

June 20, 1933.

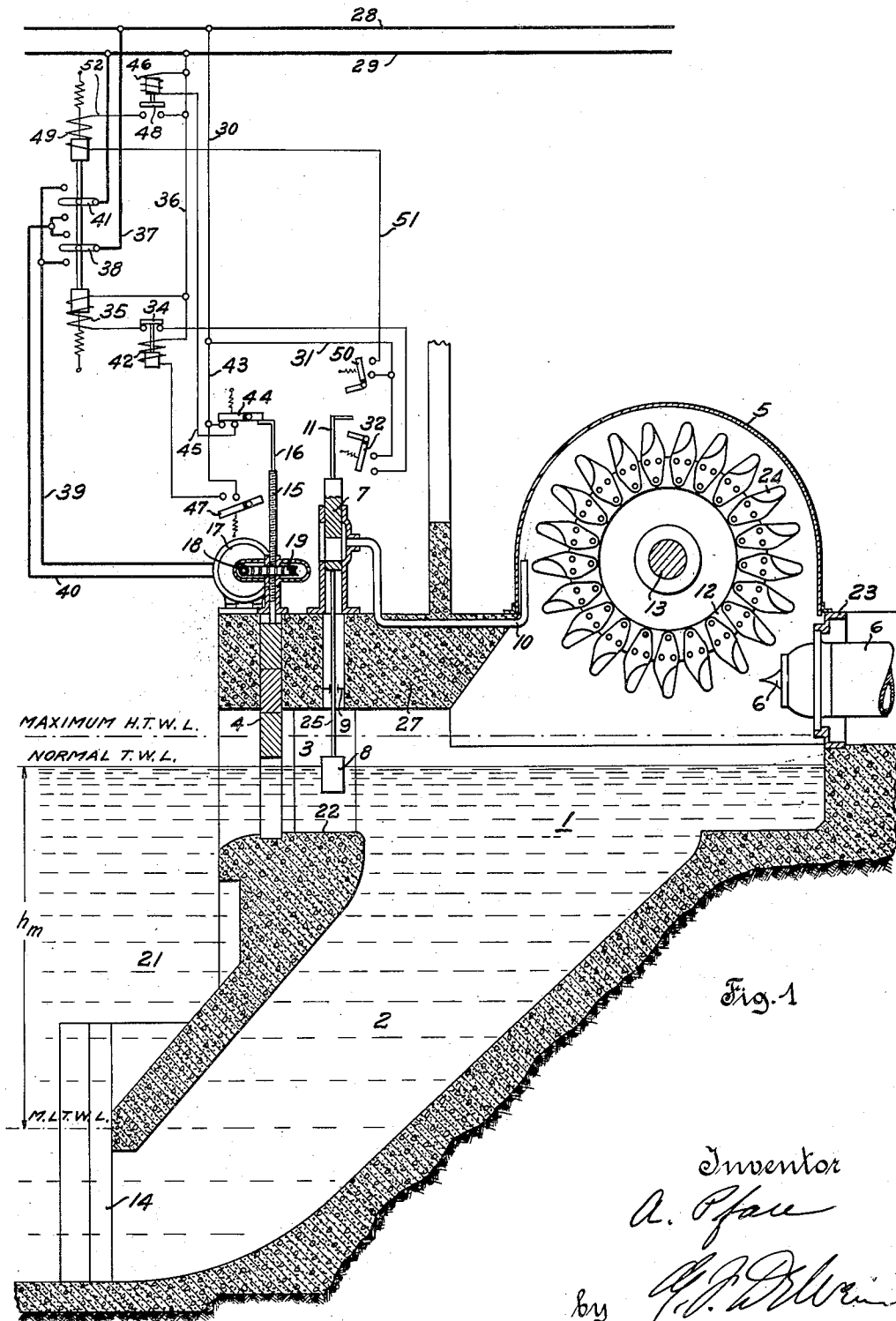
A. PFAU

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HYDRAULIC IMPULSE TURBINE

Filed Feb. 12, 1931

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

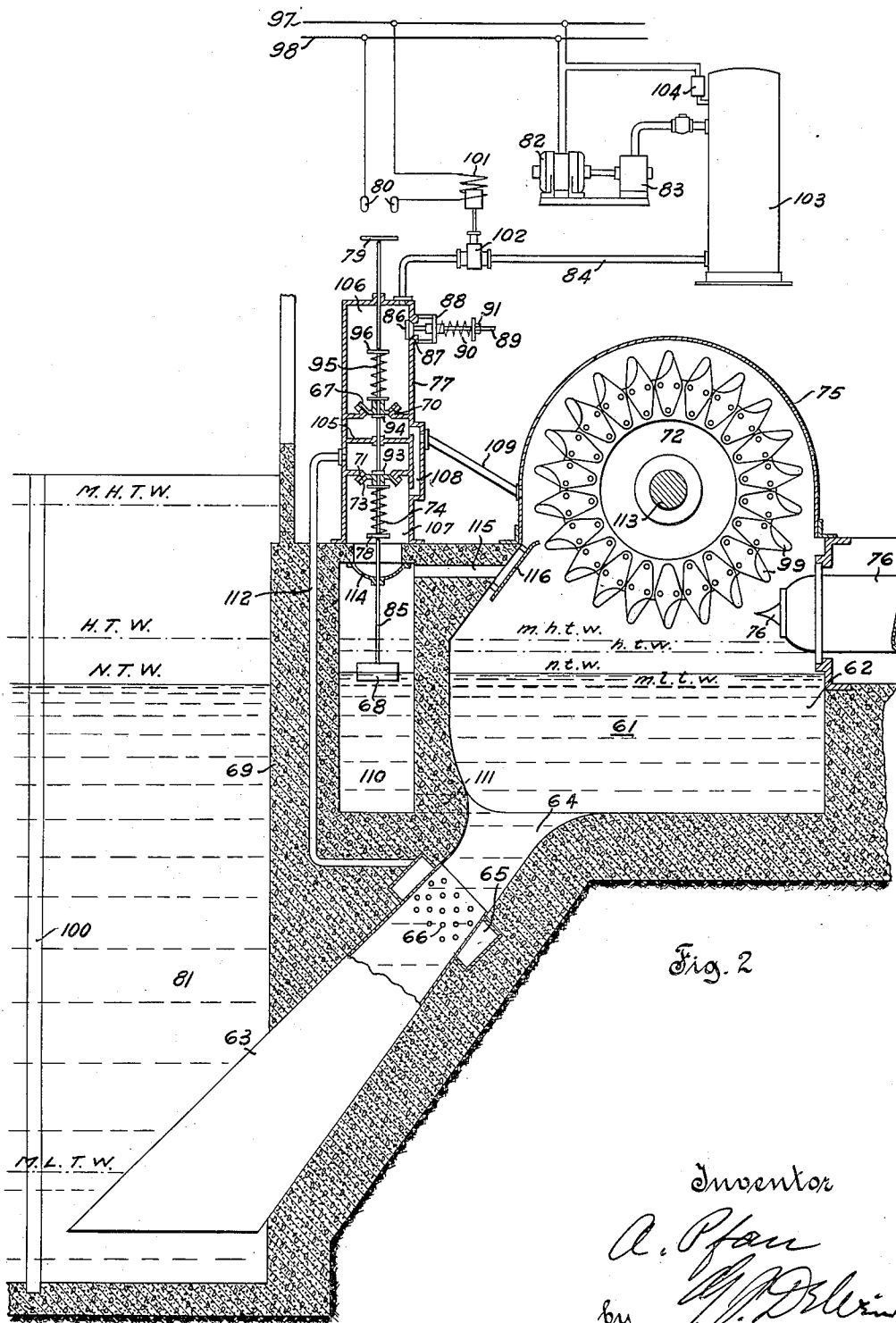


Fig. 2

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HYDRAULIC IMPULSE TURBINE

Application filed February 12, 1931. Serial No. 515,268.

This invention relates in general to the art of hydraulic turbine settings and relates more specifically to an impulse turbine setting for sites subjected to tailwater elevations falling considerable distances below normal level, and also rising some distances above the normal tailwater elevation.

An object of the invention is to provide an impulse turbine setting especially well adapted for sites having the named tailwater characteristics, wherein a substantially constant discharge water level, as close to the normal tailrace elevation as is possible, is provided for effecting the discharge of the hydraulic fluid from the submerged discharge pit into the tailrace.

Another object of the invention is to provide an impulse turbine setting especially well adapted for sites having the named tailwater characteristics, wherein drowning of the buckets of the impulse wheel is effectively prevented.

It is of primary importance for successful and efficient operation of impulse turbines that their buckets never become drowned in the tailwater. This applies to the vertical, as well as to the horizontal shaft type of impulse turbine, having one or more jets impinging upon the buckets and having one or more runners on the shaft. When the buckets become submerged in the tailwater they collect water from it, which causes the wheel housing to become filled with water. This results in a considerable drop in the power developed by the wheel and therefore also in the efficiency thereof, and should be prevented. It has therefore been heretofore necessary to position the buckets a safe distance above the tailwater level to prevent said drowning or submergence of the buckets. It can be readily seen that for sites having substantially constant tailwater elevations, that the distance, necessary between the tailwater elevation and the buckets, to preclude drowning, is a minimum. That is, the head corresponding to said distance, between the tailwater level and the centerline of the nozzle or jet impinging upon the buckets, is a minimum.

