

March 5, 1946.

R. R. McINTOSH

2,395,973

PRESSURE CONTROL APPARATUS

Filed April 30, 1942

4 Sheets-Sheet 1

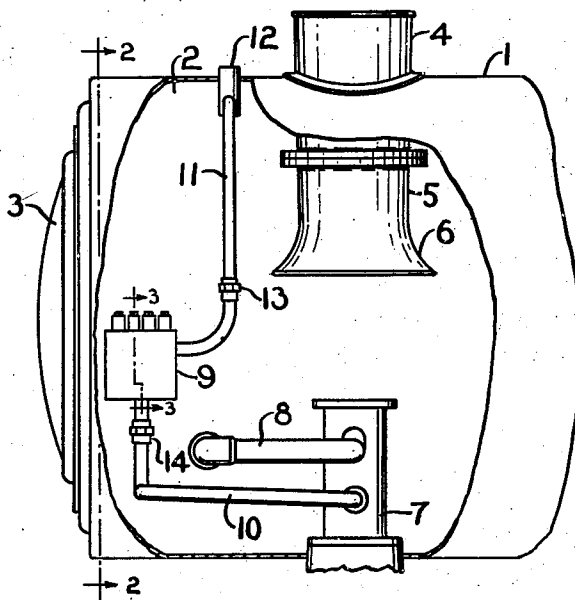


FIG-1

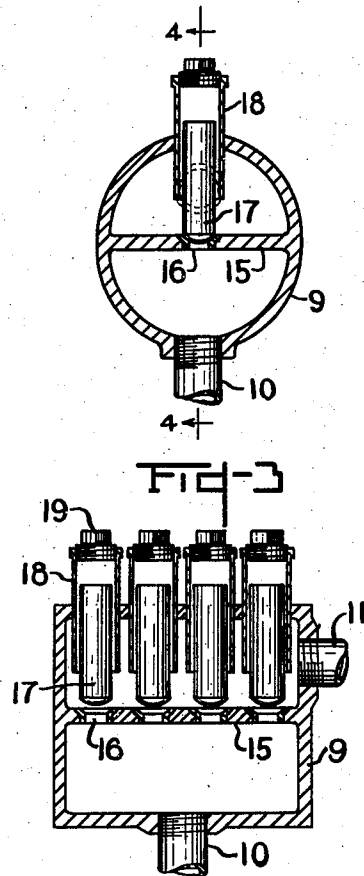


FIG-4

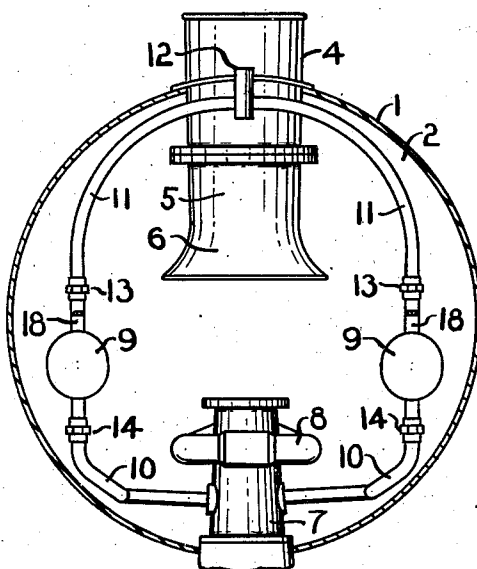


FIG-2

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PRESSURE CONTROL APPARATUS

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4 Sheets-Sheet 2

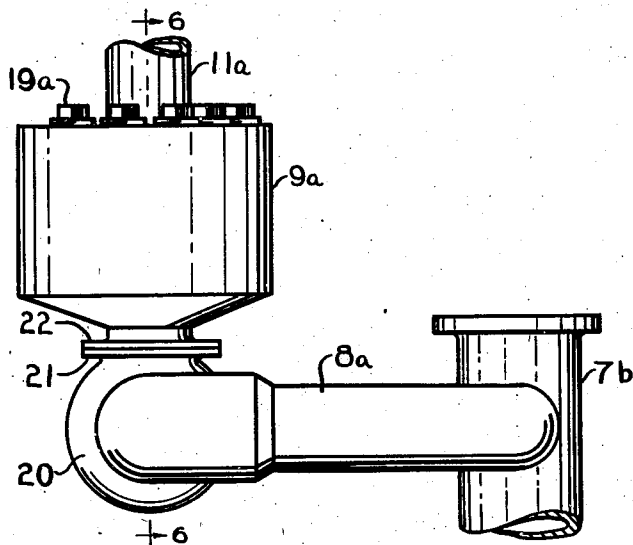


FIG-5

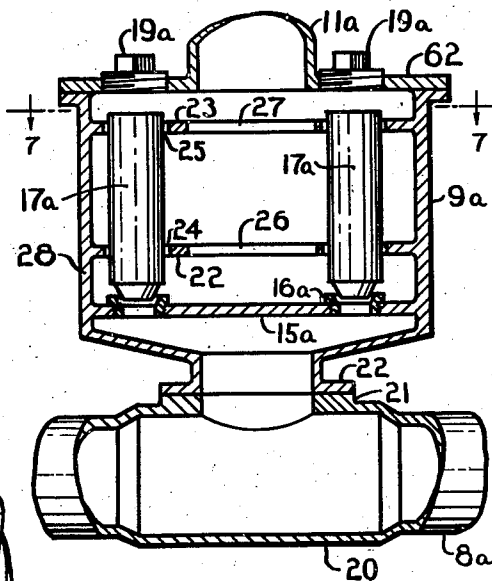


FIG-6

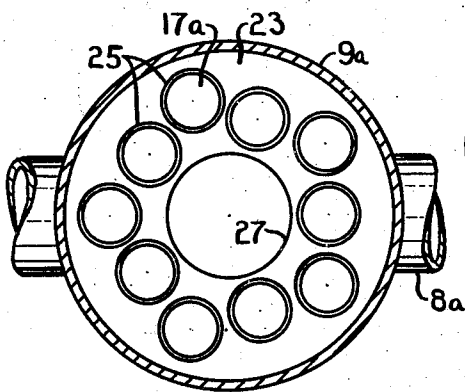


FIG-7

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PRESSURE CONTROL APPARATUS

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4 Sheets-Sheet 3

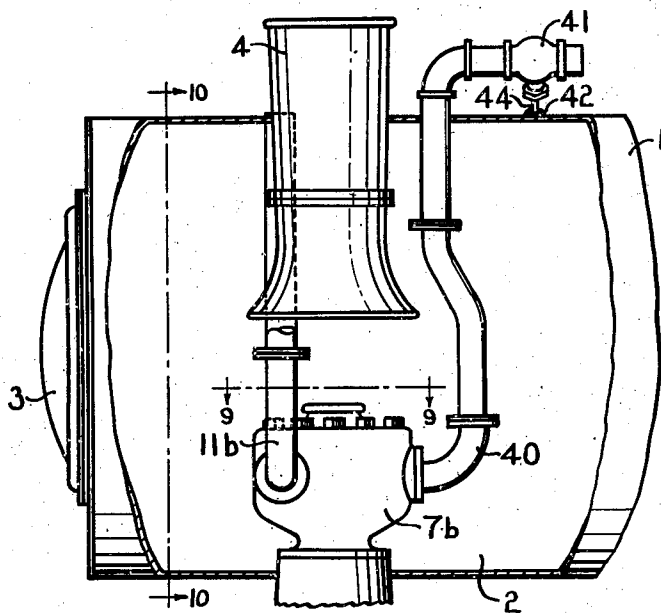


FIG-8

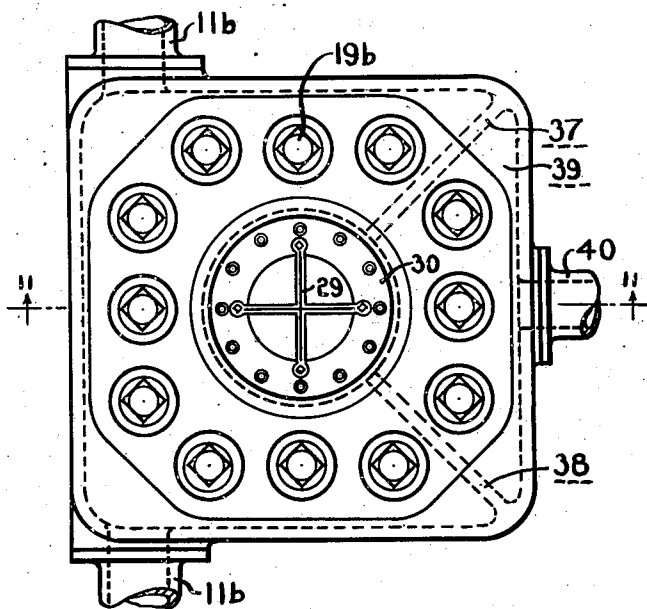


FIG-9

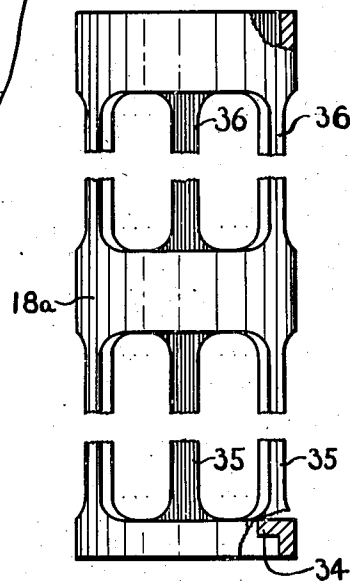


FIG-12

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PRESSURE CONTROL APPARATUS

Filed April 30, 1942

4 Sheets-Sheet 4

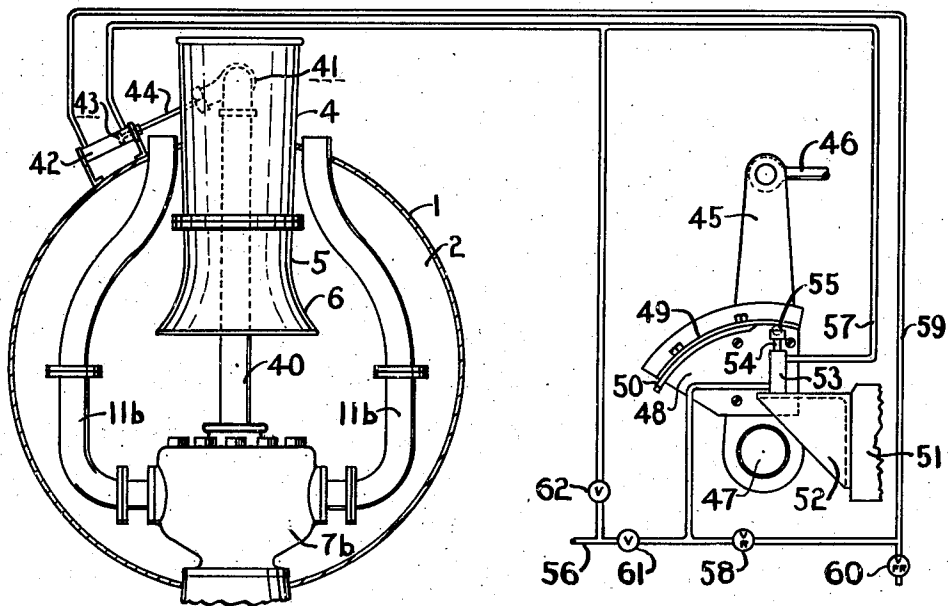


FIG-10

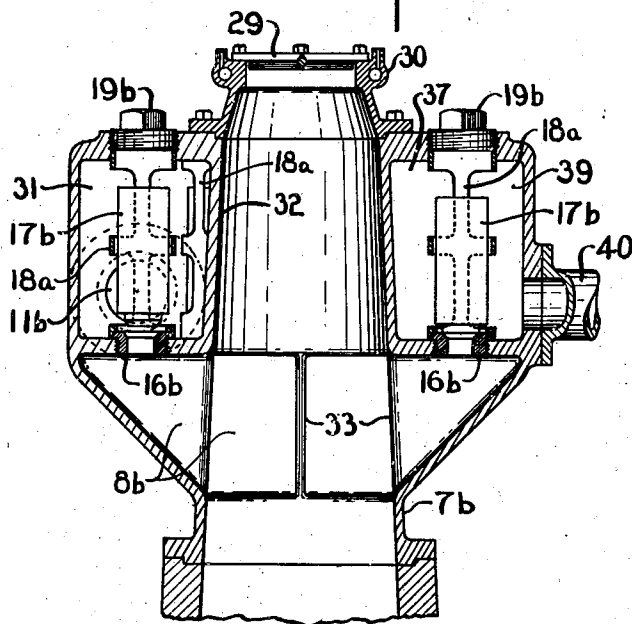


FIG-11

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UNITED STATES PATENT OFFICE

2,395,973

PRESSURE CONTROL APPARATUS

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Application April 30, 1942, Serial No. 441,095

18 Claims. (Cl. 60—90)

The present invention relates broadly to pressure control apparatus, and in its specific phases to apparatus for volume-velocity control of the flow of exhaust steam from fixed area exhaust orifice, suction inducing, nozzles in steam locomotive front ends to govern among other things, the back pressure of said exhaust steam.

The present-day steam driven railroad locomotives are provided with an exhaust stand in the smoke box at the front end thereof. Steam exhausted from the locomotive cylinders is passed through this exhaust stand and the fixed area nozzle mounted thereon and directed out of the smoke stack to create suction pressure in the smoke box and draft through the locomotive to promote combustion in the