

SAE Manual on Shot Peening - SAE J808a

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This manual is an updating and extension of the previous SAE Manual of Shot Peening .
originally published in 1952 . Much of the original material developed by the Handbook
Subcommittee of Iron and Steel Technical Committee Division 20 has been retained .

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Chapter I Introduction

This Manual on Shot Peening is intended to be a practical aid to engineers, designers, and men in the shop, pointing out some of the possibilities and some of the limitations of the process. It has been prepared by a group of men broadly experienced in the process, whose leadership in the field is acknowledged.

Shot peening may be defined as the process of cold working the surface of a structural or machine part by means of a driven stream of hard shot. The purpose of the process is to improve the fatigue properties of the shot peened part.

While all factors which affect the improvement are not completely understood, it is generally attributed to the introduction of compressive stresses in the surface layer and to the slight hardening effect caused by the peening action of the shot. It is said that most fatigue failures occur only in tension, so the compressive stress in the shot peened object is in effect a preloading device, opposite in direction to the stress applied in service. Thus, the actual service stresses are reduced to a safe level by the countereffect of the preloading induced by shot peening.

The principle of improving strength of metals by cold working undoubtedly was discovered early in civilization, as ancient man hammered out his tools and weapons. In more recent times, the blacksmith hammered the tension side of buggy springs because he knew it made them better. However, it was not until 1927 that the glimmerings regarding this process were voiced by Herbert in his paper, "Work Hardening of Steel by Abrasion." (1)* At a later date, def-

inite claims were made in another paper, "Cloudburst Process for Hardness Testing and Hardening" (2).

None of this information was very definite, but it was sufficient to arouse interest and to start additional investigations, largely in the spring industry. These investigations and their results were summarized in a paper given in 1940 by F. P. Zimmerli (3). This encouraged the publication of many articles from numerous laboratories which added much to the pool of knowledge.

Shot peening is not the only method by which these beneficial surface stresses may be introduced into a part. The most important of the other methods are as follows:

1. Cold working by rolling, by stretching, by compressing, by bending, and by twisting. These techniques are covered in SAE J811, Surface Rolling and Other Methods for Mechanical Prestressing of Metals (4).
2. Heat treating and, in particular, surface treatments by induction and flame treating.
3. Changing the chemical composition of the surface layer by carburizing, nitriding, etc.

Shot peening possesses several advantages over any of these methods, such as flexibility, control of stress intensity, safety from the point of view of not introducing unwanted or harmful stresses by accident and, in many instances, economy.

*Numbers in parentheses designate References listed in Chapter XI.

Chapter II Description of Process

The shot peening process is carried out usually in a cabinet in order to confine the shot and facilitate its collection for reuse, as well as to suppress dust.

The work to be peened is introduced into the shot stream usually by a mechanical means, which is so contrived as to expose the critical areas to the shot according to a predetermined program.

The shot consists of hard particles which are classified as to size, and the usual sizes range from 0.016-0.094 in. in diameter. Various kinds and types of shot are available. (See SAE J444, Chapter 5). Shot may be propelled by air, water, or by a wheel, with velocities of the order of 200 fps.

The area covered by the shot stream is called the "shot pattern." * In the case of the pneumatic type of machine, shot delivered from a nozzle and the shot pattern covers

a circular area about 2 or 3 in. in diameter, depending on nozzle size and the distance to the work. The shot pattern from a wheel is fan shaped, with an included angle of about 40 deg and a width somewhat greater than the width of the wheel itself. The length and width of the pattern depends on the distance of the work from the wheel.

Shot peening causes plastic flow in the surface of the object, stressing the material beyond its yield strength, which results in a residual compressive stress. The depth to which this compressive stress extends is dependent upon the properties of the material, the characteristics of the blast, and the amount of shot striking the area being peened. The properties of the blast are defined by the velocity of the shot and its size and type. The amount of shot striking the area being peened is a function of the quantity of shot flowing, the shot pattern, manipulation of the work, and the time of exposure to the blast. Measurement of these factors is described in Chapter VI.

*Sometimes called blast or spray pattern.

Chapter III Effect of Shot Peening

Peening is generally applied to increase resistance to fatigue failure. Fatigue failures are quite easily recognized and almost without variation emanate from a focal point at the surface. These focal points are stress raisers, such as fillets, holes, keyways, seams, laps, tool marks, Stamp marks, or variations in structure. When fatigue failures are encountered, the stress raisers should be removed or avoided, if possible.