In sites where the tailwater level rises

above and drops below the "normal" tailwater level, the wheels must be positioned so that the buckets thereof are spaced from the "highest" tailwater level. Accordingly, the wheel is positioned at a higher elevation than necessary for normal tailwater conditions of operation, which results in loss of head on the wheel, equivalent to the distance between the normal and said highest tailwater elevation. Then also when the tailwater level drops below normal, an additional head on the wheel is lost, equivalent to the distance between this lower elevation and the normal elevation of the tailwater.

To illustrate these losses in head, let us assume a site having a total head of 1000 feet and a maximum rise in tailwater elevation of 10 feet above the normal. This would amount to 1% of the total head or to a $1\frac{1}{2}\%$ reduction in the output of the wheel. And if its maximum drop of tailwater elevation is 20 feet below the normal, this loss in head is 2% of the total head, or a 3% output loss. So that the total loss of output, for flood level, or highest tailwater and lowest tailwater conditions of operation of the turbine is $4\frac{1}{2}\%$, constituting a material reduction in the revenue realizable on the turbine installation investment.

It is a more specific object of this invention to provide an impulse turbine setting with means for utilizing the additional head available in sites subjected to tailwater elevations dropping substantial distances below normal tailwater elevation, by creating a sub-atmospheric pressure within the wheel housing, by reason of which the windage losses of the revolving buckets is also reduced and thus further enhancing the efficiency of the turbine setting.

It is an additional specific object of this invention to provide an impulse turbine setting having a discharge pit, the discharge end of which is constantly submerged by the tailrace water even at the maximum low tailwater elevation, with means for limiting the effect of the head measured between high and maximum high tailwater elevation as controlling the elevation of the discharge water in the discharge pit, whereby the det-

rimental effect of said floor head on the wheel may be avoided and the buckets of the impulse wheel may be positioned a distance nearer the discharge level as measured by said head limitation and still not be drowned at maximum high tailwater elevation.

Fig. 1 is a transverse section of a hydraulic impulse turbine setting, capable of carrying out the objects of the invention stated in the paragraph next to the above.

Fig. 2 is a transverse section of a modified form of hydraulic impulse turbine setting, capable of carrying out the objects of the invention as is the setting shown in Fig. 1 and provided with means for additionally carrying out the objects of the invention stated in said above paragraph.

Referring to the drawings on which Fig. 1 embodies an impulse turbine setting constructed according to this invention, reference numeral 1 designates generally the novel impulse turbine setting. This comprises a discharge pit 2 of rectangular or circular cross-section and being in controllable communication through a stop log gate 14 with the tailrace 21. At its upper end the discharge pit 2 is provided with a transverse, auxiliary outlet 3, having a bounding, sill portion 22, to afford a direct outlet for the discharged water, at the upper end of the discharge pit 2, when the setting is subjected to flood or high tailwater conditions. The concrete material portion 27 forming the upper boundary of the auxiliary outlet 3, cooperates with the wheel housing 5, of suitable material, to withstand the maximum suction head, and the plate 23 supporting nozzle 6 to form a closed space for the wheel 12 when the gate 4 controlling the auxiliary outlet 3 is in closed position.

A pipe 10 communicates at one end with the interior of the wheel housing 5, outside of the orbit of rotation of the peripheral portions of the buckets 24, to admit air at atmospheric pressure into the housing. This air admission is controlled by means of a sliding type of air valve 7 to which the other end of pipe 10 is connected. The air valve 7 is regulated according to the level of the discharge water below the wheel 12 by means of a float 8, free to rise and fall, to which the air valve 7 is connected by a rigid stem 25, said stem being guided by brackets 9 positioned within an opening provided in concrete material portion 27 to receive the stem.

The gate 4 is guided in slots provided in the opposed side walls of the auxiliary outlet 3 and when in closed position its lower and upper ends are, respectively received within a groove in sill portion 22 and within an aligned, transverse opening in concrete portion 27. The gate 4 is provided with an operating rod 15 having an external screw thread in a portion of its length. This screw

thread is engaged by the similarly threaded rod-surrounding portion of a worm wheel 19 fixed for rotation within a housing held in spaced relation with respect to an electric driving motor 17 having a worm 18 on its shaft, which cooperates with the worm wheel 19.

