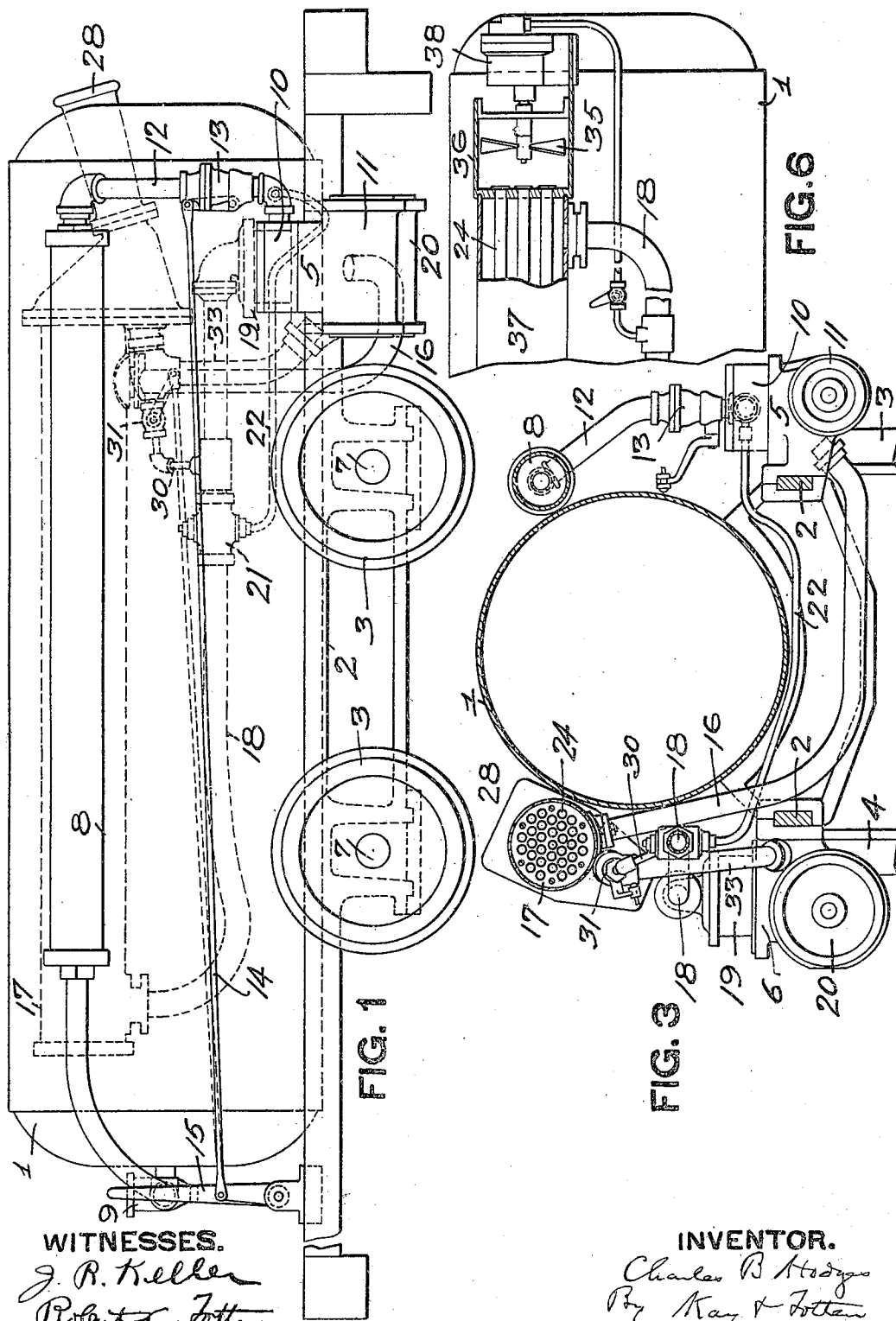


C. B. HODGES.
METHOD OF OPERATING COMPOUND COMPRESSED AIR ENGINES.
APPLICATION FILED JUNE 11, 1909.

953,335.

Patented Mar. 29, 1910.