fire box. The exhausting of a small amount of steam in this manner through an exhaust stand having, according to common practice, a fixed outlet area of approximately one-twelfth the area of one of the locomotive cylinders, such as is standard practice with an existing 4-8-4 type Grand Trunk Western U-3-a locomotive, produces little suction pressure in the smoke box, while the exhaust of a large amount of steam under the same conditions produces extreme suction pressures and high back pressures on the locomotive cylinders. These high back pressures adversely affect the power output of the locomotive due to their reduction of the mean effective pressure on the piston in each of the cylinders. Abnormally high draft created in this manner, if applied directly to the fire bed in the fire box, would tear same and not only adversely affect combustion efficiency but promote serious discharge of burning coal and cinders from the locomotive with attendant abnormal scouring effect on the tubes, superheater units, and other parts in the path of flow of the products of combustion. To reduce this condition it is standard practice to install baffles and netting in the locomotive smoke box as well as to employ restrictive arches in the fire box and reduced size openings in the grates. Those familiar with the art involved thus recognized that the draft must be held down at its upper levels and took care of same in a limited way by means of the choking effect of the baffles, et cetera. That procedure, however, results in highly variable and generally unsatisfactory combustion conditions, does not reduce the detrimental effect of high back pressures, and moreover it increases the amount of exhaust steam which must be passed through the exhaust stand in a given unit of time to meet the minimum draft requirements. Those condi-

tions, in turn, result in undesirable smoke emission and require the use of live steam from a blower ring, normally mounted on the top of the exhaust stand, to maintain sufficient draft for minimum operation requirements.

