Aug. 29, 1961 H. G. ALLEN 2,997,959

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Filed Jan. 24, 1958 2 Sheets-Sheet 1

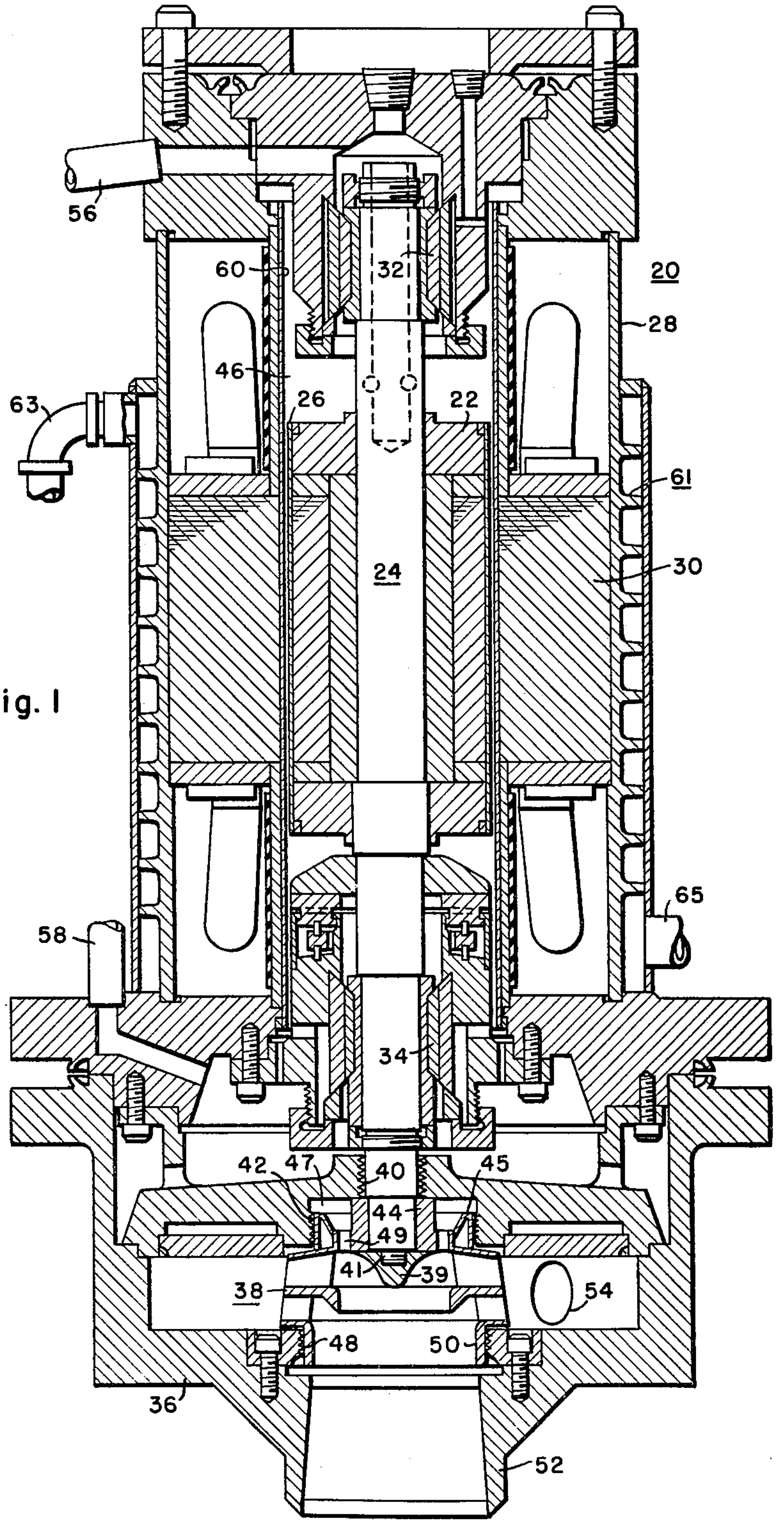

Fig. I

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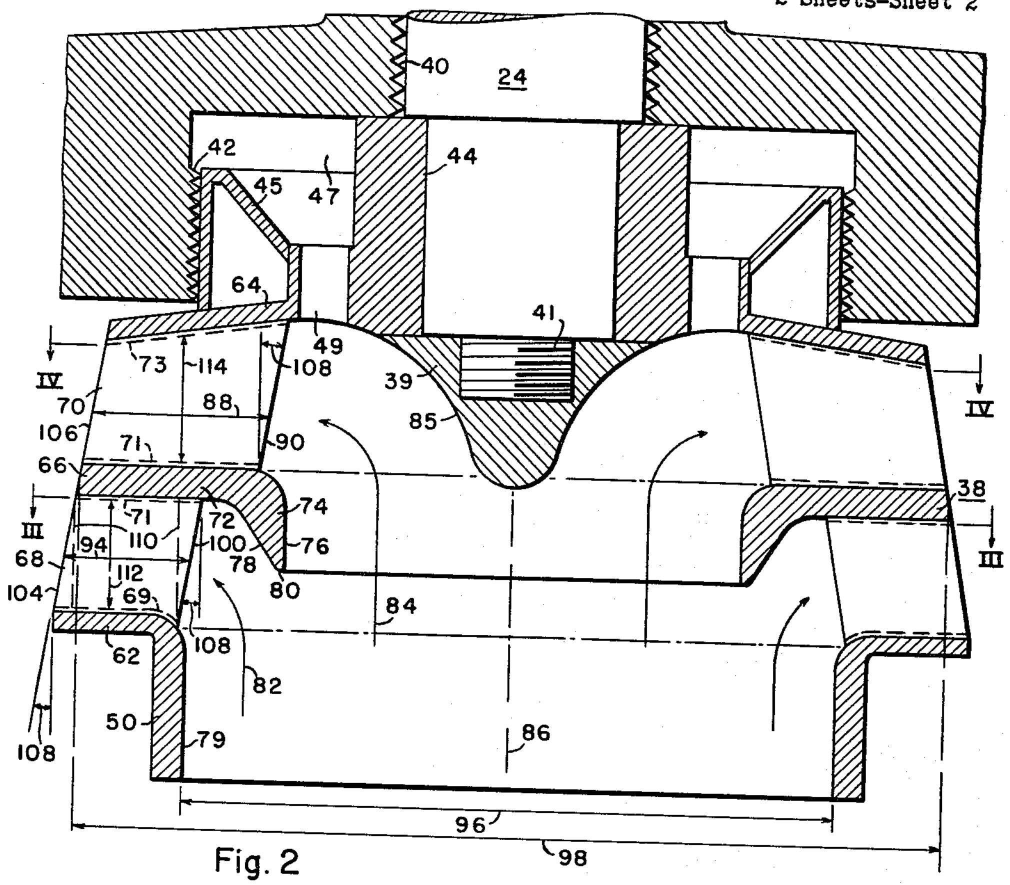

