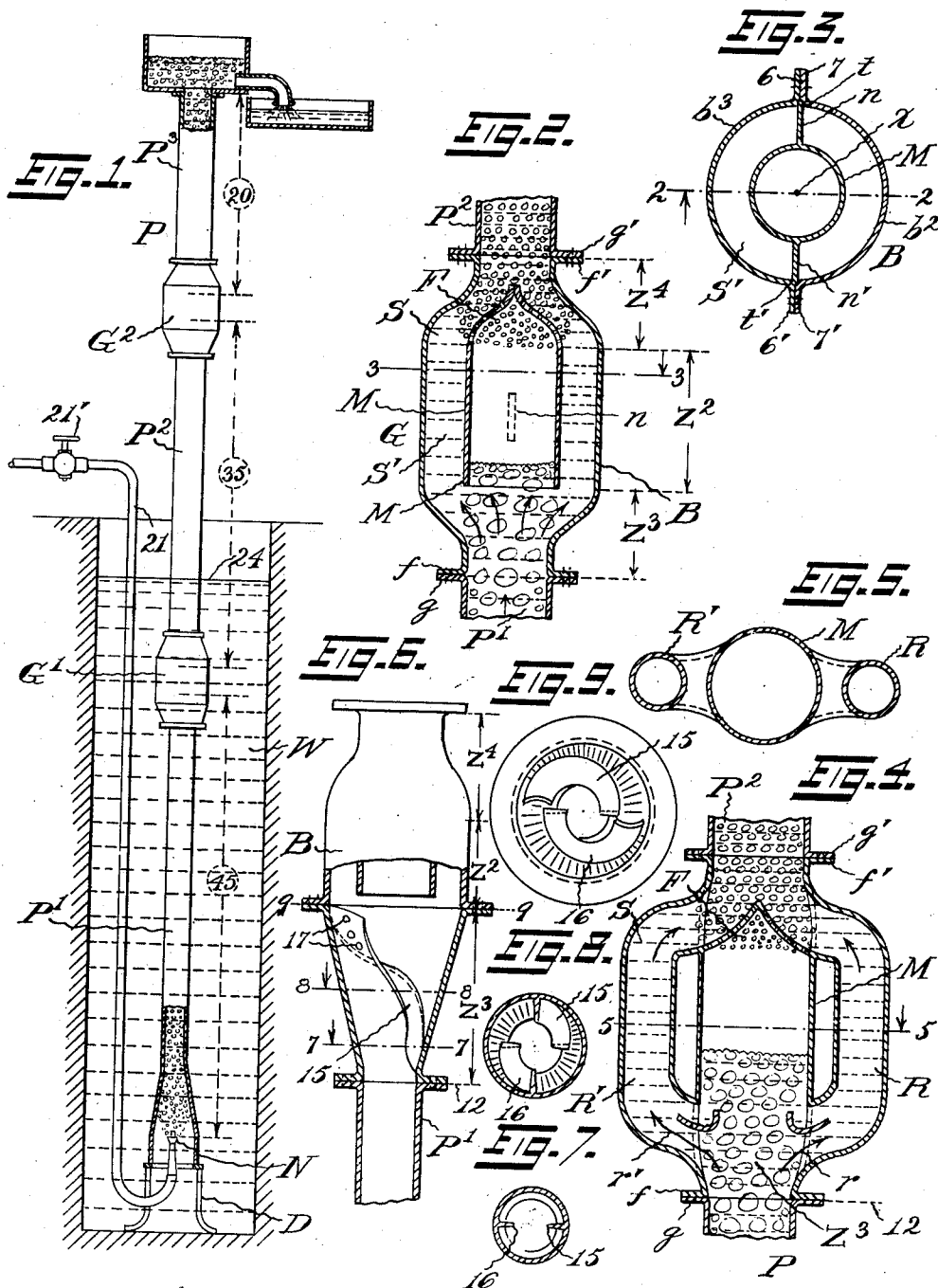


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AIR LIFT APPARATUS.
APPLICATION FILED APR. 5, 1920.

1,374,952.

Patented Apr. 19, 1921.



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UNITED STATES PATENT OFFICE.

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AIR-LIFT APPARATUS.

1,374,952.

Specification of Letters Patent.

Patented Apr. 19, 1921.

Application filed April 5, 1920. Serial No. 371,392.

To all whom it may concern:

Be it known that I, EDWIN M. ROGERS, a citizen of the United States, residing in New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Air-Lift Apparatus, of which the following is a specification.

This invention relates to liquid-elevating apparatus of the class commonly known as air-lifts, and a principal object is to furnish for use in such apparatus, an improved means or regenerator, whereby to regenerate a liquid column consisting of mixed liquid and large or coalesced air-bubbles, into a column of mixed liquid and small bubbles, and thereby reduce the "slippage" of the air-bubbles upwardly in the column, and reduce the loss otherwise normally incident to that well-known action. A further object is to provide a regenerator of that class adapted to effect said object in a continuous-moving column, so that the column need not be subjected to a cessation of upward flow at any point in the height thereof, and thus to reduce or avoid the loss of *vis viva* otherwise normally occurring from such causes. Further objects and advantages are pointed out and explained in the course of the following description.

The present invention is thus, in part, in the nature of an improvement on the air-lift apparatus which is described and claimed in United States Patent No. 1,339,137 granted to me May 4, 1920, on my copending application Serial No. 320,652, filed August 29, 1919.

