Working-Cold Process
Shot Peening
Sept 1947

47000

Shot Peening Increases Life of Machinery Parts

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SHOT PEENING of machinery parts is a process for strengthening structural materials against failure by fatigue caused by frequent oscillations of stress, failure by impact, and for protection against fretting corrosion and against stress corrosion cracking.

The process is as the name implies — for instance in peening over a rivet head by a series of hammer blows, or indenting the metal surface by a series of hammer blows, rolling, and shooting the surface with a series of balls, etc. Since peening, if used, must be economical, it is found that shooting the surface with a series of balls or shot is the most logical method; the same as is applied in blast cleaning, sand blasting, shot and grit blasting, etc. In this method a large number of balls may be projected or thrown against a surface with a system and equipment already being used.

There are two systems now being used, namely (1) Air Blast, which uses compressed air to carry the round balls or shot through a tube and discharge them through a nozzle at relatively high velocity against the work surface; and (2) Centrifugal Blast, using a paddle wheel and throwing the balls or shot at relatively high velocity against the work surface.

The shot used in peening is generally a good quality of grey iron. In the making of shot, it is chilled, having a nominal hardness of 45-60 Rc. Shot may be had in sizes ranging from .007″ to .125″ diameter, and is graded according to Fig. 1.

Surface peening with shot is a cold working process and produces a series of small indentations

Fig. 1 — S.A.E. Standard Peening Shot Numbers Adopted by Subdivision on Shot Peening, Sept. 21, 1944

Prior to 1945	Shot Number	Min. To Max. Size	None on Screen No.	Max. On	Screen No.	Screen Aperture	Min. On	Screen No.	Screen Aperture	Max. On	Screen No.
	P 157	.157-.187	3½	2%	4	.187″	90%	5	0.157″	5%	6
	P 132	.132-.157	4	2%	5	.157	90%	6	0.132	5%	7
9	P 111	.111-.132	5	2%	6	.132	90%	7	0.111	5%	8
	P 93	.093-.111	6	2%	7	.111	90%	8	0.0937	5%	10
10C	P 78	.078-.093	7	2%	8	.0937	90%	10	0.0787	5%	12
	P 66	.066-.078	8	2%	10	.0787	90%	12	0.0661	5%	14
10											
12	P 55	.055-.066	10	5%	12	.0661	85%	14	0.0555	7%	16
14	P 46	.046-.055	12	5%	14	.0555	85%	16	0.0469	7%	18
16											
	P 39	.039-.046	14	5%	16	.0469	85%	18	0.0394	7%	20
20	P 33	.033-.039	16	5%	18	.0394	85%	20	0.0331	7%	25
	P 28	.028-.033	18	5%	20	.0331	80%	25	0.0280	12%	30
26	P 23	.023-.028	20	5%	25	.0280	80%	30	0.0232	12%	35
	P 19	.019-.023	25	5%	30	.0232	80%	35	0.0197	12%	40
30	P 16	.016-.019	30	5%	35	.0197	80%	40	0.0165	12%	45
	P 13	.013-.016	35	5%	40	.0165	75%	45	0.0138	17%	50
40	P 11	.011-.013	40	5%	45	.0138	75%	50	0.0117	17%	60
	P 9	.009-.011	45	5%	50	.0117	70%	60	0.0098	22%	70
	P 8	.008-.009	50	5%	60	.0098	70%	70	0.0083	22%	80
90											
	P 7	.007-.008	60	5%	70	.0083	70%	80	0.0070	22%	100
	P 6	.006-.007	70	5%	80	.0070	70%	100	0.0059	22%	120

NOTE:
(1) Maximum 3% fines allowed through smallest screen.
(2) Shot number is roughly the size of the shot pellets in thousandths of an inch.
(3) Percentages given above are on basis of weight as determined by prescribed tests.

Old Pangborn Numbering System	New S.A.E. Numbering System	High Limit Screen: Shot Retained, Per Cent Max.	High Limit Screen: Screen Number and Aperture	Nominal Screen: Shot Retained, Per Cent Min.	Nominal Screen: Screen Number and Aperture	Low Limit Screen: Shot to Pass Per Cent Max.	Low Limit Screen: Screen Number and Aperture
4	S-1320	0	4 (.187)	85	6 (.132)	5	7 (.111)
5	S-1110	0	5 (.157)	85	7 (.111)	5	8 (.0937)
6 & 7	S-930	0	6 (.132)	85	8 (.0937)	5	10 (.0787)
9	S-780	0	7 (.111)	80	10 (.0787)	10	12 (.0661)
10-C	S-660	0	8 (.0937)	80	12 (.0661)	10	14 (.0555)
10 & 12	S-550	0	10 (.0787)	80	14 (.0555)	10	16 (.0469)
14	S-460	0	12 (.0661)	75	16 (.0469)	15	18 (.0394)
16	S-390	0	14 (.0555)	75	18 (.0394)	15	20 (.0331)
20	S-330	0	16 (.0469)	75	20 (.0331)	15	30 (.0232)
26	S-230	0	18 (.0394)	70	30 (.0232)	20	40 (.0165)
30	S-170	0	20 (.0331)	70	40 (.0165)	20	50 (.0117)
40	S-110	0	30 (.0232)	65	50 (.0117)	25	80 (.0070)
90	S-70	0	40 (.0165)	65	80 (.0070)	25	120 (.0049)

Fig. 1a

in the surface; the surface being deformed or stretched at each point of indentation. Since these indentations are close together and overlapping, there is set up in the surface a static stress. In other words, the surface is pre-stressed in compression. The thin surface layer in compression naturally has its opposing stress in the under layers, which are in tension.

The peened layer may have a depth of .001″ to .005″, depending upon the peening impact and the hardness of the work surface. The tensile stress in the under layers being within the yield point of the fibers, an equilibrium of stresses results, and the surface fibers are said to be in residual compression, when a part is flexed in service. The peened or pre-stressed surface layer has the ability to expand to something near its original state before the fibers are subjected to a tensile stress. Therefore, since the tensile stress is less severe on these surface fibers the element of fatigue is less intense and the point of exhaustion is delayed. The theoretical value of surface peening is in the pre-stressing of the surface layer in compression.

Failures in machine parts have their beginning at the surface. They are the result of a tensile stress; tearing apart of the fibers. Machine elements subjected to frequent on and off stressing, or frequent reversal of stress, tension and compression, or reverse twisting or torsional stressing, may fail ultimately through a fracture beginning at the surface. This failure is called fatigue and is readily understandable from the simple experiment of frequent bending of a small rod until it fails or is broken. This is an example of rapid fatigue and one which surface peening would not benefit.

A straight pull and release or pull-push will also result in failure from fiber fatigue. Here again the beginning of failure is a surface crack. A straight compression stress may transmit a tensile stress to certain surface fibers and ultimately result in a fatigue failure.

In designing machinery parts it is quite often desirable and frequently necessary to restrict the size of parts, because of limited space, and for the advantage of less weight, as in aircraft and automobile construction. A supplementary process such as shot peening becomes necessary in order to prevent an early failure of these parts.

We then have a value in surface peening which may not be obtained in any other process.

Surface peening may be applied to lower grade materials and make them equal to higher grade materials in endurance. It may be applied to high grade materials to make them better.

Peening will show little benefit on materials with low elasticity or, in other words, materials in which the fibers are broken apart by hammer blows or which do not respond to bending.

There are exceptional cases in which surface peening applied to low elastic materials such as cast iron, aluminum, bronze, etc., has shown improved life in use.

Most applications, ,however, are on steel parts which in use are subjected to frequent oscillations of stress.

A few examples may serve to illustrate:

Valve Rocker Arms for Aircraft Engines—Fig. 2

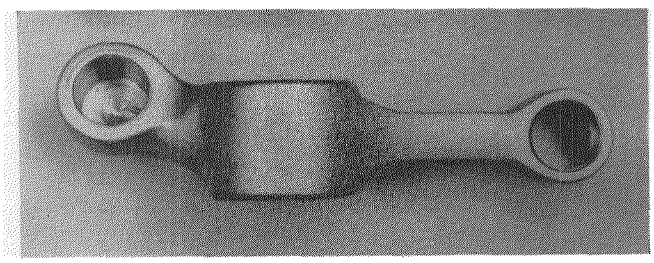

Fig. 2

Materials: Steel
Shot Used: P-28 .028 dia.
Test Strip Reading: .015A2
Failure in operation before peening at point A
Life increase after peening 1400%
These rocker arms were peened all over except the holes.

