

July 7, 1931.

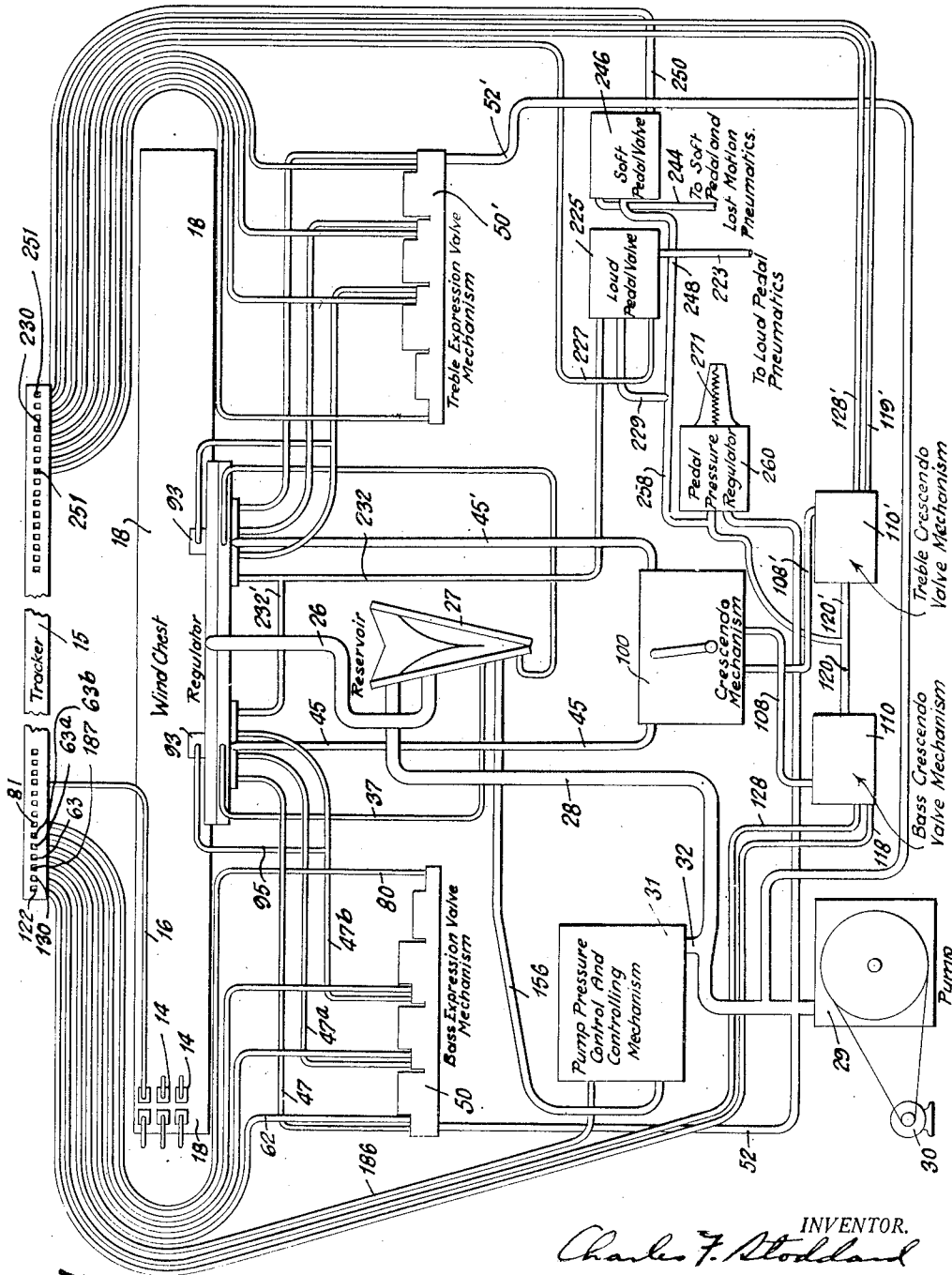
C. F. STODDARD

1,813,097

AUTOMATIC MUSICAL INSTRUMENT

Filed June 18, 1926

9 Sheets-Sheet 1



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July 7, 1931.

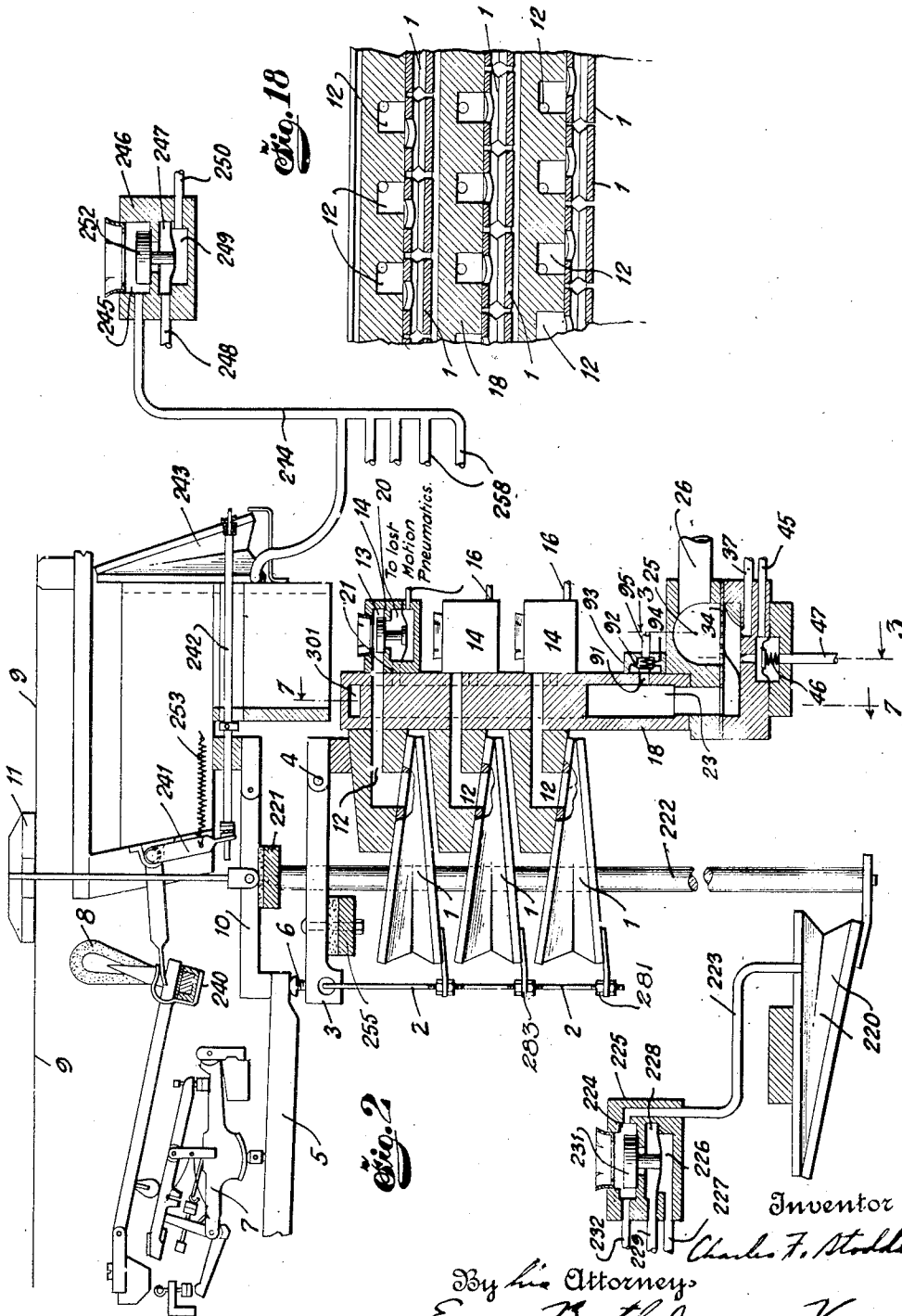
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9 Sheets-Sheet 2



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AUTOMATIC MUSICAL INSTRUMENT

Filed June 18, 1926

9 Sheets-Sheet 3

Fig. 3

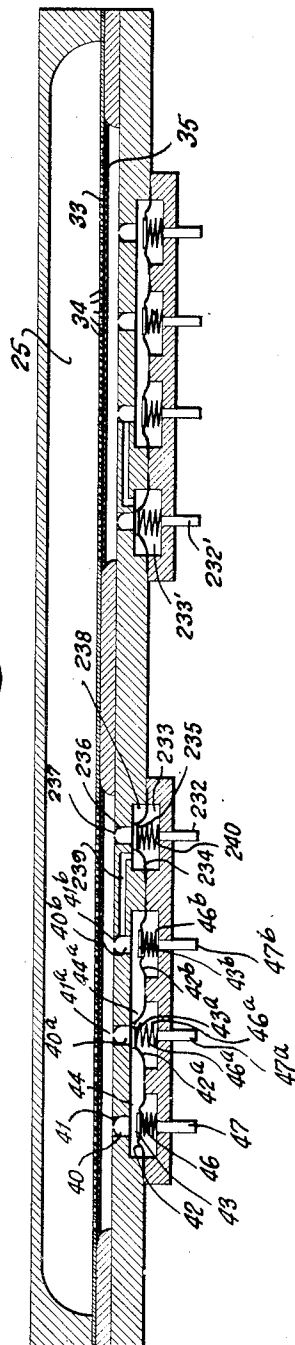
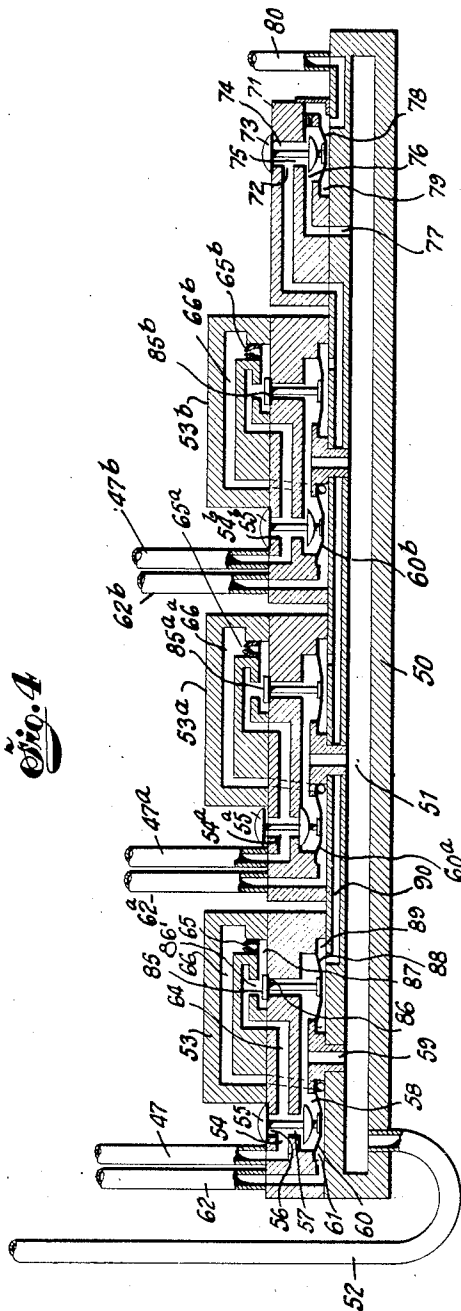


Fig. 4



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9 Sheets-Sheet 4

Fig. 5

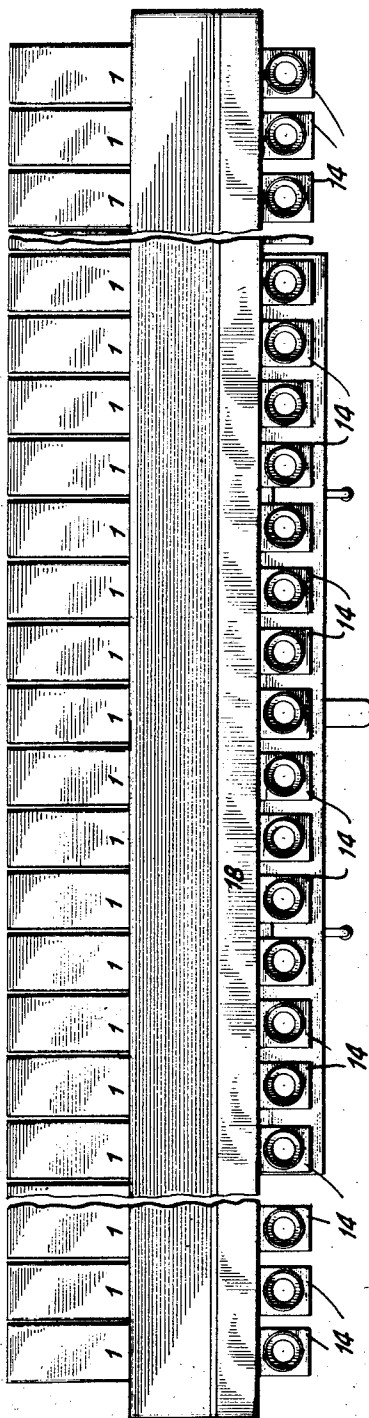
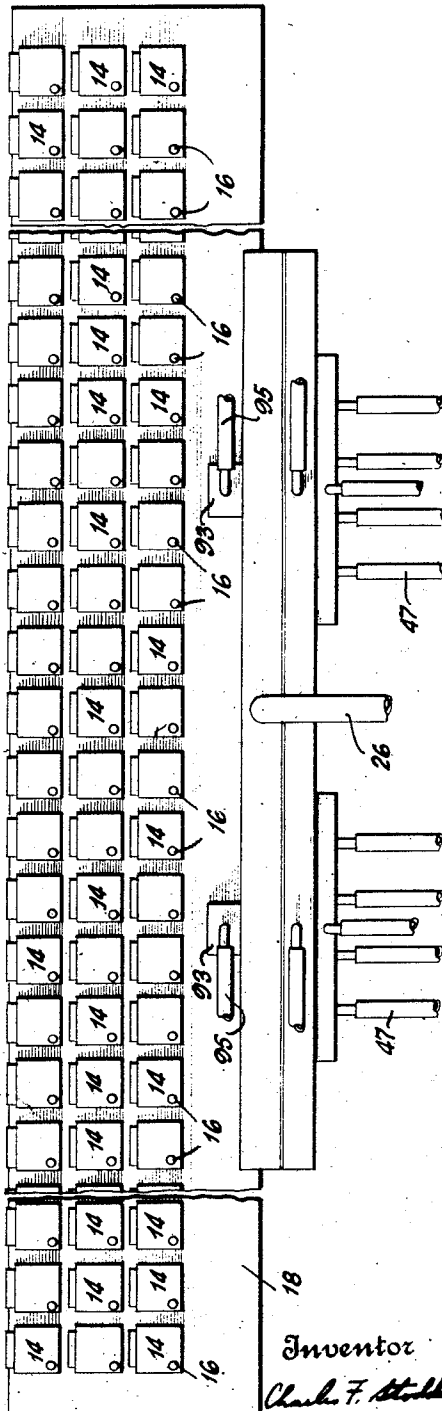


