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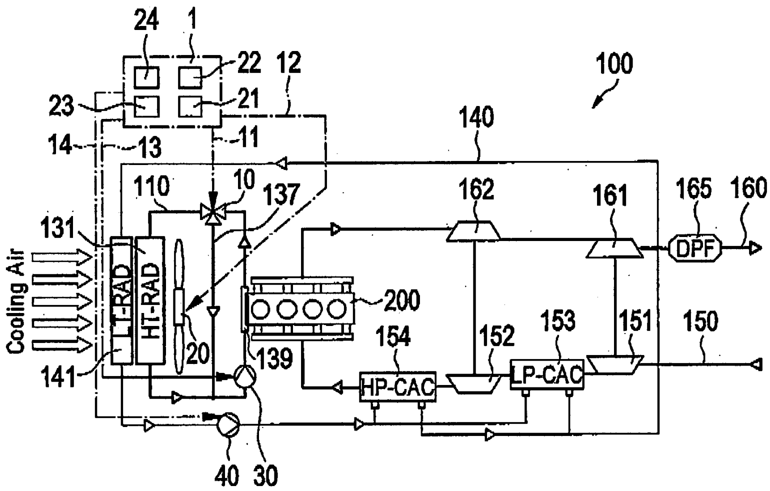
(54) Method for the control of an engine supercharging system, control system, computer programm product, storage medium and an engine supercharging system

(57) The invention starts from a method for the control of an engine supercharging system for a charge fluid with a low-temperature coolant circuit for indirect cooling of the charge fluid and a high-temperature coolant circuit. The low-temperature coolant circuit comprises a low-temperature pump and at least one heat exchanger for the charge fluid and a law-temperature radiator. The high-temperature coolant circuit comprises a high-temperature pump and a map-controlled thermostat and a high-temperature radiator. At least one radiator fan associated with a low-temperature radiator and/or the high-temperature radiator. According to the concept of the invention, for optimum operation within the framework of comprehensive thermal management it is provided that the thermostat, the radiator fan, the high-temperature pump and the low-temperature pump are controlled as actuators of a control system. The invention leads to a corresponding control system, a computer program product and an engine supercharging system.

Fig. 1



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Description

[0001] The invention concerns a method for the control of an engine supercharging system for a charge fluid; the system having a low-temperature coolant circuit for indirect cooling of the charge fluid, the low-temperature coolant circuit comprising: a low-temperature pump, at least one heat exchanger for the charge fluid, a low-temperature radiator; and the system having a high-temperature coolant circuit, the high-temperature coolant circuit comprising: a high-temperature pump, a thermostat, a high-temperature radiator; and wherein at least one radiator fan of the system is provided for the low-temperature radiator and/or the high-temperature radiator. The invention further concerns a control system for an engine supercharging system, a computer program product, a storage medium and an engine supercharging system.

[0002] An engine supercharging system for a charge fluid - in particular an engine supercharging system for a charge fluid in form of charge air and/or exhaust gas - is used in modern vehicles inter alia on account of legal provisions in order to lower particle and pollutant emissions, in particular nitrogen oxide emissions. As the requirements of purity of the exhaust gas become stricter, larger exhaust gas mass flows are required, which can be controlled only to a limited extent with known engine supercharging systems. For this purpose, as a rule charge-fluid cooling is required - in commercial vehicles this is usually direct charge-fluid cooling, whereas in the field of passenger cars indirect charge-fluid cooling is preferred. Exhaust recirculation systems are known in a single-stage design, as in US 6,244,256 B1, or in a two-stage design, as in DE 600 24 390 T2. Similarly charge-air cooling systems in single-stage and two-stage designs are known.

[0003] The temperature trend on the coolant side is determined amongst other things by the design of an usually map-controlled thermostat, a performance of the radiator fan and a throughput of the high-temperature and/or low-temperature pump. It is known, for example, that a radiator fan can be suitably controlled by speed regulation - thus described for example in the applicant's application 06-B-323 which has been filed but not yet published and which is quoted under the internal file number. Comprehensive control and in particular thermal management of a circulatory system like the supercharging system of the introduction hereinbefore with separate low-temperature coolant circuit and separate high-temperature coolant circuit proves to be comparatively complex, however. The requirements of the whole system are not in every case characterised by maximum charge-fluid cooling, for example charge-air cooling. On the contrary, desired charge-fluid cooling, in particular charge-air cooling, depends on the operating state of the vehicle. Firstly, during critical operation mode of the system, for example in a cold or hot environment, the functionality should be guaranteed, whereas, secondly, during normal operation fuel consumption should be kept as low as possible, and furthermore opposing effects should be avoided.

[0004] This is where the invention comes in of which it is the object to provide a method and a control system for an engine supercharging system as well as a computer program product, a storage medium and an engine supercharging system in which on the one hand the functionality of the system is guaranteed in a critical mode and on the other hand comparatively effective operation under favourable boundary conditions is guaranteed during a normal operation mode, and in particular fuel consumption is to a large extent kept low.

[0005] Concerning the method, the object is achieved by the invention by means of a method of the kind mentioned in the introduction hereinbefore in which, according to the invention, it is provided that at least the thermostat, the radiator fan and the high-temperature pump and the low-temperature pump are controlled as actuators of a control system.

[0006] Concerning the control system, the object is achieved by the invention by means of a control system of the kind mentioned in the introduction hereinbefore in which, according to the invention,' it is provided that at least the thermostat, the radiator fan and the high-temperature pump and the low-temperature pump are controllable as actuators of the control system.

[0007] The invention leads to a computer program product and a storage medium according to the further independent claims.

[0008] Concerning the engine supercharging system, the object is achieved by the invention by means of an engine supercharging system of the kind mentioned in the introduction hereinbefore in which, according to the invention, it is provided that at least the thermostat, the radiator fan and the high-temperature pump and the low-temperature pump are controllable as actuators of a control system. In particular, the engine supercharging system has a control system according to the invention.

[0009] The thermostat is preferably a map-controlled thermostat. The charge-fluid is preferably a charge air and/or exhaust gas.

[0010] The invention starts from the consideration that at least the low-temperature pump, the high-temperature pump, the thermostat and the radiator fan are essential as actuators for a comprehensive thermal management of the engine supercharging system. Thus the invention, amongst other things, is based on the consideration that, as explained in Figure 1 and Figure 2, for each operating point maximum charge-fluid cooling can be achieved by a given coolant throughput with a low-temperature pump. The invention further starts from the consideration that maximum obtainable charge-fluid cooling should not always be the aim of a comprehensive thermal management, but rather charge-fluid cooling should be selected as a function of the operating state of the vehicle. The invention also takes into consideration that the high-temperature pump essentially regulates the coolant throughput in the high-temperature circuit and the, in particular map-controlled, thermostat fixes the temperature level of the high-temperature circuit, while a radiator fan, particularly during critical operation, is used for necessary cooling-air requirements. Furthermore, the low-temperature pump regulates the coolant throughput in the low-temperature circuit. The latter has at least one heat exchanger - depending on whether it is a single-stage, two-stage or multi-stage charge-fluid cooling system - which implements heat exchange with the charge fluid, for example charge air. Starting from the consideration that coordination of at least the four above-mentioned actuators is a complex task, the invention works from the essential knowledge that, in coordination with the operating state of the system, a comprehensive regulation strategy is possible with the coordination of at least the above mentioned four actuators. Working from this knowledge, the concept of the invention is based on the measure of making in particular the low-temperature pump capable of being regulated in addition to the high-temperature pump, the map-controlled thermostat and the radiator fan. Consequently according to the concept of the invention, the low-temperature pump in the low-temperature circuit of an indirect charge-fluid cooling system is also driven and is available as an actuator of the control system within the framework of the regulation strategy. As a result, within the scope of the concept of the invention for practically all operating states, effective operation of the engine supercharging system can be guaranteed, i.e. during normal operation mode comparatively optimised operation can be achieved, particularly with lower fuel consumption, while the functionality of the whole system is guaranteed in a critical operating mode.

[0011] In an advantageous manner it is for example possible to achieve a comparatively low fuel consumption during a normal operation mode. In a critical operating mode, for example in a hot environment or a cold environment, protection of components can be guaranteed advantageously within the scope of the concept of the invention, so that the overall functionality of the system is maintained, even in case of critical ambient temperatures. In a further critical mode referred to as the braking mode, so-called "turbobrake" or "retarder" operating states can be supported by maximum cooling and if occasion arises regulated in connection with further demands such as e.g. acoustic compatibility. In a warm-up stage, the concept of the invention makes it possible for an engine to reach the operating temperature comparatively quickly. Within the framework of the operating state of exhaust gas treatment, the exhaust gas temperature can be advantageously raised by the concept of the invention and so assist the exhaust gas treatment system, for example an exhaust gas treatment system which has particle filters, catalytic converters or the like.

[0012] In general the concept of the invention makes it possible,' by coordinated regulation of at least the four actuators mentioned above, namely the thermostat, the radiator fan and the high-temperature pump and low-temperature pump, to let an engine function under optimum boundary conditions throughout the system during normal running and there, for example, enable comparatively low fuel consumption. In other modes such as e.g. when warm-up mode, additional savings can be obtained as the engine quickly reaches the operating temperature. Not in any state does failure of the system occur - not even in critical operating states such as in a hot environment mode, cold environment mode or braking mode. Furthermore, the concept of the invention makes it possible to assist functions such as treatment of the exhaust gas.

[0013] Advantageous developments of the invention can be found in the dependent claims, and in detail provide advantageous possible ways of realising the concept described above' within the scope of the object and with respect to further advantages which will be described in detail below.

[0014] In a particularly preferred development, it is provided that each of the actuators, i.e. the thermostat, the radiator fan, the high-temperature pump and the low-temperature pump, is driven by a control signal which is produced by the comparison of two or more mode parameters, in particular by performing one or more extreme value operations with the two or more mode parameters. In particular, it proved to be advantageous to control the radiator fan via a fan coupling, for example an ERS coupling. The control signal is preferably formed in the form of a PWM signal.