Connecting Rods Articulating for Aircraft Engines—Fig. 3

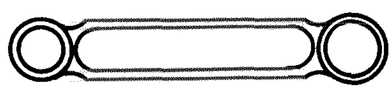

Fig. 3

Material: Steel
Shot Used: P-19 .019 dia.
Test Strip Reading: .012A2
Life increase after peening 106%.

Coil Springs — Automobile—Fig. 4

Material: Steel
Shot Used: P-28 .028 dia.
Test Strip Reading: .015A2
Life Increases: 2000 to 5500%.

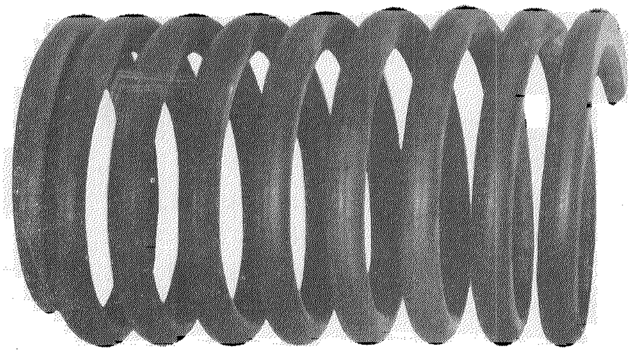

Fig. 4—Automobile coil spring

Leaf Springs — Automobile—Fig. 5
Material: Spring Steel
Shot Used: P-28 .028 dia.

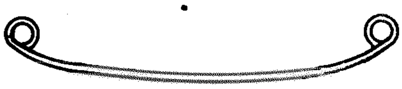

Fig. 5

Test Strip Reading: .016A2
Life Increase: 100 to 600%.

Gears — Transmission—Fig. 6

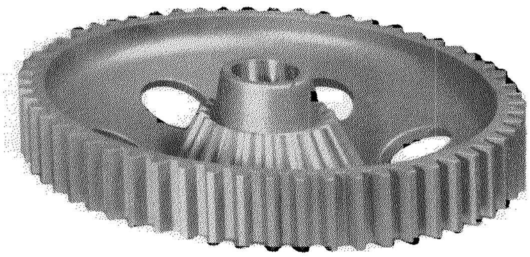

Fig. 6

Material: Steel
Shot Used: P-28 .028 dia.
Test Strip Reading: .012 to .016A2
Life Increase: 100 to 300%.

Crankcase — Aircraft Engines—Fig. 7

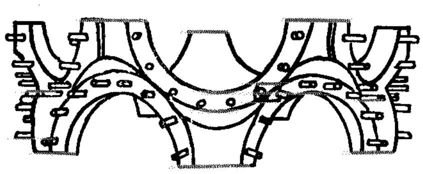

Fig. 7

Material: Aluminum alloys
Shot Used: P-28 .028 dia.
Test Strip Reading: .010 to 012A2
Life Increase: Approximately 30%.

Steering Knuckles — Automobile—Fig. 8
Material: Steel A-4042

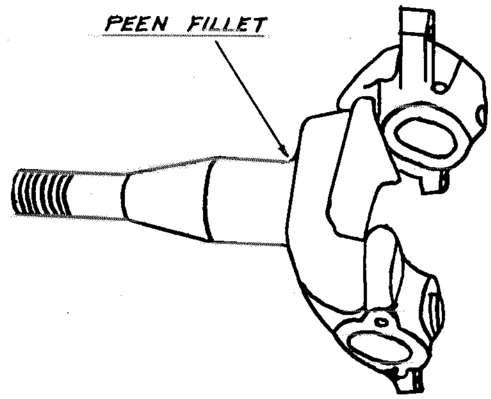

Fig. 8

Shot Used: P-28 .028 dia.
Test Strip Reading: .026A2
Life Increase: Over 400%.

Intensity is determined by *impact value* which is the result of *shot size* or *weight* and *velocity of shot* at instant of impact, *hardness* of shot, *angle* at which the shot strikes the surface and the number of *shot grains* applied to a given area.

Intensity, therefore, is the relation of impact value and the number of shot grains applied to a given area. Time or duration of peening with a given flow of shot will determine the number of shot grains applied.

"Coverage" may be expressed as "full coverage" or "sparse coverage", and has visual value only. Full coverage may be only 50% full intensity, or full saturation, but full or 100% intensity will be full coverage.

Measurement of Intensity

The degree of intensity is variable and may be measured by comparison. As, for instance, a test strip peened with a given impact for a short time period compared with another for a longer time period.

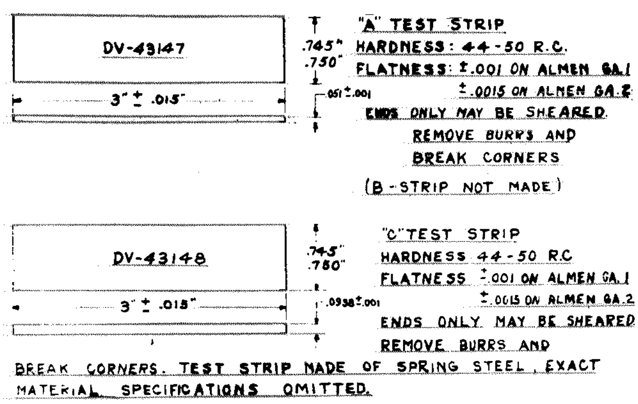

Fig. 9—The Almen test strip

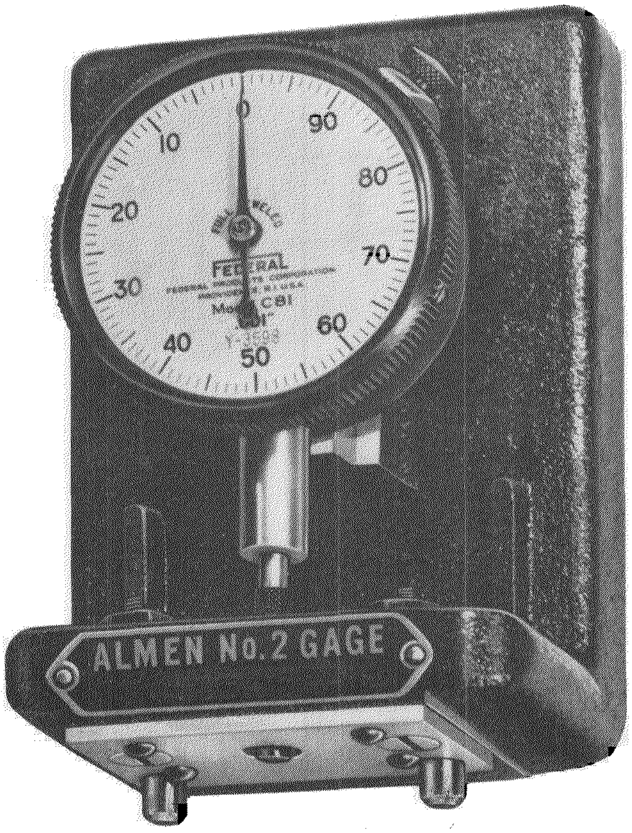

Fig. 10—The Almen dial indicator gauge

The Almen Test Strip

A strip of steel, of known quality, and a fixed size, when peened on one surface will respond in the form of an arc longitudinally and more or less transversely (Fig. 9). The measurement of the test strip curvature or the "arc height" indicates the peen "intensity". By peening this test strip in a manner similar to, or exactly like the peening of the part, we have measurement by comparison.

The Almen Gauge

The Almen gauge is a dial indicator gauge having four bearing points in fixed positions, accurately spaced, bearing on the unpeened surface of the test strip. The dial indicator plunger also bears on the unpeened surface, midway between the four points, and gives the test strip arc height reading (Fig. 10).