Fig. 6



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AUTOMATIC MUSICAL INSTRUMENT

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9 Sheets-Sheet 5

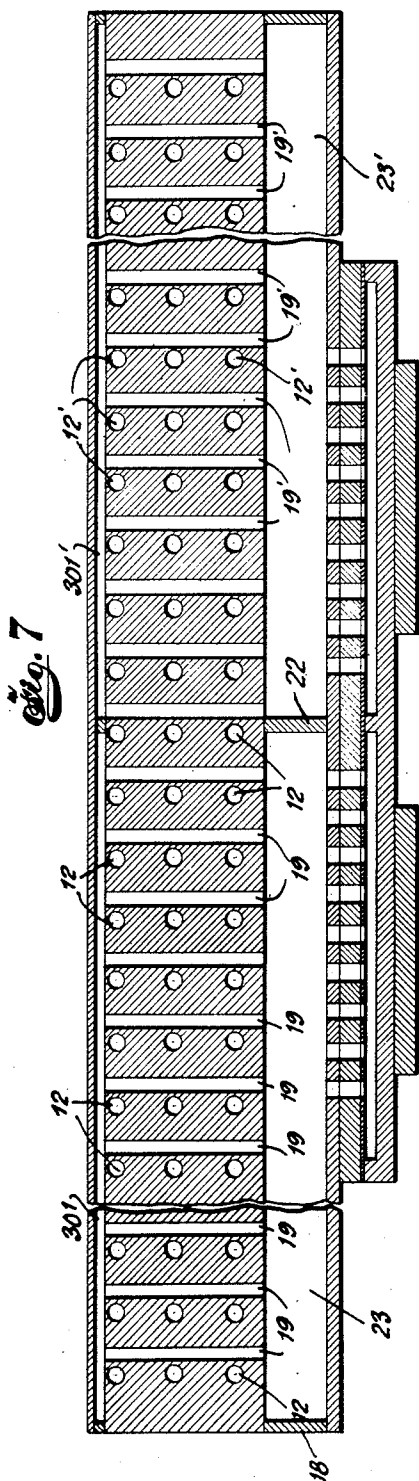


Fig. 9

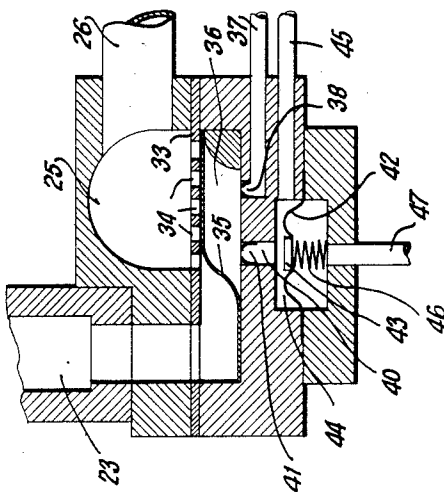
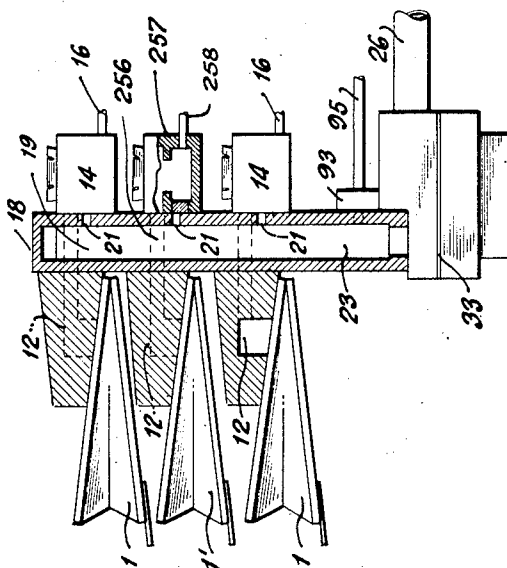


Fig. 8



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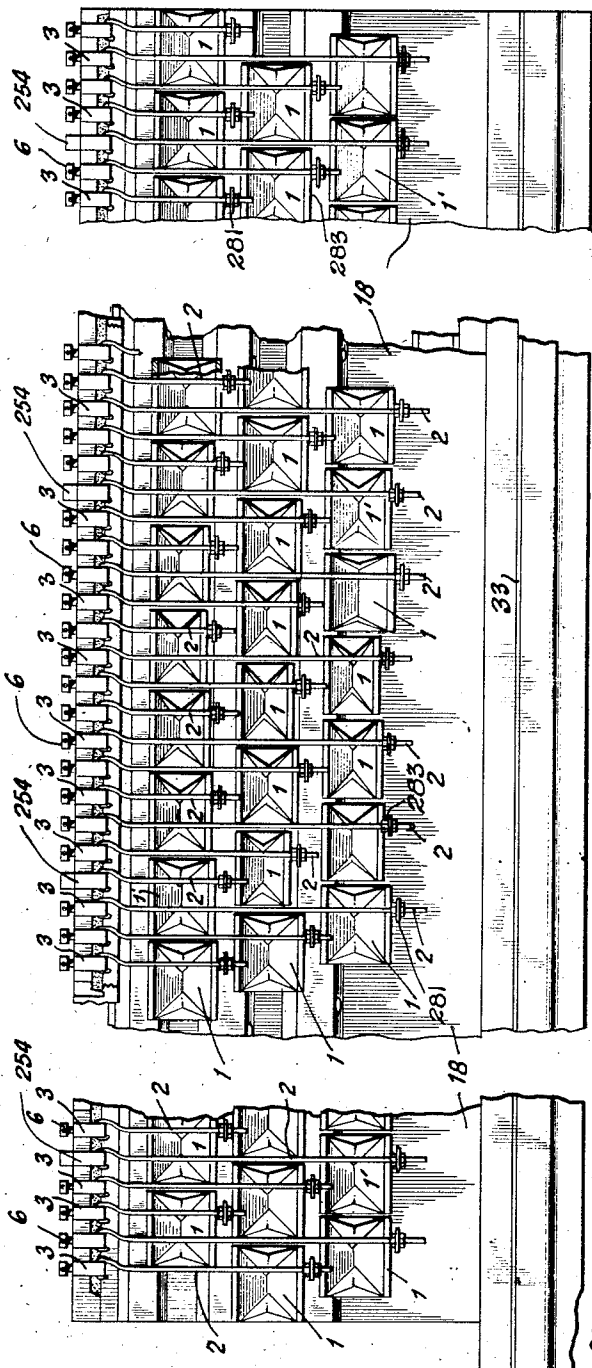
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AUTOMATIC MUSICAL INSTRUMENT

Filed June 18, 1926

9 Sheets-Sheet 6

Fig. 10



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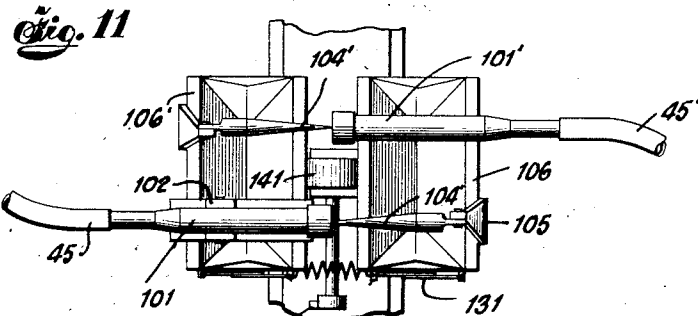
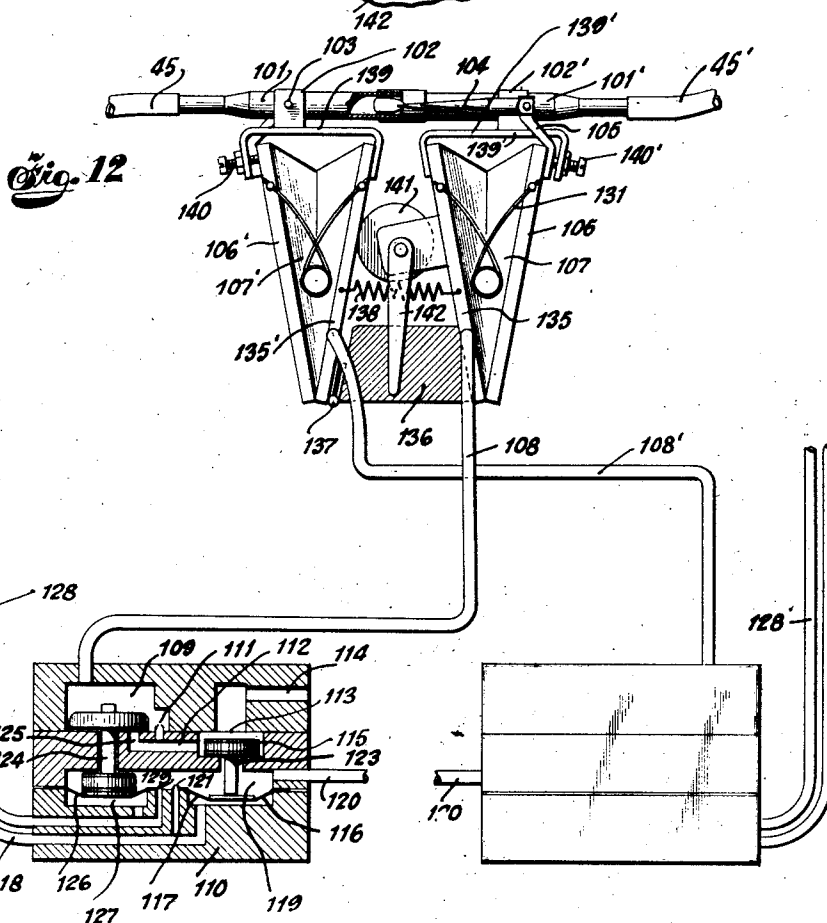
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1,813,097

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Filed June 18, 1926

9 Sheets-Sheet 7.



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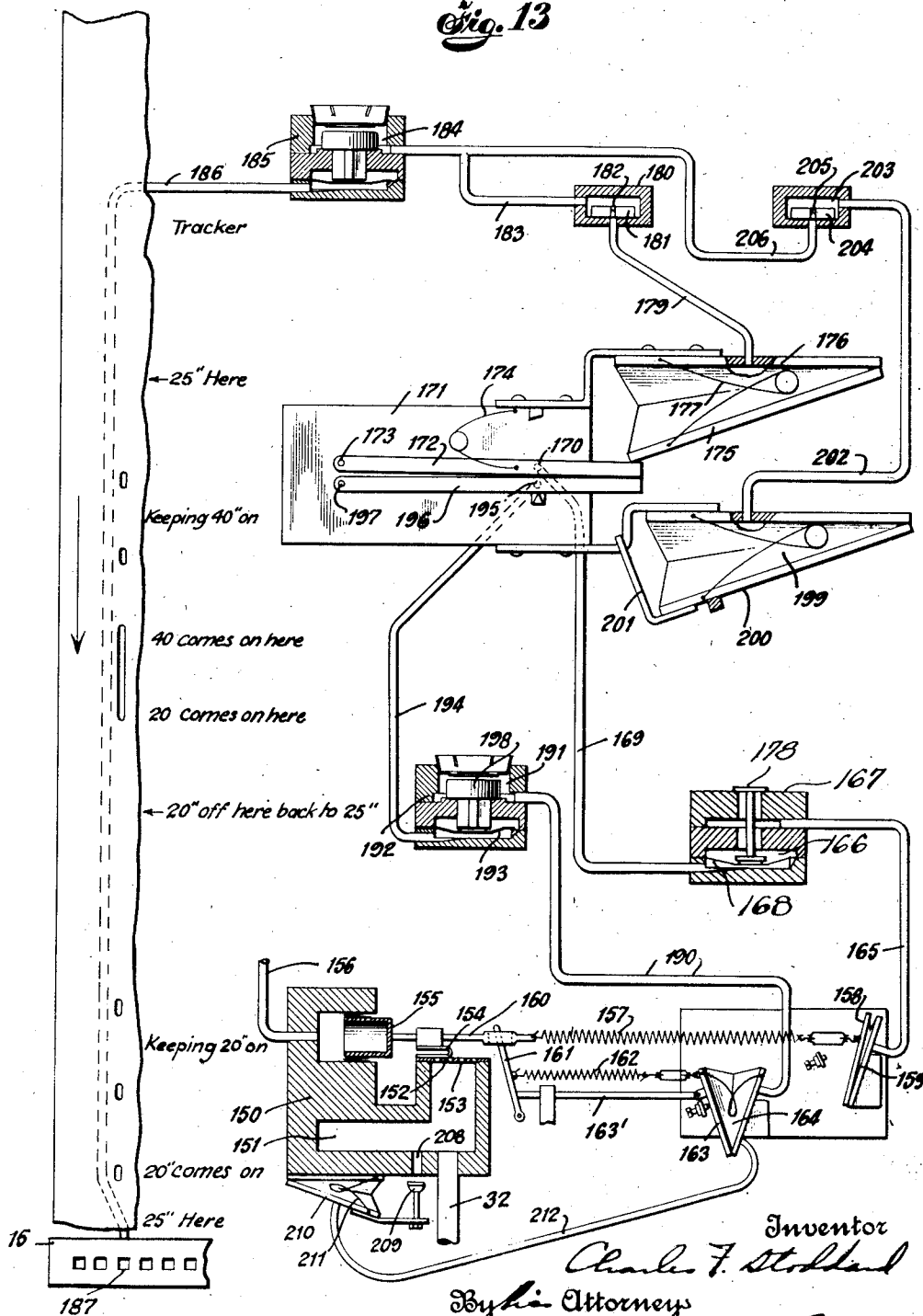
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AUTOMATIC MUSICAL INSTRUMENT

Filed June 18, 1926

9 Sheets-Sheet 8

Fig. 13



July 7, 1931.