[0015] Evaluating an extreme value during comparison means an operation in which two or more values are compared with each other as the initial values of an operator, and the largest and/or smallest of the values is outputted as the output value to form the control signal. The development described can be carried out with comparatively little expenditure on computing, and allows mode parameters of prior rank to prevail over mode parameters of lower rank. There may be one or more processes of forming extreme values carried out in parallel with each other or sequentially one after the other.

[0016] As input values for forming extreme values, preferably one or more mode parameters for at least one or more of the modes of operation are available, which are selected from the group consisting of: normal operation mode, braking mode, exhaust gas treatment mode, warm-up mode, cold environment mode, hot environment mode. By contrast with the mode of normal operation, the mode of operation in a cold environment or hot environment or in the braking mode involves comparatively critical operating states which, if occasion arises, in individual cases make it necessary for a procedure of normal operation with optimum fuel consumption to be abolished in favour of the critical mode. In the warm-up and exhaust treatment modes, additional functions can be established, with which additional savings can be obtained because the engine e.g. reaches the operating temperature faster and/or in which exhaust treatment is positively assisted by, for example, keeping the charge fluid at a higher temperature in order to produce a more favourable operating temperature for a particle filter and/or catalytic converter.

[0017] In a preferred development, it is provided that a control signal for the, in particular map-controlled, thermostat is produced by combining the mode parameters for normal operation mode and braking mode, preferably by evaluating a maximum value from comparison thereof.

[0018] In a further preferred development it is provided that a control signal for the high-temperature pump is produced by combining the mode parameters for normal operation mode and warm-up mode, preferably by evaluating a minimum value thereof. Additionally or alternatively, it is preferably provided that a control signal for the high-temperature pump is produced by combining at least the mode parameters for braking mode and hot environment mode, preferably by evaluating a maximum value thereof, in particular taking into consideration the minimum value from the comparison of the mode parameters for normal operation mode and warm-up mode.

[0019] In a further preferred development, it is provided that a control signal for the radiator fan is produced by combining at least the mode parameters for normal operation mode, braking mode and hot environment mode, preferably by evaluating the maximum value thereof, in particular taking into consideration further modes of operation and/or operating requirements.

[0020] Lastly, in a particularly preferred development it is provided that a control signal for the low-temperature pump is produced by combining the mode parameters for normal operation mode, exhaust gas treatment mode, warm-up mode and cold environment mode, preferably by evaluating the minimum value thereof. Additionally or alternatively, preferably a control signal can be produced by combining the mode parameters for braking mode and hot environment mode, preferably by evaluating the maximum value thereof, in particular taking into consideration the minimum value from the comparison of mode parameters for normal operation mode, exhaust gas treatment mode, warm-up mode and cold environment mode.

[0021] In addition, it proved advantageous that a mode parameter is also obtained for one or more further modes which are not listed here in detail, or for further operating requirements. This can be an A/C state, for example. Advantageously, the concept of the invention within the scope of this development can therefore be extended by further mode parameters to take into consideration for a control signal for the actuators. In case of need, this can lead to the number of actuators being increased as well, as explained.

[0022] In particular, the above steps of the method can be implemented within the framework of control modules - for one actuator each - and/or control submodules - for one mode each - within the framework of control. For instance, according to a development of the control system it is provided that at least one control module and/or control channel is provided, preferably for each of the actuators one control module and/or control channel, which is designed to output a control signal for driving the actuator(s). The control module preferably receives as the input value - depending on the mode of operation - one or more mode parameters from a control submodule and processes the mode parameters - depending on the actuator to be driven - within the scope of forming one or more extreme values during comparison of one or more mode parameters. In particular, a control module contains at least one operator and/or comparator which compares one or more mode parameters as the input variable and delivers as the output variable a control value for forming a control signal, in particular a PWM signal, for the corresponding actuator as the output.

[0023] According to a development of the control system, it is provided that at least one control submodule is provided for obtaining mode parameters for at least one or more of the modes of operation, which are selected from the group consisting of: normal operation mode, braking mode, exhaust treatment mode, warm-up mode, cold environment mode, hot environment mode. Furthermore it proved advantageous that at least one control submodule is provided for obtaining mode parameters for one or more further modes of operation or operating requirements.

[0024] To obtain controllable mode parameters, a control submodule may - depending on the control purpose, i.e. depending on the actuator to be driven, i.e. depending on whether the high-temperature pump, the thermostat, the radiator fan or the low-temperature pump is to be driven - contain one or more mapping lines, tables of values or the like which are characteristic or typical of a mode of operation.

[0025] For example, a mapping line or the like for a high-temperature pump' and/or low-temperature pump can show a mass throughput as a function of a coolant temperature or a mass throughput correlation as a function of a speed or torque of the engine.

[0026] A mapping line for the thermostat can indicate a nominal coolant temperature in relation to the speed of the engine or the torque of the engine.

[0027] A mapping line for the fan coupling can show a speed of the fan over a temperature trend. The above-mentioned mapping lines are suitable for characterising a normal mode of operation.

[0028] The control submodules for critical operating states - i.e. hot environment mode, cold environment mode or braking mode - provide for example temperature comparisons and/or temperature scans of the coolant and the environment, as well as speed comparisons and/or speed scans of the pumps. The scans within the scope of a control submodule for the warm-up mode are provided by the comparative scan of coolant temperature after the engine in the hot and cold states. The control submodule for exhaust gas treatment provides the ECU requirements as input variables.

[0029] The mapping lines or scanned values or limit values deposited in a control submodule, whether maximum or minimum values, can be obtained or extended in particular by measurement, simulation and/or estimation.

[0030] Preferred embodiment examples of the invention will now be described below with the aid of the drawings. The latter are intended to show the practical examples not necessarily to scale, but instead the drawings, where it is expedient for an illustration, are in schematised and/or sightly distorted form. With respect to additions to the instructions which can be seen directly from the drawings, reference is made to the relevant state of the art. In this case allowance must be made for the fact that diverse modifications and alterations can be made concerning the form and detail of an embodiment without departing from the general idea of the invention. The characteristics of the invention disclosed in the description, in the drawings and in the claims may be essential to the development of the invention both individually and in any combination. Also within the scope of the invention are all combinations of two or more of the characteristics disclosed in the description, the drawings and/or the claims. The general idea of the invention is not confined to the exact form or detail of the preferred embodiment shown and described below, or confined to a subject which would be restricted in comparison with the subject claimed in the claims. In the case of given ranges of measurement, values which are within the limits mentioned are also intended to be disclosed as limit values and may be used and claimed as desired.

[0031] In detail, the drawings show:

Fig. 1: the schematic view of a preferred embodiment of an engine supercharging system;

Fig. 2: as an example, a graph of charge air cooling as a function of the throughput of the low-temperature pump for one operating point and given cooling air throughput;

Fig. 3A: a flow chart for a preferred embodiment of the control module for a map-controlled thermostat;

Fig. 3B: a flow chart for a preferred embodiment of a control module for a high-temperature pump;

Fig. 3C: a flow chart for a preferred embodiment of a control module for a radiator fan;

Fig. 3D: a flow chart for a preferred embodiment of a control module for a low-temperature pump;

Fig. 4A: a flow chart with mapping lines for a preferred embodiment of a control submodule for the normal mode of operation with the map-controlled thermostat;

Fig. 4B: a flow chart with mapping lines for a preferred embodiment of a control submodule for the normal mode of operation with the high-temperature pump;

Fig. 4C: a flow chart with mapping lines for a preferred embodiment of a control submodule for the normal mode of operation with the radiator fan;

Fig. 4D: a flow chart with mapping lines for a preferred embodiment of a control submodule for the normal mode of operation with the low-temperature pump;

Fig. 5: a flow chart with mapping lines for a preferred embodiment of a control submodule for the braking mode of operation;

Fig. 6A: a flow chart with mapping lines for a preferred embodiment of a control submodule for the hot-environment mode of operation;

Fig. 6B: a flow chart with mapping lines for a preferred embodiment of a control submodule for the cold-environment mode of operation;

Fig. 7: a flow chart with mapping lines for a preferred embodiment of a control submodule for the warm-up mode of operation;

Fig. 8: a flow chart with mapping lines for a preferred embodiment of a control submodule for the exhaust-treatment mode of operation.

[0032] While the invention proves to be particularly beneficial for use with a two-stage engine supercharging system for a charge fluid in the form of a charge air and with indirect charge-air cooling, and while the invention is described in detail below with the aid of examples relating to such an engine supercharging system, it should nevertheless be clear that the concept described here, as claimed, is very generally beneficial within the framework of engine supercharging systems which for example are based on a different charge fluid, or which are for example designed with only one stage.

[0033] Taking this into consideration, with the aid of Figure 1 by way of example there is described a two-stage engine supercharging system 100 with indirect charge-air cooling in a separate circuit, in which the concept of the invention is implemented within the framework of a method and a control system 1 for thermal management of the engine supercharging system.

[0034] Figure 1 shows for this purpose an engine supercharging system 100 which in the present case has a separate high-temperature coolant circuit 110 and a separate low-temperature coolant circuit 140 for indirect cooling of charge fluid in the form of charge air which is conducted in a charge-air delivery means 150 to the engine 200. The charge-air delivery means 150 is arranged on the engine input side and has, for compression of the charge air, a two-stage construction with a first compressor 151 and a second compressor 152. The charge air is cooled after the first compressor 151 in a first low-pressure/low-temperature heat exchanger 153, and cooled in the second stage after the second compressor 152 in a high-temperature/high-pressure heat exchanger 154, and then delivered to the engine 200 on the input side. On the output side of the engine, via an exhaust removal means 160, corresponding to the two-stage design of the engine supercharging system 100, the second compressor 152 is driven via a second high-pressure exhaust-driven turbine 162 in the exhaust removal means - the first compressor 151 is driven via a first exhaust turbine 161 arranged in the exhaust removal means 160. The exhaust is discharged into the environment in the exhaust removal means 160 via a cleaning system which is equipped with a particle filter 165 amongst other things.