Fig. 2

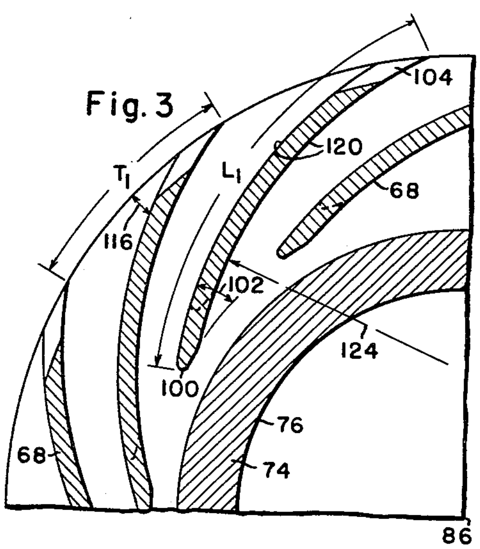

Fig. 3

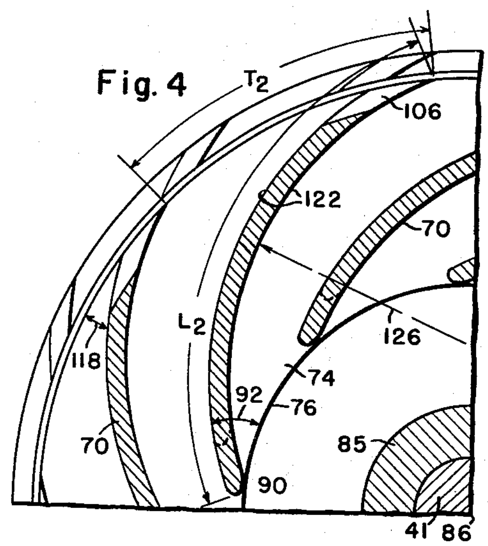

Fig. 4

United States Patent Office

2,997,959

Patented Aug. 29, 1961

2,997,959

PUMP

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Filed Jan. 24, 1958, Ser. No. 710,892
6 Claims. (Cl. 103—103)

The present invention relates to motor-pump units and more particularly to the pump portion of such units.

In certain applications of power operated pumps, it is necessary to fabricate the hydraulic components thereof from extremely hard materials. In the case of pumps handling a slurry or suspension or other highly errosive or corrosive fluid at relatively high flow volumes, the hydraulic components of the pump desirably are fabricated from a material having a very high wear resistance, for example, titanium, which, however, cannot be cast readily in the relatively large sizes required. Therefore, the titanium or similar material must be forged, and such forgings are very difficult to shape and form in a conventional manner. This problem is accentuated by the machining processes required for the hydraulic components of the pump, particularly the impeller thereof, when furnished in known designs adaptable for high specific speeds.

The general design of known low specific speed impellers employs blades or vanes having single or simple curvatures, which permit fabrication from extremely hard materials by ordinary forging and machining operations. However, in the case of high velocity power pumps, the vanes or blades of the high specific speed impellers required therefor are fabricated with a known design usually referred to as a Francis blade which has a double or compound curvature. The compound curvature is employed in known designs to compensate the varying distances from the axis of the impeller, at which portions of the inlet edges of the vanes are disposed. The aforesaid varying distances are occasioned by the fact that the inlet aperture or eye of the impeller is large in comparison with the overall diameter of the impeller in the high specific speed or high volume impellers. Consequently, these high specific speed impellers, when extreme hardness or toughness of material is specified, are very difficult to fabricate from forged and machined shapes. As a result, when employing impellers of known designs, it is necessary to provide larger and consequently more expensive pumps when employed in the aforementioned high volume applications. The enlarged size of the pump results from increasing the overall size of the impeller and reducing the rotative speed thereof in order to utilize a low specific speed impeller, which can be fabricated from vanes of simple curvature by presently known design and manufacturing techniques.

For purposes of this invention a singly curved blade surface is defined to comprise a blade member curved along its longitudinal dimension and wherein each transverse section through the blade defines a straight line. In other words, a singly curved surface is the surface described by a transverse straight line following a planar curve.

In view of the foregoing, an object of the present invention is to provide a novel and efficient pumping.

Another object of the invention is to provide a pumping impeller of the character described adapted for high volume pumping applications.

A further object of the invention is to provide a novel impeller wherein the component parts thereof are formed with surfaces of simple or single curvature.

More specifically, it is an object of the invention to provide a pumping impeller adapted for high pumping volume or high specific speed applications but fabricated from components having surfaces of simple curvature.

Still another object of the invention is to provide a high specific speed impeller whose vanes or blades are arranged in a novel manner and whose surfaces can be forged and machined readily.

