(No Model.) 2 Sheets—Sheet 1.

H. H. WESTINGHOUSE & F. M. RITES.

METHOD OF DISTRIBUTING MOTIVE FLUID IN COMPOUND ENGINES.

No. 395,935. Patented Jan. 8, 1889.

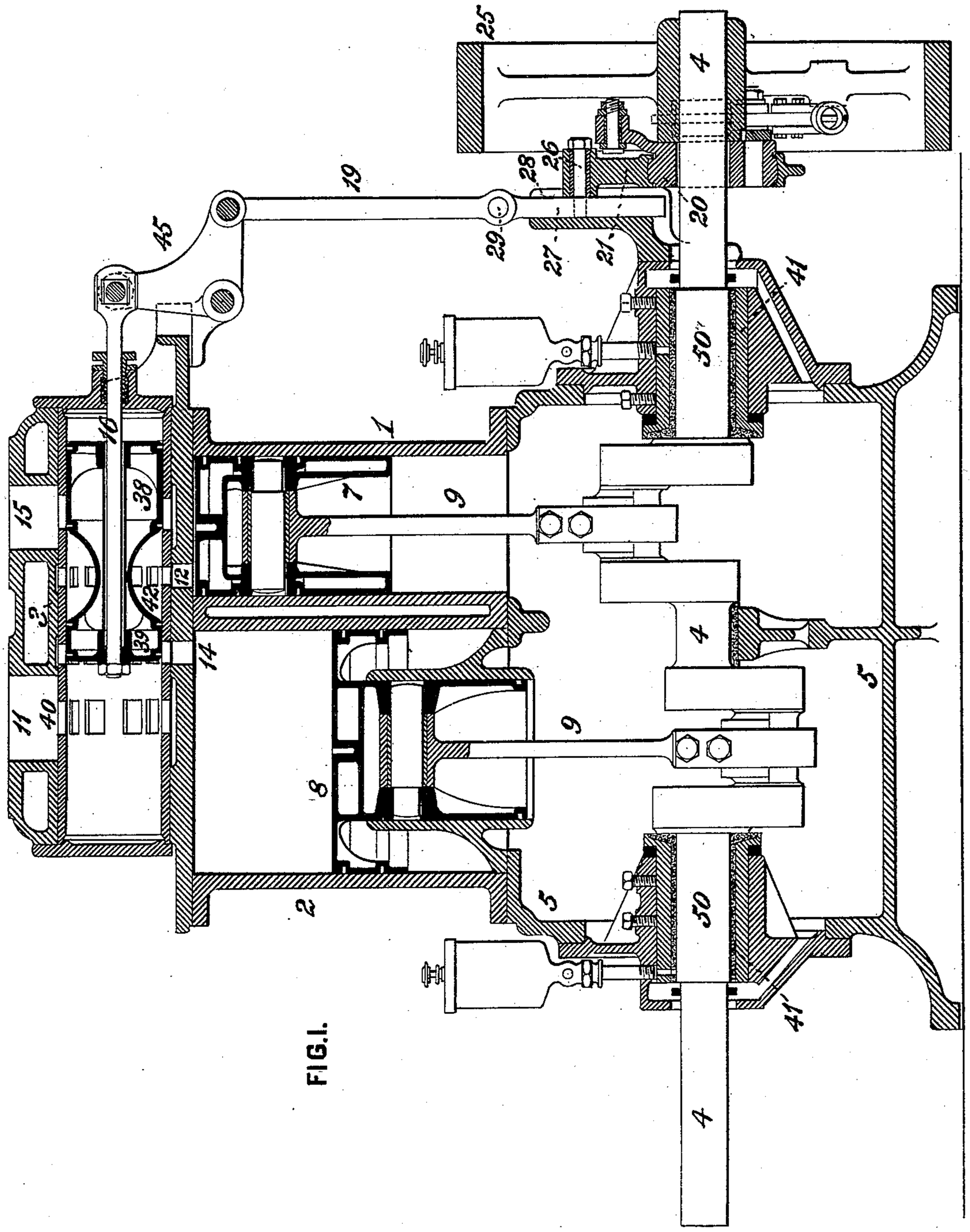

FIG. I.

