Usefulness, Effectiveness, and Process Technology of Glass Bead Shot Peening

By Gerald P. Balcar, and W. Earl Hanley
Potters Industries, Inc. and The Ballotini Group, S.A.

Steel shot peening as a means of developing substantially increased fatigue resistance through the creation of a layer of residual compressive stress on high performance alloys of steel, aluminum and titanium was introduced in the 1930's by Almen, Fuchs, Matteson, Straub, and others. Specific application of the process to the aircraft industry, and its importance as a means of preventing stress corrosion has been reported by Moore, Kurz, Suess, Noble, and others. The purpose of this article is to update the knowledge of the use of glass beads as a shot peening media with advantages they may offer to increase design capability and to develop more economical peening processing.

It was Noble who first proved the value of glass beads as a shot peening media with two specific advantages. He used them at a variety of intensities on aluminum surfaces to avoid the necessary passivation or processing required to remove the contamination of steel shot, and he established that glass beads could be used to peen relatively delicate parts of narrow dimensions or with fillet areas of narrow radii with maximum control of results. He demonstrated that glass beads could serve as a shot peening media quite different in characteristics from the traditional steel shot.

Figure 1 is a simple comparison of the chemical and physical properties of glass beads vs. steel shot, which may be the first indication of their usefulness as a peening media.

In terms of density, soda lime type glass is normally 2.5 grams per cubic centimeter vs. steel with 7.2 grams per cubic centimeter. Useful intensities can be obtained with glass beads since beads, being lighter, accelerate to higher velocities.

When you compare chemical characteristics, you find steel is reactive in conventional corrosive environments while glass is virtually inert, reacting readily only with hydrofluoric acid as indicated. In applications involving aluminum by using glass bead peening to avoid passivation, there can be significant cost-savings.

Normally, pre-blasting is not necessary to insure adequate uniformity of total mass and fracture resistance of shot material. The smaller sizes and lower density of glass beads make possible their use in peening cutting tools, punches, and other sharp-edged surfaces which, in certain circumstances, can increase tool life. Further, their lower density is easier to control at low intensities and is insurance against overpeening.

GLASS BEAD PEENING INTENSITIES

Matteson with the objective of showing the saturation intensities that might be achieved in shot peening in favorable circumstances, used a ¼ in. direct pressure straight bore nozzle and a suction-induction system with a ½ in. nozzle and ¼ in. air jet.

Figures 2 and 2A show the intensities which have been obtained with various diameters of beads with the suction-induction system. Figures 3 and 3A those which were achieved with the direct pressure system.

Figure 4 is a table for comparison listing and of the nominal masses and the range of masses of the nominal particle sizes. Ritter prepared this information and it serves as a background to the effects of the two exponential functions that come to bear in shot peening. Of course, the function I or K equals $\frac{MV^2}{2}$ is fundamental. It is, however, important to note that

\begin{table}
\begin{tabular}{|c|c|c|}
\hline
\textbf{Hardness} & Glass Beads & Steel Shot \\
\hline
\textbf{Rockwell C} & 46-48 & 40-50 \\
\textbf{Specific Gravity (gm/cc)} & 2.45-2.55 & 7.0-7.2 \\
\textbf{Chemical durability in N.50 H$_2$SO$_4$ at 90°, 24 hrs. max.} & reacts readily into oxides, sulfides, halides etc. and with acids. & \\
\textbf{Max. size in commercial stock} & approx. 5-6 mm. & 3-4 mm. \\
\textbf{Min. size in commercial stock} & 20-40 microns & 110-130 microns. \\
\hline
\end{tabular}
\end{table}
The variance between the weight of the individual particles or each nominal range serves to show the effect of the exponents to the 3rd power on the mass of particles and thereby on the peening intensity which is obtained.

Once again, it should be emphasized that the purpose of these tests were to generalize the peening intensities that could be obtained with glass beads to provide guidelines for testing of specific machines or applications. It should be noted that similar nozzle and air jet sizes would be necessary to duplicate these intensities.

GLASS BEAD PEENING RESULTS

Noble reports a series of tests showing the results of glass bead peening at various intensities on surfaces of various hardnesses.

Figure 5 demonstrates the depth of residual compressive stress after peening with glass beads nominally .015 in. (380 microns) in diameter. This was done by determining arc and stress characteristics of samples after the removal of gradients from the surface by etching. The hardnesses shown are RC 40 and 60. The arc heights are .022N and .018N. These curves are known as "typical stress gradients."

