May 20, 1941. W. TRAUPEL 2,242,767

GAS TURBINE PLANT

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Fig. 1,

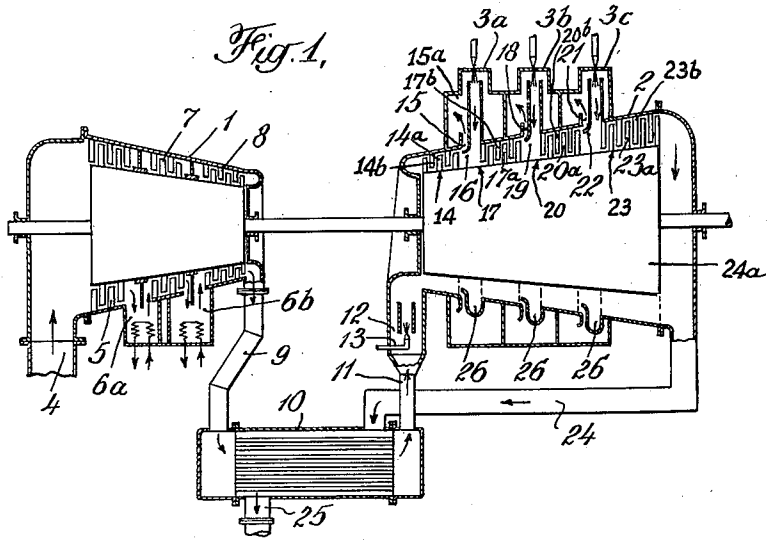


Fig. 2,

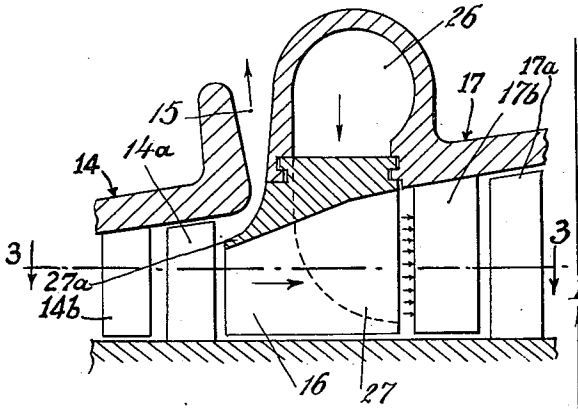


Fig. 4,

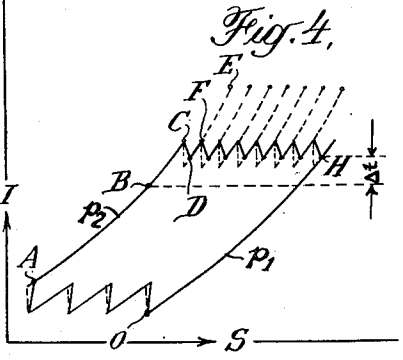
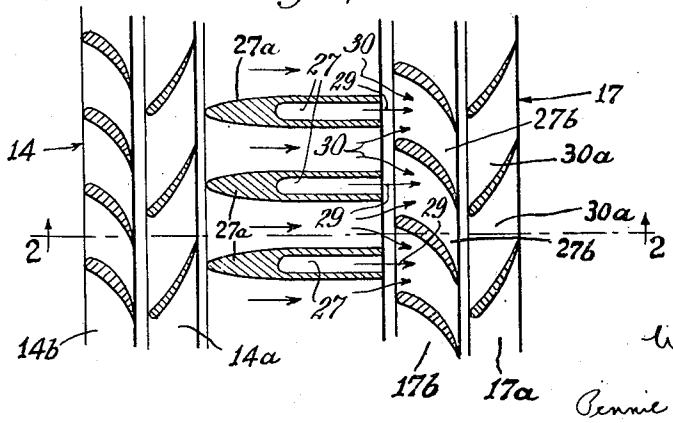