Since intensity is variable, the test strip "arc height" is also variable. The test strip, therefore, provides a means of determining or controlling the intensity applied to a given part. The results governing this procedure are comparatively simple, but do produce reliable results. Refer to Fig. 11.

The thinner section parts may be peened to a low intensity, as for instance, an arc height reading of .005 to .007A2. Average sections to an arc of .012, .015, etc. Heavy sections .018, .025, etc. Materials of low tensile strength will be confined to the lower intensity ranges. Parts permitting only a minimum of distortion, elongation, etc., will also be confined to the lower intensity ranges.

In any controlled peening operation we must first recognize and understand the use of the test strip.

The "A" Test Strip — Spring Steel (Good quality)—Fig. 9

Thickness .0510″ plus or minus .001.
Hardness Rockwell "C" 44 to 50.
Width .745″ to .750″—may be rolled as a strip.
Length 3″ plus or minus .015″.

Close thickness tolerances are important for sake of uniformity in response to peening. Close hardness tolerance is important for sake of uniformity in response to peening. Range of arc height .002 to .025 on No. 2 gauge.

The "C" Test Strip—Spring Steel (Good quality)

Thickness .0938″ plus or minus .001″.—Otherwise same as "A" Strip.

Range of arc height .005 to .020.

The "B" test strip, if used, would be an intermediate thickness, otherwise the same as the "A" strip. So far found unnecessary.

The "A" test strip is used generally for most machine parts and when using shot .010 diameter to .055 diameter. An arc height of .025 on the "A" strip indicates a high peen intensity and relatively high stressing of the part surface.

The "C" test strip is used for higher intensities generally, and may be used in the lower intensity ranges. (See Fig. 12).

The Almen Gauge — The Test Strip Holding Block—Fig. 13

To determine the desired intensity for a peening application, an intensity curve must be developed by the following procedure—Fig. 11:

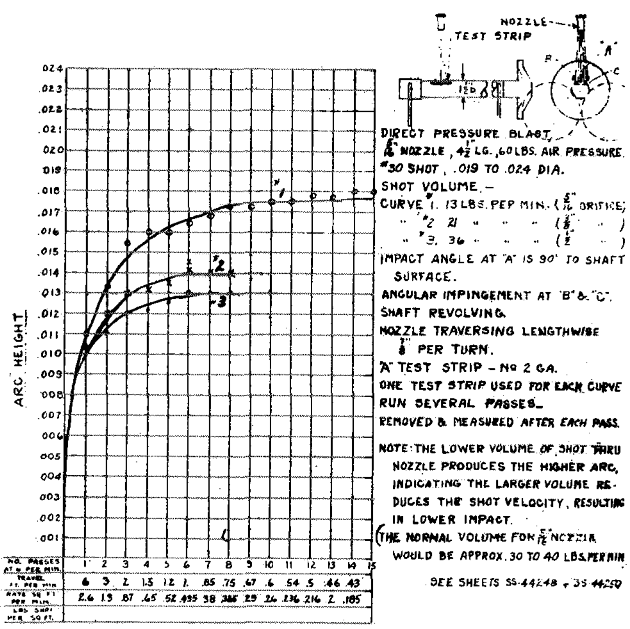

Fig. 11—Illustration of variable intensity applied to part

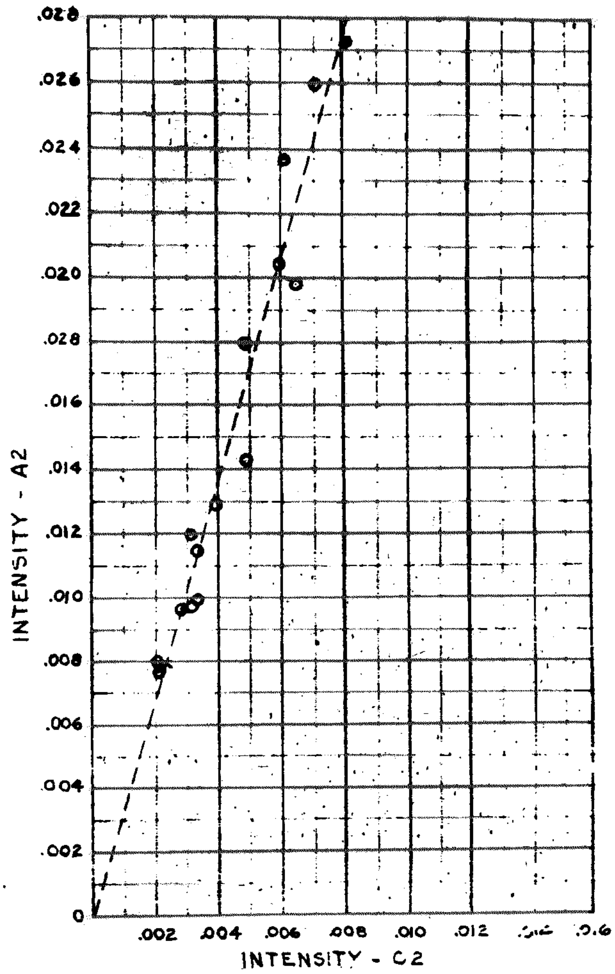

Fig. 12—The "C" test strip used in lower intensity ranges

Using a given shot, say P-28 or (S-230) .023 to .030 diameter, projected against the test strip, at a given shot velocity.

By Air Blast — Covering the entire strip uniformly.

By Centrifugal Blast — Covering the entire strip uniformly.

No. 1 Strip:

For a short time period, or a fast rate of appli-cation, measure the test strip arc height on No. 2 gauge. Mark reading on intensity curve chart.

No. 2 Strip for say 25% longer time. Mark on chart.

No. 3 Strip for say 50% longer time. Mark on chart.

No. 4 Strip for say 75% longer time. Mark on chart.

No. 5 Strip for say 100% longer time. Mark on chart.

Plot curve on chart.

The curve should be similar to Fig. 11.

Additional test strips peened for longer time should tend to follow the horizontal line. Full intensity is indicated by the knee of the curve, which is also full coverage. Excessive exposure time will tend to produce greater transverse curvature, and is considered excessive peening.

Lower intensity may be produced by lower air pressure, or lower centrifugal wheel speed, or smaller shot.

Comparable results may be obtained by small shot at higher velocity or large shot at lower velocity, or by varying the angle of impingement. A 90° or perpendicular impingement produces the maximum impact for a given shot size at a given velocity.

The impact varies as the sine of impingement angle.

Effective impact equals potential impact x sine of angle.

At 45° the effective impact is .707 of the 90° impact, etc.

In considering shot size, which is graded commercially within a certain range, as indicated by the shot specification chart, now standardized (Fig. 1) it will be apparent that the small sizes may have a lower potential impact at a given velocity.

Closely graded sizes are decidedly preferable. The scatter on the intensity curve (Fig. 11) may be due to non-uniformity of shot mixture, bunching of large small shot, variation in air pressure, or variation in wheel speed, irregular shot feed, and to some extent, variations in test strips. Excessive shot volume or flooding in air blast, reduces shot velocity, as indicated by Fig. 11, consequently gives lower impact value. Likewise a reduced flow produces a higher shot velocity and a higher impact value. Therefore, in processing a number of test strips for each time period under supposedly uniform conditions, we may find some scatter in plotting the curve. This scatter may represent a number of curves, high and low intensities. The average representing the general trend, the usual acceptable tolerance being about .003" in arc height.

Checking Peening Operations

From the foregoing it will be seen that the determination of correct peening intensity requires

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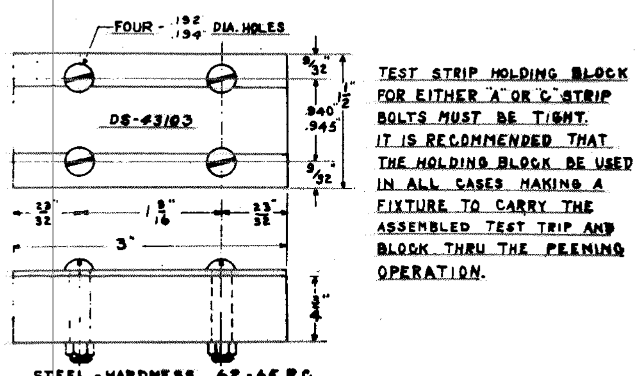

Fig. 13—The test strip holding block

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peening a number of test strips and developing the intensity curve. A single test strip may be used for the full range of exposure time by first peening for a short time, measuring and reclamping in the test strip holding block and processing again, and again until the curve begins to level off. A number of intensity curves may be necessary in order to arrive at a desired peening intensity. After this has been determined, and close regulation of the various factors maintained, periodical processing of a single strip for each critical area will provide the desired check on the peening operation.