Shot peening is widely used on springs; in many cases, it is the difference between success and failure. Table 1 shows increases in fatigue limit that have been obtained.

On larger spring sections with metallurgically sound material, similar values hold. It must be realized that even as small an increase as 10% in the fatigue limit could make an axle shaft or spring just on the borderline in giving failures very successful, so that the percent of increase over the previous life might be several thousand. This fact should be kept in mind when increases in life are given. Exact diagrams are not available for all materials in either torsion or bending. Hence, an increase is determined as an increase in the part life. This may be due to several factors other than peening; for instance, better lubrication due to roughening which forms oil pockets, or an actual radius change in a fillet, both possible under normal peening conditions.

With the foregoing explanation, several examples of peening effects may be of interest. The railway spring industry reports increases in life due to peening of 438-1150%. Shot peening increases the fatigue life of gears to such an extent that gears which, unpeened, failed in 50 hr were running under the same conditions in perfect shape at 250 hr, or a clear increase of 500%. Other tests on drive pinions give 40-414% life increase with peening. Steering knuckles show up to 121% increase in cycles to failure after peening, while crankshafts gave 100-1000% increase in life at the same loads. In many instances, satisfactory transmission or rear axle gears are shot peened and then the loads increased so that they can be used on heavier cars and equipment. These increases vary with design from 17 to 50% and constitute a marked saving in material space. This is one of the important effects of shot peening which design engineers are now widely using.

3.1 EFFECT OF HEAT ON THE FATIGUE PROPERTIES OF SHOT PEENED SPRINGS (3)

Investigations on shot peened springs indicate that heating after peening may have an injurious effect on the expected benefits derived from peening.

At room temperature, the stress range of automotive valve spring wire in the "as received" condition and not peened is 20,000-95,000 psi for 10 million loadings with no failures. Calling the baseline 95,000 psi or 100% endurance range, experience has shown that peening increases this range about 45%, so that the stress range of peened springs becomes 20,000-135,000 psi for the same test.

If springs are not heated after peening, they show more set and, while the endurance range remains the same, the top and bottom stresses are lower. When heated to 450 F and tested at room temperature, optimum results are obtained with very little set (Fig. 1). As the heating is increased after shot peening, a slight decrease is noted at 500 F, and from there to 825 F, the effect of shot peening decreases to the original stress range of 20,000-95,000 psi. Higher heating incites further reductions and lower mechanical properties all along the line.

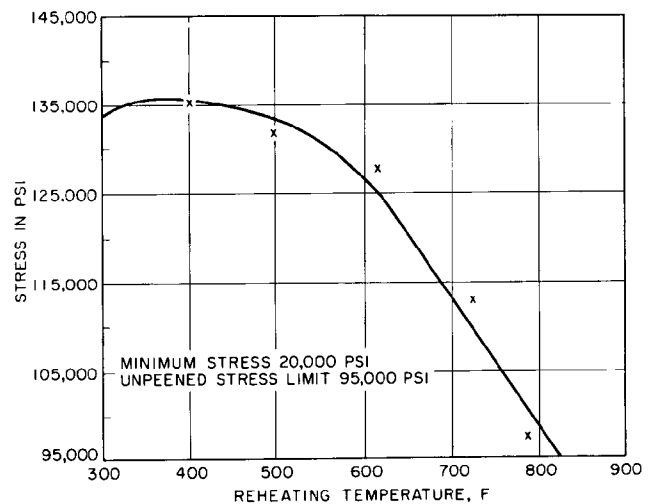


Fig. 1 - Effect of heat on shot blasted springs

Table 1 - Increases in Fatigue Limit

Material	Range Unpeened, psi	Range Peened, psi	Increase, %
Carbon Spring Steel, SAE 1074	75,000	115,000	54
Alloy Spring Steel, SAE 6150	70,000	115,000	60
Stainless Steel, Type 302	45,000	90,000	100
Phosphor Bronze, SAE 81	15,000	30,000	100

Chapter IV Shot Peening Machines

Shot peening machines may be classified into three major categories, depending on the medium which propels the shot. These are air blast machines, centrifugal blast machines, and vapor blast machines.