A few attempts have been made to solve these difficulties, but such attempts have failed to recognize that the problem involved is a matter of volume-velocity control of the flow of exhaust steam from a fixed area orifice and that the solution of such, in turn, should be based on a careful consideration of the speed, output, and cut-off settings for any given class of locomotive under consideration. Where control of draft has been attempted by bypassing part of the exhaust steam, there has been no recognition by the art that a smaller fixed area orifice should be used at the top of the exhaust stand, nor that by such procedure a relatively small amount of exhaust steam would meet the requirements for creating minimum draft, thus making a better operating and more efficient construction. The apparatus which has been devised for varying the normal exhaust of steam through the smoke stack has been ordinarily referred to as draft control apparatus, while in reality it is a form of back pressure control apparatus wherein draft control is incidental. The apparatus of my present invention deals in its specific phases with back pressure control of steam exhausted from locomotive cylinders, at least a part of which is directed up the locomotive smoke stack for the creation of suction pressure in the locomotive smoke box. This back pressure control apparatus cooperates with a true draft control apparatus such as I have described in my copending patent applications, Ser. No. 381,290, filed March 1, 1941, now Patent No. 2,379,916, and Ser. No. 428,262, filed January 26, 1942, now Patent No. 2,377,895, to produce a highly efficient operating combination. A study of the shortcomings, difficulties, and misconceptions of the prior art led to the discovery and development of the present invention.

Accordingly among the objects of the present invention is the provision of an apparatus for automatically controlling the back pressure on the locomotive cylinders while producing sufficient back pressure to obtain the minimum draft required for combustion purposes with a relatively smaller amount of exhaust steam.

Another object is to provide an apparatus for holding the back pressure under substantially all locomotive operation conditions above the amount required for creating adequate draft for combus-

tion purposes and yet at the same time holding this back pressure moderately close to the minimum amount required for adequate draft under varying conditions.

Another object of the present invention is to provide an exhaust steam expansion space between the outlet from the cylinders and the fixed area exhaust orifice at the top of the exhaust stand, so as to reduce the extreme pulsations of exhaust from the cylinders and cause same to assume a more uniform flow.

A further object is to provide a back pressure control mechanism utilizing gravity held valves for controlling exhaust steam back pressure and by-passing part of the exhaust steam whenever said back pressure tends to rise above the level for which said valves are set to open.

A further object is to provide an apparatus of the character described wherein the gravity held back pressure control valves are freely movable and float on a cushion of exhaust steam as same flows thereunder under normal operating conditions.

A further object is to provide an apparatus wherein the exhaust stand nozzle is of reduced size so as to produce the minimum required suction pressure in the smoke box with a relatively smaller flow of exhaust steam, said reduced size exhaust stand nozzle being supplemented with suitable valves to handle a portion of the exhaust from the locomotive cylinders and maintain reduced back pressure on same.

A further object is to provide an exhaust stand assembly utilizing therein not only a reduced size exhaust nozzle, but also an expansion space, and a chamber or chambers having suitable valves therein for controlling the back pressure of the exhaust steam flowing into the assembly from the locomotive cylinders.

A still further object is to provide a pressure controlling apparatus which is very flexible in operation and adapted for a wide range of use.

A still further object is to provide an auxiliary compartment or compartments, preferably including suitable valves therein to meet special back pressure requirements, and if desired the auxiliary compartment or compartments may be built into the exhaust stand itself.

A still further object is to provide means in connection with an auxiliary compartment or compartments for automatically controlling the operation of same under special conditions.

Still further objects and advantages of the present invention will appear as the description proceeds.

To the accomplishment of the foregoing and related ends, the invention, then, consists of the means hereinafter fully described and particularly pointed out in the claims, the annexed drawings and the following description setting forth in detail certain means for carrying out the invention, such disclosed means illustrating, however, but several of various ways in which the principle of the invention may be used.

In said annexed drawings:

Figure 1 illustrates a locomotive front end in side elevation with part of the shell of same broken away to show an assembly of one form of the present invention.

Figure 2 is a front elevational view taken along line 2—2 of Figure 1, looking in the direction of the arrows.

Figure 3 is a partially sectioned and enlarged elevational view taken along line 3—3 of Figure 1, looking in the direction of the arrows.

Figure 4 is a partially sectioned elevational view with the valve members shown elevated for clarity, said view being taken along line 4—4 of Figure 3, looking in the direction of the arrows.

Figure 5 illustrates a side elevational view of a modified form of apparatus embodying the present invention.

Figure 6 illustrates a partially sectioned view taken along line 6—6 of Figure 5, looking in the direction of the arrows, all but two of the valve members being omitted, and they shown slightly elevated for clarity of understanding.

Figure 7 illustrates a section view taken along line 7—7 of Figure 6, looking in the direction of the arrows.

Figure 8 illustrates a locomotive front end in side elevation with part of the shell broken away to show the assembly of a preferred apparatus embodying the present invention.

Figure 9 illustrates a top view of a modified construction exhaust stand as viewed in the direction of the arrows 9—9 of Figure 8.

Figure 10 illustrates a front elevational view of the assembly shown in Figure 8, looking in the direction of the arrows 10—10 thereof, and diagrammatically illustrating on enlarged scale a control mechanism for use with same.

Figure 11 illustrates a partially sectioned elevational view taken along line 11—11 of Figure 9, looking in the direction of the arrows.

Figure 12 shows an enlarged and partially sectioned side elevational view of a preferred form of valve guide sleeve usable in the assembly illustrated in Figure 11.

