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United States Patent

Baughman

[11] **3,705,510**

[45] **Dec. 12, 1972**

[54] **SHOT PEENING METHOD**

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[73] Assignee: **The Carborundum Company**, Niagara Falls, N.Y.

[22] Filed: **June 30, 1970**

[21] Appl. No.: **51,125**

[52] U.S. Cl. 72/53

[51] Int. Cl. C21d 7/06

[58] Field of Search 72/53, 40; 51/8, 9, 319, 320

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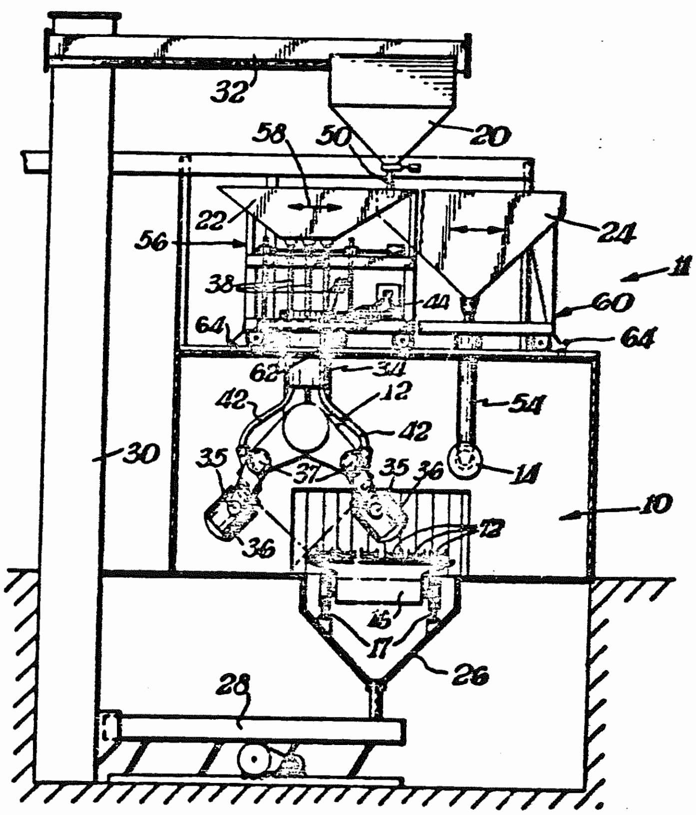
Assistant Examiner—Gene P. Crosby
Attorney—David E. Dougherty and Robert E. Walker

[57] **ABSTRACT**

Metal sheets are peen formed by projecting peening shot from centrifugal shot throwing wheels against the sheet passing thereunder. The centrifugal shot throwing wheels are also used for saturation peening metal objects.

12 Claims, 15 Drawing Figures



SHOT PEENING METHOD

BACKGROUND OF INVENTION

This invention relates to peen forming metal sheets and other peening procedures and is particularly adapted for use in the aircraft industry.

Ideally, the aircraft engineer, in the design of such structures as cantilevered aircraft wings, should use one piece structures to prevent the requirement of weight adding splices. Also, such structures should have constantly tapering thicknesses to carry the necessary loads with minimum structural weight. He is usually thwarted in this goal, however, by the limitations imposed by available manufacturing techniques. For example, aircraft skins with simple airfoil curvatures are usually contoured by bumping in a press brake or rolling between forming rolls. These techniques are not practical for long tapered skin sections.

Compound contoured skins, especially of heavy sections, are very difficult to form with consistent accuracy. They are usually stretch formed over massive contoured dies. The material is in a soft condition and is stretched through its yield point to induce permanent set at the contour desired. The parts must later be heat treated to a hard condition and the excess material required for the stretch operation is trimmed away and discarded. Parts of high strength materials may require hot forming, in which case both the part and the die must be pre-heated. This method also limits the part size to the size of the stretch press or form dies, both of which have practical size limitations. Parts that are tapered in thickness cannot be stretch formed.

Shot peen forming overcomes these limitations in that it can form simple or compound contours in tapered skins. Peening shot is applied directly to material in its hard state or final temper and therefore requires no subsequent heat treatment. Parts can be cut to a predictable undersize and after peening will be to exact size eliminating waste of expensive material. Shot peen forming further requires no expensive contoured stretch dies thereby eliminating allied storage and transportation problems. The process is versatile in that with proper automated controls any contour within the capabilities of the system can be repeated accurately. Subtle application changes are possible to accommodate known variations in the material or the process. Part length need not be limited by this system. Shot peen forming is also used to contour extruded or machined structural shapes. It is also used to straighten parts which have been misformed by other manufacturing methods. Another major advantage of peen forming is that the surface layer of compressive stresses resulting from peening can significantly improve the fatigue life of the parts and help prevent stress corrosion cracking.

The application of simple curvatures to aircraft skins by shot peen forming is not new. It has been done with air nozzle peening for many years as exemplified by U.S. Pat. No. 2,701,408. Methods have been developed to control part deformation while peening so that compound curvatures could be generated. On heavier skins pre-stressing is required and the use of large diameter balls, three-sixteenths inch and one-fourth inch, is sometimes necessary. The feasibility of shot peen forming has long been appreciated, but its use has been

restricted to relatively small structures or low production applications because of the problems inherent in the use of air nozzles and the requirement for large quantities of compressed air.

SUMMARY OF INVENTION

An object of this invention is to provide a method of shot peen forming which overcomes the disadvantages of conventional peen forming by use of air nozzles.

A further object of this invention is to provide such a method which lends itself to high production rates as is necessary in mass production.

In accordance with this invention metal sheets are peen formed by projecting peening shot from centrifugal shot throwing wheels against the sheet passing thereunder. In accordance with another aspect of this invention the centrifugal shot throwing wheels are also used for saturation peening metal objects.

In an advantageous form of this invention the peening shot is projected from a bank of centrifugal throwing wheels with the individual wheels being mounted on a common mounting member in a staggered arrangement in that the set of wheels on one side of the mounting member are intermediate the wheels on the other side thereof. The wheels may be disposed across the moving sheet with the shot patterns produced by the wheels overlapping to assure complete coverage of the sheet and to eliminate the necessity for oscillating the wheels as is conventional with air nozzle methods.

An additional free roving wheel may be utilized for touch-up work by disposing this additional wheel downstream or upstream from the bank of wheels.

The same apparatus for peen forming may also be used for saturation peening by rotating the bank of wheels 90° and oscillating the bank in a transverse direction back and forth over a plurality of longitudinally moving metal members such as stringers. With this particular arrangement of wheels a novel pattern is obtained whereby 100 percent coverage with the peening shot is assured.

The concepts of this invention may also be applied to form intricate shapes such as saddle back or dihedral shapes utilized in wing structures. Thus, for example, the air foil contour may be imparted to the wing skin in accordance with this invention and then dihedral shape may be imparted thereto by masking areas of the skin outside the saddle back so that only the saddle back area is exposed to the shot.

THE DRAWINGS

FIG. 1 is an elevational end view partly in section of an apparatus for peen forming and saturation peening in accordance with this invention;

FIG. 2 is a side view of the apparatus shown in FIG. 1;

FIG. 3 is a plan view showing the feed structure of the apparatus shown in FIG. 1;

FIG. 4 is an end elevational view of the apparatus shown in FIG. 1 in one phase of operation;

FIG. 5 is a plan view of the apparatus shown in FIG. 4;

FIG. 6 is an end view similar to FIG. 4 in a different phase of operation;

FIG. 7 is a plan view of the apparatus shown in FIG. 6;

FIGS. 8–11 are plan views showing the peening pattern resulting from the use of the apparatus shown in FIGS. 6–7;

FIG. 12 is a plan view illustrating the forming of a saddle back in an aircraft wing skin section;

FIG. 13 is a side view of the wing skin shown in FIG. 12; and

FIGS. 14–15 are schematic showings of the circuitry utilized with this invention.