[0035] Recooling of the heat exchangers 153, 153 takes place on the coolant side via the low-temperature coolant circuit 140 in which the heat exchangers 153, 154 are connected in parallel on the coolant side. The coolant is circulated in the low-temperature coolant circuit 140 by the low-temperature pump 40, and after the heat exchangers 153, 154 is delivered to the low-temperature radiator 141, cooled therein and again delivered to the low-temperature pump 40. Furthermore, engine cooling takes place directly via a separate high-temperature coolant circuit 110 in which the coolant is circulated by means of a high-temperature pump 30 and delivered to an engine radiator 139. Then the coolant in the high-temperature coolant circuit 110 is delivered at elevated temperature to a map-controlled thermostat 10 which in the present case is combined together with a three-way valve. If there are no recooling requirements, the coolant in the high-temperature coolant circuit 110 can be delivered via a bypass 137 directly back to the high-temperature pump 30. In the event that there are recooling requirements for the coolant in the high-temperature coolant circuit 102, the coolant is delivered to a high-temperature radiator 131 and from there back to the high-temperature pump 30.

[0036] According to the concept of the invention, in this embodiment of an engine supercharging system 100 the map-controlled thermostat 10, the radiator fan 20 which is associated with the low-temperature radiator 141 and the high-temperature radiator 131, the high-temperature pump 30 and the low-temperature pump 40 are made capable of being controlled. For this purpose, in the present case a control system 1 is provided for thermal management of the engine supercharging system 100, which is designed for control of the map-controlled thermostat 10, the radiator fan 20, the high-temperature pump 30 and the low-temperature pump 40. For this purpose the control system 1 in the present case has separate control channels 11, 12, 13 and 14 which are designed to transmit control values within the framework of a control signal to the map-controlled thermostat 10, the radiator fan 20, the high-temperature pump 30 and the low-temperature pump 40, and are connected to the control system 1 or control modules in the control system 1 described below.

[0037] Figure 2 shows by way of example for the engine supercharging system 100 of Figure 1 that, for a given cooling air throughput, the low-temperature pump 40 determines the charge-air cooling. Accordingly, in the graph the temperature of the charge air (TcA) after the indirect high-pressure charge-air cooler in the form of the heat exchanger 154 is plotted over the throughput of the low-temperature pump 40. It can be seen that for each operating point the maximum charge-air cooling can be reached by a given low-temperature pump coolant throughput. The present concept furthermore does not always have maximum charge-air cooling as the aim of the overall regulation strategy, but instead desired charge-air cooling as a function of the operating state of the vehicle. Taking this into consideration, the design of the control system 1 with control modules 21, 22, 23, 24 and control submodules 31, 32, 33, 34, 55, 88, 77, 66A, 66B according to the concept of the invention is described in detail below. The concept basically provides that, within the scope of the novel thermal management of the engine 200, during normal operation a comparatively low fuel consumption is made possible, while during critical operation - for example, in a cold environment, hot environment or in braking mode - the functionality of the engine supercharging system 100 as a whole is ensured. It is taken as a starting point that the high-temperature pump 30 determines the coolant throughput in the high-temperature circuit 110, the map-controlled thermostat 10 determines the temperature level in the high-temperature circuit 110, and the coupling of' the radiator fan 20 which in the present case is designed as an ERS coupling essentially determines the cooling air requirements for the radiator fans 131, 141 - and furthermore, as can be seen from Figure 2, the low-temperature pump 40 determines the coolant throughput in the low-temperature circuit 140.

[0038] The design of the control system 1 or of the method for controlling the engine supercharging system 100 works in the present case by the fact that each of the actuators - in the form of the map-controlled thermostat 10, the radiator fan 20, the high-temperature pump 30 and the low-temperature pump 40 - is assigned a control module or main program 21, 22, 23, 24 described in more detail in Figures 3A to 3D.

[0039] A control module or main program 21, 22, 23, 24 in turn coordinates, for each of the four actuators 10, 20, 30, 40, control submodules 31, 32, 33, 34, 55, 88, 77, 66A, 66B or subprograms which are described in more detail in Figure 4 to Figure 8 and which are characteristic of a respective mode of operation.

[0040] Thus for example in Figure 4A to Figure 4D is shown a preferred embodiment of a control submodule/ subprogram 31, 32, 33, 34, which in each case for the normal mode of operation and specifically for one of the actuators 10, 20, 30, 40 delivers a mode parameter which can be delivered in the form of a control value to form a control signal via a control channel 11, 12, 13, 14 to the actuators 10, 20, 30, 40 in controlling fashion.

[0041] Figure 5 shows the design of a control submodule/subprogram for generating a mode parameter for the braking mode. Figure 6A and Figure 6B each show the design of a control submodule/subprogram 66A, 66B for generating a mode parameter for the hot-environment mode 66A or cold-environment mode 66B.

[0042] Figure 7 shows the design of a control submodule/subprogram 77 for generating a mode parameter for warm-up.

[0043] Figure 8 shows the design of a control submodule/subprogram 88 for the exhaust gas treatment mode.

[0044] In detail, the design or run of a control module/ main program or control submodule/subprogram is as follows:

[0045] The control module/main program 21 for the map-controlled thermostat 10 in Figure 3A coordinates the output signals of normal operation and braking mode by forming the maximum of both output signals. The mode parameters 31', 55' delivered by the control submodules 31, 33 are subjected to formation of the maximum value. The output of the control module/main program 21 is the PWM signal of the map-controlled thermostat in the control channel 11. The map-controlled thermostat 10 is not influenced by regulation of the control submodules/subprograms 88, 77, 66A, 66B, i.e. of exhaust gas treatment mode and the mode of warm-up, hot environment, cold environment, as the map-controlled thermostat has no effect on the charge-air temperature.

[0046] The control module/main program 22 for the high-temperature 30 in Figure 3B forms the minimum between the PWM signals of the warm-up and normal modes. The mode parameters 32', 77' delivered by the control submodules 32, 77 are subjected to formation of the minimum value. In the event that a warm-up strategy is necessary, the PWM signal of the high-temperature pump is reduced. In the event that the braking mode or hot-environment mode occurs, however, the maximum of the PWM signals is to be formed in order to increase the coolant throughput. The mode parameters 55', 66A' delivered by the control submodules 55, 66A are subject to formation of the maximum value. Regulation of the high-temperature pump 30 is not affected by an increase in the charge-air temperature for exhaust gas treatment and a cold-environment operating state.

[0047] The control module/main program 23 for the radiator fan 20 in Figure 3C forms the maximum from the PWM signals of the control submodules for the normal and braking modes, the critical state of hot environment and other requirements such as e.g. in order to ensure cooling requirements in braking mode, the critical hot-environment mode and other requirements. The mode parameters 33', 55' 66A' which are delivered in the control submodules 33, 55, 66A are subjected to formation of the maximum value. Otherwise the PWM signal of the fan coupling corresponds to the nominal values of normal operation mode. In the cold-environment and warm-up modes, the fan is not running because the coolant is cold. Fan regulation is not influenced by the operating mode of exhaust gas treatment. In the event that the fan 20 is running, the fan has to regulate the coolant temperature in the high-temperature circuit to the desired temperature level - as a result the coolant requirements cannot be reduced in order to increase the charge-air temperature.

[0048] The control module/main program 24 for the low-temperature pump 40 in Figure 3D combines all the operating states, as the charge-air temperature is relevant to all operating states. In the event that the charge-air temperature is to be raised, the PWM signal of the low-temperature pump 40 is reduced - forming the minimum mode parameters of normal operation mode, exhaust gas treatment mode, warm-up mode and cold environment mode. The mode parameters 34', 88', 77', 66B' which are delivered by the control submodules 34, 88, 77, 66B are subjected to formation of the minimum value. In the event that a braking or hot-environment mode occurs, the PWM signal of the low-temperature pump is increased - formation of the maximum. The mode parameters 55', 66A delivered by the control submodules 55, 66A are subjected to formation of the maximum.value.

[0049] All modes of operation are, as already explained, realised as a control submodule/subprogram and are coordinated by the control modules/main program.

[0050] The control submodules/subprograms 31, 32, 33, 34 for normal operation each generate for all four actuators (high-temperature pump 30, thermostat 10, radiator fan 20 or ERS coupling, low-temperature pump 40) a PWM signal 31', 32', 33', 34' as the output signal. The subprograms have maps M, T, N, P, K which can be generated both by engine tests, competent measurements and simulations or estimations or from the indication of experimental values. The linking of these maps M, T, P, K for the four actuators 10, 20, 30, 40 is shown respectively in Figure 4A to Figure 4D of the subprograms 31, 32, 33, 34 for normal operation. Input variables of the maps other than those shown are also possible. A map M takes engine values into consideration as the input. A map T takes temperatures into consideration as the input. A map P.delivers a PWM value. A map K delivers a correction. In Fig. 4C the aim of normal operation mode is in particular to minimize fuel consume. At partial load operation a desired temperature value can be raised above a desired value for the map-controlled thermostat.

[0051] In the braking mode - e.g. in the turbobrake or retarder mode - as shown in Figure 5 the charge-air exhaust heat is extracted. For this the throughput of the low-temperature pump is adapted and the fan speed conveys enough air so that the charge-air exhaust heat (via LTK), the compression energy (generated in the engine by the braking mode) and the retarder exhaust heat can be extracted. In the process an acoustically compatible value is ensured. The throughput of the high-temperature pump is increased to match the cooling air of the throughput, in order to extract all the exhaust heat (braking mode and retarder) into the high-temperature circuit (retarder requirements of m_{CM}). The map-controlled thermostat 10 according to Figure 5 is regulated by a PWM signal of a map P which shows the nominal coolant temperature in the braking mode (retarder requirements of T_{CM}).

