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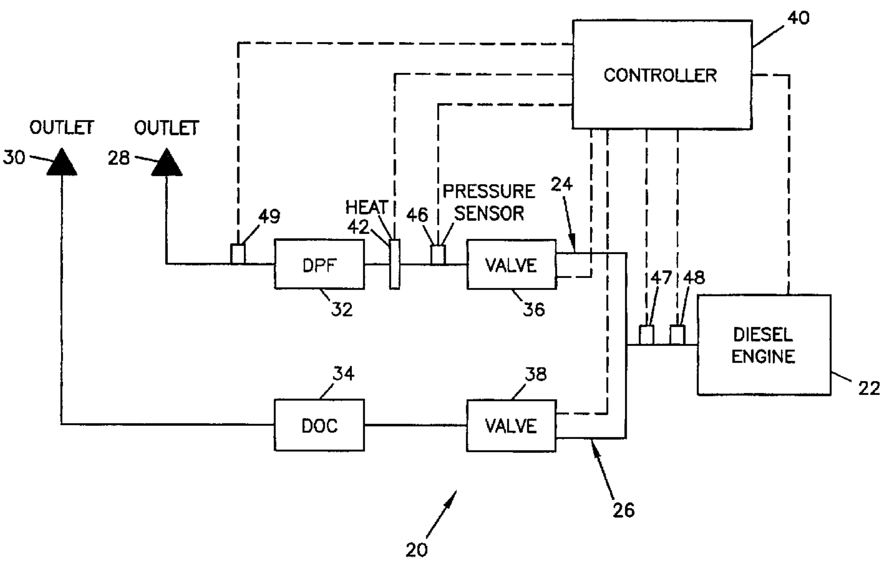
(54) Title: EXHAUST TREATMENT CONTROL SYSTEM FOR AN INTERNAL COMBUSTION ENGINE



(57) Abstract: The present invention relates to an engine exhaust treatment system (20) including a first exhaust gas path (24) having a diesel particulate filter (32) and a second exhaust gas path (26) having a catalytic converter (34). The system also includes a valve arrangement (36, 38) for controlling exhaust gas flow between the first and second paths (24, 26). The system (20) further includes a controller (40) for sensing/monitoring operating conditions of the engine (22) and the condition of the diesel particulate filter (32). The controller (40) shifts exhaust gas flow between the first and second paths (24, 26) based on the operating condition of the engine (22) and/or the condition of the diesel particulate filter (32) to optimize filtration efficiency while preventing unacceptable levels of backpressure and detrimental regeneration of the filter (32).

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EXHAUST TREATMENT CONTROL SYSTEM FOR AN INTERNAL COMBUSTION ENGINE

This application is being filed as a PCT international patent application in the name of Donaldson Company, Inc., a U.S. national corporation (applicant for all designations except the U.S.), and in the names of Wayne M. Wagner, Edward A. Steinbrueck, and Julian A. Imes, all citizens and residents of the U.S. (applicants for the U.S. designation only), on 25 October 2002, designating all countries.

Field of the Invention

The present invention relates generally to exhaust treatment systems having cores such as catalytic converters or diesel particulate filters.

Background of the Invention

To reduce air pollution, vehicle emissions standards have become increasingly more stringent. With respect to both internal combustion and diesel engines, catalytic converters have been used to reduce the concentration of pollutant gases (e.g., hydrocarbons, carbon monoxide, nitrogen oxides, etc.) in the exhaust stream. Also, with respect to diesel engines, diesel particulate filters have been used to reduce the concentration of particulate matter (e.g., soot) in the exhaust stream.

A typical catalytic converter includes a substrate mounted in an outer casing or "can." The substrate defines a plurality of longitudinal channels that extend through the catalytic converter. Exemplary substrate materials include ceramic (e.g., extruded magnesia alumina silicate) and corrugated metal (e.g., stainless steel). A catalyst is provided on the substrate for promoting the oxidation of a gaseous pollutant. For example, the catalyst can include a precious metal such as platinum, palladium or rhodium, a base metal or a material such as zeolite. In some cases, a material such as zeolite can be included as both a substrate and a catalyst.

A typical diesel particulate filter includes a ceramic substrate mounted in an outer casing. The ceramic substrate is porous and defines a plurality of longitudinal channels. Adjacent longitudinal channels are plugged at opposite ends of the core as described in United States patent No. 4,851,015 that is hereby incorporated by reference in its entirety. The plugged ends forces exhaust gases to flow through the walls of the substrate so that soot is collected on the walls as the gases pass therethrough. For some applications, a catalyst can be provided on the substrate such that the filter functions like a catalytic converter to reduce the concentration of pollutant gases.

Summary of the Invention

One aspect of the present invention relates to an engine exhaust treatment system including a first exhaust gas path having a diesel particulate filter and a second exhaust gas path having a catalytic converter. The system also includes a valve arrangement for controlling exhaust gas flow between the first and second paths. The system further includes a controller for sensing/monitoring operating conditions of the engine and the condition of the diesel particulate filter. The controller shifts exhaust gas flow between the first and second paths based on the operating condition of the engine and/or the condition of the diesel particulate filter.

A variety of other aspects of the invention are set forth in part in the description that follows, and in part will be apparent from the description, or may be learned by practicing the invention. The aspects of the invention relate to individual features as well as combinations of features. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention as claimed.

Brief Description of the Drawings

Figure 1 shows an exhaust treatment system constructed in accordance with the principles of the present invention;

Figure 2 is a particulate mass reduction efficiency graph corresponding to the system of Figure 1;

Figure 3 is a further exhaust treatment system constructed in accordance with the principles of the present invention, the system includes structure for reducing nitrogen oxide emissions;

Figure 4 is a passive filter regeneration exhaust treatment system constructed in accordance with the principles of the present invention;

Figures 5A-5L show example flow logic for controlling the system of Figure 4;

Figure 6A shows an exhaust system packing arrangement that is an embodiment of the present invention, the view is a longitudinal cross-section of the system;

Figure 6B is a cross-sectional view taken along section line 6B-6B of Figure 6A;

Figure 6C shows an alternative packing arrangement that is an embodiment of the present invention;

Figure 7 shows a multi-filter exhaust system that is an embodiment of the present invention;

Figure 8A shows an exhaust system packing arrangement corresponding to the system of Figure 7, the view is a longitudinal cross-section of the system;

Figure 8B is a cross-sectional view taken along section line 8B-8B of Figure 8A; and

Figure 8C shows an alternative packing arrangement that is an embodiment of the present invention.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail below. It is to be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the invention is intended to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

Detailed Description

In the following detailed description, references are made to the accompanying drawings that depict various embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized, and structural and functional changes may be made without departing from the scope of the present invention.

I. System With Active Filter Regeneration

Figure 1 illustrates an exhaust treatment system 20 in accordance with the principles of the present invention. The system is adapted for use in treating the exhaust emissions of a diesel engine 22 such as the diesel engine of a vehicle (e.g., a truck, bus or off-road vehicle). The system 20 includes a first exhaust gas pathway 24 and a second exhaust gas pathway 26. The pathways 24, 26 direct gases emitted from the engine 22 to outlets 28 and 30. A diesel particulate filter 32 (DPF) is positioned along the first gas pathway 24 and a catalytic converter 34 (DOC) is positioned along the second gas pathway 26. Valves 36 and 38 control gas flow from the engine 22 to the first and second gas pathways 24, 26. A controller monitors the operating condition of the engine 22 and the overall system 20, and also controls operation of the valves 36, 38. Depending on the operating condition of the engine 22 and the overall system 20, the controller causes the valves 36 and 38 to direct flow to either the first gas path 24 or the second gas flow path 26. In certain embodiments, the controller 40 can selectively proportion flow to both flow paths 24, 26 to control backpressure and optimize the particulate matter mass reduction efficiency of the system.

The diesel particulate filter 32 can have a variety of known configurations. An exemplary configuration includes a monolith ceramic substrate having a "honey-comb" configuration of plugged passages as described in United States patent No. 4,851,015 that is hereby incorporated by reference in its entirety. In certain embodiments, the substrate can include a catalyst. Exemplary catalysts include precious metal catalysts such as platinum, palladium or rhodium, or other types of catalysts such as base metals or zeolites.

The diesel particulate filter 32 preferably has a particulate mass reduction efficiency greater than 75%. More preferably, the diesel particulate filter has a particulate mass reduction efficiency greater than 85%. Most preferably, the diesel particulate filter 34 has a particulate mass reduction efficiency equal to or greater than 90%. For purposes of this specification, the particulate mass reduction efficiency is determined by subtracting the particulate mass that enters the filter from the particulate mass that exits the filter, and by dividing the difference by the particulate mass that enters the filter.

The catalytic converter 34 can have a variety of known configurations. Exemplary configurations include substrates defining channels that extend completely therethrough. Exemplary catalytic converter configurations having both corrugated metal and ceramic substrates are described in United States patent No. 5,355,973, that is hereby incorporated by reference in its entirety. The substrates preferably include a catalyst. For example, the substrate can be made of a catalyst, impregnated with a catalyst or coated with a catalyst. Exemplary categories of catalysts include carbon monoxide (CO) catalysts, hydrocarbon (HC) catalysts, lean NOx (oxides of nitrogen such as nitric oxide) catalysts and selective reduction catalysts. Exemplary catalysts include precious metal catalysts such as platinum, palladium or rhodium, or other types of catalysts such as base metals or zeolites.

The catalytic converter 34 typically will have a reduced particulate reduction efficiency as compared to the filter 32. In one embodiment, the catalytic converter 34 has a particulate mass reduction efficiency less than 50% or less than 40%. In one embodiment, the particulate mass reduction efficiency for the catalytic converter 34 is about 30%.

Referring still to Figure 1, the system 20 includes a heating element 42 for heating the filter 32 to regenerate the filter 32 by burning off excess soot. The heating element 42 can have a variety of configurations such as an electric heater, a burner such as a diesel fuel burner, or an injector for injecting fuel into the filter 32 to promote oxidation of the soot. A typical diesel fuel burner includes a chamber is which diesel fuel is injected and ignited. Hot exhaust gas from the chamber can be used to burn the soot on the filter. In some embodiments, an air injector is provided upstream of the heating element 42 (see U.S. Patent No. 4,851,015 that was previously incorporated by reference) to provide a controlled amount of oxygen to the filter 32 to support combustion of the soot.

The controller 40 of the system interfaces with a pressure sensor 46 that measures the pressure on the upstream side of the filter 32 and a pressure sensor 49 that measures the pressure at the downstream side of the filter. Data from these sensors can be used to determine the loading of the filter. In certain embodiments, the downstream side of the filter 32 can be assumed to be at atmospheric pressure thereby eliminating the need for sensor 49.

The controller 40 can also interface with a pressure sensor 47 located upstream of the valves 36, 38. Preferably, the sensor 47 is located in relatively close proximity to the engine and is used to measure the pressure downstream from the engine as compared to atmospheric pressure (i.e., the 47 sensor measures the "back pressure" of the system).

The controller can also interface with a temperature sensor 48 that measures the temperature of the exhaust gas emitted from the engine 22. The controller 40 can further interface with pressure sensors (not shown) located on opposite sides of the catalytic converter 34 to measure the pressure gradient across the converter 34. The controller 40 also can interface with sensors to monitor a variety of other parameters such as the speed of the engine (RPM), the rate of acceleration of the engine, the air intake of the engine, air flow exhausted from the engine, the rate at which fuel is supplied to the engine, the air flow rate through each of the flow paths 24, 26, the oxygen concentration in the exhaust gas, and the length of time of a regeneration cycle of the filter 32 and engine loading.

While two separate valves 36, 38 have been shown, a single proportional valve or other type of valve could also be used. Also, while two outlets 28, 30 have been shown, the flow paths 24, 26 could also be outputted through a common outlet. Further, the filter 32 or the catalytic converter 34 can each be packaged in a muffler (as shown in United States patent No. 5,355,973 which is incorporated by reference in its entirety) along with other structures such as flow distribution arrangements.

II. Proportional Flow to Optimize Filtration While Preventing Unacceptable Backpressure

In the embodiment of Figure 1, the controller 40 can proportion flow to both of the flow paths 24 and 26 to control the backpressure of the system and to optimize the particulate mass reduction efficiency. For example, as the diesel particulate filter 32 becomes loaded or flow rates increase, backpressure of the system may approach a manufacturer set maximum such as 3 inches of mercury. To prevent the backpressure from exceeding 3 inches of mercury, the controller 40 can divert a portion of the flow through the catalytic converter 34 while a majority of the flow is still directed through the diesel particulate filter 32 to provide a high particulate mass reduction efficiency. Because the catalytic converter 34 provides a flow path with significantly less flow restriction than the filter 32, the backpressure of the system will be reduced by passing at least some of the flow through the catalytic converter 34.

Figure 2 shows a particulate material mass reduction efficiency graph for a catalytic converter having an efficiency of 30% and a diesel particulate filter having an efficiency of 90%. Line 92 shows how flow can be proportioned between the diesel particulate filter and the catalytic converter to achieve a net desired particulate material mass reduction efficiency in the range of 30-90 percent mass reduction efficiency. For example, to achieve a particulate mass reduction of 30%, all of the mass flow is directed through the catalytic converter 34. To achieve a particulate mass reduction of 90%, all of the mass flow is directed through the filter 32. To achieve a particulate mass reduction of 60%, half of the mass flow is directed through the filter 32 and the other half of the mass flow is directed through the catalytic converter 34.

III. Reduction of Nitrogen Oxides

The system 20 can also include separate structures for reducing nitrogen oxide (NOx) emissions. For example, in addition to the diesel particulate filter 32 and the catalytic converter 34, nitrogen oxide reducing structures can be positioned along the first flow path 24, the second flow path 26 or along both flow paths 24, 26 upstream or downstream from the filter 32 and the catalytic converter 34. Alternatively, the diesel particulate filter 32 and the catalytic converter 34 could themselves be configured for reducing nitrogen oxide emissions. Further, a separate path in parallel with flow paths 24, 26 could be equipped with structure for reducing nitrogen oxide emissions. Exemplary structures include selective reduction catalytic converters, lean NOx catalytic converters and NOx traps/absorbers. Example structures for reducing nitrogen oxide emissions are disclosed in U.S. Patent No. 6,182,443 that is hereby incorporated by reference in its entirety.

For systems configured to reduce nitrogen oxide emissions, the flow paths 24 and 26 can include structures for injecting chemicals used to enhance NOx conversion. For example, hydrocarbons can be injected for lean NOx catalysts and urea or ammonia can be injected for selective reduction catalysts.

Figure 3 shows another system 200 constructed in accordance with the principles of the present invention. The system 200 has the same configuration as the system of Figure 1 except that structures 89 for reducing nitrogen oxide emissions have been provided along the first and second flow paths 24, 26.

IV. System with Passive Filter Regeneration

Figure 4 shows another system 300 constructed in accordance with the principles of the present invention. The system 300 has the same configuration as the system of Figure 1 except no heating structure is provided for heating the filter 32. Thus, the system 300 uses the heat of the exhaust gas to burn soot from the filter 32 during a regeneration cycle.

V. General System Control Features

In the systems of Figures 1, 3 and 4, the controller 40 is preferably adapted to adjust flow through the flow paths 24 and 26 based on the operating condition of the filter 32 and the engine 22. For example, to prevent plugging of the filter 32, the controller can be configured to route flow exclusively through the catalytic converter 34 when the exhaust gas temperature measured at sensor 48 is less than the minimum temperature (e.g., about 525°F). When the exhaust gas exceeds the minimum temperature, the controller 40 can route all flow through the filter 32.

The systems can also include a control feature that routes flow through the filter 32 during times of high soot production (e.g., when the engine is rapidly accelerating or rapidly undergoing increased loading). These types of conditions can be detected by monitoring if the rate of change of the speed of the engine exceeds a predetermined level, or if the time rate of change of flow through the engine exceeds a predetermined level. If a high soot generating condition is detected, flow to the catalytic converter 34 is preferably stopped and all flow is routed to the filter 32. This sequence preferably overrides the sequence described above such that flow is directed to the filter 32 even if the exhaust temperature is less than the minimum exhaust temperature.