Removal of Cracked Shot

This is an important phase of the peening process, in order to maintain uniform results. The cracked shot should be removed continuously as the shot mixture is returned for re-use. A good high percentage of whole shot would be about 85% to 95%. Perfection in removal of cracked shot has not been attained. Attempts at removal of the cracked shot by screening, as employed in grading shot, have encountered difficulties mainly in blinding of the screens, particles lodging in the screen mesh, consequently requiring frequent cleaning which is too bothersome for production operations. Even without the blinding, screening is not better than 85% efficient. The air wash separator described in Fig. 14 is capable of maintaining a whole shot mixture of 90 to 95%.

Briefly the separation of cracked shot from whole shot in the air wash separator may be explained by the simple fact that a stream of air or wind for instance, acts on shot particles in proportion to their mass, as a mild wind will carry dust or grains of sand, but not pebbles. In the separator illustrated the mixture of shot is caused to flow over an inclined smooth plate uniformly distributed over the plate surface. The segregation phenomena in this action cause the broken smaller particles to flow underneath the larger particles and leave the plate edge on the under side of the shot stream and at lower velocity. A draft of air indicated by the small arrows flowing through the stream of segregated shot particles, forces the broken smaller particles out of their path of flow into the trap, and are thus removed from the mass of good shot.

The failure of shot in a peening machine is due to a fracture from impact, instantaneously or from fatigue after continued use. The chilled hard shot has the ability to retain its round shape without deformation under continued use until it is fractured. This quality has its value in processing hardened parts. The same chilled shot malleabilized becomes more ductile and will withstand a greater number of impacts before fracture. It may even be reduced in size from repeated use. This quality has its value in processing parts of low hardness.

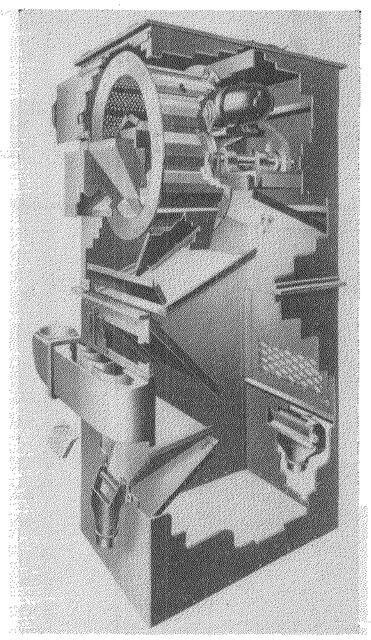

Fig. 14—This air wash separator is capable of maintaining a whole shot mixture of 90 to 95%

A secondary value is greater economy by reason of longer life, less breakdown, etc. Broken shot in the mixture has less weight, therefore, less impact value at a given velocity, and serves no useful purpose. It further occupies space in the mixture and tends to increase the time required to produce the desired peen intensity.

By again examining the intensity chart, Fig. 11, which shows some scatter, several curves may be plotted through these points, the low points representing the smaller shot grains, or broken shot, which may have colonized in the mixture and have been applied to a particular test strip. It, therefore, may be easily expected that a part processed with a similar mixture would show a low or high peen intensity as compared with another part. Excessive broken shot or fines in the mixture could produce a peen intensity decidedly below the desired range. Uniformity of shot size is, therefore, important.

(To be continued)

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Taft-Hartley Bill Available In Chart Form

"How the Taft-Hartley Bill Will Affect Your Employee Relations", a chart published by The National Foremen's Institute, Inc., Deep River, Conn. Two colors, six columns; $1.00 (quantity discounts).

This chart was prepared by the labor relations staff of the Institute and is designed to help you steer a clear and straight course through the many technical aspects of the law. Prepared in chart form, 16 by 22 inches in size, this guide explains in simplified form the various issues raised by the new labor legislation.

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PART II

AFTER the shot has been projected through the media of air blast nozzle or the centrifugal wheel it is collected in cabinet hopper by gravity or by conveyor, thence to elevator and in turn delivered to the separator, thence flowing by gravity to a storage bin, the separator performing the important function of removing the broken shot and fines. The shot storage bin, usually directly below the separator, receives the shot and delivers it by gravity to the shot projecting unit.

The capacity and design of storage bin deserve careful consideration in order to provide a constant flow, and to avoid excessive withholding of shot from use. Replenishing or adding of new shot to replace worn and broken shot also deserves careful consideration. An automatic continuous replenishing system is possible and may consist of a relatively small bin placed close to floor, as in Fig. 15. This bin may hold a supply for one shift and be re-filled at the beginning of each shift. The simplest form of a shot replenisher is one which is controlled by an overflow from the main storage bin, so arranged as to maintain a constant level in main bin, the overflow serving to stop the flow of new shot and adding new shot at the exact rate of breakdown. Thus a small percentage of new shot is mixed with the used returned shot, the system being stabilized continuously. It requires no attention other than re-filling.

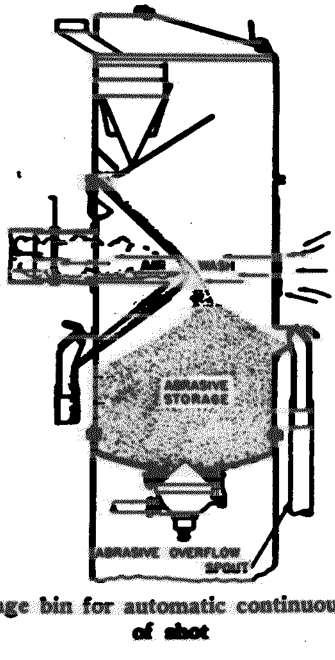

Fig. 15—Storage bin for automatic continuous replenishing of shot

A large capacity storage bin may also be used to replenish new shot automatically without the supplementary replenishing bin. In this case ,new shot may be put into cabinet hopper at the beginning of shift, the new shot being delivered to main storage bin through elevator and separator, the separator removing the undesirable fines and irregular particles, if any are contained in the new shot. In operation, the returned used shot is delivered to storage bin on the top surface. The flow to outlets from a bin is always from the top surface — never from the sides or bottom of bin. Thus the used returned shot is continuously discharged first. As disintegration reduces the returned volume, the new shot stored in bin is gradually fed always from the top