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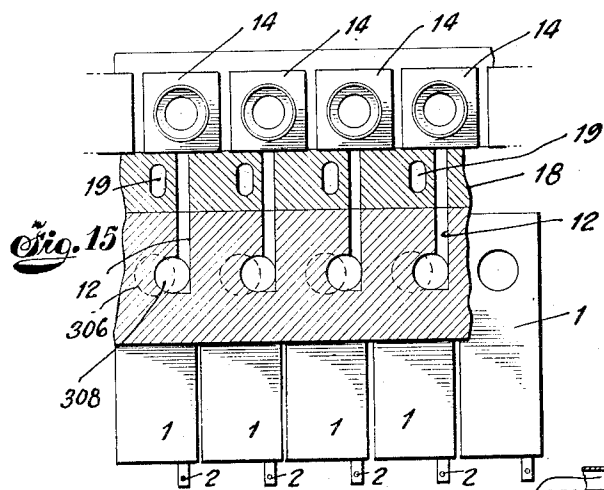


Fig. 14

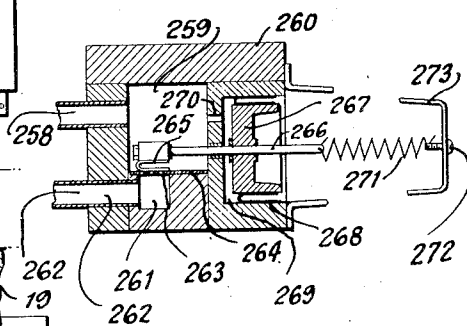
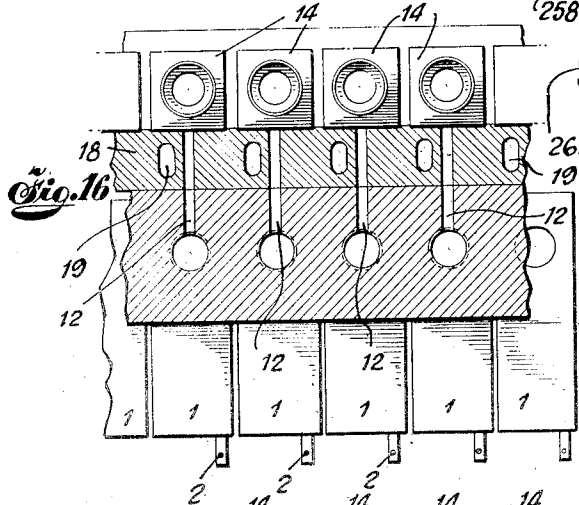
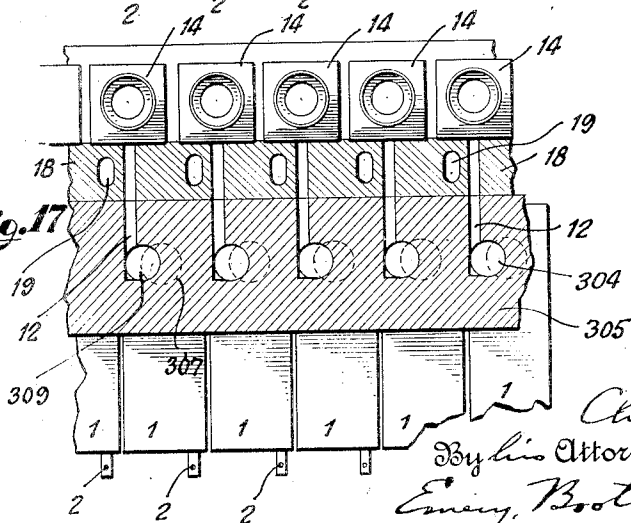


Fig. 17



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UNITED STATES PATENT OFFICE

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AUTOMATIC MUSICAL INSTRUMENT

Application filed June 18, 1926. Serial No. 116,787.

This invention relates to automatic musical instruments, and pertains more particularly to mechanisms and methods for improved expression control, or for improving the control of the dynamic forces with which individual notes or groups of notes of a given composition are sounded.

The apparatus illustrated in the drawings and described more particularly hereinafter relates especially to that class of instruments now known to the trade and general public as reproducing pianos, because they are intended to reproduce, automatically, under control of a perforated note sheet, the manual performances of artists or other pianists.

The problem of controlling the instrumentalities of a piano by automatic means in such manner as to simulate manual playing brings with it the problem of coordinating such instrumentalities as they are coordinated by the artists in manual playing in order that those subtle refinements and delicate nuances which distinguish the playing of the artist may not be lost, but may be accurately reproduced by the automatic mechanisms. Accurate reproduction of these delicate effects implies more than the mere transmission to the hammer mechanism for striking each note of the composition of a dynamic force equal or proportional to that transmitted to the hammer or key by the artist in the manual performance. There are, for instance, progressions of notes occurring one after another which possess their characteristics as a group and must be treated as a group for proper reproduction; there are pedaling effects which must be accurately coordinated with the playing of the notes themselves; and there are variations within individual instruments which are compensated unconsciously by the artist who is familiar with the "feel" of his instrument which must be compensated for to secure accurate reproduction by an automatic instrument.

It is an object of the present invention to provide mechanisms which shall cooperate in such manner as to reproduce manual playing automatically with the results just de-

scribed in addition to other results herein-after more particularly described.

It is a further object of the invention to improve various parts of the expression mechanism in order that the coordinated result of the whole may be correspondingly improved.

Other objects and advantages of the invention will appear hereinafter.

A preferred embodiment of the invention selected for purposes of illustration is shown in the accompanying drawings, in which,

Figure 1 is a diagrammatic view showing the pneumatic connections between the co-operating units of the apparatus.

Figure 2 is a semi-diagrammatic sectional view taken through the stack and expression mechanism.

Figure 3 is a longitudinal section taken on the line 3—3 of Figure 2.

Figure 4 is a section through the bass expression valve mechanism.

Figures 5 and 6 are top plan and front elevational views respectively of the stack.

Figure 7 is a longitudinal section taken on the line 7—7 of Figure 2.

Figure 8 is a section through the stack showing in section one of the dummy valves for controlling the lost motion pneumatics.

Figure 9 is an enlarged sectional view illustrating the construction and operation of the regulator.

Figure 10 is a rear elevation of the stack showing the pneumatics adjusted to compensate for differences between individual notes.

Figure 11 is a top plan view of the crescendo mechanism.

Figure 12 is a front elevation of the same, the valve mechanism and certain other parts being shown in section to better illustrate the construction and operation thereof.

Figure 13 is a semi-diagrammatic view illustrating the construction and operation of the pump pressure controlling mechanism.

Figure 14 is a sectional view of the pedal pressure regulator.

Figures 15, 16, 17 and 18 are sectional views illustrating the construction of the stack and the arrangement of the valve units and striker pneumatics thereon.

For purposes of convenience in description,

and in order that the construction and mode of operation of the preferred embodiment of the invention may be more easily understood, the pneumatic regulator will be first described, and then, in the order named, the incremental expression control, the crescendo and diminuendo control, the pump pressure control, the loud pedal control and compensation, the soft pedal control, the individual note compensation, and, finally, the wind chest construction and such other incidental features as may not be conveniently included in one of the foregoing sub-divisions.

The regulator

Referring to the drawings, the striker or player pneumatics 1 are provided which are connected by rods 2 to levers 3 pivoted at 4 to a fixed part of the piano structure. The outer ends of the levers 3 lie underneath the rear ends of the keys 5 of the piano and are adapted to actuate the keys through the adjustable screws 6 mounted in the end of the levers 3. Movement of the keys operates the usual hammer actions 7 to actuate the hammers 8 to strike the piano strings 9 in the same manner that the hammers are actuated when the piano is played manually. Upward movement of the keys 5 also actuates the levers 10 to lift the dampers 11 from the strings to permit free vibration thereof in the usual manner. As will be understood, a sufficient number of striker pneumatics 1 are provided to operate the entire piano action.

Each of the striker pneumatics 1 is connected by a passage 12 to the valve chamber 13 of a valve unit 14 which may be connected to the tracker bar 15 by a suitable duct 16. The valve units 14 and the striker pneumatics 1 may be conveniently mounted on opposite sides of a board 18 which is provided with a series of vertical passages 19 to which the exhaust chambers 20 of the valve units are connected through the passages 21. Each of the passages 19 is connected with a compartment which may be conveniently divided by the partition 22 into two sections 23 and 23', one for the base and one for the treble section of the piano. Each section of this compartment, together with the passages 19 leading therefrom to the valve units, may be referred to as a regulated exhaust chest, since, as will be hereinafter explained, the exhaust therein is regulated by the mechanisms provided to control playing intensities.

As will be understood, the force of the blow delivered by a hammer to a string by the collapse of a motor pneumatic will depend largely upon the degree of exhaust maintained in the regulated exhaust chest. That is, if a high degree of exhaust is maintained in said chest, the collapse of any given pneumatic, when its controlling valve is operated to subject the pneumatic to exhaust, will be more rapid than when the degree of exhaust main-

tained in the chest is less. It will thus be apparent that by varying the degree of exhaust maintained in the regulated exhaust chest, the force of the blows delivered to the strings by the collapse of the motor pneumatics may be varied, and further that by maintaining the degree of exhaust therein substantially constant the force of the blows delivered to the string may be maintained substantially constant.

In the present embodiment means are provided for governing the degree of exhaust maintained in the regulated exhaust chest and for thereby governing the force of the blows applied to the strings of the piano.

For purposes of explaining the general character of the regulator and to exemplify one practical embodiment thereof for controlling the degree of exhaust maintained in the wind chest, the apparatus particularly shown in Figures 2 and 9 of the drawings has been selected in which the high exhaust chest 25 is connected by a conduit 26 to a reservoir bellows 27 which is connected, as will be hereinafter more fully explained, through conduit 28 to a suitable source of exhaust 29. Any of the well-known forms of exhaust means may be employed in connection with the present invention, that shown herein comprising the ordinary bellows type pump driven by an electric motor 30. As will be hereinafter explained, a pump pressure controlling mechanism designated generally by reference numeral 31 may be operatively connected to the conduit 28 through conduit 32, the said mechanism serving to control the exhaust supplied by the pump to the reservoir 27.

Means are provided for controlling the degree of exhaust maintained in the regulated exhaust chests 23 and 23', as for example by restricting more or less communication between said chests and the high exhaust chest 25. In the specific illustrative embodiment of the apparatus shown in the drawings, this restrictive action is performed by a movable member of very little weight, influenced, as will be hereinafter explained, by the pneumatic forces to which it is exposed. This movable member is arranged to cooperate with a fixed supporting member which comprises, in the present embodiment, a plate or screen 33 provided with a multiplicity of perforations 34 to permit the passage of air.

In the embodiment illustrated, the movable member comprises a diaphragm or membrane 35 of leather, rubber cloth, or other suitable flexible material. Preferably, this movable member is arranged to have one side exposed partly to the high exhaust maintained in the chest 25 and partly to the regulated exhaust maintained in the chest 23. As shown, the diaphragm 35 in operation extends along the plate or screen 33 in position to cooperate therewith to control the passage of air there-

through from the chest 23 to the chest 25, thus forming in effect a valve controlling the flow of air from the action or regulated exhaust chest to the high exhaust chest.

Means are provided to act upon the movable member, herein the diaphragm 35, in such manner as to increase the effect of high exhaust upon regulated exhaust, as for example, to tend to peel the diaphragm away from the screen or plate 33 to thereby increase the effective opening between the chests. The said means herein includes a chamber 36, which may be known as a controlled exhaust chest, separated from the regulated exhaust chest 23 and the high exhaust chest 25 by the diaphragm 35, and means to maintain in said chamber a certain degree of exhaust, which for the present may be assumed to be constant, although as will appear later, this degree of exhaust may be changed for the purpose of securing expression variations.

In the specific embodiment of the invention illustrated the chamber 36 is connected through a conduit 37 to the reservoir 27, a bleed opening 38 being interposed in the passage to constrict the communication therebetween. As will readily be understood, any desired degree of exhaust less than high exhaust may be maintained in the chamber 36 by the relative adjustment of the sizes of the bleed opening 38 and certain atmosphere vents opening into chamber 36 hereinafter described, and preferably said degree of exhaust is maintained at a somewhat higher level than the desired degree of regulated exhaust, the precise degree depending upon the particular design and arrangement of the parts. The passage 37 leading to the reservoir 27 may preferably enter the same at a point near the hinged end thereof in order that the exhaust communicated to the controlled exhaust chest 37 may be influenced as little as possible by the aspirative effect of currents of air which may pass through other portions thereof, for, as will hereinafter appear, it is desirable to maintain controlled exhaust as far as possible without fluctuation.

The differential between high exhaust in chest 25 and controlled exhaust in chest 36 acting on that part of the diaphragm exposed to high exhaust will exert an upward force urging the diaphragm against the screen 33 to thereby cover the perforations of the screen to prevent the passage of air therethrough and to restrict communication between high and regulated exhaust chests. On the other hand, the differential between regulated exhaust in chest 23 and controlled exhaust in chest 36 acting upon that part of the diaphragm exposed to regulated exhaust exerts a downward force urging the diaphragm in a downward direction. As will be apparent, this downward force will tend to peel a portion of the diaphragm subjected to high ex-

haust away from the screen 33, thus serving to open certain perforations to permit the passage of air therethrough. Thus the area of the diaphragm exposed to high exhaust may be divided into two portions. That portion which is forced against the screen by the differential of pressures acting thereon may be termed an inactive or dead area, and that portion which is drawn away from the screen by the action of pneumatic forces thereon may be termed an active area. As will be observed, the active area subjected to high exhaust may vary as the diaphragm is peeled away from the screen or returned thereto in operation.

