March 11, 1952 K. HEFEL 2,588,627

CONTROL FOR DIESEL-ELECTRIC DRIVES

Filed Jan. 10, 1950 2 SHEETS--SHEET 1

Fig.1

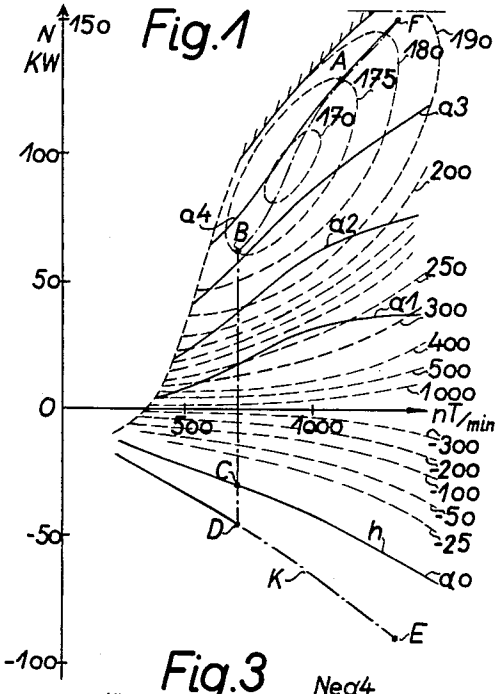



Fig.6

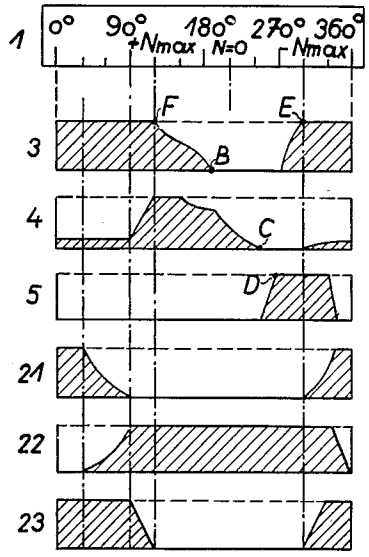



Fig.3

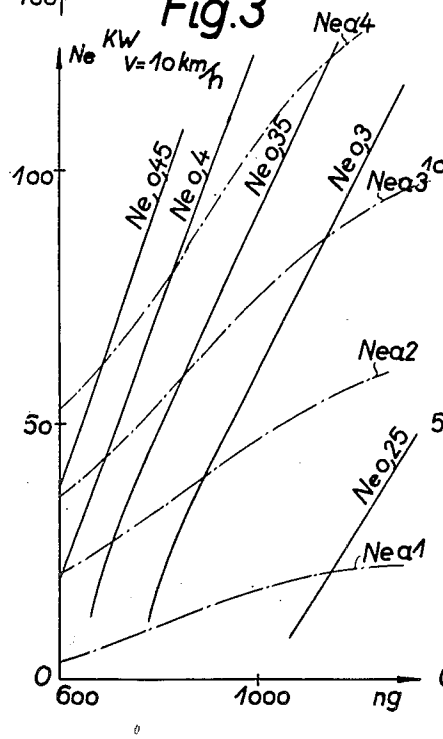
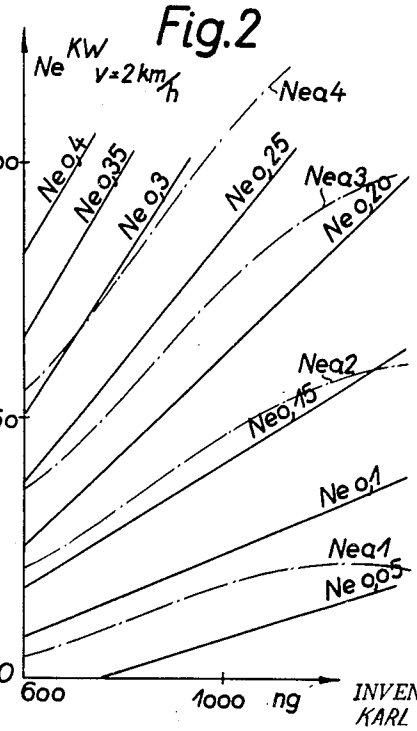