Fig. 3,



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Fig. 5,

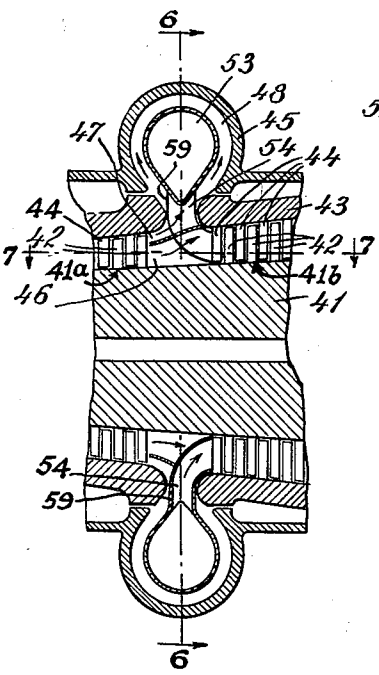


Fig. 6,

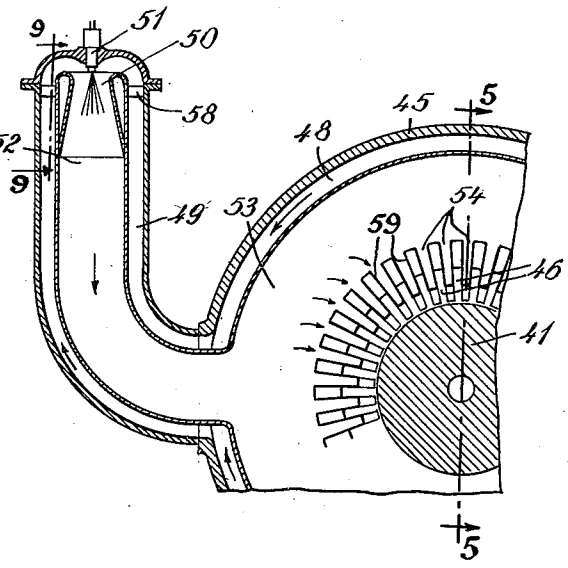


Fig. 7.

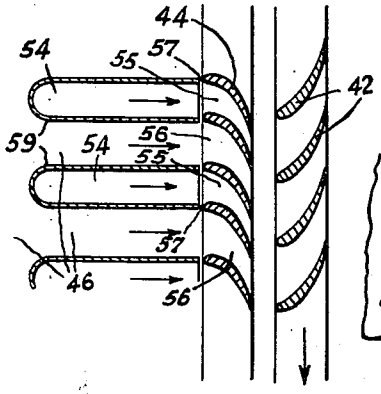
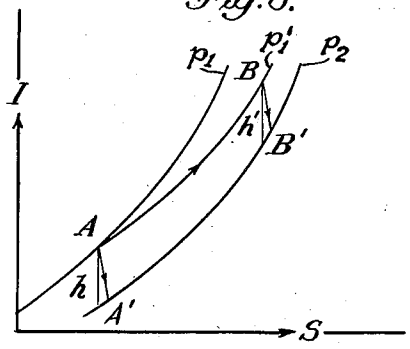


Fig. 8.



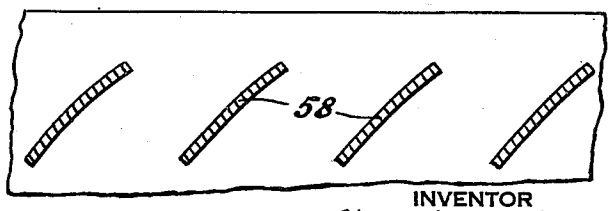


Fig. 9.

