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O. H. HARTMANN ET AL

PROCESS AND APPARATUS FOR REGULATING MULTISTAGE STEAM ENGINES OF THE HIGH PRESSURE TYPE

Filed Oct. 8, 1924 2 Sheets-Sheet 1

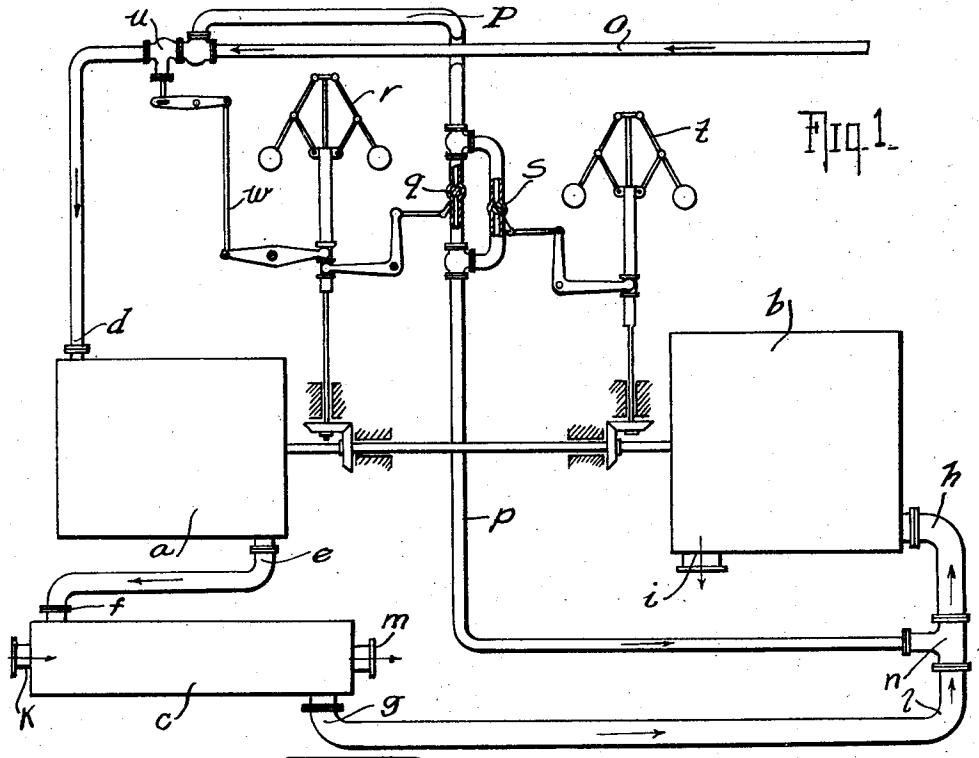


Fig. 1.

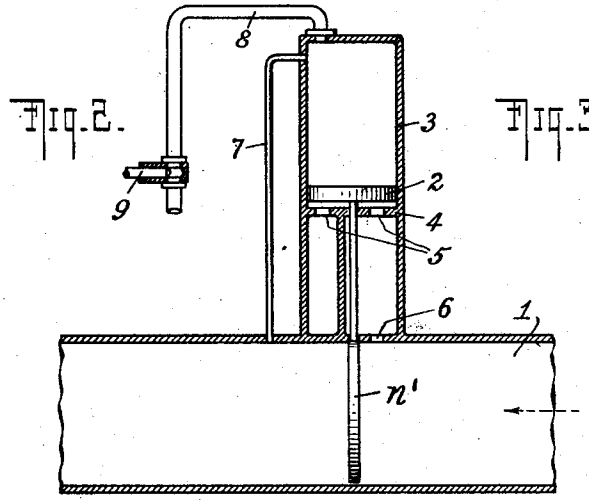


Fig. 2.

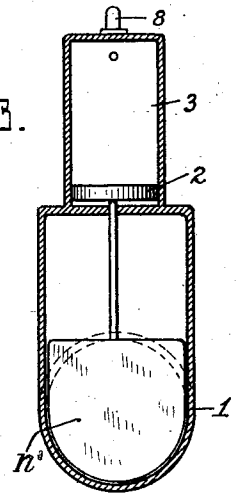


Fig. 3.