In the drawing accompanying and forming a part of this specification, Figure 1 is a side elevation of an air-lift apparatus and system arranged in accordance with my present invention; this view illustrates the general arrangement, including the use of a plurality of the regenerators, as G^1 , G^2 , and a system of upwardly progressing gradation as regards the regenerators, the conduit members of an uptake pair, and of successive uptake pairs, as hereinafter more fully explained.

Fig. 2 is a vertical, central section,—on line 2, 2, Fig. 3,—through one of said re-

generators, and is drawn partially in a diagrammatic manner for more clearly indicating the mode of action of this apparatus.

Fig. 3 is a cross-sectional view in line 3, 3, of Fig. 2, for showing a preferred way of constructing and arranging the casing and the inclosed air-collecting chamber of the regenerator.

Fig. 4 is a view similar to Fig. 2, for illustrating a modification as regards certain features of the invention, as hereinafter more fully explained.

Fig. 5 is a cross-sectional view in line 5—5, of Fig. 4.

Fig. 6 is a side elevation of a modified form of the regenerator, and the lower portion is here shown broken away to exhibit an additional improvement which is applied in such a manner as to accelerate the segregation of the air in the de-aerating zone.

Figs. 7, 8 and 9 are cross-sectional views in lines 7—7, 8—8, and 9—9, respectively, of Fig. 6, for more fully illustrating a preferred form or arrangement of the improvements specially shown in Fig. 6.

Similar characters designate like parts in all the views.

In the form of apparatus shown in Fig. 1, the total submergence effect should correspond, substantially as in ordinary practice, to the total height to which the fluid is to be elevated and the quantity of air to be used for aerating the uptake column to sufficiently reduce the weight thereof as compared with the weight, or gravity effect, of the submergence column. In some instances, if desired, the total submergence effect may be obtained, by a relatively short height of the submergence column combined with a mechanically operated fluid-impelling means; this arrangement is not herein illustrated, but one form thereof is described in my prior Letters Patent No. 1,319,797 dated October 28th, 1919, to which reference may be had.

In considering the operation of the present apparatus, it will be convenient to regard the up-flowing column as being composed of two streams, one composed of liquid and the other of air, these streams being each incorporated in, or with the other, and the air stream having an upward flow within (and

relatively to) the liquid stream. This compound stream on arriving, or as it arrives, at the entrance of a regenerator, is there segregated so that each of said parts (or individual streams) thereof is concentrated, and the two streams thus formed are diverted each from the other, into separate channels, respectively. This separation and diversion is herein shown accomplished by a method according to which the liquid stream is slackened in velocity simultaneously,—or nearly so,—with the discharge of the air-contents into an air-collecting chamber, which chamber also forms a conduit member for the air stream. The diverted liquid stream passes upward through a separate conduit member, or channel, and is recharged with the air-stream in an upper zone of the regenerator. Thus said two streams after being for a brief time segregated or dis-incorporated, are finally re-incorporated into a compound stream which then enters an uptake conduit at the upper end of the regenerator. And, during these successive operations or stages, each said stream flows on continuously, but has for a short distance, a modified velocity.

In the arrangement of the air-lift apparatus, as herein shown in Fig. 1 for the purposes of illustration, the uptake line or column comprises a lower air-lift pipe or uptake conduit, as P, a second such pipe or conduit, as P², and the upper and similar pipe or conduit P³. The lower pair of pipes P¹, P², are connected by a regenerator G¹ and the next pair of pipes P², P³, are similarly connected by a regenerator, G². Said uptake line may be supported in practice in any convenient manner, as for instance, by some suitable stand or base as D; this is shown in Fig. 1, arranged for directly supporting the pipe P. Instead of this support, the entire uptake line may be suspended in some instances, if desired, by means of apparatus such as commonly employed for analogous purposes in mining operations, but such devices being well-known, are not herein illustrated.

Said uptake line, comprising a plurality of pipes, P, and a plurality of connecting regenerators, G, is shown in Fig. 1, set in a deep well W corresponding, for instance, to a mine shaft. The pipe 21, having therein a regulating valve, or stop valve 21', is shown leading down said shaft to the lower end of the uptake line for the purpose of conveying compressed air from a suitable source thereof (not herein shown) to an aerating nozzle at N. This nozzle may be of any ordinary or well known description, such, for instance, as commonly used in the lower end of air-lift pipes, and hence this device is not herein particularly illustrated or described. However, in practice I prefer to employ as such initial aerating means, an

ordinary perforated air-lift nozzle, this being preferably arranged within a surrounding hood in a well known manner, whereby to finely sub-divide or comminute the air into small masses or "bubbles."

The shading at line 24, (Fig. 1), indicates a water level, and the distance from said line to nozzle N being the submergence head. To make the system operative, of course, the contents of the uptake line must be lightened by the aeration as to be over-balanced by the submergence effect at the level N; this, however, is a principle now well understood.

The detailed construction of a preferred form of the air-bubbles regenerator, G, is best indicated in Figs. 2 and 3. The casing or body, B, is tubular in form, and much larger than conduit P¹, P², and is preferably substantially cylindrical in section, (Fig. 3). This casing, B, is also preferably divided longitudinally into two parts, (preferably but not necessarily alike), these parts being releasably united by suitable means,—as, for instance, flanges and bolts indicated in Fig. 3. The mid-length part, or zone, Z², (Fig. 2) is shown cylindrical, and as having at each end thereof converging zones, Z³, Z⁴, formed in a nearly conical manner, and provided with means, as flanges f, f' for releasably attaching the casing B to the conduits P¹ and P², respectively.