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UNITED STATES PATENT OFFICE

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GAS TURBINE PLANT

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Application April 5, 1939, Serial No. 266,229
In Switzerland April 7, 1938

6 Claims. (Cl. 60—41)

The invention refers to a gas turbine plant in which the air used for combustion is compressed by a multi-stage compressor and the power gas is expanded in a multi-stage gas turbine with intermediate heating between separate stages. The invention consists in that only a part of the gas flowing from one stage of the turbine to the next is taken from the turbine and heated in an intermediate reheater with the help of a burner and then mixed with the gas not taken from the turbine, in order to allow the combustion in the intermediate reheater to take place at as high a temperature as possible while using a small amount of excess air. The reheated power gas can be led by means of inlet devices into the centre of guide passage cross-sections, where it is mixed with the non re-heated gas. The quantity of power gas taken from the turbine is preferably led through a diffuser into the intermediate reheater.

It may be advantageous to arrange the passages for leading the gas to the intermediate reheater and the passages for leading the gas back from the intermediate reheater at least approximately circularly symmetrical with regard to the turbine axis. Preferably the gas will be given a swirl before entering the intermediate reheater. Also some of the passages in a guide piece may have hotter gas flowing through them than the other passages in the guide piece. In this case preferably the conducting passages for the hotter gas and the conducting passages for the cooler gas have different cross-sections. For example, a guide passage for the hotter gas and a guide passage for the cooler gas may follow each other alternately. It is also preferable to choose the cross-sections of flow in the intermediate reheater and in the passages for the hotter gas in such a way that a pressure drop occurs which gives at the outlet of the guide passages for the hotter gas approximately the same speeds as the cooler gas has at the outlet of the guide passages. If slits are provided at the entrance to the passages conducting the hotter gases, a part of the colder gas can enter the passage containing the hotter gases in order to form a cooling boundary layer along the surfaces of the guide blades.

Two examples illustrating the object of the invention are given more or less diagrammatically in the accompanying drawings.

Fig. 1 shows a longitudinal section through the whole group of machines;

Fig. 2 is an enlarged fragmentary longitudinal view along the line 2—2 of Fig. 3;

Fig. 3 is a sectional view along the line 3—3 of Fig. 2;

Fig. 4 is an entropy diagram showing the change of state of the gases in the turbine of Fig. 1;

Fig. 5 is a longitudinal sectional view through a modified turbine embodying the invention taken along the line 5—5 of Fig. 6;

Fig. 6 is a fragmentary cross sectional view along the line 6—6 of Fig. 5;

Fig. 7 is a view along the line 7—7 of Fig. 5;

Fig. 8 is an entropy diagram showing the thermal changes taking place in the machine according to Figs. 5 and 6, and

Fig. 9 is an enlarged fragmentary view along the line 9—9 of Fig. 6.

The gas turbine plant according to Fig. 1 comprises a multi-stage compressor 1, which compresses the air required for combustion, and a multi-stage gas turbine 2, with several intermediate reheaters 3*a*, 3*b* and 3*c*, which heat the gases during their expansion between separate stages of the turbine.

The compressor 1 draws the air required for combustion through the branch 4 and compresses it in a first stage 5. The air then passes into the first intermediate cooler 6*a*, is compressed further in another stage 7, again cooled in a further intermediate cooler 6*b*, and compressed to the final pressure in the last stage 8. The compressed air flows from the compressor through the pipe 9 into the heat exchanger 10, and from this through pipe 11 into the combustion chamber 12.

Through the burner 13 a power gas with a temperature of about 500–600° C. is produced, which passes first of all into a first turbine stage 14. At the end of this stage a part of the power gases goes through the passage 15 and through a diffuser 15*a* into the combustion chamber of the intermediate reheater 3*a*. The other part of the gases flows through the passage 16 direct to stage 17. On entering stage 17 this latter part of the power gas mixes again with the first part of the power gas from the intermediate heater, in such a way that the temperature again becomes about 500–600° C. At the outlet of stage 17 the gases are again divided into two parts, which go through the passages 18 and 19 respectively. The part flowing through the passage 18 is heated in the intermediate reheater 3*b* and mixed again with the part flowing through the passage 19, so that at the inlet to stage 20 the temperature again becomes about 500–600° C. A similar subdivision between passages 21 and 22,