The controlling of back pressure in a railroad locomotive, or the like, involves several factors. In the first place, the back pressure on the locomotive driving cylinders should be maintained as low as possible since the lower the back pressure is maintained, the higher is the mean effective pressure on the driving cylinders with correspondingly increased horsepower output for a given quantity of steam consumed, other factors remaining constant. The volume and velocity of the steam exhausted through a fixed size orifice at the top of the exhaust stand, according to present-day standard practice, varies almost directly with the back pressure of the exhaust steam on the locomotive cylinders. Accordingly, the suction pressure in the locomotive smoke box, due to the discharge of this exhaust steam out of the smoke stack, increases substantially in step with the increase of back pressure. The steam demand of the locomotive which causes this variation in back pressure also varies the rate at which fuel must be consumed in the locomotive fire box to maintain the required steam generation. Efficient burning of this fuel at the same time requires the draft to be correspondingly varied. In other words, where a high rate of fuel consumption is required, a higher draft is necessary and this in turn requires a sufficiently higher back pressure to create that draft. So far as back pressure is concerned, there are thus two problems involved, first, that of holding the back pressure at the lowest possible point so as to increase the horsepower output of the cylinders for a given steam consumption, and second, the necessity of maintaining the back pressure sufficiently high to provide for adequate draft requirements. To meet these two problems it thus becomes necessary, for efficient operation, to maintain the back pressure at a point normally just above that which will take care of the minimum draft requirements under various operating

conditions. Another problem in connection with draft concerns the pulsating exhaust from the cylinders, the effect of which is extreme under open throttle at high percentage of cut-off, and relatively low speeds. The adverse effect of these pulsations can be greatly reduced and a much more smooth exhaust produced by connecting an exhaust steam expansion chamber to the exhaust passage between the exhaust outlet from the cylinders and the fixed orifice at the outlet end of the exhaust stand. The draft requirements for combustion purposes does not necessarily vary directly with the speed of the locomotive or the normal uncontrolled rise of the back pressure of the steam exhausted from the locomotive cylinders, since these factors, for instance, may be varied by varying systems and methods of operation practiced by different locomotive engineers as well as special requirements of operation at different points on the railroad line. To take care of this contingency, auxiliary supplemental parts may be used to raise, lower, or hold a particular draft pressure when those conditions arise. This again makes possible further increased efficiency of operation, and is one phase of the present invention.

Referring more particularly to Figures 1, 2, 3, and 4, of the drawings, the locomotive 1 has a smoke box 2 at the front end thereof with a conventional door 3 for access thereto. Extending out of the top of the smoke box is a smoke stack 4 with a downwardly depending extension 5 normally having an outwardly flared bottom 6. The exhaust from the cylinders (not shown) is directed into the bottom of the exhaust stand 7 which is preferably provided at its upper end with a removable fixed area exhaust nozzle and spreader bridge (not shown), or the equivalent, which spreads the exhaust steam and makes same forcibly contact the inner walls of smoke stack 4, or depending extension 5 thereof, to form a seal and thus create a partial vacuum in the smoke box which in turn induces draft through the locomotive. An expansion chamber 8 is shown attached to exhaust stand 7 so as to permit the pulsating exhaust from the locomotive cylinders (not shown) to expand therein and thus make the exhaust steam delivered to the smoke stack take on a more smooth and less pronounced pulsating flow. This, in turn, makes the draft more uniform and substantially even through the locomotive and thus reduces the common tearing effect of excess pulsating draft upon the fire bed in the locomotive fire box (not shown).

Where all or at least substantially all of the exhaust steam which is not to be used for water preheating, or the like, is directed up the smoke stack, according to standard practice, it creates abnormal draft suction pressures under conditions of high steam consumption, a thing which at the present time necessitates the use of baffles, restrictive arches, et cetera, in order to hold the suction pressure created in the smoke box from getting so far beyond combustion requirements as to carry large pieces of burning coal from the fire bed and through the boiler tubes with the wear incident thereto, as well as danger of starting fires with the discharged burning particles. In order to overcome this situation, a back pressure control system is utilized, one form of which is shown in Figures 1, 2, 3, and 4. This back pressure control system utilizes one or more back pressure valve assemblies 9, the bottom of each of which is connected by means of tubular member 10 to exhaust stand 7, or at some other suit-

able point between the exhaust outlet of the cylinders and the outlet from the top of exhaust stand 7. The upper portion of each valve assembly 9 is provided with a tubular outlet member 11 which for convenience may terminate in a discharge member 12 with outlet outside of the smoke box. Where two or more valve assemblies are utilized, the tubular outlet members from each valve assembly may terminate in a common discharge member if desired. For ease of assembly and disassembly of the apparatus, ground joint couplings 13 and 14 may be utilized.

Referring more particularly to Figures 3 and 4, the valve assembly 9 may be provided with a horizontal partition 15 which for convenience may be placed substantially at the middle thereof. Mounted in partition 15 is a valve seat or seats 16 which may be fastened in place in conventional manner. The upper face of these seats is preferably hardened and ground to form a suitable sealing seat for the corresponding end of valve members 17. Valve guide sleeves 18 are mounted in substantially fluid tight manner in the upper portion of valve assembly 9 so that valve members 17 will be guided in an up and down movement to and from valve seats 16. For ease of insertion and renewal of valve member 17, as well as valve seats 16, the upper end of valve guide members 18 may be threaded and closed by means of suitable plugs 19. Valve members 17 are preferably made solid with the lower end of each hardened and ground for engaging and sealing on valve seats 16. The use of solid valve members 17 permits them to operate on the gravity principle and does away with any need of using valve springs for holding the valves on their seats at pressures below which they are set to open. The use of valves of this type also presents the advantage of floating action cushioned by the by-passed exhaust steam under normal flow thereof, while the mass of each valve member retards vibration incident to exhaust pulsations.

The use of a back pressure controlling system such as is shown in Figure 2 permits the fixed orifice area at the top of exhaust stand 7 to be reduced in size so that a smaller quantity of exhaust steam will create the minimum draft suction required to take care of an adequate air supply for efficient combustion in the fire box (not shown). This also presents the further advantage of eliminating the need of delivering live steam up the smoke stack from a conventional blower ring (not shown) under light operating conditions until what is known as drifting operation is almost reached. This in turn, results in a considerable saving of live steam which would be required for creation of draft under operating conditions over a considerable range of locomotive operation according to standard practice.

It is well recognized that there is an optimum amount of suction pressure draft required for each rate of combustion of fuel in the locomotive fire box if efficient combustion is to be availed of. In other words, for a low rate of combustion the draft required is less than that where a higher rate of combustion is necessary. With this in mind, the back pressure controlling valve assemblies may be set to by-pass part of the exhaust steam when the minimum draft required for efficient combustion purposes has been reached, and substantially maintain the back pressure and draft at that point until a higher rate of combustion is required. Under conditions involving higher rates of steam consumption, the amount of steam exhausted from the driving cylinders

will increase and the amount of fuel to be burned will require increased draft. This can also be taken care of in various ways by the valve assemblies described. For instance, if a back pressure of five pounds per square inch gage is all that is required to take care of producing the minimum required draft over a moderate range of operation, then valve members 17 may be made of a suitable weight to start elevating for by-passing of some exhaust steam when that pressure is reached. The fixed area of the exhaust stand nozzle under these conditions should be such as to keep the back pressure approximately at five pounds per square inch gage even under light operating conditions, thereby providing a substantially constant exhaust steam cushion for the valves. As the amount of steam consumed increases, the back pressure will tend to increase, and that in turn will elevate valve members 17 further and further until their maximum capacity for releasing steam approximately at that pressure is reached, whereupon the back pressure and draft will gradually increase at a more rapid rate. By determining the maximum draft and back pressure necessary under maximum combustion requirements, the proper size and number of valves with adequate size connections can be provided to readily control the draft and prevent same from rising considerably above the maximum required at any given time or phase of locomotive operation. Operation in this manner thus produces the minimum draft required under minimum operating conditions and prevents excessive draft under maximum operating conditions. The weight of the valves to be used may be closely approximated by multiplying the area of the valve opening in square inches by the pressure in pounds per square inch at the level which they are to maintain.