Another consideration addressed by the above systems is loading of the filter 32. If the pressure sensors detect a backpressure at the filter 32 that exceeds a predetermined level (e.g., 3 inches of mercury), the controller preferably reduces or stops flow to the filter 32, and opens from through the catalytic converter 34. In an active system, a heater can then be activated to regenerate the filter 32. After regeneration, flow can again be directed though the filter 32. If the system relies on passive regeneration, the temperature of the exhaust gas will determine whether regeneration is possible. For example, the system can continue to route flow through the catalytic converter 34 until the temperature of the exhaust gas exceeds the minimum temperature at which catalysis will occur at the filter 32 (e.g., about 625°F). When the exhaust temperature exceeds the catalysis temperature, the controller routes flow back to the filter 32 such that the hot exhaust gas causes the filter to regenerate via combustion of the soot on the filter.

During regeneration, it is important to maintain a controlled combustion at the filter. To achieve this end, a timer is preferably started at the start of the regeneration cycle. If the operating conditions of the engine change during a predetermined regeneration cycle period (e.g., 10 minutes as determined by the timer) so as to increase the likelihood of uncontrolled combustion, flow to the filter 32 is preferably stopped thereby depriving the filter of oxygen for combustion. Example types of conditions where it would be desirable to stop the regeneration cycle include situations where the oxygen content of the exhaust gas exceeds a predetermined level. Typically this might occur if the load on the engine dramatically drops or if the engine is shifted to idle. High oxygen conditions can be indirectly detected by detecting if the temperature of the exhaust gas falls below a predetermined level or if the speed of the engine falls below a predetermined level. Both of these factors can be indicative of a situation in which a high level of oxygen is present in the exhaust gas.

VI. Example Control Logic for System with Passive Filter Regeneration

Figures 5A-5L show logic that is indicative of basic controller software suitable for controlling the controller 40 of the passive filter regeneration system of Figure 4. Figures 5A-5E show the logic of a main control loop. Figures 5F-5L show sub-routines that branch from the main control loop. Figure 5L shows an error handling routine.

In the flow chart of Figures 5A-5L, process blocks are shown as rectangles. Decision blocks are shown as diamonds. Sub-routines are shown as rectangles with double side walls. Connection points are shown as circles with labels as required.

A number of variables are used in the flow chart. Example variables include back pressure, temperature, RPM and flow. Back pressure is measured in the exhaust ducting common to both the diesel particulate filter 32 and the catalytic converter 34. Temperature is measured in the exhaust flow upstream from the filter 34 and the catalytic converter 32. RPM (i.e., rotations per minute) is measured from the engine. Flow is measured in the exhaust flow stream upstream from the separate flow paths 24, 26.

The flow chart uses a number of flow control variables. For example, the flow chart includes MASTER_STATE variables that control program execution in the main loop. The MASTER_STATE variables range from level 0 to 7. MASTER_STATE level 0 corresponds to a state where the system is off and waiting for the engine to be started. MASTER_STATE level 1 corresponds to an initialization state. MASTER_STATE level 2 corresponds to a BACKPRESSURE RELIEF STATE (i.e., a state where flow is directed through the catalytic converter 34 to relieve back pressure). MASTER_STATE level 3 corresponds to a DPF TEMPERATURE ONLINE STATE (i.e., a state where flow is routed through the filter 32 because the temperature of the exhaust gas is suitable for filtration). MASTER_STATE level 4 corresponds to a DPF REGENERATION STATE (i.e., a state where flow is routed through the filter 32 and the temperature of the exhaust gas is suitable to cause active regeneration of the filter). MASTER_STATE level 5 corresponds to a DPF REGENERATION COOL_DOWN STATE (i.e., a state where flow is diverted from the filter to prevent a thermal run-away caused by uncontrolled soot combustion at the filter 32). MASTER_STATE level 6 corresponds to a DPF_RPM/FLOW ONLINE STATE in which the diesel particulate filter is placed online due to operating conditions that produce high concentrations of soot such as high engine acceleration rates or high flow rate changes. MASTER_STATE level 7 corresponds to a SYSTEM FAULT STATE in which an error in the system has occurred.

Other flow control variables include BP_STATE, DPF_ONLINE, and REG_COOL_STATE. The BP_STATE variable controls execution of the BACKPRESSURE RELIEF sub-routine. This variable has levels 0-3. The DPF_ONLINE variable is a Boolean variable that control execution of diesel particulate filter calculation routines (e.g., diesel particulate filter loading, diesel particulate filter duty cycles, mass flow through the diesel particulate filter, and particulate material mass reduction efficiencies). The DPF_ONLINE variable is either TRUE (indicating that all flow is being directed through the filter 32) or FALSE (indicating that all flow is not being directed through the filter 32). The REG_COOL_STATE variable controls the execution of the regeneration cool down sub-routine. This variable has levels 0-2.

The flow chart also utilized a number of constants. The constants include:

TEMP_ENGINE_MIN: the minimum temperature that the controller considers necessary for operation (e.g., about 150°F);

BP_MAX: the maximum back pressure allowed by the engine manufacturer (e.g., about 3 inches Hg);

RPM_MIN: the minimum rpm indicative of a running engine (e.g., about 500)

TEMP_LOW: the minimum temperature allowed for exhaust flow to be directed through the diesel particulate filter (e.g., about 525°F);

T_CATALYSIS: the minimum temperature at which catalysis actively occurs (e.g., about 625°F);

RPM_ACCEL: the minimum engine annular acceleration for an engine accelerating under load (e.g., about 200 rpm/s);

FLOW_ACCEL: the minimum engine exhaust flow for an engine accelerating under load (e.g., about 200 cfm/s);

LOADING_MAX: the maximum diesel particulate loading that is allowed before a system fault is entered;

BP_TIMER_MAX: the maximum time period allowed in the back pressure relief state (e.g., about 15 seconds); and

T_CATALYSIS_LOW: the lower temperature limit used to exit from the diesel particulate filter regeneration state (e.g., about 450°F).

A. MAIN LOOP

This section described the initialization sequence of the controller. During this description, it is assumed that no operating conditions are present that would cause flow to be directed through the filter 32.

Referring to Figure 5A, the flow chart starts at oval 600. As shown by rectangle 602, the system is initially set to MASTER_STATE level 0 while the system waits for indication that the engine has been started. During this time period, the diesel particulate filter and catalytic converter valves are both open as indicated by parallelogram 604. The system remains at MASTER_STATE level 0 until the system detects that the temperature of the exhaust gas is greater than TEMP_ENGINE_MIN or the rpm is greater than RPM_MIN (see diamond 606).

Once the system has detected that the engine has started, the system is set to MASTER_STATE level 1 as indicated by block 608. Also, the BP_STATE variable is set to level 0 and the DPF_ONLINE variable is set to FALSE as indicated by block 610. With the MASTER_STATE variable set at level 1, the routine proceeds through diamond 612 (shown at Figure 5B) to the DPF_OFFLINE state indicated by rectangle 614. The sub-routine corresponding to the DPF_OFFLINE state is shown at Figure 5G. In the sub-routine, the catalytic converter valve is opened and the diesel particulate filter valve is closed as indicated by parallelogram 616. Also, the BP_STATE is again set to level 0 and the DPF_ONLINE state is again set to false as indicated by block 618. At the completion of the sub-routine of Figure 5G, flow returns to diamond 620 of the main loop that is shown at Figure 5B.

Diamond 620 inquires if the backpressure of the system is greater than BP_MAX. If the backpressure does not exceed BP_MAX, flow proceeds to diamond 622. If the backpressure does exceed BP_MAX, flow proceeds to rectangle 621 where the MASTER_STATE variable is set to level 2 corresponding to the back pressure relief state. From rectangle 621, flow proceeds to diamond 622.

Diamond 622 inquires whether the MASTER_ STATE variable is at level 2. If the variable is at level 2, flow proceeds to block 623, which corresponds to the BACKPRESSURE RELIEF STATE. The subroutine corresponding to the BACKPRESSURE RELIEF STATE is shown at Figure 5f. If the MASTER_STATE variable is not at level 2, the logic will proceed to diamond 624 (shown at Figure 5C).

Diamond 624 inquires whether the MASTER_STATE variable is at level 4. If the MASTER_STATE variable is at level 4, flow proceeds to rectangle 626 that represents the DPF_REGENERATIONSTATE. The sub-routine for the DPF_REGENERATIONSTATE is shown at Figure 5I. If the MASTER_STATE variable is not at level 4, flow proceeds from diamond 624 to diamond 628.

Diamond 628 inquires whether the MASTER_STATE variable is at level 5. If the MASTER_STATE variable is at level 5, flow is directed to rectangle 630 corresponding to the regeneration COOL_DOWN STATE. The sub-routine corresponding to the regeneration COOL_DOWN STATE is shown at Figure 5J. If the MASTER_STATE variable at level 5, flow proceeds to from diamond 628 to diamond 632.

Diamond 632 inquires whether the MASTER_STATE variable is at level 6. If the MASTER_STATE variable is at level 6, flow proceeds to block 634 corresponding to the DPF_RPM-FLOW ONLINE STATE. The sub-routine corresponding to the DPF_RPM-FLOW ONLINE STATE is shown at Figure 5K. If the MASTER_STATE variable is not at MASTER_STATE level 6, flow proceeds from diamond 632 to diamond 636.

Diamond 636 inquires whether the MASTER_STATE variable is at level 3. If the MASTER_STATE variable is at level 3, flow proceeds to rectangle 638 corresponding to the DPF_TEMPERATURE ONLINE STATE. The subroutine corresponding to the DPF_TEMPERATURE ONLINE STATE is shown at Figure 5H. If the MASTER_STATE variable at level 3, flow proceeds to from diamond 636 to diamond 640 on page 5D.

Diamond 640 inquires whether the temperature is greater than T_CATALYSIS. If the temperature is greater than T_CATALYSIS, the MASTER_STATE variable is changed to level 4 as indicated at rectangle 642. Otherwise, the logic will proceed to diamond 644.

Diamond 644 inquires whether the DPF_ON_LINE variable is set to TRUE (i.e., the logic checks whether all flow is being directed through the particulate filter). If the DPF_ON_LINE variable is not set to TRUE, the logic checks whether the exhaust system is in a condition in which it would be suitable or desirable to direct flow through the filter 32. For example, diamond 646 inquires whether the time rate of change of RPM is greater than RPM_ACCEL, diamond 648 inquires whether the time rate of change of flow is greater than FLOW_ACCEL and diamond 650 inquires whether the temperature is greater than the TEMP_LOW. If the answer to the question presented in either diamond 646 or diamond 648 is yes, the MASTER_STATE variable is changed to level 6 as indicated by rectangles 652 and 654. If the answers to the inquiries set forth by diamonds 646 and 648 are no, the logic proceeds to diamond 650. If the answer to the inquiry of diamond 650 is yes, the MASTER_STATE variable is set to level 3 as indicated by rectangle 656. If the answer to the inquiry of diamond 650 is no, flow proceeds to diamond 658 shown on Figure 5E.

Diamond 658 inquires whether a system error has occurred. If a system error has occurred, the MASTER_STATE variable is set to level 7 at box 660 and the SYSTEM FAULT STATE sub-routine of Figure 5L is implemented at box 662. If no system error has occurred, flow proceeds to diamond 664.

Diamond 664 inquires whether the DPF_ON_LINE variable is set to TRUE. If the DPF_ON_LINE variable is set to TRUE, the controller calculates the loading of the DPF as indicated at box 666. Diamond 668 then inquires whether the DPF loading is equal to or greater than loading max (e.g., the loading where the diesel particulate filter can no longer be regenerated using only passive techniques). If the answer to the inquiry of diamond 668 is yes, flow proceeds to box 660 where the MASTER_STATE variable is set to level 7. If the answer to diamond 668 is no, a diesel particulate filter duty cycle is calculated at box 670 and the average mass flow through the diesel particulate filter is calculated at box 672. From box 672, flow proceeds to box 674 where variables such as flow, rpm, back pressure and temperature are updated. From box 674, flow proceeds back to diamond 612 of Figure 5B and the main loop of the routine is repeated.

B. BACKPRESSURE RELIEF

The flow chart of Figures 5A-5L includes a subroutine loop for preventing excessive backpressure in the system. For example, if the backpressure in the system exceeds BP_MAX, diamond 620 (see Figure 5B) of the main loop directs the control logic to rectangle 621 where the MASTER_STATE variable is set to level 2. With the MASTER_STATE variable set to level 2, flow proceeds through diamond 622 to rectangle 623 where the back pressure relief sub-routine of Figure 5F is implemented. Within the backpressure relief subroutine, the DPF_ON_LINE variable is set to FALSE at box 700. Diamond 702 then inquires whether the BP_STATE variable equals 0. If the BP_STATE variable equals 0, the logic proceeds to box 704 where the FLOW_IN variable is set to the real-time exhaust flow value of the exhaust system. Thereafter, a BP_TIMER value is set to a maximum value (e.g., 15 seconds) at rectangle 706. Flow is then opened to both the catalytic converter 34 and the diesel particulate filter 32 at parallelogram 708. The BP_STATE variable is then set to 1 at rectangle 709 and flow proceeds back to the main loop.

In the next cycle through the main loop, since the MASTER_STATE variable remains set at level 2, flow is again directed to the back pressure relief sub-routine of Figure 5F. Since the BP_STATE variable has previously been set to 1, flow proceeds through diamond 702 to diamond 712. From diamond 712, flow proceeds to a count-down leg of the subroutine that includes box 714 where the BNP_TIMER value is incremented down by 1 unit. After the timer value has been incremented down by 1 unit, flow proceeds to diamond 716, which inquires whether the BP_TIMER value equals 0. The logic flow will continue be cycled between the main loop back and the count-down leg of the subroutine until the BP_TIMER value equals 0. When this occurs, the BP_STATE value is set to 2 at rectangle 717. Logic flow then returns to the main loop.

With the BP_STATE value set to 2, the next time through the subroutine the flow proceeds through diamond 712 to diamond 718. Diamond 718 inquires whether the BP_STATE value equals 2. If the answer is yes, flow proceeds to diamond 720. Diamond 720 inquires whether the current exhaust flow through the system is less than or equal to a portion (e.g., 85%) of the FLOW_IN value. If the answer is yes, the BP_STATE value is set to 3 at box 722. By setting the BP_STATE value to 3, the next time through the sub-routine flow will proceed downwardly through diamond 718 to rectangle 724. At rectangle 724, the BP_STATE value is set to 0. Next, at rectangle 726, the MASTER_STATE variable is set to 1 and the sub-routine is complete. If the answer to diamond 720 is no, flow continues to cycle between the subroutine and the main loop.

The timer feature described above provides the system with sufficient time for the operating condition of the system to change before the control logic attempts to reopen the diesel particulate filter. This prevents valves from being opened and closed in rapid succession. Also, if the total flow through the system hasn't dropped during the period set by the timer, it is unlikely that backpressure in the system would have been reduced. Thus, diamond 720 prevents the system from stopping the backpressure relief sub-routine until the system determines that flow through the system has dropped by a predetermined factor.

C. DPF REGENERATION STATE

If the temperature of the exhaust gas is greater than T_CATALYSIS as inquired by box 640 on Figure 5D, rectangle 642 sets the MASTER_STATE variable to level 4. With the MASTER_STATE variable set to level 4, diamond 624 of the main loop (see Figure 5C) causes the regeneration sub-routine to be implemented at rectangle 626. The regeneration sub-routine is shown at Figure 5I. In the regeneration sub-routine, diamond 750 inquires whether the temperature of the exhaust gas is less than T_CATALYSIS_LOW. If the answer is no, the valve to the diesel particulate filter is opened and the valve to the catalytic converter is closed. By opening flow to the filter, the hot exhaust gas traveling through the diesel particulate filter causes combustion of soot on the filter thereby allowing the filter to regenerate. After the diesel particulate filter has been opened and the catalytic converter closed, the BP_STATE variable is set to 0 and the DPF_ON_LINE variable is set to TRUE at box 754.