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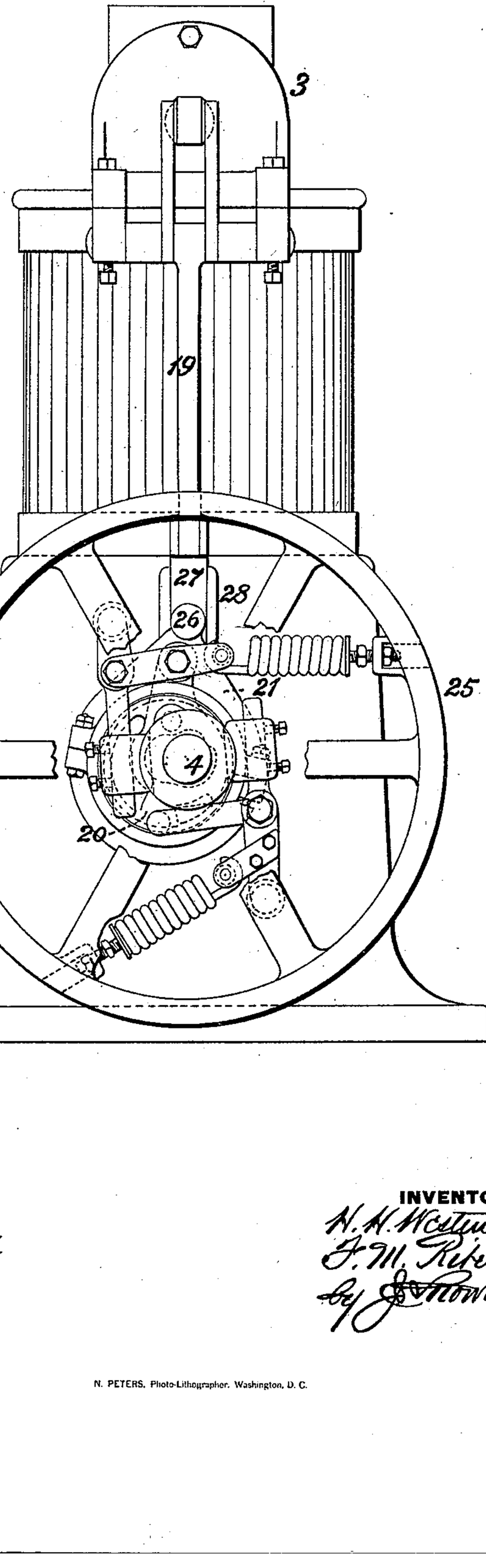
FIG. 2.



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UNITED STATES PATENT OFFICE.

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METHOD OF DISTRIBUTING MOTIVE FLUID IN COMPOUND ENGINES.

SPECIFICATION forming part of Letters Patent No. 395,935, dated January 8, 1889.

Application filed September 19, 1888. Serial No. 285,801. (No model.)

To all whom it may concern:

Be it known that we, HENRY HERMAN WESTINGHOUSE and FRANCIS M. RITES, citizens of the United States, residing at Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented or discovered certain new and useful Improvements in the Method of Distributing Motive Fluid in Compound Engines, of which improvements the following is a specification.

The object of our invention is to effect the utilization of the expansive force of steam or other elastic fluids, when applied in engines of the compound type, more completely and perfectly than has heretofore been practicable, by the avoidance of an intermediate reduction of pressure and a loss of motive fluid in filling clearance-spaces, unaccompanied in either case by the performance of useful work, both of which objections obtain to a greater or less degree in prior constructions.

To this end our invention, generally stated, consists in a novel method of effecting the distribution functions of a compound engine by supplying motive fluid throughout a portion of the stroke of the piston to a preliminary or high-pressure cylinder and a continuously-communicating clearance-space expanding such motive fluid in said cylinder and clearance-space throughout the remaining portion of the stroke, exhausting the motive fluid directly into a secondary or low-pressure cylinder, expanding the motive fluid between the primary and secondary cylinders throughout a portion of the stroke of the piston of the latter, terminating the stroke of said piston under simple expansion and coincidently compressing motive fluid in the preliminary cylinder and clearance-space to initial pressure, and, finally, exhausting the motive fluid from the secondary cylinder.

The improvements claimed are hereinafter fully set forth.

To completely attain the recognized economic advantage of cylinder compression, it is necessary that the same shall be finally raised to the degree of initial pressure, or that exerted upon the piston at the commencement of the stroke, and there being in the operation of a compound engine in practical service frequent variations in pressure or load, or both, the attainment of the advantage above referred to is further necessarily dependent upon the correspondence of terminal compression with initial pressure at each of the different grades of expansion or initial motive-fluid pressure under which the engine may from time to time be operated. Such maintenance of correspondence of terminal compression with initial pressure independent of variations of load or motive-fluid supply pressure, which we do not know or believe to have been effected prior to our invention we attain by preventing variations of the point of initial compression from inducing variations in the degree of terminal compression through the induction of corresponding variations in pressure at the point of initial compression.

