

DESCRIPTION

5 **Cooling system of a combat vehicle, and pressure cascade for cooling at least
one electronic unit in a combat vehicle by means of a cooling system**

10 The present invention describes a cooling system and a pressure cascade for cooling
at least one electronic unit in a combat vehicle. The electronics to be cooled can be
diverse drive electronics, control electronics and/or sensor electronics in the combat
vehicle. The cooling system itself serves for air conditioning various zones in the
combat vehicle, in particular workstations of the operating personnel.

15 Cooling systems serve for air conditioning in a combat vehicle. Since it can become
very hot in a combat vehicle because of the drives and motors, the concentration and
operating capability of the operating personnel suffers in the heat. In the event of
sunlight on the combat vehicle, this production of heat can be promoted further. This is
especially true in sunny areas of use.

20 In order to counteract the production of heat, cooling systems are required. The latter
are first of all intended to make a bearable working climate possible for the operating
personnel in the combat vehicle. However, within the context of this invention, the
cooling system can also serve for cooling electronic units.

25 A cooling system for combat vehicles is known, for example, from DE 34 45 336 C2. In
this case, cooled compressed air is supplied to a cab. The cooling is undertaken via a
compressor, and the compressed air is produced via turbines.

30 Electronic units are necessary in combat vehicles in order to control electric power
units, such as drives. Not inconsiderable quantities of heat can arise here, depending
on the power consumption of the power units. Since said heat which arises, which is in
the form of a power loss, opposes the efficiency of the electronic units, it is imperative,
in the case of electronic units, to dissipate the arising heat as readily as possible or to
cool the corresponding electronic unit.

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The combat vehicles mentioned here likewise comprise armored combat vehicles.

Electronic units, for example for activating the drives in a combat vehicle, are customarily arranged in compartments provided specially for them in the combat vehicle, and therefore heat exchange via the air through the demarcated compartment often proves difficult. The heat which is produced, specifically in the case of the electronic units for the drives, can be of such a magnitude that it can only be inadequately removed by conventional cooling via cooling fins and/or via outputting heat to the chassis of the combat vehicle. In order to keep the resulting power loss low, additional cooling means have to be provided for the electronic units.

- For example, DE 10 2012 100 906 A1 presents a cooling means for electronic units. In this laid-open application, a cooling system within an installation compartment for an electronic unit is described, in which a ventilator is used to conduct an air flow past the electronic units to be cooled so that the heat is conducted away by the air flow. However, for this purpose, a corresponding cooling unit with a ventilator has to be constructed within the installation compartment.

A further cooling possibility is described in DE 10 2010 013 331 A1. A cooling coil, through which cooling fluid is conducted, is operatively connected to the installation compartment. By means of this construction, the installation compartment is cooled per se from the outside and therefore indirectly so are the internal electronic units which are to be cooled.

Similarly, DE 10 2008 055 849 B4 describes a corresponding cooling of the air in an interior compartment of an armored vehicle, wherein general interior compartments in the armored vehicle are cooled here rather than any electronic units specifically. The cooling device presented here is therefore of correspondingly complex design.

The present invention is based on the object of ensuring cooling of the air in a combat vehicle via a cooling system, wherein the cooling system is intended to be fitted in a space-saving manner. It is also the object of the present invention to ensure the cooling of at least one electronic unit using the existing cooling system with as little technical outlay as possible and with a high degree of efficiency.

This object is achieved with the characterizing part of claim 1 and of claim 9. It is proposed to provide a cooling plant in an existing compartment of a combat turret of a combat vehicle, wherein the cooled air is distributed via a hose system to the zones to

be cooled in the combat vehicle. A cooling plant which is present is furthermore used for cooling electronic units in a combat vehicle. The cold and dehumidified air which is generated by the cooling plant and is distributed via hoses in the combat vehicle is likewise added to the installation compartment of the electronic units via at least one
5 additional hose. As a result, positive pressure arises in the installation compartment. At the same time, the air heated by the electronic unit is sucked off to the cooling plant via an aperture to the cooling plant by the negative pressure prevailing in the cooling plant.

Modern combat vehicles have at least one cooling plant in order primarily to air
10 condition the crew compartment. Decontamination means are often provided at the same time in order to keep the air specifically in the crew compartment clean and compatible for humans, for example in respect of ABC contaminations. This is advantageously undertaken by means of filters. Such an ABC protection is described, for example, in DE 10 2008 017 521 A1.