The DPF_REGENERATIONSTATE continues unless the temperature of the exhaust gas falls below the T_CATALYSIS_LOW value. The low temperature is indicative of a situation in which high oxygen content in the exhaust gas could cause a thermal run away at the filter. When a temperature less than T_CATALYSIS _LOW is detected, the MASTER_STATE variable is set to level 5 and the REG_COOL_STATE value is set to 0 at box 756 of the regeneration subroutine.

With the MASTER_STATE value set to 5, diamond 628 of the main loop (see Figure 5C) will cause the REGENERATION COOL_DOWN sub-routine to be initiated at box 630. The REGENERATION COOL_DOWN subroutine prevents a thermal runaway from occurring by stopping exhaust flow to the particulate filter. The REGENERATION COOL_DOWN subroutine is shown at Figure 5j. At parallelogram 800 of the REGENERATION COOL_DOWN subroutine, flow to the diesel particulate filter is stopped and rerouted to the catalytic converter. At rectangle 802 the DPF_ON_LINE variable is set to FALSE. Flow then proceeds to diamond 804, which inquires if the REG_COOL_STATE is set to 0. Since this value was set to 0 during the DPF_REGENERATION sub-routine of Figure 5I, flow proceeds to rectangles 806 and 807 where the COOLDOWN_TIMER is set to COOL_MAX (e.g., 20 seconds) and the REG_COOL_STATE is set to 1. The sequence then proceeds back through the main loop and returns to the regeneration sub-routine.

Upon return to the regeneration sub-routine of 5J, the logic flows to diamond 808. Diamond 808 asks whether the REG_COOL_STATE equals 1. Since this variable was set to 1 at box 807, flow proceeds to a timer countdown leg of the subroutine that includes box 810 where the COOLDOWN_TIMER value is sequenced down by 1 unit. Diamond 812 then inquires whether the COOLDOWN_TIMER value equals 0. The logic will continue to be cycled between the main loop and the timer countdown leg of the subroutine until the COOLDOWN_TIMER has been sequenced to 0. When the COOLDOWN_TIMER has been sequenced to 0, flow moves to rectangle 814, which sets the REG_COOL_STATE value to 2. With the REG_COOL_STATE variable set to 2, during the next pass through the COOL_DOWN subroutine flow will move through diamond 808 to rectangle 816. At rectangle 816, the REG_COOL_STATE is set to 0 and the MASTER_STATE variable is set to level 1. The regeneration COOL_DOWN state is then complete. Preferably, the timer of the sub-routine is sufficiently long to ensure that combustion at the diesel particulate filter has been extinguished.

D. DPF RPM/FLOW ONLINE STATE

If the system detects a condition indicative of a high rate of soot condition (e.g., rapid acceleration of the engine or a rapid change in the rate of flow through the exhaust system), the MASTER_STATE variable is set to level 6 (see diamonds 646 and 648 and blocks 652 and 654 of Figure 5D). With the system set at MASTER_STATE level 6, diamond 632 of the main loop (see Figure 5C) causes the DPF_RPM/FLOW ONLINE STATE sub-routine of block 634 to be initiated. This sub-routine is shown at Figure 5K. Upon entering the sub-routine, diamond 900 checks to ensure that the high soot generating condition is still present. If the condition is not present, flow is directed to rectangle 902 where the system is reset to MASTER_STATE level 1. If the high soot production condition is present, flow proceeds from diamond 900 to parallelogram 904. At parallelogram 904, the diesel particulate filter is opened and the catalytic converter is closed so that filtration takes place. Also, at block 905, the BP_STATE is set to 0 and the DPF_ON_LINE state is set to TRUE.

It will be appreciated that the DPF_RPM/FLOW ONLINE STATE sub-routine allows for filtration during high soot producing periods even if the temperature of the exhaust gas is relatively low. It will also be appreciated that other sub-routines such as the BACKPRESSURE RELIEF sub-routine, the DPF REGENERATION subroutine and REGENERATION COOL_DOWN subroutine have priority in sequence over the DPF_RPM/FLOW ONLINE sub-routine.

E. DPF TEMPERATURE ONLINE STATE

The DPF_TEMPERATURE ONLINE subroutine is preferably adapted to turn the diesel particulate filter online when the exhaust temperature exceeds

TEMP_LOW. For example, referring to diamond 650 and block 656 of Figure 5D, when the exhaust temperature exceeds TEMP_LOW, the MASTER_STATE variable is set to level 3. With the MASTER_STATE variable set to level 3, diamond 636 on Figure 5C of the main loop causes implementation of the DPF_TEMPERATURE ONLINE subroutine as indicated by block 638. The sub-routine for the DPF_TEMPERATURE ONLINE state is shown at Figure 5H. Diamond 920 within the DPF_TEMPERATURE ONLINE sub-routine inquires whether the temperature is greater than TEMP_LOW. If the temperature is not greater than TEMP_LOW, the MASTER_STATE variable is reset to 1 (see rectangle 922) and the sub-routine is terminated. If the temperature is greater than TEMP_LOW, the diesel particulate filter valve is opened and the catalytic converter valve is closed at parallelogram 924. Also, the BP_STATE variable is set to 0 and the DPF_ONLINE variable is set to true at rectangle 926. Flow then returns to the main loop.

F. SYSTEM FAULT

If a system error is detected at diamond 658 of the main loop (see Figure 5E), the MASTER_STATE variable is set to 7 at box 660. Similarly, if it is detected at diamond 668 that the DPF loading is greater than or equal to LOADING_MAX, the MASTER_STATE variable is also set to 7. Once the MASTER_STATE variable is set to 7, the system fault sub-routine is initiated at block 662. The system fault sub-routine is shown at Figure 5L. Within the sub-routine, diamond 950 inquires whether a controller system fault has occurred. Also, diamond 952 inquires whether DPF loading is greater than or equal to LOADING_MAX. If the answer to either of the questions presented at diamonds 950 and 952 is yes, the sub-routine proceeds to parallelogram 954 where the diesel particulate filter valve is closed and the catalytic converter valve is opened. Thereafter, a fault light is turned on at parallelogram 956 and an error code is transmitted at parallelogram 958. The system is then disabled.

If the answers to the inquiries presented at diamonds 950 and 952 are no, the MASTER_STATE variable is reset to 1 at rectangle 960 and the routine returns to the main loop.

VII. Packaging Arrangement

Figures 6A and 6B show a packaging arrangement 100 for packaging the system 20 of Figure 1. The arrangement 100 includes an oval muffler body 102 (i.e., a muffler shell) having an inlet 104 and an outlet 106. While not shown, the inlet 104 can include structures for attenuating sound and for distributing flow. Valves 36 and 38 are mounted adjacent the inlet end of the muffler body 102. An oval valve plate 108 is mounted within the muffler body 102. The valve plate 108 defines openings 109 and 110 that are respectively opened and closed by the valves 36 and 38. The perimeter of the plate 108 is preferably welded to the muffler body 102 with a continuous connection (e.g., a continuous weld bead) so as to form an airtight seal. Oval mounting plates 112 are mounted within the muffler body 112 downstream from the valve plate 108. The mounting plates 112 define openings 113 and 114 in which the diesel particulate filter 32 and the catalytic converter 34 are respectively mounted. The diesel particulate filter 32 includes an outer casing 116 that extends toward the inlet end of the muffler body 102 and is welded to the valve plate 108. The first flow path 24 extends through the casing 116 and the second flow path 24 is defined by the region of the muffler body 102 located outside of the casing 116. The mounting plates 112 preferably seal the muffler body 102 such that flow cannot exit the muffler body 102 without passing through either the catalytic converter 34 or the particulate filter 32.

Figure 6C shows a packaging arrangement 100' that is the same as the packing arrangement of Figures 6A and 6B except that the arrangement has a side inlet 104' and a side outlet 106'. As shown the inlet 104' and the outlet 106 are offset 180 degrees relative to one another. It will be appreciated that the inlet and the outlet can be offset at any number of different angles relative to one another to correspond to different exhaust system configurations. In other embodiments the system, the system could include an axial inlet and a side outlet or a side inlet and an axial outlet.

It will be appreciated that other components of the system (e.g., pressure and temperature sensors and the heating element) can also be incorporated within the muffler body 102. It will further be appreciated that structures for reducing nitrogen oxide emissions can also be incorporated into the muffler body.

VIII. Multi-Filter Embodiment and Corresponding Packaging Arrangement

Figures 7 shows another system 400 constructed in accordance with the principles of the present invention. The system 400 has the same configuration as the system of Figure 1 except an additional flow path 80 parallel with flow paths 24 and 26. Flow path 80 includes an additional diesel particulate filter 32, a heater 42, a pressure sensor 46 and a valve 36. Based on the operating condition of the system, the controller 40 can route flow to the different flow paths 24, 26 and 80. For example, if the filter 32 of the first flow path 24 is plugged, flow can be re-routed through path 80 until the plugged filter 32 of flow path 24 regenerates.

Figures 8A and 8B show a packaging arrangement 500 for packaging the system 400 of Figure 7. The system 500 has the same configuration as the system of Figures 6A and 6B except for the addition of the third flow path 80 within muffler body 502. The system 500 includes two mounting plates 512 each having 3 separate openings for respectively mounting the two filters 32 and the converter 34. The system also includes a valve plate 508 having openings corresponding to the two valves 36 and the valve 38. Also, the arrangement includes a side inlet 504 and an axial outlet 506. The flow paths 24 and 26 are isolated from each other and the flow path 80 by extending the casings 116 of the filters 32 to the valve plate 508.

Figure 8C shows a packaging arrangement 500' that is the same as the packing arrangement of Figures 8A and 8B except that the arrangement has a side outlet 506'.

It will be appreciated that the embodiments described herein are merely exemplary. For example, the various constant values provided herein are for illustration purposes only, and may vary from system to system and catalyst to catalyst. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

WHAT IS CLAIMED IS:

1. An exhaust treatment system for treating exhaust gas, the system comprising:

a first flow path including a particulate filter;

a second flow path including a catalytic converter;

a valve arrangement for controlling flow to the first and second flow paths; and

a controller that interfaces with the valve arrangement to modify flow between the first and second flow paths in response to changes in the operating conditions of the system.

2. The system of claim 1, wherein the controller proportions flow between the first and second flow paths.

3. The system of claim 1, wherein the controller opens and closes flow to the first and second flow paths.

4. The system of claim 1, wherein the controller directs flow to the second flow path when a backpressure of the system exceeds a predetermined value.

5. The system of claim 1, wherein the particulate filter has a particulate mass reduction efficiency greater than 80 percent.

6. The system of claim 5, wherein the catalytic converter has a particulate mass reduction efficiency less than 50 percent.

7. The system of claim 1, wherein the catalytic converter and the particulate filter are mounted in a single housing.

8. The system of claim 7, wherein the single housing comprises a muffler shell.

9. The system of claim 1, further comprising a structure positioned along at least one of the first and second flow paths for reducing nitrogen oxide emissions.

10. The system of claim 1, further comprising a temperature sensor for measuring exhaust temperature that interfaces with the controller, wherein the controller directs flow to the second flow path when the temperature of the exhaust gas is less than a predetermined temperature, and wherein the controller directs flow to the first flow path when the temperature of the exhaust gas exceeds the predetermined temperature.

11. The system of claim 10, wherein the exhaust gas is generated by a diesel engine, wherein the controller monitors an operating condition of the engine to detect a condition indicative of high soot production, and wherein the controller directs flow to the first flow path when a condition indicative of high soot production is detected even if the temperature is less than the predetermined temperature.

12. The system of claim 1, wherein the exhaust gas is generated by a diesel engine, wherein the controller monitors an operating condition of the engine to detect a condition indicative of high soot production, and wherein the controller directs flow to the first flow path when a condition indicative of high soot production is detected.

13. The system of claim 3, further comprising a heating device for regenerating the particulate filter.

14. The system of claim 13, wherein the heating device includes an electric heating element.

15. The system of claim 13, wherein the heating device includes a diesel fuel burner.

16. The system of claims 1, wherein the controller directs flow to the first flow path when a temperature of the exhaust gas exceeds a predetermined level to promote passive regeneration of the particulate filter.

17. The system of claim 13 or 16, wherein the controller suppresses regeneration of the particulate filter if a condition indicative of a detrimental regeneration is detected.

18. The system of claim 17, wherein the controller suppresses detrimental regeneration of the particulate filter by closing flow to the first flow path.

19. An exhaust treatment system for treating exhaust gas, the system comprising:

a first flow path including a particulate filter; and

a second flow path including a catalytic converter, the second flow path and the first flow path being arranged in parallel relative to one another.

20. The exhaust treatment system of claim 19, further comprising a muffler shell in which both the catalytic converter and the particulate filter are mounted.

21. A method for treating exhaust gas using a system including a catalytic converter and a particulate filter, the method comprising;

modifying flow provided to the catalytic converter and the particulate filter in response to operating conditions of the system.

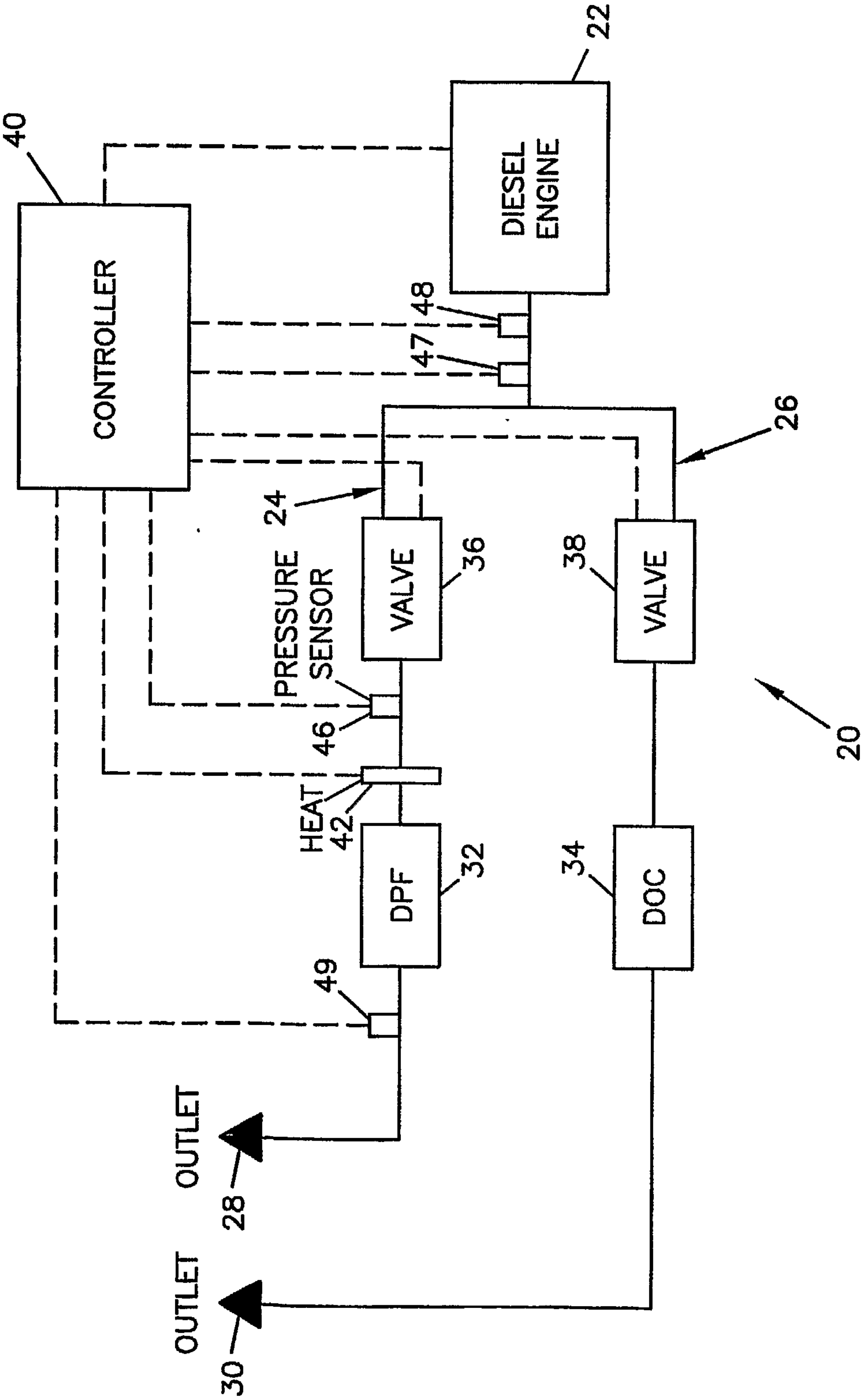

CONTROLLER
40
DIESEL
ENGINE
22
48
47
26
24
VALVE
36
VALVE
38
PRESSURE
SENSOR
46
HEAT
42
DPF
32
DOC
34
49
20
OUTLET
28
OUTLET
30