Having now described the essential elements of the novel impulse turbine setting, the principle underlying the setting shown in Fig. 1 will now be explained. The figure shows the setting operating at normal tailwater condition, the normal elevation being so designated on the figure. The maximum high tailwater elevation also indicated on the figure is seen to be a safe distance from the buckets of the wheel 12. The maximum low tailwater elevation also indicated on the figure is of a sufficient value to constantly submerge the discharge end of the discharge pit 2. The head between this elevation and the normal elevation is designated h_m , since it is the maximum head that may be added to the head on the wheel, under conditions of operating the impulse wheel 12 at the said maximum low tailwater elevation. Intermediate values of head h , may be gained on the wheel 12 depending upon the particular intermediate values of low tailwater elevations below the normal elevation. The particular head h so gained adds to the available head on the turbine wheel, thereby increasing the discharge capacity and the output of the wheel. Said heads h being realized by creating a sub-atmospheric pressure in the discharge pit and wheel housing, so that the windage loss of the revolving buckets is correspondingly reduced to further enhance efficiency of the wheel. And as long as the tailwater level lies above the sill 22 of the auxiliary outlet 3 the gate 4 could be in open position so that a free outlet would be had, that is, the wheel housing would be in open communication with the atmosphere as shown.

When the tailwater level drops a certain distance below normal to a level which renders it profitable to utilize the corresponding head, the float 8 also drops thereby accomplishing two things. First, it shuts off the air supply to the wheel housing. Secondly, it closes the circuit of motor 17 in a direction such that the gate 4 is lowered to its closed position. The water discharged from the buckets 24 of the wheel 12 must now enter the tailrace 21 through the discharge pit 2.

The discharge of the water from the buckets of an impulse wheel takes place at a high velocity. The said discharged water further carries air entrained from the air present within the wheel housing. In this manner the wheel housing becomes more and more devoid of air and the water in the discharge pit 2 rises in consequence thereof. This rise of water level in the discharge pit 2 would

soon tend to submerge the buckets 24, a condition to be avoided. Therefore, in order to prevent further rise in said level and to in fact lower same, instrumentalities should be provided to suppress or lower the said level.

The drawings show air admission means for effecting this result. With the disclosed means the water level in the discharge pit 2 can be held close to the value of the normal tailwater elevation, and the distance between the low tailwater elevation and the elevation of the water in the discharge pit 2 represents the head h , so gained.

With both the tailrace 21 and the discharge pit 2 subjected to atmospheric air pressure there must be a higher level for the water in the discharge pit than the level of the water in the tailrace 21 in order that a flow of the discharge water ensue through the discharge pit. Therefore, the water level in the discharge pit 2 when the auxiliary outlet 3 is closed will always be somewhat higher than the tailwater level by an amount which corresponds to the head necessary to effect the flow of the said discharge water through the sealed discharge pit 2. Accordingly, if we now assume a rise in the tailwater level and such a rise to bring it up to or above its normal value, the level of the water in the still sealed discharge pit 2 would be above this normal value. The effect of this undesirable rise of the water in the discharge pit 2 is to cause the float 8 to rise and close the circuit of the electric motor 17 in the reverse direction, to again raise the gate 4, so as to restore a discharge from the discharge pit 2 through the auxiliary outlet 3.

Again referring to Fig. 1 of the drawings wherein is shown automatically controlled means by which the principle just described and underlying this invention is applied, the operation thereof will now be fully described. The figure it will be noted shows the impulse turbine setting 1 in open gate condition, the bucket discharged water passing directly into the tailrace 21 through auxiliary outlet 3, the gate 4 being fully open and the float 8 in approximately the mid-position of its vertical range of movement. If the tailwater level falls a certain distance the switch actuating arm 11 on the air valve 7 will be permitted by the float 8 to fall into engagement with switch 32 to close the same. When the switch 32 is closed the air valve 7 will have been moved to closed position, in which no air can be admitted into the wheel housing 5 through pipe 10, which clearly appears from the drawings. Also, since the gate 4 is still in open position in which the switch actuating arm 16 thereon engages the switch 44 and holds it in closed position, the upper relay switch 48 is in open position whereas the similar, lower relay switch 34 is in closed position which conditions must be satisfied in order that the winding 35 be energized