Figure 6 is a stress gradient on a Rockwell C 40 surface. This indicates the depth of stress achieved at the indicated intensities.

**ECONOMICS OF GLASS BEAD PEENING**

Because of the material characteristics of glass, impact consumption is a consideration in the use of glass bead peening. We conducted tests from our own protocol to determine the nature of this impact consumption and to measure it as accurately as possible. In preparing the protocol it was necessary to consider the variables which, in this case, are three dimensional. First, the specific ammen peening intensity; second, the size of the glass bead material being used (i.e. diameter or mass); third, the hardness of surface. A fourth variable exists in the nozzle angle which we have studied in isolated tests. Indications are that impact consumption may be reduced by use of a reflecting nozzle angle which would reduce the possibility of glass impacting on glass through reflection of glass particles back into the nozzle stream. In order to reduce the complexity of the testing we adopted the 90 degree angle as being the one most acceptable in shot peening processes.
To establish a universal quantity of impact consumption we adopted the term “percent per cycle” which is a figure that can be multiplied by any feed rate to create an estimated consumption. To illustrate how we arrive at the “percent per cycle” take a flow rate of 100 lbs. per hour through a nozzle with a percent per cycle consumption of 3 percent, the consumption would be 3 lbs. per hour. If the flow rate is 500 lbs. in a multi-nozzle machine the “percent per cycle” consumption would then account for a use of 15 lbs. per hour.

The tests were based on blasting in specific conditions with carefully controlled cycles. Consumption was defined as the increase of material passing the bottom screen of the nominal size range or the increase in material that was smaller than the smallest screen opening of the nominal size range.

Testing of particle size before and after blasting was controlled. Samples were carefully slit with Tyler 16 to 1 or 1 to 1 sample reducers according to the methods which give a statistically representative sample. All size testing was done in duplicate. Consumption testing was also done in duplicate and the results averaged. Following the test all material was withdrawn from the generator and the dust bags were cleaned with the material in them added to the test charge. Any loss or gain in material was recorded and calculated into the findings. Figure 7 shows a summary of impact consumption for the size ranges of glass beads for intensities for which they would be normally used. The figure represents an average of four cycles. Consumption may vary during individual cycles.

Figure 7 A shows the impact consumption data we have observed at a 60 degree angle, for some of the intensities and hardnesses in figure 7 are lower. In each case blasting pressure was increased to reach the same arc height with the nozzle 60 degrees to the aluminum strip surface. A 10 in. distance was used at both angles.

This data should be used as a general indication only. Normally we recommend individual tests of specific applications for more exact data. From the general curves, however, it can be concluded that the harder the surface the higher the consumption of glass beads is likely to be at a given intensity. It is also evident that larger glass beads appear to consume less rapidly than smaller glass beads at the same peening intensity. Generally the actual consumption normally is less than the theoretical 90 degree consumptions given here because blast angles vary on parts of varying geometry and because partially consumed material is included in the active charge, this reduces the flow of active material. Of course, the total economics of any process must be judged by the cost of subsequent operations and the total savings or total value that can be realized by use of glass. In general, the consumption cost of glass should be compared against the cost of passivation or subsequent treatment that might be necessary with other media. Any value that might be ascribed to the more attractive surface which results from glass bead blasting should also be considered.

Of course, sometimes the consideration of fillet radius; requirements for low intensities; for particular surface finishes; to avoid metal removal; or to avoid harm to cutting edges would indicate the use of glass
Sinter or braze with precise repeatability...

That's what you get with a Surface standard rated continuous belt furnace. For annealing, brazing or sintering, you can rely on fast cycle change, assured repeatability at any desired temperature, temperature precision to ±10°F. Features, application examples and specifications are described in our recent bulletin, "Surface Standard Rated Continuous Belt Furnaces" (Bulletin SC-197).

Free. Write 2375 Dorr Street, Toledo, Ohio 43607.

SURFACE COMBUSTION DIVISION
Midland-Ross Corporation
For further information circle No. 5

LoTemp — Low Cost.

Harris LoTemp Industrial Freezers are the finest engineered and manufactured units you can buy at any price. And any price means low cost models too.

For shrink-fitting, freeze hardening, stabilizing, environmental testing, calibration, processing, storage or laser cooling, Harris makes the top-rated line for top performance anywhere.