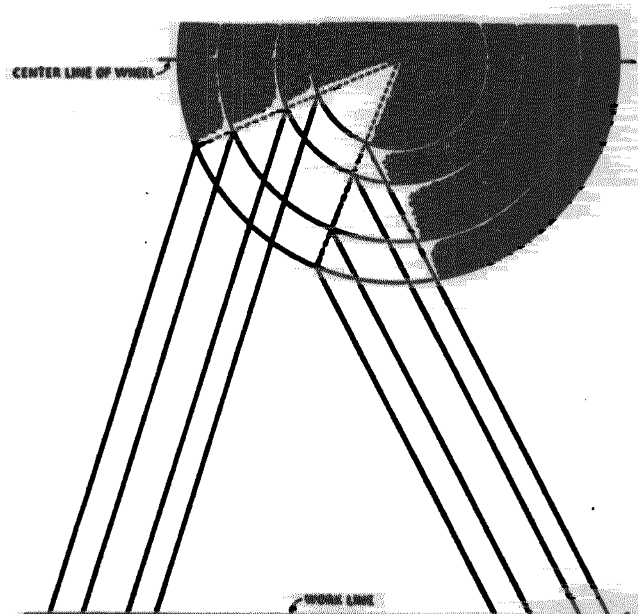

Fig. 16—Blast stream showing shot paths from a centrifugal wheel

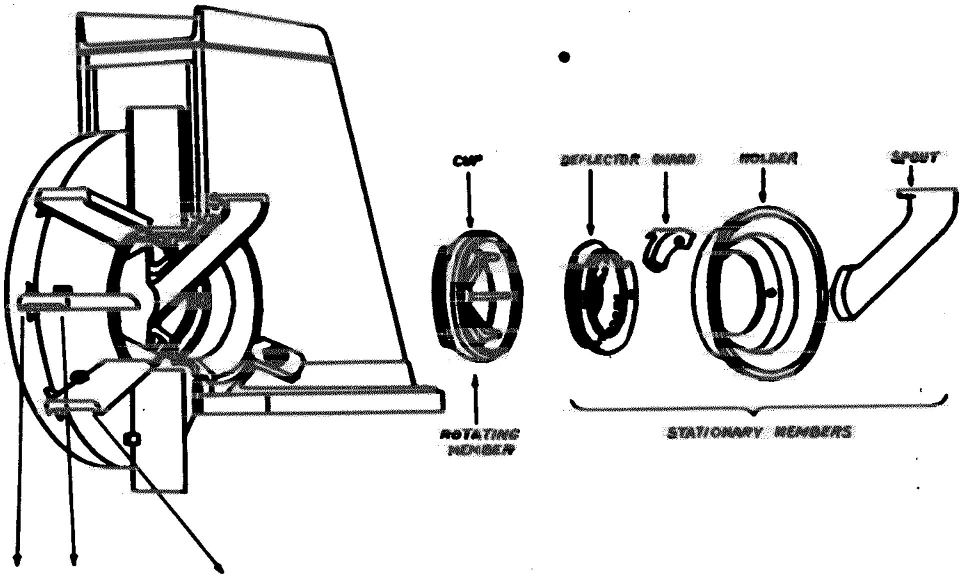

Fig. 17—Centrifugal wheel employed as a shot projector. Shot velocity varies according to peripheral speed of the wheel

level. Thus the main storage bin may serve as a constant replenisher of new unused shot and maintain a constant uniform mixture for use. Further, since all shot in bin passes through the separator, it is cleaned before use. Low level and high level indicators are necessary. In a blast cleaning operation where coarse and fines are necessary, the supplementary replenisher is better, since it avoids the period of using all coarse new abrasive after re-filling.

Oversize storage bins simply store up a quantity of shot which never gets into circulation and may easily amount to several tons. This condition may be avoided by proper design and the use of the automatic replenisher.

Shot Projector — Centrifugal Wheel

Any good centrifugal wheel is a good shot projecting unit. Figs. 16 and 17 illustrate blast stream and centrifugal wheel, respectively. The resultant shot velocity is determined by the peripheral speed of the wheel. The normal speed gives a shot velocity corresponding closely to that produced by the original compressed air (direct pressure) system operated at 80 lbs. P.S.I. The normal volume of shot handled by the centrifugal wheel is about 10 times the volume handled with a ⅜" diameter nozzle, and in power consumption is relatively about one-tenth. The delivery from the centrifugal wheel is not a close concentration. Some of the shot is not effectively used and, therefore, the usable shot ratio to the ⅜" nozzle may be only about 8 to 1, and the power about one-eighth.

A centrifugal wheel, operated with a 20HP motor and handling 400 lbs. of shot per minute, is equal to ten (10) ⅜" diameter nozzles operating at 80 lbs P.S.I., requiring 1900 CFM and 200 HP. The fan shaped delivery — Fig. 16 from the centrifugal wheel is determined largely by the manner in which shot is placed on the wheel vanes. A certain amount of lag in delivery from the vanes is inevitable in all centrifugal wheels This lag is commonly called tail stream. Without this lag, it would not be possible to produce a fan shape delivery, and we would then have a more concentrated delivery or, in other words, shot delivered in a small stream, whereas the fan shape delivery is highly desirable. In most applications, the fan shape delivery corresponds to a spread as may be covered by the six (6) or eight (8) ⅜" nozzles, spaced about 2½" apart.

Surface Peening Machines For Production

The centrifugal wheel having certain known and, more or less, definite qualities, it becomes desirable to take advantage of these qualities and provide means for its effective and efficient use, and so, also, with any shot projecting media.

In providing equipment for surface peening a great variety of parts must be considered—

1. Gears — spur, all sizes; bevel, all sizes; helical, all sizes.
2. Connecting rods, various designs.
3. Crankshafts, various designs.
4. Coil Springs — Compression, tension, all sizes. Flat Leaf Springs, all sizes.
5. Gun parts, ,various shapes and sizes.
6. Aircraft parts of various shapes and sizes.
7. Torsion bars.
8. Sucker rods, various sizes and lengths.
9. Steering knuckles.
10. Rear axle shafts.
11. Steering levers, and many other parts.

Items 1 to 11 inclusive represent quite a variety of parts which suggest there should be a machine of more or less universal character so as to avoid resort to highly specialized machines, one for each type piece, and further designs for various sized pieces.

The multi-table machine is equipped with a centrifugal wheel mounted so as to project the shot stream against a single piece on table or a multiplicity of pieces on table, and to give uniform coverage and uniform intensity against vertical surfaces as well as horizontal surfaces, fillets, etc., at any position on table surface.

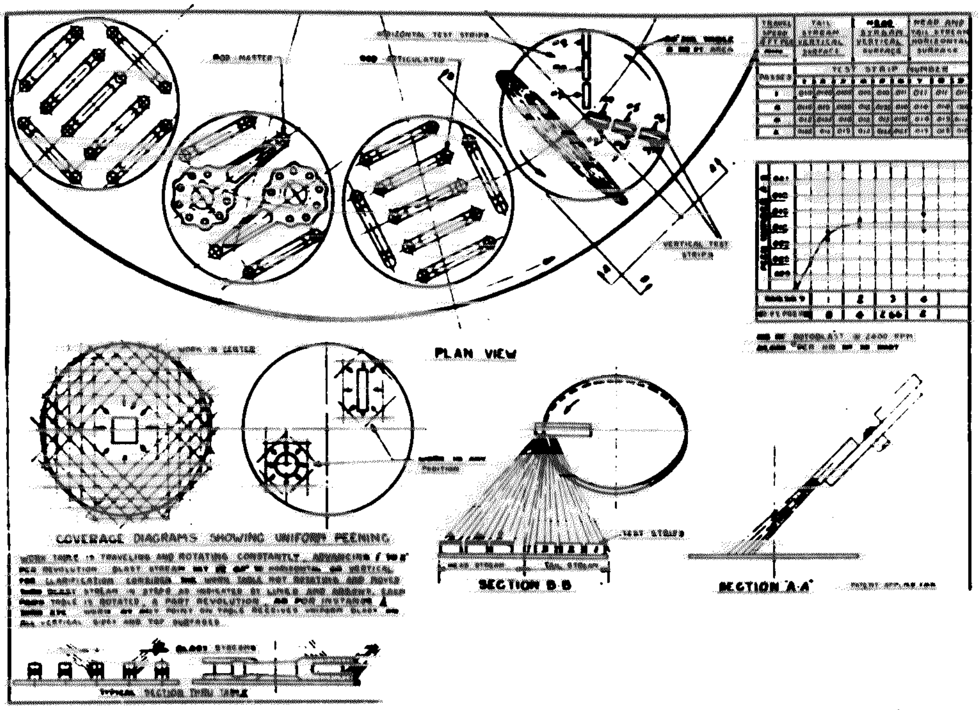

Fig. 18—Coverage diagram utilized to effect equal impact and intensity

When a work table of a certain diameter, say 24", 30" or 36", etc., is passed through a stream of shot from the centrifugal wheel, it should be in such a manner that the shot strikes all exposed surface uniformly. Since the work piece will have surfaces parallel to table surface, other surfaces perpendicular to table surface, and still other surfaces at various angles, the blast, therefore, should be applied at an angle of 45 degrees to table surface.