as soon as switch 32 is closed to cause it to close the motor switch 41—38. The circuits involved and the last two closing in the order stated are first, through switch 44; line 28—30—43—44—45—46—line 29. Second, through switch 32: line 28—30—31—32—34—35—36—line 29. Third, through motor switch 41—38: line 28—37—38—39—17—40—41—52—line 29. Energization of the circuit of motor 17 in the direction stated causes it to close the gate 4. The under pressure which under this closed gate condition of the setting 1 is being created in the wheel housing 5 tends to bring the level of the water in the discharge pit 2, now sealed against the atmosphere, to the normal level of the tailwater, even though the tailwater level is low. The float 8 must then rise to this level and in so doing raises the air valve 7 to its open position and admitting air into the wheel housing 5 through pipe 10, thereby tending to restore atmospheric pressure in the discharge pit 2 to which pressure water in the tailrace 21 is always subjected. Under this condition the elevation of the water in the discharge pit 2 must be of a somewhat greater value than the particular low elevation of the tailwater, to provide the head necessary to effect a flow of the discharge water through the discharge pit 2.

Now, if the tailwater level rises to or beyond the normal level, the level in the discharge pit 2 which has been maintained near the tailwater normal level, will rise a corresponding amount. Float 8 then also rises further to cause the switch arm 11 to engage and close switch 50, air valve 7 being open during this time, to cause the air admitted through pipe 10 to suppress this rising level in the discharge pit. The switch 47 is at this time held closed by arm 16 on the gate rod 15, since the gate 4 is down or in closed position. This effects the energization of the winding 42 to open relay switch 34 and to deenergize winding 46 to permit a gravity closing of the relay switch 48. When the switch 50 is then closed, a closed circuit through the winding 49 is established to cause the switch 38—41 to close the circuit to the motor 17 in the reverse direction to again raise the gate and restore the different elements of the setting to the positions in which they are shown on the drawing.

The circuits involved under the condition just stated and the last two closing in the order stated are first, through switch 47: line 28—30—43—47—42—36—line 29. Second, through switch 50: line 28—30—31—50—51—49—48—line 29. Third, through motor switch 38—41: line 28—37—38—40—17—39—41—52—line 29.

Now referring to Fig. 2 which shows a setting provided with means for also adjusting the level in the submerged discharge pit for tailwater elevations between high tailwater

elevation and maximum high tailwater elevation, reference numeral 61 designates the impulse turbine setting generally. 62 is a discharge pit with the outlet portion constructed in the form of an aspirator for producing a suction utilized to extract the air from the wheel housing 75, the tapered draft tube or tailrace end portion 63 thereof being constantly submerged by the water in the tailrace 81, as is the discharge pit 2 of the setting shown in Fig. 1. The outlet portion of the discharge pit 62 has a throat portion 64 the walls of which being provided with apertures, said apertures being in communication with an aspirator chamber 65.

Located in the vertical wall portion 69 is a chamber 110 in communication at its lower end with the discharge pit 62 through a passage 111 and in communication at its upper end with the wheel housing 75 through a horizontal venting passage 115 terminating opposite a deflector plate 116. Positioned above the chamber 110 is a valve casing 77, sealed from the chamber 110 by a stem-receiving, cover plate 114 and divided by a partition 105 into an upper chamber 106 and a lower chamber 107. The lower chamber 107 is in controllable communication only with the interior of the wheel housing 75, through a pipe 109 and a common passage 108 formed in the valve casing 77 and with the aspirator chamber 65 through a conduit 112. The chamber 110 contains a float 68 having a relatively long, rigid stem 85 extending through the valve casing 77 and terminating in a switch 79. The stem 85 is guided by the partition 105 and by the cover plate 114 which are provided with openings to receive it. The means for controlling the communication between the interior of the wheel housing 75 and the aspirator chamber 65 comprises a suction valve 73 having a seating portion 71 in the valve housing 77. The valve 73 is limited by a fixed collar 93 to a displacement relative to the stem 85 in the seating direction, and is limited by a compression spring 74 and an adjustable collar 78, to a displacement relative to the stem 85 in the valve opening direction.

Located within the upper chamber 106 is a seating portion 70 for an air valve 67 which seats in the downward direction, whereas the suction valve 73 already described seats in the reverse or upward direction. Valve 67 is similarly limited by a fixed collar 94 to a displacement relative to the stem 85 in the seating direction and is limited by a compression spring 95 and an adjustable collar 96 to a displacement relative to the stem 85 in the opening direction.

Chamber 106 is in communication at its lower end with the common passage 108 and at its upper end is in controllable communication with the atmosphere through a check valve 86 having a seating portion 87 and a

guide stem 89 which is supported and guided within a cage 88 extending from the valve casing 77. The valve 86 is normally gently held in closed position by a compression spring 90 the ends of which cooperate with the cage 88 and with an adjustable collar 91.