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Fig. 4.

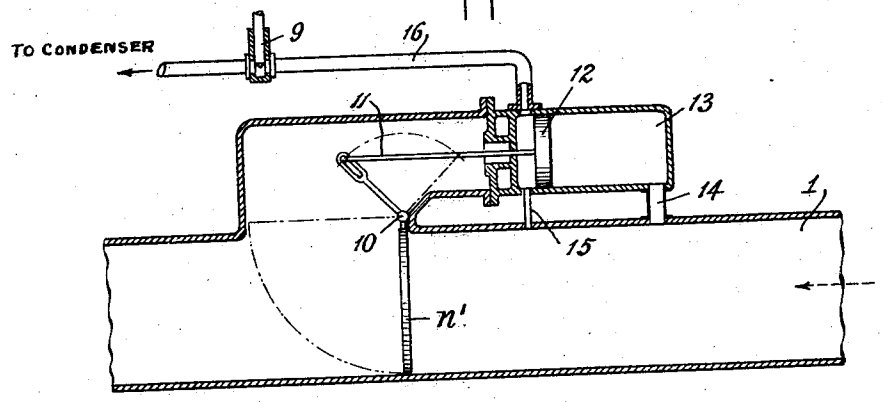


Fig. 5.

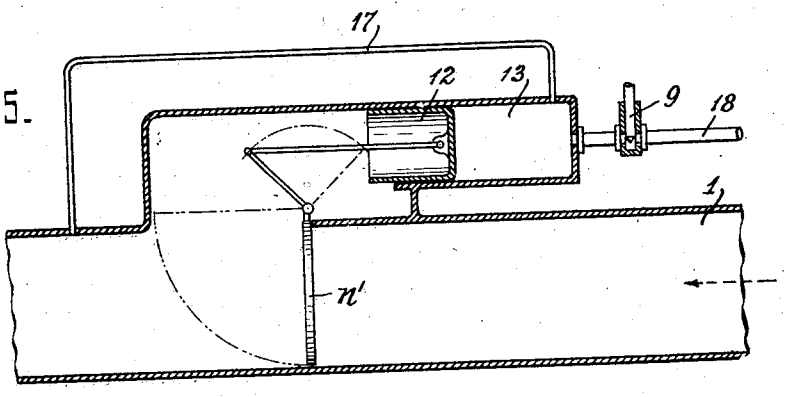
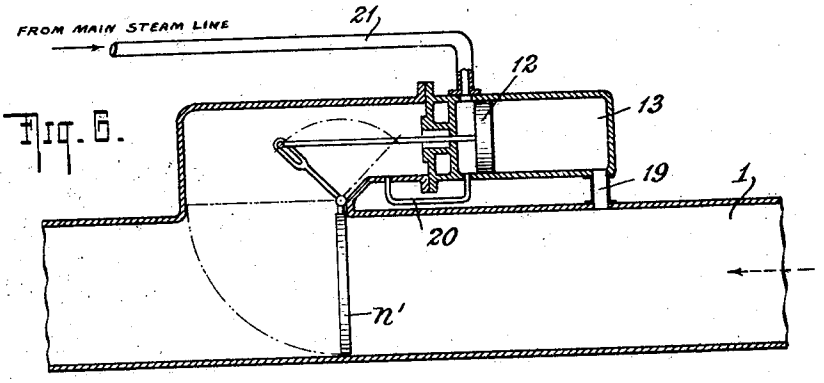


Fig. 6.



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PROCESS AND APPARATUS FOR REGULATING MULTISTAGE STEAM ENGINES OF THE HIGH PRESSURE TYPE

Application filed October 8, 1924, Serial No. 742,302, and in Germany October 30, 1923.

