Diesel locomotives with compressed air transmission are known, in which the Diesel engine drives a separate compressor which supplies the compressed air required for performing work in the locomotive cylinders. The construction in question is quite suitable for small and medium locomotives, but in the case of high power locomotives has the drawback that the whole installation becomes comparatively heavy and expensive. Moreover, these locomotives necessitate the use of recooling installations for the cooling water of the Diesel engines and the compressor, which installations increase with the increase in the size of the locomotive, and in that way the difficulties of construction are still further increased and in the case of very large engines, make it even necessary to tow a separate cooling car.

The method of working according to the present invention has the advantages of the compressed air transmission, whilst avoiding the drawbacks above referred to by again compressing in the locomotive cylinders, to the temperature of ignition of the fuel, the compressed air supplied by the compressor after it has done its work in the locomotive cylinders, and by then injecting fuel into the said compressed air. The Diesel engine has therefore to supply only a small portion of the locomotive power, which is then increased in the locomotive cylinders owing to the latter operating during the second part of a working cycle as an internal combustion engine, after having worked during the first part of the cycle as a compressor. In its application to double acting two stroke engines, the method of working is preferably carried out in such a manner that compressed air is first supplied to one piston side of the cylinder and expands and performs work therein; the expelled air is then conveyed to the opposite piston side through a receiver, and is heated by compression to the temperature of ignition of the fuel which is then rejected.

Before its admission into the locomotive cylinders, the compressed air is preferably preheated to such an extent that, after work has been performed, a compression to the pressures hitherto usual in locomotives (about 15 atmospheres) is sufficient for the automatic ignition of the fuel. For heating the compressed air the exhaust gases of the internal combustion engine are preferably used, though naturally any other suitable means could be used for the purpose.

The new method of working is diagrammatically illustrated for four stroke working in Figure 1 of the drawings. Figure 2 shows diagrammatically by way of example a construction of the locomotive. Figure 3 is the diagram for two stroke working and Figure 4 is a section through a correspondingly built double acting two stroke locomotive cylinder. Fig. 5 shows diagrammatically a locomotive construction employing the double acting driving cylinder of Fig. 4. Figs. 6, 7 and 8 are partial vertical sectional views through the right hand end of the driving cylinder of Fig. 4 illustrating the starting valve arrangement and the fuel valve. Fig. 6 illustrates the positions of the parts for starting when the piston is in the right hand dead center position. Fig. 7 illustrates the positions of the parts for starting when the piston is adjacent the left hand dead center position. Fig. 8 illustrates the positions of the parts with the starting valve arrangement in operative position as for normal running operation.