DETAILED DESCRIPTION

FIGS. 1–2 show the general arrangement for peen forming and saturation peening metal pieces in accordance with this invention. In general this arrangement 11 includes a treating chamber 10 having a bank 12 of centrifugal throwing wheels 36 therein with an auxiliary wheel 14 also located in chamber 10. A work piece conveying device 16 rides on tracks 17 and moves the metal pieces being treated under the centrifugal throwing wheels. Each end of chamber 10 includes sealant doors which may be of any suitable construction such as rubber flaps 18 to prevent the peening shot from escaping from the chamber 10.

Shot is delivered from main hopper 20 into a pair of hoppers 22, 24 and ultimately to the throwing wheels. Spent shot is collected in the tapered portion 26 at the bottom of the treating chamber 10 and ultimately recycled back to hopper 20 through conventional separating and elevating devices 28, 30, 32.

FIGS. 4–5 show the utilization of this invention for peen forming skins of aircraft wings. As indicated therein and in conjunction with FIG. 1, the bank 12 of throwing wheels includes centrally mounted rotatable boom 34 to which is connected four individual throwing wheels 36. Advantageously, wheels 36 are of the type illustrated and disclosed in detail in copending application Ser. No. 687,701; filed Dec. 4, 1967, the details of which are incorporated herein by reference thereto. Accordingly, reference will not be made to the specific details of these throwing wheels except where necessary to facilitate an understanding of these wheels within the concepts of this invention. It is noted that the wheels are mounted directly on a motor and are capable of obtaining universal type movement so as to provide an infinite variety of adjustments for the throwing pattern of the shot propelled by each wheel. The wheels 36 may, for example pivot about axes 35, 37, while support boom 34 may rotate, move up and down, and move back and forth. Shot is fed from bin 22 through individual conduits 38 for each of the throwing wheels 36. Each conduit 38 terminates in a compartment 40 (FIG. 3) in the compartmentalized boom 34. The shot travels down compartments 40 and exits therefrom through conduits 42 into the individual throwing wheels 36. By proper adjustment it is possible to close off certain of the conduits so that any number of the throwing wheels 36 may be rendered inactive for smaller jobs.

As later described boom 34 is connected for 90° rotation by means of any suitable actuating member such as cylinder 44 having piston rod 46 reciprocating therein and connected to bracket 48 to oscillate or rotate the boom 34 upon movement of the piston rod 46 into and out of cylinder 44. As is apparent from FIG. 3, although the boom 34 oscillates, by the arrangements of the compartments 40 wherein each compartment is arcuate with an arc length greater than 90° each conduit 38 remains in registry with its compartment 40 regardless of the rotational position of boom 34, thereby assuring continuous feed of shot to the wheels 36.

As shown in FIG. 5 the wheels 36 are arranged in two sets in a staggered fashion wherein each set is on a separate side on the boom or common mounting member 34. FIG. 5 also shows the inclusion of an additional throwing wheel 14 downstream from the bank of wheels 12. Wheel 14 is also of the same general construction as the type of universally mounted wheel shown and described in copending application Ser. No. 687,701; filed Dec. 4, 1967. This wheel 14 is likewise fed from common hopper 20. For example as shown in FIG. 2 hopper 20 has two outlet pipes 50, 52 for feeding shot into hoppers 22 and 24. The shot from hopper 24 is then fed through conduit 54 into wheel 14.

As shown in FIGS. 1–2 bank 12 is mounted on car 56 whereby the entire bank of wheels may move in the direction indicated by the arrow 58. Conduit 50 is so arranged as to remain in registry with hopper 22 regardless of the position of its supporting car 56. Similarly, wheel 14 is not only universally mounted, per se, but is also mounted on car 60 for oscillating in the direction of the arrow 58. Additionally, the bank of wheels 36 and the individual wheel 14 may be moved in a vertical direction. FIG. 1 for example shows the guide rollers 62 to assure proper vertical orientation of the bank 12. Moreover, limit switches 64 are suitably arranged to control the oscillatory movement of the cars 56 and 60. Thus, for example car 56 would move toward the left as shown in FIG. 1 until limit switch 64 is contacted whereupon the direction of the driving motor would be reversed to change the direction of movement of car 56 to the right until a further limit switch is contacted to again reverse the direction of movement of car 56. Similar operations would also take place with respect to car 60.

As shown in FIGS. 1–2 bank 12 is mounted on car 56 whereby the entire bank of wheels may move in the direction indicated by the arrow 58. Conduit 50 is so arranged as to remain in registry with hopper 22 regardless of the position of its supporting car 56. Similarly, wheel 14 is not only universally mounted, per se, but is also mounted on car 60 for oscillating in the direction of the arrow 58. Additionally, the bank of wheels 36 and the individual wheel 14 may be moved in a vertical direction. FIG. 1 for example shows the guide rollers 62 to assure proper vertical orientation of the bank 12. Moreover, limit switches 64 are suitably arranged to control the oscillatory movement of the cars 56 and 60. Thus for example car 56 would move toward the left as shown in FIG. 1 until limit switch 64 is contacted whereupon the direction of the driving motor would be reversed to change the direction of movement of car 56 to the right until a further limit switch is contacted. Similar operations would also take place with respect to car 60.

FIGS. 4–6 show the utilization of apparatus 11 of peen forming aircraft wing skin sections. As indicated therein a flat metal sheet 66 is placed on forms 68 and clamped thereto by any suitable devices such as C-clamps 70 to bend the sheet in the desired air-foil conture. On thinner sheets this pre-forming or pre-stressing on forms is not required, part is peened flat, and the C-clamps are not required or act only as locators. Forms 68 are in turn mounted on an elongated car 16 for travelling under the various centrifugal throwing wheels. As illustrated in FIGS. 4–5 free roving wheel 14 is arranged longitudinally offset from the bank of wheels 36 so that the combination of wheels 14 and 36 forms a plurality of peening patterns which extend completely across the sheet 66. For smaller dimension sheets the bank of wheels 36 would be sufficient to provide the necessary peening coverage with the shot and for even smaller sheets certain individual wheels 36 can be inactivated. Peening shot is projected from the wheels 14 and 36 to permanently deform and thus provide the desired contour to sheet 66. With this arrangement it is not necessary to impart any oscillating movement as is required with conventional air nozzles.

As can be appreciated the inclusion of free moving wheel 14 lends much versatility to apparatus 11. Wheel 14 may for example be used for skin straightening or touch-up work. This wheel can be remotely controlled to move horizontally or transverse to the work car travel or to move up and down. Moreover, the wheel can rotate around a vertical axis or can roll on its own horizontal axis. The wheel 14 can be used in combination with the bank of wheels for either adding to the transverse coverage of the combination of wheels or to alter the general curvature of the skin by locating it directly downstream from one of the other wheels so that a certain portion of the skin will be subject to greater peening action.