4.1 TYPICAL PEENING MACHINE

A typical peening machine is made up of the following major parts:

4.1.1 SHOT PROPELLING DEVICE - For accelerating the shot to the desired velocity.

4.1.2 ELEVATOR - For returning the shot to the separator after passing through the projecting device.

4.1.3 SEPARATOR - For removing broken or undersized shot.

4.1.4 SHOT ADDING DEVICE - For replacing broken and undersized shot with new shot.

4.1.5 WORK CONVEYOR - For handling the work so as to subject it to a definite controlled cycle under the blast.

4.1.6 CABINET - For confining the shot within the machine.

4.1.7 DUST COLLECTOR - For removing the dust resulting from the blast.

4.2 AIR BLAST MACHINES

These machines may be subdivided into three kinds, depending on the method of introducing the shot into the air stream.

4.2.1 SUCTION-INDUCTION MACHINES (Fig. 2) - In this type of machine, compressed air is allowed to expand through a nozzle which is provided with a port or auxiliary tube through which the shot enters the nozzle, as shown in

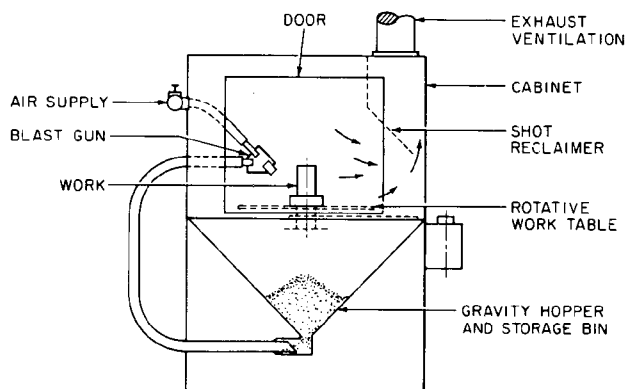


Fig. 2 - Typical suction-induction peening machine

Fig. 3. The shot is drawn into the air stream by entrainment and is then accelerated by the air which is traveling at relatively high velocity.

This is the simplest machine and is used topeen small parts or small quantities, or when the required intensity of peening is low. It is used for laboratory work and for other applications when the shot size is changed frequently.

4.2.2 GRAVITY-INDUCTION MACHINES (Fig. 4) - In this type of machine, the nozzle is identical to that of the suction-induction type, but the shot is introduced to the nozzle by means of gravity. This results in better control of velocity and flow rate.

These machines have a slightly higher blast efficiency than the suction-induction type. They are used where a relatively fixed nozzle position is satisfactory and where the vacuum is not sufficient to lift shot from the lower storage bin.

The induction types have minimum air requirements.