Considerable difficulty is experienced in regulating the number of revolutions of multi-stage steam engines having relatively large steam spaces, for instance, receivers interposed between successive stages. Regulation in such cases is rendered difficult owing to the presence of relatively large amounts of steam in the spaces between successive stages, so that even if the main throttle or corresponding controlling valve admitting steam to the high pressure stage has been closed, steam from said large spaces will pass on to the lower stage and continue to perform work therein. Even with piston engines of the multi-stage character, this entails considerable drawbacks, but the difficulties are even greater in the case of multi-stage steam turbines which are more sensitive to regulation than piston engines and in which frequently there are employed between stages, receivers constructed as intermediate superheaters. The effect of this phenomenon is increased particularly when the steam employed is of the high pressure of 20 atmospheres or more, in view of the fact that steam of such pressure has a considerable weight per unit of volume. In these cases, therefore, the drawbacks referred to above will be particularly strong, as regards the detrimental effect of steam flowing on to the lower stage from the steam spaces located between the stages. These amounts of steam contained in the intermediate spaces are not under the influence of the regulator or governor, so that, for instance, if the centrifugal governor should shut off completely the admission of steam to the highest pressure stage, the engine may still exceed, in a dangerous manner, the maximum number of revolutions allowed, owing to the expansion, in the low pressure stage, of the steam stored in the intermediate superheater; this would not be prevented either by the ordinary centrifugal governor or by a special quick acting governor of the same type.

The invention relates to apparatus for obviating the difficulties mentioned above. The invention is of special value in connection with turbines using intermediate superheating and high pressure steam. According to our invention, we employ not only a main admission valve controlling the supply of live steam to the high pressure stage of the engine, but we employ a further steam shut off device operating automatically whenever a predetermined number of revolutions is exceeded, to shut off the admission of steam to that stage of the engine which follows the relatively large steam space, for instance, an intermediate superheater. This additional steam shut off device is interposed between the intermediate superheater and the next succeeding working stage of the engine, and may be controlled either by the existing centrifugal governor or by a special governor of its own. This steam shut off device has the function of cutting off entirely or partly the steam conduit leading from the intermediate superheater to the next succeeding working stage, whenever the number of revolutions of the engine exceeds a predetermined figure. It is desirable that this conduit should be shut off before the quick acting governor enters into operation. The effect of this special steam shut off device is a double one; not only is the work performed in the lower stage diminished, but the back flow of the steam in the preceding part of the engine causes a quick decrease of the work done in the upper stage, owing to increased ventilation or windage losses. The actuation of this steam shut off device from the centrifugal governor or from a special governor may be accomplished in various ways. For instance, live steam or any other indirectly acting pressure medium may be employed for controlling the steam shut off device; but it would be within the scope of our invention to employ a direct connection between the governor and the shut off device.

The invention will now be described in detail with reference to the accompanying drawings, which illustrate as examples several embodiments of apparatus operating according to this invention. Fig. 1 is a diagrammatic general view of a steam power plant embodying this invention. Fig. 2 is a vertical section of an embodiment of our inventon illustrating a simple form of steam shut-off device and its actuator. Fig. 3 is a

section of the same at right angles to Fig. 2. Fig. 4 shows a modification embodying our new system of regulation. Fig. 5 shows still another modification thereof. Fig. 6 illustrates a still further modification.