[0052] For the critical operating mdoes - hot environment or cold environment - two control submodules/subprograms 66A, 66B are carried out and shown in Figure 6A, Figure 6B. For the hot-environment mode, after detecting whether the maximum coolant temperature is exceeded, it is decided whether the requirements of maximum cooling are to be adjusted. In the event that the coolant temperature is not critical, but the charge-air temperature has exceeded the maximum temperature, the ERS coupling is caused to adapt the fan speed to the charge-air requirements. In the event that no hot-environment mode is detected, the output signals - speed of the low-temperature pump, the high-temperature pump and the fan coupling - are adjusted to artificially low values. This allows coordination of the different subprograms in the main programs 21, 22, 23, 24.

[0053] For the cold-environment mode there is the risk that freezing will occur on the charge-air side in the charge-air cooler. If there is a risk of freezing, e.g. the ambient temperature T_{umg} is lower than 2°C, the throughput of the low-temperature pump is reduced so that the charge-air temperature for both charge-air coolers 153, 154 remains above freezing point. It is the aim of the regulation strategy for the critical operating states to preserve the functionality of the whole system, i.e. to ensure protection of components.

[0054] For the warm-up strategy, as shown in Figure 7 - in the event that the engine is cold after detection of a drop - the engine is supplied with hot charge air. For this, at the low-temperature pump 40 the speed is reduced (if necessary the pump stops), so that the charge-air temperature adjusts the maximum value which the engine 200 can stand. At the high-temperature pump 30 the speed is also reduced, so that cooling in the engine is comparatively low without exceeding a given coolant temperature difference above the engine. If no warm-up strategy is necessary, i.e. if the engine is already warm for operation, the speed is set to artificially high values for the low-temperature and high-temperature pumps, as shown in Figure 7. This allows coordination of the subprogram 77 with the different other subprograms 32, 55, 88, 66B, 66A in the main programs 21, 22, 23, 24.

[0055] For the mode assisting exhaust gas treatment in Figure 8 the charge-air temperature is increased by controlling the low-temperature pump as for the warm-up mode in Figure 7. As a result, the engine 200 is supplied with little uncooled charge air, which contributes to increasing the exhaust gas temperature.

[0056] In summary the invention starts from a method for the control of an engine supercharging system for a charge fluid with a low-temperature coolant circuit for indirect cooling of the charge fluid and a high-temperature coolant circuit. The low-temperature coolant circuit comprises a low-temperature pump and at least one heat exchanger for the charge fluid and a law-temperature radiator. The high-temperature coolant circuit comprises a high-temperature pump and a map-controlled thermostat and a high-temperature radiator. At least one radiator fan associated with a low-temperature radiator and/or the high-temperature radiator. According to the concept of the invention, for optimum operation within the framework of comprehensive thermal management it is provided that the thermostat, the radiator fan, the high-temperature pump and the low-temperature pump are controlled as actuators of a control system. The invention leads to a corresponding control system, a computer program product and an engine supercharging system.

Claims

1. Method for the control of an engine supercharging system for a charge fluid; the system having a low-temperature coolant circuit for indirect cooling of the charge fluid, the low-temperature coolant circuit comprising:

    - a low-temperature pump,
    - at least one heat exchanger for the charge fluid,
    - a low-temperature radiator

    and the system having a high-temperature coolant circuit, the high-temperature coolant circuit comprising:

    - a high-temperature pump,
    - a thermostat;
    - a high-temperature radiator

    and wherein at least one radiator fan of the system is provided for the low-temperature radiator and/or the high-temperature radiator;
    characterised in that
    at least the thermostat, the radiator fan, the high-temperature pump and the low-temperature pump are controlled as actuators of a control system.

2. Method according to claim 1, **characterised in that** each of the actuators is driven by a control signal, which is produced by the comparison of two or more mode parameters, in particular by forming one or more extreme value operations with the two or more mode parameters.

3. Method according to claim 1 or 2, **characterised in that** a mode parameter is obtained for at least one or more of the modes of operation selected from the group consisting of: normal operation mode, braking mode, exhaust gas treatment mode, warm-up mode , cold environment mode, hot environment

mode.

4. Method according to claim 3, **characterised in that** a mode parameter is obtained for one or more further operation modes and/or operation requirements.

5. Method according to any of claims 1 to 4, **characterised in that** a control signal for the thermostat is produced by evaluating a maximum value from comparison of the mode parameters for normal operation mode and braking mode.

6. Method according to any of claims 1 to 5, **characterised in that** a control signal for the high-temperature pump is produced by evaluating a minimum value from comparison of the mode parameters for normal operation mode and warm-up mode and/or by evaluating a maximum value from comparison of at least the mode parameters for braking mode and hot environment mode, preferably by additionally taking into account the minimum value from the comparison of the mode parameters for normal operation mode and warm-up mode.

7. Method according to any of claims 1 to 6, **characterised in that** a control signal for the radiator fan, in particular for a coupling of the radiator fan, is produced by evaluating a maximum value from comparison of at least the mode parameters for normal operation mode, braking mode and hot environment mode, preferably by additionally taking into account further operation models and/or operation requirements.

8. Method according to any of claims 1 to 7, **characterised in that** a control signal for the low-temperature pump is produced by evaluating a minimum value from comparison of the mode parameters for normal operation mode, exhaust gas treatment mode, warm-up mode and cold environment mode, and/or by evaluating a maximum value from comparison at least the mode parameters for braking mode and hot environment mode, preferably by additionally taking into account the minimum value from the comparison of the mode parameters for normal operation mode, exhaust gas treatment mode, warm-up mode and cold environment mode.

9. Method according to any of claims 1 to 8, **characterised in that** a mode parameter is produced as a result of scanning at least one mapping line, in particular a mapping line which is obtained by measurement, simulation and/or estimation.

10. Control system for an engine supercharging system for a charge fluid having a low-temperature coolant circuit for indirect cooling of the charge fluid, the low-temperature coolant circuit comprising:

- a low-temperature pump,
- at least one heat exchanger,
- a low temperature radiator,

and having a high-temperature coolant circuit, the high-temperature coolant circuit comprising:

- a high-temperature pump,
- a thermostat,
- a high-temperature radiator,

and wherein at least one radiator fan is provided for the low-temperature radiator and/or the high-temperature radiator; in particular control system for carrying out the method according to any of the preceding claims,
characterised in that
at least the thermostat, the radiator fan and the high-temperature pump and the low-temperature pump are controlled as actuators of the control system.

11. Control system according to claim 10, **characterised in that** at least one control channel for a control signal is provided for a number of actuators and/or at least one control module for output of a control signal is provided for driving the actuators.

12. Control system according to claim 10 or 11, **characterised in that** the control signal is produced by performing one or more extreme value operations upon comparison of two or more mode parameters.

13. Control system according to any of claims 10 to 12, **characterised in that** at least one control submodule is provided for the output of a mode parameter for at least one or more of the modes, which are selected from the group consisting of: normal operation mode, braking mode, exhaust gas treatment mode, warm-up mode, cold environment mode, hot environment mode.

14. Control system according to any of claims 10 to 13, **characterised in that** at least one control submodule is provided for obtaining mode parameters for one or more further operation modes and/or operation requirements.

15. Control system according to any of claims 10 to 14, **characterised in that** a mode parameter is produced as a result of scanning at least one mapping line in a control submodule, in particular a mapping line which is obtained by measurement, simulation and/or estimation.

16. Computer program product, storable on a storage medium and readable by an arithmetic and logic unit, in particular a control system according to any of claims 10 to 15, for the controlling of an engine su-

percharging system, comprising a software code section which causes the arithmetic and logic unit to carry out the method according to any of claims 1 to 9 when the computer program product is executed on the arithmetic and logic unit.

17. Storage medium with a computer program product according to claim 16.

18. Engine supercharging system, in particular comprising a control system according to any of claims 10 to 15, having a low-temperature coolant circuit for indirect cooling of the charge fluid, the low-temperature coolant circuit comprising:

- a low-temperature pump,
- at least one heat exchanger for the charge fluid,
- a low-temperature radiator;

and having a high-temperature coolant circuit, the high-temperature coolant circuit comprising:

- a high-temperature pump,
- a thermostat,
- a high-temperature radiator;

and wherein at least one radiator fan is provided for the low-temperature radiator and/or the high-temperature radiator;
characterised in that
at least the thermostat, the radiator fan and the high-temperature pump and the low-temperature pump are controllable as actuators of a control system.

19. Engine supercharging system according to claim 18 in the form of a two-stage engine supercharging system, in particular a two-stage charge-air and/or exhaust supercharging system for a charge fluid in the form of charge air and/or exhaust gas.

20. Engine supercharging system according to claim 18 or 19, **characterised in that** the low-temperature coolant circuit has at least one high-temperature heat exchanger and at least one low-temperature heat exchanger for the charge fluid.

21. Engine supercharging system according to any of claims 18 to 20, **characterised in that** the high-temperature coolant circuit is designed for engine cooling and/or indirect cooling of the charge fluid.

