output signal to operate the power output stage **20** is directly proportional to the pulse width. Therefore, by varying the pulse width from pulse generator **18**, the width of the pulse modulation to power output stage **20** can be varied.

Within the power output stage **20**, the sonic signal from sonic generator **14** is amplified to give the necessary power to drive sonic transducers. The output from power output stage **20** is directly connected to sonic transducer **22** which vibrates cleaning tank **24**. By a proper switching arrangement **26**, other sonic transducers **28** can be connected to the output of power output stage **20** to vibrate other cleaning tanks **30**. The number of transducers and the number of cleaning tanks operated by the power output stage **20** is limited only by the power capabilities of the individual system. As a means of checking the power requirements for a given transducer, switch **32** may be closed which connects test transducer **34** to the power output stage **20** through the Fluke volt-amp-watt meter **36**. Test transducer **34** vibrates test tank **38**. The Fluke meter **36** measures the amount of power required to vibrate the test tank **38** to produce sonic cleaning. By a measurement of the power requirements for a test transducer and knowledge of the power capabilities of the power output stage **20**, a person can calculate the number of transducers that can be driven by a single power output stage. One of the major functions of the test circuit is for the Fluke meter **36** to measure the power requirements as the pulse generator output is varied. This allows the selection of the most efficient mode of operation.

Referring now to FIG. 2, reference numeral **40** designates generally a portion of the low-power trigger circuitry of sonic generator **14**. A sonic frequency signal is fed into terminals A and B of the low-power trigger circuitry **40**. The sonic frequency is generated in another portion of the sonic generator **14** that is not shown in the detailed schematic of FIG. 2. A positive signal from the sonic frequency input A triggers transistor **42** which provides isolation between the low-voltage DC supply $-V_{DC}$ and the high-voltage DC supply $=V_{CC}$. The resistors **44** and **46** serve as current limiters to a transistor **42**. The diode **48** in series with resistor **44** across winding **50** of transformer **52** provides protection for a transistor **42** to keep it from exceeding its maximum current limitations. Diode **54** connected between the base and emitter of transistor **42** is also included to keep transistor **42** from exceeding its maximum current limitations. Transformer **52** uses winding **56** as a feedback network for a transistor **42**. Upon receiving a sonic frequency input at terminal A, transistor **42** operates as a blocking oscillator. Winding **58** of transformer **52** is used for coupling the sonic frequency received at terminal A to the succeeding circuitry, as will be described subsequently.

When the sonic frequency input at terminal A goes in the positive direction, transistor **42** begins to conduct. The conduction of transistor **42** causes current to flow through windings **50** and **56** of transformer **52** and resistor **46**. When a positive voltage no longer exists on the base of transistor **42**, the transistor stops conduction. However, because current in windings **50** and **56** cannot stop instantaneously, the winding **50** discharges through the resistor **44** and diode **48**, and winding **56** discharges through resistor **46** and diode **54**. Winding **56** is mutually coupled to winding **50** to provide a feedback from the output winding **50** to input of transistor **42**. The mutually coupled winding **58** has a voltage signal that is directly proportional to the current flowing in winding **50**. However, the turns ratio between windings **50, 56** and **58** of transformer **52** can vary according to the desired voltage output or the desired feedback. A typical turns ratio between winding **50, 56** and **58** would be 5:1:1, respectively.

The gate circuit **16** of sonic generator **14** is enclosed in broken lines in FIG. 2. The output in the pulse generator **18** is fed into terminal C of sonic generator **14**. Terminal C is connected through resistor **60** to the base of gating transistor **62**. Resistor **64** provides the necessary biasing to turn transistor **62** into the conducting stage when a negative signal is received at its base. The relationship between resistors **60** and **64** determine the voltage from the pulse generator **18** necessary to change transistor **62** to the conducting stage. Voltages as low as 1 volt may be used. Assuming that the signal from the pulse generator **18** is a zero to negative signal, then transistor **62** will only conduct when a negative signal is received from the pulse generator. The negative signal represented by $-V_P$ is fed through resistor **60** into the base of transistor **62**. Upon receiving the negative signal, transistor **62** starts conducting thereby connecting winding **58** to input terminal B. However, if no signal is being received from the pulse generator **18**, winding **58** will be connected through low value resistor **66** to a negative DC supply represented by $-V_{DC}$. The supply $-V_{DC}$ can vary over a range of negative voltages with about 8 volts being needed to produce a typical negative control signal as will be subsequently described.