Assuming that the forces exerted on the diaphragm by high exhaust and controlled exhaust remain substantially constant, a condition of equilibrium is established such that regulated exhaust will also be maintained substantially constant, because if, for example, regulated exhaust tends to increase then the downward force of the differential between regulated exhaust and controlled exhaust is decreased and a tendency toward an upward movement of the diaphragm results. This in turn tends to further restrict communication between the high and regulated exhaust chests by closing certain of the perforations 34, permitting regulated exhaust to be decreased by the influx of air until the condition of equilibrium is restored. On the other hand, if regulated exhaust tends to decrease, then the differential between regulated exhaust and controlled exhaust tends to increase with the result that there is a tendency toward a downward movement of the diaphragm to open additional perforations 34 to thereby increase the effective opening between the high and regulated exhaust chests, thus permitting additional air to be withdrawn from the regulated exhaust chest to thereby increase the degree of exhaust maintained therein until the condition of equilibrium is restored. Thus there is a constant tendency on the part of the diaphragm to maintain a position such that the balanced condition shall always prevail.

In the ordinary operation of the piano, several factors may act separately or may combine tending to cause variations in regulated exhaust. For example, there may be more or less constant leakage of atmospheric air to the regulated exhaust chest, which, even though slight, tends to reduce regulated exhaust. By the action just described, however, this would result in a movement of the diaphragm sufficient to permit a corresponding leakage to the high exhaust chest through the perforations 34, thus permitting regulated exhaust to remain substantially constant.

As a further example, in the normal operation of the piano by the motor pneumatics 1 under control of the usual note sheet, each of the motor pneumatics before collapse is filled

with air at atmospheric pressure. Immediately that the valve 14 is operated to collapse the pneumatic 1 there is an inrush of atmospheric air into the wind chest past the valve
 5 as it travels from one seat to another, followed immediately by the air that is withdrawn from the pneumatic as it collapses.

Due to the action just described, whenever such an inrush of air occurs, the force of
 10 regulated exhaust acting upwardly on the diaphragm thereby tends to decrease thus permitting the diaphragm to be peeled away from the plate 33 to thereby open additional perforations 34 to permit a corresponding
 15 quantity of air to be withdrawn to the high exhaust chest. Consequently, there is a tendency to increase regulated exhaust until a condition of equilibrium is again reached.

Such action may take place so promptly
 20 and quickly, that, in effect, the action is to maintain the degree of exhaust in the regulated exhaust chest substantially constant, or, in other words, the practical effect is that of maintaining rather than correcting. And
 25 this capacity of the apparatus to maintain a constant degree of regulated exhaust rather than to correct changes in regulated exhaust is increased over prior art structures having a similar capacity due to the fact that the
 30 diaphragm 35 is substantially without inertia. In other words, such action as occurs results almost wholly from the action of juxtaposed pneumatic forces upon each other, and there is no lag or overthrow such
 35 as would otherwise occur with parts having substantial weight.

This capacity of the apparatus to maintain a constant degree of regulated exhaust is also increased over prior art structures due
 40 to the construction and arrangement of the parts whereby the regulator is placed in close proximity to the player pneumatics. Due to this provision the waves of pressure or change of pressure have a less distance to travel than
 45 in prior art structures in which the regulator and action wind chest have been arranged as separate units connected by suitable conduits or wind trunks and consequently an increase
 50 in the speed of the regulating action is noted. It will also be observed that in the embodiment of the invention illustrated herein the regulator extends for a substantial distance
 55 along the bottom of the wind chest and thereby provides direct communication between the regulator and the most frequently used player pneumatics in the middle range of the instrument.

Thus, in the playing of a single note there may be several contributing factors tending
 60 to reduce regulated exhaust below its normal level which, if not compensated for, might reduce the force with which the blow is struck. As has been explained, however, the restoring action operates so quickly due to
 65 the absence of inertia that in practical effect

regulated exhaust is maintained substantially constant.

Obviously, in the operation of a piano the number of motor pneumatics operated during the playing of a musical composition varies
 70 widely from time to time. As will be apparent, however, due to the action just described, the degree of exhaust maintained in the regulated exhaust chest and the wind chest
 75 will tend to remain substantially constant no matter how many motor pneumatics are operated at any given time and the effective opening between the high and regulated exhaust chests will be automatically
 80 varied to permit the effectual removal of the air admitted to the regulated exhaust chest.

Incremental expression control

Thus far it has been assumed that the degree of exhaust maintained in the controlled
 85 exhaust chest 36 remains substantially constant, and that it thus exerts a substantially constant downward pull on the diaphragm 35. That is, the apparatus thus far has been considered purely as a regulator. Means
 90 are provided, however, acting in conjunction with the regulator for changing the degree of exhaust maintained in the controlled exhaust chest to thereby change the degree of
 95 exhaust maintained in the regulated exhaust chest.

Before passing to a consideration of the means illustrated to accomplish this purpose, it may be convenient to consider the effect
 100 of a change in controlled exhaust on the operation of the apparatus, and particularly on regulated exhaust. As has been explained, regulated exhaust and high exhaust exert an upward pull on the diaphragm, while controlled
 105 exhaust exerts an opposed downward pull thereon. Consequently, assuming that high exhaust remains substantially constant, an increase in controlled exhaust must result in an increase in regulated exhaust in order
 110 that the condition of equilibrium may be maintained. That is, having increased the force acting downwardly on the diaphragm, the force acting upwardly must also increase in order to maintain the condition of equilibrium. As a specific example of what may
 115 occur under these conditions, if controlled exhaust is increased, there first results a tendency to peel the diaphragm 35 away from the plate 33 thus opening additional perforations to permit a larger quantity of air to be
 120 withdrawn from the regulated exhaust chest whereby the exhaust therein is increased. This increase in turn exerts an increased upward pull on the diaphragm tending to return
 125 it somewhat toward the plate to restore a condition of equilibrium at the higher level of regulated exhaust. In like manner any decrease in controlled exhaust will cause a decrease in regulated exhaust and in the
 130

degree of power applied to the strings by the hammers.

As has been set forth before, the particular degree of exhaust maintained in the controlled exhaust chest 36 depends on the relative sizes of the separate vents leading from this chamber to the reservoir and to the atmosphere. Obviously, if the size of the vent to atmosphere is increased controlled exhaust will be decreased and conversely if the size of the vent to atmosphere is decreased, controlled exhaust will increase. Means are provided for varying the size of the vent to atmosphere by distinct increments in order that controlled exhaust and hence regulated exhaust may be varied to thereby obtain incremental expression variations in playing.

For this purpose there are provided, leading into the chamber 36 a plurality of vent passages 40, 40a and 40b in which may be placed bleed cups 41, 41a and 41b, the cups being provided with openings of progressively increasing areas, the opening in the cup 41 being the smallest opening, the opening in the cup 41a being somewhat larger and the opening in the cup 41b being the largest. When all of the passages 40, 40a and 40b are opened to permit the passage of atmospheric air to the controlled exhaust chest 36, playing intensities will be at their softest, because the large inflow of atmospheric air relative to the small outflow through the constricted passage 37 causes only a slight degree of exhaust to be maintained in chest 36, and as before explained, a relatively low degree of exhaust will be maintained in the regulated exhaust chest 23. On the other hand, as one or more of the passages 40, 40a and 40b are closed to prevent the passage of atmospheric air to the controlled exhaust chest 36 the degree of exhaust maintained therein is increased with corresponding increases in the exhaust maintained in the regulated exhaust chest 23.

In order to close the passages 40, 40a and 40b, the pouches 42, 42a and 42b are provided having relatively flat stiffened portions 43, 43a and 43b serving as valves to cover the outer ends of the passages. The pouches 42, 42a and 42b are mounted within a chamber 44 having a conduit 45 leading to atmosphere and are provided with light coil springs 46, 46a and 46b which assist in returning and holding the valves 43, 43a and 43b on their seats. Leading to the inside of each of the pouches is a duct 47, 47a and 47b which may be connected to a valve mechanism hereafter described for supplying either exhaust or atmosphere to the pouches. As will be apparent, when the pouches are subjected to exhaust, a differential of pressure is created which forces the pouches downward away from the passages 40, 40a and 40b thereby opening the same. On the other hand, when atmosphere is admitted to the pouches, the

pressure differential is reversed, the pouches are returned to their seats under the influence of the springs 46, 46a and 46b and are retained thereon under the combined influence of the springs and the pressure differential.

In order that the pouches may be controlled automatically from the tracker bar the valve mechanism 50 is provided having a chest 51 connected to high exhaust through the conduit 52.

Inasmuch as the valve mechanisms for controlling the base and treble sections of the piano are duplicates only one will be described in detail herein, it being understood that a valve mechanism 50' is provided for controlling the treble section of the piano in a manner similar to that in which the valve action 50 controls the base section of the action.

The valve action 50 includes three valve units 53, 53a and 53b connected to the pouches 42, 42a and 42b by the ducts 47, 47a and 47b respectively. Inasmuch as each of these valve units are of the same construction only one will be described in detail herein. The duct 47 is connected to a valve chamber 54 controlled by a duplex valve 55 arranged to control a port 56 to atmosphere and a port 57 leading to the exhaust chest 58, said exhaust chest 58 being connected to the chest 51 through the passage 59.

The valve 55 is controlled and operated by a diaphragm 60 covering the diaphragm chamber 61 into which opens the duct 62 leading to the tracker bar 15. When the tracker bar vent 63 controlling the admission of atmosphere to the duct 62 is opened, the differential of pressure between the diaphragm chamber 61 and the exhaust chest 58 causes the valve 55 to be raised to close the port 57 to thereby cut off exhaust from the chamber 54 and to open the port 56 to thereby admit atmospheric air to the chamber 54. Thus, under normal conditions with the tracker bar vent 63 closed and the valve 55 lowered the chamber 54 is maintained under exhaust from the exhaust chest 58 and when the valve 55 is raised atmospheric air is admitted to the chamber 54 and exhaust is cut off.

When the valve 55 is once raised by venting the tracker duct 62 the valve preferably remains in raised position even though the tracker vent may be immediately closed. In the specific apparatus illustrated, this results from the fact that once the valve 55 is opened to admit atmosphere to the valve chamber 54 said valve 55 is held in that position by atmosphere admitted past the valve 55 into a duct 64 from which it passes through a bleeder vent 65 through the duct 66 which communicates with the diaphragm chamber 61. Thus so long as atmosphere is admitted through the duct 64 the diaphragm 60 will remain lifted and atmosphere will continue to be admitted to the chamber 54.

From the preceding discussion it will appear that small perforations in a note sheet controlling the tracker vents 63, 63a and 63b may be employed which may be immediately closed if desired. When used with the illustrative apparatus each such perforation has the effect of introducing atmosphere to one of the chambers 54, 54a and 54b and even after the tracker vent is closed atmosphere will continue in the corresponding chamber until purposely exhausted at any subsequent time in a manner such as that about to be described.

In the preferred embodiment of the apparatus illustrated in the drawings, a single valve mechanism controlled by a single tracker vent is employed to cooperate with all or any of the three above described valve mechanisms to negative the effect of opening one or more tracker vents 63, 63a and 63b. Such valve mechanism is designated in the drawings by 71. This valve mechanism comprises a valve chamber 72 controlled by a duplex valve 73 arranged to open the port 74 to atmosphere and to close the port 75 to exhaust from the chest 76 connected to the exhaust chest 51 by means of the duct 77. The valve is operated by diaphragm 78 mounted over the diaphragm chamber 79 which communicates by means of the duct 80 with a tracker vent 81.

When the tracker vent 81 is opened by a suitable opening in the note sheet, atmosphere is admitted to the diaphragm chamber 79 and the differential of pressure between the diaphragm chamber and the exhaust chamber 76 causes the valve 73 to be raised to cut off exhaust from the valve chamber 72 and to permit atmospheric air to enter the chamber.

As already stated, the valve 55 is held in raised position by the atmosphere which is admitted to the diaphragm chamber 61 through the ducts 66 and 64. As will be apparent, if communication between these ducts is cut off and suction applied to the duct 66 the differential of pressures which causes the valve 55 to be raised would be equalized and the valve 55 would return to its normal position. Means are provided for performing this operation, such means comprising the valve 85 which normally remains in seated position covering the port 86 leading to the exhaust chamber 58. If this valve is raised, the port 86' will be closed thus cutting off communication between the ducts 64 and 66. At the same time the valve chamber 87 will be subjected to exhaust through the port 86 and this exhaust communicated through the bleed vent 65 and duct 66 will cause the valve 55 to return to normal position as before described.

The valve 85 is operated by diaphragm 88 covering the diaphragm chamber 89 which is in communication with the valve chamber

72 before described through the duct 90. Accordingly, when the valve 73 is in its lowered position the diaphragm chamber 89 is subjected to exhaust and the valve 85 remains in lowered position. When the valve 73 is raised by the admission of atmospheric air through the tracker vent 81, atmospheric air is also admitted to the diaphragm chamber 89 with the result that the valve 85 is raised and the valve 55 is returned to normal position. In this manner by opening the tracker vent 81 any of the chambers 54, 54a and 54b which have been opened to atmospheric air are again subjected to exhaust.

The operation just described so far as it concerns the specific illustrative mechanism depends upon bleeding the diaphragm chamber 61. If the tracker duct 62 be opened through its vent 63 at the same time the vent 81 is opened to initiate the bleeding of the diaphragm chamber 61, atmosphere will enter the chamber 61 more rapidly than it can be exhausted therefrom by the described bleeding, and, therefore, the effect of opening the vent 81 is negatived and under such circumstances the valve 55 will remain in raised position and atmosphere will continue to be admitted to the chamber 54.

Also, if the tracker vent 63, for instance, be opened simultaneously with the tracker vent 81, the latter will inaugurate a tendency to bleed the chamber 61 and keep the valve 55 lowered in the position shown, but the simultaneous opening of the tracker vent 63 will admit atmosphere to the chamber 61 more rapidly than it can be exhausted by the bleeder vent and, therefore, the valve 55 will be lifted in spite of the opening of the tracker vent 81.

From the above description it will be understood that whether or not the tracker vent 81 be opened, the opening of any of the vents 63, 63a and 63b will have its normal and usual effect to admit atmosphere to the appropriate chamber 54, 54a or 54b. This will be true if any vent 63, 63a or 63b be opened with or without simultaneously opening the tracker vent 81.