15 The cool air produced by the cooling plant is transported via a hose system to the necessary zones in the combat vehicle. Means for regulating the cooled air are often provided in situ, in the compartment to be cooled of the combat vehicle. It is thus possible to regulate the supply of the cooled air, for example in the crew compartment,
20 by means of a valve or a flap.

The hose system of the cooling system runs from the cooling plant to the zones to be cooled in the combat vehicle. Since the cooling plant is preferentially introduced into a combat turret, the hoses also run in the combat turret so as not to restrict the freedom
25 of movement of the combat turret. If, however, zones in the chassis of the combat vehicle are also intended to be reached with the cooled air, joint parts in the hose permit the free movement of the combat turret. In this case, the joint part is fitted in the axis of rotation of the combat turret.

30 Air is supplied by air transport means, such as, for example, ventilators. The air flow to the individual zones to be cooled can be undertaken by means for regulating the air at the individual zones. It is also possible to control and/or to regulate the entire supply of air in an accessible location in the combat vehicle. For this purpose, a control panel is preferably introduced into the cooling system in the unbranched part of the hose
35 system behind the cooling plant.

It is possible by means of such a control panel to adjust the strength of the air flow in the hose system, and also the temperature of the cooled air. Optical and/or acoustic signal transmitters are likewise integrated in the control panel in order to indicate to the operator possibilities for optical and/or acoustic adjustment, or warnings.

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The cooling plant of the combat vehicle is arranged in a separate compartment in the combat turret of the combat vehicle. It is proposed preferably to provide the cooling plant in an equipment compartment. Equipment compartments, i.e. spaces for equipment parts, such as sleeping bags, camouflage nets, etc., are frequently present in combat vehicles and can be used for the installation of the cooling plant. The provision of separate cooling compartments is thereby not required, and the cooling plant is installed in a space- and time-saving manner. In the case of a Leopard tank, for example, the compartment between a rear door and a flap to an electronics compartment is suitable for the installation of the cooling plant. For the supply of air, it is advantageous if access to the compartment of the cooling plant from outside the combat turret is ensured, such as, for example, in the case of the abovementioned equipment compartment. The equipment items themselves can then be stowed at another location in the combat vehicle.

20 The cooling system according to the invention comprises at least one compressor and liquefier unit, at least one air treatment apparatus and a hose system for distributing the cooled air in the combat vehicle. A heat flow from the air to be cooled is absorbed in the air treatment apparatus with the aid of a refrigerant. The compressor and liquefier unit serves for cooling the heated refrigerant, for example with the aid of ventilators.

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The hose system guides the cooled air from the cooling system to the individual zones in the combat vehicle that require cooling. These are in particular the compartments for the operating personnel of the combat vehicle. However, other compartments in the combat vehicle, such as, for example, equipment compartments may also need cooling.

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In a development of the invention, the cooled air produced by the cooling plant is now also used to cool electronic units in the combat vehicle, such as, for example, drive electronics of a weapon system. Corresponding electronic units are often arranged in installation compartments provided for this purpose, in order to protect said electronic units against external influences.

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The proposed cooling system therefore can advantageously be used not only for cooling the various zones in the combat vehicle, but also for cooling the electronic units. This makes it possible to avoid the technical outlay on designing dedicated cooling for each installation compartment of the electronic unit.

The hose system which distributes the cooled air in the combat vehicle is now supplemented, according to the invention, by an additional hose which additionally introduces the cooled air produced by the cooling plant into the installation compartment of the corresponding electronic unit.

For this purpose, an additional hose is added to the hose system. However, air can also be branched off from a hose which is already present by means of a Y piece. It is thereby possible, for example, also to use the air supplied to the crew compartment to cool the corresponding electronic unit.

In this example, the Y piece is introduced before that end of the hose which supplies the air cooled by the cooling plant to the crew compartment, in order to conduct the cooled air, which passes to the crew compartment, also to the installation compartment of the electronic unit. In this case, the efficiency of the cooling is dependent on how much air is supplied by the regulating means to the crew compartment or to the compartment from which the cooled air is branched.

The additional hose which supplies the air cooled by the cooling plant to the installation compartment of the corresponding electronic unit can be supplied to the installation compartment through a hole in a wall of the corresponding installation compartment or through openings which are already present, if the installation compartment is not self-contained.