These and other objects, features and advantages of the invention will be exemplified in greater detail during the forthcoming description of the invention with the description being taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a longitudinally sectioned view of a motor-pump unit employing the improved impeller of the invention;

FIG. 2 is an enlarged, sectional view of the impeller illustrated in FIG. 1;

FIG. 3 is an enlarged sectioned partial view taken along lines III—III of FIG. 2; and

FIG. 4 is an enlarged sectioned partial view taken along lines IV—IV of FIG. 2.

In accordance with the invention, a pumping impeller is provided with a novel vane arrangement whereby the impeller can be adapted for application requiring large pumping volumes, without the necessity of employing vanes having a double curvature, which curvature obviously cannot readily be machined. The disposition of the vanes of the impeller is such that the differences in "tip speed" or rotative speed of various portions of inlet edges across the combined width or height of the impeller blades is compensated at the various locations within the eye or intake opening of the impeller. As will be described subsequently, these differences in tip speed dictate differing inlet angles across the combined width of the impeller blades. More specifically, in accordance with the invention, the aforesaid vanes are provided with appropriate singly curved surfaces and are arranged in number and in configuration as to be most efficient in handling the pumped fluid in that portion of the impeller eye which communicates with these vanes. Additionally, the impeller of the invention is provided with means for dividing portions of the incoming fluid being pumped in an appropriate manner among certain ones of the aforesaid vanes, when grouped in accordance with the invention.

Referring now more particularly to the drawings, the pumping impeller of the invention is illustrated in FIG. 1 in connection with an hermetically sealed motor-pump unit indicated generally by the reference character **20**. In this application of the invention, a windingless rotor **22** is mounted upon a driving shaft **24** and is hermetically sealed within a rotor "can" or enclosure **26**. The aforesaid rotor and shaft are mounted for rotation within a motor housing **28** and coaxially of a hollow stator assembly **30** also mounted within the housing **28**. The driving shaft **24** is supported adjacent its ends on suitable antifrictional means, for example, the journal or sleeve type bearings **32** and **34**. The driving shaft **24** extends through the lower bearing **34** and terminates within a pump casing **36**, which is secured to the motor casing **28**. The driving shaft **24** is joined to an impeller **38** which is thus mounted for rotation within the pump casing **36**. In this arrangement, the impeller is secured to the lower end of the shaft **24** by means of a mounting nut **39** threaded to a stud portion **41** of the driving shaft **24**.

Suitable labyrinthine seals **40** and **42** are mounted in the pump casing **36** at positions adjacent the driving shaft **24** and the hub **44** of the impeller **38**, respectively. The aforementioned seals **40** and **42** are employed, when the rotor is immersed in the fluid being pumped and maintained at elevated temperatures, to prevent more than pressure-equalizing seepage of the material handled by the motor-pump unit from passing from the pump casing 36 into the rotor cavity 46, and thereby to prevent transfer of heat from the pump casing to the motor section. In the case of slurry pumps, the labyrinthine seals 40 and 42 permit limited flow into the pump casing 36 of a purging fluid employed to flush slurry particles out of the rotor cavity and associated components. In this example, the purging fluid is derived from the rotor coolant which is supplied by means of conduits 56 and 58 and which is desirably the vehicle or carrier of the slurry being pumped. The coolant is maintained at a slightly higher pressure than that within the pump casing 36 to ensure the purging flow will be downwardly toward the pump casing and not vice versa. A similar labyrinthine seal 48 is provided adjacent the eye 50 of the impeller 38 in order to prevent the fluid leaving the impeller 38 from passing back into the stream of incoming fluid which enters the motor pump unit 20 through the pumping inlet port 52. The fluid handled by the pump is conveyed out of the pump casing 36 thereof by means of an outlet port 54. When the motor-pump unit 20 is employed in hermetically sealed systems, the inlet and outlet ports 52 and 54 can be seal-welded into the system or otherwise hermetically sealed thereto, in a known manner.