2 SHEETS—SHEET 1.

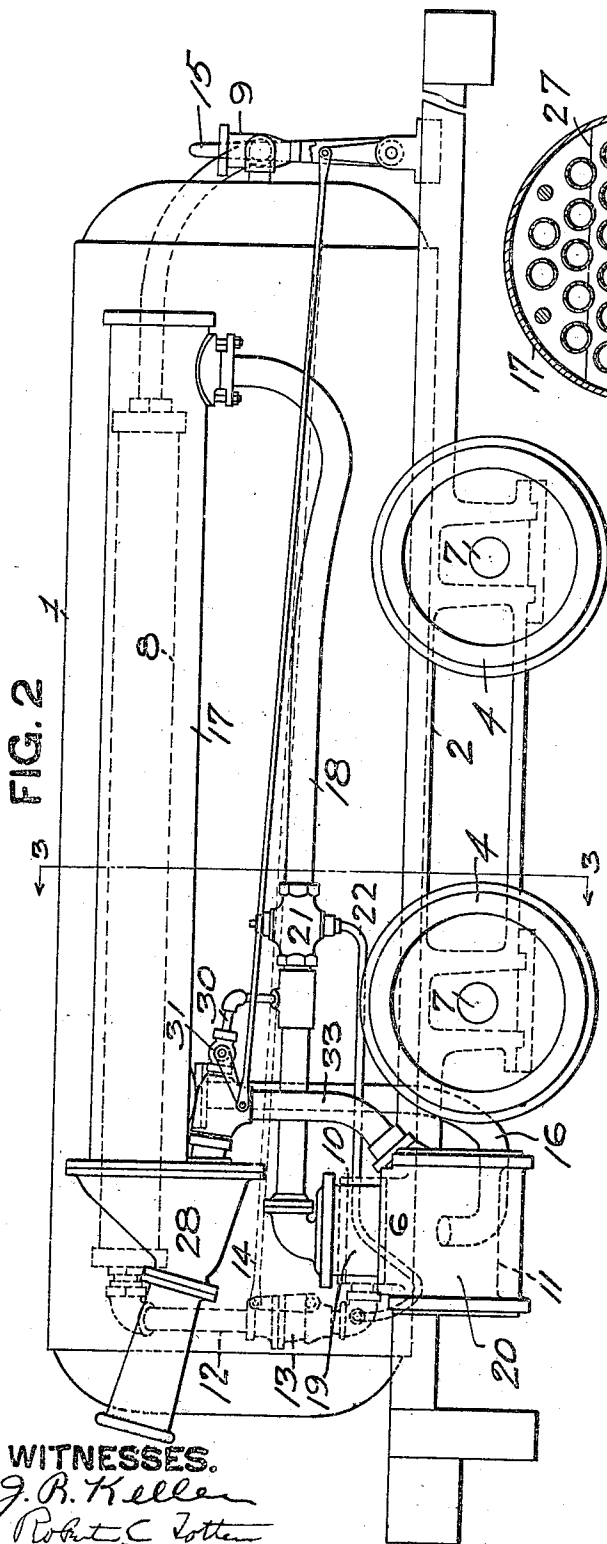


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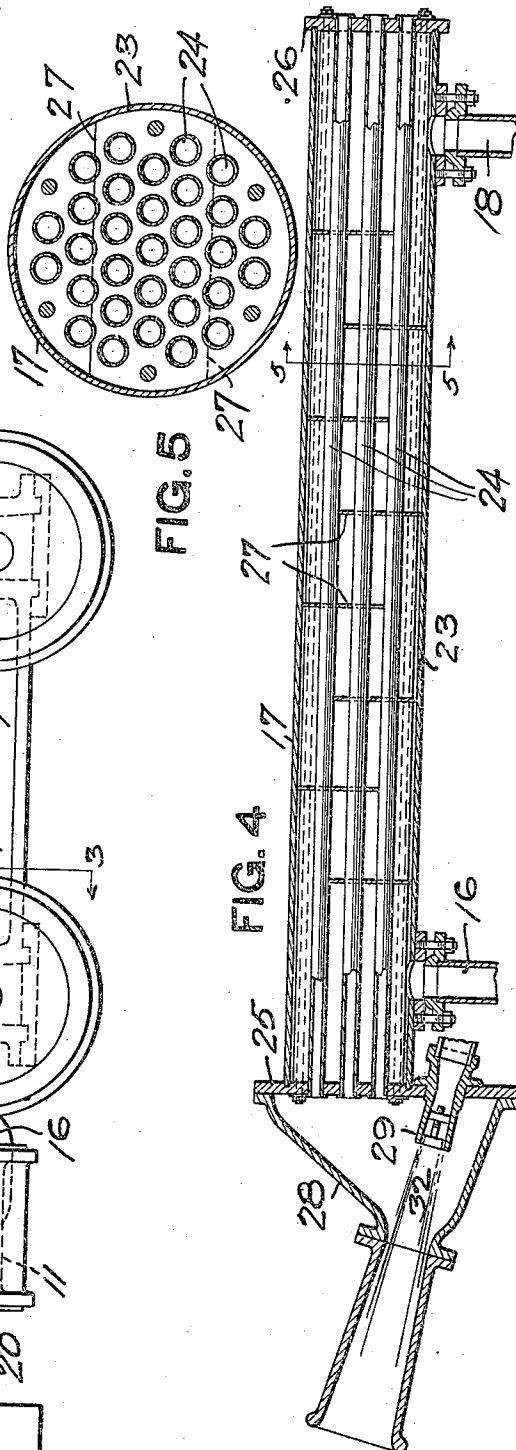
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METHOD OF OPERATING COMPOUND COMPRESSED-AIR ENGINES.

