Sept. 29, 1964 E. UMBRICHT ETAL 3,150,467

HYDRAULIC SURFACE TREATING PROCESS AND EQUIPMENT

Filed Feb. 19, 1960 2 Sheets-Sheet 1

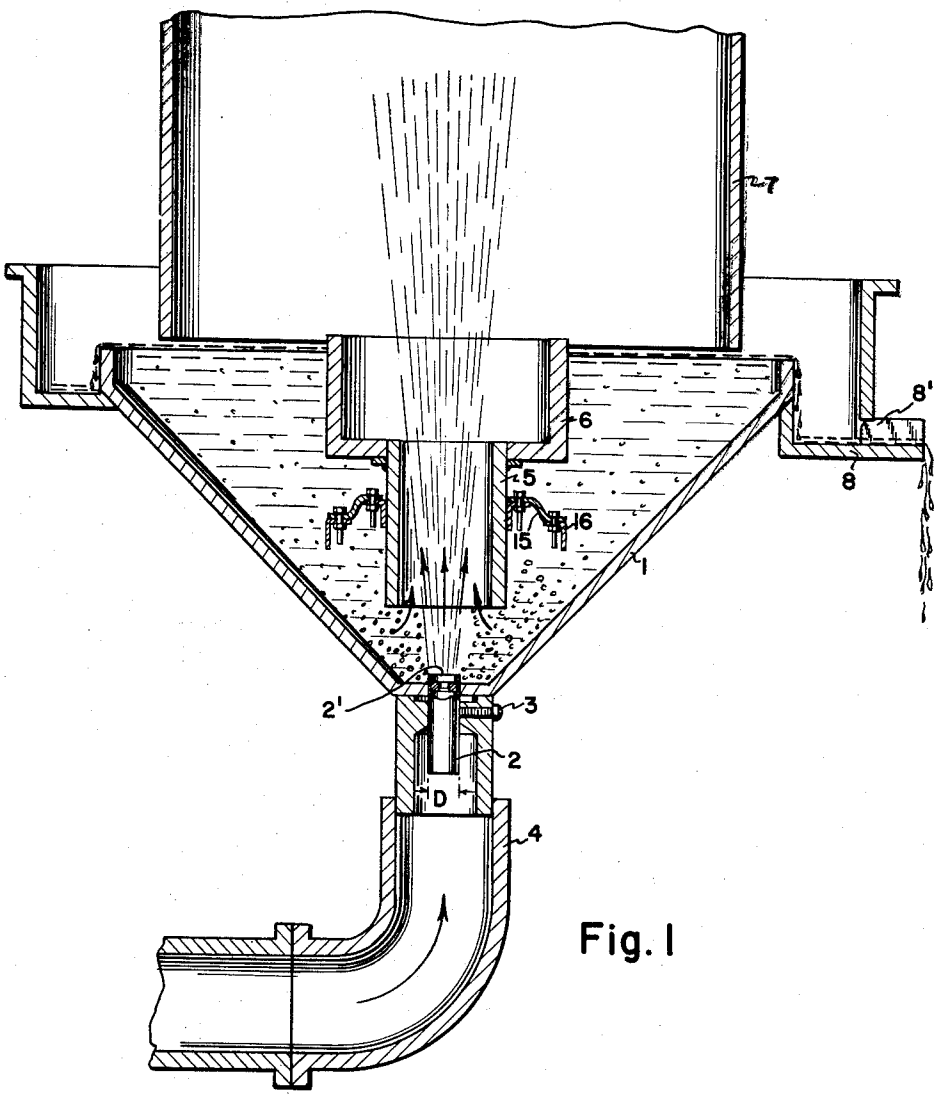


Fig. 1

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2 Sheets-Sheet 2

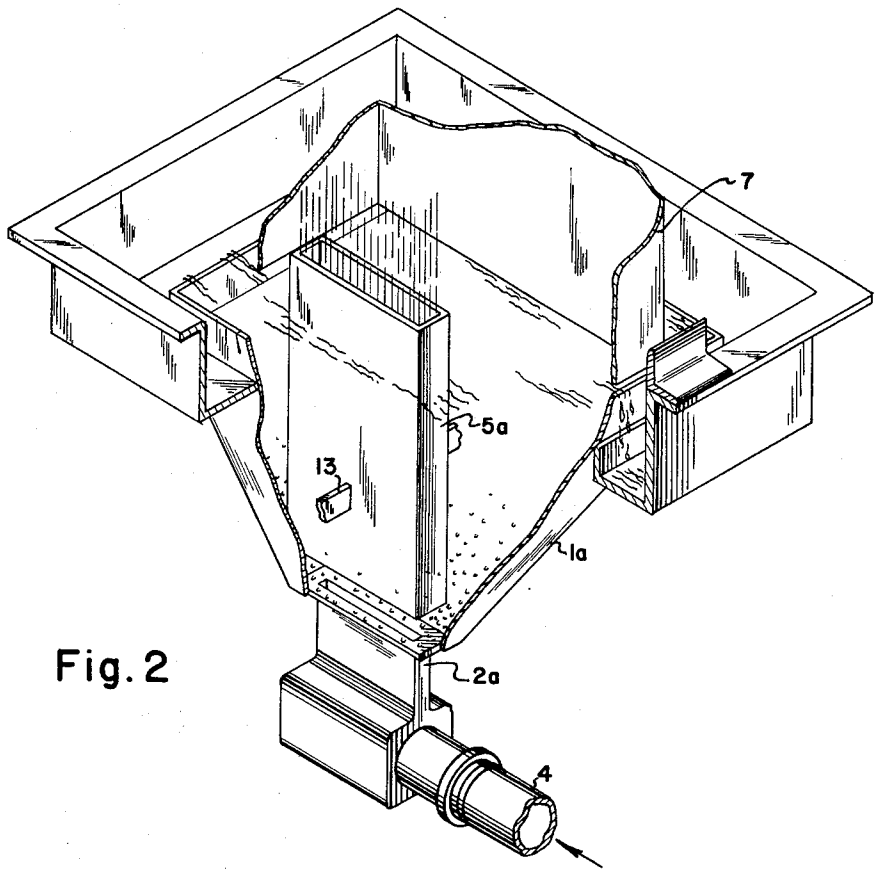


Fig. 2

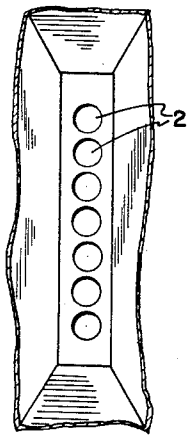


Fig. 3

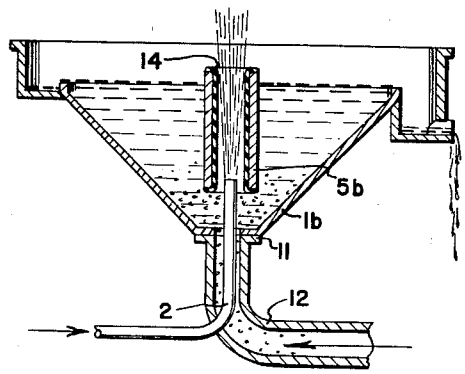


Fig. 4

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3,150,467 HYDRAULIC SURFACE TREATING PROCESS AND EQUIPMENT

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15 Claims. (Cl. 51—8)

This invention relates to a process and apparatus for abrasive grinding, polishing, compacting, trimming or other surface altering of particles. The invention utilizes hydraulic means for imparting the required energy to abrasive or surface altering particles e.g., abrasive grains or "blasting grit" or shot-peening, which are used in the invention. More particularly the invention includes automatic reclamation and classification of cleaned surface treating particles in the same equipment which is used for the abrading or peening or other surface altering of the articles.

There is a serious problem in thus altering the surface of materials, for example, for removing flash, sprue and other protrusions from cast metal or plastic articles, the removal of scale from heat treated metal articles, the preparation of predetermined surfaces on metals by abrading or other compacting or polishing means and the altering of surfaces of metal articles by processes which reform the surface e.g., by abrading away undesired surface material or altering molecular or crystalline arrangements on the surface material. Typical of the last type of surface treatment is a shot peening process.