and intermediate heating in an intermediate reheater **3***c*, takes place before entering the last stage **23**. The power gases, which are still very highly heated, then flow out of the turbine through pipe **24** into the heat exchanger **10**, and from there through pipe **25** to the atmosphere. Each of the three stages **14**, **17**, **20** and **23** comprises a plurality of groups of rotor blades **14***a*, **17***a*, **20***a* and **23***a* respectively mounted on the rotor **24***a* and a plurality of groups of guide blades **14***b*, **17***b*, **20***b* and **23***b*.

Figs. 2 and 3 show the outlet of the gases from the first stage **14**, the dividing of the gases into two passages **15** and **16**, and their entrance into the following stage **17**. The gas branching off through passage **15** and then heated in the intermediate reheater, is distributed over the whole periphery of the turbine through a substantially annular passage **26** and led through a number of inlet passages **27** in a plurality of radially disposed hollow guide members **27***a* to the guide passages **27***b* between the guide blades in such a way that the heated power gases flow into the middle of the guide passage cross-sections as indicated by the arrows **29**, while the power gases that are not re-heated flow first along the guide members **27***a* as indicated by the arrows **30**. The gases that have been heated in the intermediate reheaters and the gases that have not been re-heated then mix in the course of flowing through the guide passages **27***b* and through the rotor passages **30***a* located between the blades **17***a*.

The working process represented in the entropy diagram on Fig. 4 refers to a gas turbine installation in which the compressed air is cooled in three intermediate coolers and the power gases are heated in seven intermediate heaters. The air is drawn in by the compressor in the state O at a pressure p_1 and passed from the compressor to the heat exchanger in the state A with the pressure p_2. There the heat of the exhaust gases from the turbine is utilised to heat the whole quantity of air to bring it into the state B. A further heating takes place in the combustion chamber arranged before the gas turbine, until a power gas with the state C is formed. These power gases are expanded in a first group of stages to the State D. After this expansion a part of the power gases are heated in an intermediate heater and brought to the state E and then mixed with the nonheated power gases, so that the total quantity of power gases comes to the state F. After the intermediate heating process has been repeated another six times the gases flow through the last group of stages and then arrive, in the state H, through the exhaust piping into the heat exchanger where their heat is transferred to the air compressed by the turbine. The difference in temperature Δt between the states B and H is utilised in the heat exchanger for transmitting the heat of the exhaust gases to the compressed air.

The turbine shown in Figs. 5, 6 and 7 comprises a number of stages **41***a* and **41***b* having groups of rotor blades **42** on the rotor **41** and groups of guide blades **44** on the support **43**. The whole is surrounded by the turbine casing **45**.

From the first stage **41***a* a part of the gases passes direct to the next stage **41***b* through a passage **46**. Another part, however, flows through a passage **47** into an annular passage **48** and from there through a ring-shaped pipe **49** into an intermediate reheater **50**. The intermediate reheater is fitted with a burner **51**, the fuel from which is burnt with the help of the oxygen contained in the gases. The heated gases then flow through the pipe **52** into the substantially annular passage **53**. From this annular passage the gases then pass into the radial passages **54** formed in the spaced baffles **59**.

The radial passages **54** (Fig. 7) lead to separate guide passages **55**. The passages **46** open into the guide passages **56**. The gases passing through the guide passages **55** are hotter than the gas passing through guide passages **56**. The cross-sections of the guide passages **55** are, as can be seen, different from those of the guide passages **56**. Preferably the cross-sections the passages **47**, **48**, **49**, **52**, **53**, **54** and **55** are of such dimensions that a certain pressure drop occurs which gives the hotter gas approximately the same speeds at the outlet of the guide passages **55**, as the cooler gas has at the outlet of the guide passages **56**. At the inlet of the guide passages **55**, slits **57** are provided, through which a part of the colder gas can enter into the passages **55** in order to form a cooling layer along the guide blade surfaces. Both the annular passage **48** as well as the annular passage **53** are arranged approximately circularly symmetrical with respect to the axis of the turbine runner **41**. With the help of the blades **58** the gas can be given a certain swirl when entering the intermediate heater.