FIG.1

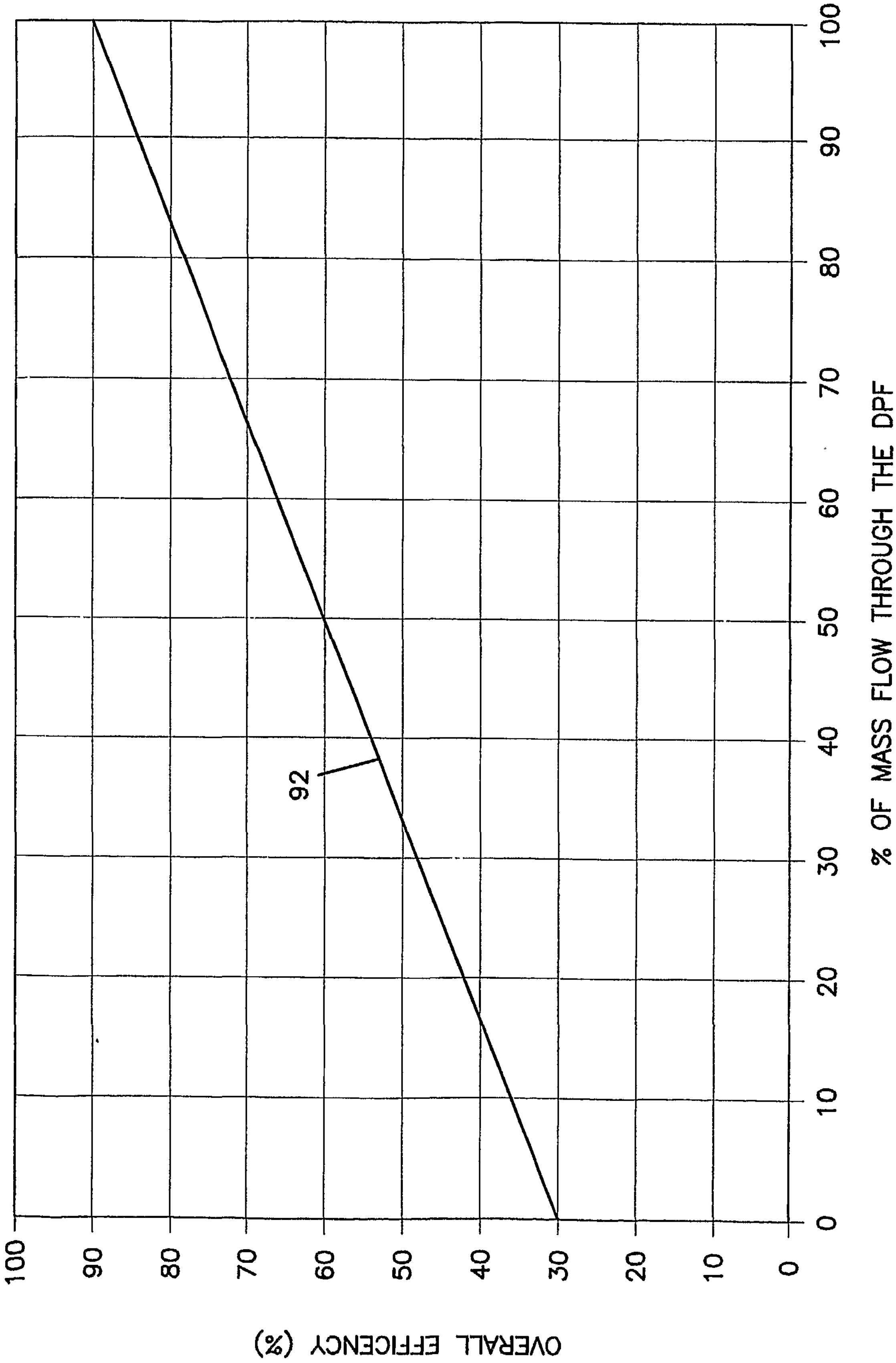

% OF MASS FLOW THROUGH THE DPF
OVERALL EFFICENCY (%)
0
10
20
30
40
50
60
70
80
90
100
92

FIG.2

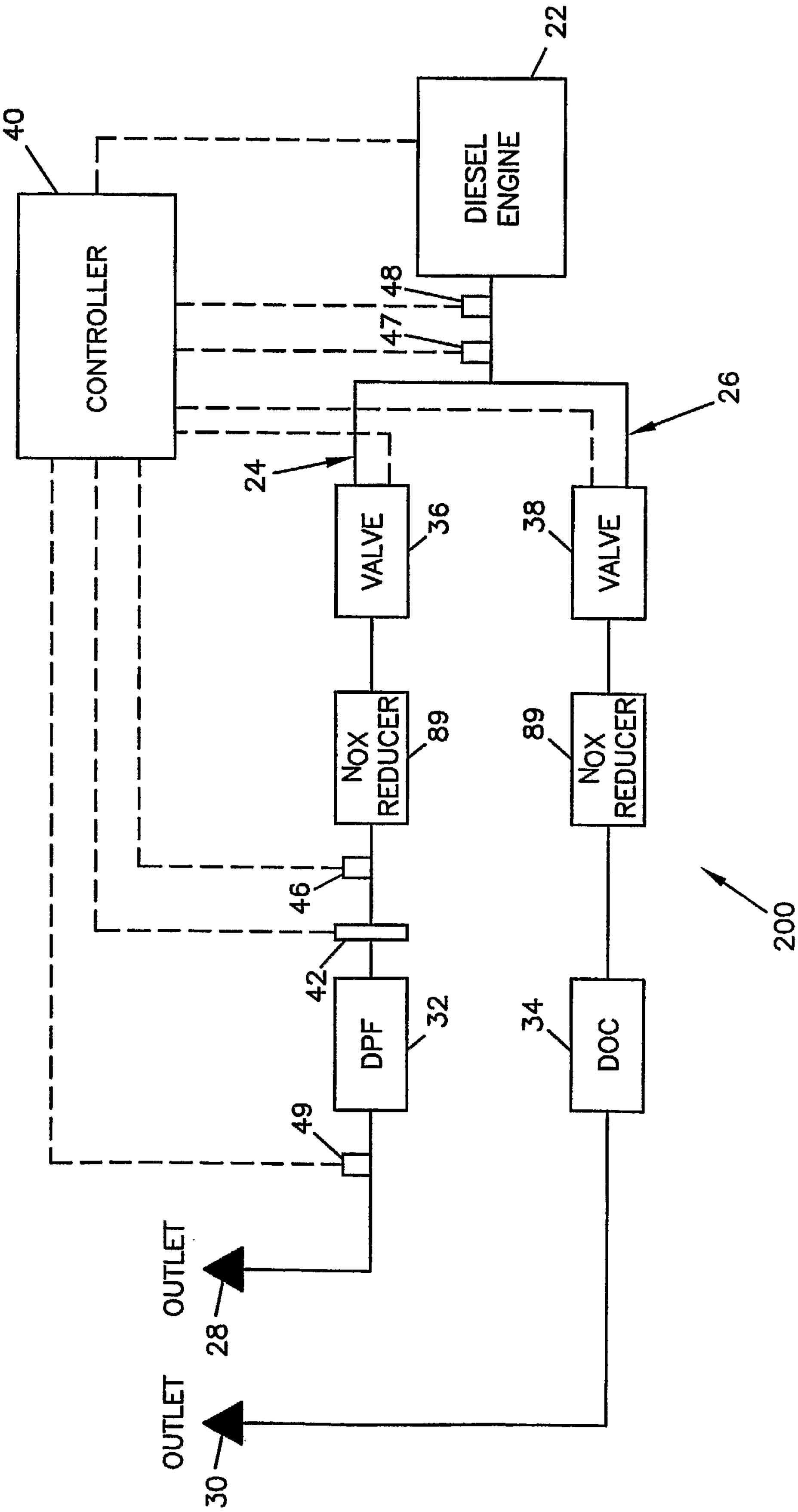

CONTROLLER
40
DIESEL ENGINE
22
48
47
26
24
VALVE
36
38
VALVE
NOX REDUCER
89
89
NOX REDUCER
46
42
DPF
32
34
DOC
49
200
OUTLET
28
OUTLET
30

FIG.3

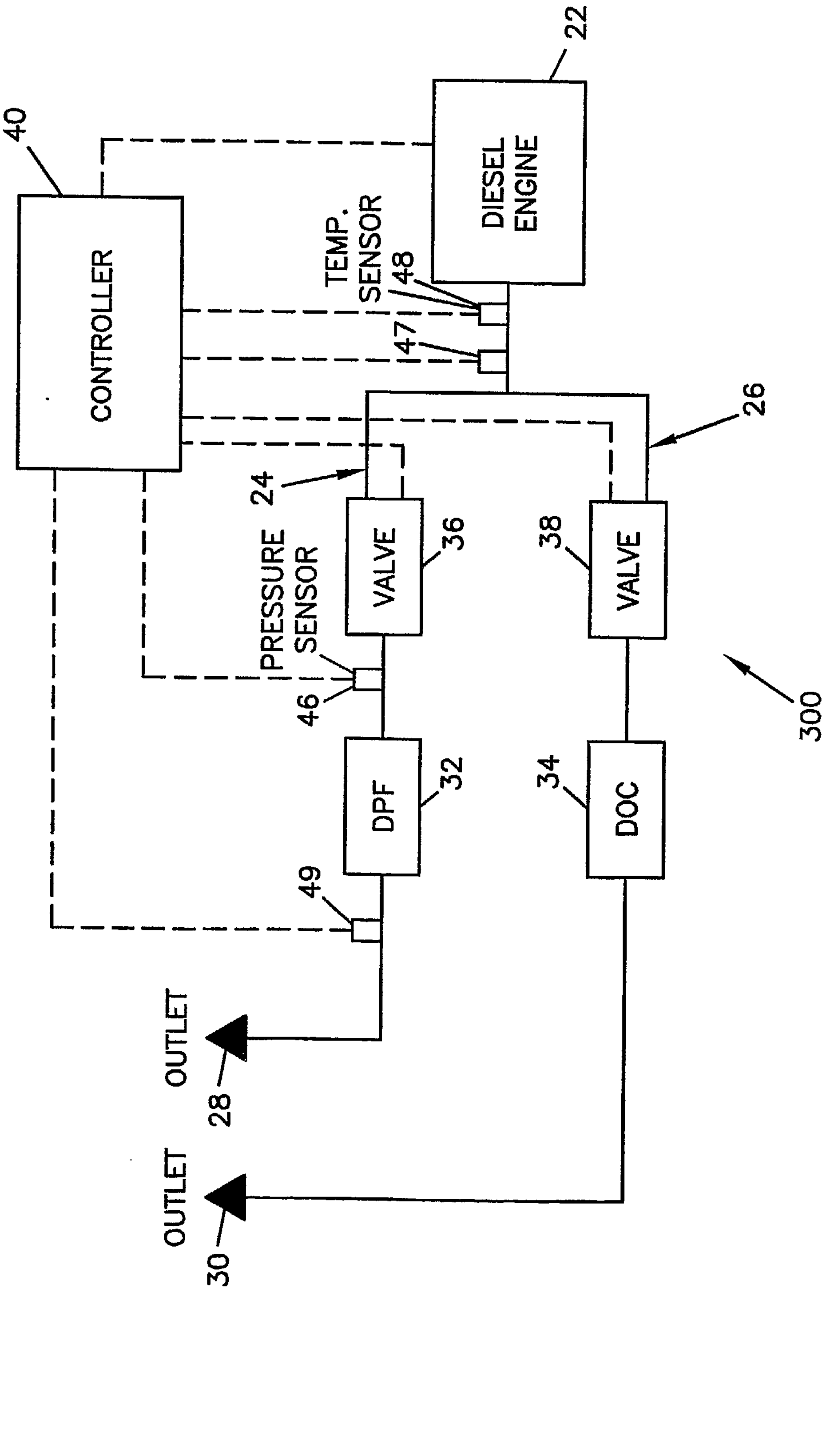

22
DIESEL ENGINE
40
CONTROLLER
TEMP. SENSOR
48
47
26
24
VALVE
36
VALVE
38
PRESSURE SENSOR
46
DPF
32
DOC
34
300
49
OUTLET
28
OUTLET
30

FIG.4

FIG.5A

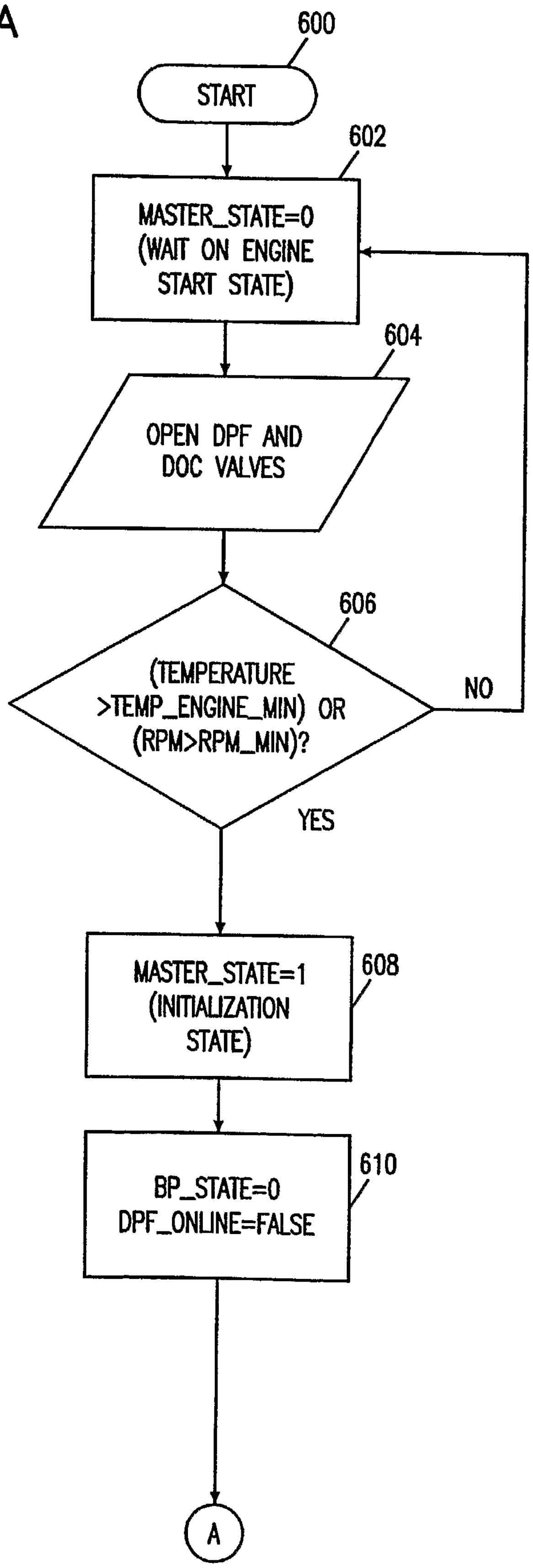

600
START
602
MASTER_STATE=0
(WAIT ON ENGINE
START STATE)
604
OPEN DPF AND
DOC VALVES
606
(TEMPERATURE
>TEMP_ENGINE_MIN) OR
(RPM>RPM_MIN)?
NO
YES
MASTER_STATE=1
(INITIALIZATION
STATE)
608
BP_STATE=0
DPF_ONLINE=FALSE
610
A