All of the operations referred to above require reforming of the surface of the article—i.e., displacement and actual removal of portions of the article itself or such energetic treatment of the surface as to alter its crystal or molecular arrangements and/or other characteristics. The procedures have in common the requirement that solid particles whether abrasive particles or peening particles must be supplied with a high degree of energy so that they can reform the surface even in material of considerable hardness and strength such as metals. Such surface treatment will be generally referred to as "reforming."

One type of process for surface reforming which has been used for a great many decades is exemplified by sand blasting. In early use of this method the high kinetic energy was imparted to the solid particles by compressed air. This process is still used but presents serious industrial hazards when used in confined spaces and for the cleaning of metals.

The dust and fire hazards can be eliminated by use of a liquid stream instead of an air stream; but attempts to utilize this commercially leaves much to be desired. The recovery of abrasive grains presents problems and the transport of the grains, e.g., through conduits is subject to clogging of relatively small passages and to abrasive damage to the equipment.

An entirely different problem is presented by the cleaning of bottles and other articles the surface of which is not to be cut or otherwise reformed. In such cases very moderate speed jets of water have been introduced into or immediately below guide tubes communicating with the bottom of a hopper or tank containing water and the soft grains to act as scrubbers. In the case of bottle washing machines, for example, a long tube extending up into the bottle projects a liquid stream entraining lead shot or rubber balls. A similar procedure has even been used for the cleaning of automobiles, small pieces of rubber sponge or similar soft, easily deformable materials being used as the scrubbers. All of these require relatively large volumes of water, and effect no reforming of the surface. These two problems have been separate and completely non-analogous. Wherever high velocity surface reforming grains have been involved, blasting by a gun technique has been used.

According to the present invention, very high speed jets of liquid can be made to entrain and accelerate a liquid mass of suspended surface reforming grains. For example, such grains can be settled in a carrier liquid in the bottom portion of a truncated conical hopper (or similar container), and thus concentrated solids can be entrained into a blasting stream by ejector action of a high velocity jet directed into a guide tube (referred to in the claims as a conduit) which surrounds the high velocity stream to a level above the surface of liquid in the hopper. Thus the surface reforming grains can be projected from the guide tube in a fluid stream with high speed. The velocities used may be varied to suit particular conditions and requirements but in general are so high that the surface-reforming grains carried therein acquire a kinetic energy sufficient for the desired abrading or peening purposes.

There is advantage in use of very high velocities in the liquid blasting or shot peening. If the surface-reforming grains are merely entrained in a high velocity liquid, excess liquid may interfere with the optimum action of the grains, but by using ultra high velocity ejector jets, it is possible to impart higher energy to the grains without excessive volume of liquid. Throughout this specification and its claims this high energy will be referred to as sufficiently high to effect surface reforming.

In the case of removing surface material, e.g., flash, sprue or other undesired projections, or descaling or deburring, there is actual removal of substantial portions of the material from the surface treated. In the case of peening processes the surface is reformed by changing its surface micro-structure, although the reformation may be sufficiently uniform that the change may not be apparent to the eye. Of course, in some peening operations also there is actual removal, e.g., knocking off, of portions of the treated surface such as brittle scale or small protrusions. Thus, for example, the invention can perform a dual function of descaling and peening. In other words, scale can be removed and the remaining surface micro-structure changed by the same operation. In both cases the surface is being reformed in the sense referred to above.

Not only has it been found practical to develop the high energy abrading or other surface reforming effects in equipment of the type described, but it is possible by using the present invention to have the equipment perform a dual function. The hopper or container not only provides a reservoir for the suspension of surface-reforming grains, but it also collects the drain-back material from the article being treated; and it can serve also as a continuous hydraulic separator. By means of this separator, the excess of water, which is added by the high velocity jets to impart the very high energy to the surface-reforming grains, is utilized for washing and hydraulic classifying of the recovered grains and is then drawn off in quiescent condition carrying the more readily suspended "dirt," while the surface-reforming grains settle in the hopper. When the spent material returns into a hopper, it displaces excess liquid which continuously overflows, advantageously over the entire periphery of the hopper.

The length of the overflowing edge may be increased to reduce the velocity of flow, e.g., by use of a larger hopper. In other words the hopper behaves as a free settling classifier of particles in an hydraulic system.