FIGS. 6–7 show how the same apparatus 11 by certain adjustments can be converted from a peen forming device to a device for saturation peening. As indicated therein the bank of wheels 36 is rotated 90° from the position indicated in FIGS. 4–5 to the position indicated in FIGS. 5–6 wherein pairs of the wheels are longitudinally aligned with respect to each other. The saturation peening unlike peen forming is not intended to deform the shape of the object being peened but rather is intended to impart certain mechanical characteristics to the object. For example the saturation peening could be utilized for stress relieving and surface improvement. During most saturation peening operations utilizing apparatus 11, free moving wheel 14 would be inactivated and the saturation peening would be accomplished by oscillating the banks of wheels 36. Wheels 36 are driven by static variable frequency drives so that very low intensities for saturation peening to very high frequencies for peen forming would be possible. The small and compact wheel design makes it possible to use a mounting which allows five motions so that the shot stream can be zeroed in wherever it is wanted. Advantageously, larger diameter shot is used to reduce surface roughness while shot loss from breakdown is almost non-existent. The shot is preferably made by ball-bearing techniques and is very smooth, spherical and consistent in size. Each wheel 36 can handle more than 36,000 pounds of shot per hour at shot velocities up to and exceeding 265 ft. per sec. with the shot up to ¼ inch diameter as compared with 1/16 inch maximum diameter shot heretofore generally used for peen forming.

The concepts of this invention may be applied for peen forming flat skins without significant stiffening members although longitudinal stiffeners do not limit peen forming of simple air foil contours. It is possible to free form thin sections merely by controlling the shot velocity, volume and coverage by use of a digital or numerical control system. Heavier sections, however, might require pre-stressing by the use of holding devices such as C-clamps 70 while the peening operation takes place. Where free formed sections are peened it is not necessary to utilize a mold or female die. Such free forming may be utilized to produce aircraft skins up to ½ inch thick as well as mold steel up to the same thickness. Thus the concepts of this invention could apply to the process of making larger-heavy wall segments for welding into cylindrical or compound shapes such as pressure vessels or radar antenna.

Since centrifugal shot peening produces a somewhat rough "orange peel" surface on the formed parts the surface can be blended and smoothed by using the same shot size and pattern at lower intensities. Larger shot gives a smoother surface because the ball radius is larger and the indentation depth and ball velocity are less.

Referring again to FIGS. 5–6 the saturation peening is accomplished by placing the objects such as longitudinal stringers 72 on the work car 16 and adjusting the bank of wheels 36 to the proper height with respect to the stringers 72. FIG. 6 for example shows how the bank of wheels 36 is capable of vertically moving the distance B. Wheels 36 are angled to the proper position such as 45° and work car 56 (FIG. 1) is set in motion to oscillate back and forth whereby an oscillatory movement equal to the distance A of FIG. 6 is imparted to the wheels 36. Because of the angular arrangement of the wheels the vertical outer side walls 72*a* disposed toward wheel 36*a* are peened by wheel 36*a*, while the vertical inner side walls 72*b* disposed toward wheel 36*b* are peened by wheel 36*b*.

As the wheels 36 oscillate back and forth above stringers 72 a novel peening pattern is formed whereby in two complete oscillations there is 100 percent saturation peening or peening coverage of a given area of the stringers. This pattern is illustrated in FIGS. 8–11. FIG. 8 illustrates the patterns *c*, *d*, *e* and *f* obtained from wheels 36*c*, 36*d*, 36*e*, and 36*f* when the wheels have moved once across the stringer 72 which in turn moves in the direction indicated by the arrow 74. As is indicated in FIG. 8 when the bank of wheels 36 has moved once completely across stringer 72 five paths are thus formed with one of the paths *g* being completely devoid of peening treatment. This vacant path results from the particular arrangement of staggered wheels 36.

FIG. 9 shows the resultant pattern after wheels 36 have moved completely back and forth across stringer 72. As indicated therein triangular areas 76, 78 and 80 as indicated by the overlapped hatching and stippling have been subjected to a double coverage. Areas 82, 84, 86 and 88, however, have only had a single application of peening, while area 90 still remains unpeened.

FIG. 10 shows the resultant patterns when the bank of wheels 36 has made its third pass or the beginning of its second oscillation over stringer 72. As indicated therein only the four triangular areas 92, 94, 96 and 98 have had a single application of shot peening while the remainder of the areas have had at least two applications of peening.

Referring again to FIG. 8 as noted above the area covered by wheels 36c–f includes the five bands indicated as c, d, g, e and f when the wheels make one pass over the stringer 72. Since the stringer, however, is moving longitudinally while the wheels are oscillating or moving perpendicular thereto, when the wheels 36 make a second pass a zig-zag pattern is formed as indicated by the bands c, d, g, e, f, h and i. (Each area designated as a band is at an angle equal to the angle of bands c, d, g, e and f of FIG. 8.) It is noted that bands h and i are only partial areas which do not extend completely across the stringer 72. These bands are then completed when wheels 36 make the third pass as indicated in FIG. 10. FIG. 11 shows the resultant pattern when the fourth pass or second oscillation is completed. As indicated therein the areas covered by the wheels 36 are designated as c, d, g, e, f, h, i, j, k although the areas j and k do not extend completely across the stringer 72. As indicated by the overlapped hatching, the area of the five bands g, e, f, h and i have been completely covered at least twice by the peening wheels 36. This five-band area corresponds in dimension to the original area c, d, g, e, and f illustrated in FIG. 8 but is shifted by two band widths because stringers 72 are moving during the peening wheel oscillation.

FIGS. 8–11 merely show the result obtained over a limited area by two complete oscillations of the bank of peening wheels. Since the peening wheels continuously oscillate while the stringers are moving, similar patterns are obtained over the entire surface of the stringers so that a complete saturation peening operation thereby results.

FIGS. 12–13 illustrate another aspect of this invention wherein the bank 12 of wheels 36 is utilized to form a dihedral or saddle back break in an aircraft wing skin section. In this embodiment such a compound contour as the dihedral break frequently is aerodymically necessary for aircraft wings but has, however, presented a particular problem to the prior art. It was commonly necessary in the prior art to separately form the skin sections on each side of the dihedral break or saddle back and also to form a separate saddle back section. All three sections were then secured together, which led to a number of disadvantages both aerodynamically and with respect to the added weight caused by securing the sections together. In accordance with this invention it is possible to form an integral aircraft wing skin having a saddle back section. This is accomplished by first forming the air foil contour on a skin section 100 in the manner described with respect to FIGS. 4–5. As indicated in FIG. 12 the contoured skin section 100 is then masked in the areas 102, 104 with the saddle back 106 being disposed between these masked sections. Any suitable masking material such as sheets of rubber or layers of heavy masking tape may be used. The bank of wheels 36 then oscillates over areas 102, 104, and 106 along for example center line 108 with the peening shot affecting only unmasked area 106 to result in a saddle back formation 110 between the areas 112 and 114 (FIG. 13) of the wing skin 100. Although FIG. 12 illustrates the bank of wheels as oscillating over the wing skin 100, for certain applications the wheels may be stationary.

By utilizing the techniques described with respect to FIGS. 4–5 and 12–13, it is thereby possible to form a pair of mating wing skins having the desired aerodynamic contour including the dihedral or saddle back sections. The pair of mating skin sections may thereafter be secured together to form a wing which is schematically illustrated as being secured to the body of the airplane 116 in FIGS. 12–13.

FIGS. 14–15 schematically illustrate possible electrical controls to assure a synchronization of the transverse movement of wheels 36 with respect to the longitudinal movement of the work car 16 to assure that a uniform pattern such as illustrated in FIGS. 8–11 will be obtained. Generally these controls include a pulse generator 118 schematically illustrated in FIG. 2 as being suitably mounted on the work car puller drive which for example may be a 7 ½ HP (SCR) DC variable speed motor. FIG. 14 illustrates the transmitter 118 which is driven by the work car and also transformer 120 driven by the car 56 for the bank of wheels 36. The signals generated by the longitudinal moving work car 16 and the traversely moving car 56 are compared by phase detector 122 to assure a synchronization of the transverse and longitudinal movements. If the movements are not synchronized the oscillation might for example be appropriately increased or decreased. FIG. 15 also illustrates the oscillating car motor drive SCR of transversing car 56.