In order to at times be able to supply the wheel housing 75 with compressed air the setting 61 is provided with a pair of power leads 97 and 98 for supplying current to an electric motor 82 drivingly connected to an air compressor 83. The discharge of the air compressor is connected to a receiver 103 having a compressed air line 84 in controllable communication with the chamber 106. This communication is controlled by a magnetically operated valve 102 having a winding 101 in series with the cooperating contacts 80 of the switch 79. The circuit to the motor 82 is controlled according to the pressure within the receiver 103 by means of a pneumatically operated switch 104.

76 is a nozzle which directs a jet upon the buckets 99 of the wheel 72 carried by a horizontal shaft 113. The shaft 113 may be horizontal as shown or vertical, and may carry one or more wheels 72 and each wheel may have one or more jets impinging upon the buckets 99 thereof.

100 represents slots in the side walls of the tailrace 81 for receiving stop logs, isolating the discharge pit 62 from the pressure of the tailrace water to permit of one's gaining access to the discharge pit 62 at flood or maximum high tailwater elevation conditions of the setting.

The lines indicating maximum low tailwater, normal, high and maximum high tailwater elevations in the tailrace 81 have been marked M.L.T.W., N.T.W., H.T.W. and M.H.T.W., respectively, on the drawings, while the lines indicating the discharge pit water elevations corresponding respectively, to these tailrace elevations have been marked *m.l.t.w.*, *n.t.w.*, *h.t.w.* and *m.h.t.w.*, respectively.

The operation of the form of hydraulic impulse turbine setting shown in Fig. 2 is as follows: The figure shows the setting operating under normal tailwater elevation conditions and the elevation of the discharge water in the discharge pit is somewhat greater than the tailwater elevation, and the check valve 86, the air valve 67 and the suction valve 73 being closed. If the level within the discharge pit 62 is caused to drop because of a drop in tailrace level, float 68 drops a corresponding amount and opens the suction valve 73 to establish communication between the wheel housing 75 and the aspirator chamber 65. The suction effect produced in the chamber 65 by the high velocity flow of discharge water, transversely past the apertures 66 in the walls of the draft tube portion 63 of the discharge pit 62, is accordingly com-

communicated to the interior of the wheel housing 75 to extract air therefrom and to place said wheel housing under sub-atmospheric pressure which action is, of course, somewhat augmented by the tendency of the impulse turbine when in operation, to create a sub-atmospheric pressure within the sealed wheel housing, as explained in connection with the setting shown in Fig. 1. The elevation of the discharge water in the discharge pit 62 accordingly may rise because of the created suction to a value indicated by the line marked *m.l.t.w.* on the drawings which may exist even with a maximum drop in tailwater level in the tailrace 81, to that indicated by the line marked *M.L.T.W.*, just sufficient to submerge the discharge end of the discharge pit 62.

The valves 67 and 73 are arranged so that the air valve 67 is ready to open when the suction valve 73 is seated, so that as the level of the water in the tailrace 81 rises through the normal value toward the indicated high tailwater elevation the aspirator suction to the wheel housing is cut off by the suction valve 73 and the level of the discharge water in the discharge pit rises a certain amount and continues to elevate the float 68, which causes the stem 85 thereof to open the air valve 67, to permit the check valve 86 to open to admit atmospheric air into the wheel housing 75, assumed to be for the time being under such moderate negative pressure, as to permit of the opening of check valve 86. When the pressure within the wheel housing reaches approximately atmospheric pressure, check valve 86 may close and the elevation of the water in the tailrace 81 when this event happens may be at the high tailwater elevation, indicated by the line marked *H.T.W.* on the drawings, and the elevation of the discharge water in the discharge pit corresponding to said tailrace elevation may be as indicated by the line marked *h.t.w.* on the drawings. And also as the said *H.T.W.* elevation in the tailrace is reached the float 68 holds the stem 85 at an elevation at which the switch 79 carried thereby bridges the contacts 80 to close the circuit to the winding 101 of the electromagnetically controlled valve 102 to open same and admit air at a desired over-pressure from the reservoir 103, into the wheel housing 75, through the air line 84, past the open air valve 67 and the connecting pipe 109. With this pressure air admission the elevation of the discharge water in the discharge pit 62 may be limited to a value as indicated by the line marked *m.h.t.w.* when the elevation of the water in the tailrace stands at its maximum high value, indicated by the line marked *M.H.T.W.* on the drawings. It is, of course, not desirable to admit more compressed air into the wheel housing 75 than necessary for the particular maximum high tailwater elevation to which