Several types of solid material may be carried in the spent liquids. For example, the portion of the surface removed from the article being treated (e.g., scale, flash, sprue, burrs and the like) comes off as particles which are sometimes considerably larger and sometimes con-

siderably smaller than the blasting grains. Mold sand which had adhered to castings, chip and filings on machined parts, ordinary dirt and oil, etc., may also be carried by the drain-off, and even the surface-reforming grains may be worn or shattered into fine particles. Such fines, for the most part, have sufficiently low settling rates so that they are washed away into overflow from the hopper.

Effective cleaning by such hydraulic classification is an important advantage of the present invention. By settling clean grains, they can be recycled for more surface reforming work, and still leave clean treated articles.

The separation of unwanted material from returned surface reforming grains is all the more surprising because the throughput in the process of the present invention is high and relatively large amounts of surface-reforming grains pass through the apparatus in a short time. Nevertheless the present invention effects good efficiency in reuse of the surface-reforming grains and satisfactory cleaning thereof. The reuse of these grains, moreover, subjects them to violent washing by the ejector jets while they are being accelerated and entrained by the liquid. Any dirt which may have adhered to the grains is thus washed off.

The nature of the surface-reforming grains used in the present invention depends substantially upon the result desired. When the surface reforming desired is abrading, the ordinary abrasive grains may be used such as, for example, sharp sand, grits of aluminum oxide, silicon carbide, iron grit, malleable grit, steel grit, hard alloy grits, or the like, or for more readily abraded surfaces, iron oxide grains. The reuse after hydraulic classification also permits effective use of some of the material removed from the surface itself.

When peening is desired, the grains used according to the present invention, may be hard, tough shot, e.g., of iron or steel alloys in the form of small spheres or a round grain coarse sand such as sea sand; or worn sands no longer sharp enough for abrasive blasting. These may be, for example, silica or zircon sands. They should not be confused with soft lead shot which have sometimes been used in bottle washing where the object is to prevent any possibility of surface alteration by abrasion, chipping or other reforming.

The shapes of the jets may vary. For small articles or articles with irregular surfaces round jets present many advantages. For other purposes, for example, descaling, peening or otherwise conditioning the surfaces of large articles, flat metal sheets, etc., a jet may advantageously be in the form of an extended ribbon, preferably oriented across the narrow dimension of the sheet or other article to be blasted, which can then be moved thereover. In the case of a wide ribbon jet the jet orifice, or nozzle, is, of course, of narrow more or less rectangular shape. A similar effect can be produced with a series of ejector jets closely spaced side by side.

With round jets, greater uniformity can be obtained by using a guide tube with a cross-section smaller at the lower end where the high speed ejector jet draws in the recycled grains and an enlargement at a higher level which enables the column of liquid to break free of friction with the tube wall 5, etc. Guide tubes of uniform cross-section may be used with advantage in some cases; the invention is, of course, not limited to guide tubes of varying cross-section but in a more specific aspect the use of such expanded cross-section is to be regarded as a specific feature of the invention.

It should be pointed out that the high effectiveness of the process and apparatus of the present invention is obtained without introducing severe maintenance problems. The only portion of the apparatus which is exposed to high speed flow of the solid particles is the guide tube, and it is advantageously large enough so that such abrasive action is light. This tube may be made of highly abrasion-resistant materials, such as very hard iron alloys

or tough rubber, and can be made readily replaceable. This greatly reduces the cost and problem of maintenance, and permits obtaining the other advantages of the present invention without offsetting economic disadvantages.

Water is the ordinary propelling liquid, but the invention will operate with other liquids of suitable gravity and viscosity to impel, and later to carry, the grains.

The jet of clear water or other non-abrasive liquid is combined with the abrasive material which is impelled thereby to high velocity in order to direct the resulting wet blast against the desired parts of the surface to be treated.