FIG.5B

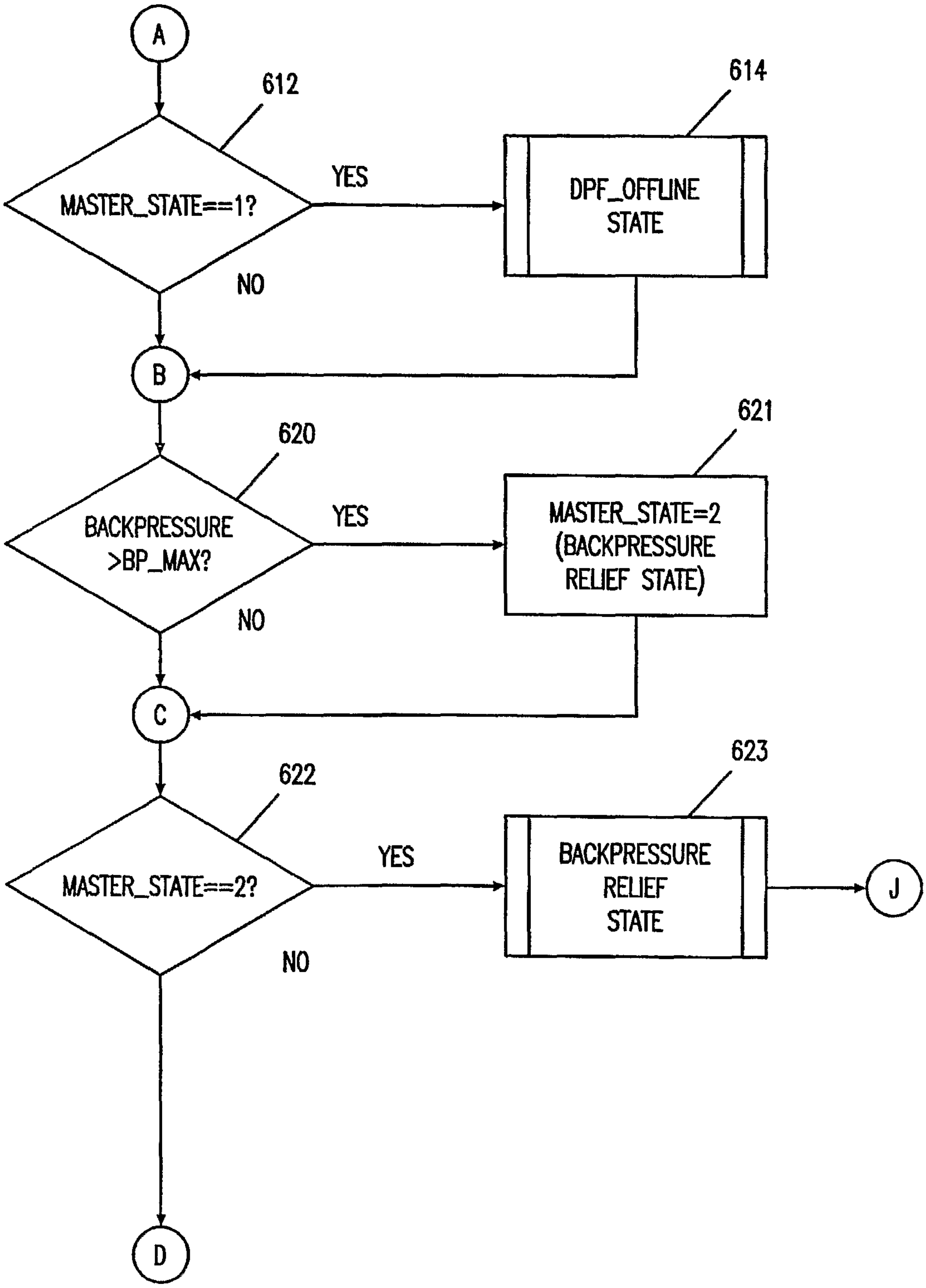

A
612
MASTER_STATE==1?
YES
614
DPF_OFFLINE STATE
NO
B
620
BACKPRESSURE >BP_MAX?
YES
621
MASTER_STATE=2 (BACKPRESSURE RELIEF STATE)
NO
C
622
MASTER_STATE==2?
YES
623
BACKPRESSURE RELIEF STATE
J
NO
D

FIG.5C

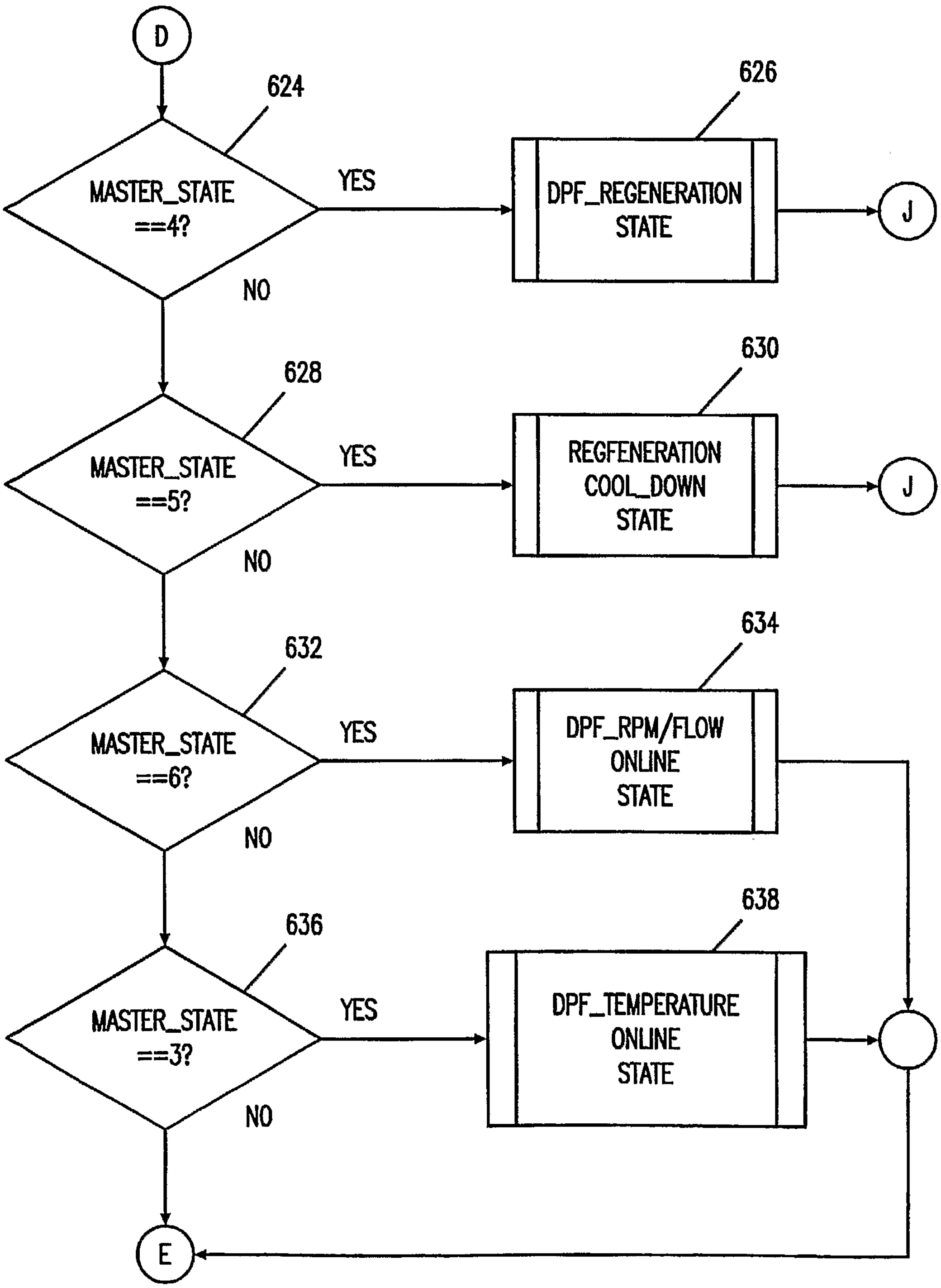

D
624
MASTER_STATE
==4?
YES
NO
626
DPF_REGENERATION
STATE
J
628
MASTER_STATE
==5?
YES
NO
630
REGFENERATION
COOL_DOWN
STATE
J
632
MASTER_STATE
==6?
YES
NO
634
DPF_RPM/FLOW
ONLINE
STATE
636
MASTER_STATE
==3?
YES
NO
638
DPF_TEMPERATURE
ONLINE
STATE
E

FIG.5D

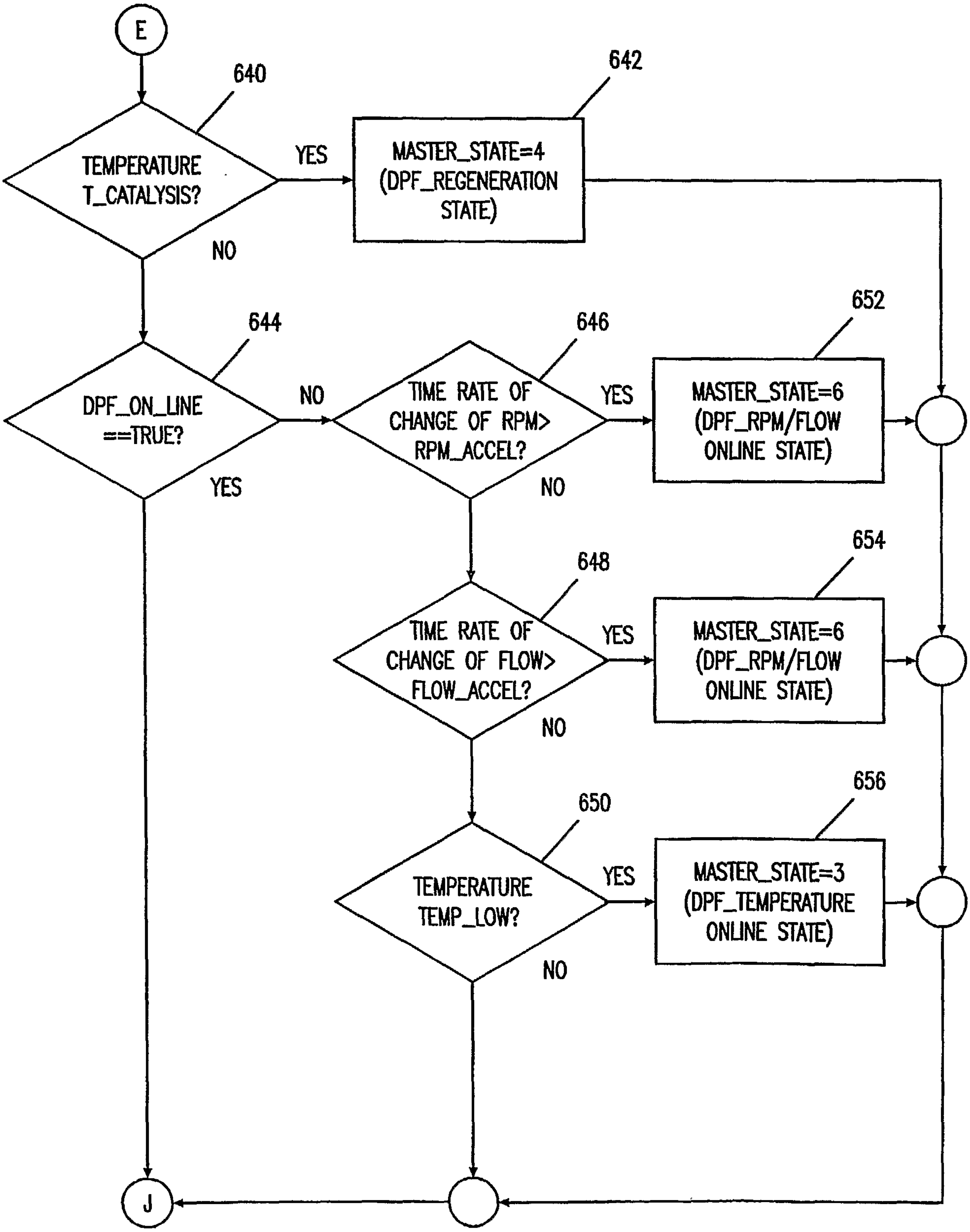

E
640
TEMPERATURE
T_CATALYSIS?
YES
NO
642
MASTER_STATE=4
(DPF_REGENERATION
STATE)
644
DPF_ON_LINE
==TRUE?
NO
YES
646
TIME RATE OF
CHANGE OF RPM>
RPM_ACCEL?
YES
NO
652
MASTER_STATE=6
(DPF_RPM/FLOW
ONLINE STATE)
648
TIME RATE OF
CHANGE OF FLOW>
FLOW_ACCEL?
YES
NO
654
MASTER_STATE=6
(DPF_RPM/FLOW
ONLINE STATE)
650
TEMPERATURE
TEMP_LOW?
YES
NO
656
MASTER_STATE=3
(DPF_TEMPERATURE
ONLINE STATE)
J

FIG.5E

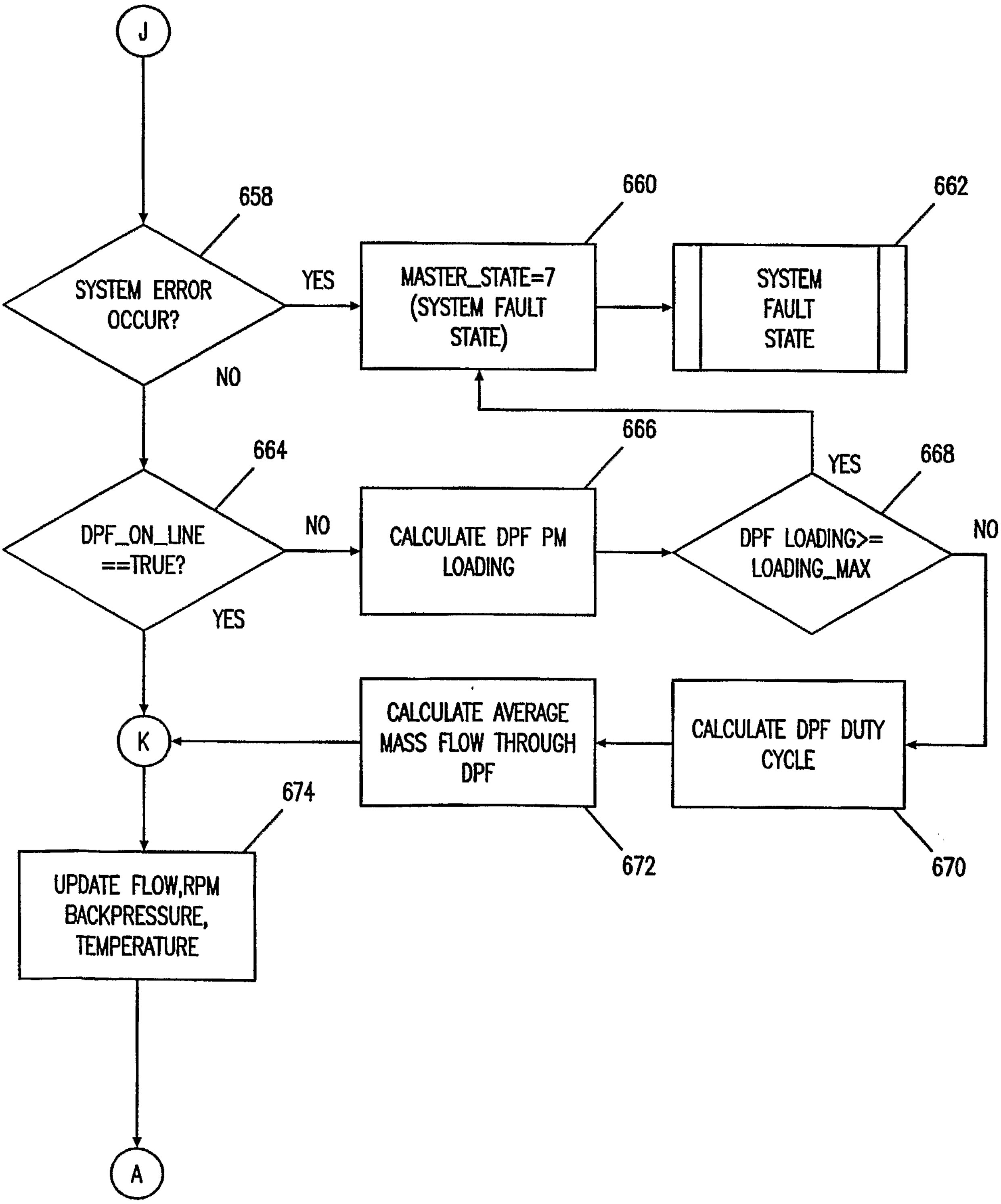

J
SYSTEM ERROR OCCUR?
658
YES
NO
MASTER_STATE=7 (SYSTEM FAULT STATE)
660
SYSTEM FAULT STATE
662
DPF_ON_LINE ==TRUE?
664
NO
YES
CALCULATE DPF PM LOADING
666
DPF LOADING>= LOADING_MAX
668
YES
NO
CALCULATE DPF DUTY CYCLE
670
CALCULATE AVERAGE MASS FLOW THROUGH DPF
672
K
UPDATE FLOW,RPM BACKPRESSURE, TEMPERATURE
674
A