In Fig. 1, *a* and *b* indicate the high pressure and the low pressure stage respectively of a two stage steam engine. *c* is an intermediate superheater through which the exhaust steam from the high pressure stage *a* passes on its way to the low pressure stage *b*. Live steam from the boiler is admitted through a conduit *o*, a valve *u* and a suitable inlet *d* to the high pressure stage *a*. From the outlet of the latter the exhaust steam passes through a conduit *e* to the inlet *f* of the intermediate superheater *c*. The latter may be of the usual two path type, the steam to be heated passing from the inlet *f* through one path to the outlet *g*, while the heating steam passes through the other path, entering at *k* and leaving at *m*. Live steam may be used as the superheating medium. From the outlet *g* the exhaust steam passes through a pipe or conduit 1 to the inlet *h* of the low pressure stage *b*, the outlet of which is indicated at *i*. Between the intermediate superheater *c* and the inlet *h* the conduit 1 contains a steam shut off device indicated at *n*. Various constructions of this device are shown in detail in Figs. 2 and 6, and Fig. 1 does not show the actuating mechanism of said shut off device. This actuating mechanism may be operated directly by the centrifugal governor *r*, or the actuation may be indirect through the medium of a fluid under pressure controlled by the governor *r*. Thus in the example illustrated by Fig. 1, a portion of the live steam from the conduit *o* is diverted through a branch pipe *p* containing a regulating or throttling device such as a damper or needle valve, as indicated at *q*, which in turn is controlled by the centrifugal ball governor *r*. We may provide a second throttling element *s* connected in parallel with the throttling element *q*, and controlled by a separate quick acting governor (safety governor) *t*. Whenever the number of revolutions of the engine exceeds a predetermined figure, the governor *r* will shut off the supply of steam to the high pressure stage *a* by closing the main steam admission valve *u* by means of the linkage *w*, and will also move the throttling or shut off device towards its closing position, by actuating the throttling device *q* in the branch pipe *p*. Should the ball governor *r* fail to work for any reason, the quick acting governor *t* will act on the throttling device *s* and cause the shut off device *n* to be closed.

In detail the shut off device *n* and its actuating mechanism may be constructed as follows:

According to Figs. 2 and 3, the shut off device *n* consists of a sliding damper *n'* connected with a piston 2 arranged to move in a cylinder 3. This cylinder is closed at the bottom by a wall 4 having openings 5. The space below said opening 5 is connected with the steam conduit 1 by means of openings 6 located on the steam supply side of the conduit, that is to say, the steam coming from the outlet *g* will reach the openings 6 even though the damper *n'* should be in the fully closed position. The space of the cylinder 3 above the piston is connected by a throttling duct 7 of relatively small cross section with the portion of conduit 1 on the other side of the damper *n'* that is, on the side toward the inlet *h*. This upper space of the cylinder is also connected with a pipe 8 of considerably greater cross section than the throttling duct 7. In this pipe 8 is arranged a throttling device 9, which may be a needle valve or the like. This throttling device 9 corresponds to the part indicated by *q* in Fig. 1, and may be under the influence, for instance, of the centrifugal governor *r*.

During the normal operation, the conduit 8 is shut off by the throttling device 9. The equalizing or by-pass connection afforded by the duct 7 causes the pressure to be about the same above the piston 2 as in the part of the conduit 1 which lies on the far side of the shut off valve *n'*. The steam contained in the conduit 1 in front of the damper *n'* passes through the openings 6 and 5 to the lower surface of the piston 2 and lifts the latter until the pressure in the conduit 1 is about the same in front and in the rear of the damper *n'*. When the number of revolutions is exceeded by a predetermined figure, the throttling device 9 in the conduit 8 is opened through the action of the governor *r* so that live steam or other medium under pressure may be admitted above the piston 2. The high pressure steam thus admitted can not escape through the duct 7 in the same ratio in which it enters through the conduit 8; therefore, pressure will be greater on the upper side of the piston and will cause the latter to shift the damper *n'* to the closed position. The specific construction shown in Figs. 2 and 3 is very simple and has therefore been chosen as the first to be explained herein, as it embodies the principles of operation. It is, however, open to the objection of giving rise to considerable friction, and for this reason we prefer other construction, several instances of which are shown in Figs. 4, 5, and 6.

In Fig. 4, the shut off device consists of a damper *n'* pivoted at 10 and actuated by means of the rod 11 connected with the piston 12, moving in a cylinder 13. That end of the cylinder from which the piston moves away when tending to close the pivoted damper *n'*, is connected with the conduit 1 by a pipe or duct 14, so that this end of the cylinder will always be under the same pressure