Just because Harris makes the best, don't assume the cost is too high for your budget. Call in Harris and find out that top engineering means top cost savings too. For further information call (617) 864-4000, or write:

LoTemp
Harris Mig. Co., Inc.
306 River Street
Cambridge, Mass. 02139
For further information circle No. 6

LoTemp — Low Cost.

Harris LoTemp Industrial Freezers are the finest engineered and manufactured units you can buy at any price. And any price means low cost models too.

For shrink-fitting, freeze hardening, stabilizing, environmental testing, calibration, processing, storage or laser cooling, Harris makes the top-rated line for top performance anywhere.

Just because Harris makes the best, don't assume the cost is too high for your budget. Call in Harris and find out that top engineering means top cost savings too. For further information call (617) 864-4000, or write:

LoTemp
Harris Mig. Co., Inc.
306 River Street
Cambridge, Mass. 02139
For further information circle No. 6

GENERAL DATA ON CONSUMPTION OF GLASS BEADS IN SHOT PEENING
90° Angle Nozzle

<table>
<thead>
<tr>
<th>Almen Intensity</th>
<th>Size</th>
<th>Rockwell Hardness</th>
<th>Blast Pressure (direct) P.S.I.</th>
<th>Average % Per Cycle for Four Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>.007 N₂</td>
<td>H(170-230)</td>
<td>74 B</td>
<td>32-37</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>30 C</td>
<td>5.37</td>
<td>5.57</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>75 B</td>
<td>2.35</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>30 C</td>
<td>5.37</td>
<td>5.57</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>50 C</td>
<td>45</td>
<td>5.37</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>75 B</td>
<td>2.35</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>30 C</td>
<td>5.37</td>
<td>5.57</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>50 C</td>
<td>45</td>
<td>5.37</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>75 B</td>
<td>2.35</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>30 C</td>
<td>5.37</td>
<td>5.57</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>50 C</td>
<td>45</td>
<td>5.37</td>
</tr>
<tr>
<td></td>
<td>H(100-140)</td>
<td>75 B</td>
<td>2.35</td>
<td>1.33</td>
</tr>
</tbody>
</table>

COMPARISON OF 60° AND 90° BLAST ANGLES FOR IMPACT CONSUMPTION (nozzle distance in 10")

<table>
<thead>
<tr>
<th>Almen Intensity</th>
<th>Pressure (direct) P.S.I.</th>
<th>Consumption % Per Cycle for Four Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>.007 N₂</td>
<td>H(US-100-140)</td>
<td>54 B</td>
</tr>
<tr>
<td></td>
<td>20-23</td>
<td>2.83</td>
</tr>
</tbody>
</table>

OTHER PROSPECTIVE BENEFITS

Certain private and proprietary tests have indicated that, at least in some circumstances, lower glass bead intensities particularly on aluminum used in aircraft manufacture will often produce greater fatigue resistance. Bock and Justission have suggested this and we are not without other instances of observation. It is possible that the resulting surface finish produced by glass beads or the effect of developing compressive stress with a low density media may have some beneficial effect. It is well known that smoothness of surface directly increases resistance to cyclic fatigue.

In order to investigate the surface finish to intensity relationship we have gathered isolated tests made at different times to determine the surface finish results that should be expected on surfaces on a particular hardness at a particular peening intensity with particular sizes of glass beads. The results for one surface are in Figure 8. Unfortunately, the data is isolated and the creation of generalized RMS information remains to be done.

The possible superior effectiveness of glass beads in
establishing greater fatigue resistance remains to be
studied in greater detail. There is, however, sufficient
evidence available that merits the testing of glass beads
in applications using intensities of less than .012A to
determine what economic advantage might be gained.

Glass bead peening may also be used as a means of
passivation of aluminum. Our tests have shown that
treatment with glass beads will leave no residual ferrous
material on an aluminum surface after normal blasting.
This was accomplished by subjecting blasted surfaces
(with glass beads) to salt spray testing to determine if
corrosion spots would appear. This further supports
the proposition that they can be used as a basic peening
media without need of passivation for removal of con-
tamination.

OVERBLASTING WITH GLASS BEADS

In line with the consideration of surface treatment,
we have also obtained information regarding the possi-
able advantages of the reduction of surface of steel
shot peened aluminum where intensities needed or other
considerations require the use of steel shot.