One of the upper labyrinthine seals 42 is disposed such that it engages a seal runner 45, which is secured to the hub 44 of the impeller 38 and to the upper shroud 64 thereof presently to be described. A cavity 47 is formed in a wall portion of the pump casing 36 at a position immediately above the seal runner 45. This cavity 47 is isolated from the rotor cavity 46 and from the interior of the pump casing 36 by means of the labyrinthine seals 40 and 42, but communicates with the interior of the impeller 38 through a connecting port 49 formed in the impeller adjacent its hub 44. During operation of the motor-pump unit 20, the movement of fluid through the impeller 38 at a substantial angle to the connecting port 49 applies suction to the top of the impeller 38. This suction counteracts the normal downthrust of the impeller caused by its drawing fluid upwardly into the eye 50 thereof.

In the operation of the motor pump, the rotor 24 usually is immersed, as aforesaid in a cooling medium which is supplied to the rotor chamber 46 by means of the conduits 56 and 58. The fluid thus circulated through the rotor chamber 46 serves to remove electrical losses in the form of heat from the rotor 22 and from the stator 30, which the coolant is prevented from contacting directly by means of a hermetically sealed stator "can" or enclosure 60. Additionally, cooling is afforded the stator 30 by means of a water jacket or the like denoted generally by the references character 61. A suitable coolant is circulated through the jacket 61 by means of the inlet and outlet parts 63 and 65.

Referring now to FIGS. 2, 3, and 4 of the drawings, the pumping impeller 38 of the invention is illustrated therein in greater detail. In addition to the impeller hub 44 and the eye 50 noted heretofore, the impeller 38 comprises a lower shroud member 62 and an upper shroud member 64. Interposed between the lower and upper shroud members 62 and 64 is a center piece 66 which is supported in this example between two groups of impeller vanes 68 and 70. More specifically, the groups of vanes 68 and 70 are inserted individually and secured as by welding into series of grooves 69, 71 and 73 formed in adjacent surfaces of the lower shroud member 62, the center piece 66 and the upper shroud member 64, respectively. Alternatively, the vanes 68 and 70 can be formed integrally with the center piece 66 by machining, particularly in the case of a very hard material such as titanium, which cannot be cast or welded readily. Mounting of the vanes 68 and 70 in this manner serves not only to secure the vanes but also to position the center piece 66 intermediate the upper and lower shroud members 64 and 62 as aforesaid.

The major portion of the center piece 66 comprises a substantially flat annular disk 72 to which is secured a flow spliting member 74. More specifically, the splitting member 74 in this example is joined integrally with the annular disk 72 adjacent the inner periphery thereof and protrudes generally at right angles thereto toward the eye 50 of the impeller 38. In this example of the invention, the inner wall surface 76 of the splitting member lies substantially parallel to the direction of fluid flow adjacent the entrance of the eye 50. On the other hand, the outer wall surface 78 of the splitting member is inclined at an angle to the inner wall surface 76, such that the member tapers to a circular edge 80 disposed adjacent the eye 50 of the impeller. The center piece 66 including the splitting member 74 thus is disposed to divide the incoming fluid which is being pumped between the two groups of vanes 68 and 70 as indicated by flow arrows 82 and 84, respectively. Thus, the outer fluid stream represented by the arrow 82 is directed between the inclined surface 78 of the splitting member 74 and the inner wall surface 79 of the eye 50 to the group of vanes 68 while the inner stream of the incoming fluid as represented by arrow 84 is directed between the inner surface 76 of the splitting member and the arcuate outer surface 85 of the impeller mounting nut 39 to the other group of vanes 70. The diameter of the circular edge 80 of the splitting member is selected desirably that the inner stream 84 is about equal in volume to the annular outer stream 82.

That portion of the fluid flow represented by the arrow 84 and comprising the fluid flowing adjacent the central axis 86 of the eye 50 and the intake port 52 (FIG. 1) is conducted during operation of the pump to the upper group of vanes 70. Because of their greater distance from the eye 50 of the impeller 38, greater lengths 88 of the individual vanes 70 can be employed. Such lengths of course, result in a lower tip speed, or angular velocity of the inlet edges 90 since these edges are disposed at positions close to the axis 86 of the impeller, and consequently, a larger inlet angle 92 (FIG. 4) can be employed.