Within said casing B, and centrally-disposed therein, the combined air-collecting chamber and air-stream conduit-member, M, is supported within said zone Z², and below the converging end Z⁴ of the casing, and has appurtenant thereto an air-comminuting means, at F, adjacent to said converging zone Z⁴; thus the space S, between said zone Z⁴ and comminutor F, constitutes a re-aeration zone, when this term is applied to an interior space.

Said chamber M is also shown in axial alinement with the casing B, and with the coactive conduit-members P¹, P², so that the comminuting device, F, is concentric with such axes, and also with the casing zone, Z⁴, which is upwardly converging when the regenerator, G, is in position for operation; also, the chamber M is shown extending from said lower, or de-aeration zone, Z³, to said upper, or re-aeration zone, Z⁴, and the air-comminuting means with which this chamber is provided, is located below said upper zone.

When the regenerator is of the general form indicated in Figs. 2 and 3 it may be constructed, in practice, in various ways. For instance, the air-chamber M having been constructed and provided with wings n, n', (Fig. 3), this member may be embedded within a core and the casing B then cast in one piece, in accordance with methods well-known to foundrymen. However,

for general use, it is deemed to be preferable to make said casing, or shell in halves, as shown in Fig. 3, each of these parts b^2 , b^3 , being provided with pairs of flanges, 6, 6¹ and 7, 7¹, respectively, by means of which these half-parts may be releasably secured together by means of ordinary bolts, (not shown). In this case, the wings n , n' may be shaped to fit into recesses formed at t , t' , and thus hold the air-chamber M securely in place, in an evident manner.

As a means for uniting the regenerator casing, or body, to the uptake pipes, said casing is shown in Fig. 2, provided at the ends thereof with flanges f , f' , and the lower and upper pipes, P^1 and P^2 , respectively, are shown similarly provided with ordinary flanges as g , g' , and these pairs of flanges may be held together by bolts, (not shown), in a usual and obvious manner. But in some instances, if desired, especially when the pipes are of small size, ordinary screwed pipe-joints may be used in place of the flanges, as will be evident to practical mechanics, without a more particular description.

One object attained by the arrangement shown in Figs. 1 and 2, is to spread the up-flowing column of liquid as this emerges from the lower conduit P^1 , so that the stream of mixed air and liquid extends around a larger circle, or zone, and thus reduces in velocity of upward flow in the separation space within zone Z^3 , for thereby accelerating and facilitating the completeness of such separation; this being accomplished, the liquid thus de-aerated is guided toward and into the chamber leading to the upper conduit; this action is indicated, approximately, by arrows and representations of enlarged bubbles in said zone, Z^3 , Fig. 2.

A further advantage of said arrangement of Figs. 1 and 2, is that the lower pipe or conduit P^1 , and the upper pipe or conduit P^2 , are in alinement, so that the apparatus is readily lowered into and lifted out of a mine-shaft, or other deep and narrow passage within which the air-lift shall be used; this is especially important when, as sometimes happens in practice, the air-lift is intended for use in a drilled well or bore. For instance, in a ten-inch hole bored down into a mine gallery or drift, a complete and operable air-lift of this kind can now be slid down when the pipes, as P^1 , P^2 , etc., are not over five or six inches in outside diameter. Also, the symmetrical arrangement of the chamber wall relative to said uptake pipes, produces an exceptionally strong connection for those pipes, so that the maximum capacity is obtained with a minimum of material in and weight of the air-lift system.

In the modification partially illustrated by the sectional side view in Fig. 4, the

liquid stream, on emerging above the line 12, is diverted a part toward the right-hand into channel R, and a part toward the left-hand into a similar channel R'. These two channels, R and R', (indicated by arrows r , r' , respectively) constitute in effect the conduit whereby the liquid stream is carried from the de-aeration zone Z^3 , past and outside of the air-stream conduit-member M, (this being also the aforesaid air-collecting chamber), which is continuous or closely adjacent to the lower end g' , of the upper uptake pipe or column P^2 . This construction of the regenerator, however, while deemed to be broadly within the purview of the present invention, is not specifically claimed herein, but is intended to constitute in part the subject matter of a separate application to be concurrently pending herewith.

The hereindescribed improvements which are specifically illustrated in Figs. 6 to 9, inclusive, are not specifically claimed herein, but will constitute in part the subject-matter of a separate application to be concurrently pending herewith.

The preferred mode of diverting and conducting said liquid stream is herein illustrated in Figs. 2 and 3, where the channel S' for the liquid stream is annular in cross-section, (Fig. 3), so that the air-conduit member M is surrounded by the casing B, and by said annular space or conduit for the separated liquid stream. By this system of organizing the regenerator, a minimum of lateral divergence of the liquid stream is required, and since this action takes place in a circular zone, so that the liquid moves outwardly in all directions from a central point, (i. e., from the conduit axis, as v , Fig. 3), this construction offers a low resistance to the liquid stream, besides having important advantages as regards manufacture, installation of plant, and maintenance.