Fig. 1

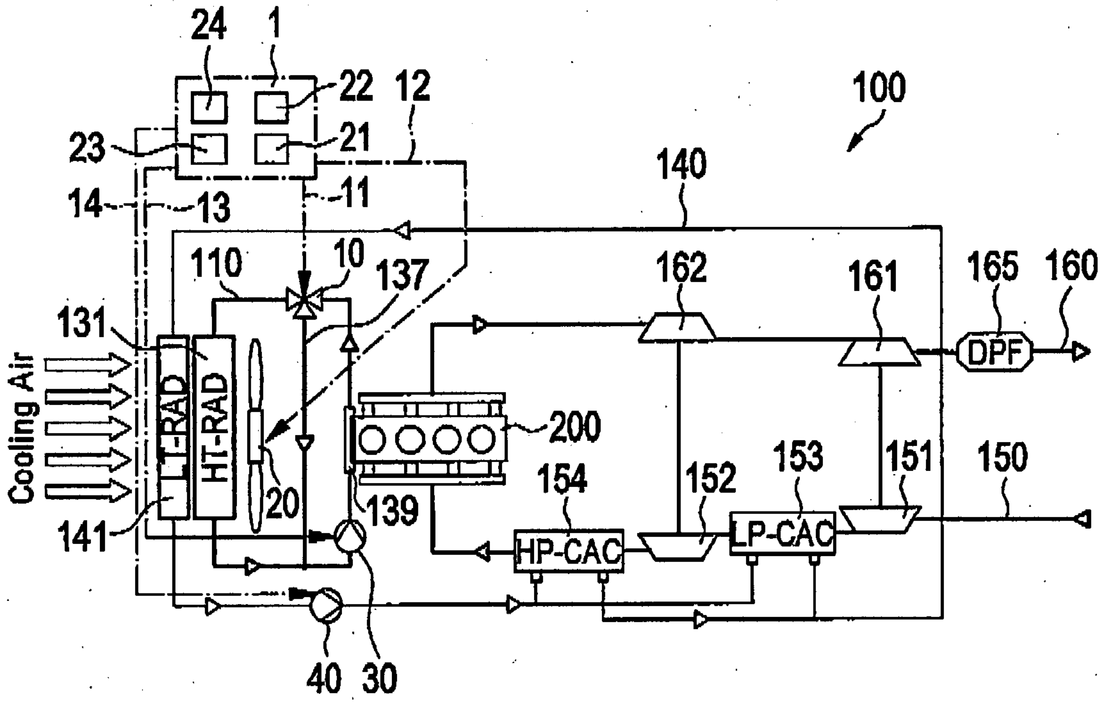


Fig. 2

Charge air cooling temperature as a function of the low-temperature pump (LT-pump) throughput for a specific operating point and given throughput of cooling air

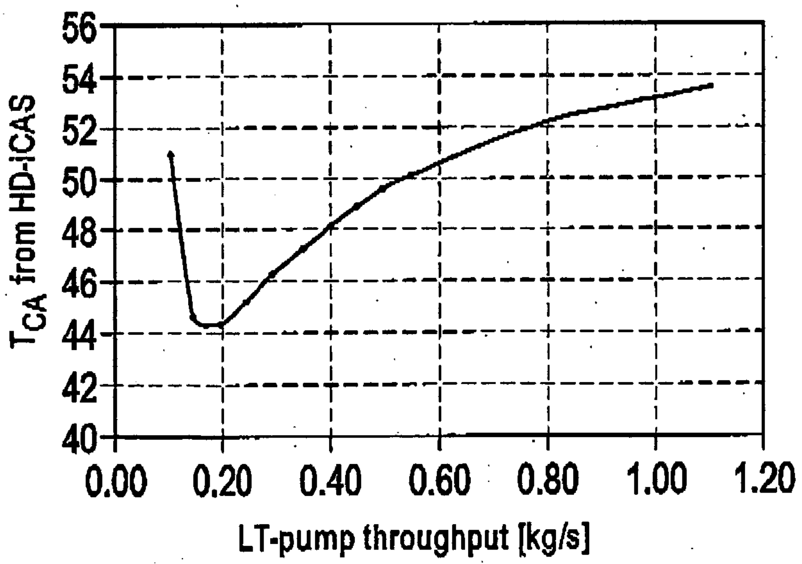


Fig. 3A

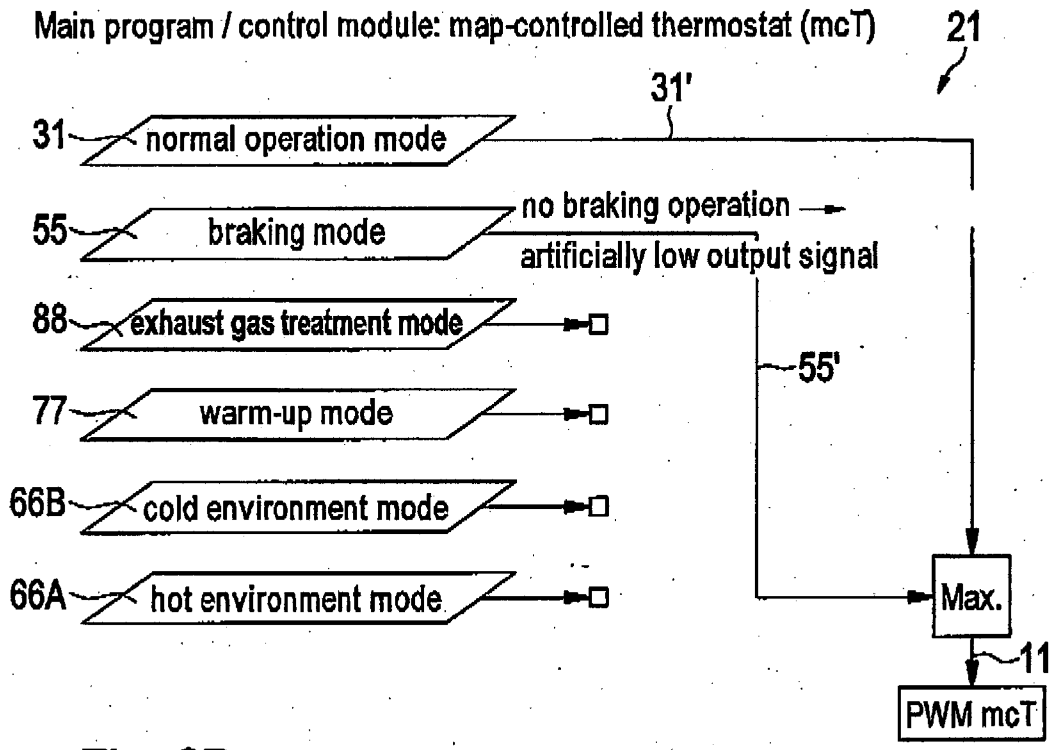

Main program / control module: map-controlled thermostat (mcT)
21
31'
31
normal operation mode
55
braking mode
no braking operation
artificially low output signal
88
exhaust gas treatment mode
55'
77
warm-up mode
66B
cold environment mode
66A
hot environment mode
Max.
11
PWM mcT

Fig. 3B

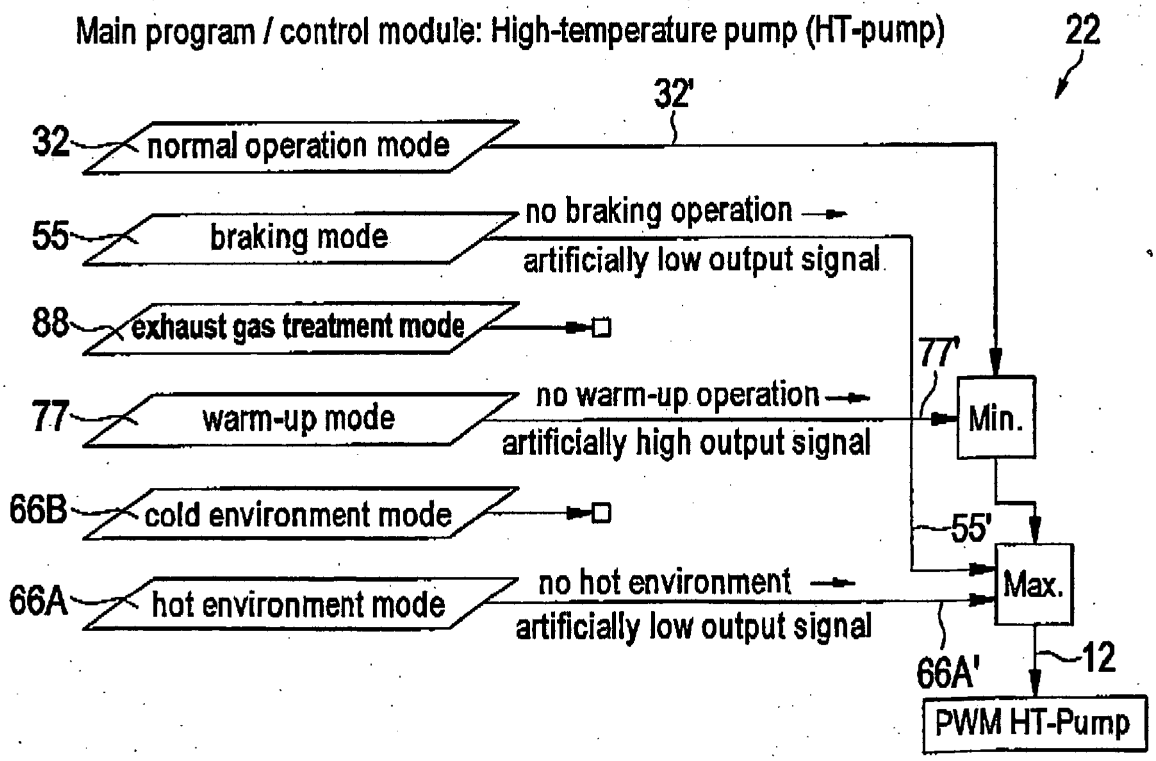

Main program / control module: High-temperature pump (HT-pump)
22
32'
32
normal operation mode
55
braking mode
no braking operation
artificially low output signal
88
exhaust gas treatment mode
77'
77
warm-up mode
no warm-up operation
artificially high output signal
Min.
66B
cold environment mode
55'
66A
hot environment mode
no hot environment
artificially low output signal
Max.
66A'
12
PWM HT-Pump