A second procedure which may be followed is to determine the back pressure required for maximum combustion requirements and then utilize valve members of sufficient weight and capacity which will hold these valve members on their seats until this back pressure is reached and will then hold the back pressure substantially at this maximum level. Where the baffles and netting in the locomotive smoke box have been removed and the restrictions in the fire box are not excessive, a variation of two or three pounds per square inch gage in back pressure is all that is necessary to handle the variation between normal minimum and maximum draft requirements. Accordingly, adjusting the valve assemblies to the maximum back pressure required for maximum combustion provides one way for improving the combustion efficiency and increasing the mean effective pressure and horsepower output under standard present-day conditions for the conventional railroad locomotive.

A still further improvement over the procedure just described consists in utilizing what may be termed the two step back pressure plan. Under these conditions the back pressures for minimum and maximum draft requirements are determined and then part of the valve members 17 set to open at a back pressure a little above that necessary for the minimum requirements, while the remaining valve members 17 may be set to open at a back pressure a little above the maximum required for maximum draft conditions. The capacity of the valve members set for the minimum draft requirements preferably should be sufficient to only hold that minimum back pressure until the draft required is about to exceed

that permitted by the minimum back pressure. This allows the back pressure to start building up at that point to take care of the increased draft requirements until the back pressure builds up to the maximum at which the remaining valve members are set to open. Under these conditions, the latter valve members should have a capacity sufficient to control the back pressure and prevent same from substantially rising above the maximum predetermined back pressure required for maximum draft purposes.

A modification of the last described procedure involves the utilization of more than two back pressure levels. For instance, if we assume that the minimum back pressure required is 5 pounds per square inch gage and the maximum back pressure 7 pounds per square inch gage, and that eight valve members 17 are sufficient to control the back pressure and prevent same from substantially rising above the predetermined maximum back pressure. Then, for instance, two of the valve members 17 can be set to start opening when the back pressure slightly exceeds that required for producing the minimum draft requirements. The next two valves can be set to start opening at a higher back pressure, for instance, 5½ pounds per square inch gage, the next two valves to open at a back pressure of 6¼ pounds per square inch gage, and the last two valves to open at 7 pounds per square inch gage. It is thus obvious that the invention is not limited to one, two, or three levels, but rather one or a plurality of levels can be utilized, and in the latter case the levels are preferably chosen so as to give step control of the back pressure and maintain same at all times just above the minimum required for draft purposes for normal conditions of operation where the back pressure tends to rise with the combustion requirements, although not necessarily directly in proportion thereto. Operation in this manner thus improves combustion efficiency and increases the mean effective pressure on the driving cylinders as well as the draw bar horsepower under normal operating conditions, other factors remaining constant.

A modified form of the apparatus embodying the present invention is shown in Figures 5, 6, and 7. Here the expansion chamber 8a is preferably made a little larger than expansion chamber 8 of Figure 2, and the central portion 20 of same is preferably made still larger and provided with a horizontal flange 21 on the upper side of same. Back pressure valve assembly 9a is provided with flange 22 for joining same in conventional manner to flange 21 for flow of steam into and through valve assembly 9a under operating conditions where the latter is controlling the back pressure in the exhaust stand. Referring more particularly to Figure 6, the valve assembly 9a is provided with a horizontal partition 15a in which are mounted, at suitable locations, a plurality of valve seats 16a. Preferably mounted above partition 15a is a pair of guide members or partitions 22 and 23 which are provided with aligned openings 24 and 25 for suitably guiding valve members 17a in their up and down movement under normal operating conditions. Partitions 22 and 23 are provided with suitable openings 26 and 27 which are preferably aligned and of sufficient size to facilitate flow of by-passed steam up through valve assembly 9a and out of same through tubular outlet member 11a to a suitable outlet (not shown) outside of the locomotive smoke box. Housing 28 of valve assembly 9a may be provided with a removable cover member

62. for ready access to valve members 17a, although normally the mounting of plugs 19a of suitable size above each of the valve members 17a will take care of this requirement. The setting of the valve opening level or levels, as well as the operation of this valve assembly, may be taken care of in substantially the same manner as has been described above in connection with valve assembly 9.

A preferred embodiment of the present invention involves the provision of an exhaust stand which has an expansion chamber as well as back pressure control valves and outlet connections built thereinto. One such construction is typically illustrated in Figures 8, 9, 10, and 11. Referring more particularly to Figure 11, the exhaust stand 7b is provided at its upper end with a predetermined fixed area exhaust nozzle and spreader bridge member 29, and a blower ring 30. The upper portion of the exhaust stand assembly is made sufficiently large to provide a chamber 31, the inner wall 32 of which, together with the inner wall of auxiliary chamber 39, forms the normal passageway for exhaust of steam flowing out of the exhaust stand through the restricted fixed area orifice of the nozzle and spreader bridge 29 and out through smoke stack 4. The bottom of chamber 31 is preferably in a horizontal plane and provided with valve seat members 16b of suitable size and location. Cooperating with these valve seat members for sealing the opening through each of same are suitable valve members 17b. Valve guide sleeves 18a are utilized for guiding valve members 17b in their up and down movement under conditions of operation. A suitable small clearance between valve member 17b and sleeve 18a is provided, and the surface of same in the sliding area lubricated by means of oil carried by the exhaust steam. Valve seat members 16b may be fastened in place in conventional manner by threading, welding, interconnecting of seats, or the like, but in preferred construction, the valve guide sleeves (Figures 11 and 12) are preferably made long enough to contact the upper and outer edge of valve seat members 16b so that when plugs 19b are tightened down, they will force valve guide sleeves 18a downward so as to hold valve seats 16b from loosening and moving out of position. The openings into which plugs 19b are threadedly fastened are preferably of sufficient size to permit the installation of valve seat members 16b, valve guide sleeves 18a, and valve members 17b, as well as the removal of same whenever necessary. A pair of suitably large tubular outlet members 11b may be conventionally connected to chamber 31 for removal of exhaust steam flowing thereinto under control of the valve assembly which includes valve members 17b and valve seat members 16b. The invention, however, is not limited to the use of two such outlets, since one or more outlets of suitable size and capacity can be used in like manner. Directly below chamber 31 is an expansion chamber 8b which opens directly into the passageway lengthwise of the exhaust stand. This expansion chamber for purposes of rigidity, and sidewise guiding of exhaust steam to the inlet end of valve seat members 16b, is preferably provided with a plurality of longitudinal vertical ribs 33. Where valve guide sleeves 18a are used to hold valve seat members 16b in place, the lower end of each of same is preferably provided with an inturned flange 34 (Figure 12) adapted to engage the upper and outer edge of valve seat member 16b. The sides of the sleeve from a point

close to the lower end of same and extending upward to a point above the maximum upper travel of valve member 17b under normal operating conditions is preferably cut away with the exception of a few upwardly extending narrow ribs 35. This permits ready escape of steam flowing from expansion chamber 8b through valve seat member 16b into chamber 31 under normal operating conditions. The upper portion of valve guide sleeves 18a is also preferably cut away except for a few narrow ribs 36, a thing which not only reduces the area in contact with valve members 17b but facilitates lubrication and free movement of valve members 17b in an up and down direction under normal operating conditions. Valve members 17b and valve seats 16b cooperating therewith may be arranged for operation in various ways, three of which have been previously described in connection with the apparatus shown in section in Figure 4.