As an element of the complete air-lift system, the regenerator may be said to constitute a re-aeration means, since the primary object and function thereof is to restore the separated air to the upflowing column and thereby re-aerate the liquid thereof with newly-formed bubbles of small size, these bubbles being composed of the same air which was previously segregated from said column. Thus the process of segregation as effected in said lower zone, as Z^3 , (Fig. 2), may be regarded not as the chief or most essential step, but as a preparatory step preliminary to the principal step of re-aeration.

Also, it should be understood that, in practice, a large part of all bubbles both large and small, coming up to said lower zone Z^3 , will normally be forced out by the hydraulic pressure and flow up into the air-chamber M, but owing to the considerable distance from one aeration means (as G^1 , Fig. 1) upwardly to the next one, (as G^2),

and the constant coalescing action in the up-flowing mixed column, a large portion of the air bubbles will have been coalesced to some extent before reaching said de-aerating zone; hence, it is considered that a chief and distinguishing function of said chamber M is for the collection therein of coalesced air-bubbles from said lower zone.

One feature of my present improvements relates to an organization, in a continuous air-lift column, of a plurality of the regenerators connecting at successive elevations, respectively, a plurality of uptake conduits having preferably, successively increasing capacities and lengths, counting from the lower conduit upwardly. This system of organization is illustrated in Fig. 1, where the three uptake pipes, or conduits, P^1 , P^2 , P^3 , are shown respectively, as having lengths in the proportion of 45, 35 and 20; of these the lower pipe P^1 is shown smallest in diameter, while the second pipe P^2 , is larger, and the upper pipe P^3 , is the largest. Also, it will be understood that of the two regenerators, G^1 , G^2 , the lower one should be fitted for action under a pressure corresponding to the head above this device, whereas the upper one, G^2 , should have a different construction or fitting, suitable for regenerating the air bubbles under a much lower pressure; and that a corresponding gradation should be followed when a larger series of regenerators is employed. These adjustments, in practice, are readily made, (aided, when necessary, by calculation and trial), by selecting a suitable number and size for the outlet holes, as at F, (Fig. 2), in the top or perforated area of the air-chamber M. Thus the lower regenerator, G^1 , is fitted (in its make-up) for action upon a given flow of air under a high pressure while the upper regenerator, G^2 , is similarly fitted for acting during the same period of time upon the same quantity of air under a lower pressure.

It will now be evident that successive uptake pipes P^1 , P^2 , P^3 , Fig. 1, are shown arranged as a series of pairs of uptake conduits, and this series may be extended, in practice, to include three or more such pairs, as may be for efficiency and economy, under the conditions which may exist in any particular instance. The lower conduit, P^1 , and the next following conduit P^2 , constitute one said pair, these two conduits being connected by and through the laterally-closed regenerator G^1 . Said second conduit P^2 and the upper conduit P^3 constitute another such uptake pair which are similarly connected by the upper regenerator G^2 . Thus the number of uptake pairs corresponds to the number of the regenerators which are comprised in the air-lift system.

For said upper connected pair P^2 , P^3 , the lower regenerator G^1 serves as a means for

the aeration of the liquid stream which is to be supplied through the lower conduit of this pair, (*i. e.*, through pipe P^2), for delivering as an aerated column upwardly into the regenerator G^2 . And for said lower connected uptake pair P^1 , P^2 , an ordinary aeration jet, N, (at the lower entrance to the system) serves as one suitable means for aerating the liquid stream which is supplied through the lower pipe P^1 to the regenerator G^1 of this lower pair. Thus, in the complete system, each said uptake pair comprises an intermediate regenerator and a means at the lower end of the pair for preliminarily aerating the liquid stream which is to be supplied to this regenerator.

When the series of regenerators are each properly graduated (as elsewhere herein explained) as regards position and working pressure, and are structurally adjusted for comminuting and delivering each the same air at successively reduced pressures, respectively, these regenerators are then a plurality arranged in a series having a progressive gradation extending from the lowermost regenerator (as G^1 , Fig. 1,) upwardly to the uppermost regenerator of the series. This feature as regards gradation also applies to the conduit-members of an uptake pair, when the upper said member of a given pair has a capacity or a cross-sectional area larger than the lower said member of the same pair; and, similarly, the successive pairs of uptake conduits may have such a progressive gradation as uptake pairs. By means of these gradations the acceleration of the upflowing compound column of air and liquid may be lessened or restricted as compared with the acceleration otherwise normally resulting from the continuous expansion of the air-content of the column in passing from the submergence pressure at the lower end of conduit member P^1 , upwardly to the outlet at atmospheric pressure.

In some instances, in an uptake column comprising a plurality of pairs of uptake conduits, only one of these pairs may have the described gradation arrangement; but this may be in a combination having the two conduit members of one of said pairs arranged in the upwardly progressing gradation; and, in such a limited combination, a series of two (or more) of the regenerators may have the described upwardly progressing gradation, while each regenerator (in whichever pair comprised) delivers into an upper conduit-member of the pair connected by such regenerator.