In a preferred embodiment, the additional hose is arranged below the electronic unit to be cooled and the cooled air is output in the direction of the electronic unit. For this purpose, the opening in the hose can point in the direction of the electronic unit. The hose can also have openings in order to be able to output the cooled air radially in regions to the hose.

In a further preferred embodiment, the hose in the installation compartment is provided at least in regions with an air-permeable sheath in order to output the air to the installation compartment via said air-permeable region.

5 By means of the supply of the cooled air, a positive pressure arises in the installation compartment. By means of the transporting away of cooled air from the cooling plant, a corresponding negative pressure arises in the compartment of the cooling plant. Said negative pressure is now used according to the invention to conduct away the hot air from the installation compartment of the corresponding electronic unit.

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For this purpose, an aperture from the installation compartment of the corresponding electronic unit to the compartment of the cooling plant is provided, said aperture preferably being located above the electronic unit to be cooled. This has the advantage that the rising hot air can be better transported away.

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Said aperture can arise by the fact that, in the case of the compartment of the cooling plant and installation compartment being located next to each other, a hole is introduced only in regions into the wall between the two compartments.

20 In the case of the compartment of the cooling plant and installation compartment not being situated directly next to each other, the aperture can also be provided by means of a connecting piece of the two compartments. This can also be a hose or structural means of the combat vehicle. For this purpose, it is likewise required to provide further access in the form of a hole to the compartment of the cooling plant.

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By means of this arrangement, a pressure cascade arises between the installation compartment of the respective electronic unit and the compartment of the cooling plant. By means of the supply of the cooled air in the installation compartment, a positive pressure arises in the latter, and, by means of the cooled air being transported away from the compartment of the cooling plant, a negative pressure arises in said compartment. By means of the supply of the cooled air through the cooling hose into the installation compartment and the aperture from the installation compartment to the compartment of the cooling plant, both pressures act on the installation compartment and make the pressure cascade possible.

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The electronic units to be cooled in a combat vehicle can also comprise, in addition to drive electronics of a weapon system, the control electronics of a combat vehicle, and also further drive electronics present in the combat vehicle. In this connection, the described drive electronics comprise electronic units for the lateral drive and/or the vertical drive of a combat tower and/or weapon system of the combat vehicle. The lateral drive is used here for rotating the combat turret and the vertical drive for elevating the weapon barrel of the weapon.

The pressure cascade according to the invention is also suitable, by means of its construction, to cool the drive electronics of an electronic weapon tracking system (EWNA), for example of the Leopard tank.

Furthermore, the electronic units to be cooled can likewise comprise sensors in the combat vehicle, such as, for example, acceleration sensors, weapon gyroscopes, turret gyroscopes and/or position transmitters for the drive.

For better heat exchange between the electronic units to be cooled and the surrounding air, the electronic units can be provided with cooling fins. For transport of the cooled air through the hose system, ventilators and/or suitable nozzles can be used.

Further features of the present invention emerge from the drawings, in which:

figure 1: shows a perspective illustration of a combat vehicle with a cooling plant,

figure 2: shows a perspective ghosted view of a combat vehicle with a cooling system,

figure 3: shows a lateral ghosted view of a combat vehicle with a cooling system,

figure 4: shows a perspective ghosted view of a combat vehicle with a cooling system and operating personnel,

figure 5: shows a region of a combat turret of a combat vehicle in a schematic illustration with interior parts, and

figure 6: shows an electronic unit to be cooled in a corresponding installation compartment according to the invention.

Figure 1 shows a combat vehicle 20, consisting of a chassis 15 and at least one combat turret 14. The combat turret comprises a weapon system 16 and a weapon barrel 17. It is also shown where a cooling plant 10 for the cooling system according to the invention is preferably installed. However, the cooling plant 10 can also be arranged in another compartment 18 in the combat vehicle. Equipment compartments 21 with items of equipment are frequently present in a combat tank 20. These existing equipment compartments 21 can be modified for the cooling plant 10 and can thus serve as a compartment 18. The cooling plant 10 consists here at least of a compressor and liquefier unit 10.1 and an air treatment apparatus 10.2.