as the portion of the conduit 1 connected with the outlet g of the intermediate superheater. At the other end the cylinder 13 is connected by a duct 15 with the same portion of the pipe or conduit 1, but the duct 15 is of relatively small cross section so as to act as a throttling device. With the same end of the cylinder is connected a fairly large conduit 16 connected with the condenser, not shown, or with any other chamber in which a relatively small pressure prevails. This conduit 16 contains the throttling device 9 controlled by the governor r. In normal operation the conduit 16 is closed by the throttling device 9. The pressure on both sides of the piston 12 will be about the same, that is the said piston is balanced, and the damper n' will, under the influence of the steam flowing through the conduit 1, lift or open to such an extent that the pressure will be about the same in front and in the rear of the damper n'. When a predetermined number of revolutions is exceeded, the governor r will cause the throttling device 9 to open so that pressure in the left hand compartment of the cylinder 13 will be reduced since said compartment is then connected with a chamber in which relatively low pressure prevails, for instance the condenser. Pressure in the right hand compartment of the cylinder 13 will thus be greater than that in the left hand compartment, since the steam can not enter through the narrow duct 15 as fast as it leaves the left hand compartment through the conduit 16. Therefore, the piston 12 will be moved toward the left in the cylinder 13 thereby shifting the damper n' toward the closed position.

In Fig. 5 the pivoted damper is connected with a sliding piston 12 in substantially the same manner as described in connection with Fig. 4. The cylinder 13, however, is open at one end so that it really has a single compartment instead of two. This compartment is connected by an equalizing duct 17 of small cross section with the conduit 1 at a point in the rear of the damper n'. Furthermore, this cylinder compartment is connected with a relatively large pipe or conduit 18 connected to the main steam line and containing a throttling device 9 under the control of the governor r. In normal operation the pressure will be substantially alike on both sides of the piston 12, since the equalizing connection or duct 17 causes the pressure within the cylinder 13 to be the same as in the conduit 1 in the rear of the damper n'. The throttling device 9 is closed in the same manner as described with reference to Fig. 4. The damper n' will therefore assume such a position that the pressure in the conduit 1 will be approximately the same in front and in the rear of said damper. When a predetermined number of revolutions is exceeded, the governor r will cause the throttling device 9 to be opened more or less so that a high pressure medium, for instance, steam of high pressure, will be able to enter the cylinder 13. The narrow equalizing duct 17 will not permit such high pressure steam to escape as fast as it is admitted through the side conduit 18, and therefore the piston 12 will be moved and the damper n' moved toward the closed position.

In the arrangements illustrated by Fig. 6, the pivoted damper n' is connected with a piston 12 moving in a cylinder divided by said piston into two compartments. One of these compartments is connected by a channel 19 with the conduit 1 and when the pressure in said compartment prevails over that in the other compartment the piston 12 will be moved in such a direction as to swing the damper n' toward its closed position. In other words, the pressure in said cylinder compartment will be always the same as that in the conduit 1 in front of the damper n'. The other compartment of the cylinder 13 is connected by an equalizing duct 20 of relatively small cross section with the portion of the conduit 1 in the rear of the damper n', or to any other place in which a relatively low pressure prevails. From the same compartment is extended a conduit 21 of relatively large cross section which leads into the steam line in the rear of the main steam valve u. In this case the conduit 21 does not contain any throttling device. In normal operation the live steam flowing through the conduit 21 into the cylinder 13 will cause the damper n' to be moved toward the open position. When a certain predetermined number of revolutions is exceeded, the governor r will cause the main steam valve u to be closed and therefore no steam will pass through the conduit 21 to the cylinder 13. From that moment on the pressure of the steam entering the cylinder through the channel 19 will shift the piston 12 towards the left and move the damper n' toward the closed position, the steam contained in the other compartment passing out through the duct 20 into the conduit 1 on the other side of the damper n'.

The invention is not restricted to the specific embodiments shown and described, but is equally applicable in all cases where a governing of the power devices by means of a medium under pressure is desired, which pressure may also serve to operate the controlling mechanism for the steam dampers. The controlling device would, of course, have to be constructed in each individual case so as to operate properly in connection with the pressure medium selected. The steam shut off device may be used not only for completely closing the steam connection between the relatively large steam camber and the next succeeding working stage, but it may also, to a certain extent, serve to regulate the passage of steam through said connection so that even

relatively small variations of load may be equalized.