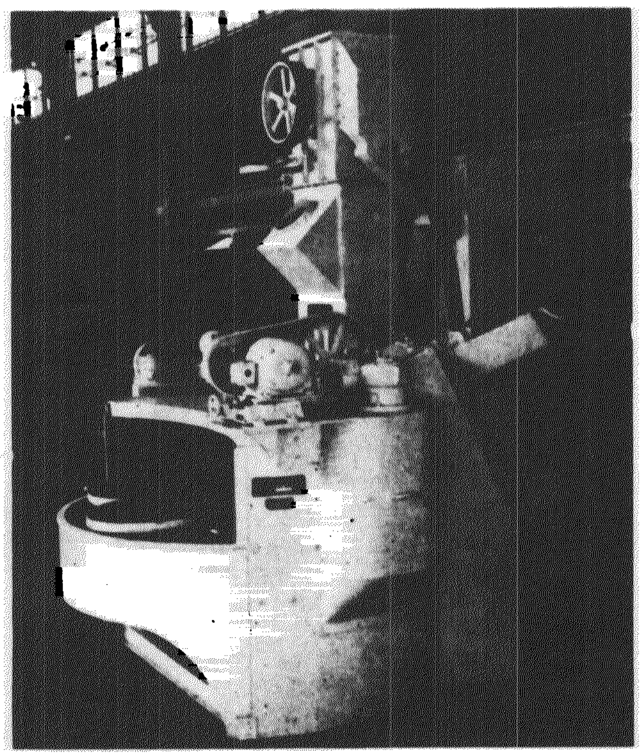

Fig. 19—Multi-table installation utilizing centrifugal wheel

Since the blast stream is applied at an angle of 45 degrees to table surface and broadside to line of table travel, it will cover the table surface as it passes through the stream somewhat like a wide brush. If, on the other hand, the fan shape stream should be applied parallel to line of travel, it will merely blast a path equal to stream width across table. If the work table is then revolved about one revolution in each 2" of travel, the various surfaces will receive a blast of about equal impact and intensity. Fig. 18 illustrates uniform peening through proper coverage. The work pieces illustrated at rim will all pass through the blast stream

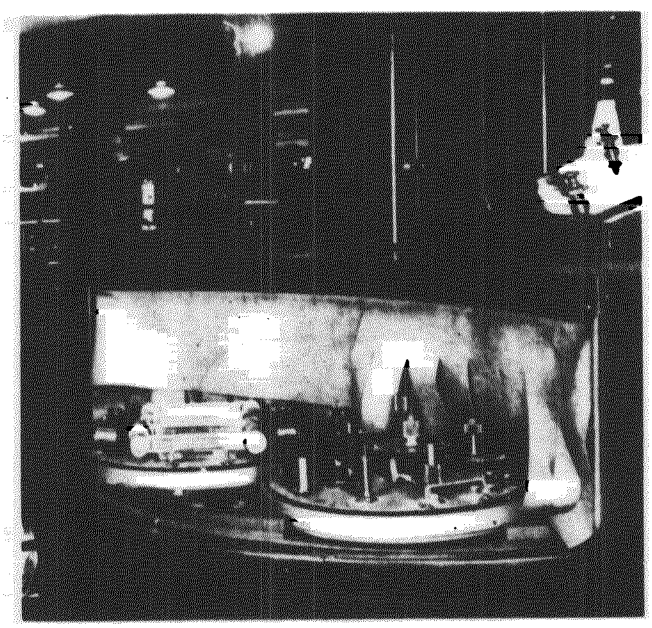

Fig. 19A—Close-up of table showing parts to be shot peened

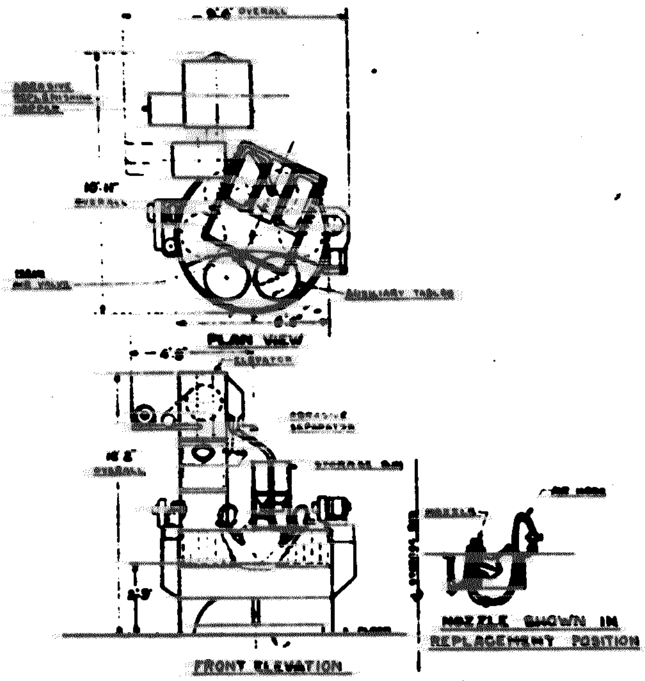

Fig. 20—Schematic design of table type shot peening unit employing air nozzles

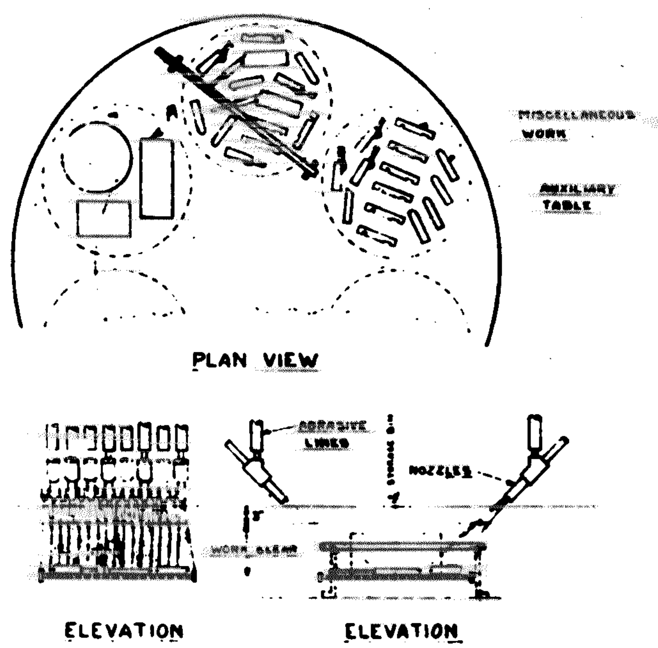

Fig. 20A—Schematic diagram of air nozzles applied to a table type machine

in each stream position or any intermediate position. Pieces at the rim of the table pass through the blast more frequently than those near center. Pieces at center pass only once, but at a slower speed. Horizontal surfaces are blasted more frequently and are, therefore, more intensely blasted. Fillets may receive a perpendicular impact. A certain amount of non-uniformity is inevitable but the overall result is within the permissible range.

To consider the more correct and scientific application, we find that the use of centrifugal wheel stream becomes quite involved, and in many cases, impractical. So also with the air blast nozzle, which becomes quite involved, requiring more or less elaborate machinery. As an example, a gear having a number of teeth on which it is desired to peen the root fillet, didendum radii, etc.; there is no way of applying a perpendicular impact to all of the various areas, and since there are numerous types, shapes and sizes of gears the multi-table 45 degree angle blast provides a very practical and efficient means for use of the centrifugal wheel in a production operation.

Fig. 19 may serve to show the simplicity of applying the centrifugal wheel to a variety of parts in production.

The characteristic of lag in delivery from the centrifugal wheel provides a shot stream of some length (Fig. 16). The length is greater at increasing distances from wheel rim, due to the diverging angles. This stream length is of considerable advantage in most cases and particularly in its application to the multi-table machine since it may be applied to the table crosswise for full coverage of auxiliary table surface (Fig. 17).

Air blast nozzles may be applied in a similar manner and it is, therefore, possible and proper to take advantage of this unique discovery in the use of air blast also. Refer to Fig. 20, which diagrammatically illustrates a series of airblast nozzles applied to the table type machine.

Numerous tests have been conducted in processing a number of test strips arranged at various positions on the auxiliary table and set at various angles, etc., running a series at fast-to-slow rate, and developing the intensity curves for each position. See Fig. 21.

The variation in these curves is due mainly to impingement angle. The curves have all begun to level off at nearly the same point (at point of saturation), which is the point of full intensity.

Air Blast Use In Surface Peening

There are two systems of air blast application—(a) Suction or induction principle; (b) Direct pressure principle.