The compressor-liquefier unit 10.1 ensures cooling of the air. The air treatment apparatus 10.2 is responsible for cleaning the air. Simple air filters can be provided as the air treatment apparatus 10.2, but so too can air treatments for ABC uses.

A cooling plant 10 which is already installed in the combat vehicle 20 can be seen in figure 2. For a cooling system according to the invention, a hose system 22 is attached to the cooling plant 10 and distributes the cooled air produced by the cooling plant 10 through the combat vehicle 20. The hose system 22 is branched for this purpose such that the cooled air can pass simultaneously to a plurality of zones in the combat vehicle 20.

In order to regulate the cooled air, a control panel 23 is provided which regulates all of the cooled air. In order to transport the cooled air, ventilators, for example, can be provided. In addition, regulating means 24 can be provided at the individual ends of the hose system 22 in order also to regulate the supply of air at an individual zone. An alternative compartment 18 for the cooling plant is also shown in figure 2.

Figure 3 for this purpose shows a cooling system according to the invention which is introduced into the combat vehicle 20 consisting of chassis 15 and combat turret 14. The cooling plant 10 is installed in a compartment 18 in the combat turret 14 and the cooled air is distributed from the cooling plant 10 via a hose system 22. A control panel 23 is provided for regulating the entire cooling system.

Figure 4 likewise shows a cooling system installed in the combat vehicle 20, wherein operating personnel are shown here in order to illustrate some of the zones to be cooled in the combat vehicle 20. The cooled air from the cooling plant 10 is supplied to the individual zones in the combat vehicle 20 via the hose system 22. The zone of the driver of the combat vehicle 20 (MKF) is arranged here in the lower region of the turret slewing ring since the best cooling can be expected here.

The air is regulated via a central control panel 23, and optionally via regulating means at the ends of the hose system 22. The zones shown for operating personnel are all arranged in the combat turret 14. Since the cooling plant 10 is likewise arranged in the combat turret 14, the freedom of movement of the combat turret 14 is not restricted. If zones in the chassis 15 of the combat vehicle 20 are also intended to be cooled, it is proposed to arrange a hose of the hose system 22, the hose being arranged centrally in the axis of rotation of the combat turret 14 and optionally having a joint piece, so that the freedom of movement of the combat turret is not restricted.

Figure 5 schematically shows a region of the combat turret 14 of the combat vehicle 20 which is not illustrated specifically here and in which the pressure cascade according to the invention is usable. Drive electronics 1 which are to be cooled and which are introduced into an installation compartment 25 provided for them can be seen. Furthermore, the region of the cooling plant 10, namely compressor and liquefier unit 10.1 and air treatment apparatus 10.2, is visible.

The control electronics 5, and also an acceleration sensor 3, a weapon gyroscope 8 and a turret gyroscope 9 are shown as likewise possible electronic units to be cooled. Depending on the embodiment of said individual electronic units 1, 3, 5, 8, 9, the latter have to be cooled if the need arises, and therefore a pressure cascade according to the invention is usable on said electronic units 1, 3, 5, 8, 9. The starting point for the further course of the description of the figures is that at least the drive electronics 1 and optionally the control electronics 5 are intended to be cooled.

The combat turret 14 which is shown of the combat vehicle 20 is integrated in a chassis 15, not shown, wherein the combat vehicle 20 has a cooling system which is arranged in the combat turret 14. From the cooling plant 10, which is arranged in a compartment 18, the cooled air is distributed via a hose system 22 in the combat vehicle 20, i.e. in the chassis and in the turret. The above-described equipment compartment 21 can

preferably act as the compartment 18. According to the invention, a pressure cascade is now built up via the hose system 22 in the installation compartment 25 of the electronic unit 1, 5 to be cooled, in order to cool the electronic unit 1, 5 via the cooled air of the cooling system.

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The drive electronics 1 which are to be cooled, shown in figure 5, control the lateral drive 2 and the vertical drive 4 of the weapon system 16 of the combat vehicle 20. In this example which is shown, the lateral drive 2 rotates the combat turret 14 and the vertical drive 4 lifts and lowers the weapon barrel 17 of the weapon system 16.

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The control electronics 5 which are optionally likewise to be cooled translate the commands from the control unit 7 for transmitting to the drive electronics 1. It is also possible to activate further control devices 6 by means of the control electronics 5.