On the other hand, the annular outer stream, designated by the flow arrow 82, is directed to the lower group of vanes 68. Inasmuch as the latter group of vanes are adjacent the eye 50 of the impeller 38, their individual lengths 94 are limited by the inside diameter 96 of the eye 50, which determines the volumetric capacity of the pump, and by the average outside diameter 98 of the impeller 38, which determines the operating head of the pump. Consequently, inlet edges 100 of the vanes 68 are traveling at a greater tip speed during operation of the pump, and a smaller inlet angle 102 (FIG. 3) desirably is employed. The lengths 94 of the individual lower vanes 68 are increased, in this example of the invention, including the inlet edges 100 and outlet edges 104 of the lower vanes vanes 68, respectively, at an angle 108 to the axis 86 of the impeller. Otherwise the length of the smaller vanes 68 would be limited as shown by dashed lines 110. Usage of a greater length of vanes is desirable in order to reduce insofar as possible the number of individual vanes in each group of vanes 68 or 70 as described hereinafter more fully. In addition, the inlet edges 90 and the outlet edges 106 of the upper vanes 70 are complementarily inclined in order to provide a continuous outlet surface for the impeller 38. The angle of inclination is made relatively small such that the slight variations in tip sped along the inlet edges 100 and 90 of the vanes 68 and 70, respectively, do not materially affect the operating characteristics of the impeller disclosed herein.

Since the streams 82 and 84 are substantially equal in volume as aforesaid, the proportions of the pumped fluid being handled by the groups of vanes **68** and **70**, respectively, likewise are about equal. Therefore, widths **112** and **114** of the lower and upper groups of vanes are substantially equal in this arrangement. Moreover, a comparison of FIGS. 3 and 4 will show that outlet angles **116** and **118** of the vanes **68** and **70** respectively, are approximately equal. This design condition is selected due to the fact that the outlet edges **104** and **106** are very nearly equidistant from the axis **86** of the impeller.

As described heretofore, the arrangement of the impeller vanes or blades into two groups **68** and **70** of vanes permits utilization of singly curved surfaces **120** and **122**, respectively. The individual radii **124** and **126** of curvature of these surfaces are determined more or less empirically by the degrees of arc required to connect the inlet and outlet edges of each vanes **68** or **70** when disposed at the appropriate inlet and outlet angles described heretofore, and measured from circles drawn concentric with the axis **86** of the impeller and tangent to the respective inlet and outlet edges **100**, **90** and **104**, **106**. Because of the larger inlet angles **92** of the upper group of vanes **70**, the singly curved surfaces **122** of these vanes are furnished with smaller radii **126** of curvature.

The number and distance between the blades or vanes of each group **68** or **70** are determined from the following relationship:

$$\frac{L}{T}=K$$

where,

L=the maximum arcuate length of each vane

T=the minimum arcuate distance between the outlet edges of an adjacent pair of vanes, as measured along the average outside diameter of each group of vanes, and

K=the optimum ratio of L to T for a given pumping application.

Usage of such relationships is well-known for establishing details of impeller design and further elaboration thereon appears unnecessary. Suffice it to say, however, that the individual L and T dimensions of the lower vanes **68** are designated as L, and T (FIG. 3) and of the upper vanes **70**, L_2 and T_2 (FIG. 4). The optimum ratio K is substantially the same for each group of vanes **68** or **70** and lies in the neighborhood of 1.5 in this example. From these considerations and from the available lengths **94** and **88** of the respective vanes **68** and **70** it has been determined in this exemplary arrangement that about thirteen of the relatively shorter, lower blades **68** and about nine of the relatively longer, upper blades **70** represent the optimum condition.