953,335.

Specification of Letters Patent. Patented Mar. 29, 1910.

Application filed June 11, 1909. Serial No. 501,642.

To all whom it may concern:

Be it known that I, CHARLES B. HODGES, a resident of Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Methods of Operating Compound Compressed-Air Engines; and I do hereby declare the following to be a full, clear, and exact description thereof.

My invention relates to a method of operating compound compressed air engines, its object being to so operate the same as to insure the maintenance of the surface of the air inter-heater in proper condition for the proper reheating of the air expanded within the high pressure cylinder and insure the proper operation of the engine.

It consists, generally stated, in carrying the compressed air at high pressure through and expanding it within the high pressure cylinder and thereby reducing it below atmospheric temperature, confining such exhaust air within a receptacle having extended exposed surfaces and reheating the same by inducing over such exposed surfaces a violent current of air at atmospheric temperature sufficient to scour from or prevent the formation of frost on such surfaces, thereby reheating and increasing the volume of such exhaust air and carrying the reheated air through the low pressure cylinder.

It also consists of certain other improvements as hereinafter set forth and claimed.

In the accompanying drawing Figure 1 is a side view of a locomotive engine adapted for the use of the invention; Fig. 2 is a side view partly broken away on the opposite side thereof; Fig. 3 is a cross section on the line 3—3 Fig. 2; Fig. 4 is an enlarged longitudinal section of the inter-heater and Fig. 5 is a cross section thereof; Fig. 6 is a detail view of one end of the inter-heater showing other means of inducing the violent current through the same.

In the original development of the compound compressed air engine such as illustrated in Letters Patent No. 868,560 granted to me October 15th, 1907, difficulty was encountered in the gathering of frost upon the exposed surfaces of the inter-heater, and as such frost acted as a non-conductor it prevented the rapid reheating of the compressed air after it was expanded in the high pressure cylinder. This frost also tended to

clog and close the tubes of the inter-heater and so reduce the amount of air carried through the tubes and diminish the reheating action of the atmospheric air and as the compressed air within the inter-heater was at a very low temperature, ordinarily entering the same 100 or more degrees F. below atmospheric temperature, the frost covering the tubes of the inter-heater would gradually increase in thickness so as to almost close the same. By the present invention I am enabled to overcome this difficulty and provide for the successful operation of the engine even where the surrounding atmosphere is of very low temperature, in fact below zero F. The apparatus best adapted for the practice of the invention is illustrated in the accompanying drawings as applied to a locomotive, having the main air reservoir 1 supported on suitable locomotive truck or under-frame 2 mounted on the driving wheels 3 and 4 on two sides of the locomotive.

On the high pressure side as shown in Fig. 1 the high pressure engine is shown at 5 connected up to the wheels 3, while on the other side the low pressure engine is shown at 6 connected up to the wheels 4, said wheels being secured to the axles 7. The auxiliary reservoir 8 is supported on the main reservoir 1 and air is fed thereto from the main reservoir through a suitable reducing valve 9 bringing the air to proper pressure for entrance to the valve chest 10 of the high pressure cylinder 11. The pipe 12 leads to the high pressure cylinder and located therein is the operating or throttle valve 13 which is connected by the rod 14 to the throttle lever 15. The pipe 16 leads from the exhaust of the high pressure cylinder 11 to the inter-heater 17 and the pipe 18 leads from the inter-heater to the valve chest 19 of the low pressure cylinder 20 from which cylinder the air exhausts. In the preferred construction I locate in the pipe 18 a stop valve 21 to hold the air within the inter-heater upon the closing of the throttle valve, said stop valve being actuated by the fluctuations of pressure in pipe 12 transmitted through pipe 22, as described in application for patent filed by me October 26, 1908, Serial No. 459,642. The preferred form of inter-heater is illustrated in Figs. 2, 4 and 5, being supported in horizontal position on the side of the main reservoir and extending