Fig. 3C

Main program / control module: radiator fan

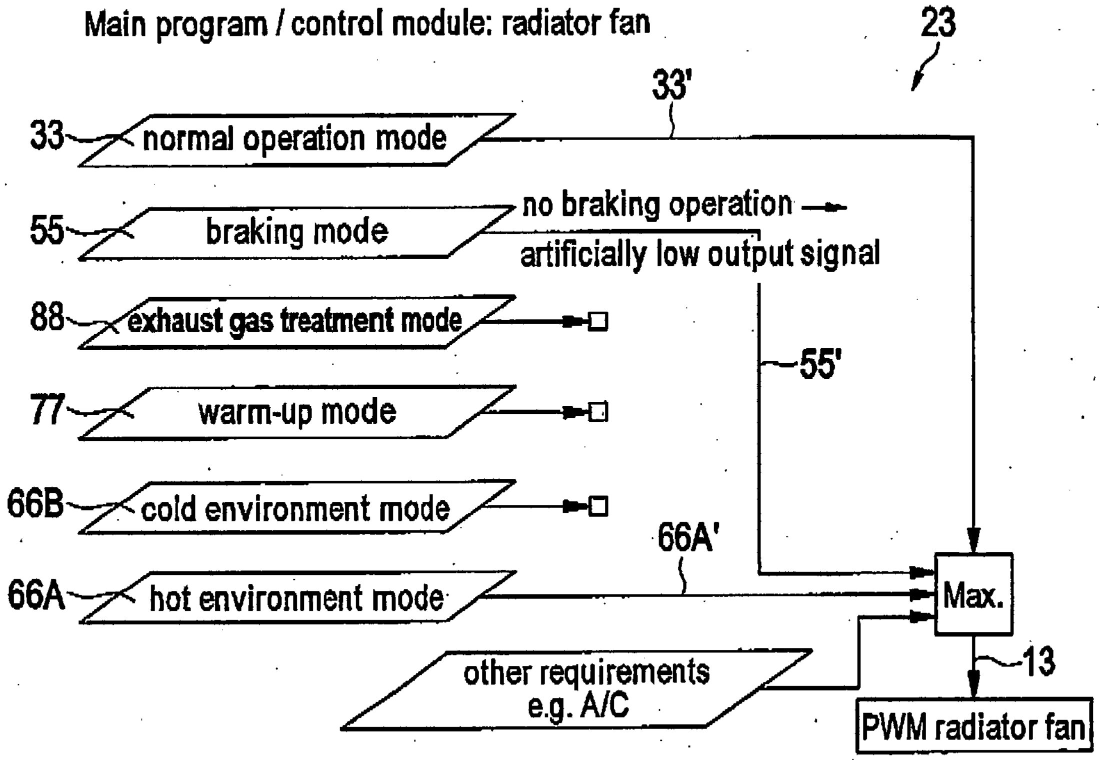


Fig. 3D

Main program / control module: low-temperature pump (LT-pump)

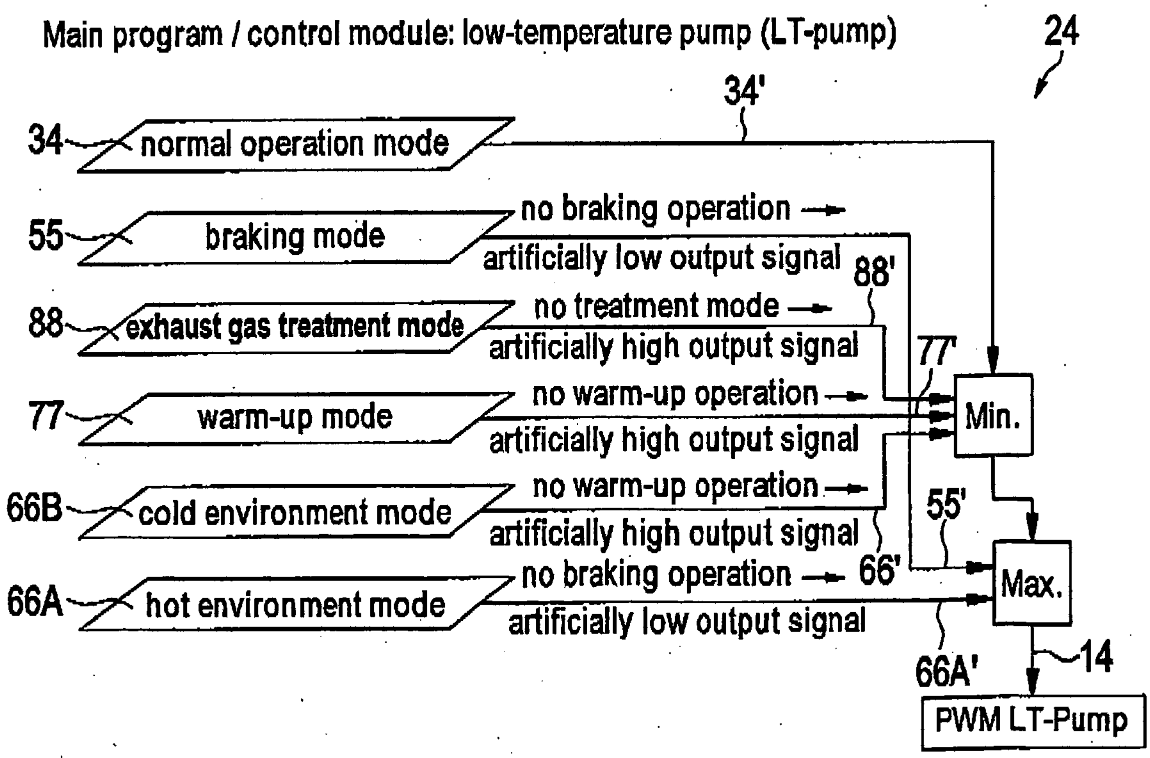


Fig. 4A

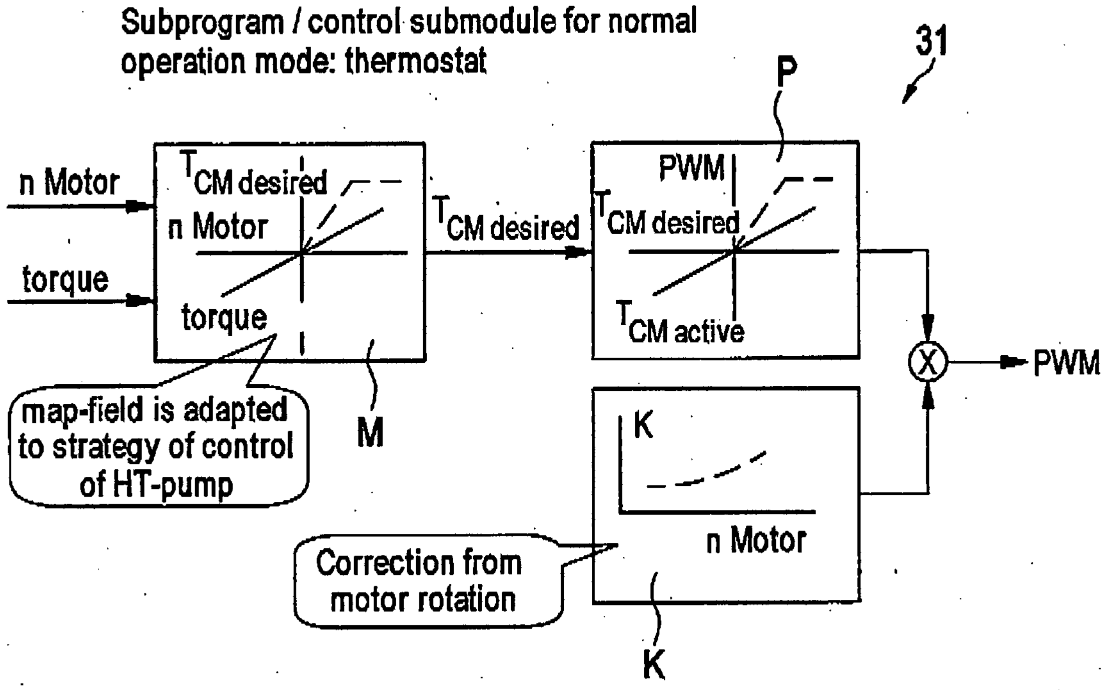

Subprogram / control submodule for normal operation mode: thermostat
31
P
n Motor
torque
TCM desired
n Motor
torque
TCM desired
PWM
TCM desired
TCM active
PWM
map-field is adapted to strategy of control of HT-pump
M
K
n Motor
Correction from motor rotation
K

Fig. 4B

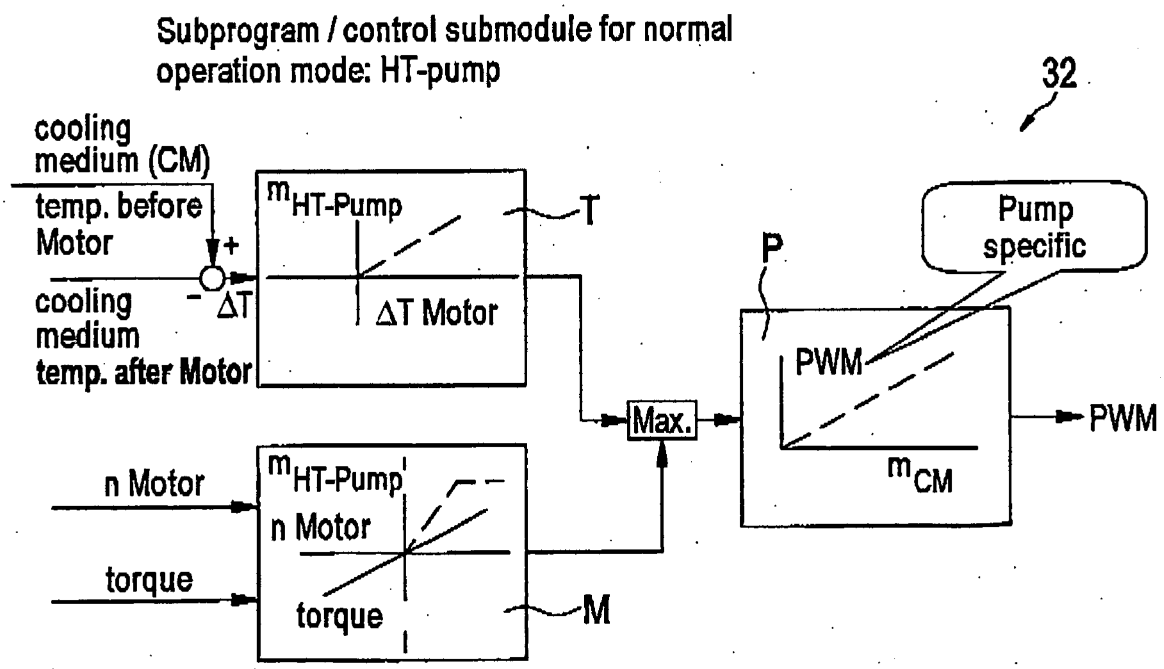

Subprogram / control submodule for normal operation mode: HT-pump
32
cooling medium (CM)
temp. before Motor
cooling medium temp. after Motor
+
-
ΔT
mHT-Pump
ΔT Motor
T
P
Pump specific
PWM
mCM
Max.
PWM
n Motor
torque
mHT-Pump
n Motor
torque
M