Fig.2




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Fig. 4

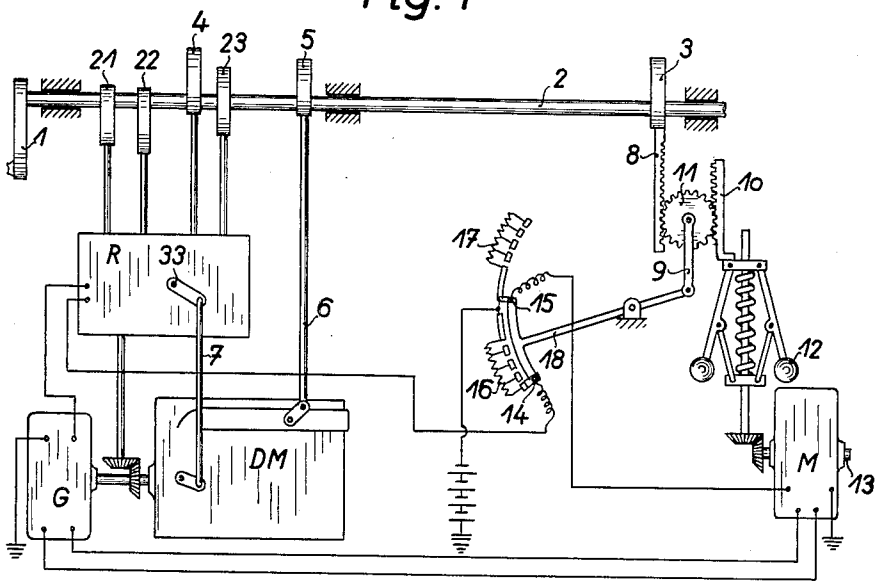
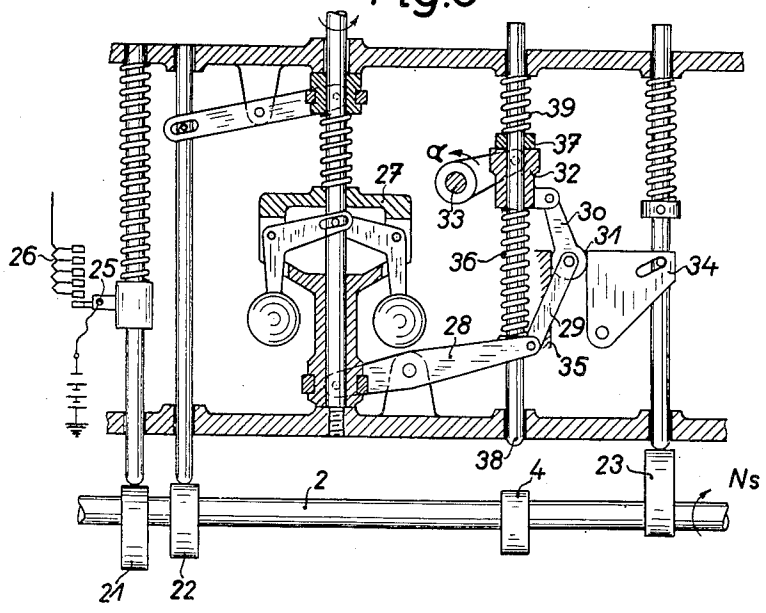



Fig. 5




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## CONTROL FOR DIESEL-ELECTRIC DRIVES

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6 Claims. (Cl. 290—17)

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The invention relates to diesel-electric drives in which the output of a diesel-engine is transformed into electric power by means of a separately excited generator, said electric power being supplied to an also separately excited electric motor, the main purpose of the invention being the regulation of the drive of diesel-electric vehicles.

With the known diesel-electric drives in which series-wound motors are used, the most economic output characteristics of the diesel-engine cannot be maintained over the entire power range, nor can the braking power of the engine be utilized. It is true that the inventor has proposed on the one hand the use of separately excited electric machines as generators for use with internal combustion engines, and that he has on the other hand suggested certain measures for maintaining the most economic output characteristics in internal combustion engines. However, diesel-engines present certain peculiarities which call for special measures. The invention consists in a controlling device combining a speed control (regulation of the R. P. M.) during the starting period, and an admission control during normal operation, both during driving and braking, the transition from the one mode of control to the other being perfectly automatic.

The invention will now be described in connection with the accompanying drawings, and with reference to an embodiment likewise represented in the drawing. The Figs. 1–3 are working graphs of the diesel-engine and the diesel-electric drive, whilst the Figs. 4 and 5 show the embodiment mentioned, Fig. 6 referring to the shape of the cams (cam-discs) of the output-selector represented in the Figs. 4 and 5. Fig. 1 is the output speed graph of a diesel-engine, the full lines showing the engine output corresponding to specified positions $a_0$—$a_4$ of the fuel regulating or governing organ, whilst the dash-lines denote the fuel consumption per unit of output and of time. By individually ascertaining the minimum fuel consumption for each output, and by connecting these points with each other, the most economic governing characteristics for the diesel-motor are obtained. In the chiefly used output range, from point A to point B, the dash-dot curve corresponds to the most economic output characteristics. The portion of the curve from A to F is determined by the smoke limit, and the vertical portion from B to C and D by the lowest speed, still warranting a smooth running of the diesel-engine. As to the consumption of fuel, both portions are highly advantageous. F re-