The suction or induction gun is a system in which a jet of compressed air is fed to the gun and blown directly into the nozzle orifice. The gun has a side inlet and, if open, outside air will be drawn in, combining with the jet stream, and forced through the nozzle. If a tube or hose is connected to the side inlet and led to a shot hopper mixing chamber, a certain amount of shot will be drawn along with the air and also forced through the nozzle and be projected as a blast stream. The jet size is normally about ½ the diameter of the nozzle, and the shot volume handled is normally about equal to the volume handled through a nozzle equal to the jet size. The velocity of the jet stream is retarded somewhat by the energy used in creating the partial vacuum in the gun and the induced air velocity may be relatively low, giving a relatively lower velocity to the shot. This system is a rather simple hook-up, and for this reason, is sometimes preferred. It consists of a suitable gun, an air supply tube or hose, a shot supply tube or hose, a shot hopper and feed valve with shotflow regulating orifice. A valve in the compressed air line serves to start and stop the blast, and the blast may be run continuously by simply supplying air and shot. Peen intensities in the low and medium ranges are possible up to .015A2.

The direct pressure system employs a pressure tank from which the compressed air and shot are conveyed through single hose to a nozzle, the air and shot being mixed in a mixing chamber at the tank. The shot is then accelerated in the nozzle and attains a higher velocity comparable to that of the air velocity.

In either system the shot volume must be metered through an orifice so as to provide the proper ratio of shot to air. A lean mixture will produce the higher velocity and, consequently, produce the higher impact and higher test strip arc. A rich mixture may produce full intensity in less time, but at a lower shot velocity and lower arc height on the test strip.

The direct pressure system employs one tube or hose through which air and shot flow to nozzle. The tank containing the shot is operated under pressure, the shot flowing by gravity through the regulating orifice in the mixing chamber and thence to the conveying tube or hose to the nozzle. Shot is admitted to the tank chamber only at atmospheric pressure, at which time blast is stopped. The automatic continuous tank has two chambers, one above the other, the upper chamber being exhausted to admit a charge, at atmospheric pressure, while the lower chamber is under pressure and discharging shot. When upper chamber is closed and both upper and lower chambers are under the same pressure, the lower chamber is refilled, thus providing continuous direct pressure blast.

The direct pressure blast provides for the full capacity of the nozzle in shot volume, and maximum shot velocity proportioned to air pressure supplied. A multiplicity of nozzles may be employed with the use of a distributing manifold running as many as eight 3⁄8" nozzles from one mixing chamber. Shot volume 35 lbs. each, 288 lbs. per minute total. At 80 lbs. P.S.I. air pressure, the shot velocity will be the maximum, approximately 250 ft./sec. The air consumption will be about 160 CFM each or 1,280 CFM for eight nozzles. The power consumption will be about 200 BHP. The peen intensity at 90° impact .020 to .025A2.

A comparable hook-up of induction type nozzle will be—

Shot volume through ½" nozzle, the most popular size, 7/32" air jets.

Three to 1 or twenty-four (24) ½" induction guns. Shot velocity about 150 ft./sec. Shot volume about 10 to 12 lbs. per minute each or 280 lbs. total per minute. Air consumption about 1,280 CFM; power consumption about 2000 BHP; and the peen intensity at 90° impact .013 to .015A2.

A comparable hook-up of centrifugal wheel will be—

Shot volume 300 lbs. per minute; shot velocity about 250 ft. per second, at normal wheel speed; power consumption 15 BHP, and the peen intensity at 90° impact .020 to .025A2.

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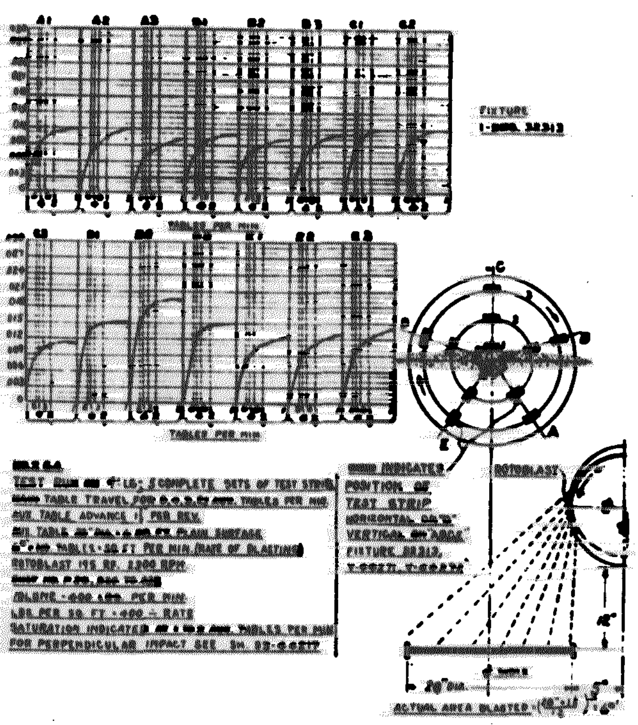
Fig. 21—Method of determining intensity curves

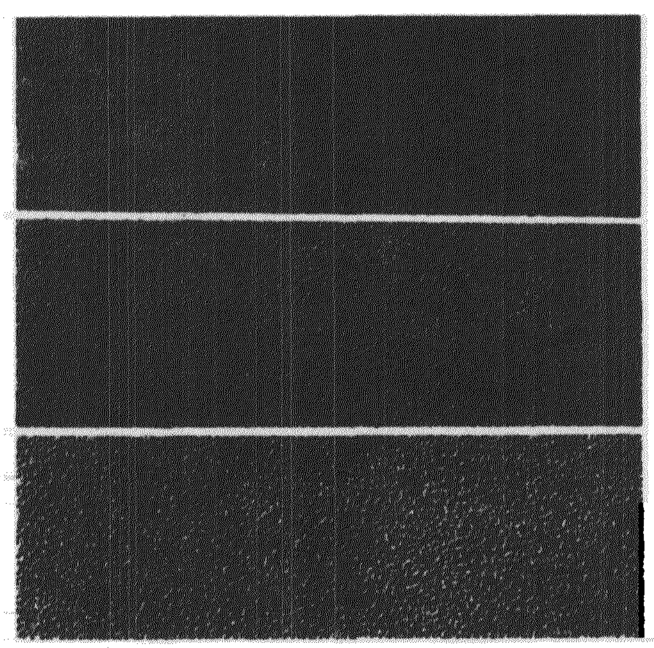
Fig. 22—Shot patterns for centrifugal wheel shot peened

Shot Peening Increases Life of Machinery Parts

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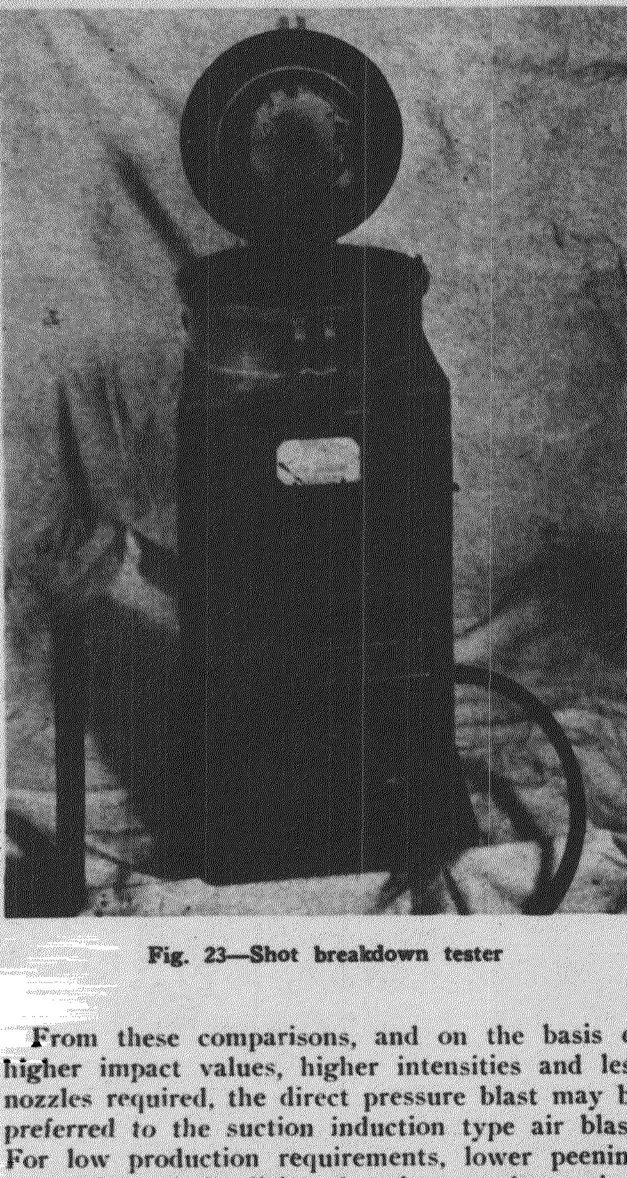