Chamber 31 may extend completely around the upper portion of exhaust stand 7b if desired, and that construction forms one aspect of the present invention. It may be, however, that it is desirable to utilize a supplementary control to take care of some special condition, several of which will be hereinafter described. One simple way of doing this is to insert partitions 37 and 38 (Figure 9) in chamber 31 so as to form an auxiliary chamber 39. This chamber may be supplied with one or more valve seat members 16b, valve members 17b, and valve guide members 18a, or the like, as previously described in connection with the valve assemblies. Valve members 17b in this case would be made of a suitable size, weight, and quantity to take care of the special condition which they are designed to handle. A suitable size tubular member 40 is connected in conventional manner for delivering steam from chamber 39 when the occasion requires. Joined to tubular connection 40 is a suitable valve 41 (Figure 10) which may be of various types of construction, although a gate valve is normally one of the most satisfactory for this purpose. Connected to this valve is an operating mechanism, a simple form of which may consist of an air or steam operated cylinder 42, the piston 43 of which is mounted on a suitable rod 44 connected to valve 41 in conventional manner so that back and forth movement of piston 43 will open and close valve 41. The opening of valve 41 will thus permit special back pressure control by means of the valve members in auxiliary chamber 39. The conventional practice on some railroads is to have the engineer, and particularly passenger train engineers, use a long, or high per cent, cut-off for steam admission to the driving cylinders as the train pulls out of the station, and maintain this cut-off without reduction until the train is moving at a relatively high rate of speed, and then reduce the cut-off setting as the train comes up to normal traveling speed. Under these conditions with the conventional front end, the back pressure builds up to a relatively high point due to the high velocity of exhaust from the exhaust stand even though the steam consumption is relatively low compared with high speed heavy operation. This high back pressure in turn will produce high draft suction pressures and high consumption of coal when the actual steam consumption does not require heavy firing. Under those conditions, the auxiliary chamber can be used to advantage by placing therein valve members 17b of a size such that they will open under a prechosen back pressure, for instance, the min-

imum back pressure at which part of the valve members 17b in chamber 31 are set, or at some lower or intermediate back pressure below the maximum back pressure at which other of the valve members in that chamber are set. The valve members 17b in auxiliary chamber 39 will not open, however, until valve 41 is opened to allow exhaust steam to flow through auxiliary chamber 39 and tubular member 40 to a suitable point of discharge. The operation of valve 41 under these conditions may be conveniently carried out as follows: The cut-off settings for the cylinders are controlled, through a pair of reverse arms 45 and links 46 on opposite sides of the locomotive. Reverse arms 45 are keyed to cross shaft 47 for operation in unison under control of the engineer. Thus when the cut-off is to be increased, reverse arm 45 is moved in a clockwise direction as viewed in Figure 10. This movement may be availed of for operating valve 41 in the following manner. A plate 48 is conventionally fastened on reverse arm 45 and provided with an outwardly projecting arcuate flange 49 on the under face of which is adjustably mounted, in conventional manner, an arcuate cam shoe 50, the center of the arc being the center of shaft 47. Frame 51 of the locomotive may be provided with a shelf member 52 on which is mounted a suitable valve 53. This valve is provided with a depressible member 54 with a roller 55, or the like, on its upper end. The depression of depressible member 54 acts to connect main air pressure line 56 for air flow to line 57 for application of pressure behind piston 43 of cylinder 42, which in turn acts through rod 44 to open valve 41. Piston 43 is normally held in retracted position, with valve 41 closed, under the influence of low pressure air delivered from main air line 56 through pressure-reducing valve 58 and pipe 59. A pressure-releasing valve 60, set to operate at a little higher pressure than pressure-reducing valve 58, acts to release pressure when piston 43 is moved to open valve 41 under the influence of the main line air pressure. Under these conditions, it is only necessary to set cam shoe 50 to depress depressible member 54 when the high percentage cut-off referred to is utilized. This in turn will cause the opening of valve 41 and permit the valve members in auxiliary compartment 39 to function and hold the back pressure and draft induced therewith at a controlled lower level than would otherwise be the case. Valve 61 may be closed under conditions where for some reason, the reduction of back pressure under long or high percentage cut-off operation and low speeds is temporarily not desired. The operation of the auxiliary chamber apparatus may also be manually controlled. For instance, valve 41 may be opened and closed through the operation of valve 62, which would normally be placed in the locomotive cab.

Another way of taking advantage of the auxiliary compartment involves the use of same where it is desired to carry a substantially uniform level back pressure under all operating conditions; for instance, all of the valve members 17b in chambers 31 and 39 would be set for the maximum back pressure required to produce the maximum draft necessary under normal operating conditions. This would give the valve members an excess capacity at the point where they are at the verge of opening, i. e. at the balance point. This balance point will normally occur when the percent cut-off is relatively low, and under these conditions, the cam shoe member would be set

to cause valve 41 to be open at all times except when the percent cut-off is low, and to allow same to close and remain closed under those conditions. Excessive capacity at the balance point tends to permit an undesired amount of leakage through the valve assemblies to take place, and by closing valve 41, this excess is reduced, a thing which also aids in steam cushioning the remaining valves in their operation when they are almost in closed position. This auxiliary compartment, by suitably controlling valve 41, can be used to increase or reduce capacity at any given back pressure level, and can also be used to increase the maximum capacity at the upper pressure level to provide a substantially positive upper back pressure limit. The use and operation of the auxiliary chamber is thus very flexible and readily adapted to handle varying requirements of auxiliary pressure control. While only one auxiliary chamber has been shown, it is to be understood that the invention is not limited to the use of only one such chamber, but rather that one or more may be used and that the showing is to be construed as diagrammatically illustrating same.

A locomotive of the 4-8-4 Northern type which, in working order, weighs 666,500 pounds, operates on two hundred and fifty pounds per square inch boiler pressure, and which has 60,200 pounds tractive effort, has been equipped with this invention. This locomotive, which is used in regular and continuous high speed manifest freight service, is giving very much improved performance in increased draw bar horsepower, greater fuel economy, more uniform and smooth operation, higher speed capability, et cetera. The fixed outlet orifice area of the exhaust stand is 34 square inches as compared with the 40 to 42 square inches normally used on this locomotive. This reduction in fixed orifice area produces the minimum draft required for combustion purposes with a much smaller amount of exhaust steam discharged per unit of time. An expansion chamber is utilized between the exhaust outlet from the cylinders and the fixed area outlet from the exhaust stand to provide a more smooth and uniform flow of exhaust steam. Connected to this expansion chamber is a back pressure valve assembly in which are nine two inch diameter valves of a size and weight which start opening at five pounds per square inch back pressure, and three two inch diameter valves of a size and weight which start opening at six pounds per square inch back pressure. These valves hold the back pressure in the exhaust stand passageway substantially in the range of from five to seven pounds per square inch for normal operation of the locomotive, a range which is ample for creating the draft necessary for combustion purposes. Since this apparatus is primarily a back pressure controlling apparatus and incidentally a draft controlling apparatus, the locomotive was also equipped with a cooperating true draft controlling apparatus, of the general type described in my aforementioned copending patent applications, to hold the draft suction pressures at approximately the levels of 5", 5½", or 6" of water depending upon the varying requirements for efficient operation of the locomotive. To facilitate inspection of the front tube sheet and superheater unit, as well as improved and more uniform drafting of the locomotive in accordance with efficient combustion requirements meeting the steam demand, the baffles and netting in the smoke box were also removed. The firebrick arch in the fire box was

also made approximately one half the size of the arch which had been used when the locomotive had the conventional front end, a thing cooperating with and facilitating the more uniform and better drafting obtained through use of my improved back pressure and draft control apparatus. The locomotive as thus equipped is exceptionally satisfactory from the standpoint of improved operation, increased power and fuel economy, reduction of cinder cutting of the boiler tubes, superheater unit, and front end, substantially balance draft from the fire box to the front end of the locomotive, and the substantial elimination of discharge of sparks from the smoke stack.