On the other hand, if the vent 63 be opened and then closed atmosphere being thereby admitted to the chamber 54, and the vent 81 be thereafter opened, the previous effect of opening vent 63 will be negatived and the chamber 54 will be opened to exhaust.

In the operation of the apparatus thus far described it may be desirable under certain conditions to vent atmospheric air to the regulated exhaust chest. For example, this might be particularly desirable in making sudden changes in regulated exhaust from a condition of relatively high exhaust to one of relatively low exhaust in order that the condition of high exhaust may be immediately relieved. For this purpose means are provided for venting atmospheric air to the reg-

ulated exhaust chest and such means are preferably controlled by the automatic valve mechanism which controls the degree of exhaust maintained therein.

In the preferred embodiment illustrated, the regulated exhaust chest 23 is provided with a vent 91 to atmosphere, said vent being controlled by the diaphragm 92 mounted on the block 93. The block 93 is recessed to provide a chamber 94 behind the diaphragm and the chamber 94 is connected by duct 95 with the duct 47b leading to the diaphragm chamber 54b controlling the vent 40b. Thus, when the duct 47b is subjected to exhaust to operate the diaphragm 42b the duct 95 is likewise subjected to exhaust to raise the diaphragm 92. It will, therefore, be apparent that at any time when vent 41b is open or that in making any change in regulated exhaust involving the opening of the vent 41b, the vent 91 will also be opened to permit the entrance of atmospheric air to the regulated exhaust chest. It will also be apparent that while the opening of the vent 91 permits an inrush of atmospheric air to relieve any temporary undesirable condition of exhaust, the continued flow of atmospheric air through the vent will not affect the operation of the instrument for the leakage of air will be compensated by a corresponding leakage past the diaphragm 35 as hereinbefore explained.

Indeed the flow of air through the vent 91 and through the regulator past the diaphragm 35 while playing the lower intensities which prevail whenever the vent 41b is open may be of positive advantage, for it has been found that the regulator sometimes operates more sensitively with an appreciable flow of air than is the case when little or no air is flowing therethrough.

The apparatus thus far described has the capacity of maintaining in the regulated exhaust chest a substantially constant degree of exhaust regardless of the number of motor pneumatics operated at any given time, and regardless of the varying amounts of air admitted to the regulated exhaust chest therefrom. It likewise has the capacity of varying the degree of exhaust maintained in the regulated exhaust chest by a series of substantially distinct steps or increments which produce similar distinct steps or increments in the intensity of the successive notes played by the instrument due to the varying force of the blows imparted to the strings by the hammers. As has also been noted, the degree of exhaust established in the regulated exhaust chest will be maintained substantially constant at any of the several degrees at which it may be set by changing the degree of exhaust in the controlled exhaust chest.

Crescendo and diminuendo control

Means are also provided for varying the degree of exhaust maintained in the regu-

lated exhaust chest not only by distinct increments or steps, as has previously been described, but also for varying the degree of regulated exhaust by substantially continuous progression in order to reproduce the crescendo and diminuendo effects which form a part of the art of skilled pianists, such means being designated generally by reference numeral 100. In the present embodiment this desideratum is attained by varying the degree of exhaust maintained in the controlled exhaust chest by substantially continuous progression just as in the previous description incremental changes in regulated exhaust were obtained by varying controlled exhaust by substantially distinct increments. And such changes in controlled exhaust are obtained in the present embodiment by progressively throttling the conduit 45 leading from the chamber 44 to atmosphere. Referring particularly to Figure 12, the conduit 45 terminates in a mouth piece 101 pivotally mounted on the brackets 102 by means of trunnions 103. Mounted to cooperate with the open end of the mouth piece 101 is a needle valve 104 pivotally secured to the bracket 105 mounted on the movable leaf 106 of the crescendo pneumatic 107.

As will be observed, any relative movement between the mouth piece 101 and the needle valve 104 will vary the effective opening to atmosphere and the pressures maintained in the controlled exhaust chest 36 will be correspondingly varied. Consequently, if the mouth piece 101 is held in a stationary position and the needle valve 104 is moved with respect thereto with a substantially uniform movement, the degree of exhaust maintained in the controlled exhaust chest will likewise be varied with substantial uniformity. If the needle valve is moved further into the mouth piece 101 in this manner, the amount of atmospheric air permitted to enter is progressively decreased, the degree of exhaust maintained in the controlled exhaust chest is progressively increased, and playing intensities are progressively increased, this progressive increase of playing intensities being known as a crescendo. On the other hand, if the needle valve is withdrawn from the mouth piece at a uniform rate the amount of atmospheric air entering the mouth piece is progressively increased, the degree of exhaust in the controlled exhaust chest decreases progressively and playing intensities decrease progressively whereby diminuendo effects are secured.

In the present embodiment automatic means are provided for securing uniform progressive movement of the needle valve with respect to the mouth piece 101, such means comprising in part the pneumatic 107 previously referred to. Pneumatic 107 is connected by means of the conduit 108 with the valve

chamber 109 formed in the crescendo valve unit 110. The chamber 109 is connected through the bleed 111 to duct 112 leading to the valve chamber 113 which is normally open to atmosphere through the passage 114. Mounted in the valve chamber 113 is a valve 115 cooperating with the diaphragm 116 having a diaphragm chamber 117 connected to the tracker bar through duct 118. The valve mechanism is also provided with a chamber 119 connected to high exhaust or in the preferred embodiment illustrated to a substantially constant exhaust less than high exhaust through the conduit 120 and a bleed 121 is provided to maintain the duct 118 and diaphragm chamber 117 normally under exhaust. When the tracker vent 122 is uncovered to admit atmosphere to the duct 118, valve 115 is raised to close the passage 114 to atmosphere and to connect the passage 112 through the port 123 with the exhaust maintained in the chamber 119. This exhaust being communicated through the bleed 111, chamber 109, and conduit 108 to the crescendo pneumatic 107, collapses the pneumatic slowly, the particular rate of collapse being determined by the size of the bleed opening 111, this bleed ordinarily being of a size to collapse the pneumatic 107 rather slowly.

It is sometimes desirable, however, to collapse the pneumatic 107 more rapidly in order to secure a more rapid crescendo effect. For this purpose the duplex valve 124 is provided having a head sufficiently large to cover the vent 125 connecting the passage 112 to the valve chamber 109. The lower end of the valve 124 cooperates with the diaphragm 126 having a diaphragm chamber 127 connected to the tracker bar through the duct 128 and to the exhaust chest 119 through the bleed 129. If, during the operation of the instrument, tracker vent 130 is opened while the tracker vent 122 is also open, valve 124 will be raised to uncover the vent 125 to permit a more rapid exhaust of the pneumatic 107 than was previously permitted through the bleed 111.

Thus it will be apparent that by collapsing the pneumatic 107 at two different uniform speeds, fast and slow crescendo effects may be secured. Fast and slow diminuendo effects may likewise be secured by controlling the rate of expansion of the pneumatic 107 under the influence of the spring 131 by controlling the rate at which atmospheric air is admitted thereto. As will be apparent, if both of the valves 115 and 124 are lowered, as when both tracker vents 122 and 130 are closed, the flow of atmospheric air to the pneumatic is controlled by the bleed 111 and a relatively slow expansion of the pneumatic is permitted and a slow diminuendo effect is thereby secured. On the other hand, if the

valve 115 remains lowered while the valve 124 is raised, atmospheric air is permitted to enter the pneumatic 107 through the vent 125 and a fast diminuendo effect is thereby secured. Thus by properly controlling the valves 115 and 124 by suitable perforations in the note sheet controlling vents 122 and 130, both fast and slow crescendo effects and fast and slow diminuendo effects may be secured.

As will be observed from Figures 1 and 12, duplicate crescendo mechanisms are provided for the base and treble sections of the wind chest. Inasmuch as the crescendo mechanisms are in all respects the same, only one has been described in detail herein.

Referring to Figure 12 the fixed leaf 135 of the pneumatic 107 is mounted on a block 136, while the corresponding fixed leaf 135' of the treble crescendo pneumatic 107' is pivotally mounted on the block 136 by means of the hinge 137. The two leaves 135 and 135' are attached by a relatively stiff coil spring 138. As will be observed, the bracket 102 carrying the mouth piece 101 is mounted on the bracket 139 having an adjusting screw 140 forming a limit stop for the pneumatic 107'. Corresponding brackets 102' are provided for holding the mouth piece 101', said brackets being mounted on the brackets 139' provided with the adjusting screw 140' forming a limit stop for the pneumatic 107. Mounted on the fixed leaf 135 of the pneumatic 107 is an eccentric disk 141 having a handle 142 and adapted to contact with the leaf 135' of the pneumatic 107'.

As will be observed, movement of the eccentric disk 141 caused by turning the handle 142 serves to displace the entire pneumatic 107' and serves to simultaneously adjust both of the vents to atmosphere as desired. For instance, moving the handle 142 to the right would cause the leaf 135' to move to the left and brackets 139 and 102 carrying the mouth piece 101 would be moved to withdraw the mouth piece somewhat from the needle valve 104, thus permitting a greater quantity of atmospheric air to enter through the vent. At the same time the leaf 106' would be moved to the left to the same extent and would withdraw the needle valve 104' from the mouth piece 101' to secure a corresponding increase in the size of this vent to atmosphere. This adjustment may be used to adjust the playing of the instrument as desired to meet the taste of the individual owner or operator. If the piano is to be used in large rooms or for concert work the handle 142 may be moved to the right to thereby raise the normal scale of playing intensities, while if the instrument is to be used in a small room, the handle 142 may be moved to the left to thereby lower the general range of playing intensities.

Pump pressure control

In the preceding description it has been explained that playing intensities are governed and controlled by opposed pneumatic forces acting on the area of the diaphragm 35 exposed thereto, such opposed forces comprising the force of regulated exhaust in the chest 23, the force of controlled exhaust maintained in chest 36 and the force of high exhaust in the chest 25. It has also been explained that variations in controlled exhaust acting on the diaphragm 35 produce variations in regulated exhaust; that by causing controlled exhaust to be varied by substantially distinct increments, regulated exhaust and playing intensities were likewise varied by substantially distinct increments; that by varying the force of controlled exhaust by substantially continuous progression, regulated exhaust and playing intensities were varied by substantially continuous progression.

It is also proposed herein to govern and control the pressure applied by the source of exhaust, herein the pump 29, to thereby additionally govern and control playing intensities. Before passing to a consideration of the means illustrated for governing and controlling pump pressures it may be convenient to consider the effect of changes in pump pressure on regulated exhaust and playing intensities.

As has been set forth before, during the operation of the specific apparatus illustrated and described herein the diaphragm 35 is constantly under the control of opposed forces tending always to balance each other and to hold the diaphragm 35, as it were, in suspension between them; that is to say, the specific apparatus tends constantly to establish a balancing equation between the opposed forces acting upon the diaphragm 35. Such movement of the valve 35 as may occur when that balancing equation is disturbed takes place practically instantaneously so that a new balancing equation appropriate to the newly initiated conditions is immediately set up.

If, under these conditions, that is, with the diaphragm 35 being held in a condition of equilibrium under the action of the opposed pneumatic forces acting thereon, high exhaust is increased, the exhaust in the reservoir 27 and in the high exhaust chest 25 is likewise increased and the upward pull on the diaphragm 35 is thereby increased. At the same time, however, exhaust in the controlled exhaust chest 36 is also increased somewhat, due to the communication maintained with the reservoir 27 through the conduit 37, and an increased downward pull on the diaphragm 35 results. Inasmuch as the active area of the diaphragm 35 exposed to high exhaust in the chest 25 is very small,

while the area of the diaphragm exposed to controlled exhaust in chest 36 is somewhat larger, the downward pull exerted by the increase in exhaust in chest 36 predominates over the upward pull exerted by the increase of exhaust in chest 25, the final result being an increase in the downward pull on the diaphragm. Consequently, in order to maintain the diaphragm in equilibrium, regulated exhaust must increase.

Thus if pump pressures are increased an increase in regulated exhaust results therefrom, and conversely, in a similar manner, if pump pressures are decreased regulated exhaust is decreased.

The changes before described occur throughout the entire range of playing intensities established by the incremental expression mechanism or by the crescendo and diminuendo mechanism previously described. That is, whatever the pressure of regulated exhaust may be, a change in pump pressure will cause a change in regulated exhaust. It follows, of course, as a logical consequence that if pump pressures are maintained at any substantially constant level, regulated exhaust will also be maintained substantially constant.

For instance, for convenience of description and explanation it may be assumed that playing intensities determined by the crescendo, diminuendo and incremental or step change mechanism could be measured by an imaginary scale upon which the numeral 5 would indicate the lowest playing intensity, while the numeral 25 would indicate the loudest playing intensity when high exhaust is being maintained at 25" as measured on a water gauge. Therefore, incremental and crescendo or diminuendo changes will be effective within the compass of this scale from 5 to 25. For instance, it may be assumed that the seven steps would fix the different playing intensities respectively at 5, 6, 7.3, 9, 12, 17 and 25.

It may further be assumed that a crescendo may be inaugurated when the playing intensity is fixed at any one of the seven points in the scale except the last, and will, if continued long enough raise the playing intensities at a greater or less speed as may be determined by the apparatus, from the point at which it is inaugurated to the highest intensity.

Thereafter a diminuendo operation may be inaugurated to decrease playing intensities to any point determined by the said step change mechanism.

If now high exhaust be decreased from 25" to 20", regulated exhaust would be decreased and playing intensities thereby decreased throughout the entire range of the imaginary scale. For instance, the lowest normal intensity 5 on the imaginary scale might be decreased to 4 and the normal intensity of 6

might be decreased to 4.8 and so on, so that the new scale of playing intensities might be represented by 4, 4.8, 5.9, 7.2, 9.6, 13.6 and 20.

On the other hand, if high exhaust should be increased from 25" to say 40", regulated exhaust would be correspondingly increased and playing intensities increased. For instance, the imaginary scale under these conditions may be as follows: 8, 9.6, 11.6, 14.4, 19.2, 27.2 and 40. Obviously the foregoing figures are presented herein for illustrative purposes only, it being desired merely to show that changes in high exhaust tend to change the entire range of playing intensities.