for practically the full length thereof and being of small diameter and relatively great length, and is filled with a large number of small tubes to provide for a relatively strong or violent draft of air through the tubes thereof for reheating the compressed air. For example, in practical use I have found that with the cylinders 5 and 10 inches in diameter by 10 inches stroke, the best form of inter-heater is made of a casing 23 about 7 feet long and about 8 inches inside diameter, this inter-heater being filled with a large number of tubes 24 extending for the full length of the inter-heater seated in the end walls 25, 26 thereof, the tubes being of small diameter, for example, about 30 tubes 1-inch diameter being employed. I also prefer to employ within the inter-heater a suitable series of baffles 27 between the tubes 24 so as to cause the compressed air to be reheated to travel in circuitous course around said reheating tubes. To induce the draft or current of atmospheric air through the inter-heater tubes I may employ different means, for example, in Fig. 2 I have illustrated the apparatus where air under pressure is utilized to induce the draft through the inter-heater. In such case I form at the exhaust end of the inter-heater the nozzle 28, and entering the same is the air jet 29, this jet being connected up to any part of the apparatus from which air under pressure can be drawn.

I prefer to draw the air for inducing the draft from the pipe 18 between the stop valve 21 and the valve chest 19 of the low pressure cylinder, as in this way said stop valve in preventing the escape of compressed air from the inter-heater upon the closing of the main throttle valve also cuts off the air from the air jet 29, there being no escape of air therefrom except when the engine is in operation. To this end I employ the pipe 30 leading from the pipe 18 and having located therein the valve 21 controlling the amount of air escaping from the air jet pipe, and to obtain a stronger inducing current the air jet is of annular form as shown at 32, for example being formed of a ring pipe with a series of jet orifices. To induce the draft through the inter-heater I may also utilize the exhaust from the low pressure cylinder as illustrated in Fig. 2, employing the same either alone or in addition to the air under pressure entering through the pipe 30. In such case the exhaust pipe 33 leads from the low pressure cylinder 20 and discharges into the nozzle 28 of the inter-heater and may communicate with the pipe 30 supplying air under pressure. This provides for the use both of the exhaust air from the low pressure cylinder and of air under pressure, so insuring the formation of a sufficiently violent draft for the scouring of the tubes of the inter-heater as hereafter de-

scribed. For the same purpose I may also employ an independent fan for inducing the draft through the inter-heater as illustrated in Fig. 6. In this case the fan 35 is located within the tubular extension 36 of the inter-heater 37 at the discharge end thereof and the fan is illustrated as driven by a suitable air motor or turbine 38 operated by air under pressure drawn from any suitable part of the apparatus, such for example, as from the pipe 18 between the inter-heater and the low pressure engine.

In the practice of the invention with the apparatus above described, the compressed air is stored at relatively high pressure, usually about 800 pounds, within the main reservoir 1, and it is maintained within the auxiliary reservoir 8 at the desired pressure for the operation of the engine, say, at about 250 pounds. Upon the operation of the throttle valve 13 the air passes to the cylinder 11 of the high pressure engine and generates power therein, escaping therefrom at a relatively low pressure, for example, in the best practice at a pressure of about 50 pounds.

The sudden and rapid expansion of the air within the high pressure cylinder causes a violent drop in the temperature of the air, this in turn contracting the same and reducing its volume. For example the air enters the high pressure cylinder at 60° F., and it passes therefrom at a temperature far below atmospheric temperature, the reduction in temperature being usually about 140° F. so that it is brought to a temperature of about 80° below zero. If the air were allowed to enter the low pressure cylinder at this temperature such cylinder would have to be smaller or the pressure less, and in either case the amount of work done in the low pressure cylinder would be much reduced, the size of the cylinder or the pressure of the air being reduced approximately one third. By the passage of the air through the interheater as above described the temperature is restored as such pressure is increased in volume so that I am enabled to obtain the same power in the low pressure cylinder which would have been obtained had no drop in temperature occurred. The difference between the temperature of the exhaust air when it leaves the high pressure engine and atmospheric temperature is so great that it quickly causes condensation of moisture carried in the atmosphere which forms as a coating of frost over the exposed surfaces of the inter-heater, such as within the tubes 24 thereof, and as above stated this frost coating serves as a non-conductor and prevents the full reheating action of the atmospheric air passing through the inter-heater, and gradually gathers so that unless removed it will clog and partially close the tubes thereof so reducing the current of