Although peen forming is old in the art the use of centrifugal throwing wheels instead of the conventional blast nozzles to accomplish the peen forming is unobvious for a number of reasons. For example it was believed by those skilled in the art that the intensity of a pattern produced by a centrifugal wheel varied across the entire pattern. It has been found, however, that actually the only variance was at the extremes of the pattern. This could be compensated for, however, by providing overlapping patterns. Additionally, the use of centrifugal wheels has a number of unexpected advantages. In this respect the wheels are actually more efficient than the prior art air nozzles since only about 20 HP is required to project the same amount of shot as compared with 420 HP of an air compressor. The emergence of the demand created by the aircraft industry thereby created needs for higher and more efficient production whereby such performance with prior art nozzles would be totally unsatisfactory. Furthermore, with the prior art air nozzles in order to change the velocity of the shot it is necessary to change the pressure which is difficult to accurately adjust because of pressure fluctuations. In contrast with the centrifugal throwing wheels accurate adjustments can be made by simply adjusting the r.p.m.

The concepts of this invention can be applied to flatten a flat sheet by moving the sheet under a stream of shot; to reshape or apply a simple contour to a sheet with or without integral stiffening ribs; to form compound contours with or without stiffeners; to form simple or compound contours in a sheet using tooling devices to pre-stress the part in the desired shape while peening; to flatten or form simple or compound contours in the sheet wherein the centrifugal wheels are universally mounted so that the aiming of the shot streams is not restricted; to flatten or form simple or compound contours in a sheet wherein the universal wheels are powered for remote actuation of targeting or aiming; and to flatten or form simple or compound contours with the universally mounted wheels having any or all of its universal movements pre-programmed by digital, numerical or other controls.

The use of centrifugal wheels for peen forming actually represents a significant advancement in the art. Heretofore shot peen forming has been treated — quite properly — as more art than science. Those who developed and practiced it considered the air nozzle a necessary tool of the art. With the advent of a centrifugal shot-throwing wheel, peen forming now ceases to be an art and becomes a cost-saving manufacturing method of great potential. Some of the user benefits are:

1. Elimination of the length restrictions on long, tapered parts with simple contours. Such parts are usually formed by bumping on a press brake or by forming rolls. Both of these processes impose length limits because of their nature.

2. Elimination of the need for massive stretch-forming dies for shaping simple contours; also, elimination of the heattreating operation that is almost always necessary after stretch forming. Parts can be peen-formed in the hardened condition or final temper without subsequent heat treatment. Since stretch forming cannot be applied to parts that taper in thickness, this is still another design limitation that can be avoided by using peen forming methods.

3. Improvement in fatigue properties of parts shaped by peen forming. The surface layer of compressive stresses produced by peen forming also helps to prevent stress corrosion cracking.

What is claimed is:

1. A method of peen forming metal sheets comprising providing centrifugal shot throwing wheel means above the sheet, said wheel means includes a bank of a plurality of centrifugal throwing wheels, each wheel of the bank being mounted to a common mounting member with one set of wheels on one side of the mounting member and the remaining set of wheels on the other side thereof, and said wheels of one set being staggered with respect to the wheels in the other set, causing relative longitudinal movement between the centrifugal shot throwing wheel means and the sheet so that the sheet has the effect of passing under the centrifugal shot throwing wheel means, disposing the bank of wheels across the sheet in a direction transverse to the direction of relative movement of the sheet, disposing each centrifugal throwing wheel to project shot in a pattern extending across the sheet to be formed, maintaining the bank of wheels fixed with respect to the transverse direction, feeding peening shot to the wheel means, projecting the peening shot from the centrifugal throwing wheels in overlapping patterns against the sheet, and permanently deforming the sheet with the peening shot.

2. A method as set forth in claim 1 including disposing a free moving centrifugal throwing wheel above the sheet in a longitudinal position displaced from the individual wheels of the bank of wheels.

3. A method as set forth in claim 1 including disposing a free moving centrifugal throwing wheel above the sheet downstream from the bank of wheels, and utilizing the free moving centrifugal throwing wheel to apply a touch-up operation to the sheet.

4. A method as set forth in claim 1 wherein said sheet is an aircraft wing skin and is deformed into an air foil contour, including the steps of masking portions of the skin to create an unmasked area therebetween corresponding to a dihedral break, disposing the masked skin under centrifugal throwing wheels, and peening the unmasked dihedral break area with shot projected from the centrifugal throwing wheels to form a saddle back integral with the remaining portions of the skin.

5. A method as set forth in claim 4 wherein a pair of the skins are formed with integral saddle backs and the pair of skins are secured together to form a wing.

6. A method as set forth in claim 5 wherein prior to the saddle back formation the bank of wheels are rotated 90° and the wheels are oscillated back and forth across the skin to form the saddle back.

7. A method as set forth in claim 1 wherein the peened surface is blended and smoothed by projecting shot from the bank of wheels at a lower intensity than was used in the peen forming operation.

8. A method of saturation peening metal objects comprising providing centrifugal shot throwing wheel means above the objects, said wheel means including a bank of a plurality of centrifugal throwing wheels, said bank being disposed in a longitudinal direction, each centrifugal throwing wheel being disposed to project shot in a longitudinal pattern against the objects to be treated, causing relative longitudinal movement between the centrifugal shot throwing wheel means and the object so that the objects have the effect of passing under the shot throwing wheel means, feeding peening shot to the wheel means, projecting the peening shot from the wheel means against the object, and oscillating the wheel means back and forth over the object transverse to the relative longitudinal movement thereof while the shot is projected from the wheel means.

9. A method as set forth in claim 8 including synchronizing the oscillatory movement of the throwing wheel means with the relative longitudinal movement to provide a uniform saturation peening.

10. A method as set forth in claim 8 wherein the wheel means includes a bank of a plurality of centrifugal throwing wheels, disposing the wheels in the bank in a staggered manner, creating an enlarged treating area equal to about the number of wheels plus one times the width of the pattern obtained from a single wheel upon the first pass of the bank of wheels across the objects with a portion of the enlarged treating area being untreated, reversing the direction of the bank of wheels back and forth over the objects for two complete oscillations with an area equal to the enlarged area being peened by at least two of the four passes of the two complete oscillations.

11. A method as set forth in claim 10 wherein the bank of wheels includes four wheels and the enlarged area is five times the area covered by a pattern produced by one of the wheels individually.

12. A method as set forth in claim 8 including mounting the individual wheels of the bank to a common mounting member with one set of wheels on one side of the mounting member and the remaining sets of wheels

on the other side thereof, and staggering the wheels of one set with respect to the wheels in the other set.