FIG.5F

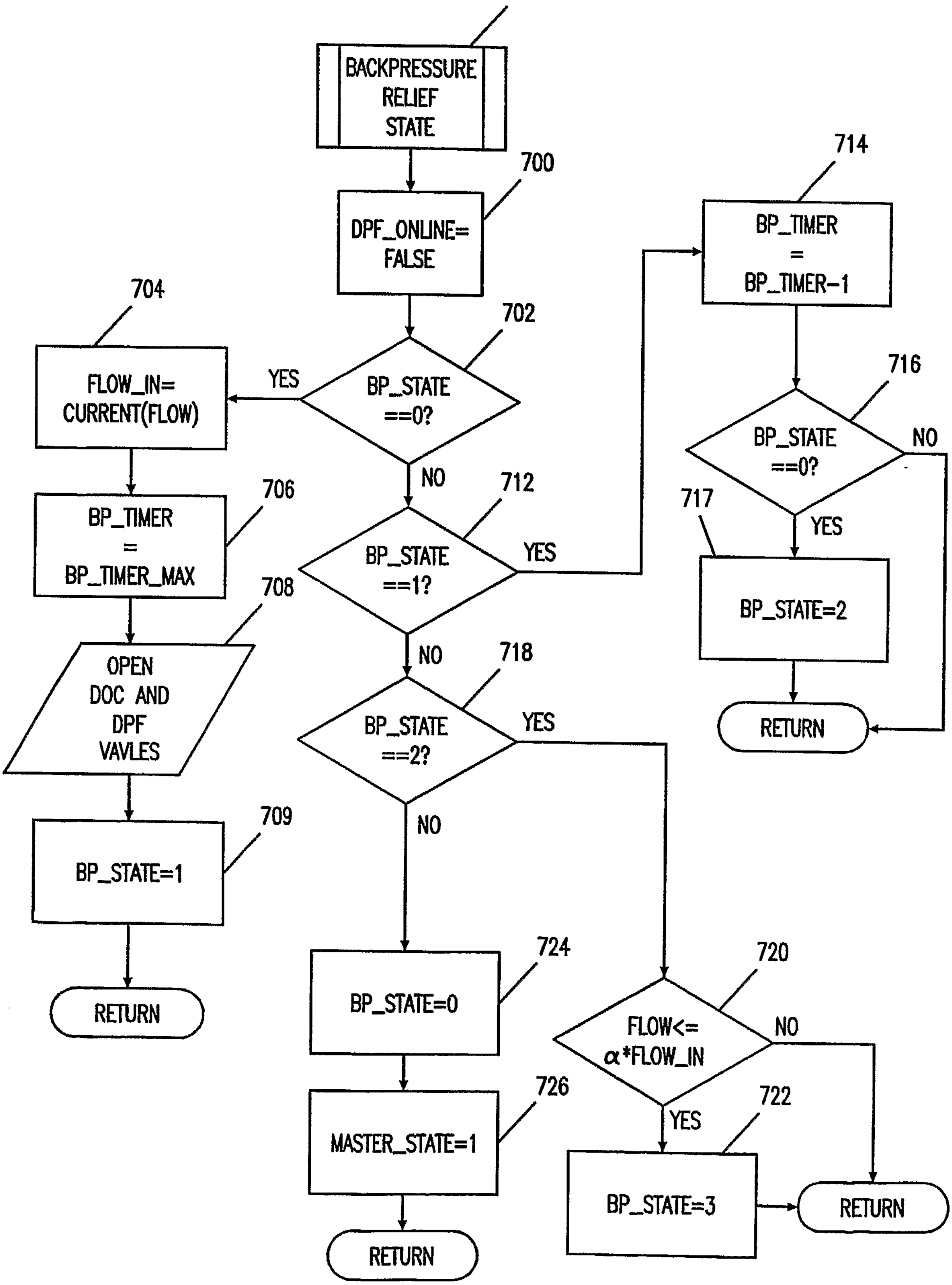

623
BACKPRESSURE RELIEF STATE
700
DPF_ONLINE= FALSE
702
BP_STATE ==0?
YES
704
FLOW_IN= CURRENT(FLOW)
706
BP_TIMER = BP_TIMER_MAX
708
OPEN DOC AND DPF VAVLES
709
BP_STATE=1
RETURN
NO
712
BP_STATE ==1?
YES
714
BP_TIMER = BP_TIMER-1
716
BP_STATE ==0?
NO
717
YES
BP_STATE=2
RETURN
NO
718
BP_STATE ==2?
YES
NO
724
BP_STATE=0
726
MASTER_STATE=1
RETURN
720
FLOW<= α*FLOW_IN
NO
YES
722
BP_STATE=3
RETURN

FIG.5G

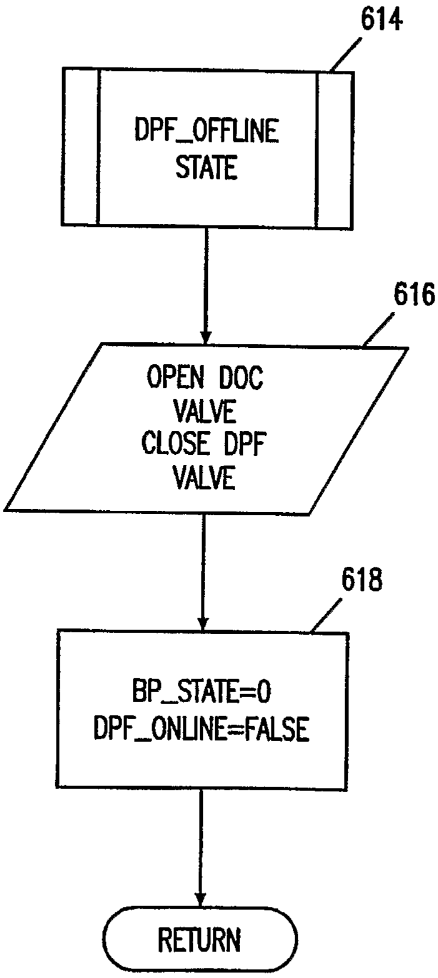

614
DPF_OFFLINE STATE
616
OPEN DOC VALVE
CLOSE DPF VALVE
618
BP_STATE=0
DPF_ONLINE=FALSE
RETURN

FIG.5H

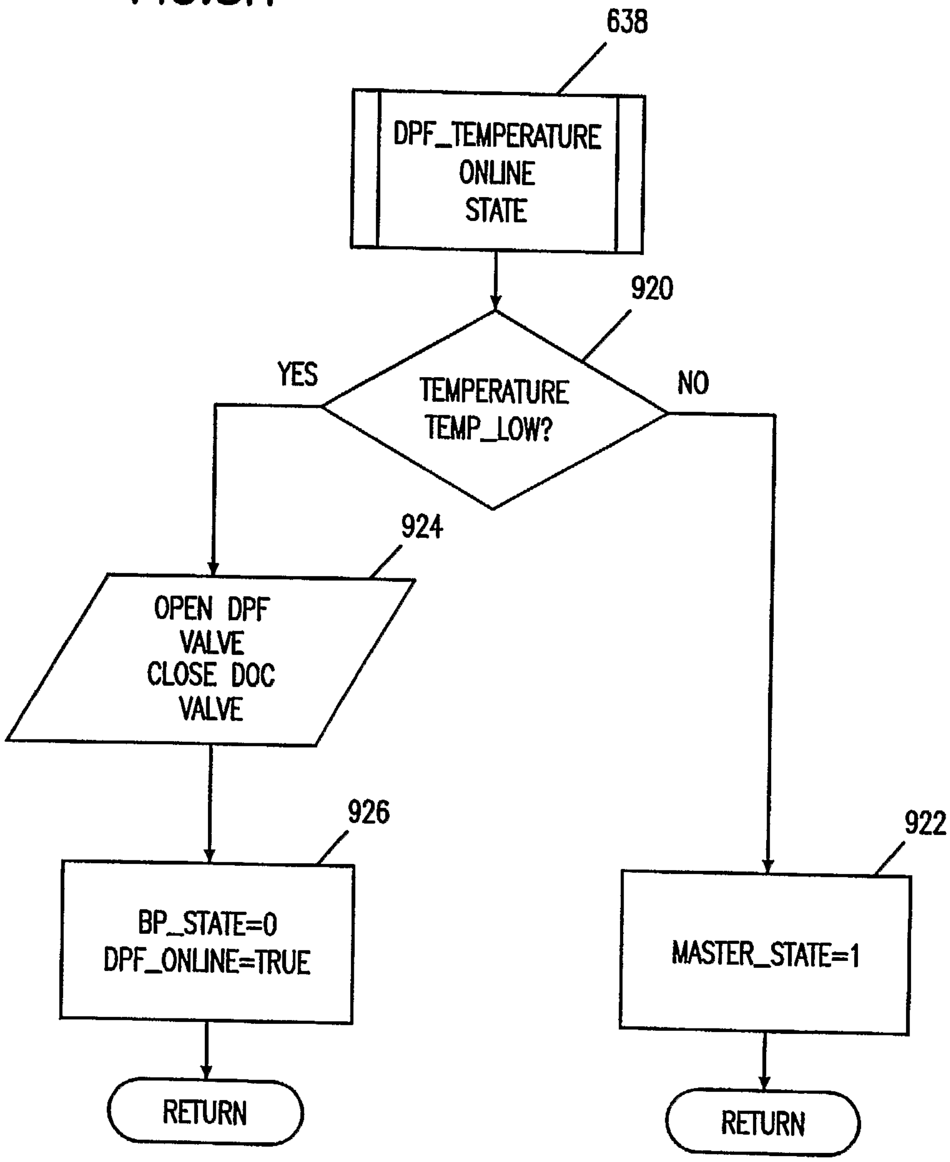

638
DPF_TEMPERATURE
ONLINE
STATE
920
YES
TEMPERATURE
TEMP_LOW?
NO
924
OPEN DPF
VALVE
CLOSE DOC
VALVE
926
BP_STATE=0
DPF_ONLINE=TRUE
RETURN
922
MASTER_STATE=1
RETURN

FIG.5I

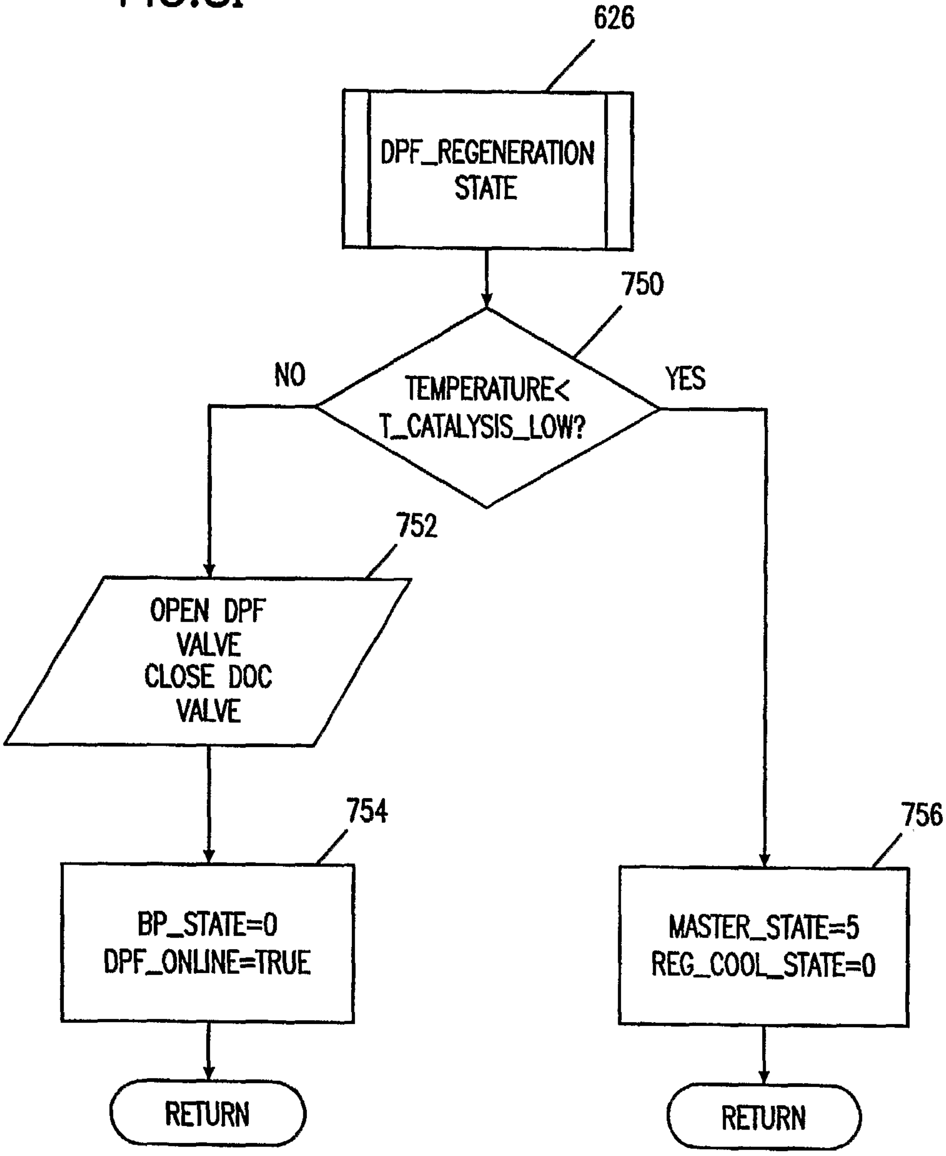

626
DPF_REGENERATION STATE
750
TEMPERATURE<
T_CATALYSIS_LOW?
NO
YES
752
OPEN DPF
VALVE
CLOSE DOC
VALVE
754
BP_STATE=0
DPF_ONLINE=TRUE
RETURN
756
MASTER_STATE=5
REG_COOL_STATE=0
RETURN