Compressed air at comparatively low pressure which is generated in a separate compressor b driven by the Diesel engine a (Figure 2), after having been preheated to a suitably high temperature, is admitted into the locomotive cylinder or cylinders as indicated by the line 1—2 of the indicator diagram of Figure 1. The heating of the compressed air could be effected by any suitable means, for instance by means of the exhaust gases from the Diesel engine in a heater c heated by the same. Let it be assumed that the compressed air thus preheated before admission into the locomotive cylinder d has for instance a pressure of 8 atmospheres and a temperature of 350° C. From the points 2 to 3 of Figure 1 expansion of the compressed air takes place. Shortly before the dead centre position of the piston at 3 the controlled outlet valve e will be opened to exhaust to
atmosphere and during the reversal of stroke will allow the compressed air to expand to such an extent that the pressure will be equalized with that of the surrounding atmosphere. At 4 the outlet valve will be closed, and the air still contained in the locomotive cylinder will then be compressed to about 15 atmospheres during the return of the piston, its temperature, owing to the preheating, rising to such an extent that the fuel injected will be automatically ignited (point 5 of Figure 1). Into this highly heated-air is injected through the nozzle f, fuel which thereupon burns for instance at a constant pressure (in Figure 1 from 5 to 6). From 6 to 7 expansion of the burnt gases then takes place. The locomotive cylinder works during this stroke as an internal combustion engine. At 7, shortly before the end of the stroke, the outlet valve is opened and then, up to the point 8 of Figure 1, the exhaust stroke follows. The end of the expansion of the compressed air at the point 4, and the end of the expulsion of the burnt gases at the point 8 are controlled by one and the same control element, viz. the cam disc g having the two cams g’ and g” which are designed accordingly. Beginning at 8, a short compression of the burnt gases still contained in the cylinder takes place, and at the point 9 then begins the renewed admission of compressed air. The working cycle is thereupon repeated in the manner above described. In the construction described, it has been assumed that the expansion of the compressed air and the subsequent combustion takes place in the same locomotive cylinders. These operations could however take place in separate cylinders or on opposite piston sides of the same cylinder. In Figures 3 and 4, compressed air at relatively low pressure, for instance at 8 atmospheres, which is generated in a separate compressor & driven to the Diesel engine o, after having been preheated to a suitably high temperature in the heater c, is first admitted through the conduit a’ into the valve chest b’ and conveyed by means of the control valve c’ (made in the form of a piston valve for example) through the port d’ to the rear face of the engine piston e’ which is thereby driven to the right. The piston e’ is connected to a crank on the driving axle of the locomotive through a crosshead and linkage arrangement as shown in Fig. 2. The piston valve c’ is connected by the rod r to a suitable operating cam arrangement g” in the manner of Fig. 2, the cam being driven from the axle of the locomotive or in coordinated driving relation with the driving cylinder in the customary manner so that the operation of the valve is coordinated with the operation of the driving cylinder. The admission of the heated compressed air takes place from 1 to 2 of Figure 3. At the point 2 of Figure 3 the edge 1 of the piston valve closes the port d’ so that from 2 to 3 of Figure 3 expansion of the compressed air takes place. At the point 3 of Figure 3 the edge 2 of the piston valve has passed the edge 3 of the port d’, and the compressed air contained in the cylinder can expand until the end of the stroke of the piston and escape through the hollow space f’ of the piston valve c’, through the conduit g’ and through the pipe h into a receiver i during the return of the piston until the point 4 of Figure 3 is reached. At this point the control edge II of the piston valve has again completely covered, during its return movement, the inlet port d’ so that the compressed air still remaining in the cylinder will be compressed during the return movement of the engine piston e’. As soon as the control edge I of the piston valve has passed the port edge IV, the admission of compressed air begins again at this piston side. During its return movement from right to left the engine piston e’ first uncovers at the point 5 of Figure 3 the outlet ports k at the opposite piston side of the cylinder so that this cylinder end can exhaust. During the continued return movement, the engine piston e’ uncovers the inlet ports l so that air can then pass from the receiver i to this cylinder side and scavenge the remainder of the burnt gases from the same. During the reverse movement of the engine piston, the scavenging will be continued and after the closing of the outlet ports k at the point 6 of Figure 3 the compression of the air contained in the cylinder begins, this compression taking place up to the point 7 of Figure 3. During the reverse movement of the piston which now takes place, fuel is supplied through suitable injection piping (not shown) in the conventional manner as employed in Diesel engines to the injection nozzle controlled by the fuel valve m and is injected into the air compressed to about 15 atmospheres at this cylinder side (line 7—9 of Figure 3) and burns at a temperature of about 600° C. From 8 to 5 the expansion of the burnt gases at this cylinder side takes place. At the point 5 the piston begins to again open the outlet ports k so that from here to the point 6 the scavenging and the recharging of this cylinder side with combustion air from the receiver i again takes place.

For starting the locomotive and for overcoming gradients or to provide for the contingency of the fuel valve failing, the internal combustion end of the cylinder is provided in the cylinder cover with two starting valves a and o, the former of which works as an inlet valve connected to a suitable source of compressed air and the other valve o connected to atmosphere works as an outlet valve. The two valves are operated by a lever p which is eccentrically and rotatably mounted on the eccentric shaft g and driven
preferably by the rod \( r \) of the control valve \( o \) from the linkage described above, in such a manner that in the right hand dead centre position of the engine piston illustrated in Fig. 6, the inlet valve \( n \) is open and the outlet valve \( o \) closed, whilst before the opposite dead centre position is reached the outlet valve \( o \) is opened and the inlet valve \( n \) closed as illustrated in Fig. 7. Accordingly, on the return of the piston, the starting air can escape again from the cylinder through the outlet valve \( o \). The eccentric mounting of the valve lever \( p \) makes it possible, after the starting of the engine at the beginning of normal working, to rotate the eccentric shaft \( g \) to move the valve lever \( p \) in such a manner that it is brought away from the valves \( n, o \), so that these two valves remain permanently closed during the normal working of the locomotive.

I claim:

1. In a locomotive constructed for cooperatively combined air motor and Diesel engine operation in a working cylinder, the method which comprises preheating compressed air, introducing the preheated compressed air into the working cylinder with expansion therein to effect work, the air being preheated before introduction into the working cylinder to a temperature such that the temperature of the air after expansion within the cylinder is at a predetermined degree above normal atmospheric temperatures coordinated with the compression pressure to be attained during the Diesel operation, recompressing at least a portion of the expanded air of predetermined temperature from the air motor operation in the working cylinder to the said compression pressure to attain an ignition compression temperature in excess of the compression temperature normally resulting from such a compression pressure, and injecting fuel into such recompressed air with resulting self-ignition and combustion to effect work, the self-ignition being thereby attained in the Diesel operation without the employment of unduly high compression pressures.