Figure 8

| TESTS OF SURFACE FINISH (RMS) AT PEENING INTENSITIES ON |
| 2024 T-3 ALUMINUM |
| (Hardness: Rockwell B 76 from original surface) |

<table>
<thead>
<tr>
<th>BEAD SIZE</th>
<th>INTENSITY</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>.010-.012 A₂</td>
<td>160 +</td>
</tr>
<tr>
<td>B</td>
<td>.008-.010 A₂</td>
<td>100 - 125</td>
</tr>
<tr>
<td>D</td>
<td>.005-.006 A₂</td>
<td>130 - 150</td>
</tr>
<tr>
<td>C</td>
<td>.004-.006 A₂</td>
<td>100 - 130</td>
</tr>
</tbody>
</table>

Barton reported the benefits of overblasting peened
titanium surfaces from the point of view of increasing
fatigue life. Also, when peened surfaces will not meet
RMS requirements for aerospace standards often over-
peening will accomplish it.

Figures 9 A, B, and C show our isolated tests of
specific circumstances for the reduction of RMS or
micro-inch of shot peened surfaces. In this data it is
interesting to note that similar surfaces may be ob-
tained even with the different sizes of beads by varying
the velocity of air pressure to retain the same over-
peening intensity. Under certain conditions you can
simplify two-step operations and do them in one ma-
chine with the same size of media.

Further, overblasting peen-formed surfaces improves
surface appearance and develops resistance to stress
corrosion. This is practiced by the United States Navy.

Peening of surfaces generally with glass beads will in-
hbit stress corrosion.

PROCESS MANAGEMENT

In dealing with the questions of peening intensity or
the development of specific surface finishes maintaining
reasonable sphericity in the glass bead active charge in a
blasting machine is perhaps the key consideration.

It is necessary, as impact consumption occurs to re-
move broken particles with a minimum amount of
spherical particles coming with them. A maximum
amount of 15 per cent broken particles is all that is al-
lowed by most specifications in peening operations. The
effect of the broken particle is to change the surface
finish, especially on non-ferrous metals.

As angular particles build up and become part of the

Problem:
Parts failed in service. The metal
contained un-transformed austenite, residual stress and
lacked the necessary toughness
to do the job.

Solution:
CINCINNATI SUB-ZERO
designed an ultralow
temperature, industrial chamber for metal treat-
ing. The low temperature
modifies the grain structure
to 97% martensite, relieves
heat treat and quench stresses
and increases hardness for longer
use-life.

Let us help solve
your problems.

CINCINNATI SUB-ZERO PRODUCTS INC.
2612 Gilbert Ave., Cincinnati, O. 45206
For further information circle No. 7

WATER SAVING
WITH TROUBLE-FREE
COOLING EQUIPMENT

NIAGARA
Aero
HEAT
EXCHANGER

Convenient
Units Up To
30,000,000
BTU Capacity

Cools your jacket water for engines or process equipment or electric apparatus. Your closed system keeps free from dirt
or maintenance troubles. You can cool air, gases, chemicals, quench baths, plating baths, welding machines, extrusion
and drawing machines. You get real precise temperatures, save rejections, lower production costs. Use NIAGARA AERO
HEAT EXCHANGER cooling with atmospheric air...saves water, pumping, piping and power; quickly saves its costs. Write for Bulletin No. 161.

NIAGARA BLOWER COMPANY
Dept. MG-2, 405 Lexington Ave.    New York 17, N. Y.
For further information circle No. 8
POCKET-SIZED BRINELL HARDNESS TESTER

Completely reliable inspection tool for field and factory use. Ideal for checking hardness of massive or complex castings and forgings. Widely used in Europe and now available in U.S.A.

$85.00 including tester, brinellscope, standard test bar, calculator and case.

BARWORTH FLOCKTON, LTD.
6526 Lindyann
Houston, Texas 77008

For further information circle No. 9

DEW POINT analyzers...

For further information circle No. 10

active charge, the percentage of particles of sufficient man to produce an appropriate peening intensity will reduce. It may, of course, endanger the fatigue characteristics of a part being peened.