Other modes of applying the principle of my invention may be employed instead of those explained, change being made as regards the articles and combinations herein disclosed, provided the means stated by any of the following claims or the equivalent of such stated means be employed.

I therefore particularly point out and distinctly claim as my invention:

1. A pressure control apparatus of the character described, which comprises a means with a passageway open at one end for flow of a gaseous fluid therethrough, a flow restricting means substantially at the open end of said passageway, a chamber, an outlet means for said chamber, said outlet means cooperating with said passageway and flow restricting means to create a suction pressure in said chamber upon forceful delivery of a gaseous fluid through said passageway, a pressure relief means, means for connecting said pressure relief means to the passageway of said first named means ahead of said flow restricting means for controlled by-pass flow of gaseous fluid to said pressure relief means, and a plurality of gravity controlled valves in said pressure relief means, said gravity controlled valves being adapted to elevate and permit the by-passing of gaseous fluid through said pressure relief means when the pressure of said gaseous fluid in said passageway exceeds the predetermined amount.

2. A pressure control apparatus of the character described, which comprises a means with a passageway open at one end for flow of a gaseous fluid therethrough, a flow restricting means substantially at the open end of said passageway, a chamber, an outlet means for said chamber, said outlet means cooperating with said passageway and flow restricting means to create a suction pressure in said chamber upon forceful delivery of a gaseous fluid through said passageway, a pressure relief means, means for connecting said pressure relief means to the passageway of said first named means ahead of said flow restricting means for controlled by-pass flow of gaseous fluid to said pressure relief means, a plurality of gravity controlled valves in said pressure relief means, a valve seat for each valve, a valve guide cage for guiding said gravity valves in their movement, and means for forcing each of said valve guide cages against one of said valve seats to hold same in place, said gravity controlled valves being adapted to elevate and permit the by-passing of gaseous fluid through said pressure relief means when the pressure of said gaseous fluid in said passageway exceeds the predetermined amount.

3. A pressure controlling apparatus, which comprises a means with open passageway for flow of a gaseous fluid therethrough, a flow restricting means substantially at the outlet end

of said passageway, an expansion means for gaseous fluid, said expansion means being connected to and opening into said passageway at a point between the inlet thereto and said flow restricting means at the outlet therefrom, a pressure relief means, said pressure relief means being connected to the passageway of said first named means ahead of said flow restricting means for controlled by-pass flow of gaseous fluid from said first named means through said pressure relief means, and valves in said pressure relief means, said valves being adapted to open for flow of said gaseous fluid through said pressure relief means when the pressure of said gaseous fluid in said passageway exceeds the predetermined amount at which said valve means has been set to start opening.

4. A pressure controlling apparatus, which comprises a means with open passageway for flow of a gaseous fluid therethrough, a flow restricting means substantially at the outlet end of said passageway, an expansion means for gaseous fluid, said expansion means being connected to and opening into said passageway at a point subsequent to the point of inlet of said gaseous fluid into said passageway, and ahead of said flow restricting means, a pressure relief means, said pressure relief means being connected to the passageway of said first named means ahead of said flow restricting means for controlled by-pass flow of gaseous fluid from said first named means through said pressure relief means, and valve means forming part of said pressure relief means, said valve means including vertically mounted gravity held valves and cooperating substantially horizontal valve seats below same, at least part of the valves of said valve means being adapted to elevate and float on the gaseous fluid flowing into and through said pressure relief means when the pressure of said gaseous fluid in said passageway exceeds the predetermined amount at which the weight of said valves has been set to determine the starting point of their opening.

5. In an apparatus of the character described for handling a pulsating flow of gaseous fluid, the combination which comprises a means with open passageway for flow of a gaseous fluid therethrough, a flow restricting means for said passageway, an immovable expansion means for pulsating gaseous fluid flowing through said passageway, said expansion means being connected to said passageway ahead of said flow restricting means, and a pressure controlled auxiliary outlet from said expansion means, whereby the pulsating flow of gaseous fluid is more smooth and uniform as it passes through said flow restricting means in said passageway.

6. In an apparatus of the character described for handling a pulsating flow of gaseous fluid, the combination which comprises a means with open passageway for flow of a gaseous fluid therethrough, a flow restricting means for said passageway, an immovable expansion means for pulsating gaseous fluid flowing through said passageway, said expansion means being connected to said passageway ahead of said flow restricting means, and a pressure controlled auxiliary outlet from said expansion means, rib members in said expansion means for guiding the flow of gaseous fluid therein, whereby the pulsating flow of gaseous fluid is more smooth and uniform as it passes through said flow restricting means in said passageway.

7. In a by-pass type of pressure controlling

apparatus, the combination which comprises a means with an open end passageway for flow of a highly fluid body therethrough, a chamber, a substantially horizontal panel bottom for said chamber; said panel having a plurality of openings therethrough, valve seats in said openings, means for connecting said chamber to said open passageway means for the application of fluid pressure in said passageway to said valve seats from below said horizontal panel, gravity control valve members above said panel and cooperating with said valve seats to form an operable valve assembly, skeleton valve cage means for guiding said valve members for movement to and from the valve seats in a direction substantially vertical to said horizontal panel, means for forcing said valve cages against the top of said valve seats to hold same firmly in place, and an outlet means connected to said chamber above said panel, said valve members being of a suitable weight to elevate and thereby open said valve for by-passing a portion of said highly fluid body through said chamber and said outlet when the pressure of said highly fluid body in said first named means exceeds a predetermined amount.

8. An apparatus for use in connection with a steam driven railroad locomotive, which comprises a housing, a substantially horizontal panel for said housing; said panel having a plurality of openings therethrough, valve seats in said openings, gravity control type valve members above said panel and cooperating with said valve seats to form a plurality of operable valve assemblies, means for guiding said valve members for movement to and from said valve seats in a direction substantially vertical to said horizontal panel, an outlet means connected to said housing above said panel, and means for delivering to the inlet of said valves at least part of the steam exhausted after use for driving said locomotive, said valve members being of a suitable weight to automatically elevate and thereby open said valves for by-passing exhaust steam through said housing and out of said outlet when the exhaust steam pressure exceeds a predetermined amount.