Fig. 4C

Subprogram / control submodule for normal operation mode: radiator fan ERS coupling temperature controller

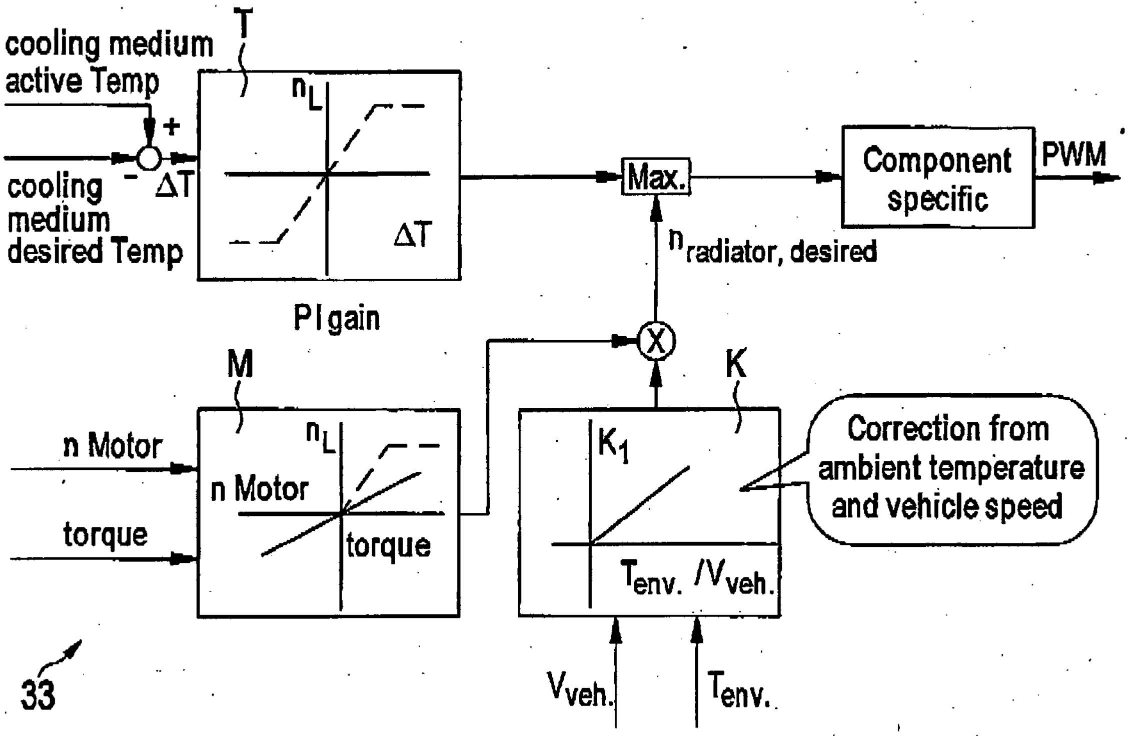


Fig. 4D

Subprogram / control submodule for normal operation mode: LT-pump

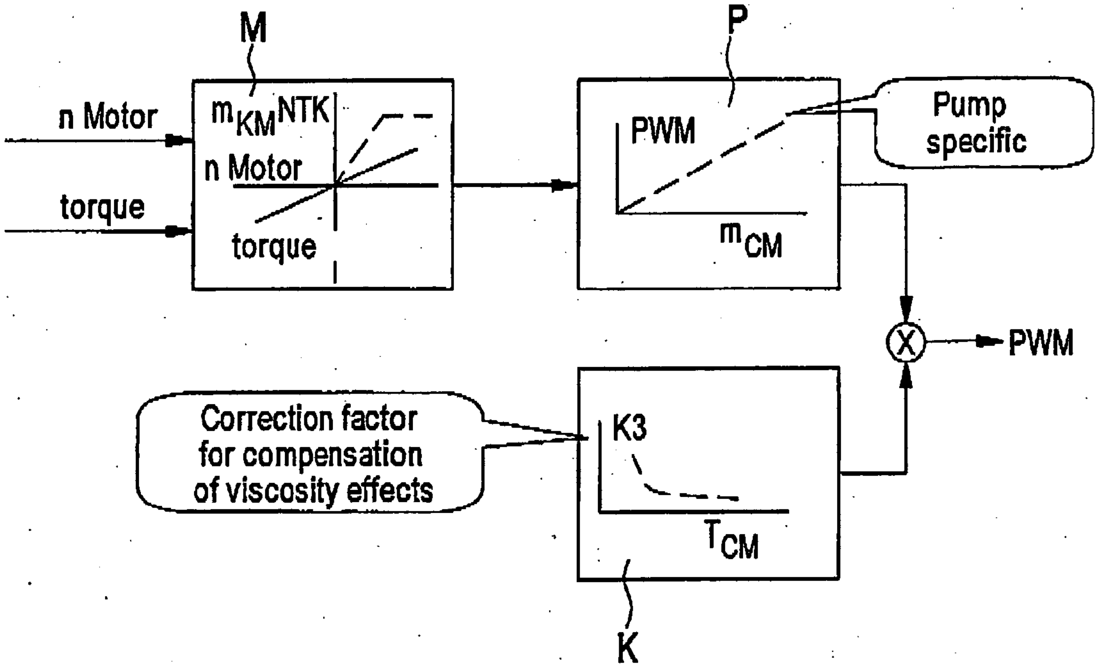


Fig. 5

Subprogram / control submodule for braking mode operation:

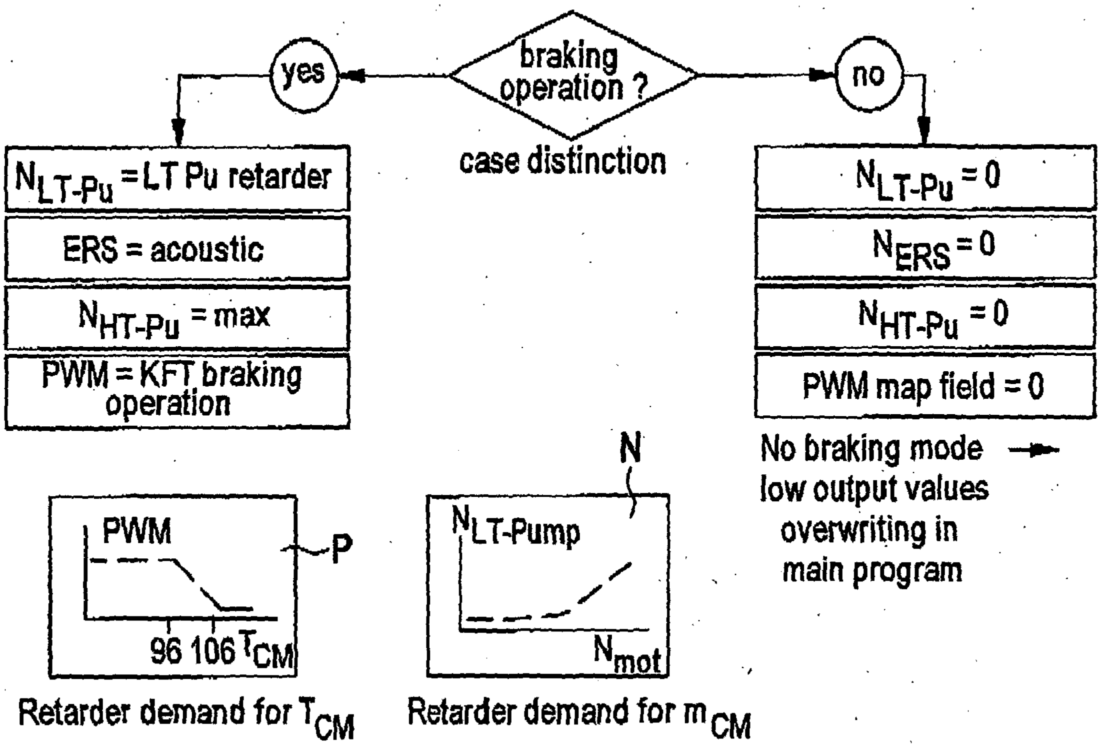


Fig. 6A

Subprogram / control submodule for critical operation mode:
hot invironment mode

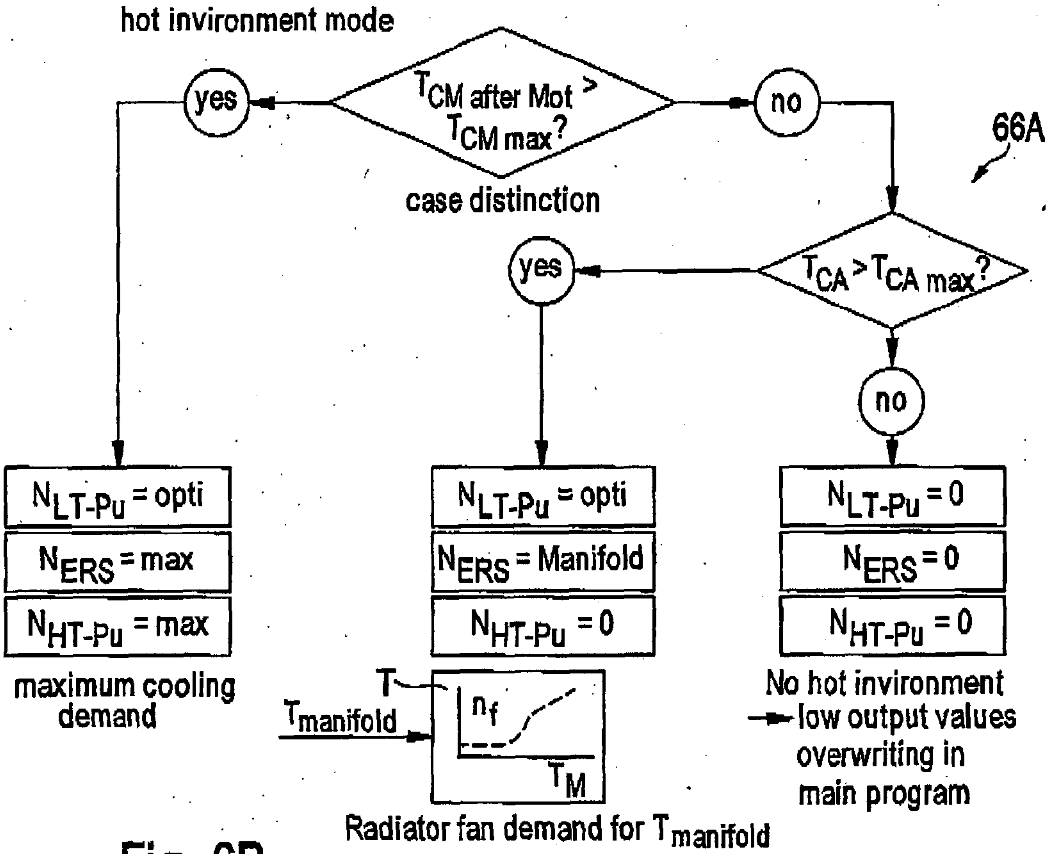


Fig. 6B

Subprogram / control submodule for critical operation mode:
cold invironment mode

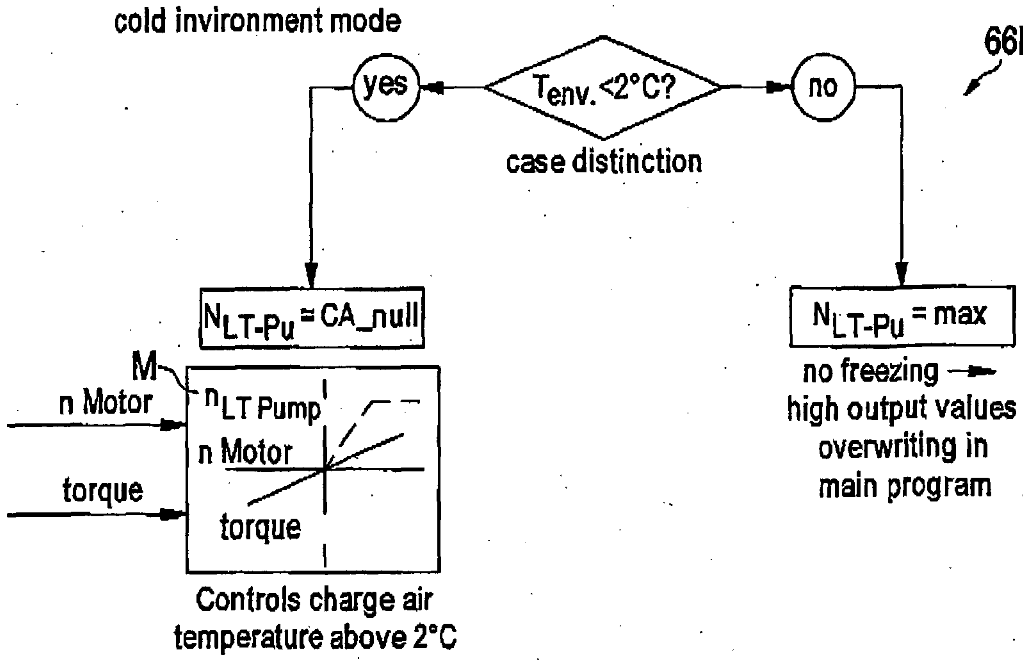


Fig. 7

Subprogram / control submodule for warm-up mode:

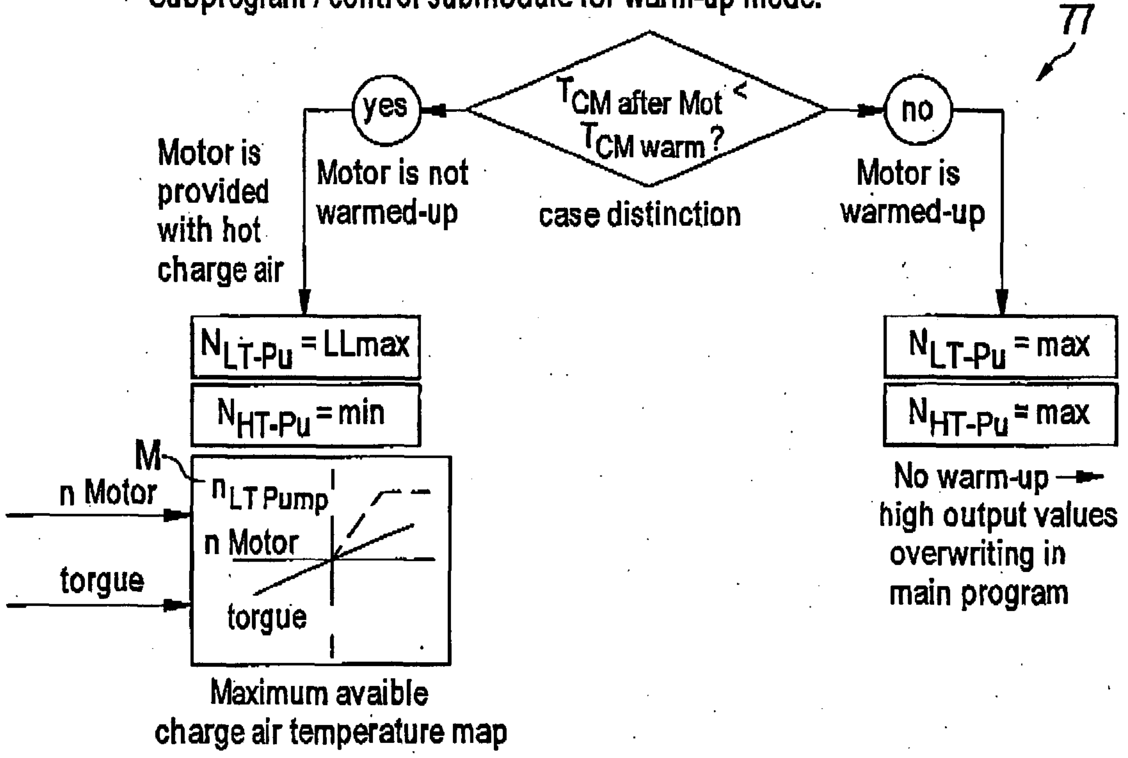
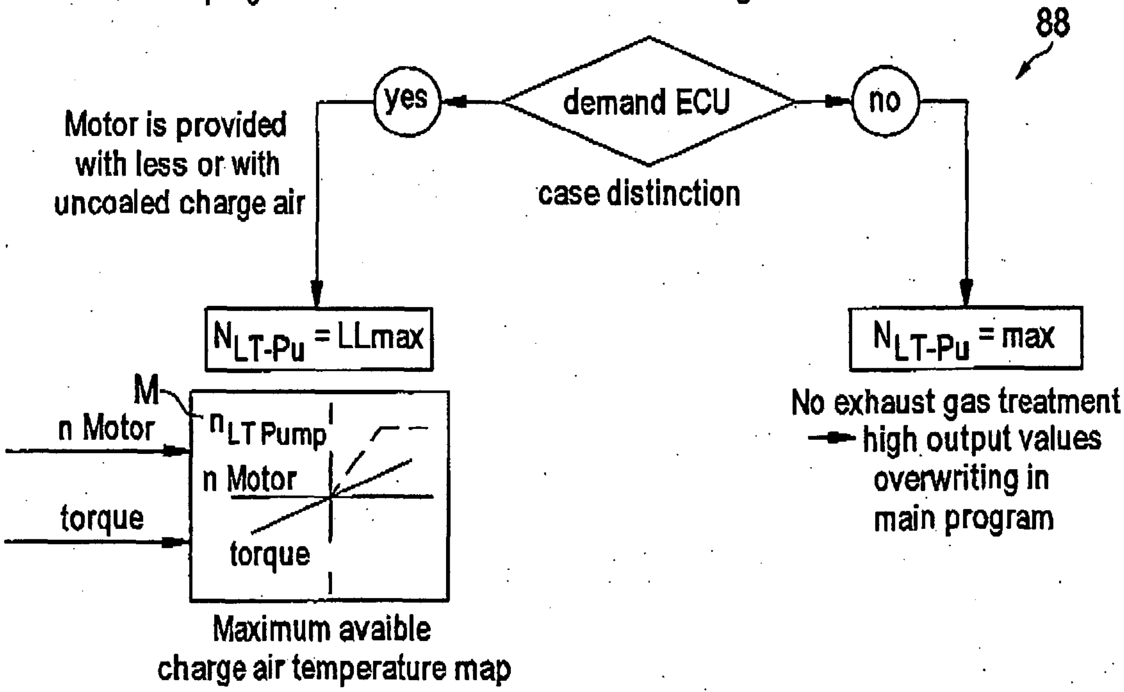


Fig. 8

Subprogram / control submodule for exhaust gas treatment mode:



European Patent Office

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Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	13 August 2008	Matray, J

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EUROPEAN SEARCH REPORT

Application Number
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Place of search	Date of completion of the search	Examiner
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