The confining walls are, of course, subject to some abrasion; but, since in practice of the present invention they need only be short tubes or equivalent inexpensive equipment, it is relatively unimportant that they may eventually wear out, as these parts subject to wear can, according to the present invention, be relatively cheap and designed for inexpensive replacement. Furthermore, wear in these parts can be minimized and in many cases almost completely eliminated by making the conduits with smooth continuous surfaces of a highly abrasion-resistant material such for example as Meehanite, or with a lining of abrasion-resistant rubber or similar elastomer. Such an elastomer lining can be made to snap into the short conduit with flanges fitting over the ends, so that replacement is only a matter of minutes. Even if wear occurs in this part, the resultant change in dimensions would not be critical, so that the part can be used until it is worn through.

The invention will be described in greater detail in conjunction with the drawings, in which—

FIG. 1 is a vertical section through the hopper portion of a simple apparatus for producing a round jet;

FIG. 2 is an isometric view, partly broken away, through an apparatus for producing a ribbon stream or jet;

FIG. 3 is a fragmentary detail in plan view of the bottom portion of the hopper of FIG. 2 showing a different nozzle form, and

FIG. 4 is a vertical section through a modified apparatus similar to FIG. 1.

In the apparatus of FIG. 1 the combined hopper and hydraulic purifier is shown as a container **1**. The hopper is in the form of a truncated cone. In the bottom there is adjustably mounted a jet tube **2** held by a set screw **3** and communicating with a pipe **4** from a source of clear water under high pressure. Above the jet tube **2** is a guide tube **5** which does not extend quite to the bottom of the hopper, but does extend above the liquid level. The liquid level is as shown in the hopper. The lower portion contains most of the suspension of the settled surface-altering grains.

At a higher level the guide tube is shown of enlarged cross-section **6** serving to hold back from the blast stream the liquid in the hopper, while releasing the stream from friction and the tube from abrasion. The smaller tube may be replaceable in the enlarged cup-like section, as shown, or the entire guide tube may be integral and replaceable as a unit.

The high velocity stream emerging from the tube **6** strikes an article (not shown) supported directly above it, the surface of which is to be treated.

After striking the article supported in the target zone, the spent blast liquid containing surface reforming grains and other materials carried in the original blast, and/or resulting from the treatment, is kept from scattering by a hood **7** and drains down into the hopper **1** causing an overflow at the periphery. The peripheral edge of the hopper is made level so that the overflow uses substantially the entire length of said edge, and a gutter **8**, which collects the overflow, is sloped toward its outlet. The effluent may be run off to a settling basin or pond in which any remaining abrasive is allowed to settle out before it is pumped. This overflow carries with it particles

having lower settling rates, such as fines, low specific gravity particles and flaky particles, the surface-reforming grains settle and are reused. Makeup grains, and chemical agents, if used, are introduced into the hopper as required.

FIGS. 2 and 3 show a modified apparatus in which the same parts bear the same reference numerals. Instead of a single round jet tube **2** there is either a narrow slot **2***a*, (see FIG. 2), or a series of round jet **2** side by side, (see FIG. 3). The guide tube **5** is of circular cross section in FIG. 1, and of narrow rectangular section, as clearly illustrated in FIG. 2. It is positioned in the hopper by the spider **13**.

The operation of the modified device of FIGS. 2 and 3 produces a ribbon blast with the surface reforming-grains impelled to high velocity for treatment of extended surfaces such as flat sheets of metal or articles having broad surfaces which may be moved over the jet.

FIG. 4 illustrates another modification of the basic apparatus shown in FIG. 1. Instead of returning all of the surface reforming particles to the hopper and allowing them to sink to or near the bottom of the guide tube **5**, where they are picked up again by the jet of liquid, only a part of the blasting grains is returned to the bottom of hopper **1***b*, and there is provided a large supply pipe **12** entering the bottom of the hopper through an annular member **11**. The jet pipe **2** is made coaxial with the supply pipe **12** but extends beyond it in the bottom of the hopper **1***b*. The pipe **12** communicates with a source producing a low velocity pump and mixer (not shown) whereby it feeds to the hopper a stream of a suspension of surface-reforming grains. Due to the low velocity of this stream, there is little abrasion in pipe **12**, but at the guide tube **5***b* the high velocity ejector jet **2** accelerates the grains to the high energy required for the desired surface-reforming. The operation on the article is as in FIG. 1; but a somewhat more precise control is made possible. As shown only the most rapidly settling particles will be recycled through hopper **1***b* into the blast stream in **5***b* but it is also feasible to omit the hopper **1***b* and merely reduce the size of guide tube **5***b* in the zone where the stream is accelerated by the jet **2**, so that the high velocity can be attained in the blast stream with a low velocity in pipe **12**.