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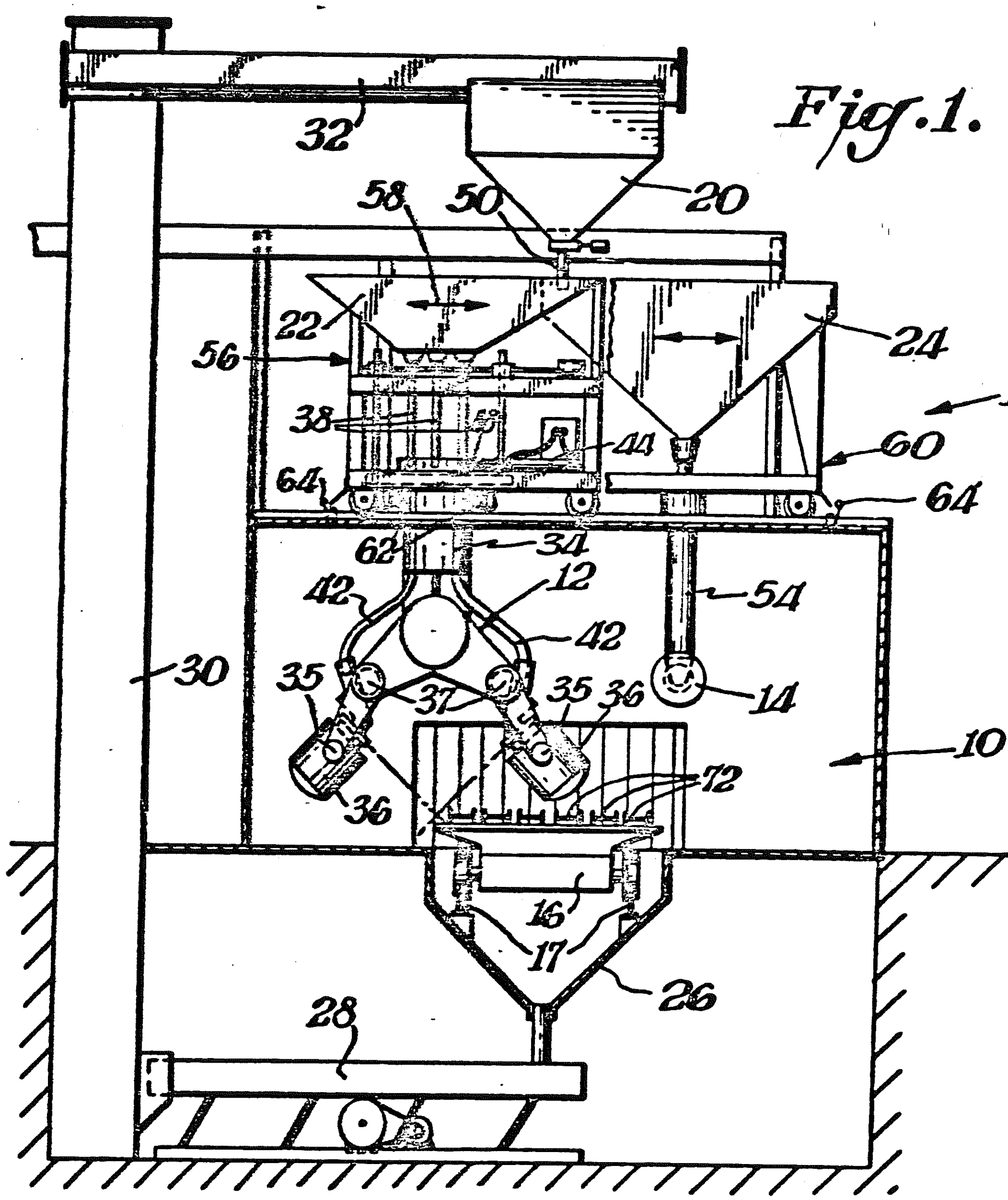

Fig. 1.

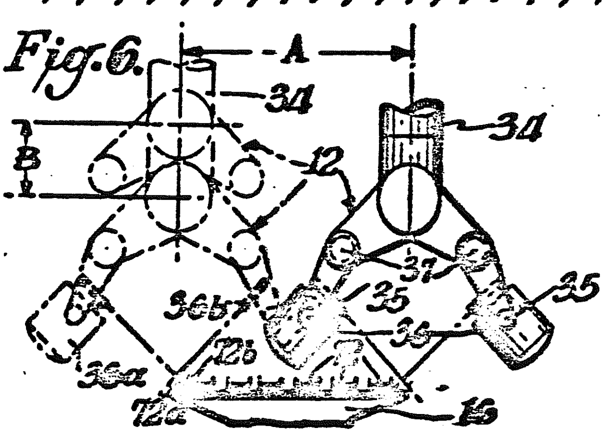

Fig. 6.

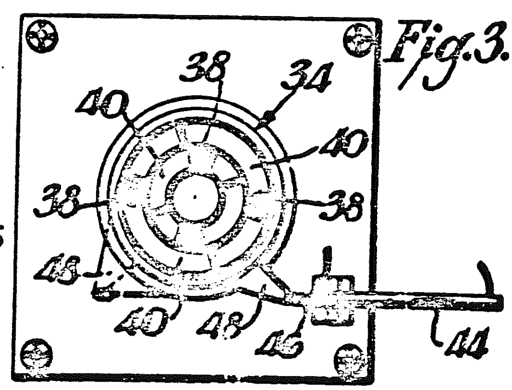

Fig. 3.

Fig. 2.

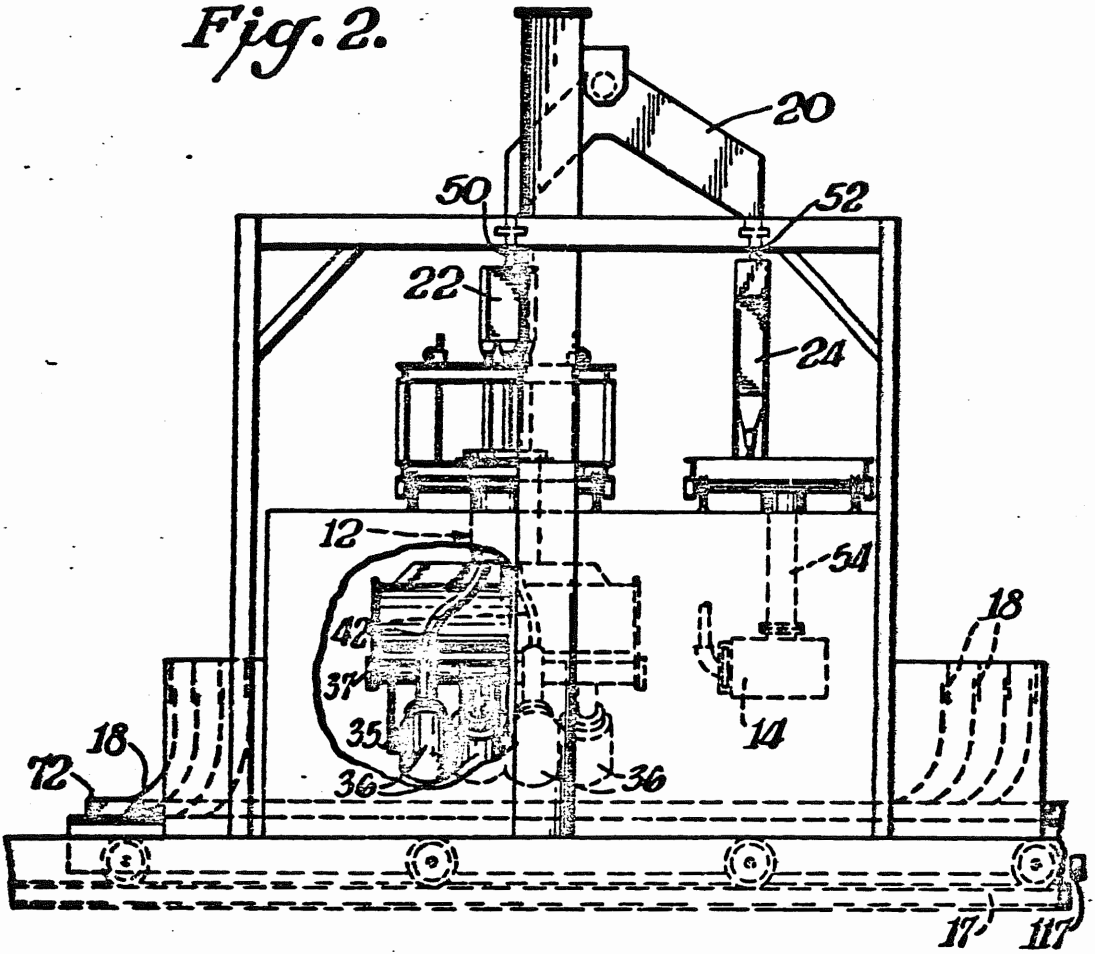
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Fig. 11.