We claim:

1. A multiple stage steam engine having a superheater for superheating the steam on its passage from one stage to the next, a device for regulating the passage of steam from said superheater to the said next stage, a governor operated by the engine according to its number of revolutions, an auxiliary motor controlled by said governor for operating the said regulating device, and a second device operated by said governor for regulating the passage of steam to said first mentioned stage.

2. A multiple stage steam engine having a superheater for superheating the steam on its passage from one stage to the next, a device for regulating the passage of steam from said superheater to the said next stage, a governor operated by the engine according to its number of revolutions, an auxiliary motor operating said regulating device, a connection by which one side of said motor is exposed to the pressure prevailing in the passage between said superheater and said next stage, another connection by which the other side of said motor is exposed to a different pressure, and an operative connection by which said governor controls said second-named connection.

3. A multiple stage steam engine having a superheater for superheating the steam on its passage from one stage to the next, a device for regulating the passage of steam from said superheater to the said next stage, a governor operated by the engine according to its number of revolutions, a device for the admission of steam to the high pressure stage, an auxiliary motor for operating said regulating device, a connection by which one side of said motor is exposed to the pressure prevailing in the passage between the superheater and said next stage, another connection by which the other side of said motor is exposed to the pressure prevailing in the rear of the device for the admission of steam to the high pressure stage, and an operative connection by which said governor controls said second-named connection.

4. A multiple stage steam engine having a superheater for superheating the steam on its passage from one stage to the next, a device for regulating the passage of steam from said superheater to the said next stage, a governor operated by the engine according to its number of revolutions, a cylinder, a piston movable in said cylinder and operatively connected with said regulating device, a connection for exposing one side of said piston to the pressure prevailing in the passage between the superheater and said next stage, another connection for exposing the other side of said piston to a different pressure, and an operative connection by which said governor controls said second named connection.

5. A multiple stage steam engine having a superheater for superheating the steam on its passage from one stage to the next, a device for regulating the passage of steam from said superheater to the said next stage, a governor operated by the engine according to its number of revolutions, a cylinder, a piston movable in said cylinder and operatively connected with said regulating device, a connection for exposing one side of said piston to the pressure prevailing in the passage between the superheater and the said regulating device, an admission device for the supply of steam to the high pressure stage of the engine, another connection for exposing the other side of the piston to the pressure prevailing in the rear of said admission device, and an operative connection by which said governor controls said second named connection.

6. In combination, a multi-stage high pressure steam turbine, an interstage superheater, a speed control governor, a throttling device controlling the flow of steam to the high pressure stage of the turbine, a second throttling device between the interstage superheater and the low pressure stage of the turbine, and means for operating both of said throttling devices in accordance with the speed of the speed control governor.

7. In a device according to claim 6, said means comprising a servo-motor having a piston, one face of said piston being exposed to the pressure within the low pressure stage of the turbine.

8. In a device according to claim 6, said means comprising a servo-motor having a piston, one face of said piston being exposed to the pressure in the low pressure stage of the turbine, the other face being exposed to a different pressure, one face of said piston being also exposed to the pressure of the steam in the high pressure stage of the turbine.

9. In a device according to claim 6, said means comprising a servo-motor, a piston therein operatively connected to the second throttling device, means for maintaining the pressure on both faces of the piston approximately equal during normal operation of the turbine, and means causing a decrease of pressure on one face of said piston in response to increase of speed above normal, whereby said second throttling device is operated.

10. In combination, a multi-stage high pressure steam turbine, an interstage superheater, a speed control governor, an emergency governor, a throttling device controlling the flow of steam to the high pressure stage of the turbine, a second throttling device between the interstage superheater and the low pressure stage of the turbine, and means for operating the second mentioned

throttling device in accordance with the speed of either governor.

11. In combination, a multistage intercoupled steam engine, an interstage superheater, a conduit for supplying steam to the high pressure stage of the engine, means for varying the effective cross-section of said conduit, means for simultaneously varying the effective cross-section of the steam passage between the superheater and the stage following it, a conduit for conducting high pressure steam from said first mentioned conduit to said means to operate the same, and mechanism responsive to the speed of the engine and associated with said means to control the same in accordance with said speed.

In testimony whereof we have hereunto set our hands.

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