FIG. 4 also illustrates the use of guide tube **5***b* of uniform cross-section and also the use of a snap-in lining **14** of abrasion resistant rubber or the like. This lining being held in place by its own resiliency is readily inserted and as readily stripped out and replaced when worn.

While it is an advantage that equipment of various sizes and designs may be used in the present invention, for optimum results some of the proportions of the elements are of importance. Turning to FIG. 1 and designating the diameter of a jet tube **2** as D, the spacing of the guide tube **5** from the bottom of the hopper is advantageously in the range from 1D to 20D, with the top of jet tube **2** advantageously well above the bottom point of the hopper, but advantageously below the guide tube by about ½D to 20D. The diameter of guide tube **5** may vary from 2D to 4D. The length of the smaller (ejector) section of tube **5** may be only enough to give the ejector action with the jet from tube **2**, although greater length is permissible. The cross-section of the enlarged portion **6** is not critical, but it has the practical limit that it must not be so large as to unduly reduce the settling area. It should be wide enough to assure freedom of the final jet emerging from the lower ejector sections, and it must be high enough to be above the liquid level in the hopper so as to keep the liquid in the hopper away from the emerging jet.

In one specific example, the jet tube **2** may be a 1¼" pipe nipple with a washer forming orifice **2'** welded into its upper end, as shown in FIG. 1. The orifice is ⅝" diameter. The guide tube **5** is 1½" outside diameter and

1" bore and about 10" long and spaced about 2" above the bottom of the hopper **1** around the jet tube **2**.

The enlarged tube portion **6** is about 5" diameter and extends upward about 10" above the top of the narrow guide tube **5** and about 1" above the liquid level in hopper **1**. Tube **6** may terminate a little below the liquid level but one then has to depend on the jet action to clear the tube and hold back the blast. The liquid depth in the hopper is shown about 20" and the width of the hopper is about 3', but wide variations in size are permissible. In this particular example operated with 60 p.s.i. in the pipe **4**, the velocity of the water leaving the orifice **2'** at the top of jet tube **2** was 4510 feet per minute and the velocity of the liquid blast leaving the top of tube **6** was 2510 feet per minute. Results with these pressure and velocity conditions were very satisfactory, but it was found that increasing the jet velocity to two or three times as high increases the effectiveness especially for deburring and abrading operations. In practical applications velocities have been used ranging from 2,200 to 11,300 feet per minute with pressures from 60 to 120 p.s.i.; but the permissible range is much wider. The desired velocities depend so much on other factors including the nature of the base metal, whether soft or hard, the extraneous surfaces to be removed in the deburring operation, the size, hardness density and shape of the abrasive particles. For instance, with soft metal softer abrasive in finer particles might be desired to prepare a surface to the proper condition while with hardened surfaces much larger abrasive particles with greater mass and/or abrading ability and generally harder characteristics are employed. With these wide variations of conditions to be met as well as the other operating factors, a wide range of velocities may be employed. It is believed that the velocities of liquid emerging from the jet tubes may be selected within the range from 700 feet per minute to 100,00 feet per minute. Pressures in the jet pipe can be as high as 30,000 p.s.i. or for reforming some materials as low as 1 p.s.i., but in practical use the range is advantageously kept below about 375 p.s.i. With any specific pressure from the pump and orifice system, the velocities of liquid emerging from the blast tube may be high or small depending upon the size of the blast tube and other accompanying conditions. In various applications of the hydraulic jet-impelled abrasive-suspended-in-liquid method velocities in the blast tube may be selected within the range 600 feet per minute to 90,000 feet per minute to arrive at successful conditions on specific abrading or deburring operations.

On a hard material such as cast iron or a fairly hard steel, good conditions are found to be an orifice velocity of 11,000 feet per minute.