From the foregoing explanations, it will now be evident that when a given quantity of air, (this being measured, in the usual way, as "free air"), is incorporated with a given quantity of water at the lower aeration nozzle N, the column of such air (in

proportion to the volume of the water) will depend on a pressure due to the total head to which the air is then subjected. The proportionate volume, however, of the air content, necessarily continues to increase through the entire height of the air-lift column,—since the air necessarily expands in proportion to reduction of head and pressure,—so that the volumetric ratio of air to water is least in lower pipe P^1 , is larger in middle pipe P^2 , and is much larger in upper pipe P^3 ; and, evidently, the weight of a given volume of the air-and-water mixture decreases at the successive elevations in a corresponding ratio. This progressive difference is measurably modified, and regulated or counter balanced, by the aforesaid enlargement of the successive uptake pipes, which serves to reduce the amount of the increase of velocity which the compound column of air and liquid would otherwise have in the upper pipe length P^3 , as compared with the lower pipe-length P^1 . The graduations of pipe lengths and capacities are coactively employed in the system of Fig. 1, in combination with the successive regenerators of graded action and effect, respectively, whereby each regenerator receives and delivers the same quantity of air as each other one, but in a volume and of a pressure due to its own position in the height of the air-lift column.

In accordance with the explanation given in my aforesaid prior application, it is contemplated, in applying my present invention, to limit each uptake conduit member,—as P^1 , P^2 , etc.,—to such moderate distances or height as will avoid any considerable loss of power by reason of increasing slippage, and to discharge the associated air and liquid directly into a regenerator for separation, and thence (after comminution) into a second or next higher air-lift pipe, as P^2 , or P^3 extending upwardly to the height required. But if the total height is deemed too great for economy of operation, three or more of the regenerators may be used in some instances, as elsewhere herein more fully explained.

When a single conduit-member, as P^1 or P^2 , extends through a considerable height, the relatively great expansion of the air-content of the upflowing column, makes it desirable to provide for converting such air into a largely increased number of bubbles for delivery to the next following conduit-member; and, hence, in practice, such next following pipe, (as P^2 , next after P^1 ; or P^3 , next after P^2 , as the case may be), may be made of a proportionately larger cross-sectional area,—as compared with such area of the next preceding pipe,—in order to avoid an undue increase in the upward velocity of the regenerated air-and-liquid column.

As also pointed out in said prior appli-

cation, the expansion of the up-flowing air bubbles results in a constantly increasing slippage velocity and pipe-surface friction of the fluid column at successive points upwardly from the aerator, and also correspondingly increase the volume of a given weight of the aerated fluid, as this approaches the discharge end of the air-lift pipe. The phenomena, which necessarily occur in each of the air-lift pipes, as P^1 and P^2 , constitute one reason why it has hitherto been found undesirable, because of waste and loss, to employ air-lifts in many situations to which otherwise, this system would be well adapted.

It will be remembered that in a mixed column of bubbles and liquid, the column normally moves more rapidly in the central portion than it does near the conduit wall, and that the larger bubbles naturally tend by reason of their higher slippage velocity, to overtake and thus coalesce with other bubbles, and thereby form by the coalescence, masses, or bodies of air constantly increasing in size and consequently of a still higher slippage velocity. Also, these augmented air bodies tend to follow a central path within the conduit, and thus partake of the most rapid velocity in the liquid column or stream, in addition to said increased slippage. Under these conditions, when the column-velocity is reduced by the upwardly and outwardly tapering part of the conduit, as shown at Z^3 , (Figs. 2, 4 and 6) in the de-aeration zone Z^3 , said high velocity of the enlarged bubbles quickly carries them upwardly through said zone Z^3 and into the open lower end, at M' , of the air-collecting chamber M . Thus the mode of action is such that the larger and centrally located bubbles may be said to be forcibly discharged upwardly out of the liquid column, which is thus de-aerated in passing through said zone Z^3 , this being done simultaneously with the diversion of said liquid into the by-pass channel,—as R , R' , Fig. 4, or S' , Fig. 2.

The column being thus freed of its air-content, or admixture, occupies a proportionally less space as a liquid, and passing into the by-pass channel moves more slowly but without cessation of flow through this channel; but, on coming into the contracting portion at Z^3 , (in the re-aerating zone) of the casing wall, the velocity of the liquid is thereby normally increased; and, since this action occurs in connection with the incorporation into the liquid of bubbles of air discharged through the numerous small openings, F , the column in a regenerated form is delivered into the upper conduit P^2 at a proper and relatively high velocity.

The gain directly resulting from a regeneration of a mixed column of liquid and large bubbles into a column having the bubbles greatly reduced in size, is understood to

be slightly counteracted by a resistance arising in the regenerator from diversion of currents and the friction due to agitation of liquid and the force required to expel the collected air through the small openings, as F, in the re-aeration means. This small loss, however, seems to be quite immaterial in comparison with an advantage resulting from a transfer of heat which is explainable in accordance with the principles of thermodynamics. As an air bubble moves upwardly it expands in volume, and is thus reduced in temperature, and at the same time is reduced in surface as compared with volume. On reaching a regenerator, the air thus cooled by expansion is divided up into small bubbles under practically the same pressure, but having,—for a given quantity of air,—a greatly increased proportionate surface. Thus the aggregate area of contact of the air with the liquid is greatly multiplied so that heat naturally will be conducted at a corresponding rapid rate from the liquid to the air, and thereby proportionately increase the volume and the consequent efficiency of such air for the reduction of the specific gravity of the air-and-liquid mixture of which the upflowing column, in that part thereof, is composed. Owing to the conditions here briefly pointed out, and when the described process is repeated at a number of places in a high lift, the aggregate advantage thus obtained becomes a matter of very great practical importance. The air expansion thus obtainable by heat-transfer, introduces an economy in the use of the air in accordance with a well-known principle. The compressed air being supplied to the lowermost aeration nozzle, at N, (Fig. 1), and this nozzle or aeration device being under the maximum submergence effect, or head, of course this head or pressure, determines the amount of air-pressure to be supplied. Owing to the normally rapid escape from the liquid of the coalesced air in the lower or de-aeration zone Z^3 , the liquid is there de-aerated to the extent of such separation, and hence may be designated as "de-aerated," since it will then retain only a small proportion of the air contained therein at the time of maximum aeration. Therefore, the term "de-aerated,"—as used for convenience of description in this and in my copending applications for improvements in air-lift apparatus and devices,—refers to and only implies a segregation or separation from the liquid of a considerable proportion of the air previously supplied thereto. In this connection, it should be understood that in some instances a portion of such contained air will or may become so absorbed, or emulsified as to follow along in the moving liquid column in its passage from said lower uptake-pipe, or conduit, as P^1 , to the