In the entropy diagram shown in Fig. 8 the pressure before the entrance of the gas into the passages **46** or **47** (Fig. 5) is indicated by p_1. p_2 represents the pressure at the outlet of the guide blades **44** (Fig. 7). A part of the gases pass directly into the guide passages **56** (Fig. 7). The state of this part of the gases consequently changes from the entrance into the passage **46** (Fig. 5) to outlet from the guide blades **44** (Fig. 7) along the line A—A' (Fig. 8). The other part of the gases that pass through the passage **47** to the intermediate reheater and from there into the guide passages **55** undergoes at first a change of state along the line A—B (Fig. 8). The pressure then falls from the value p_1 to the value p'_1. The point B corresponds to the state of the gas at the inlet into the guide passage **55**. In the guide passages the gas expands to the state B'. From the entropy diagram it can be seen that by giving the passages a suitable shape the heat drops h and h' for the gas in the guide passages **56** and also for the gas in the guide passages **55** respectively can be chosen the same size. The speeds occurring at the outlet from the passages **55** and at the outlet from the passages **56** will consequently also be equal.

Through the described division of the gas stream into one part that passes through the intermediate heater and into a second part that flows direct to the next group of stages, the flow losses that are connected with the intermediate heating are considerably reduced, since the kinetic energy at the outlet of that part of the gas that flows direct through is utilised again in the first stage after the intermediate heating, whilst on the other hand the flow losses in the intermediate heater affect only the highly heated part of the gas. The flow losses that are connected with the intermediate heating are thus reduced to a minimum, whilst at the same time the space required by the machine is considerably smaller, since the cross-sections of flow and the dimensions of the intermediate heater are considerably reduced.

I claim:

1. A multi-stage gas turbine which comprises a casing, a plurality of stages within the casing, the adjacent stages being arranged close to each other in the axial direction, an intermediate reheater between the adjacent stages, means for passing a part of the gas from one stage to the intermediate reheater, conduit means to conduct the gases from the reheater to the next stage, and a passage within the casing for passing another part of the gas directly to the said next stage, said passage being arranged in the axial direction of the turbine thereby effectively avoiding changes in direction of the gas flow.

2. A multi-stage gas turbine according to claim 1 which comprises a gas diffuser arranged between the separate stages and the reheaters.

3. A multi-stage gas turbine according to claim 1 which comprises a substantially annular passage into which the reheated gases from the reheaters are discharged, a plurality of spaced guide-members mounted along the inner side of the annular passage and between the adjacent stages, each of said guide members being provided with a passage through which the gases from the annular passage may pass to the next stage, said guide members being so arranged that the gases passing directly from one stage to the next pass therebetween.

4. A multi-stage gas turbine which comprises alternate groups of rotor blades and groups of guide blades in each stage, a substantially annular passage arranged between adjacent stages, means for passing a part of the expanded gases from one stage into the annular passage, means for heating the gases from the annular passage, a second substantially annular passage arranged to receive the heated gases, a plurality of spaced baffles arranged radially between the adjacent stages forming passages for directing the heated gases from the second annular passage to the first group of guide blades of the next stage, and passage means extending in the axial direction of the rotor for passing another part of the expanded gases from one stage directly to the next stage.

5. A multi-stage gas turbine according to claim 4 in which the passage means extending in the axial direction of the rotor includes a plurality of passages formed between the said baffles.

6. A multi-stage gas turbine according to claim 4 in which the passages in the baffles and the passage means extending in the axial direction of the rotor are arranged to discharge the heated gases and the other part of the expanded gases in the spaces between the guide blades of the said first group of guide blades.

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