FIG.5J

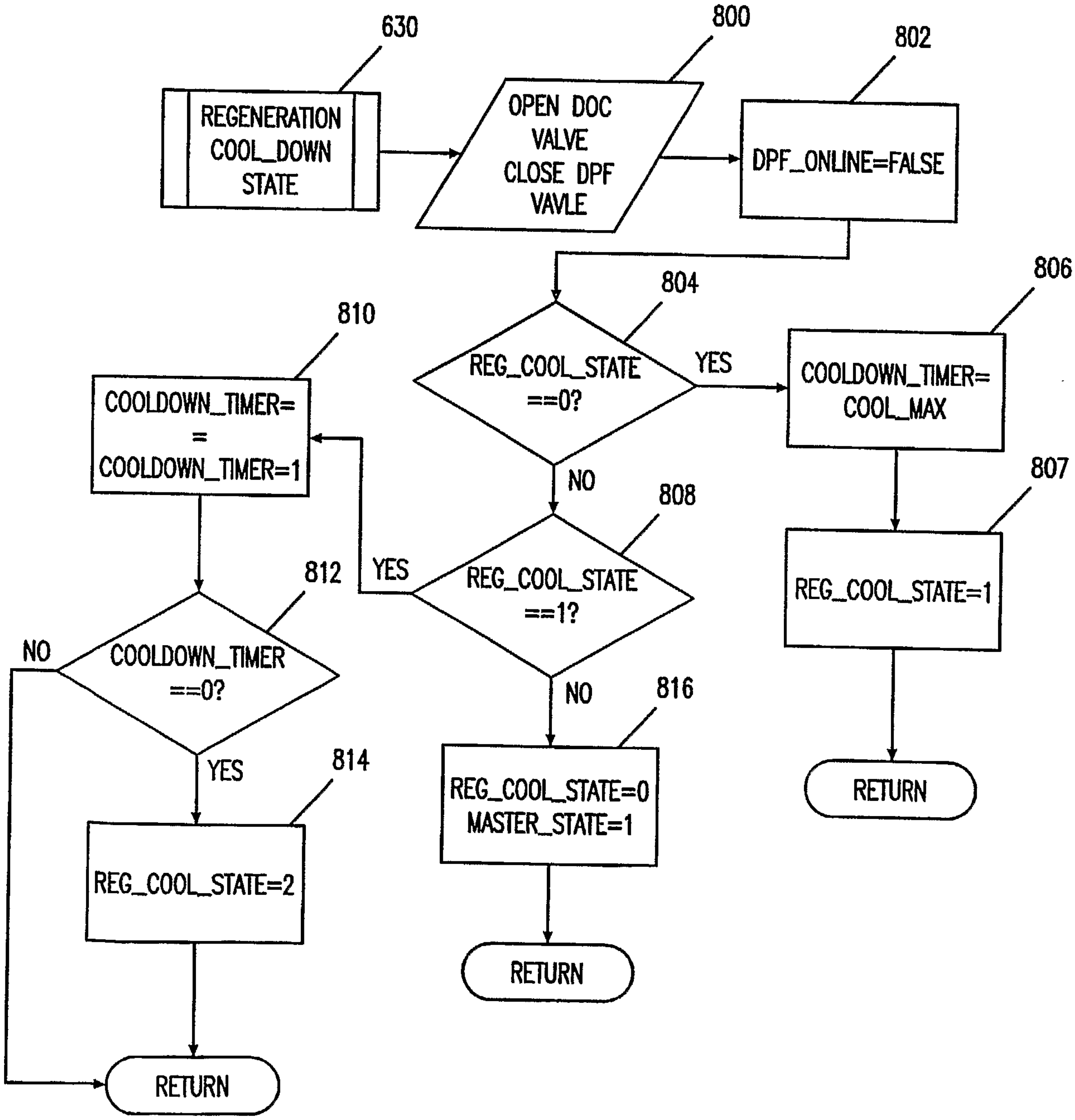

630
REGENERATION COOL_DOWN STATE
800
OPEN DOC VALVE CLOSE DPF VAVLE
802
DPF_ONLINE=FALSE
804
REG_COOL_STATE ==0?
YES
806
COOLDOWN_TIMER= COOL_MAX
807
REG_COOL_STATE=1
RETURN
NO
808
REG_COOL_STATE ==1?
YES
810
COOLDOWN_TIMER= = COOLDOWN_TIMER=1
812
COOLDOWN_TIMER ==0?
NO
YES
814
REG_COOL_STATE=2
RETURN
NO
816
REG_COOL_STATE=0 MASTER_STATE=1
RETURN

FIG.5K

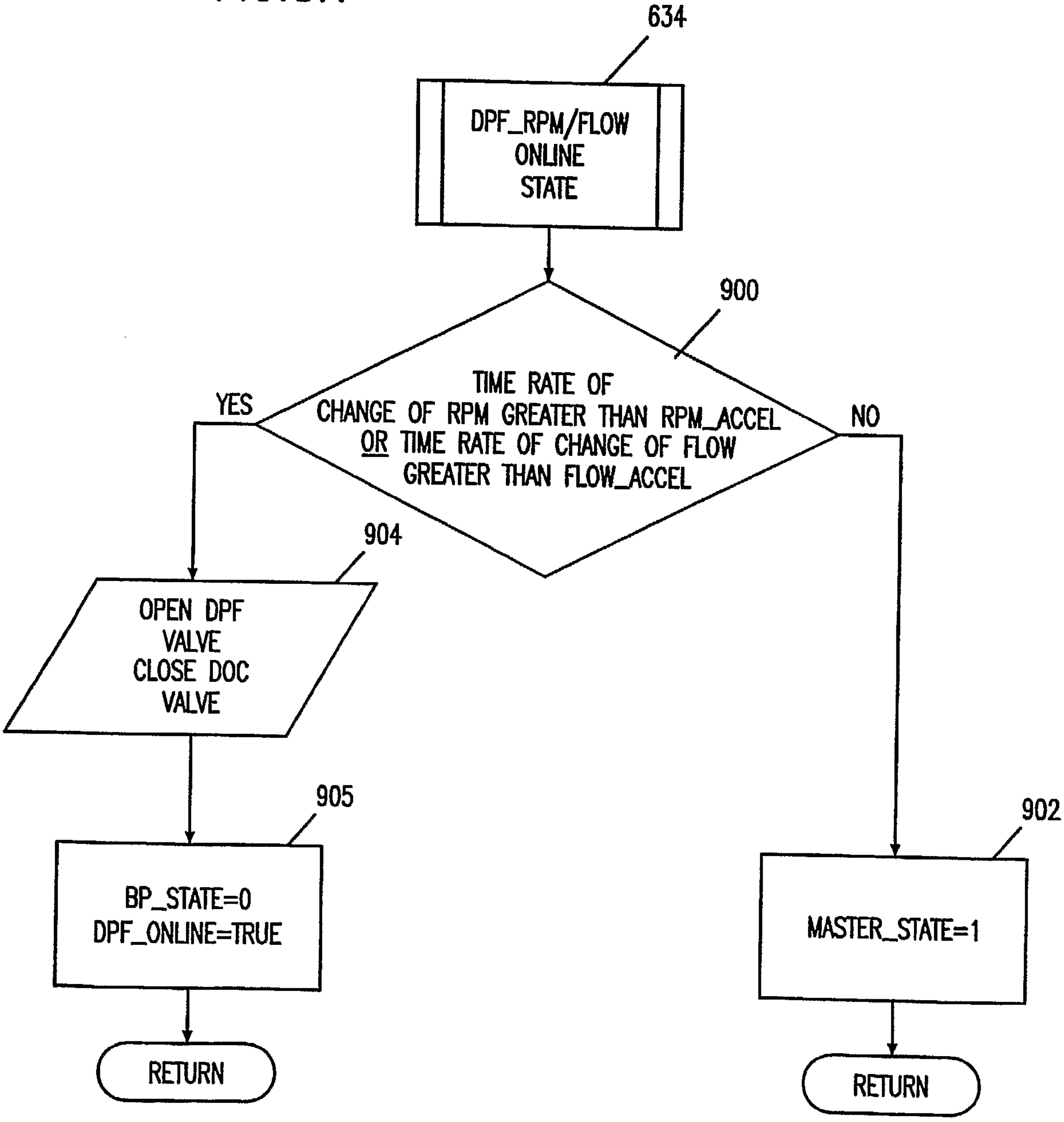
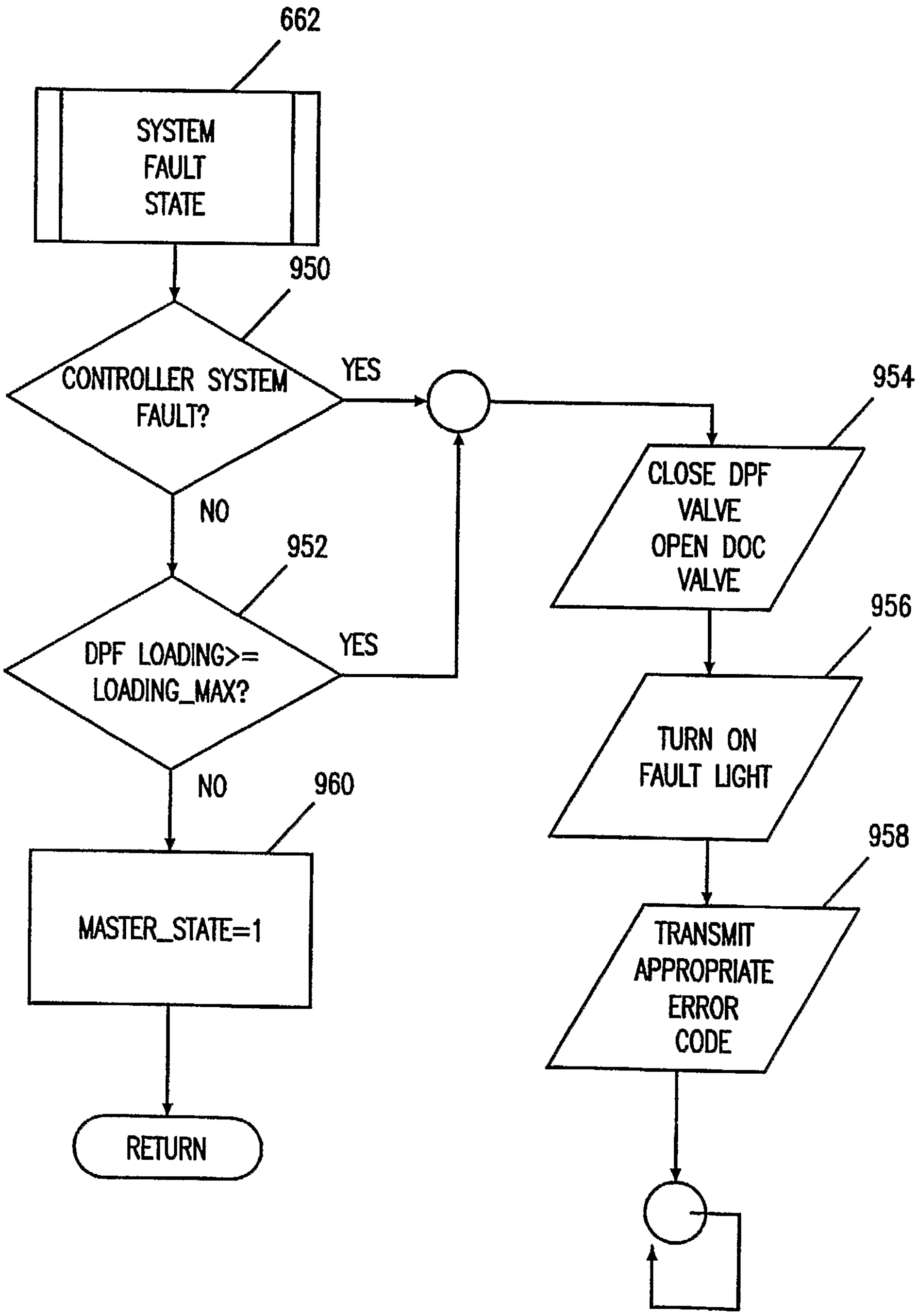

634
DPF_RPM/FLOW
ONLINE
STATE
900
TIME RATE OF
CHANGE OF RPM GREATER THAN RPM_ACCEL
OR TIME RATE OF CHANGE OF FLOW
GREATER THAN FLOW_ACCEL
YES
NO
904
OPEN DPF
VALVE
CLOSE DOC
VALVE
905
BP_STATE=0
DPF_ONLINE=TRUE
RETURN
902
MASTER_STATE=1
RETURN

FIG.5L


662
SYSTEM FAULT STATE
950
CONTROLLER SYSTEM FAULT?
YES
NO
952
DPF LOADING>= LOADING_MAX?
YES
NO
960
MASTER_STATE=1
RETURN
954
CLOSE DPF VALVE OPEN DOC VALVE
956
TURN ON FAULT LIGHT
958
TRANSMIT APPROPRIATE ERROR CODE