9. In a railroad locomotive having steam operated driving cylinders, the combination of an exhaust stand having a passageway through which a major portion of the exhaust steam from said cylinders is normally passed, a flow restricting means substantially at the outlet end of said exhaust stand, a pressure relief means connected to said passageway through the exhaust stand, said pressure relief means being adapted to by-pass part of the exhaust steam flowing through said passageway when the pressure thereof exceeds a predetermined amount, an auxiliary pressure relief apparatus connected in parallel to said first named pressure relief apparatus, and means for controlling the time at which said auxiliary pressure relief apparatus becomes operative, whereby the effect of said first named pressure relief means upon the pressure of the exhaust steam flowing through said exhaust stand is varied in predetermined manner.

10. In a railroad locomotive having steam operated driving cylinders, the combination of an exhaust stand having a passageway through which a major portion of the exhaust steam from said cylinders is normally passed, a flow restricting means substantially at the outlet end of said exhaust stand, a pressure relief means connected to said passageway through the exhaust stand, said pressure relief means being adapted to by-

pass part of the exhaust steam flowing through said passageway when the pressure thereof exceeds a predetermined amount, an auxiliary pressure relief apparatus connected in parallel to said first named pressure relief apparatus, and means for controlling the time at which said auxiliary pressure relief apparatus becomes operative, whereby the effect of said first named pressure relief means upon the pressure of the exhaust steam flowing through said exhaust stand is varied in predetermined manner, said means for controlling the time at which said auxiliary compartment becomes operative comprising a tubular outlet means from said auxiliary compartment, a shut-off valve for said tubular outlet means, and a cam controlled assembly for controlling the opening and closing of said shut-off valve in accordance with predetermined settings of the valve cut-off assembly for controlling the inlet of steam to the driving cylinders.

11. In an apparatus of the character described, the combination which comprises a means with an open passageway for flow of gaseous fluid therethrough, a pressure relief means, means for connecting said pressure relief means to the passageway of said first named means, ahead of the outlet therefrom, for by-pass flow of gaseous fluid to said pressure relief means, a multiplicity of valves in said pressure relief means for by-passing a portion of said gaseous fluid when the pressure of same in said first named passageway exceeds the pressure at which said valves are set to open, part of said valves being adapted to open at a different pressure from the others, an auxiliary pressure relief means connected to said passageway in parallel to said first named pressure relief means for supplemental control of the pressure in said passageway, and means controlling the time and condition under which said auxiliary pressure relief means is permitted to operate.

12. A steam locomotive exhaust stand, which comprises in combination a body member having a normally open exhaust passageway therethrough, a chamber in said body member, a valve means responsive to pressure in excess of a predetermined amount in said passageway for controlling the inlet flow of exhaust steam from said passageway into said chamber, said valve means being in said chamber; and means connected to said chamber for discharging therefrom the exhaust steam flowing thereinto under control of said valve means.

13. A steam locomotive exhaust stand, which comprises in combination a body member having a normally open passageway therethrough and an expansion means connected to the latter, a chamber in said body member, valve means responsive to pressure in excess of a predetermined amount in said passageway for controlling the inlet flow of exhaust steam from said passageway; and expansion means into said chamber, said valve means being in said chamber; and means connected to said chamber for discharging therefrom the exhaust steam flowing thereinto under control of said valve means.

14. A steam locomotive exhaust stand, which comprises in combination a body member having a normally open passageway therethrough and an expansion means connected to the latter, a flow restricting means at the outlet end of said normally open passageway, said flow restricting means acting to decrease the free outlet area so as to increase the velocity of exhaust for a given volume of steam exhausted in a unit of time

through said flow restricted outlet of said passageway, a chamber in said body member, valve means responsive to pressure in excess of a predetermined amount in said passageway for controlling the inlet flow of exhaust steam from said passageway and expansion means into said chamber, said valve means being in said chamber, and means connected to said chamber for discharging therefrom the exhaust steam flowing therein into under control of said valve means.

15. A steam locomotive exhaust stand, which comprises in combination a body member having a normally open passageway therethrough, an exhaust expansion means connected to said passageway, an exhaust nozzle and steam spreader means at the outlet end of said normally open passageway, said exhaust nozzle acting in conjunction with said steam spreader to decrease the free outlet area so as to increase the velocity of exhaust for a given volume of steam exhausted in a unit of time through said restricted outlet of said passageway while said spreader means also acts to spread the stream of exhaust steam flowing through said outlet, a chamber in said body member, valve means responsive to pressure in excess of a predetermined amount in said passageway for controlling the inlet flow of exhaust steam from said passageway and expansion means into said chamber, and means connected to said chamber for discharging therefrom the exhaust steam flowing therein into under control of said valve means.

16. A steam locomotive exhaust stand, which comprises in combination a body member having a normally open passageway therethrough, an exhaust nozzle, and steam spreader means at the outlet end of said open passageway, said exhaust nozzle acting in conjunction with said steam spreader to decrease the free outlet area so as to increase the velocity of exhaust for a given volume of steam exhausted in a unit of time through said restricted outlet of said passageway while said spreader means also acts to spread the stream of exhaust steam flowing through said outlet, an exhaust expansion means connected to said passageway in said body member at a point ahead of the exhaust outlet therefrom, a chamber in said body member, a plurality of valve means in said chamber, said valve means being responsive to pressure in said passageway for admitting exhaust steam from said passageway into said chamber, part of said valve means operating to open at one pressure and at least one valve adapted to open at a higher pressure so as to control the inlet flow of exhaust steam from said passageway and expansion means into said chamber, and means con-

nected to said chamber for discharging therefrom the exhaust steam flowing therein into under control of said plurality of valve means.

17. A steam locomotive exhaust stand, which comprises in combination a body member having a normally open passageway therethrough, an exhaust expansion means connected to said passageway, an exhaust nozzle and steam spreader means at the outlet end of said normally open passageway, said spreader means acting to both spread the stream of exhaust steam passing same and to decrease the free outlet area of said normally open passageway so as to increase the velocity of exhaust for a given volume of steam exhausted through same in a unit of time, a chamber in said body member, valve means for controlling the inlet flow of exhaust steam from said passageway and expansion means into said chamber, means connected to said chamber for discharging therefrom the exhaust steam flowing therein into under control of said valve means, an auxiliary chamber, valve means for controlling the inlet flow of exhaust steam from said passageway and expansion means into said auxiliary chamber, and means connected to said auxiliary chamber for discharging therefrom the exhaust steam flowing therein into under control of said valve means.

18. A steam locomotive exhaust stand, which comprises in combination a body member having a normally open passageway therethrough, an exhaust expansion means connected to said passageway, an exhaust nozzle and steam spreader means at the outlet end of said normally open passageway, said spreader acting to both spread the stream of exhaust steam passing same and to decrease the free outlet area of said normally open passageway so as to increase the velocity of exhaust for a given volume of steam exhausted through same in a unit of time, a chamber in said body member, valve means for controlling the inlet flow of exhaust steam from said passageway and expansion means into said chamber, means connected to said chamber for discharging therefrom the exhaust steam flowing therein into under control of said valve means, an auxiliary chamber, valve means for controlling the inlet flow of exhaust steam from said passageway and expansion means into said auxiliary chamber, tubular means connected to said auxiliary chamber for discharging therefrom the exhaust steam flowing therein into under control of said valve means, separate valve means for opening and closing said tubular means connected to said auxiliary chamber, and means for controlling the operation of said last named valve means.

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