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fers to the maximum driving power, and E to the maximum braking power of the engine. The output curve for the fuel supply zero, with the exhaust opened, is marked *h*, and with the exhaust closed with *k*. In other words the continuous lines passing through the points F—A—B—C—D—E represent the most favourable governing characteristics of the diesel-engine. The selection of this continuous line or graph permits of taking into consideration the electric losses without constructive outlay, which however do not cause any perceptible deviation from the economic optimum.

In the Figs. 2 and 3 the diesel-engine outputs *Ne* are plotted in dash-dot lines against the generator speeds (R. P. M.) *ng* according to the positions $a_1$—$a_4$ of the fuel regulating device, and the generator outputs *Ne* in full lines with reduced excitation. With the generator outputs the figures added are meant to signify the intensity of the excitation, *Ne* 0,3 being e. g. the output curve which corresponds to a 30% generator excitation. The output curves according to Fig. 2 have been taken at a travelling speed of 2 km., and those of Fig. 3 of 10 km. p. h. For rendering possible a stable output adjustment, the diesel-engine and the generator output curves must show unambiguous points of intersection at specified values of revolution. With the curve according to Fig. 2 this is not the case, hence no stable output can be adjusted by means of the positions $a_0$—$a_4$ of the fuel regulating device. With a travelling speed of 10 km. p. h., however, the points of intersection are unambiguous so that an admission regulation is possible. Consequently, the invention provides for using the speed (R. P. M.) regulation during the starting period, and the admission regulation during the normal operation.

Fig. 4 shows a control device according to the invention, whereas Fig. 5 is an illustration, on a larger scale, of the starting device as outlined in Fig. 4 and marked by the letter R. By means of the device illustrated, it is possible to adjust any output within the entire driving and braking range of the diesel-engine in such a manner that the fuel consumption is always at the lowest possible level. The diesel-electric device is composed of the diesel-engine DM, the separately excited generator G, coupled with it, and the vehicle actuating motor M which is also separately excited, and is supplied with current from the generator G. The output selector consists of the actuating device 1 e. g. a crank, the cam shaft 2 and the cams (cam discs) fastened to it which serve for adjusting the various operative factors.

Fig. 6 shows the shapes of the various cams, as depending on the angle of deviation of the crank 1 of the selector output. The figures on the left hand side referring to the actuating devices and the cams (cam discs) tally with those in the Figs. 4 and 5, whereas the letters BCDEF correspond to the same letters used in Fig. 1. The cams function as follows: The cam 3 is used for adjusting the theoretical number of R. P. M.'s of the diesel-engine, the cam 4, joined to the rod 7, for governing the fuel supply in case of admission regulation, the cam 5, joined to the rod 6, for opening and closing the exhaust valve, the cam 21 for switching on and regulating the generator circuit, the cam 22 for adjusting the spring tension of the speed governor, and the cam 23 for operating the switch device which automatically effects the change-over from speed to admission regulation. The cam 3 displaces the rack 8 according to the log *ns*, whereby *ns* is the theoretical speed corresponding to the selected output Ne of the diesel-engine. A centrifugal governor 12, driven by the shaft 13 of the vehicle propelling motor M, displaces the rack 10 conformably to log *ni*, the actual speed *ni* at the time being that of the vehicle propelling motor M. Between the racks 8 and 10 the differential wheel 11 is made to move conformably to

$$\log ns - \log ni = \log \frac{ns}{ni}$$

i. e. according to the transmission ratio which is necessary for bringing the actual diesel-engine speed to the level of the value *ns*, prescribed by the output selector by way of the cam 3. The rod 9 leads to the transmission governor composed of the switching lever 18, the sliding contacts 14 and 15, the exciter resistances 17 of the vehicle propelling motor M and 16 of the generator G.

Fig. 5 serves for explaining the starting device. In the idling or running light position of the output selector the sliding contact 25 corresponds to a null contact, whereby the generator excitation is interrupted. By displacing the output selector the cam 21 moves the sliding contact 25 over the resistance 26 of the exciter circuit down to the lowest value compatible with normal operation. With the switching lever 16 occupying the position shown in Fig. 4, the motor excitation is at a maximum value. The further switching of the generator excitation is then taken care of by the switching lever 18. In running light, the cam 22 adjusts the spring tension of the pendulum-governor 27, driven by the diesel-engine, to the idling speed. By turning the output selector into the starting range the cam 22 tensions the spring of the pendulum-governor more and more, until finally the pendulum-governor is adjusted to the maximum speed of the diesel-engine when the output selector has attained the terminal position provided for the starting range. The spring tension corresponding to the maximum speed then remains unaltered in all positions of the output selector corresponding to normal travelling operation.