the setting is subjected. The compressed air provides the additional head necessary to force the discharge water from the wheel through the submerged discharge pit to the outside and even against the maximum high tailwater. This back pressure reduces the head at the nozzle or jet resulting in a loss of output and also increases the windage losses of the buckets at high tailwater conditions of operation of the setting. It, however, prevents drowning of the wheel which would result in a much greater loss of output and of efficiency, and it permits of utilizing the full head at normal and, partly at least, at low tailwater conditions of operation of the setting. The discharge pit water elevation may with this form of setting be maintained as close to the normal elevation, as possible, under conditions of maximum high tailwater elevation-operation, as well as, under maximum low tailwater conditions of operation of the setting. It therefore is applicable for sites having a greater variation between maximum low and the maximum high tailwater elevation than is the case with the setting shown in Fig. 1.

It will be seen that the setting arrangement shown in Fig. 2 takes care of the requirements fulfilled by the setting shown in Fig. 1, but it would be unnecessarily complicated to warrant its use at sites where no extreme flood tailwater elevations are involved. And it may be here noted that, ordinarily it would not be necessary to introduce the compressed air supply means, if the flood elevation or the maximum high tailwater elevation is less than, say 25 feet above the maximum low tailwater elevation.

It should be understood that it is not desired to limit the invention to the exact details of construction shown and described, for obvious modifications may occur to persons skilled in the art.

It is claimed and desired to secure by Letters Patent:

1. In a hydraulic impulse turbine setting, a wheel housing, a tailrace, a discharge pit in communication with said wheel housing and being sealed from the outside by the water in said tailrace, an auxiliary outlet for discharged water, in communication with said wheel housing and with said discharge pit, a gate for controlling said auxiliary outlet, and means responsive to the changes in level of the discharge water for operating said gate.

2. In a hydraulic impulse turbine setting, a wheel housing, a tailrace, a discharge pit in communication with said wheel housing, an auxiliary outlet for discharged water, in communication with said wheel housing said tailrace and with said discharge pit, and means for closing said auxiliary outlet, said discharge pit being sealed by the water in the tailrace from the atmosphere when said auxiliary outlet is closed.

3. In a hydraulic impulse turbine setting for sites having tailwater levels dropping considerably below the normal level, a wheel housing, a wheel in said housing, a tailrace, a discharge pit submerged by the tailrace water and forming a passage for the water discharged from said wheel, and an auxiliary outlet for said discharged water and being in communication with said wheel housing.
4. In a hydraulic impulse turbine setting for sites having tailwater levels dropping below the normal level, a tailrace, a wheel housing, a wheel having peripheral buckets, fixed for rotation within said housing, a discharge pit in communication with said wheel housing and sealed against the atmosphere by the water in said tailrace, an auxiliary outlet for discharged water, in communication with said wheel housing and being normally in communication with the tailrace and the atmosphere and means for maintaining a substantially constant distance between said buckets and the adjacent discharge water level.
5. In a hydraulic impulse turbine setting for sites having tailwater levels dropping below the normal level, a tailrace, a wheel housing, a discharge pit in communication with said wheel housing, a portion thereof being continuously submerged by the water in said tailrace, an auxiliary outlet for discharged water, in communication with said wheel housing and with said discharge pit, said discharge pit being in open communication with normal elevation tailwater through said outlet, and means connected with said discharge pit for maintaining a column of water in said discharge pit whose elevation conforms closely to the normal tailwater elevation.
6. In a hydraulic impulse turbine setting for sites having tailwater levels dropping below the normal level, a tailrace, a wheel housing, a discharge pit in communication with said wheel housing and sealed against the atmosphere by the water in said tailrace, an auxiliary outlet for discharged water, in communication with said wheel housing and being normally in communication with the tailrace and the atmosphere, and means connected with said auxiliary outlet and said wheel housing for maintaining a substantially constant level of the water in said discharge pit.
7. In a hydraulic impulse turbine setting for sites having tailwater levels falling below the normal level, a wheel housing, a discharge pit in communication with said wheel housing, a tailrace, a portion of said discharge pit being continuously submerged by the water in said tailrace, an auxiliary outlet for discharged water, in communication with said wheel housing said tailrace and with said discharge pit, and means for closing said auxiliary outlet when the tailwater level falls below the normal level.
8. In a hydraulic impulse turbine setting for sites having tailwater levels falling below the normal level, a wheel housing, an impulse wheel positioned within said housing, a discharge pit in communication with said wheel housing, a tailrace, a portion of said discharge pit being constantly submerged by the water in said tailrace, an auxiliary outlet in direct communication with said wheel housing and with said tailrace, said auxiliary outlet being closed when the tailwater level falls below normal, and means for opening said auxiliary outlet to establish a discharge of water discharged from the wheel of said wheel housing through said outlet when the tailwater subsequently rises to above normal elevation.
9. In a hydraulic impulse turbine setting for sites having tailwater levels falling below the normal level, a wheel housing, an impulse wheel positioned within said housing, a discharge pit in communication with said wheel housing, a tailrace, a portion of said discharge pit being constantly submerged by the water in said tailrace, an auxiliary outlet in direct communication with said wheel housing and with said tailrace, said auxiliary outlet being closed when the tailwater level falls below normal, means for opening said auxiliary outlet to establish a discharge of water discharged from the wheel of said wheel housing through said outlet when the tailwater subsequently rises to above normal elevation, and means connected with said means for admitting air into the wheel housing while the tailwater level is so rising.
10. In a hydraulic impulse turbine setting, a wheel housing, an impulse wheel positioned within said housing, a tailrace, a discharge pit in communication with said wheel housing and having its discharge end continuously submerged by the water in said tailrace, and an aspirator chamber connected with said discharge pit and being in controllable communication with the interior of said wheel housing, said aspirator chamber being actuated by the water flowing through said discharge pit and serving when its controllable communication with the wheel housing is open to withdraw air from the interior of said wheel housing.
11. In a hydraulic impulse turbine setting for sites having tailwater levels rising above and falling below the normal level, a tailrace, a single chamber wheel housing, an impulse wheel positioned within said housing, a discharge pit in communication with said wheel housing and being sealed against the atmosphere under normal tailwater elevation-condition of operation of the setting, means connected with and cooperating directly with said discharge pit, and means including said