In the present embodiment for purposes above described, the spill valve regulator mechanism 150 is provided having a chamber 151 connected to the conduit 28 through the conduit 32. On one side of the chamber is mounted the grid 152 having a multiplicity of perforations 153 therein, said perforations being adapted to be covered or uncovered by the flexible curtain 154 of very little weight connected to the sleeve pneumatic 155 also of very little weight to control the passage of atmospheric air to the chamber 151. The sleeve pneumatic is also connected to the reservoir 27 through the conduit 156 so that a condition of exhaust is constantly maintained therein tending to draw the sleeve pneumatic toward the left as shown in Figure 7 to thereby uncover certain of the perforations 153 to spill atmosphere to the chamber 151.

As will be observed, if the exhaust in reservoir 27 increases, additional exhaust is communicated to the sleeve pneumatic 155, and the force acting on the valve 154 and tending to move the same to uncover additional perforations is increased. Additional quantities of air are thereby admitted to the chamber 151 reducing the exhaust therein, and due to the communication with the reservoir 27 through conduits 32 and 28 the exhaust therein is decreased. Conversely, if exhaust in the reservoir 27 tends to decrease the force acting on the sleeve pneumatic 155 tending to open the valve 154 is decreased, the amount of atmosphere entering through the perforations 153 is decreased and the exhaust in the chamber 151 and the reservoir 27 is thereby increased.

As will be seen, the action just described results in maintaining in the reservoir 27 a substantially constant degree of exhaust and whatever fluctuations, due to change in pump speed or to other conditions such as the admission of abnormal quantities of air to the main regulator, may tend to occur therein are automatically compensated by admitting more or less atmospheric air.

The cooperative effect between the main regulator and the spill valve or pump pressure regulator may be briefly referred to herein. For example, if, during the opera-

tion of the instrument, while operating at any given degree of regulated exhaust, an unusually large number of motor pneumatics are operated simultaneously, a large quantity of air is admitted to the main regulator and is permitted to pass the throttle valve in the manner previously described in order that playing intensities may be maintained at a substantially constant level. As soon as the air admitted has passed the throttle valve, there is a tendency to reduce the exhaust maintained in the conduit between said valve and the source of exhaust. This tendency, however, results in disturbing the balance of the forces acting on the spill valve, for the force of exhaust acting on the sleeve pneumatic 155 tends to be decreased thereby. Consequently, the spill valve tends to close, cutting off the normal inflow of atmospheric air thereby tending to increase exhaust therein until the opposed forces are again equalized and the condition of equilibrium restored. On the other hand, if an abnormally small number of motor pneumatics are operated, or if a temporary lapse in playing occurs in which none of the motor pneumatics are operated, there is a tendency to increase the degree of exhaust maintained in the system between the throttle valve and the source of exhaust, which tendency, acting on the sleeve pneumatic tends to collapse the same to increase the effective spill valve opening to thereby admit a greater quantity of atmospheric air to counteract the tendency toward increased exhaust.

Thus it will be seen that due to the cooperation between the main regulator and the pump pressure regulator the exhaust applied by the source of exhaust is maintained at a substantially constant level, and this in turn assists in securing accurate regulation by the main regulator as is desirable.

In the present embodiment the pneumatic force acting on the sleeve pneumatic 155 is opposed by the force of the spring 157, so that in effect the valve 154 is balanced between the two opposed forces. As has been explained, changes in the pneumatic force applied to the sleeve pneumatic 155 automatically regulate the exhaust in the chamber 151 and the reservoir 27 to maintain a substantially constant exhaust therein. On the other hand, changes in the opposing force, or in the present embodiment, changes in the tension of the spring 157 cause changes in the degree of exhaust maintained in the sleeve pneumatic 155 in order that the tension of the spring 157 may be balanced and opposed at all times by an equal pneumatic force, and consequently the degree of exhaust maintained in the chamber 151 and in the reservoir 27 is thereby changed. Specifically, if the tension of the spring 157 is increased the exhaust in the chamber 151 and reservoir 27 is increased while if the tension of the spring

157 is decreased the exhaust in the chamber 151 and reservoir 27 is decreased.

For example, if we assume an increase in the tension of the spring 157 without a corresponding immediate increase in the exhaust applied to the sleeve pneumatic 155 the sleeve pneumatic is moved to the right and valve 154 is thereby permitted to cover additional perforations 153 to thereby additionally restrict the admission of atmospheric air. This additional restriction results in increasing the exhaust maintained in chamber 151 and in the reservoir 27 and consequently the exhaust communicated to the sleeve pneumatic 155 through conduit 156 is increased, and such increase continues until the pneumatic force applied is equal to and balances the tension of the spring 157. Similarly a decrease in the tension of the spring 157 results in a decrease in the exhaust maintained in the chamber 151 and reservoir 27.

Means are provided for varying automatically the tension applied to the valve 154 by the spring 157 and opposing the exhaust applied to the pneumatic 155. Preferably means are provided for either increasing or decreasing this tension with respect to a predetermined normal tension, and such automatic mechanisms are preferably controlled from a single opening of the tracker bar.

For this purpose the end of spring 157 is attached to the movable leaf 158 of the pneumatic 159 and the rod 160 which connects the other end of the spring 157 to the valve 154 and pneumatic 155 is preferably slotted to receive one end of the lever 161 which is connected by means of the spring 162 to the movable leaf 163 of the pneumatic 164.

Pneumatic 159 is connected by means of the passage 165 to the exhaust chamber 166 of the outside valve mechanism 167 of usual construction, so that the pneumatic 159 is normally subjected to exhaust, and is therefore normally collapsed to exert a greater tension on the spring 157 than would be the case were the pneumatic 159 in expanded condition. The diaphragm chamber 168 of the valve mechanism 167 is connected by means of a duct 169 to a vent 170 in the block 171, said vent normally being closed by means of an arm 172 pivoted at 173. Acting on the arm 172 is a spring 174 tending to raise the arm 172 to uncover the vent 170. The end of the arm 172 engages the movable leaf 175 of the pneumatic 176 and the spring 177 of the pneumatic being stronger than the spring 174 the arm 172 normally remains in position to cover the vent 170, except when the pneumatic 176 is collapsed, at which time the spring 174 raises the arm 172 to uncover the vent 170. As will be observed, when the vent 170 is uncovered valve 178 is raised to thereby admit atmosphere to the chamber 166 and to the pneumatic 159 to permit the same

to expand to thereby decrease the tension of the spring 157.

Pneumatic 176 is connected by means of the passage 179 to valve box 180 having a check valve 181 therein, said check valve being provided with a bleed duct 182. The valve box 180 is connected by means of the duct 183 with the valve chamber 184 of the primary valve mechanism 185 so that the valve box 180 is normally open to atmosphere and the pneumatic 176 is normally in expanded condition. The primary valve 185 is connected to the tracker bar 15 by means of the duct 186 having a tracker vent 187. Operation of the primary valve 185 by suitable openings in the note sheet cooperating with vent 187 will subject the valve box 180 and the pneumatic 176 to exhaust as the check valve 181 will be raised by the flow of air as the pneumatic 176 is collapsed. When the vent 187 is closed, however, the check valve 181 will be seated and pneumatic 176 will expand slowly, the rate of expansion being controlled by the size of the bleed opening 182 in the check valve.

Pneumatic 164 is connected by means of the passage 190 to the valve chamber 191 of the inside valve mechanism 192 so that the pneumatic 164 remains normally in expanded condition. The diaphragm chamber 193 of the valve mechanism 192 is connected by means of the duct 194 with the vent 195 in block 171, said vent being normally closed by the arm 196 pivoted to block 171 at 197. The pivot 197 is preferably sufficiently tight to cause the arm 196 to remain in any position to which it is moved. When the arm 196 is raised to open vent 195 to atmosphere valve 198 is raised and the pneumatic 164 is collapsed to thereby tension the spring 162 and through lever 161 to increase the spring tension acting on valve 154 to thereby increase the exhaust maintained in chamber 151 and reservoir 27.

The arm 196 normally remains in position to cover the vent 195, but may be raised by pneumatic 199 having a movable leaf 200 carrying the lug 201 adapted to engage the end of arm 196, lug 201 being of a length to engage the arm 196 only during the latter part of the collapse of pneumatic 199. Pneumatic 199 is connected by means of a passage 202 with valve chamber 203 having a check valve 204 with a bleed opening 205 therein. The valve chamber 203 is connected by means of the duct 206 with the valve chamber 184 of the primary valve 185 previously described. It will be apparent that valve chamber 203 and pneumatic 199 are normally open to atmosphere and pneumatic 199 is normally expanded. When the tracker vent 187 is open to exhaust by suitable openings in the note sheet, duct 206 is subjected to exhaust but due to the interposition of the check valve 204 pneumatic 199 is exhausted slowly

through the bleed 205. When the vent 187 is closed, however, pneumatic 199 may expand rapidly as the check valve 204 is raised by the flow of air.

5 It will be apparent from the foregoing that when the tracker vent 187 is closed both of the pneumatics 176 and 199 assume an expanded condition and both of the vents 170 and 195 are closed to atmosphere. If, however, 10 the vent 187 is opened by a perforation in the note sheet, the pneumatic 176 is collapsed rapidly while the pneumatic 199 is collapsed slowly. If, however, after both pneumatics are completely collapsed the tracker vent 187 15 is closed pneumatic 176 will expand slowly while the pneumatic 199 may expand rapidly.

When the pneumatics 164 and 159 are both expanded as illustrated in Figure 13 an intermediate degree of exhaust is maintained in the chamber 151 and the reservoir 27,— 20 intermediate, because both higher and lower degrees of exhaust may be maintained therein as hereinafter explained. If pneumatic 25 159 is permitted to expand, the spring 157 exerts a less degree of tension on the valve 154 and a less degree of exhaust is maintained in the chamber 151. On the other hand, if pneumatic 164 is collapsed, spring 162 is 30 subjected to tension which exerts an additional tensioning force on the valve 154 opposed to the pneumatic force exerted by the pneumatic 155. The spring 162 is so arranged in connection with the pneumatic 35 164 and lever 161 that when the pneumatic 164 is expanded the spring 162 exerts no tension on the valve 154, the lever 161 sliding freely in the slot provided in the rod 160 and for this reason the push rod 163' is provided 40 to engage the lever 161 to move it to the left when the pneumatic 164 expands.

For purposes of convenience in description a section of note sheet has been illustrated in Figure 13 having perforations indicated 45 therein adapted to control the mechanisms provided. Referring thereto, in the absence of perforations the intermediate pressure will be maintained in the chamber 151 which pressure may for convenience be assumed to be 50 25" as measured on a water gauge. If, under these conditions, a short perforation crosses the vent 187 of the tracker bar, pneumatic 176 will be collapsed rapidly permitting the arm 172 to be lifted by spring 174 to 55 uncover vent 170 to open the pneumatic 159 to atmosphere, thus reducing the tension on the spring and reducing the exhaust maintained in chamber 151 and reservoir 27 to 20" for example. At the same time pneumatic 199 starts to collapse but as this pneumatic collapses very slowly due to the bleed 205, it fails to reach the arm 196 before the 60 end of the short perforation crosses the vent 187, at which time both pneumatics 176 and 199 commence to expand. Pneumatic 199

expands rapidly, but pneumatic 176 expands slowly, and unless an additional short perforation passes the vent 187, the expansion of the pneumatic 176 will cause the arm 172 to 70 again close the vent 170. If, however, a second short perforation crosses the tracker vent 187 before the pneumatic 176 has expanded sufficiently to close vent 170, the pneumatic 176 will again be collapsed rapidly and the condition of reduced exhaust previously established will be maintained. Thus by providing a series of spaced short perforations a condition of reduced exhaust may be maintained indefinitely.

If, however, a longer perforation crosses 80 the tracker vent 187 the pneumatic 176 is collapsed and vent 170 is opened and by the continued application of exhaust to pneumatic 199, the arm 196 is raised to open vent 195 to collapse the pneumatic 164. In its upward 85 travel the arm 196 closes the vent 170 previously opened, whereby the pneumatic 159 is again collapsed, the final result thus being the collapse of both the pneumatics 164 and 159 and an increase in the exhaust maintained in chamber 151 and reservoir 27 to 40" for 90 example. When the end of the longer perforation crosses the tracker vent 187 pneumatic 199 immediately expands rapidly, but the pneumatic 176 expands slowly and does 95 not return the levers 172 and 196 to their normal position for an appreciable interval. If the pneumatic 176 is permitted to expand fully, the levers are returned to normal position and the intermediate exhaust is maintained in the chamber 151. It will be apparent, however, that by providing a series of spaced short perforations, pneumatic 176 100 may be collapsed intermittently with the result that both pneumatics 164 and 159 may be retained in collapsed position and the higher degree of exhaust may be indefinitely maintained in the chamber 151 in this manner.

It has been found advisable, under some circumstances, to provide means to by-pass 110 the pump pressure regulator previously described, and to provide a supplemental flow of air to the source of exhaust. Accordingly, the chamber 151 is provided with a port 208 to atmosphere, said port being controlled by 115 the valve 209 mounted on the movable leaf 210 of the pneumatic 211. The interior of the pneumatic 211 may be connected by means of the conduit 212 with the interior of the pneumatic 164, so that whenever the 120 pneumatic 164 is subjected to exhaust, pneumatic 211 is also subjected to exhaust and is collapsed against the tension of its spring. Upon collapse of the pneumatic valve 209 closes port 208 to prevent the admission of 125 atmosphere.

As has been previously explained, whenever the pneumatic 164 is subjected to exhaust pump pressures are maintained at a high level, and under these conditions it is 130

desirable that the by-pass port be closed in order that the full power of the source of exhaust may be utilized. On the other hand, when pump pressures are maintained at a lower level it has been found that the regulator responds more sensitively to changes in pneumatic conditions if air is by-passed through the port 208 instead of being admitted through the perforations 153 of the regulator itself.