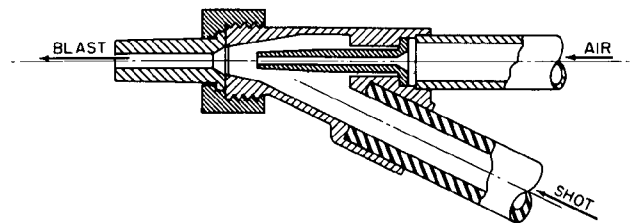


Fig. 3 - Induction nozzle

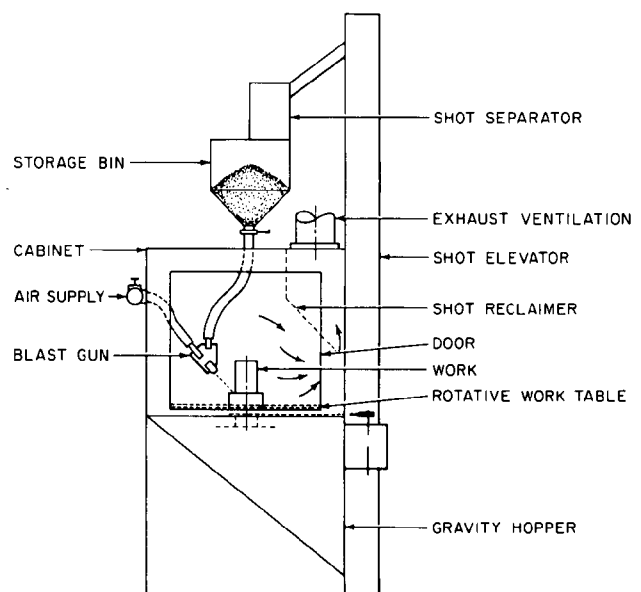


Fig. 4 - Typical gravity-induction peening machine

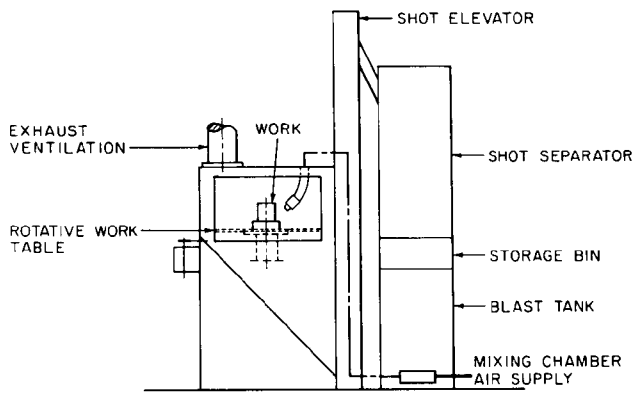


Fig. 5 - Typical direct pressure peening machine

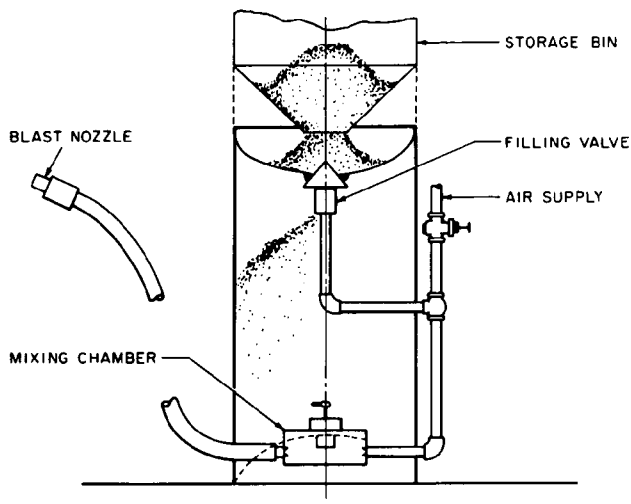


Fig. 6 - Pressure blast tank (intermittent filling)

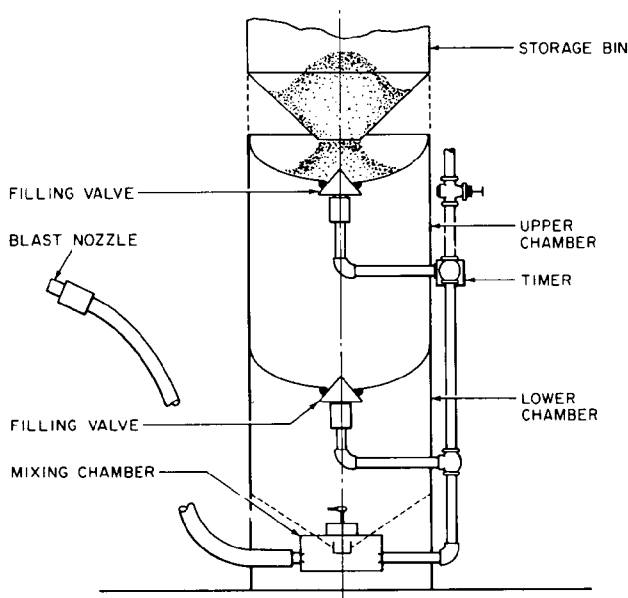


Fig. 7 - Pressure blast tank (continuous filling)

4.2.3 DIRECT PRESSURE MACHINES (Figs. 5-7) - In this type of machine, the shot is stored in a pressure vessel which is maintained at the same pressure as the air blast. The shot is fed by gravity into a mixing chamber in the pressure vessel, where it is caught in the air blast and discharged through a nozzle.

This is the most elaborate type of air blast and has more flexibility, since greater nozzle movements are possible. It is used for peening small areas, such as fillets, at the higher intensities.

4.2.4 NOZZLES - In all three types of air blast machines, the shot is discharged through a nozzle which is expendable, due to the abrasive action of the shot. The life is dependent upon the composition of the nozzle and of the material flowing through it. "Long life" nozzles have the added advantage of providing a uniform shot stream because of the nearly constant orifice size.

It is important in air machines to provide a good pressure regulator and water trap in the compressed air line because any condensation which is admitted to the shot supply tends to "freeze" the shot into a solid mass.

4.3 CENTRIFUGAL BLAST MACHINES (FIGS. 8 AND 9)

In this class of machines, the shot is propelled by centrifugal force. The shot is gravity fed to the hub of a rotating wheel which has radial vanes or blades. By means of a control unit, the shot is directed onto the blades of the wheel, whence it is thrown in a fan shaped stream by centrifugal force.

In cases where flat work is to be peened, this fan shaped stream should be as concentrated as possible for efficient peening. The desired direction of the blast is obtained by an angular adjustment of the control unit which is stationary during the operation of the wheel.