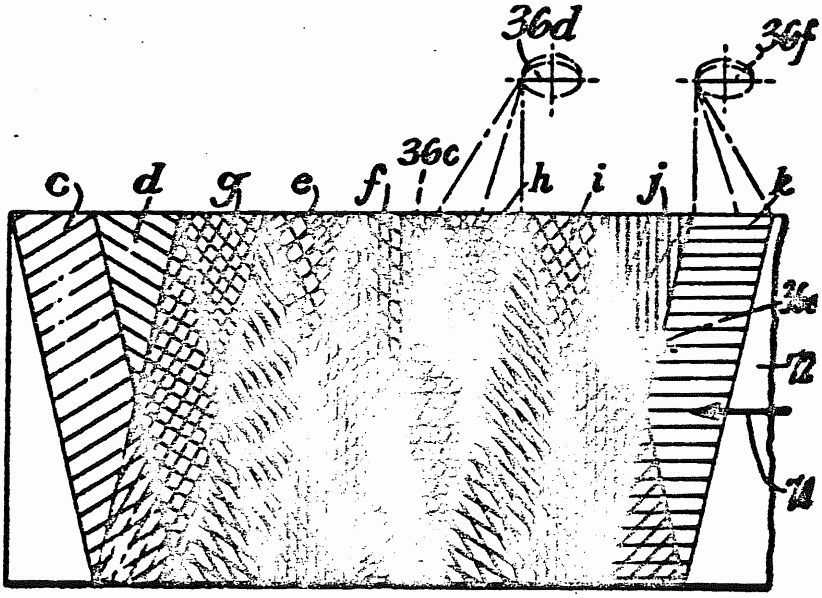
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Fig. 7.

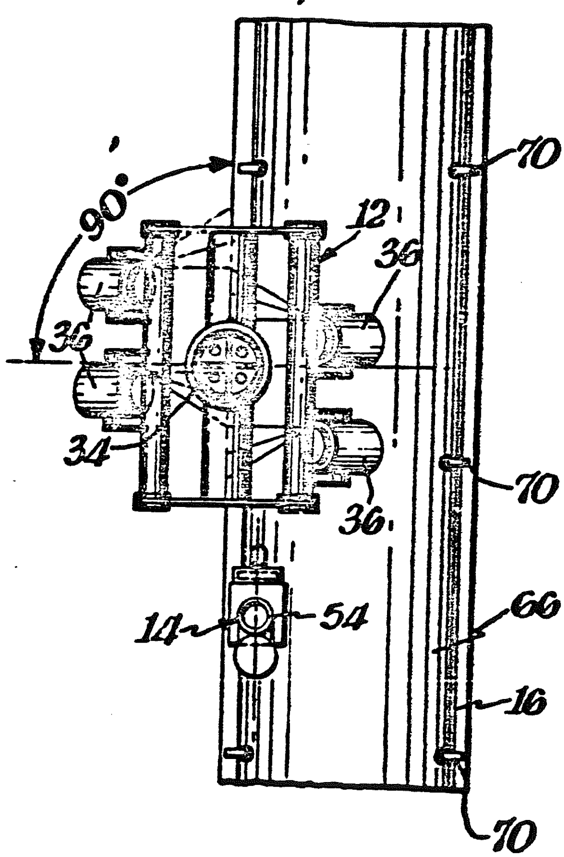


Fig. 5.

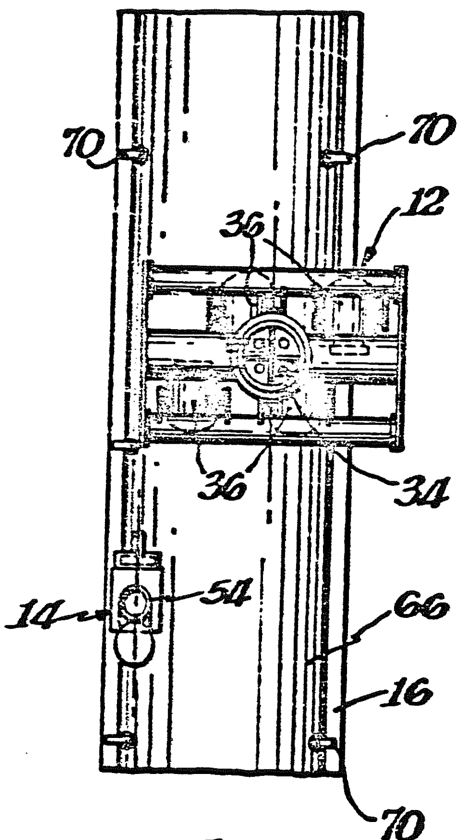


Fig. 4.

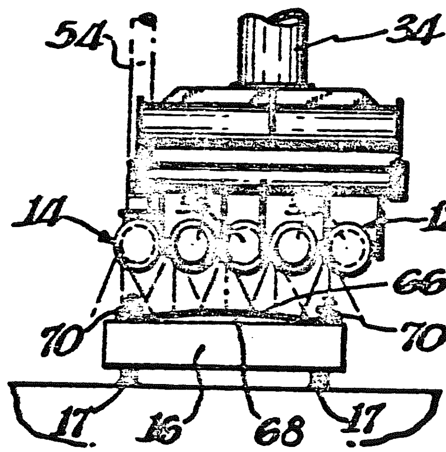


Fig. 8.

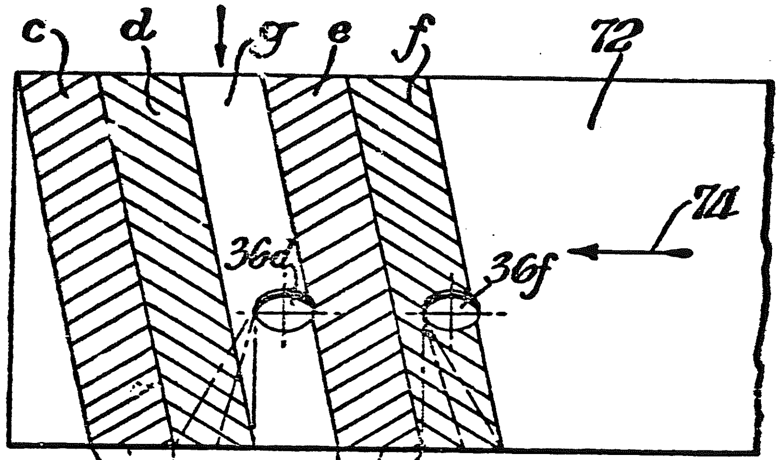


Fig. 9.