Loud pedal control and compensation

To the preferred embodiment of the invention illustrated and described thus far there may be added means for controlling the operation of the loud or damper pedal mechanism, and for this purpose the pneumatic 220 may be provided which is operatively connected to the damper rail 221 through the rod 222. As will be apparent, upon collapse of the pneumatic 220 the damper rail 221 which extends across the entire piano will be raised to lift all of the arms 10 thus lifting all of the dampers 11 from the strings 9 to permit the same to vibrate freely in the usual manner. Pneumatic 220 is connected by means of a conduit 223 with the valve chamber 224 of the valve unit 225, the diaphragm chamber 226 of the unit being connected to the tracker bar through the duct 227. The exhaust chamber 228 of the valve unit is connected to the source of exhaust in a manner described more in detail herein-after through the conduit 229. When a suitable opening in the tracker bar uncovers the tracker vent 230, the valve 231 is raised, pneumatic 220 is subjected to exhaust and is collapsed to lift the dampers 11.

As will be observed, when the dampers are lifted in the manner just described a certain amount of weight is removed from the keys 5, and the amount of energy which is necessary to strike a blow of any given intensity to the strings is thereby decreased due to the fact that the dampers do not have to be lifted by the striker pneumatics. In other words, in order to strike a blow of the same intensity when the dampers are lifted less energy need be applied.

In the present embodiment means have been provided by which under certain conditions when the pedal mechanism is operated to lift the dampers, regulated exhaust is automatically decreased by a certain amount so that at all times regardless of whether the dampers are raised or lowered the blow imparted to the string will be of the same intensity. For this purpose the valve chamber 224 of the valve unit 225 is provided with a duct 232 which may be divided to provide a duct 232', said ducts leading respectively to the chambers 233 and 233' (see Figure 3) for the bass and treble sections of the piano. As the chambers 233 and 233' are similar in construction and op-

eration only one will be described in detail herein. The chamber 233 is covered by a diaphragm 234 having a relatively flat stiffened portion 235 adapted to close the end of the vent 236 having a bleed 237 arranged therein. Above the diaphragm 234 is a chamber 238 which communicates with the passage 40b through the duct 239. Whenever the diaphragm 42b is lowered, the chamber 238 is in communication with the chamber 44 and diaphragm 234 is subjected on one side to the exhaust maintained therein and on the other side to atmosphere admitted to chamber 233 through the duct 232. Under these conditions, therefore, the vent 236 is closed due to the differential of pressure and to the provision of the light coil spring 240.

If, under these conditions, the valve 231 is operated to collapse the pneumatic 220 to raise the dampers, the chamber 233 is also subjected to exhaust through the duct 232, the diaphragm 234 is lowered and air may pass through the duct 239 through vent 236 and bleed 237 to the controlled exhaust chest 36, thereby reducing the degree of exhaust therein somewhat and, since, as has been hereinbefore explained, reductions in controlled exhaust result in a reduction in regulated exhaust, regulated exhaust will be somewhat reduced. The amount of the reduction may be determined by the size of the bleed opening 237, and the size of this bleed may be calculated to provide the desired reduction in regulated exhaust depending upon the weight of the dampers and connected parts in any given instrument.

It will be observed, however, that if the diaphragm 42b is in raised position closing the vent 40b and bleed 41b, the chamber 238 will be maintained under exhaust from the controlled exhaust chest communicated through the duct 239. Under these conditions, therefore, if the diaphragm 234 is lowered by exhausting the chamber 233 the opening of the vent 236 and bleed 237 will have no effect on controlled exhaust.

It may be noted, however, that the bleed 41b to which the duct 239 is connected is the largest of the bleeds, 41, 41a and 41b, so that at any time when the bleed 41b is closed to the passage of air, reasonably high degrees of exhaust are maintained in the controlled and regulated exhaust chests respectively. Under such conditions, therefore, it is of less importance to compensate for the weight of the dampers when the pedal is operated, because at the higher intensities the ratio of the force required to lift the dampers to the total force required is much less than at the lower intensities. Indeed, at the higher intensities reduction of regulated exhaust to compensate for damper weight might be a positive disadvantage, for at the higher intensities it is desirable to transmit all possible force to the hammers and strings.

Soft pedal control

Means are also provided in the preferred embodiment illustrated for controlling the mechanisms commonly referred to in pianos as the soft pedal mechanisms. In the ordinary grand piano action such as illustrated herein, soft pedal effects are ordinarily obtained by lifting the hammers somewhat nearer to the strings in order that the blows transmitted thereby may be somewhat softened.

For this purpose, in the present embodiment automatic means have been provided, including a rail 240 lying beneath the hammers which may be connected through the bell crank 241 and rod 242 to the movable leaf of pneumatic 243. As will be apparent, if the pneumatic 243 is collapsed the hammers 8 will be raised to a position somewhat closer to the strings. The pneumatic 243 is connected by means of conduit 244 to the valve chamber 245 of the valve unit 246, the exhaust chamber 247 of said valve unit being connected through the conduit 248 to the source of exhaust in a manner to be described more particularly hereinafter. The diaphragm chamber 249 of the valve unit is connected through the duct 250 to the tracker vent 251.

When the valve 252 of the valve unit 246 is in the position illustrated, pneumatic 243 is expanded under the influence of spring 253 acting upon one arm of the bell crank lever 241. If a perforation in a note sheet crosses the tracker vent 251, however, valve 252 is raised and pneumatic 243 is collapsed to raise the hammers 8.

When the hammers 8 are raised in the manner described, however, a certain amount of lost motion results in the action which it may be desirable to take up. Accordingly, certain of the striker pneumatics 1' which are not necessary for connection to hammer actions are connected to arms 254 similar to the arms 3 which arms, however, are bolted or otherwise secured to the rail 255 which lies underneath all of the arms 3 and 254.

As will be apparent, if the lost motion pneumatics are collapsed the arms 254 and rail 255 will be lifted to raise all of the arms 3 and the ends of all of the keys 5 thus taking up any lost motion in the hammer action which may have been created by the lifting of the hammers 8. The lost motion pneumatics are connected through passages 256 and through dummy valves 257 to the conduits 258 which are connected to the conduit 244 previously described so that whenever the valve 252 is actuated to collapse pneumatic 243, the lost motion pneumatics are collapsed simultaneously to take up the lost motion in the hammer action.

As previously described, the conduits 229 and 248 leading respectively to the exhaust

chambers 228 and 247 of the loud and soft pedal valve mechanisms which are connected to the main source of exhaust. It has been desirable, however, in some instances to regulate the exhaust applied to the pedal valves and pneumatics in order that the action of the pedal mechanisms may be uniform at all times regardless of changes which may take place in high exhaust as created by the main source of exhaust. For this reason conduits 229 and 248 are joined and are connected through a conduit 258 to the chamber 259 of the pedal pressure regulator 260. This regulator is also provided with a chamber 261 connected to the main source of exhaust through the conduit 262. Communication between the chambers 259 and 261 is had through a plurality of perforations 263 in the plate or screen 264, such communication being controlled by a flexible curtain valve 265 connected to the end of the rod 266. Also mounted on the rod 266 is the member 267 to which is connected the flexible sleeve 268. Communication between the chamber 259 and the chamber 269 behind the sleeve mechanism is maintained through the unrestricted passage 270. The end of the rod 266 is connected to a spring 271 which is also attached to the adjusting screw 272 carried by the bridge 273.

If the exhaust maintained in chamber 259 tends to be reduced as by the influx of a large quantity of atmospheric air, the exhaust maintained in the chamber 269 acting on the sleeve mechanism is thereby reduced and under the influence of the spring 271 valve 265 will uncover additional perforations 263 to permit additional air to be withdrawn from the chamber 259 thereby tending to increase the degree of exhaust maintained therein. In a similar manner if the degree of exhaust in the chamber 259 tends to increase above the desired amount, the sleeve mechanism and valve will be moved in a direction to cover additional perforations 263, thus reducing the amount of air withdrawn from the chamber 259 and reducing the exhaust therein.

Thus a substantially uniform degree of exhaust is maintained at all times as a supply for operating the loud and soft pedal mechanisms and the crescendo mechanisms, regardless of any variations which may occur in high exhaust produced by the pump. By varying the tension of the spring 271, the exhaust supplied to these mechanisms may be adjusted to any suitable level as desired.

Individual note compensation

In the course of the preceding description extremely sensitive regulator means have been described which serve to maintain any given degree of regulated exhaust with great accuracy. Means have also been described by which regulated exhaust may be varied by

substantially distinct increments and by substantially continuous progression to secure incremental changes and crescendo changes in playing intensities. It has been explained that due to the construction and mode of operation of the main regulator and the spill valve or pump pressure regulator, whereby the inertia of moving parts is reduced to a minimum, and due in part to the cooperation between the two regulators, tendencies toward pressure variations are rapidly overcome.

It has been found, indeed, that the regulation thus provided was more accurate and sensitive than the player and piano action with which it was intended to cooperate. Accordingly as a further means of improving the performance of the piano, the pneumatics comprising the automatic action of the preferred embodiment illustrated may be adjusted in such manner that for any given degree of regulated exhaust maintained in the regulated exhaust chest, all notes throughout the entire range of the instrument will be struck in such manner as to cause them to sound with equal audible intensities.

It has been found that many factors are present in the playing of an automatic instrument which cause different notes of the piano to sound with different audible intensities, even though the hammers may be actuated by exactly the same degrees of exhaust. For instance, the piano action or the mechanisms by which different hammers are caused to strike the strings may operate with varying degrees of frictional resistance; the mass of the hammers in one section of the piano may be, and customarily is, different from that of other sections of the piano; the mass of the strings themselves varies throughout the piano; and the effectiveness of the various pneumatics throughout the stack may vary due to varying frictional resistance, slight unintentional variations in dimension, or to variations in the controlling valves.

To these mechanical variations, which may, if they are cumulatively present, give rise to widely different audible intensities, even though the notes may be actuated by exactly the same degree of exhaust, may be added the fact that the ear of the average hearer is more sensitive to the vibrations of certain sections of the piano than it is to the vibrations of other sections. For example, it has been determined as a scientific fact that the average ear is more sensitive to tones within the middle range of the piano, than it is to the tones at either end of the scale. In order words, notes at the ends of the scale must be sounded with greater energy to provide equal audible intensities.

The variations, referred to above, while present in manual playing, are of less importance than in automatic playing, because in manual playing, a skilled pianist quickly

learns the "feel" of his instrument, and consciously or unconsciously compensates for such variations to secure that smoothness of tone and action which characterize his performances.

According to the present invention applicant proposes to so adjust the pneumatic action, preferably by varying the position of the travel of the movable leaf of the striker pneumatics in such manner that all variations between various individual notes throughout the scale, including those enumerated above, may be compensated for, so that for any given degree of regulated exhaust, all notes of the scale will be sounded with the same audible intensity.

For this purpose, referring to Figures 2 and 10, the ends of the rods 2 are threaded and are provided with the nuts 281 which engage the lugs 283 secured to the movable leaf of the striker pneumatics 1. As will be apparent, by properly adjusting the nuts 281 the position of the travel of the striker pneumatics 1 may be adjusted as desired. For instance, by turning up on the nuts, the movable leaf of any pneumatic is moved to a position closer to the fixed leaf and the travel of the movable leaf therefore to cause the hammer to strike the string takes place within a range in which the bellows cloth of the pneumatic is folded inwardly so that the pneumatic delivers less power to the hammer than when opened more widely. Conversely, of course, if the nut is turned to open the pneumatic, its power during its closing movement is somewhat increased.

In the course of assembling the piano after the pneumatic action has been installed and connected to the hammer action the position of the throw of the individual striker pneumatics may be adjusted in the manner just described to provide uniform audible intensities. As a convenient method of procedure, a single note within the middle register of the piano may be taken as standard and other notes at octave or double octave intervals may be adjusted by comparison with this note or adjacent adjusted notes. Following this, the notes within the octaves may be adjusted by comparison with the adjusted notes at either end of the octave.

Other methods of procedure in making the adjustment may be used if desired. For instance, the entire scale may be played from one end to another and readings of the audible intensities may be made from which it is possible to determine the proper adjustment to be given the pneumatics to provide equal audible intensities. Or readings of the regulated exhaust which it is necessary to apply to play individual notes with the same audible intensity may be made and from these readings, with proper calibration, proper adjustments of the pneumatics may be made.

It will, of course, be understood that while

the adjustment just described is of particular value when used in connection with the very sensitive regulator system before referred to, it is also capable of use in connection with other less sensitive regulators with valuable results.

When finally adjusted, the appearance of the pneumatic stack may be similar to that illustrated in Figure 10, the pneumatics at either end of the scale being somewhat more widely expanded than the pneumatics within the middle range of the instrument. As illustrated, the adjustments of adjacent notes may frequently be different and the difference in the adjustment between the middle range of the instrument and the ends of the scale may be quite marked. The adjustment will vary, however, for each instrument, depending upon the particular peculiarities of the action which are intended to be compensated, the adjustment shown in Figure 10 being provided merely for illustrative purposes.

Wind chest construction and incidental features

In order to still further improve the automatic control to better simulate manual playing, certain special structural features of wind chest and stack construction may be incorporated if desired. It will be understood, however, that while such features are of particular value in the organization described as a whole herein, because of the extreme sensitiveness of the regulator and the refinement of the entire system, they may also be useful in other less sensitive and less highly refined systems.

As has been previously explained, the bass and treble expression regulators are mounted on the bottom of the wind chest or stack and extend for an appreciable distance along the bottom of the stack in order that pressure variations may be quickly transmitted from the regulators to the striker pneumatics without the necessity of passing or being communicated through extended passages or conduits. As has also been explained, the chests 23 are connected to the exhaust chambers 20 of the valve units 14 through the vertical passages 19 and connecting passages 21, while the pneumatics 1 are connected to the valve chamber 13 of said valve units by means of the passages 12.

In order that there may be free communication between all of the passages 19, the board 18 is provided with a channel 301 at the bass end of the stack communicating with each of the passages 19, and a similar channel 301' at the treble end which communicates with each of the passages 19'. By providing the channels 301 and 301' complete circuits are provided through which any pressure variations which may tend to be created may be readily equalized.

As will be observed from Figures 10 and 18,

the striker pneumatics 1 are arranged in series of three and are offset with respect to one another in order that they may be readily connected to the individual striker levers 3, while the valve units 14 are also arranged vertically in series of three, one beneath the other for communication with the passages 19. In the case of the bottom pneumatic of each group, an opening 304 formed in the shelf 305 directly above the center of the pneumatic will provide communication with the passage 12 leading to the valve chamber of the controlling valve unit as illustrated in Figure 17. In the case of the top and middle pneumatics, however, since these pneumatics are offset to the right and left respectively of the passages 12, the passages 306 and 307 communicating with the pneumatics are connected to the passages 12 by suitable lateral passages 308 and 309.