From the foregoing, it will be apparent that a novel and efficient impeller **38** has been disclosed herein. The impeller of the invention is adapted specially for use in high volume pumping applications and with highly corrosive or errosive fluids. Consequently, the invention permits a high volume impeller to be fabricated from components having relatively easily machined configurations. More particularly the invention permits a high volume or high specific speed pumping impeller to be fabricated with vanes or blades having singly curved surfaces. The descriptive material employed herein in disclosing the invention is presented for illustrative purposes only, and therefore, is not to be construed as limitative of the invention.

Accordingly, numerous modifications of the invention will appear to those skilled in the art to which it pertains without departing from the spirit and scope of the invention. For example, three or more individual groups of vanes can be employed instead of the two groups of vanes **68** and **70**, by utilizing, for example, two or more of the center pieces **66** and associated splitting members **74**. With the latter arrangement, the incoming fluid being pumped can be divided among three or more groups of blades in which the differing tip speeds and inlet angles of the respective groups are compensated still further, and the individual vanes of the impeller can be designed to approach still more closely the theoretical optimum efficiency thereof, especially when vanes of single curvature must be utilized.

Therefore, what is claimed as new is:

1. In a pumping impeller, the combination comprising means for dividing the incoming fluid being pumped into at least two streams, a like number of groups of vanes, each of said vanes having singly curved surfaces and means for mounting said vanes to intercept said streams respectively, the vanes of one of said groups having relatively longer radii of curvature than that of the remaining vanes.

2. A pumping impeller comprising a plurality of groups of vanes, each of said vanes having singly curved surfaces, said impeller forming an intake port, means for dividing intake fluid entering said port into a like number of streams, means for mounting said groups in tandem array relative to said port, the vanes in that group farther removed from said port having a greater length than that of nearer vanes, the inlet edges of said longer vanes being disposed closer to the axial center line of said impeller than the corresponding edges of the remaining vanes, said inlet edges of said longer vanes forming relatively larger inlet angles with the direction of intake flow of said fluid at said edges than the corresponding edges of said nearer vanes, and means for conducting said streams to said groups of vanes, respectively.

3. A pumping impeller comprising a plurality of groups of vanes, each of said vanes having singly curved surfaces, said impeller forming an intake port, means for dividing intake fluid entering said port into a like number of streams, means for mounting said groups in tandem array relative to said port, the vanes in that group farther removed from said port having their inlet edges disposed relatively closer to the axis of said impeller and having their inlet edges forming relatively larger angles than the corresponding edges of said nearer vanes with the direction of intake fluid flow adjacent said edges.

4. A pumping impeller comprising a plurality of groups of vanes, each of said vanes having singly curved surfaces, said impeller forming an intake port, means for dividing intake fluid entering said port into a like number of streams, means for mounting said groups in tandem array relative to said port, the vanes in that group farther removed from said port having a greater length than that of nearer vanes, the inlet edges of said longer vanes being disposed closer to the axial center line of said impeller than the corresponding edges of the remaining vanes, said inlet edges of said longer vanes forming relatively larger inlet angles with the direction of flow of said intake fluid adjacent said edges than the corresponding edges of said nearer vanes, and means for conducting said streams to said groups of vanes, respectively, the outlet edges of each group of vanes forming approximately equal angles with the outer peripheral surface of said impeller.

5. In a pumping impeller, the combination comprising a plurality of groups of impeller vanes, each of said vanes having singly curved surfaces, means for dividing the incoming fluid being pumped into a like number of streams and means for mounting said groups of vanes to intercept said streams respectively, the inlet and outlet edges of each of said vanes being inclined at substantially the same angle to the axis of said impeller to increase effectively the length of at least some of said vanes.

6. In a pumping impeller, the combination comprising a plurality of groups of impeller vanes, means for dividing the incoming fluid being pumped into a like number of streams, means for mounting said groups of vanes to intercept said streams respectively, each of said vanes

having singly curved surfaces, the outlet and inlet edges of each of said vanes being inclined at substantially the same angle to the axis of said impeller to increase effectively the length of at least some of said vanes, and the inclinations of said outlet edges of said groups being substantially colinear so that variations in exit flow conditions along the height of said impeller are minimized.

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