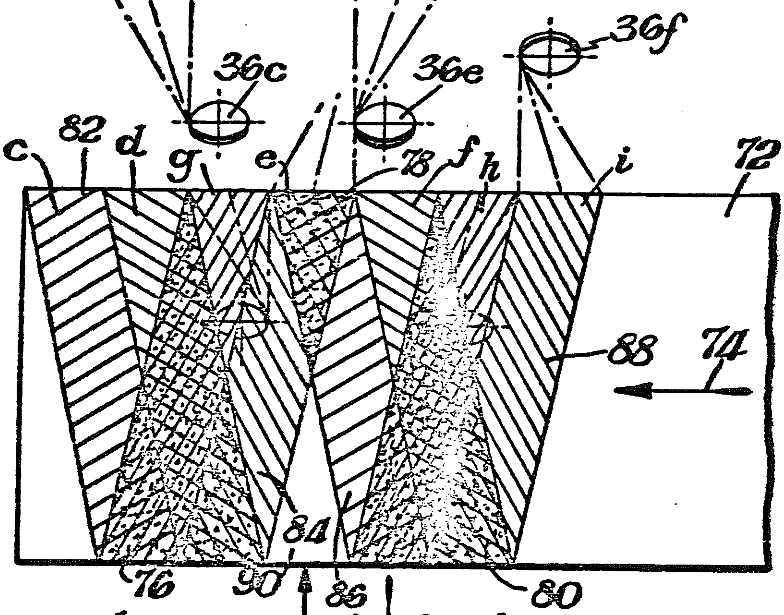


Fig. 10.

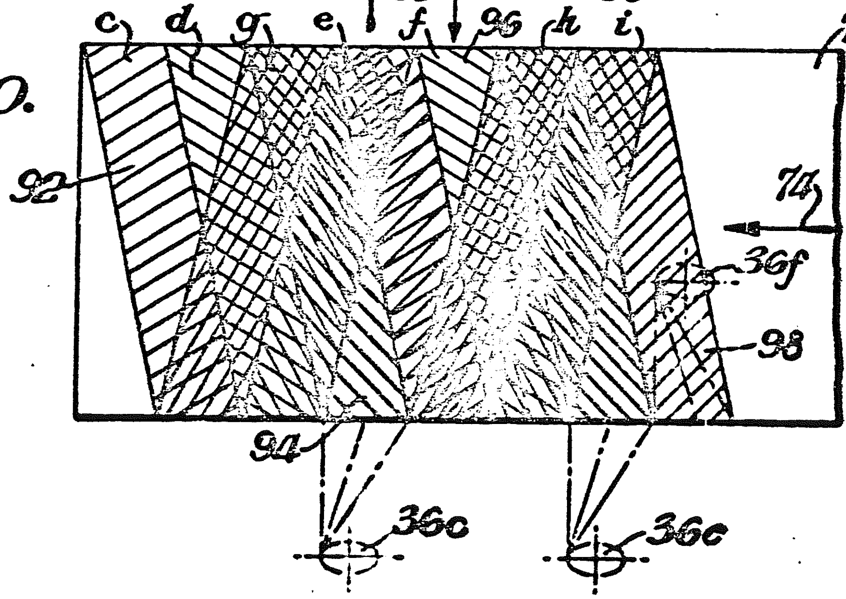


Fig. 12.

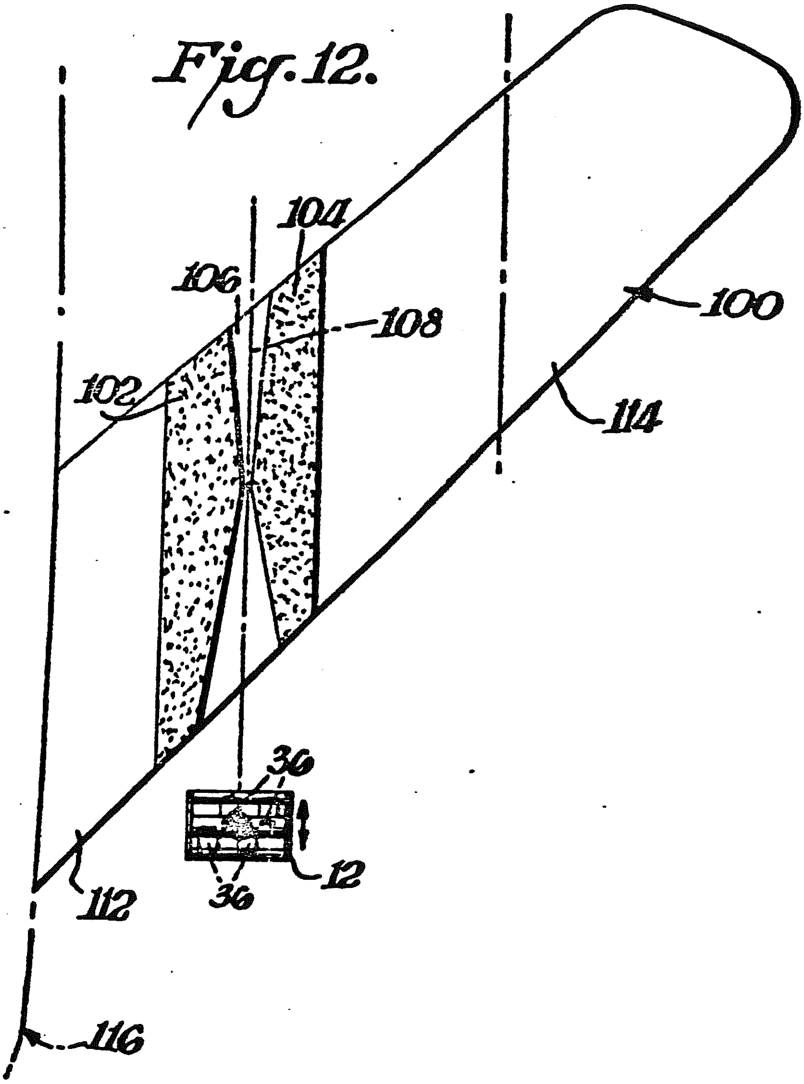


Fig. 13.