upper said pipe or conduit, as P^2 , but, this action will normally and ordinarily occur only in a moderate degree, not harmful to the operation of the re-aeration means considered as a whole.

Since, as well-known, the function of the air bubbles is to lighten the specific gravity of a given mass of the content of the column, it is obvious that any available gases may be used in place of atmospheric air, and hence it is to be understood that the term "air" is herein employed as a generic term for designating the air or other gases which may in any given instance be available for use in effecting the necessary reduction in the weight of the fluid contained within a given length of the uptake pipe.

A further improvement is illustrated in Figs. 6 to 9, whereby to accelerate the aforesaid segregative action arising from a slacking and broadening of the upflowing column, within the de-aerating zone Z^3 . This zone is shown in Fig. 2 as having a relatively short height, but in Fig. 6 this height, between lines 12 and 9, is much greater, and hence the velocity-reduction of said column is also less rapid. This portion, Z^3 , of the regenerator is here shown (Fig. 6) made in the form of a separate and tapering tubular member which is an extension of the main casing B. The three parts, casing B, pipe P^1 , and connecting tube Z^3 , are readily connected together in practice, in a releasable manner by means of pairs of co-active flanges, and by bolts (not shown) in the simple manner clearly indicated by the drawings.

Within the tubular member Z^3 , (Fig. 6), this being tapering, a column-rotating means is provided whereby to turn the liquid column as this moves upwardly in the member Z^3 . The object of this rotation is to impart to the liquid an outward momentum or centrifugal effect, to thereby increase the fluid-pressure in the outer portion and thus more rapidly force the air-bubbles toward the center of the column, and to do this while the slippage is increasing by reason of the slacking of the upflow velocity of the liquid stream.

The form of said column-rotating means herein particularly illustrated, consists in a spirally positioned guide or blade, or guide-vane, as 15, fixed within said tubular part Z^3 of the uptake conduit. This conduit portion, whether structurally integral with or separate from the casing B, is herein considered to be, in effect and functionally, a part of the regenerator G. Preferably the guide 15, or liquid-column-rotator, may be in the form of a removable blade of a form about as indicated in the drawing; but, for convenience of illustration, said blade 15, is herein shown as if integral with the conduit-wall. Also, said guide 15, is shown having

an increasing width from the lower end (Fig. 7) upwardly to the top thereof,—Fig. 9; also, it will be desirable in some instances, to have the spirality of an increasing pitch.

5 In the present instance, two of said guides are shown, 15 and 16, but in the case of conduits of small diameter, one of these may be omitted; in the case of exceptionally large conduits, three or more of said guides or blades may be employed. Also, the width and length of these guides, as 15, 16, may be varied to adjust their effects to the requirements of any given installation.

15 In some instances, especially where the apparatus or air-lift system operated in a fluctuating manner, (which is sometimes unavoidable), so that relatively large masses of air impinge against the guide or vane, as 15, this guide may have a series of small perforations, as 17, (Fig. 6), for permitting a part of such air to pass through and thus form small bubbles. In such a case, these newly formed bubbles, being of small size and located well toward the outer side of the liquid stream, may be carried with this stream through the by-pass conduit and thus flow upwardly into and through the re-aeration zone, there to mix with the bubbles coming up from the central air chamber.

30 Having thus described my invention, I claim:—

1. A regenerator apparatus for air-lifts comprising, in combination, a casing for connecting a lower uptake-conduit for delivering an aerated liquid column upwardly into the casing and an upper uptake-conduit for receiving re-aerated liquid from the casing, said regenerator having a lower de-aeration zone and an upper re-aeration zone, and intermediate to these two zones having an air-collecting chamber in position and adapted for collecting coalesced air-bubbles from said lower zone, and provided with means for comminuting and then delivering said collected air into said upper zone, and also having a separate passage-way for a continuously moving column of liquid from said de-aeration zone to said re-aeration zone, whereby a column of liquid mixed with relatively large air-bubbles may be regenerated without cessation of upflow, into a column of liquid mixed with relatively small air-bubbles composed of air previously segregated from said column.

55 2. A regenerator apparatus for air-lifts comprising, in combination, a casing for connecting a lower uptake-conduit for delivering an aerated liquid column upwardly into the casing and an upper uptake-conduit for receiving re-aerated liquid from the casing, said regenerator having a lower de-aeration zone and upper re-aeration zone, and intermediate to these two zones having an intermediate air-stream conduit-member in position and adapted for collecting air

from said lower zone, and for delivering this air in a comminuted form into said upper zone, and also having a separate passage-way for a continuously moving column of liquid from said de-aeration zone to said re-aeration zone, whereby a column of liquid mixed with relatively large air-bubbles may be regenerated without cessation of upflow, into a column of liquid mixed with relatively small air-bubbles composed of air previously segregated from said column.