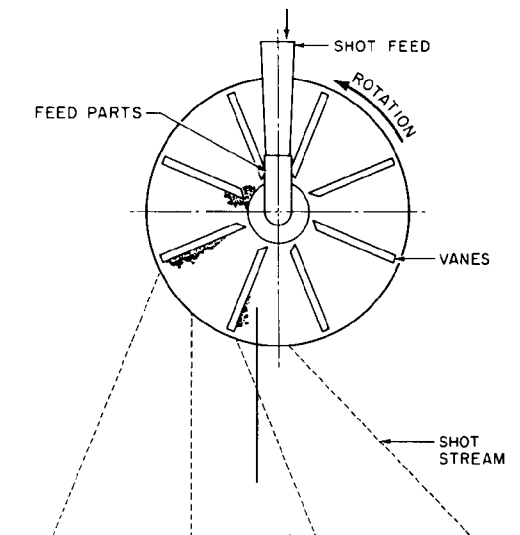


Fig. 8 - Centrifugal wheel peening equipment

4.4 VAPOR BLAST MACHINES

Since vapor blasting is primarily used for cleaning and surface finishing, the description of this process will be found in the SAE Manual on Blast Cleaning. (5)

4.5 WORK HANDLING

In order to obtain as uniform peening as possible, various handling devices have been developed to present the surface to the shot stream.

4.5.1 SINGLE ROTARY TABLE - The principle of operation of this type of machine involves a table rotating on a vertical axis in a fixed position as illustrated in Fig. 10 which shows a hub being shot peened. The hub is located on the center of the table so that the fillet will be peened uniformly.

4.5.2 ROTARY TABLE - STRAIGHT LINE TRAVEL - In this type of machine, a rotating table travels through the blast in a straight line, as shown in Fig. 11. The illustration shows a steering knuckle being shot peened. The straight line travel permits concentration of the blast stream on the center of the table throughout the length of the blast.

4.5.3 ROTARY TABLE - CIRCULAR TRAVEL - In this type of machine, the rotating table travels in a circular path, as

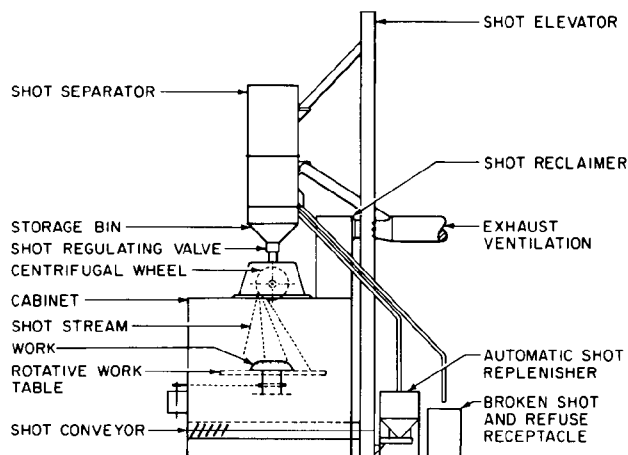


Fig. 9 - Typical centrifugal wheel peening machine

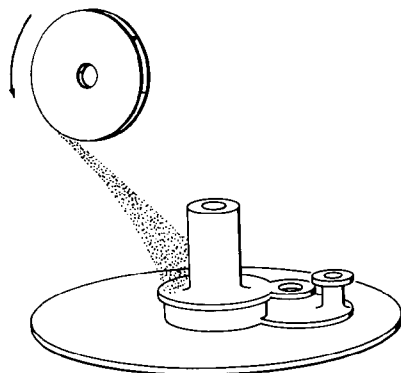


Fig. 10 - Rotary table on vertical axis in fixed position

illustrated in Fig. 12, in which a bevel gear is being peened. The blast is positioned so that the desired coverage is obtained on the areas of the part to be peened.

4.5.4 ANGULAR ROLL - This device involves a series of angularly mounted dished rolls to provide rotation of the work about a horizontal axis with straight line travel parallel to the axis of rotation. This movement is illustrated in Fig. 13 which shows a torsion bar being peened.

4.5.5 PARALLEL ROLL - This device consists of two horizontal and parallel driven work rolls to provide a motion similar to that previously described, but for shorter lengths. A feed device advances the work through the machine. Fig. 14 illustrates this motion in peening a coil spring.