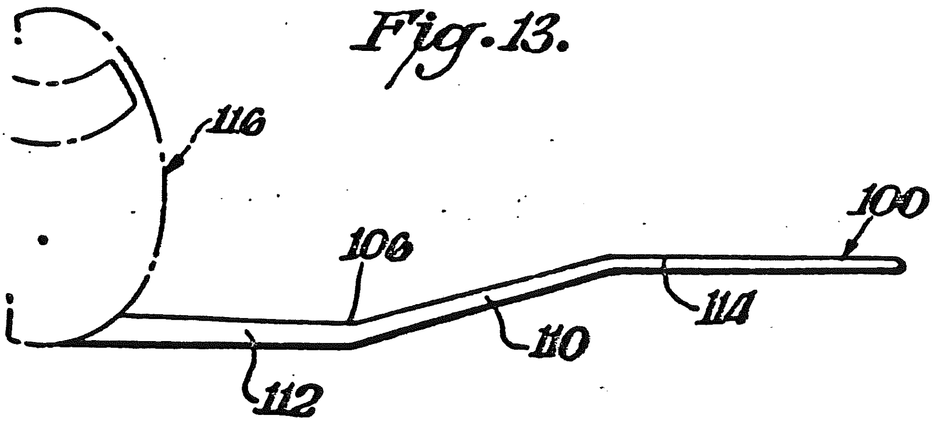
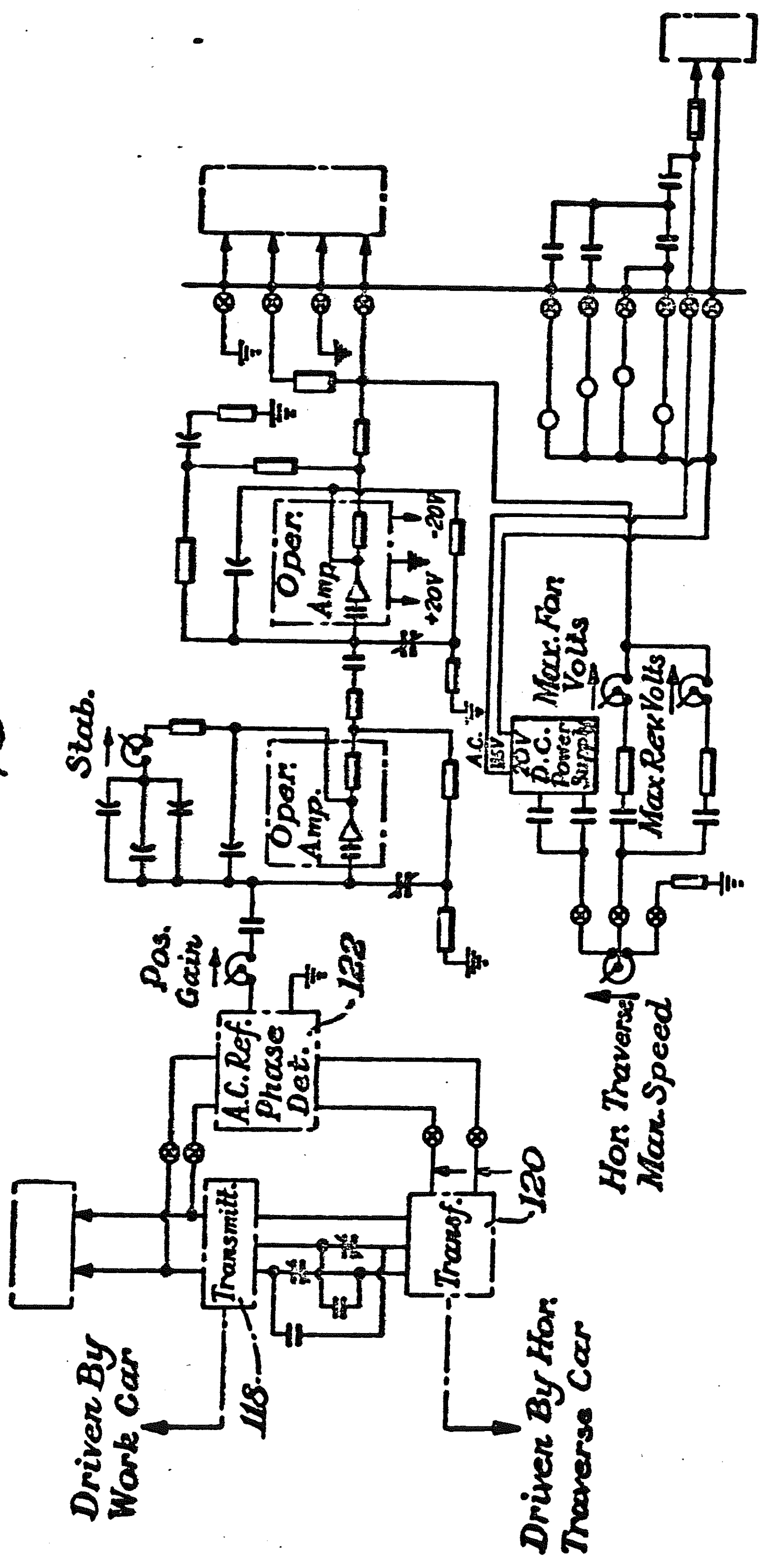


Fig. 14.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-20V
+20V
Oper. Amp.
Stab.
Pos. Gain
122
A.C. Ref. Phase Det.
Transmitt.
Transf.
120
118
Driven By Work Car
Driven By Hor. Traverse Car
Hor. Traverse Max. Speed
A.C.
115V
20V D.C. Power Supply
Max. For. Volts
Max. Rev. Volts

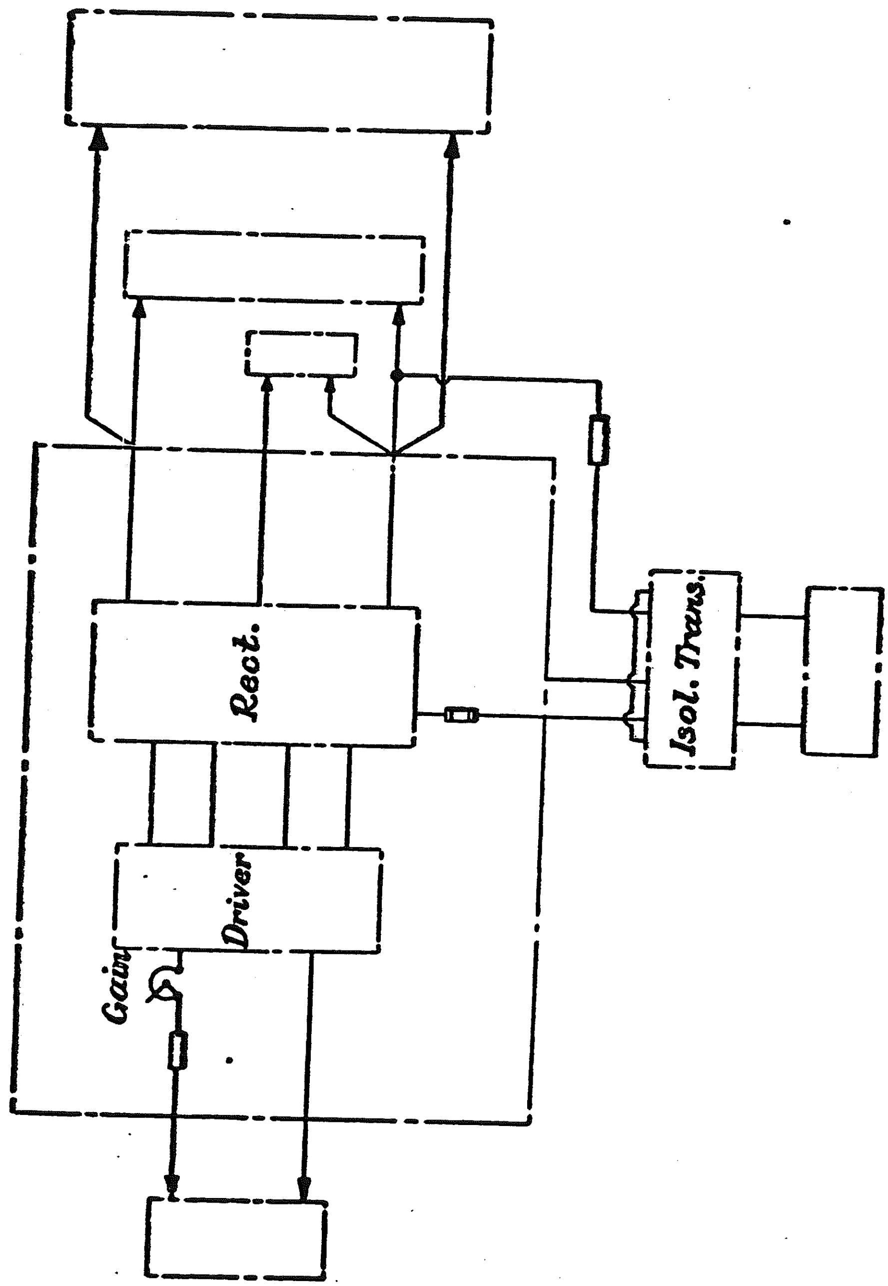

Fig. 15.