2. In a locomotive of the character described having a driving axle, a combined air motor and Diesel engine driving cylinder for said locomotive, a piston therein operatively connected to said driving axle, means for supplying highly heated compressed air to said driving cylinder with resultant expansion for air motor operation therein to drive said piston on one working stroke, means providing for recompressing expanded air from the air motor operation within said cylinder to a predetermined compression pressure not substantially exceeding fifteen atmospheres, the heated compressed air and its expansion during the air motor operation being such as to provide expanded air having a residual temperature above normal atmospheric temperatures such that recompression to said predetermined compression pressure gives a compression temperature sufficient to cause self-ignition of fuel injected therein, means for injecting fuel into said cylinder for Diesel engine operation therein to drive said piston on alternate working stroke, and means for controlling the residual temperature and pressure of the expanded air from the air motor operation.

3. In a locomotive of the character described having a driving axle, a combined air motor and Diesel engine driving cylinder for said locomotive, a piston therein operatively connected to said driving axle, means for supplying highly heated compressed air to said driving cylinder with resultant expansion for air motor operation therein to drive said piston on one working stroke, a receiver of substantial volume to provide a pressure equalizer and to damp out pressure surges, means for controlling the exhausting of expanded air from the air motor operation into said receiver whereby the exhausted air may be stored therein at a residual temperature above normal atmospheric temperatures, means controlling the supply of air from said receiver to the opposite end of said driving cylinder whereby combustion air of a predetermined high temperature is supplied to said opposite end and compressed therein by said piston to a predetermined compression pressure not substantially exceeding fifteen atmospheres to attain a compression temperature sufficient to cause self-ignition of fuel injected therein at said predetermined compression pressure, and means for injecting fuel into the compressed air within said opposite cylinder and with resultant self-ignition and combustion providing a Diesel op-
eration to drive said piston on an alternate working stroke.

5. In a locomotive of the character described having a driving axle, a double-acting combined two-cycle air motor and two-cycle Diesel engine driving cylinder for said locomotive, a piston therein operatively connected to said driving axle, means for supplying highly heated compressed air to one end of said driving cylinder with resultant expansion for air motor operation therein to drive said piston on one working stroke, a receiver of substantial volume to provide a pressure equalizer and to damp out pressure surges, means for controlling the exhausting of expanded air from the air motor operation into said receiver whereby the exhausted air may be stored therein at a residual temperature above normal atmospheric temperatures and at a residual pressure, said driving cylinder having inlet and exhaust ports in the wall thereof controlled by the piston at the opposite Diesel operating part of the cylinder, a passage connecting the said receiver with said inlet port whereby air at a residual temperature and pressure is supplied to the said Diesel part of the driving cylinder on the exhaust stroke of the piston therein to scavenge said Diesel part of the cylinder and supply thereto combustion air of a predetermined high temperature such that upon compression of the air therein on the compression stroke of the piston an ignition compression temperature is produced sufficient to cause self-ignition of fuel injected therein, and means for injecting fuel into the compressed air within said opposite Diesel part of the cylinder with resultant self-ignition and combustion providing a Diesel operation to drive said piston on an alternate working stroke.

6. In a locomotive of the character described having a driving axle, a double-acting combined air motor and Diesel engine driving cylinder for said locomotive, a piston therein operatively connected to said driving axle, means for supplying compressed air to one end of said driving cylinder with resultant expansion for air motor operation therein to drive said piston on one working stroke, a control member for controlling the introduction of compressed air into the Diesel end of said cylinder to cooperate in bringing the locomotive into operation.

7. In a locomotive of the character described having a driving axle, a double-acting combined air motor and Diesel engine driving cylinder for said locomotive, a piston therein operatively connected to said driving axle, means for supplying compressed air to one end of said driving cylinder with resultant expansion for air motor operation therein to drive said piston on one working stroke, a control member for controlling the introduction of the compressed air into and the exhausting of the expanded air from said end of the cylinder, means for driving said control member in coordinated time relationship with said piston, means for introducing combustion air and for injecting fuel into the other end of said cylinder to provide for Diesel operation therein to drive said piston on an alternate working stroke, a pressure air starting mechanism for the Diesel end of said cylinder, an operative interconnection between said control member and said air starting mechanism whereby the introduction of compressed air into the air motor end of the cylinder is coordinated with the introduction of pressure starting air into the Diesel end of the said cylinder to cooperate in bringing the locomotive into operation.

8. In a locomotive constructed for cooperatively combined air motor and Diesel engine operation, the method which comprises introducing highly heated compressed air into the air motor with expansion therein to effect work, exhausting expanded air from the air motor operation at a residual temperature above normal atmospheric temperatures, introducing exhaust air having such a residual temperature from the air motor operation into the Diesel engine with resultant recompression therein to a compression pressure not substantially exceeding 15 atmospheres and injecting fuel into such recompressed air with resulting self-ignition and combustion to effect work.

In testimony whereof I have affixed my signature.

JOSEF GEIGER.