Fig. 23—Shot breakdown tester

From these comparisons, and on the basis of higher impact values, higher intensities and less nozzles required, the direct pressure blast may be preferred to the suction induction type air blast. For low production requirements, lower peening intensities and simplicity of equipment, the suction-induction type air blast may be preferred. For higher volume production, avoiding use of compressed air, and advantages of a self contained machine, the centrifugal wheel equipment may be preferred.

The replacement costs of the centrifugal wheel may be compared with compressed air costs and maintenance cost of nozzles, etc. The overall economy will be in favor of the centrifugal wheel.

For the low range of peen intensities the induction gun will produce a smoother finish, and may be capable of producing desired results with a wider range of shot sizes in the mixture. Comparable smoothness of finish with the centrifugal wheel requires close grading or more uniformity of shot sizes.

The theoretical reason for smoother finish with air blast is the difference in acceleration of the various shot sizes. In air blast the smaller sizes accelerate faster, and produce impact values somewhere near equal to larger sizes, avoiding the deeper craters.

In centrifugal wheel blast the larger and smaller shot are accelerated at the same rate, the larger shot producing many times higher impact values than the smaller sizes with resulting deeper craters for the larger shot. This comparison points up the necessity of close grading of shot sizes for use in centrifugal wheel blast The additional tendency of bunching or colonization of large or small shot in storage bin accentuates the irregularity in the use of the centrifugal wheel. In the overall consideration, however, there is still the strong influence to use the centrifugal whel in production operations. See pattern of shot finish—Fig. 22.

Shot For Peening

SAE standard peening shot grading (Fig. 1) adopted by subdivision of the SAE Standards committee and agreed to by shot manufacturers and users, provides uniformity of labeling for all shot manufacturers and users, provides uniformity of labeling for all shot manufacturers. The prefix P stands for peening shot. The number represents the shot size in thousandths inch as P-28 shot will be nominally .028 diameter, etc. Size range .028 to .033.

Fig. 1a is a classification for shot used in cleaning, but somewhat wider margins in grading. The prefix "S" is to differentiate shot from grit, which has a prefix "G". The number S-230 has a nominal diameter of .023". Size range .016" to .039" diameter. The "S" sizes are used in peening when the "P" sizes are not available. In the preceding discussion it is stated that the closely graded shot sizes are important for better uniformity of peening intensity, particularly in the use of the centrifugal wheel.

Quality is also an important factor. Low quality shot having a low crushing strength disintegrates rapidly and becomes a loss to the peening operation. The removal of cracked shot from the mass becomes a greater problem with low quality shot. The shot should be essentially round and have fatigue durability. The available and most commonly used shot is a chilled white iron, the molten metal being broken up into globules which are quenched in water giving a hardness of 45 to 60 Rockwell "C". Heat-treating this material, it becomes more ductile and is then known as malleabilized shot. In this form it has greater fatigue durability and longer life as whole shot. The malleablized shot is somewhat softer than the normally chilled shot, and may be used on work with a hardness range up to 40 Rc.

The standard Almen test strip has a hardness of 44 to 50 Rockwell C, which must be used in checking peening intensities for the malleablized shot.

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as well as for the hard shot. Steel shot has been used experimentally and found to be quite satisfactory, having longer life but is higher in first cost, and not available in quantity.

Shot Tester

Some progress is being made in providing a shot breakdown tester. Standards of durability may now be set up.

There will undoubtedly be several designs of shot break down testers with somewhat different impingement anvils. This condition will be similar to the variations in hardness testing machnes as Brinell, Rockwell, Scleroscope, etc. Comparisons of various shot grades may be made with any one tester, and correlation charts may be compiled for the various types.

In the development of the shot breakdown tester, a miniature centrifugal wheel is considered ideal (see Fig. 23). The small diameter bladed wheel may be run at speeds giving the same peripheral velocity as the larger wheel and, therefore, produce like velocities to the discharged shot, and corresponding impact values. For maximum impact value the anvils would be such that the shot impingement would be at 90° or perpendicular to the anvil surface. An angle less than 90° will produce an impact value in direct proportion or as the sine of the angle, as for instance, an impingement angle of 80° would produce 98.4% of the 90° angle. From analysis, it is impossible to provide this 90° anvil impingement for all shot discharged from the wheel; likewise, it is impossible to always apply a 90° impingement in a peening process.

The use of one shot tester at a uniform speed will give comparable results in shot durability of different makes or grades.

In testing shot for durability and quality, a small quantity such as 100 grams to 500 grams may be used. This small quantity is run through the tester at a wheel speed which produces the impact for the size being tested, the broken shot to be screened out after each pass. Successive passes and screening until 55% of the lot has been disintegrated will indicate the average life of the shot. Several grades of shot may be compared with each other or may be compared with a standards chart.

In checking shot for quality, the wheel speed should be determined by developing the arc height on the Almen test strips, using 500 grams of shot, and plotting the intensity curve for each wheel speed. The speed which produces a full intensity of .019 to .021 will be correct for the size shot to be checked. A number of trials may be necessary to arrive at the correct wheel speed.

One of the main hindrances to more general use of surface peening is the lack of a closely graded good shot supply. It is pointed out that wider shot tolerances may be used with good results in air blast, but with more or less indifferent results in the centrifugal wheel blast. The use of the centrifugal wheel, being a more self contained machine and more economical, it naturally is preferred for production operations. It is also pointed out that a universal type machine employing the centrifugal wheel may be used for applying surface peening to a wide variety of parts, avoiding the necessity of special designs for each particular part. It is further pointed out that air blast may be employed in these universal machines but requiring a relatively high compressed air demand. The varied requirements and technicalities involved indicate that competent specialists are important in planning and setting up a production surface peening operation. The continuation of the operation then becomes a matter of training operators in the proper handling of the work.

The resulting value of surface peening to a part may be determined by observing and checking the performance and endurance of the part in use. Short range endurance tests may also be employed on certain parts, and thus secure an indication of the results to be expected from actual use

Surface peening in some cases may be considered for finish, as well as peening, thus obtaining a twofold result.

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H. O. Hill Elected President of the American Welding Society

The American Welding Society has elected Harold O. Hill as its president for the year 1947-48. Mr. Hill will assume that office on Friday, October 24, at the conclusion of the 1947 Annual Meeting at the Hotel Sherman, Chicago.

Mr. Hill is assistant chief engineer, fabricated steel construction, of the Bethlehem Steel Company, at Bethlehem, Pennsylvania. Born in Ontario, Canada, he was educated at the University of Toronto, from which he received the degree of B.A. Sc. in Mechanical Engineering.

He commenced his engineering career with the Riter-Conley Company of Pittsburgh, Pennsylvania, fabricators of plate and structural steel. Here he served in many capacities and was chief engineer when this company was merged into McClintic-Marshall Company in 1916, when he became assistant chief engineer of the enlarged company in charge of the engineering on tank and platework. When the McClintic-Marshall Co. was merged with the Bethlehem Steel Company in 1931 he continued his same duties with the Bethlehem Steel Company.

Mr. Hill has held many offices in the Society and has been on numerous important committees during the 16 years he has been a member of the Society. He is also a member of the A. P. I., A. S. T. M., A. I. E. E., A. S. C. E., A. S. M. E., A. W. W. A., a registered professional engineer in the State of Pennsylvania and past-president of the Bethlehem Rotary Club.