air carried therethrough. To keep the tubes of the inter-heater clear from frost and maintain the full action of the atmospheric reheating I induce a very violent draft through the tubes of the inter-heater by the suction or forcing action obtained in any suitable way, such as by air under pressure as shown in Fig. 2, or by the exhaust air from the low pressure cylinder as shown in said figure, or both, or by means of the fan as shown in Fig. 6. Such violent draft of atmospheric air through the tubes of the inter-heater acts to scour over the surfaces thereof on account of the large amount of atmospheric air carried through the small tubes gives a sufficient reheating of the compressed air within the interheater to prevent the formation of frost on the exposed surfaces of such tubes and to scour off any such frost in case it is formed therein, so keeping the tubes of the inter-heater clear from frost and enabling the air carried therethrough to impart its full reheating action to the compressed air confined within the inter-heater.

I have found that by providing such violent scouring draft through the tubes of the inter-heater I am enabled to keep such tubes clear from frost even when operating the engine at atmospheric temperatures considerably below zero F., and thus obtain the efficient operation of the engine under such extreme conditions. Where the exhaust from the low pressure engine is insufficient for this purpose it may be supplemented as above described, by the use of compressed air, and the amount of air under pressure used controlled by the valve 31 within the air jet pipe 30 leading from the pipe 16 between the inter-heater and the low pressure cylinder. As through the stop valve 21 in said pipe the escape of air from the inter-heater is prevented upon the closing of the main throttle valve no air under pressure is wasted for the operation of the inter-heater when the engine is not in operation but it is automatically fed to the air jet as soon as the throttle valve is open and the stop valve is opened to admit air from the inter-heater to the low pressure engine.

The general method of operating compressed air engines in which the air at high pressure is carried through one cylinder and thereby reduced below highest atmospheric temperature and the exhaust air therefrom is reheated when confined by extended exposure to air at atmospheric temperature and is then carried through a low pressure cylinder, and the specific methods in which exhaust air from the low pressure cylinder while still under pressure is discharged to induce a draft over the exposed surface of the interheating receptacle, form the subject matter of application filed by me of even

date herewith Serial No. 501,641. The apparatus for producing a draft over the exposed surface of the interheater by means of a fan, as illustrated in this application, forms the subject matter of an application filed by me of even date herewith Serial No. 501,640. The construction of the interheater and the connections taken from the pipe leading to the low pressure cylinder for providing air for inducing a draft over the exposed surface of the interheater, form the subject matter of an application filed by me of even date herewith Serial No. 501,643.

What I claim is:

1. The method of operating compound compressed air engines, consisting in carrying the compressed air at high pressure and expanding it within one cylinder and thereby reducing it below atmospheric temperature, confining such exhaust air from said cylinder within a receptacle and inducing over the exposed surfaces of said receptacle a violent current of air at atmospheric temperature sufficient to scour from or prevent the formation of frost on the exposed surfaces of said receptacle and thereby reheating and increasing the volume of such exhaust air and its capacity to generate power, and carrying the reheated air through a low pressure cylinder.

2. The method of operating compound compressed air engines, consisting of carrying the compressed air through and expanding it within one cylinder and thereby reducing it below atmospheric temperature, confining such air within a receptacle having a series of tubes passing through the same and inducing a violent current of air at atmospheric temperature through the tubes of such receptacle sufficient to scour from or prevent the formation of frost therein, thereby reheating and increasing the volume of such exhaust air and carrying the reheated air through a low pressure cylinder.

3. The method of operating compressed air engines, consisting in carrying the air at high pressure through one cylinder, confining the exhaust air therefrom within a receptacle having extended exposed surfaces and then through a low pressure cylinder, and inducing a current of air at atmospheric temperature over the surfaces of the confining receptacle by a jet of air at as high pressure as that entering the low pressure cylinder.

In testimony whereof, I the said CHARLES B. HODGES have hereunto set my hand.

CHARLES B. HODGES.

Witnesses:

ROBERT C. TOTTEN,
J. F. WILL.