The distinguishing feature of our invention is the coincident effection of low-pressure expansion and high-pressure compression within a space of determined volume and the maintenance of high-pressure terminal compression uniformly at initial pressure independently of variations of load or pressure by corresponding variations in the grade of expansion, the variations of pressure at the point of high-pressure compression compensating the variations of the point of high-pressure compression, and terminal high-pressure compression being thereby caused to be equal to initial pressure at all grades of expansion in operation. The high-pressure compression curves produced in indicator diagrams will necessarily vary with variations of initial pressure; but their terminal in the several variations will coincide in each case with the initial pressure.

The practical application of our method of distributing motive fluid—that is to say, of performing the several functions involved in the exertion of its expansive action upon the pistons of a compound engine—is exemplified in the operation of the engines set forth in an application for Letters Patent filed by us under date of March 17, 1888, Serial No. 267,519, and will be herein explained by reference to an engine illustrated in the drawings, which, while differing in minor structural features from those of said application,

accords therewith in the embodiment of the mechanical elements requisite for the employment of our method.

In the accompanying drawings, Figure 1 is a vertical longitudinal central section through a compound engine adapted to the practice of our invention; and Fig. 2, an end view, in elevation, of the same, as seen from the right.

The drawings illustrate a single-acting compound engine of the Westinghouse type having a preliminary or high-pressure cylinder, 1, and a secondary or low-pressure cylinder, 2, which are secured side by side to the top of a closed crank-case, 5, constituting the bed or support of the engine, and serving also as a tank or receptacle for the lubricating material of the journals and crank-pins of the crank-shaft 4, the journals 50 of which rotate in bearings 41, fixed in the ends of the crank-case 5. The cylinders 1 and 2 are fitted, respectively, with pistons 7 and 8, which are coupled by connecting-rods 9 to the crank-pins of double-cranks 10, set oppositely or with their pins one hundred and eighty degrees apart on the crank-shaft 4.

Motive fluid is admitted to the high-pressure cylinder 1, exhausted therefrom to the low-pressure cylinder 2, and thence exhausted into the atmosphere or into a condenser by a single distribution-valve which reciprocates in a valve-chest, 3, provided with nozzles or passages 15 and 11, to which a supply and an exhaust pipe are respectively connected and communicating with the high and the low pressure cylinders by ports 12 and 14. The valve-chest is preferably lined with a bushing, 40, communicating by proper series of ports with the supply and exhaust passages 15 and 11 and the cylinder-ports 12 and 14. The distribution-valve, which in this instance is of the piston type, is composed of a high-pressure section, 38, and a low-pressure section, 39, which are secured upon and reciprocate coincidently with a valve-stem, 16, actuated by an eccentric, 20, which is mounted freely upon the crank-shaft 4, and is varied and adjusted in position relatively to the crank-line, so as to effect variation of the degree of expansion in accordance with variations of pressure or load, or both, by an automatic cut-off governor of any suitable and preferred construction. The governor illustrated, which is mounted upon a supporting-wheel, 25, fixed upon the crank-shaft 4, is adapted, through pivoted weight-arms and springs, to effect the movement of the adjustable eccentric 20 transversely to the crank-line, and thereby to vary the grade of expansion or point of cut-off, as above stated. The valve-stem 16 is connected to one arm of a bell-crank lever, 45, pivoted in bearings on the cap-plate of the cylinders, the other arm of said lever being coupled to an eccentric-rod, 19, which is connected to the strap 21 of the eccentric 20. In the engine of similar type, illustrated in our application, Serial No. 267,519, before referred to, the bell-crank lever 45 was coupled directly to the eccentric-strap by the eccentric-rod 19, this construction involving a minimum angularity of said rod, and consequently minimum disturbance of lead due to such angularity, in order that the variation of the grade of expansion should be equal, as nearly as may be, in the two cylinders, such equality being desirable for the attainment of the best result with the employment of saturated steam and within the practicable range of regulation by the governor. In the present instance a construction is shown under which the action of a substantially greater angularity of the eccentric-rod is exerted upon the distribution-valve, the eccentric-strap 21 having a short upwardly-projecting arm, which is coupled by a pin, 26, to a sliding bar, 27, fitted to reciprocate in guides 28, secured to the crank-case, and coupled by pin, 29, to the eccentric-rod 19.