4.5.6 BELT CONVEYOR - In this type of machine, the work travels through the machine in a straight line without rotation. The motion is illustrated in Fig. 15, which shows leaf springs being peened. The work is carried through the blast zone on an endless conveyor.

4.5.7 TUMBLING MACHINE - In this device, the work is tumbled under the wheel blast. This type of machine may be used on small parts where high production is required.

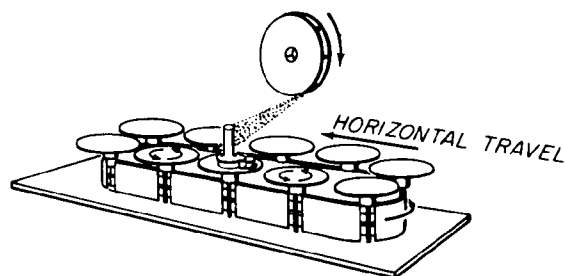


Fig. 11 - Rotary table traveling through blast in straight line

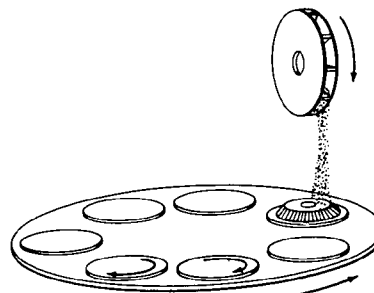


Fig. 12 - Rotary table traveling in circular path

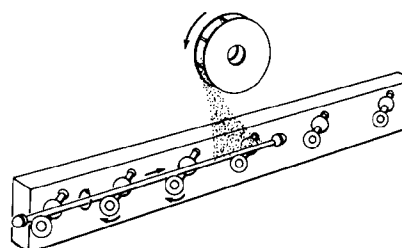


Fig. 13 - Angular roll

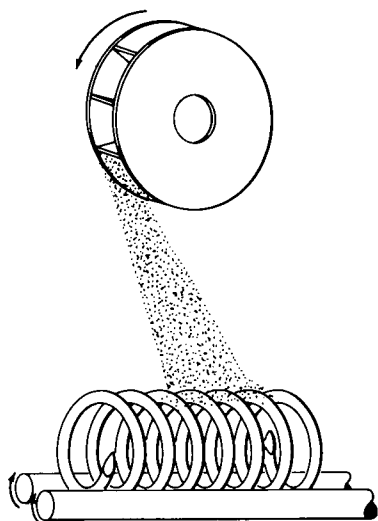


Fig. 14 - Parallel roll

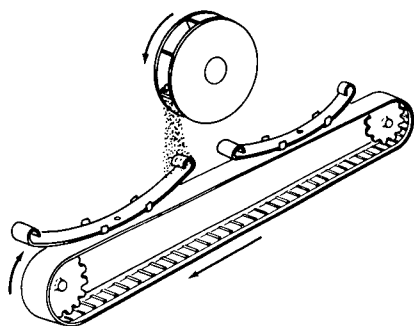


Fig. 15 - Work travels in straight line, no rotation

4.5.8 SPECIAL CABINETS - Many peening applications will require the use of a special peening machine to fit the requirements of the particular parts to be peened, such as size and shape of parts, production requirements, etc.

4.5.9 SHOT HANDLING - The enclosure, or cabinet, surrounding the shot peening equipment serves as a shield to prevent the escape of flying shot, with its accompanying hazards. It also confines the dust which is generated by the process so that, by means of a suitable outlet, the dust can be removed by a conventional dust collector.

The cabinet is also provided with a hopper in which the shot is collected after it strikes the work. From this hopper, the shot is conveyed by gravity or otherwise to an elevator which transports the shot to a separator for removal of broken shot and "fines".

The shot from the elevator enters a screen which removes any large foreign particles which might be in the system. The whole and broken shot falls through the screen and, by means of a distributing device, is deposited uniformly on an inclined plate. By means of gravity, it flows down the plate towards a storage bin, smaller particles gravitating to the underside of the mass.

A controlled air gap in the plate affects the actual separation, as the small particles and the broken shot are pulled through the gap by a regulated air flow. The whole shot, having a greater inertia, fall past the air gap and into the storage bin. Means are provided for varying the air gap and the air stream velocity, depending on the size shot used.

For a peening operation, the separator should be capable of removing broken or undersized shot. The degree to which broken particles are removed varies considerably in practice. Usually, the specific conditions for a given part are established by laboratory fatigue testing.

To maintain uniform peening conditions, shot should be added continuously. Equipment for accomplishing this is available.