I claim as my invention:

1. In an automatic musical instrument, in combination, hammer actions, and a plurality of striker pneumatics connected thereto, said pneumatics being adjusted to cause each respective note throughout the entire range of the instrument to sound with substantially the same audible intensity when actuated by substantially equal degrees of exhaust, and means for maintaining a substantially constant degree of exhaust for actuating said pneumatics comprising a regulator having a controlling valve consisting of a flexible movable member of very little inertia, said regulator being provided with chambers in which are maintained different degrees of exhaust acting directly on said valve to control the same, and means for varying the exhaust in one of said chambers to thereby vary the exhaust in another chamber whereby playing intensities are varied.

2. In an automatic musical instrument, in combination, hammer actions, and a plurality of striker pneumatics connected thereto, said pneumatics being adjusted to cause each respective note throughout the entire range of the instrument to sound with substantially the same audible intensity when actuated by substantially equal degrees of exhaust, and means for maintaining a substantially constant degree of exhaust for actuating such pneumatics comprising a regulator having a controlling valve consisting of a flexible movable member of very little inertia, said regulator being provided with chambers in which are maintained different degrees of exhaust acting directly on said valve to control the same, a damper rail, means to lift said damper rail to permit free vibration of the strings and means to reduce the exhaust applied to said striker pneumatics when said damper rail is lifted.

3. In an automatic musical instrument, in combination, hammer actions, and a plurality of striker pneumatics connected thereto, said

pneumatics being adjusted to cause each respective note throughout the entire range of the instrument to sound with substantially the same audible intensity when actuated by substantially equal degrees of exhaust, and means for maintaining a substantially constant degree of exhaust for actuating said pneumatics comprising a regulator having a controlling valve consisting of a flexible movable member of very little inertia, said regulator being provided with chambers in which are maintained different degrees of exhaust acting directly on said valve to control the same, a damper rail, means for lifting said damper rail to permit free vibration of the string, a hammer rail, means to lift said hammer rail to secure soft pedal effects, means to operate both said damper rail lifting means and said hammer rail lifting means pneumatically, and means for maintaining the exhaust for operating said hammer and damper rail operating means at a substantially constant level.

4. In an automatic musical instrument, in combination, hammer actions, and a plurality of striker pneumatics connected thereto, said pneumatics being adjusted to cause each respective note throughout the entire range of the instrument to sound with substantially the same audible intensity when actuated by substantially equal degrees of exhaust, and means for maintaining a substantially constant degree of exhaust for actuating said pneumatics comprising a regulator having a controlling valve consisting of a flexible movable member of very little inertia, said regulator being provided with chambers in which are maintained different degrees of exhaust acting directly on said valve to control the same, a source of exhaust, and a second regulator for governing the degree of exhaust applied by said source to the chambers of said first regulator.

5. In an automatic musical instrument, in combination, hammer actions, and a plurality of striker pneumatics connected thereto, said pneumatics being adjusted to cause each respective note throughout the entire range of the instrument to sound with substantially the same audible intensity when actuated by substantially equal degrees of exhaust, and means for maintaining a substantially constant degree of exhaust for actuating said pneumatics comprising a regulator having a controlling valve consisting of a flexible movable member of very little inertia, said regulator being provided with chambers in which are maintained different degrees of exhaust acting directly on said valve to control the same, a source of exhaust, means providing an unrestricted passage from said source of exhaust to one of said chambers, means providing a constricted passage from said source of exhaust to another of said chambers, and means for maintaining the exhaust applied to

said chambers at a substantially constant level.

6. In an automatic musical instrument, in combination, hammer actions, and a plurality of striker pneumatics connected thereto, said pneumatics being adjusted to cause each respective note throughout the entire range of the instrument to sound with substantially the same audible intensity when actuated by substantially equal degrees of exhaust, and means for maintaining a substantially constant degree of exhaust for actuating said pneumatics comprising a regulator having a controlling valve consisting of a flexible movable member of very little inertia, said regulator being provided with chambers in which are maintained different degrees of exhaust acting directly on said valve to control the same, a source of exhaust, and a second regulator for governing the degree of exhaust applied by said source to the chambers of said first regulator, and means to vary the degree of exhaust maintained by said second regulator.

7. In an automatic musical instrument, in combination, hammer actions, and a plurality of striker pneumatics connected thereto, said pneumatics being adjusted to cause each respective note throughout the entire range of the instrument to sound with substantially the same audible intensity when actuated by substantially equal degrees of exhaust, and means for maintaining a substantially constant degree of exhaust for actuating said pneumatics comprising a regulator having a controlling valve consisting of a flexible movable member of very little inertia, said regulator being provided with chambers in which are maintained different degrees of exhaust acting directly on said valve to control the same, a source of exhaust, means providing an unrestricted passage from said source of exhaust to one of said chambers, means providing a constricted passage from said source of exhaust to another of said chambers, and means for maintaining the exhaust applied to said chambers at any one of a plurality of different substantially constant levels.

8. In an automatic musical instrument, in combination, hammer actions, and a plurality of striker pneumatics connected thereto, said pneumatics being adjusted to cause each respective note throughout the entire range of the instrument to sound with substantially the same audible intensity when actuated by substantially equal degrees of exhaust, and means for maintaining a substantially constant degree of exhaust for actuating said pneumatics comprising a regulator having a controlling valve consisting of a flexible movable member of very little inertia, said regulator being provided with chambers in which are maintained different degrees of exhaust acting directly on said valve to control the same, a source of exhaust, a second

regulator for varying the degree of exhaust applied by said source to the chambers of said first regulator, a damper rail, means for lifting said damper rail to permit free vibration of the strings, a hammer rail, means for lift said hammer rail to secure soft pedal effects, means to operate both said damper rail lifting means and said hammer rail lifting means pneumatically, and a third regulator means for maintaining the exhaust for operating said hammer and damper rail operating means at a substantially constant level, regardless of variations in the exhaust supplied by said source of exhaust.

9. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having communication with said player pneumatics, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means affected by exhaust maintained in said controlled exhaust chest for governing communication between said regulated and high exhaust chests, and a reservoir interposed between said high exhaust chest and said controlled exhaust chest and said source of exhaust.

10. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having conduit communication with said player pneumatics, a high exhaust chest having conduit communication with said source of exhaust, a controlled exhaust chest having restricted conduit communication with said source of exhaust, means affected by exhaust maintained in said controlled exhaust chest for governing communication between said regulated and high exhaust chests, and a reservoir interposed between said high exhaust chest and said controlled exhaust chest and said source of exhaust, the conduit from said reservoir to said controlled exhaust chest entering said reservoir near the dead end thereof.

11. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having communication with said player pneumatics, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means affected by exhaust maintained in said controlled exhaust chest for governing communication between said regulated and high exhaust chests, and a reservoir interposed between said high exhaust chest and said controlled exhaust chest and said source of exhaust, the conduit from said reservoir to said controlled exhaust chest entering said reservoir at a point removed from air currents passing therethrough.

12. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having communication with said player pneumatics, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means for governing communication between said regulated and high exhaust chests, said means being influenced by the exhaust maintained in all of said chests, and means interposed between said source of exhaust and said high and controlled exhaust chests for controlling and varying the degree of exhaust applied thereto.

13. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having communication with said player pneumatics, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means for governing communication between said regulated and high exhaust chests, said means being influenced by the exhaust maintained in all of said chests, and means interposed between said source of exhaust and said high and controlled exhaust chests for varying the degree of exhaust applied thereto.

14. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having communication with said player pneumatics, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means for governing communication between said regulated and high exhaust chests, said means being influenced by the exhaust maintained in all of said chests, and means interposed between said source of exhaust and said high and controlled exhaust chests for varying the degree of exhaust applied thereto, and means for controlling said means from a single tracker bar opening.

15. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having communication with said player pneumatics, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means for governing communication between said regulated and high exhaust chests, said means being influenced by the exhaust maintained in all of said chests, and means for maintaining exhaust in said controlled exhaust chest substantially constant, said means including a regulator pneumatic and spring.

16. In an automatic musical instrument having player pneumatics and a source of

exhaust, in combination, a regulated exhaust chest having communication with said player pneumatics, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means for governing communication between said regulated and high exhaust chests, said means being influenced by the exhaust maintained in all of said chests, means for maintaining exhaust in said controlled exhaust chest substantially constant, said means including a regulator pneumatic and spring, and means for varying the tension of said spring to thereby vary simultaneously controlled, high and regulated exhausts.

17. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having communication with said player pneumatics, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means for governing communication between said regulated and high exhaust chests, said means being influenced by the exhaust maintained in all of said chests, and means for maintaining exhaust in said controlled exhaust chest substantially constant, said means including a regulator pneumatic and spring, said means being interposed between said source of exhaust and said controlled exhaust chest.

18. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having communication with said player pneumatics, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means for governing communication between said regulated and high exhaust chests, said means being influenced by the exhaust maintained in all of said chests, means for admitting atmosphere to said controlled exhaust chest to vary the exhaust therein, and means for admitting atmosphere to the line of communication between said source of exhaust and said controlled exhaust chest to additionally vary exhaust therein.

19. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having communication with said player pneumatics, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means for governing communication between said regulated and high exhaust chests, said means being influenced by the exhaust maintained in each of all chests and means to vary the exhaust maintained in said controlled

exhaust chest, comprising a plurality of vents to atmosphere arranged in a wall of said chest, and means to selectively open and close said vents.

20. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, a regulated exhaust chest having communication with said source of exhaust, a high exhaust chest having communication with said source of exhaust, a controlled exhaust chest having restricted communication with said source of exhaust, means for governing communication between said regulated and high exhaust chests, said means being influenced by the exhaust maintained in all of said chests, and means to vary the exhaust maintained in said controlled exhaust chest, comprising a plurality of vents to atmosphere of varying effective area in a wall of said chest, and means to selectively open and close said vents.

21. In an automatic musical instrument having player pneumatics and a source of exhaust, in combination, means dividing said player pneumatics into two sections, one for the treble and one for the bass, a pair of crescendo pneumatics, one for each section, valve controlled means to collapse said pneumatics separately at a substantially uniform rate, atmosphere vents controlled by said crescendo pneumatics, and means for adjusting said pneumatics simultaneously with respect to said vents.

22. In an automatic musical instrument having the usual player pneumatics and source of exhaust, in combination, a tracker, means for governing the exhaust supplied by said source of exhaust to maintain the same at a substantially constant level, and means controlled by a single vent in said tracker for increasing or decreasing the exhaust maintained by said last named means.

23. In an automatic musical instrument, in combination, a tracker bar having a vent therein adapted to cooperate with a note sheet, pneumatic means controlled by said vent and note sheet for controlling the operation of said instrument, and means whereby a relatively short perforation in said note sheet causes said pneumatic means to function in a different manner from a relatively long perforation.

24. In an automatic musical instrument, in combination, a tracker bar having a vent therein adapted to cooperate with a note sheet, a regulator, pneumatic means to tension said regulator, and means controlled by said vent and note sheet for controlling said pneumatic means to increase or decrease the tension on said regulator.

25. In an automatic musical instrument, a spill valve regulator, comprising, in combination, a chamber having communication with a source of exhaust and with other pneumatic devices, said chamber being provided with

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two ports to atmosphere, a valve cooperating with one of said ports to control admission of atmosphere to said chamber, a pneumatic connected to said valve, said pneumatic having communication with said chamber, a valve cooperating with the other of said ports to additionally control the admission of atmosphere to said chamber, a pneumatic connected to said valve, and valve controlled means to admit exhaust or atmosphere to said pneumatic to collapse or expand the same respectively.

26. In an automatic musical instrument, a spill valve regulator, comprising, in combination, a chamber having communication with a source of exhaust and with other pneumatic devices, said chamber being provided with two ports to atmosphere, a flexible curtain cooperating with one of said ports to control the admission of atmosphere to said chamber, a pneumatic connected to said curtain, said pneumatic having communication with said chamber, means to tension said pneumatic, a valve cooperating with the other of said ports to control the admission of atmosphere to said chamber, a pneumatic connected to said valve, and valve controlled means to admit exhaust or atmosphere to said pneumatic to collapse or expand the same respectively.

27. Controlling mechanisms for automatic musical instruments having a tracker bar, a source of exhaust and pneumatic devices to be controlled, comprising, a pair of motor pneumatics, means whereby one of said pneumatics may be collapsed slowly and expanded rapidly, means whereby the other of said pneumatics may be collapsed rapidly and expanded slowly, means operated by said motor pneumatics having connections to said pneumatic devices to be controlled and means for admitting atmosphere or exhaust to each of said motor pneumatics simultaneously.

28. Controlling mechanisms for automatic musical instruments having a tracker bar, a source of exhaust and pneumatic devices to be controlled, comprising, a pair of motor pneumatics, means whereby one of said pneumatics may be collapsed slowly and expanded rapidly, means whereby the other of said pneumatics may be collapsed rapidly and expanded slowly, means operated by said motor pneumatics having connections to said pneumatic devices to be controlled, and means including a valve unit and a single vent to said tracker bar to admit exhaust or atmosphere to said motor pneumatics simultaneously.

29. In an automatic musical instrument, a spill valve regulator, comprising, in combination, a chamber having communication with a source of exhaust and with other pneumatic devices, said chamber being provided with a port to atmosphere, a flexible curtain cooperating with said port to control the

admission of atmosphere to said chamber, a pneumatic connected to said curtain, said pneumatic having communication with said chamber, means to tension said pneumatic, a tracker bar, and means controlled by a single tracker bar opening for increasing or decreasing the tension on said pneumatic.

30. In an automatic musical instrument, a spill valve regulator, comprising, in combination, a chamber having communication with a source of exhaust and with other pneumatic devices, said chamber being provided with a port to atmosphere, a flexible curtain cooperating with said port to control the admission of atmosphere to said chamber, a pneumatic connected to said curtain, said pneumatic having a communication with said chamber, means to tension said pneumatic including a spring, and pneumatic means for increasing or decreasing the tension of said spring.

In testimony whereof, I have signed my name to this specification this 17th day of June, 1926.

CHARLES F. STODDARD.