It will be seen that the effect of the angularity of the eccentric-rod upon the valve at late grades of expansion or points of cut off, the valve being set square for a determined intermediate point, is materially greater than in the engine of application, Serial No. 267,519, and that therefore there will be in such cases an increase of lead on the high-pressure port at the expense of an equal decrease on the low-pressure port, by which a longer cut off will be effected in the high-pressure than in the low-pressure cylinder, in order to enable compression in the high-pressure cylinder to be raised to a higher degree than that which would be resultant upon an equal point of cut off in both cylinders. On the other hand, the relatively decreased angularity of the eccentric-rod at early points of cut off induces an increase of lead on the low-pressure port and a decrease on the high-pressure port, and consequently a relatively longer cut off in the low-pressure than in the high-pressure cylinder. This provision for a relative variation of the points of cut off in the two cylinders is made in order to render the engine adaptable to operation with motive fluids having the characteristics of perfect gases, or those not containing condensible elements within the range of working pressures, as superheated steam or compressed air, with which the curve of compound expansion, not being influenced by condensation and re-evaporation, differs from that induced in the employment of superheated steam.

The distance between the sections 38 and 39 of the distribution-valve and their relation in position and degree of traverse to the port 12 of the high-pressure cylinder are so fixed that the space within the valve-chest bushing 40, between the sections 38 and 39, together with that within the port 12, shall constitute a clearance space or chamber, 42, which is continuously in communication with the high-pressure cylinder. We have found in practice that with the employment of saturated steam and within the ordinary range of variation of expansion the most perfect results have been obtained by the use of a clearance-

chamber the capacity of which bears substantially the same ratio to the volume of the high-pressure cylinder as that of the latter to the volume of the low-pressure cylinder; but it will be obvious that the capacity of the clearance-chamber may, under the conditions last recited, be increased or diminished with a corresponding variation from maximum useful effect.

The duty of the valve-section 38 is to open and close the port or series of ports in the valve-bushing 40 communicating with the supply-passage 15, thereby performing the functions of admission and cut off for the high-pressure cylinder, the cut off being effected at different points in the stroke of the piston, respectively, in accordance with the variations of position of the eccentric 20 by the governor. The travel of the valve is such that the high-pressure port 12 is continuously open, and hence the exhaust and compression of the high-pressure cylinder are effected independently of the valve-section 38, the duty of which, other than as a boundary of the clearance-space 42, is limited to the functions first above stated. The valve-section 39 effects the opening and closure of the low-pressure port 14, and thereby performs the functions of admission, cut off, exhaust, and compression for the low-pressure cylinder, and also those of exhaust for the high-pressure cylinder during the period of the stroke in which the low-pressure port 14 is open and the valve-bushing ports of the supply-passage 15 are closed, and of compression for the high-pressure cylinder during the period in which both the low-pressure port 14 and the valve-bushing ports of the supply-passage 15 are closed. In each case, moreover, the valve-section 39 acts as an end boundary of the clearance-space 42.

In operation motive fluid supplied from the passage 15 to the clearance-chamber and the space above the piston 7 of the preliminary or high-pressure cylinder 1 effects the downward movement of said piston at substantially initial pressure throughout the preliminary portion of its stroke at a point in which, regulated by the governor under existing conditions of load and pressure, the valve-section 38 closes the ports communicating with the passage 15 and cuts off the supply of motive fluid, the remainder of the stroke of the high-pressure piston being effected by the expansion of the motive fluid previously admitted and remaining in the clearance-chamber and high-pressure cylinder. In the further traverse of the valve the valve-section 39 opens the low-pressure port 14 and admits the motive fluid contained in the clearance-chamber and high-pressure cylinder to the low-pressure cylinder, which motive fluid effects the preliminary portion of the stroke of the low-pressure piston 8 under compound expansion exerted between the smaller and larger cylinders. The distribution-valve has meanwhile commenced its traverse in the opposite direction, in the course of which, at a point regulated by the governor, its section 39 closes the low-pressure port 14, cutting off the supply of motive fluid from the low-pressure cylinder and coincidently closing the clearance-chamber 42, and thereby commencing high-pressure compression. The remaining portion of the stroke of the low-pressure piston is effected under simple expansion—that is to say, by the expansion of the motive fluid inclosed in the low-pressure cylinder, the motive fluid inclosed in the high-pressure cylinder and clearance-chamber being meanwhile, in and by the upward stroke of the high-pressure piston, compressed at its terminal to substantially initial pressure. Further movement of the valve in the same direction effects the exhaust of the motive fluid which has impelled the low-pressure piston, and admits motive fluid to the clearance-chamber and high-pressure cylinder for the next succeeding stroke of the piston of the latter, such new supply being subject to no reduction of pressure in filling the clearance-chamber, as it meets therein a previous supply of equal pressure, which is utilized in the exertion of such pressure upon the high-pressure piston in the stroke about to be made.