The output of winding **58** is effected in the following manner. If transistor **62** is conducting, the output of winding **58** will be a small positive signal (6 volts being a typical example) of the same frequency as the sonic input on input terminal A. However, if transistor **62** is not conducting, winding **58** will be connected through low value resistor **66** to the voltage supply $-V_{DC}$ to give a small negative signal output (minus 6 volts being a typical example) of the same frequency as the sonic signal connected to input terminal A. The range of voltage outputs from winding **58** could be varied according to the desired parameters of an individual system. Coupling resistor **68** provides a current-limiting function for the winding **58**.

The power output stage **20** is controlled by the small control signal received from winding **58**. The control signal triggers silicon control rectifier (SCR) **70** which begins to conduct upon receiving a positive signal from winding **58**. The SCR **70** is connected in series with resonant inductor **72** and commutating capacitor **74**. A load is connected across output terminals D and E in series with high impedance coil **75** and high-voltage source $+V_{CC1}$. A low impedance capacitor **77** is connected in parallel with high impedance inductor **75** and high-voltage source $+V_{CC1}$ to give a constant voltage output equal $+V_{CC}$. The load and the high-voltage source $+V_{CC1}$ are connected across commutating capacitor **74**. A transient suppressor network consisting of resistor **76** and capacitor **78** is connected across resonant inductor **72** to reduce transient noise problems. Also, diode **80** allows a reverse current to flow in the power output stage **20**.

A description of how this circuit operates is most easily understood when analyzing one cycle of operation. When the AC power is applied to the control portion **10**, the commutating capacitor **74** charges toward the voltage supplied by the high-voltage source $+V_{CC1}$. The SCR **70** being off and in parallel with commutating capacitor **74** receives the same voltage. When the voltage across commutating capacitor **74** is nearing its peak, a trigger pulse appears at the gate of the SCR **70** changing it to its low impedance condition. Because of the resonant discharge of commutating capacitor **74** through resonant inductor **72**, a sinusoidal current will flow from anode to cathode of the SCR **70**. The resonant discharge current is much larger than the DC charging current from the high-voltage supply $+V_{CC1}$. Therefore, commutating capacitor **74** will be discharged and charged in the reverse direction. Since the SCR **70** cannot conduct in the reverse direction, it turns to a high impedance off condition. Commutating capacitor **74** continues to discharge through diode **80** and the high-voltage power supply $+V_{CC1}$ then begins to recharge after diode **80** turns off. The cycle then repeats itself.

As long as a positive sonic frequency signal input is being received on the gate of SCR **70**, a sonic power output is realized across load terminals D and E. However, if due to the gate circuit **16**, a negative sonic frequency signal is received by SCR **70**, it will not be switched to its low impedance stage. Since commutating capacitor **74** is charged to a voltage approximately equal to the high-voltage supply $+V_{CC1}$, no voltage will be realized across the output terminals D through E. The time period wherein the gate circuit **16** allows a positive signal to trigger the SCR **70** is equal to the duty cycle of the sonic generator. By varying the input to the gate circuit **16**, the duty cycle of modulation can be varied. The gate circuit **16** is varied by the external pulse generator **18**.

To a person of ordinary skill in the art, it should be obvious that the frequency of the power output is of the same frequency as the sonic input at terminals A and B. However, the output voltage at terminals D and E has been pulse modulated by the gating circuit **16** which effectively inverts portions of the signal received at the gate of SCR **70**. By varying the pulse width of the signal received from pulse generator **18**, varying amounts of pulse width modulation or duty cycle can be obtained. Also, by varying the frequency of pulse generator **18**, the repetition rate of the pulse width modulation can also be varied. By varying both the pulse width and the pulse frequency, a person can select the most efficient type of pulse width modulation for a sonic generator. By utilizing the test tank **38** and the test transducer **34** in series with Fluke meter **36**, a person could vary the pulse width and the pulse frequency of the output signal from pulse generator **18** to select the most efficient mode of operation. When the most efficient mode of operation has been selected, the Fluke meter **36** could be removed or the power output stage **20** could be switched to an identical tank and transducer.