means for maintaining a substantially constant level of the water in said discharge pit, notwithstanding rises and falls of the level of the tailwater from its normal level.

5 12. In a hydraulic impulse turbine setting for sites having tailwater levels rising above and falling below the normal level, a tailrace, a single chamber wheel housing, an impulse wheel positioned within said housing, a discharge pit in communication with said wheel housing, the discharge end thereof being continuously submerged by the water in said tailrace, said discharge pit being sealed against the atmosphere under normal tailwater elevation condition of operation of the setting, means connected with and cooperating directly with said discharge pit, and means including said means for adjusting the pressure within said wheel housing in accordance with the tailwater levels, above and below the normal level.

13. In a hydraulic impulse turbine setting for sites having tailwater levels dropping considerably below the normal level, a wheel housing, an impulse wheel positioned within said housing, a tailrace, a discharge pit in communication with said wheel housing, the discharge end thereof being continuously submerged by the water in the tailrace, suction means associated with said discharge pit, said means being in controllable communication only with the interior of said wheel housing, and means responsive to changes in level of the discharge water in the discharge pit for controlling said communication, said suction means being actuated by the water discharged from said wheel and flowing through said discharge pit.

14. In a hydraulic impulse turbine setting for sites having tailwater elevations varying from the normal elevation, a single chamber wheel housing, an impulse wheel positioned within said housing, a tailrace, a discharge pit in communication with said wheel housing, the discharge end thereof being continuously submerged by the water in said tailrace, means permitting evacuation of the air within said wheel housing when the tailwater level falls below normal and means for permitting admission of atmospheric air into said wheel housing when the tailwater level subsequently rises above the normal level.

15. In a hydraulic impulse turbine setting for sites having tailwater elevations varying from the normal elevation, a single chamber wheel housing, an impulse wheel positioned within said housing, a tailrace, a discharge pit in communication with the wheel housing, the discharge end thereof being continuously submerged by the water in said tailrace, means for effecting evacuation of the air within said wheel housing when the tailwater level falls below normal, and means for admitting compressed air to said wheel housing when

the tailwater level has risen above the normal level.

16. In a hydraulic impulse turbine setting for sites having tailwater elevations varying from the normal elevation, a single chamber wheel housing, an impulse wheel positioned within said housing, a tailrace, a discharge pit in communication with the wheel housing, the discharge end thereof being continuously submerged by the water in said tailrace, said discharge pit being sealed against the atmosphere under normal tailwater elevation-condition of operation of the setting, means for effecting evacuation of the air within said wheel housing when the tailwater level falls below normal, and means for admitting compressed air to said wheel housing when the tailwater level has risen above the normal level.

In testimony whereof, the signature of the inventor is affixed hereto.

ARNOLD PFAU.

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