The dimensions set out above for FIG. 1 are applicable also to the ribbon type spray apparatus of FIGS. 2 to 5 by considering "D" as the smaller of the two dimensions of the slot **2***a* and similarly the diameter of the rectangular guide **2** as being the smaller of the two dimensions.

The pressure at which liquid is supplied to the jet **2** drives it out through orifice **2'** at such high velocity as to impart the necessary kinetic energy to the surface-reforming grains which flow into the guide tube **5**. The ejector action of the jet **2** in the guide tube causes a substantially solid stream of slurry of the surface-reforming grains to be driven upward from tube **5** against the surface to be treated, and it spreads out only slightly (e.g., about 15°) when it is freed from the tube **5**.

It is advantageous to have the surface to be treated positioned in a target zone quite close to the end of the guide tube, e.g., about 6" but it is not essential, so long as it is not so far away that the energy of the grains is seriously dissipated, e.g., in some cases 36" is found satisfactory. This greater distance of course may require greater initial velocity and/or a greater volume in the blast stream.

The relative volumes in the blast and in the settling

hopper and the velocity of the blast are adjusted so that a concentrated slurry of the surface-reforming grains is maintained in the bottom of the hopper to a level well above the bottom of guide tube 5 e.g., to a depth of several inches to a foot or more. To facilitate this for different operations, guide tube 5 may be adjustable vertically in clamp-bracket 15 mounted on fixed supporting bars 16.

The above dimensions and velocities and pressures may be affected by other conditions, as will be clear to those skilled in this art. Thus, if the viscosity of the liquid used in the hopper 1 and the jet 2 is changed, a change in the kinetic energy will follow. Thus a corresponding change in the liquid velocity may be made; and the ability of the liquid to entrain the surface reforming grains can be controlled as required.

Change in the specific gravity of the liquid—whether by substitution of a different liquid or by additives—will affect both the buoyancy (and consequently the settling rates) of the grains in the liquid and the kinetic energy of the liquid blast when it strikes the surface being treated.

In most commercial installations more than one jet will be needed, and several of these can be included in the same tank (1, 1*a*, 1*b*, etc.). The shape of the tank will depend in part upon the nature of the surface being treated and the number of blasts required. Ordinarily a sloping bottom as shown is advantageous to facilitate concentrating of a slurry near the jet, but such concentration can be effected in a supplemental apparatus or settling may be to a more or less flat bottom with mechanical scraper device to gather the settled solids.

The location of the orifice of jet tube 2 can be varied from below the bottom of tank 1 flush with the bottom, between the bottom and the lower end of guide tube 5 and within the guide tube. The important point is that it is located to give a maximum jet action, i.e., acceleration to the surface-treating grains which pass through the guide tube 5 into the blast on the surface being treated.

Depending upon the efficiency of the jet action, a greater or less amount of clear liquid has to be pumped into the jet, and an equal amount is drained out of the system. A certain amount of this is necessary to wash out the dirt and broken down abrasive etc., and to make up for inevitable losses of liquid but beyond that it is undesirable and I have found that good efficiencies are maintained with ratios of about 0.65/1 to 1.5/1, or advantageously 1/1 to 1.5/1, recycled slurry to fresh liquid in the jet.

From the foregoing, it will be apparent that the present invention provides a novel process for hydraulic surface treatment for abrasive cutting, trimming or surface altering of articles.

Although there is shown in the drawings and described above an embodiment of this invention and certain alternatives and indicated ranges of variation, it will be understood that these are not exhaustive but are given rather to aid others skilled in the art in adapting and modifying the invention so as to be best suited to the conditions and requirements of each particular use.

We claim:

1. In apparatus for hydraulic blasting "reforming" of surfaces by surface reforming impact with hard blasting grains hydraulically jet impelled against said surface with surface reforming velocity and kinetic energy, the combination which comprises a target area where said surface reforming is to be effected, an open ended conduit spaced from said target area and directed theretoward for conducting a hydraulic blasting jet stream to said target area, a container around said conduit and spaced adjacent one end thereof forming a reservoir for maintaining a supply of said hard blasting grains as a liquid slurry for admixture in a jet stream, high velocity and high pressure liquid jet means spaced from and directed into said conduit for providing a high velocity high pressure liquid jet through said supply of blasting grains in said reservoir and into said conduit for entraining said blasting grains in said jet and for impelling said grains through said conduit and against said surface in said target area with said reforming velocity and kinetic energy for impinging on said surface to effect said reforming thereof, and means for supplying said liquid to said jet means at said high pressure for providing said hydraulic blasting jet flow.