As an example, suppose a conventional 150 watt sonic generator that performs a circuit cleaning operation in 1 minute has been modified for a gated sonic power output. By adjusting the pulse generator **18** so that a sonic power output at terminals D through E is available only 10 percent of the time, it may be found that the cleaning operation can be performed in 1½ minute. Since the AC power input at this particular duty cycle is only one-tenth that of the unmodified cleaning system, a significant reduction in cleaning costs has been achieved.

As a typical example of the voltage levels in FIG. **2**, the high-voltage supply $+V_{CC}$ may operate at 100 volts DC. The negative supply $-V_{DC}$ may operate between 0 and -10 volts. A typical voltage operation level would be approximately -8 volts. The signal received from the pulse generator **18** at the base of transistor **62** should be large enough to switch transistor **62** from the nonconducting to the conducting stage. The output voltage across terminals D through E is dependent upon the quiescent operating point of the system determined by resonant inductor **72** and commutating capacitor **74**. A typical example would be an output voltage that varies from $+200$ to -200 volts. Considering terminal E as being equal to ground, then output voltage across the load would vary from 0 to 400 volts. The duty cycle can be varied from 10 to 90 percent and the frequency can be varied 10 to 300 cycles per second for most sonic generators. Other variations, though possible, would not produce a more efficient cleaning by the sonic generator.

I claim:

1. A sonic generator for operating a liquid cleaning apparatus at an optimum efficiency by modulation of an operational pulsing signal, said generator comprising:

measuring means connected to said cleaning apparatus for determining an optimum operating frequency with varying loads;

means for converting AC line voltage into a constant voltage;

means for generating a control signal from said constant voltage, said control signal functionally corresponding to said optimum operating frequency;

gate means having a transistorized switch connected in series with an output section of a transformer coupling for separating said control signal into an inverted portion and a noninverted portion;

pulse-generating means adaptable with said measuring means and connected to said transistorized switch of said gate means for regulating the duration and frequency of the inverted and noninverted portion of the control signal to produce an output signal;

rectifying means for switching from a conducting to a nonconducting mode in response to said noninverted portions of said control signal; and

- a series resonant circuit in parallel with said rectifying means and connected to an oscillating device which vibrates said load, said resonant circuit having a capacitive portion, said capacitive portion being charged and discharged with the same frequency as said inverted and noninverted portions of said control signal to create a pulse modulated output voltage operating said oscillating device to produce maximum cavitation in the liquid cleaning apparatus as determined by said measuring means.

2. The pulse-modulated sonic generator, as recited in claim 1, wherein said switching means is a silicon controlled rectifier with a trigger being received from said control signal.

3. A control system for providing a pulse-modulated power output to operate a liquid cleaning apparatus at an optimum cavitation frequency, comprising:

- measuring means connected to said cleaning apparatus for determining the maximum effective operating frequency with varying loads;
- means for generating control pulses from a voltage source in response to an internally controlled frequency derived from said measuring means;
- first switching means for interrupting said control pulses for a predetermined time interval to produce a pulsed output voltage signal, said time interval being variable in frequency and duration to allow for the selection of an operating mode which will give maximum efficiency corresponding to said measuring means;
- pulse-generating means connected to said first switching means for providing signals to control the duration of said time interval;
- second switching means connected to said control pulse generating means for relaying a DC voltage across a coupling means, said coupling means being electrically connected to said first switching means for sequentially interrupting said control pulse;
- third switching means connected to said first switching means and in parallel with a resonant circuit and a capacitor circuit, said third switching means controlling charging and discharging of said resonant circuit in response to the pulsed output voltage from said first switching means to produce a controlled output voltage operational signal; and
- output means connected to said resonant circuit and said cleaning apparatus, said output means producing uniform cavitation in the liquid cleaning apparatus in response to said controlled output voltage.

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