Figure 9 (A) RMS

TEST OF REDUCING RMS OF PEENED FINISH OF 7075 T-6-51 ALUMINUM

<table>
<thead>
<tr>
<th>RMS ORIGINAL</th>
<th>BEAD SIZE</th>
<th>P.S.I.</th>
<th>RMS AFTER PROCESSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-110</td>
<td>D</td>
<td>5</td>
<td>60-71</td>
</tr>
<tr>
<td>100-110</td>
<td>D</td>
<td>10</td>
<td>66-71</td>
</tr>
<tr>
<td>100-110</td>
<td>C</td>
<td>7.5</td>
<td>66-71</td>
</tr>
<tr>
<td>100-110</td>
<td>AH</td>
<td>15</td>
<td>80-88</td>
</tr>
<tr>
<td>77-82</td>
<td>D</td>
<td>5</td>
<td>72-77</td>
</tr>
</tbody>
</table>

(size AH is U.S. Sieve 170-325 or 44-77 microns in diameter)
Tests were performed on a direct pressure machine using a 3/8 nozzle and a 5/32" grit stem.

Figure 9 (B)

TESTS OF REDUCING RMS OF PEENED SURFACES—
2024 T-3 51 Hardness: 74-76 B

<table>
<thead>
<tr>
<th>ORIG RMS</th>
<th>BEAD SIZE</th>
<th>P.S.I.</th>
<th>NOZZLE DISTANCE</th>
<th>ANGLE</th>
<th>NOZZLE RADIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>120-160</td>
<td>D</td>
<td>6</td>
<td>60°</td>
<td>90-100</td>
<td>30°</td>
</tr>
<tr>
<td>120-160</td>
<td>D</td>
<td>6</td>
<td>60°</td>
<td>90-100</td>
<td>30°</td>
</tr>
<tr>
<td>100-112</td>
<td>C</td>
<td>15</td>
<td>60°</td>
<td>90-100</td>
<td>30°</td>
</tr>
<tr>
<td>80-100</td>
<td>D</td>
<td>4</td>
<td>90°</td>
<td>90-100</td>
<td>30°</td>
</tr>
<tr>
<td>50-60</td>
<td>C</td>
<td>5</td>
<td>90°</td>
<td>90-100</td>
<td>30°</td>
</tr>
</tbody>
</table>

Figure 9C

TESTS OF REDUCING SURFACE FINISH OF 2024 T-3 51 (Rockwell B 76) BY PEENING INTENSITY

<table>
<thead>
<tr>
<th>ORIGINAL RMS</th>
<th>BEAD SIZE</th>
<th>ALMEN INTENSITY</th>
<th>FINAL INTENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>160+</td>
<td>D</td>
<td>.007-.008 N</td>
<td>60-80</td>
</tr>
<tr>
<td>160+</td>
<td>D</td>
<td>.010-.012 N</td>
<td>90-120</td>
</tr>
<tr>
<td>100-120</td>
<td>D</td>
<td>.007-.008 N</td>
<td>60-80</td>
</tr>
<tr>
<td>130-150</td>
<td>D</td>
<td>.007-.008 N</td>
<td>60-80</td>
</tr>
<tr>
<td>100-130</td>
<td>C</td>
<td>.006-.008 N</td>
<td>60-80</td>
</tr>
<tr>
<td>100-125</td>
<td>AG</td>
<td>.005-.006 N</td>
<td>60-80</td>
</tr>
<tr>
<td>100-125</td>
<td>AF</td>
<td>.004-.006 N</td>
<td>60-80</td>
</tr>
<tr>
<td>100-125</td>
<td>B</td>
<td>.006-.008 N</td>
<td>60-80</td>
</tr>
<tr>
<td>100-125</td>
<td>E</td>
<td>.005-.007 N</td>
<td>60-80</td>
</tr>
<tr>
<td>100-125</td>
<td>C</td>
<td>.006-.007 N</td>
<td>60-80</td>
</tr>
<tr>
<td>100-125</td>
<td>D</td>
<td>.007-.008 N</td>
<td>60-80</td>
</tr>
</tbody>
</table>

Regular time-to-intensity curves (illustrated in Figure 10) for glass bead peening are used to determine the time needed for exposure to achieve specified peening results. As in any peening operations it's probably desirable to seek a time-to-intensity curve for the particular saturation intensity that is required on the machine used in a specific process. Moore has reported that the narrower ranges of glass bead material produces more satisfactory time-to-intensity curves and points toward the desirability of narrow size ranging not only for careful control of peening intensities but also possibly for the reduction of process time and labor cost.

For peening intensity control Figure 11 shows...
Alloy Engineering
Fabricated Furnace Trays
Cut costs in high temperature production

U. S. Patent No.
2,417,085

Articulated carburizing tray made of castings with wrought interlock bars and reversible grid. The quality standard of the industry. For Lindberg GVRT furnaces 24” x 36”, 24” x 48” and 30” x 48”.