Over the entire starting range of the output selector the cam 23 keeps the pivotable switching member 34 in the position according to the drawing so that the fulcrum 31 of the rods 28, 29, 30 in dependence on the position of the pendulum governor, cannot but operatively move up and down between the fixed guide 35 and the switch member 34. Thus the motion of the governor is transmitted on the sleeve 32, and thence on the



adjusting shaft 33 of the injection pump regulating rod, whereby the sleeve 32 is pushed by the spring 36 on to the stop 37 of the rod 38, so that the entire rod 38 is bound to participate in the motion of the pendulum governor.

When the travelling speed of about 10 km. p. h. is attained, the actuating member 1 is adjusted to the output desired (e. g. $+N_{max}$), whereby the switching member 34 is tilted in the clockwise direction by the cam 23, so as to release the fulcrum 31, the result being that the speed governor cannot furthermore increase the fuel supply. Then the spring 39 presses the rod 38 on to the cam 4, thus activating the admission regulation. This transition is perfectly automatic.

However, the governor 27 continues to act as a safety device preventing the danger of the highest admissible speed of the diesel-engine being exceeded, as the fulcrum 31 rests on the fixed guide 35 whenever the speed maximum is overstepped, whilst the sleeve 32 is displaced downwards against the action of the spring 36 so as to reduce the fuel supply, though the rod 38 is held fast by the cam 4.

The device according to the invention presents the advantage, hitherto unknown in diesel-engines controls, that by the output selector, specified theoretical speed- and fuel-values are adjusted for any position, equivalent to an unambiguously defined output of the diesel-engine, both in the driving and the braking range, so that determined regulation characteristics can be maintained, the ratio of transmission resulting unambiguously from the travelling speed and the position of the actuating member 1. The invention renders separately excited electrical machines also useful as electric transmission gears for diesel-drives in the starting range. The entire switching lay-out is simple, and easily drafted, so that for this reason too it should be considered as safer in operation than the hitherto known diesel-electric power transmission.

What I claim is:

1. In a diesel-electric drive composed of a diesel-engine, a separately excited generator, and a separately excited electric motor, a controlling device comprising an output selector, a differential mechanism, a speed governor, and a regulator for the excitation of the electric machines, the output selector consisting of an actuating device for setting the output desired, at least three curved guides connected to said actuating device, and adjusting means for the fuel supply and the theoretical speed of the diesel-engine as well as for the adjustment of the speed governor, the differential mechanisms having three members of which the first is operatively connected to said curved guide for the theoretical speed, the second being connected to a device dependent on the speed of the vehicle propelling motor, whilst the third is connected to a governor employed for the excitation of the electrical machines.

2. Controlling device according to claim 1, containing a switching member interrupting during the starting period the operative connection between said adjusting means for the fuel supply and the curved guide of the output selector appertaining thereto, the output selector being provided with an additional curved guide and adjusting means for actuating said switching means.

3. Controlling device according to claim 1, the output selector being fitted with two further curved guides and adjusting means for the said speed governor and for a switching member, pre-

venting during the starting period the actuation of the fuel supply device by means of a curved guide of the output selector according to claim 1, the speed governor being provided with a variable tension spring, whilst the curved guide of the output selector for the speed governor is so shaped and so connected to said spring, that the spring tension increases during the starting period.

4. Controlling device according to claim 1, said output selector consisting of an actuating device, a camshaft and several cams, the actuating device being coupled to the camshaft, the cams being fastened to the camshaft, and the cams being so shaped, that for each output, set by the actuating device, those values for the fuel supply and the speed are adjusted which yield the lowest fuel consumption per unit of output and of time.

5. Controlling device according to claim 1, containing a switching organ for opening and closing an exhaust tube for said diesel-engine.

6. Controlling device according to claim 1, containing a guide in connection with said speed governor and said fuel supply adjusting means, said guide transmitting, in the starting period, the motion of the speed governor to the fuel



regulating device, and preventing in the normal output range the diesel-engine from exceeding the highest admissible speed, said guide comprising a crank, a cam shaft, and mounted thereupon, a plurality of cams having shapes correspondent to the angle of deviation of said crank, one cam acting to govern the fuel supply, another to operate the exhaust valve, another to adjust the speed governor, and another to change from speed to admission regulation.

KARL HEFEL.


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