3. A regenerator apparatus for air-lifts comprising, in combination, a casing for connecting a lower uptake-conduit for delivering an aerated liquid column upwardly into the casing, and an upper uptake-conduit for receiving re-aerated liquid from the casing, said regenerator having a lower de-aeration zone and upper re-aeration zone, and intermediate to these two zones having inclosed therein a combined air-stream conduit-member and air-collecting chamber which is in position and adapted for collecting air from said lower zone, and is provided with means for comminuting and then delivering said collected air into said upper zone, and also having an annular air-chamber-inclosing passage-way for a continuously moving column of liquid from said de-aeration zone to said re-aeration zone.

4. In an apparatus for air-lifting liquids, in combination, a re-aeration means, a lower uptake-conduit connected for delivering liquid upwardly into the re-aeration means, and an upper uptake-conduit connected for receiving re-aerated liquid from the re-aeration means, said re-aeration means constituting a laterally-closed connection for said uptake-conduits and having in the upper portion thereof a re-aeration zone at the lower end of said upper conduit, and in the lower portion thereof, having an air-and-liquid separation zone at the upper end of said lower conduit, and also having an air-collecting chamber in position and adapted for collecting coalesced air-bubbles from said lower conduit through said separation zone, and provided with means for comminuting and then delivering said collected air into the liquid in said re-aeration zone at the lower end of said upper conduit, said re-aeration means also comprising a by-pass channel in position and connected for conducting a continuously moving column of liquid from said separation zone and outside of the air-collecting chamber to said re-aeration zone for delivery into the lower end of said upper uptake-conduit, whereby the segregation of coalesced air-bubbles is effected from a continuously moving column which without cessation of upflowing movement is re-aerated by newly formed small bubbles composed of the same air which was thus segregated from said column.

5. In an apparatus for air-lifting liquids, 130

in combination, a regenerator, a lower uptake-conduit connected for delivering an aerated liquid column upwardly into the regenerator, and an upper uptake-conduit
 5 connected for receiving a re-aerated liquid column from the regenerator, said regenerator constituting a laterally closed conduit connector, and having in the upper portion thereof a re-aeration zone at the lower end
 10 of said upper conduit, and in the lower portion thereof having a de-aerating zone for air-and-liquid separation at the upper end of said lower conduit, and also having an air-collecting chamber vertically intermediate to said zones and in position for collecting air from said lower conduit, and provided with means for comminuting and then delivering said collected air into the liquid in the re-aeration zone at the lower end
 15 of said upper conduit, said regenerator being also provided with a channel arranged for conducting a continuously moving column of liquid from said separation zone and outside of the air-collecting chamber to said re-aeration zone and then into the lower end of said upper uptake-conduit.

6. In an apparatus for air-lifting liquids, in combination, an uptake column comprising a plurality of pairs of uptake conduits
 20 arranged in a series in which the pairs have an upwardly progressing gradation, and a series of conduits-connecting regenerators one for each said uptake pair and also arranged in an upwardly progressing gradation,
 25 the regenerator of each said pair constituting a laterally-closed conduit connector, and having means in position for first collecting air and for then comminuting and delivering the collected air into the liquid
 30 at the lower end of an upper conduit of the pair connected by such regenerator, whereby a continuously upflowing compound column of air and liquid may be restricted as to acceleration, and may be successively regenerated at successive elevations, respectively,
 35 into a column of liquid mixed with relatively small air-bubbles composed of air previously segregated from said column.

7. In an apparatus for air-lifting liquids, in combination, an uptake column comprising a plurality of pairs of uptake conduits and having the two conduit members of one said pair arranged in an upwardly progressing gradation, and a series of conduits-connecting regenerators one for each said uptake pair, said regenerators each constituting a laterally-closed conduit connector, and having means for first collecting air and for then comminuting and delivering the collected air into the liquid at the lower end of an upper conduit of the pair connected by such regenerator, whereby a continuously upflowing compound column of air and liquid may be restricted as to acceleration,
 60 and may be successively regenerated at successive elevations, respectively, into a column of liquid mixed with relatively small air-bubbles composed of air previously segregated from said column.

cessive elevations, respectively, into a column of liquid mixed with relatively small air-bubbles composed of air previously segregated from said column.

8. In an apparatus for air-lifting liquids, 70 in combination, an uptake column comprising a plurality of pairs of uptake conduits and having two conduit members of one said pair arranged in an upwardly progressing gradation, and a series of conduits-connecting regenerators one for each said uptake pair and also arranged in an upwardly progressing gradation, said regenerators each constituting a laterally-closed conduit connector, and having means for first collecting air and for then comminuting and delivering the collected air into the liquid at the lower end of an upper conduit of the pair connected by such regenerator, whereby a continuously upflowing compound
 85 column of air and liquid may be restricted as to acceleration, and may be successively regenerated at successive elevations, respectively, into a column of liquid mixed with relatively small air-bubbles composed of air
 90 previously segregated from said column.