Horizontal interlock tray for roller bottom furnaces. Exceptional flexibility and strength of interlock construction allows great thermal expansion-contraction without fatigue.

Send for our bulletins on fabricated furnace trays and related products.

THE ALLOY ENGINEERING COMPANY
838 Thacker St. - Berea, Ohio 44017

For further information circle No. 12

DYNAMIC HARDNESS TESTING SHORE SCLEROSCOPE

Over 40,000 in use.

Pioneer American Standard since 1907.

Model C-2

Model D

Capable of over 1000 tests an hour. Essentially a non-marring test. Penetration less than 0.001” on mild steel and 0.0025” on hardened steel. The Model C-2 Scleroscope has unique capabilities in portable free-hand testing of die blocks, hardened and ground machine tool ways, rolls, cast iron pipe, crankshafts, forgings etc. The Model D Dial Recording Scleroscope is graduated in equivalent Brinell & Rockwell C hardness numbers. Write for complete details.

THE SHORE INSTRUMENT & MFG. CO. INC.
90-35 HT VAN WYCK EXPRESSWAY, JAMAICA, N.Y. 11435

For further information circle No. 13

variations in mass of particles between standard narrow and broad range materials based on U. S. Sieve size. It's obvious that material within the broad specifications may lean much more easily to the large or to the small. If this were the case substantial changes in peening operations might be experienced.

Upon receipt of glass bead peening media, it is desirable to check particle size and sphericity against material specifications. We've experienced instances of variations in intensity results due to poor screening, excessive angular particles and to excessive air in the particles.

SUMMARY

The use of glass beads as a shot peening media is developing considerable precedent. Beads are used as a peening media where low intensities are required for or penetration of small fillet areas. Further, non-ferrous or exotic alloy surfaces they can produce economies by avoiding passivation. Evidence indicates that glass beads should be tested to determine if superior fatigue characteristics may result in applications involving intensities of .012A or less. Overblasting with glass beads can be used to perform surface reduction and to prevent stress corrosion. The incidence of successful applications is increasing rapidly.

Figure 11

COMPARISON OF MASS RELATIONSHIPS OF NARROW NOMINAL SIZE RANGE GLASS BEADS WITH WIDEST RANGES

<table>
<thead>
<tr>
<th>U.S. SIEVE</th>
<th>DIAMETER INCHES</th>
<th>DIAMETER MICRONS</th>
<th>RANGE MASSES (micrograms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-30</td>
<td>0.0313-0.0234</td>
<td>814-595</td>
<td>272-765</td>
</tr>
<tr>
<td>25-45</td>
<td>0.0278-0.0159</td>
<td>707-357</td>
<td>57-459</td>
</tr>
<tr>
<td>30-55</td>
<td>0.0234-0.0117</td>
<td>595-297</td>
<td>96-272</td>
</tr>
<tr>
<td>50-70</td>
<td>0.0117-0.0083</td>
<td>297-210</td>
<td>33-212</td>
</tr>
<tr>
<td>60-80</td>
<td>0.0083-0.0056</td>
<td>210-178</td>
<td>50-178</td>
</tr>
<tr>
<td>80-100</td>
<td>0.0056-0.0035</td>
<td>178-142</td>
<td>12-142</td>
</tr>
<tr>
<td>100-120</td>
<td>.0035-0.0025</td>
<td>142-120</td>
<td>8-120</td>
</tr>
<tr>
<td>120-140</td>
<td>.0025-0.0005</td>
<td>120-90</td>
<td>0.2-90</td>
</tr>
<tr>
<td>140-160</td>
<td>.0005-0.00025</td>
<td>90-65</td>
<td>9-65</td>
</tr>
<tr>
<td>160-180</td>
<td>.00025-0.0001</td>
<td>65-35</td>
<td>0.2-35</td>
</tr>
<tr>
<td>180-200</td>
<td>.0001-0.00005</td>
<td>35-25</td>
<td>0.1-25</td>
</tr>
<tr>
<td>200-250</td>
<td>.00005-0.000005</td>
<td>25-10</td>
<td>0.05-10</td>
</tr>
<tr>
<td>250-300</td>
<td>.00001-0.000005</td>
<td>10-5</td>
<td>0.01-5</td>
</tr>
</tbody>
</table>

References

14. U.S. MIL SPEC 513165 B.
15. U.S. MIL SPEC 513165 B.