2. Apparatus as recited in claim 1 in which said container also extends throughout the transverse extent of said target area for providing a collection zone to receive liquid and blasting grains and material actually removed from said surface after said hydraulic blasting thereof.

3. Apparatus as recited in claim 2 in which said container also includes means for effecting differential settling of said blasting grains and said removed material through said liquid therein for separating said removed material from said blasting grains and for returning said separated blasting grains to said supply thereof adjacent said conduit, and overflow means for withdrawing from said container a portion of said liquid with said removed material suspended therein after said blasting grains have settled therefrom.

4. An apparatus according to claim 1 in which the means for producing a high velocity jet are adapted to give the jet a ribbon shape, and the confining conduit is of narrow rectangular cross-section whereby a stream of suspended solids and liquid is produced in ribbon-like form.

5. An apparatus according to claim 4 in which the ribbon jet producing means includes a slit-shaped nozzle at the bottom of the container.

6. An apparatus according to claim 4 comprising means for introducing a suspension of surface-reforming solids in liquid at low velocity into the bottom of the container adjacent the high velocity liquid jet producing means.

7. An apparatus according to claim 4 in which the ribbon jet producing means includes a plurality of circular nozzles side by side in the bottom of the container.

8. An apparatus according to claim 1 in which the conduit is provided with an abrasion resisting inner surface.

9. An apparatus according to claim 1 comprising means for introducing a suspension of surface-reforming solids in liquid at low velocity into the bottom of the container adjacent the high velocity liquid jet producing means.

10. In a method for hydraulic blasting surface treatment of castings and molded articles and the like for "reforming" the surface thereof by displacement and actual removal or altering the molecular structure of surface portions of the article by surface reforming impact with hard blasting grains hydraulically jet impelled against said surface of said article at a surface reforming velocity and kinetic energy, the steps which comprise positioning said article in a target zone for said hydraulic blasting and with the surface of said article to be reformed disposed to receive said blasting, forming a high velocity and high pressure liquid jet at a jet source spaced from said target zone and with said jet directed toward said target zone, and with said jet confined within an open-ended conduit spaced from both said jet and said target zone, maintaining as a reservoir adjacent said jet source a quantity of said blasting grains as a liquid slurry for said hydraulic blasting, directing said liquid jet through said reservoir of blasting grains for entraining in said liquid jet blasting grains from said reservoir thereof for impelling toward said surface of said article in said target area, impelling said grains against said surface to be reformed at a reforming velocity and pressure and kinetic energy, and effecting said reforming of said sur-

face of said article by impact of said jet-impelled grains against said surface.

11. The method of hydraulic blasting surface "reforming" as recited in claim 10 in which the velocity of said high velocity liquid jet is at least about 700 feet per minute for imparting to said impelled grains kinetic energy for said reforming.

12. The method of hydraulic blasting surface "reforming" as recited in claim 10 in which said article being reformed is metal and in which the pressure of said high pressure liquid jet is within the range of about 60 to 120 p.s.i. for imparting to said impelled grains kinetic energy for said reforming.

13. The method of hydraulic blasting surface "reforming" as recited in claim 10 in which the velocity of said high velocity liquid jet is at least about 2200 to 11,300 feet per minute for imparting to said impelled grains kinetic energy for said reforming.

14. The method of hydraulic blasting surface "reforming" as recited in claim 10 in which said entraining and impelling jet liquid is water supplied at a substantial high pressure up to about 375 p.s.i.

15. The method of hydraulic blasting surface "reforming" as recited in claim 10 which also includes steps of collecting said blasting grains and material actually removed from said surface of said article admixed with

said liquid in a collection zone after said impelling against said article, separating and withdrawing from said collection zone said material removed from said surface of said article, and returning said blasting grains from said collection zone to said reservoir of blasting grains adjacent said liquid jet source for subsequent impelling against said surface to be reformed.

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