15 Figure 6 shows a possible realization of the pressure cascade according to the invention in an installation compartment 25 of the electronic unit 1, 5, shown by way of the example of the drive electronics 1.

A section through the installation compartment 25, in which the drive electronics 1 are located, can be seen. The latter are equipped for better output of the arising heat by means of cooling fins. From the existing hose system 22 of the cooling system, at least one hose 12 is introduced into the installation compartment 25 and, in the present case, is arranged below the drive electronics 1.

25 The hose 12 has openings 13 via which the air can be output into the installation compartment 25. Said openings 13 can constitute holes in the hose 12, specifically can be arranged at the end of the hose 12 and also radially in the sheath 19 of the hose. However, as illustrated, the sheath 19 of the hose 12 can also be configured to be air-permeable in regions.

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In all cases, air from the cooling plant 10 is supplied by the hose 12 to the installation compartment 25 and therefore also to the drive electronics 1 to be cooled. A positive pressure thus arises in the installation compartment 25.

35 Furthermore, an aperture 11 is provided in the installation compartment 25 of the drive electronics 1 to be cooled, said aperture connecting the installation compartment 25 to

the compartment 18 of the cooling plant 10. Said aperture 11 can be designed as a simple hole in the wall if the compartment 18 of the cooling plant 10 is arranged directly next to the installation compartment 25. Otherwise, a connecting hose or other structural means of the combat vehicle is used in order to connect the installation
5 compartment 25 to the compartment 18 of the cooling plant 10.

Since the air in the compartment of the cooling plant 10 is cooled and subsequently transported away by the hose system 22, a negative pressure prevails in the compartment of the cooling plant 10. Said negative pressure also acts on the
10 installation compartment 25 through the aperture 11. Owing to the fact that the supplied, cooled air in the installation compartment 25 produces a positive pressure and the aperture a negative pressure, the supplied, cooled air is conducted past the drive electronics 1 to be cooled and removed again via the aperture 11.

15 It is of importance in the case of this pressure cascade arrangement that the supplied air is guided past the drive electronics 1 to be cooled on the way to the aperture, in order to be able to conduct away the heat of said drive electronics.

This construction produces a pressure cascade which, without great technical outlay,
20 provides cooling of the electronic elements to be cooled using the existing means of a combat vehicle.

The invention is not restricted to the features mentioned in the description. On the contrary, further refinement possibilities are conceivable. A plurality of cooling plants
25 and cooling compartments could be present in combat vehicles. Also conceivable would be control electronics which regulate a minimum supply of air in the installation compartment, and corresponding sensors which determine the temperature which prevails in the installation compartment in order then to be able to correspondingly regulate the supply of air.

List of reference numbers

	1	drive electronics
5	2	lateral drive
	3	acceleration sensor
	4	vertical drive
	5	control electronics
	6	control device
10	7	control unit
	8	weapon gyroscope
	9	tower gyroscope
	10	cooling plant
	10.1	compressor and liquefier unit
15	10.2	air treatment apparatus
	11	aperture
	12	cooling hose
	13	openings in 12
	14	combat turret
20	15	chassis
	16	weapon system
	17	weapon barrel
	18	compartment
	19	sheath
25	20	combat vehicle
	21	equipment compartment
	22	hose system
	23	control panel
	24	regulating means
30	25	installation compartment

P a t e n t C l a i m s

1. A pressure cascade for cooling at least one electronic unit (1, 5) in a combat vehicle (20),

5 having at least one installation compartment (25) for the electronic unit (1, 5),
 having at least one cooling system, and a compartment (18) in which a cooling plant (10) of the cooling system is arranged,
 wherein a negative pressure is produced in the compartment (18) of the cooling plant (10) by the cooled air which is transported away from the cooling plant (10),

10 **characterized**
 in that the cooling plant comprises a hose system (22) which supplies the air cooled by the cooling plant (10) to zones to be cooled in the combat vehicle (20),
 in that cooled air is supplied by at least one hose of the hose system (22) to the installation compartments (25), as a result of which a positive pressure arises in

15 the installation compartments (25),
 in that an aperture (11) leads from each installation compartment (25) to the compartment (18) of the cooling plant (10), as a result of which the negative pressure acts on the installation compartments (25) and ensures that the air supplied to the cooling plant (10) is transported away.