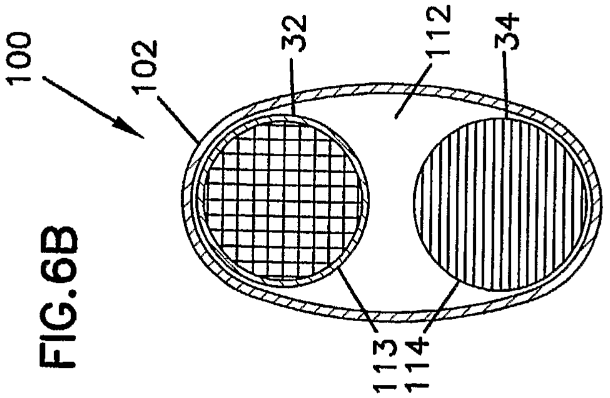

100
102
32
112
34
113
114

FIG.6B

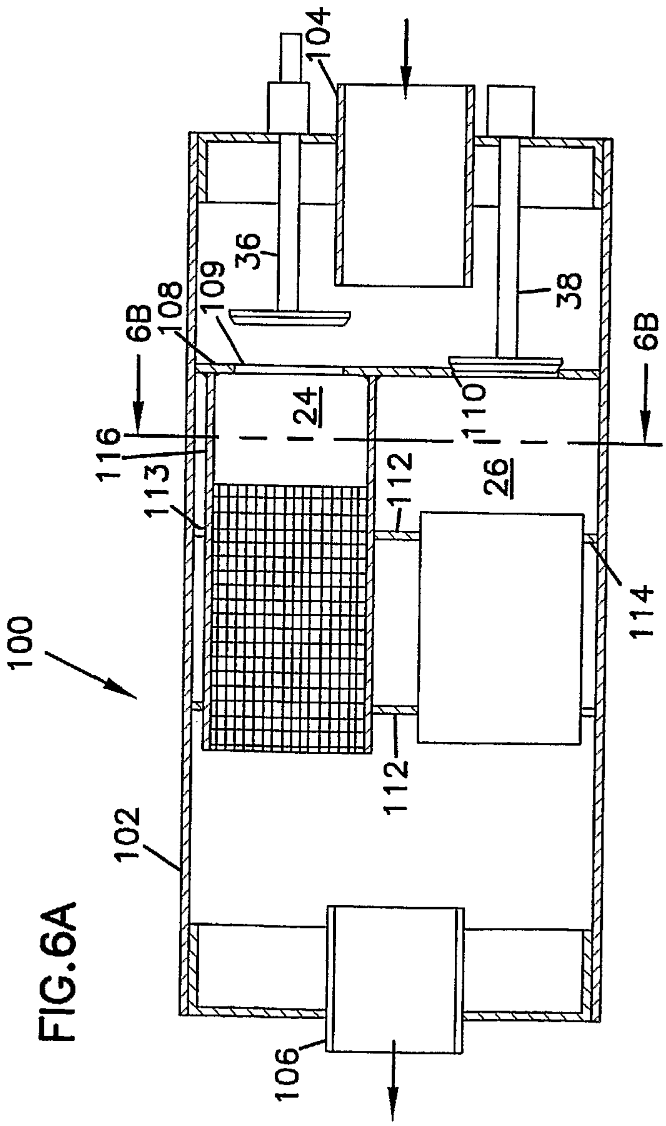

104
36
38
109
108
6B
6B
24
110
116
113
112
26
114
100
112
102
106

FIG.6A

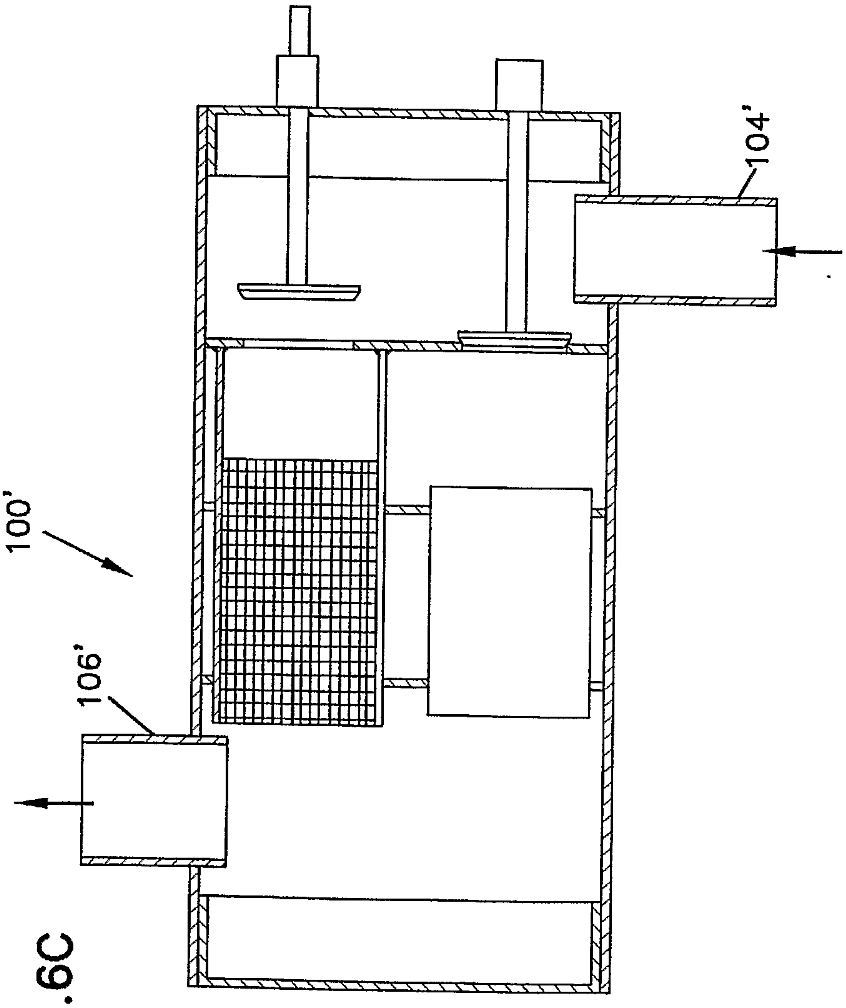


FIG.6C

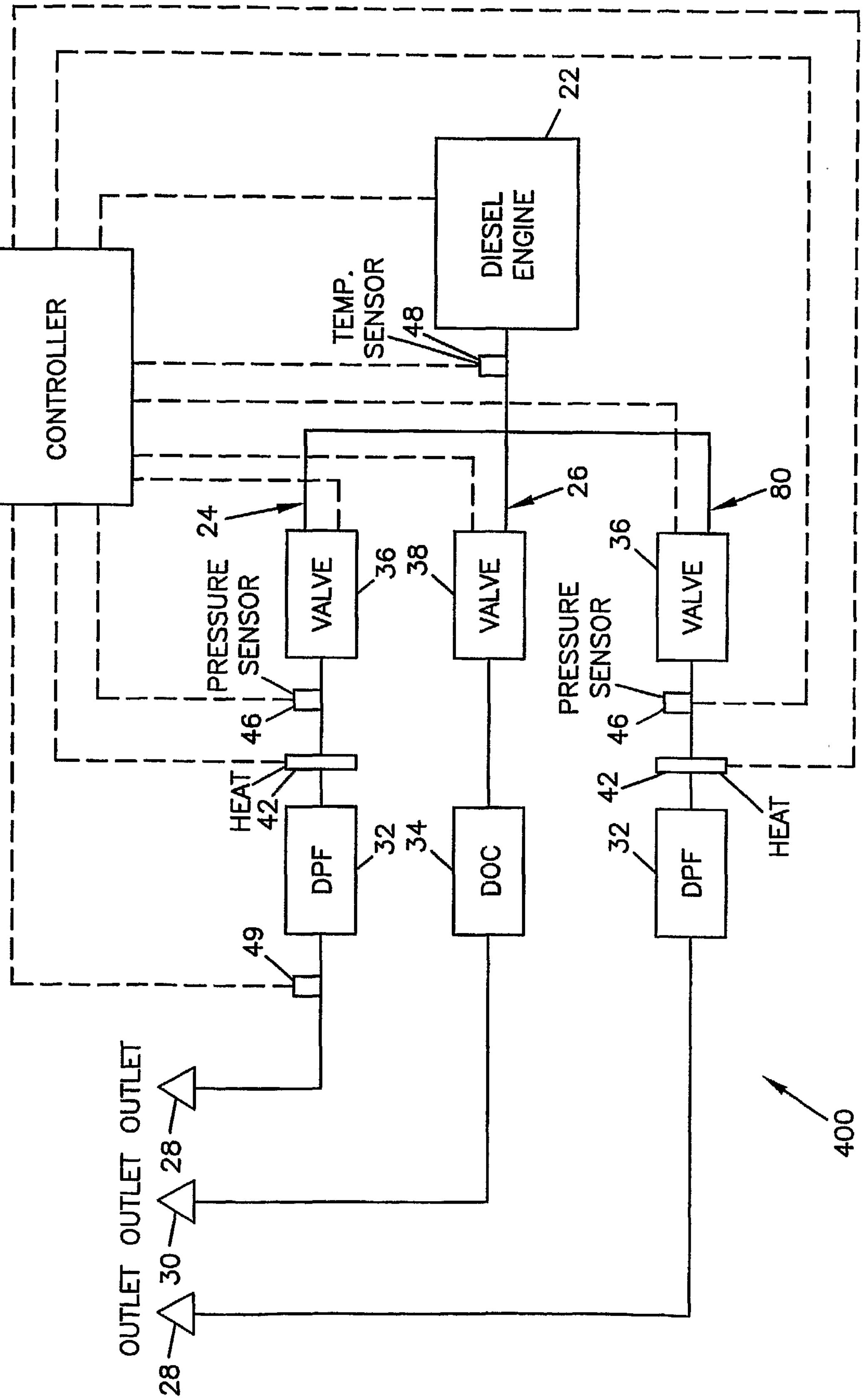
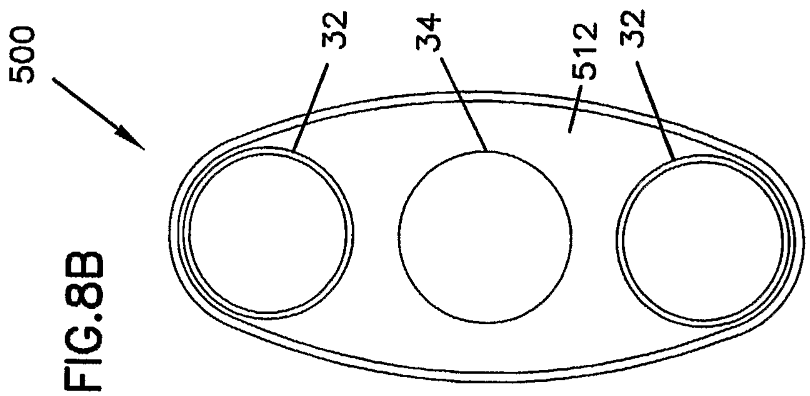

CONTROLLER
40
DIESEL ENGINE
22
TEMP. SENSOR
48
26
80
24
VALVE
36
38
VALVE
36
PRESSURE SENSOR
46
HEAT
42
DPF
32
DOC
34
49
OUTLET
28
30
400

FIG.7


500
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34
512
32

FIG.8B

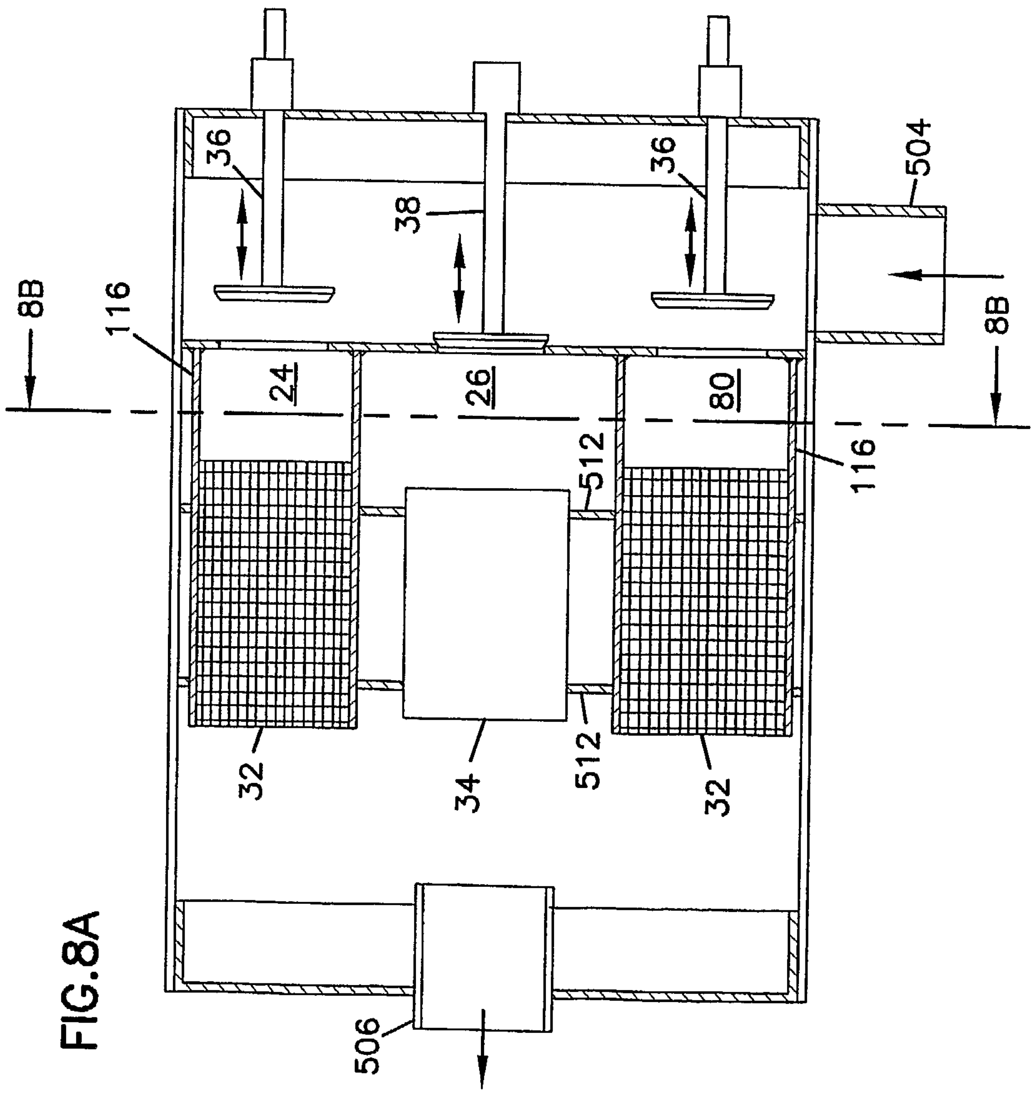
36
38
36
504
8B
116
24
26
80
8B
512
116
32
34
512
32
506

FIG.8A

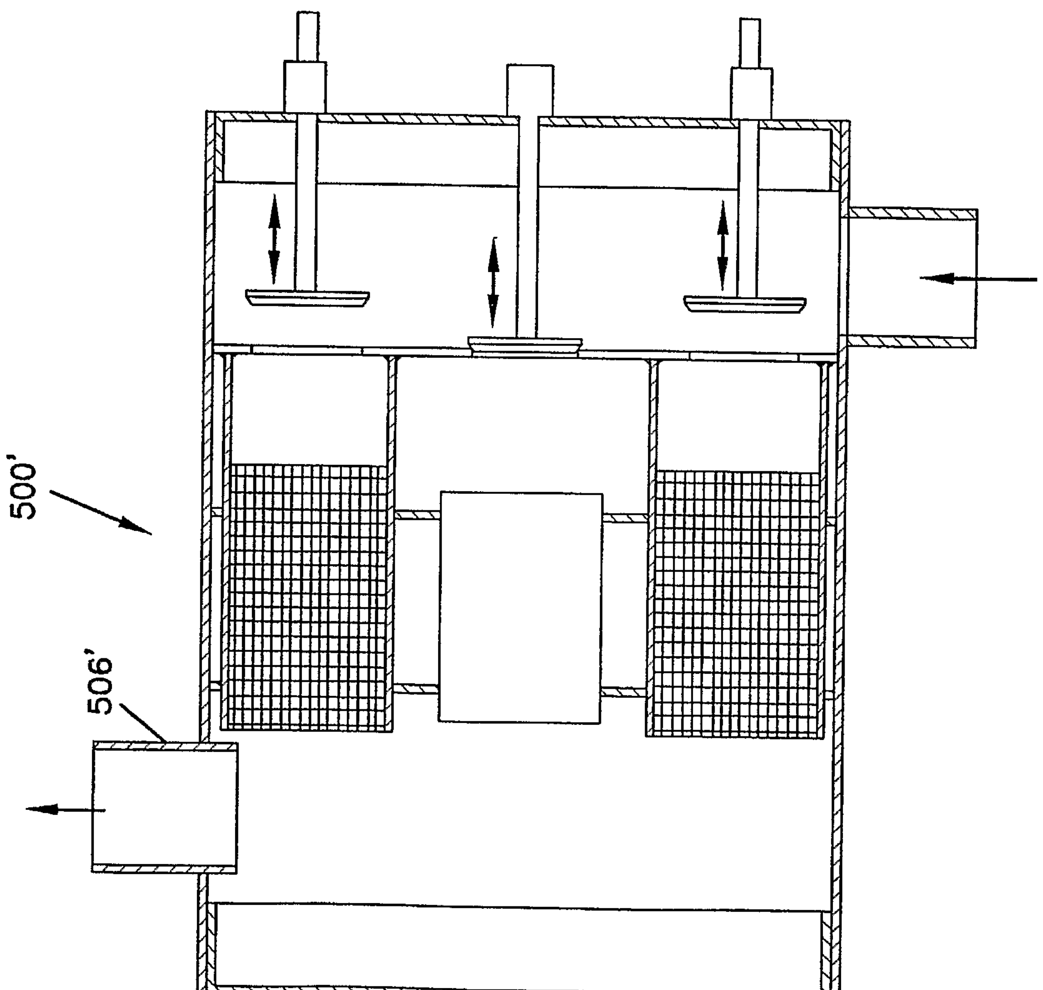

FIG.8C

INTERNATIONAL SEARCH REPORT

Internati Application No
PCT/US 02/34518

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F01N3/035 F01N3/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 067 319 A (MOSER FRANZ) 26 November 1991 (1991-11-26) column 1, line 16 - line 20 column 3, line 11 - line 31 column 3, line 37 - line 41 figures 1,3	1,3,7, 10-12, 16,19-21
X	DE 42 07 005 A (NISSAN MOTOR) 10 September 1992 (1992-09-10)	19,20
A	abstract figure 7	1,16,21

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 March 2003	09/04/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Ikas, G

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/34518

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 485 622 A (TAKEUCHI YUKIHISA ET AL) 4 December 1984 (1984-12-04) cited in the application column 3, line 15 -column 5, line 18 claims 7-9 figures 1-4	1,3,7,8, 13,14, 19-21
A	US 5 246 205 A (GILLINGHAM GARY R ET AL) 21 September 1993 (1993-09-21) column 6, line 45 -column 8, line 37 figure 3	1,3,7,8, 13-15, 19,20

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INTERNATIONAL SEARCH REPORT

Ini tion on patent family members

International Application No
PCT/US 02/34518

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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			DE	4207005 A1	10-09-1992
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US 5246205	A	21-09-1993	NONE		