9. In an apparatus for air-lifting liquids, in combination, a series of pairs of uptake conduits, and a series of conduits-connecting regenerators one for each said uptake pair, said regenerators each connecting a lower uptake-conduit with an upper uptake conduit, each said regenerator constituting a laterally-closed conduit connector, and having means for collecting coalesced air-bubbles from a lower conduit, and for comminuting and then delivering said collected air into the liquid at the lower end of an upper conduit, whereby a continuously upflowing column of liquid may be successively
 105 regenerated at successive elevations, respectively, from a column of liquid mixed with relatively large air-bubbles into a column of liquid mixed with relatively small air-bubbles composed of air previously segregated
 110 from said column.

10. In an apparatus for air-lifting liquids, in combination, a series of uptake conduits, and a series of conduits-connecting regenerators one for each said uptake pair, said regenerators each connecting a lower uptake-conduit with an upper uptake conduit, each said regenerator having means for comminuting air and delivering into a continuously upflowing column of liquid air-bubbles composed of air previously segregated from said column.

11. An air-lift apparatus comprising, in combination, two uptake conduits arranged one above the other and in alinement, and
 125 a regenerator intermediate to and connecting said conduits and having therein an air-collecting chamber in alinement with the upper one of said conduits and provided with air comminuting means, said regenerator 130

having a de-aeration zone below said chamber and an upwardly contracting zone for re-aeration above said chamber, and also having a passageway for de-aerated liquid to flow from said de-aeration zone to said re-aeration zone without passing through said chamber.

12. An air-lifting apparatus comprising, in combination, a lower uptake conduit, and an upper uptake conduit in axial alinement and connected by a regenerator casing in axial alinement with said conduits and having a diameter larger than said conduits, said casing having at the lower end thereof an upwardly diverging zone and having at the upper end thereof an upwardly converging zone and having supported therein a combined air-collecting chamber and air-stream conduit member extending from said lower zone to said upper zone, and provided with air-comminuting means located below said upper zone.

13. An air-bubble regenerator for air-lifts, comprising a casing-body substantially cylindrical in form and longitudinally divided into two parts and having means for releasably uniting these parts, said casing-body having at each end thereof a converging zone and means for a releasable connection with an uptake conduit, in combination with a centrally-disposed air-collecting and comminuting chamber releasably supported within a mid-length zone of said casing, whereby an inclosed space surrounding said chamber constitutes a passageway for de-aerated liquid.

14. An air-bubble regenerator for air-lifts, comprising, in combination, a casing tubular in form and having a converging zone at one end therefor, and an air-chamber tubular in form and shorter than the casing, and supported within and longitudinally of the casing, and air-comminuting means appurtenant to said chamber and adjacent to said converging zone of the casing.

15. An air-lift apparatus comprising, in combination, two uptake conduits arranged one above the other and in alinement, and a regenerator intermediate to and connecting said conduits and having therein an air-collecting chamber in alinement with the upper one of said conduits and provided with air means, said apparatus also comprising a de-aeration zone below said chamber and an upwardly contracting zone for the re-aeration of de-aerated liquid, and said regenerator also having a passageway for de-aerated liquid to flow from said de-aeration zone to said re-aeration zone without passing through said chamber.

16. An air-lifting apparatus comprising, in combination, two uptake conduits arranged one above the other and in alinement, and a regenerator intermediate to and connecting said conduits and having therein

an air-collecting chamber in alinement with the upper one of said conduits and provided with air comminuting means, said regenerator having a de-aeration zone below said chamber and an upwardly contracting zone for the re-aeration of de-aerated liquid, and also having a passageway for de-aerated liquid to flow from said de-aeration zone to said re-aeration zone without passing through said chamber.

17. An air-lift apparatus comprising, in combination, a lower uptake conduit, and an upper uptake conduit in axial alinement and connected by a regenerator casing in axial alinement with said conduits and having a diameter larger than said conduits, said casing having at the lower end thereof an upwardly diverging zone and having at the upper end thereof an upwardly converging zone, and having supported therein a combined air-collecting chamber and air-stream conduit member extending from said lower zone to said upper zone, and provided with air-comminuting means located below said upper zone.

18. An air-lift apparatus comprising, in combination, a lower uptake conduit and an upper uptake conduit connected by a regenerator casing in axial alinement with said upper conduit and having a diameter larger than said conduits, said casing having at the lower end thereof an upwardly diverging zone and having at the upper end thereof an upwardly converging zone, and having therein a combined air-collecting chamber and air-stream conduit member intermediate to said lower and upper zones, and air-comminuting means appurtenant to said chamber.

19. An air-bubble regenerator for air-lifts, comprising, in combination, a chambered casing-body longitudinally divided into two parts and having means for releasably uniting these parts, means for releasably connecting the casing-body with an uptake conduit, and a centrally-disposed air-collecting and comminuting chamber releasably supported within a mid-length zone of said casing, whereby an inclosed space surrounding said chamber constitutes a passageway for de-aerated liquid.

20. An air-bubble regenerator for air-lifts, comprising, a casing-body substantially cylindrical in form and longitudinally divided into two parts and having means for releasably uniting these parts, said casing-body having at each end thereof a converging zone and means for a releasable connection with an uptake conduit, in combination with a centrally-disposed air-collecting and comminuting chamber releasably supported within a mid-length zone of said casing, whereby an inclosed space surrounding said chamber constitutes a passageway for de-aerated liquid.

21. An air-bubble regenerator for air-lifts, comprising, in combination, a casing tubular in form and having a converging zone at one end thereof, and an air-chamber
5 tubular in form and shorter than the casing, and supported within and longitudinally of the casing, and air-comminuting means ap-

purtenant to said chamber and adjacent to said converging zone of the casing.

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