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2. The pressure cascade as claimed in claim 1, **characterized in that** the air supplied to the installation compartments (25) is branched off from the remaining hoses by at least one additional hose (12).
- 25 3. The pressure cascade as claimed in claim 2, **characterized in that** the branching is undertaken by a Y-shaped hose piece which is introduced into one of the existing hoses.
4. The pressure cascade as claimed in one of claims 1 to 3, **characterized in that**

30 the hose (12) in the installation compartment (25) has openings (13) via which the cooled air is supplied to the installation compartment (25).
5. The pressure cascade as claimed in one of claims 1 to 4, **characterized in that**

35 the hose in the installation compartment (25) has an at least partially air-permeable sheath (19).

6. The pressure cascade as claimed in one of claims 1 to 5, **characterized in that** the electronic units (1, 5) comprise the drive electronics (1) of a weapon system of the combat vehicle and/or the control electronics (5) of the combat vehicle (20).
7. The pressure cascade as claimed in one of claims 1 to 6, **characterized in that** the electronic units (1, 5) control the drives (2, 4) of a weapon system (16) and/or of a combat turret (14) of the combat vehicle (20).
8. The pressure cascade as claimed in one of claims 1 to 7, **characterized in that** existing sensors in the combat vehicle (20) are likewise cooled as an electronic unit, namely an acceleration sensor (3) and/or a weapon gyroscope (8) and/or a tower gyroscope (9).
9. The pressure cascade as claimed in one of claims 1 to 8, **characterized in that** the electronic unit (1, 5) has cooling fins by means of which improved heat exchange between electronic unit (1, 5) and cooled air is ensured.
10. The pressure cascade as claimed in one of claims 1 to 9, **characterized in that** the cooled air is transported through the hoses by ventilators in the cooling plant (10).
11. The pressure cascade as claimed in one of claims 1 to 10, **characterized in that** the compartment (18) in which the cooling plant is arranged is an equipment compartment (21) and is accessible from outside the combat turret (14).
12. A cooling system for cooling various zones in a combat vehicle (20),
Wherein the combat vehicle (20) is constructed from a chassis (15) and at least one rotatable combat turret (14) and
has a compartment (18) in the combat turret (14),
characterized
in that a pressure cascade as claimed in one of claims 1 to 11 is provided,
in that at least one cooling plant (10) is introduced into the compartment (18),
wherein the cooling plant (10) comprises at least one compressor and liquefier unit (10.1) and at least one air treatment apparatus (10.2),

in that a hose system (22) conducts the air cooled by the cooling plant (10) to the zones in the combat vehicle, wherein the hose system (22) consists of a plurality of branched hoses, and

in that the cooling plant (10) produces an air flow which is conducted through the hose system (22) to the zones.

13. The cooling system as claimed in claim 12, **characterized in that** the air treatment apparatus (10.2) is configured in such a manner that it processes even ABC contaminated air so as to be breathable, i.e. air contaminated due to atomic, biological and/or chemical threat.

14. The cooling system as claimed in either of claims 12 and 13, **characterized in that** the zones in the combat vehicle (20) comprise compartments for the operating personnel.

15. The cooling system as claimed in one of claims 12 to 14, **characterized in that** the zones in the combat vehicle (20) comprise installation compartments (25) of electronic units.

16. The cooling system as claimed in one of claims 12 to 15, **characterized in that** a control panel (23) is provided via which the air flow and/or the temperature of the air flow in the hose system (22) can be regulated.

17. The cooling system as claimed in claim 16, **characterized in that** the control panel (23) has means for regulating the air flow, and also optical and/or acoustic indicators.

18. The cooling system as claimed in one of claims 12 to 17, **characterized in that** the hose ends of the hose system (22) likewise have means for regulating (24) the air flow.

19. The cooling system as claimed in one of claims 12 to 18, **characterized in that** the compartment (18) in which the cooling plant is arranged is an equipment compartment (21) and is accessible from outside the combat turret.

20. A combat vehicle (20) comprising a chassis (15) and at least one combat turret (14),

having at least one compartment (18) in the combat turret (14),

characterized

5 in that a cooling system as claimed in one of claims 12 to 19 is provided.

21. A combat vehicle comprising a chassis (15) and at least one combat turret (14),

having at least one electronic unit (1, 5) which is fitted in an installation compartment (25),

10 **characterized**

in that a pressure cascade as claimed in one of claims 1 to 11 is provided.