Variations of the grade of expansion in the operation of the engine would under previous practice involve different degrees, respectively, of terminal high-pressure compression, from the fact that greater or less volumes of motive fluid are, proportionately to the lateness or earliness of the cut off, admitted to the high-pressure cylinder, while the compressive action of the piston, being exerted through the same space in each case, is uniform at all points of cut off. In the practice of our invention we counteract and compensate for such tendency to variation of the degree of terminal compression above or below initial pressure by effecting each and every grade of low-pressure expansion coincidently with the initiation of high-pressure compression within a clearance-space of such volume as has been determined by experimental research to be requisite to admit of the degree of terminal compression being raised to without exceeding that of initial pressure at the commencement of the stroke. Each change of the point of cut off is consequently accompanied by a corresponding change of pressure at the point of initial compression, (which point corresponds with the point of cut off,) due to the greater or less amount of motive fluid which has been expanded from the high-pressure cylinder into the low-pressure cylinder, so that the later the cut off and the less the volume of motive fluid on which compression is to be exerted the greater will be the pressure of said volume, and, conversely, the earlier the cut off and the greater the volume of motive fluid to be compressed the less will be its pressure.

It will be seen that the practice of our invention involves a substantial departure from

that which has heretofore generally prevailed, to wit: reducing clearance to the least measure practicable. We have discovered, and demonstrated by experiment as the basis of our present invention, that such reduction of clearance is unnecessary to the successful and economical utilization of the expansive force of motive fluids, and, further, that a material advantage is attained by an increase of clearance much beyond the degree heretofore deemed desirable or even admissible when employed as an agent in effecting compression to initial working-pressure, such advantage being by our invention rendered continuously available, under the conditions existing in ordinary service, by a distribution of motive fluid which maintains the correspondence of terminal compression and initial pressure without disturbance from the variations of pressure and load, which are normally encountered and provided for in the operation of the standard constructions known and approved in present steam-engineering practice.

The engine herein described and shown is not claimed as of our present invention, being introduced only to facilitate the description thereof by reference to a mechanism suitably adapted to its application, and according, moreover, in its essential elements with that set forth in our application, Serial No. 267,519, hereinbefore referred to.

We claim as our invention and desire to secure by Letters Patent—

1. The improvement in the method of disdributing motive fluid in compound engines, which consists in supplying the same to a preliminary or high-pressure cylinder and a continuously-communicating clearance-chamber of determined volume, substantially greater than that required to serve as an avenue for the passage of motive fluid, exhausting the same under compound expansion into a secondary or low-pressure cylinder, and thereafter closing the exit from said clearance chamber and raising high-pressure compression to initial pressure therein, substantially as set forth.

2. The improvement in the method of distributing motive fluid in compound engines, which consists in raising high-pressure compression to initial pressure in a chamber of suitable determined volume without limitation by or disturbance from variations of load or initial pressure by commencing high-pressure compression coincidently with low-pressure expansion, substantially as set forth.

3. The improvement in the method of distributing motive fluid in compound engines, which consists in supplying the same to a preliminary or high-pressure cylinder and a continuously-communicating clearance-chamber of suitable determined volume, exhausting the same under compound expansion into a secondary or low-pressure cylinder, varying the grade of simple expansion in the same direction in both the high and the low-pressure cylinders, and effecting high-pressure compression to initial pressure in the clearance-chamber by initiating said compression coincidently with each and every variation of the grade of low-pressure expansion, substantially as set forth.

4. The improvement in the method of distributing motive fluid in compound engines, which consists in counteracting and compensating for the tendency of variations of the point of cut off to induce variations in terminal high-pressure compression by effecting a corresponding variation of pressure at the point of initial compression coincidently with each variation of the point of cut off, substantially as set forth.

In testimony whereof we have hereunto set our hands.

HENRY HERMAN WESTINGHOUSE.
FRANCIS M. RITES.

Witnesses:
J. SNOWDEN BELL,
R. H. WHITTLESEY.