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(54) COMPOSITIONS AND METHODS RELATING TO TRIBOLOGY

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(57) **ABSTRACT**

Systems, compositions, methods, etc., that provide significantly enhanced tribological properties to a target substrate such as metal, plastic, wood, glass, etc., by bombarding or showering the target material with bombardment particles substantially saturated with a desirable lubricant composition, typically comprising at least one primary lubricant such as a molybdenum disulphide (MoS_2) and at least one polymeric lubricant, such as polytetrafluoroethylene (PTFE), such that the lubricant composition imbeds into the surface of the target material (also called a target substrate).

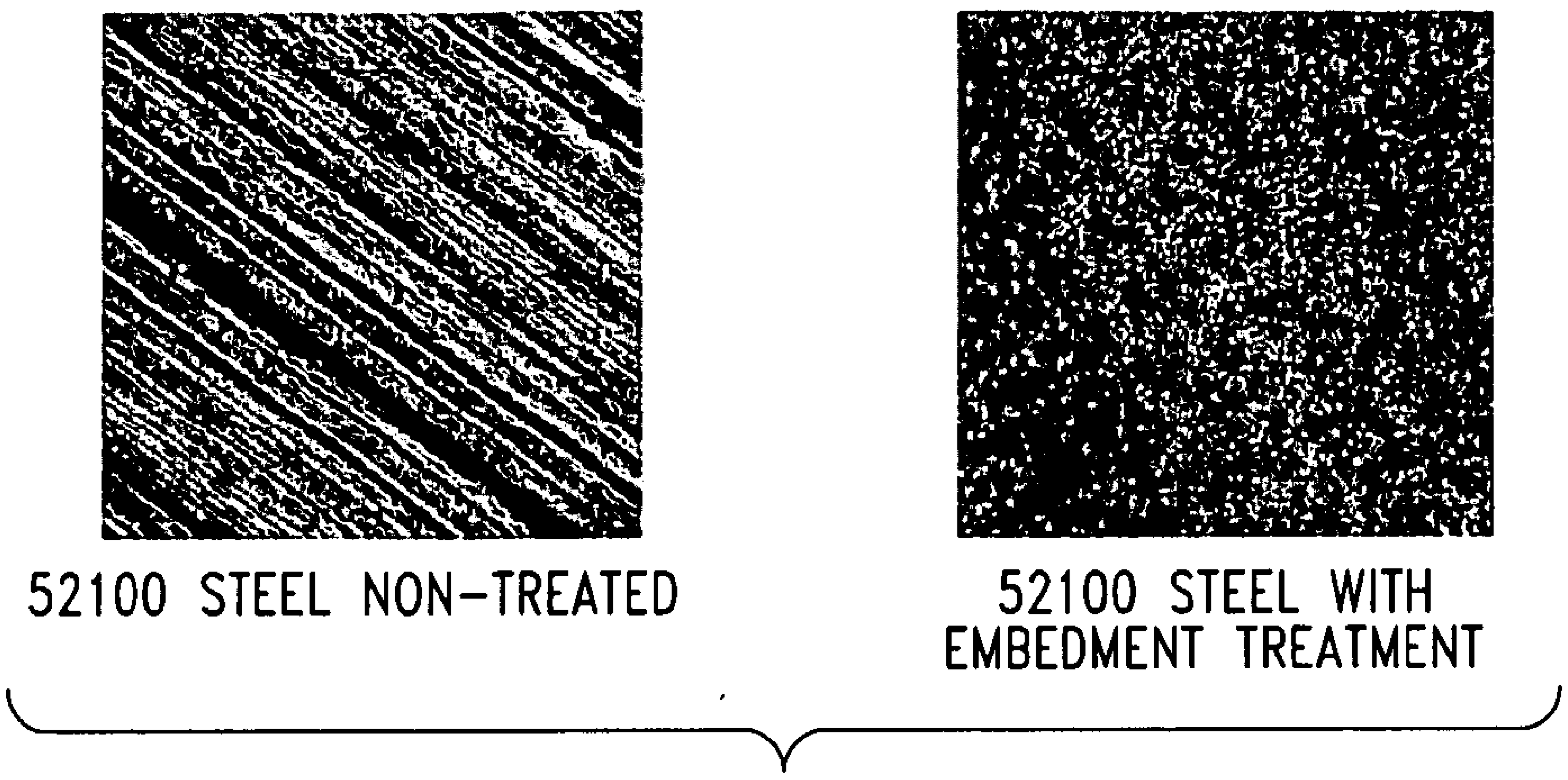


Fig. 1

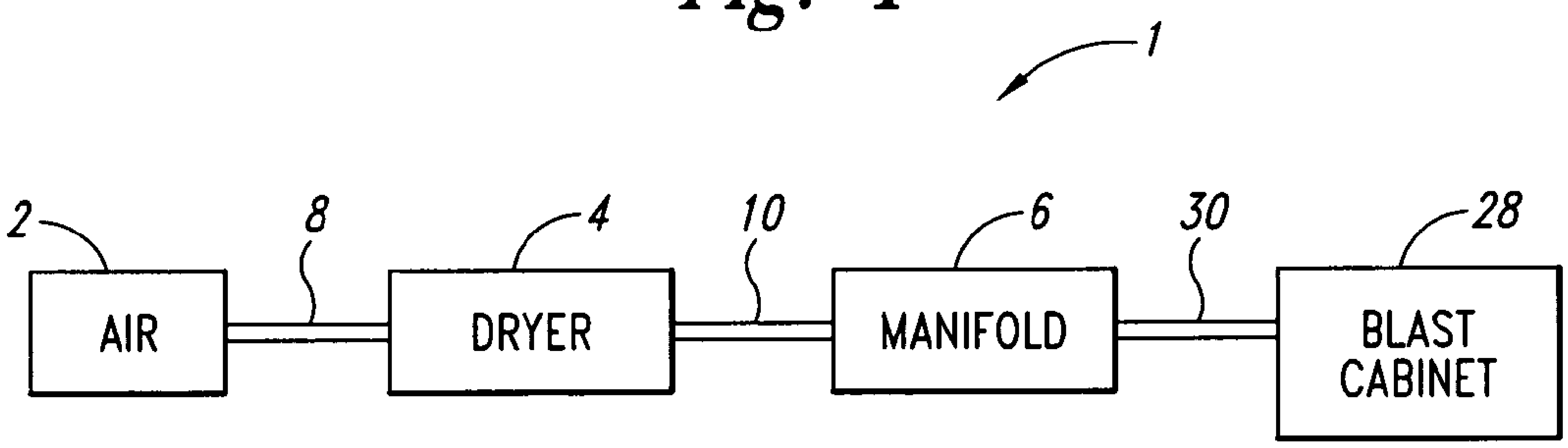


Fig. 2

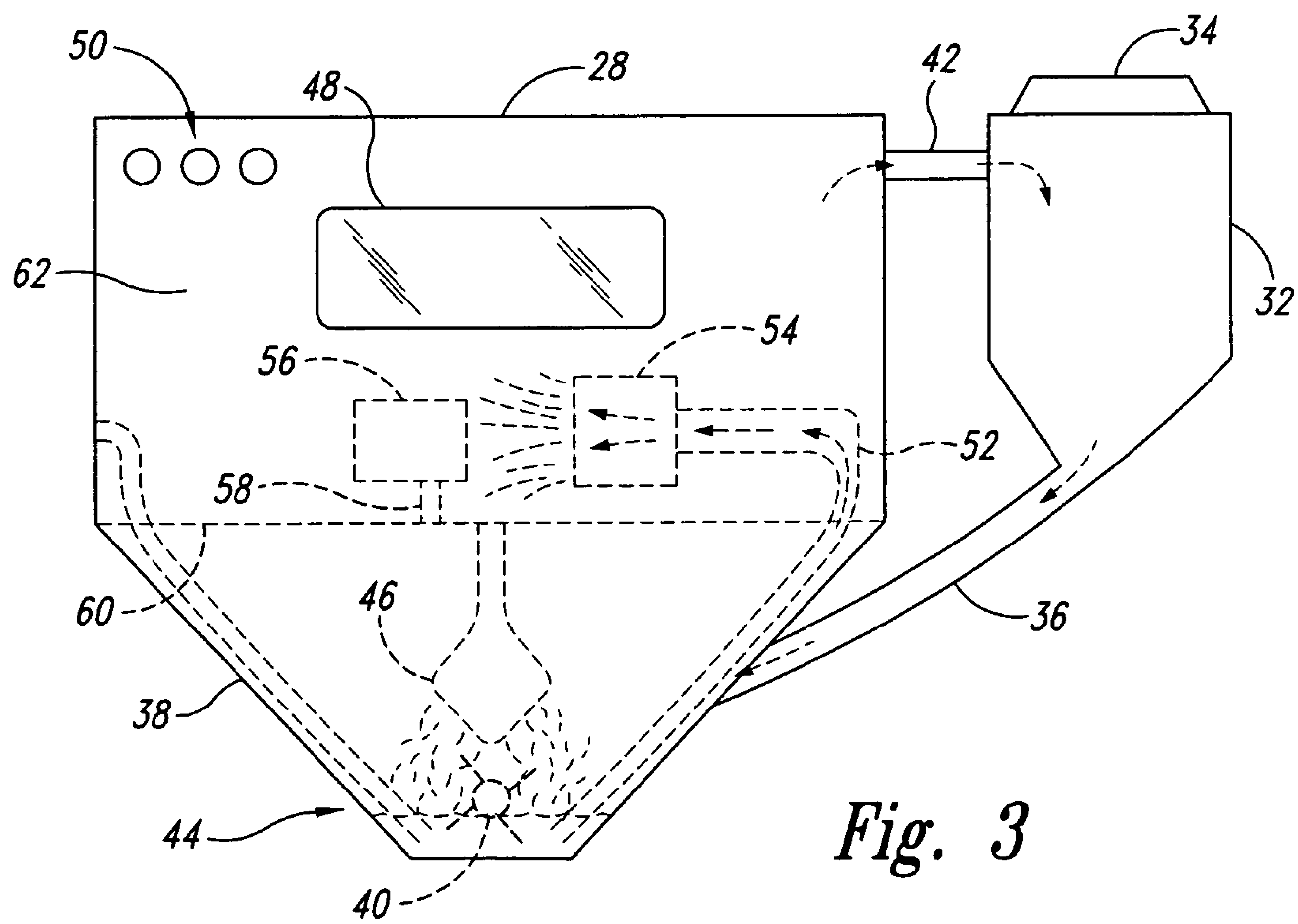


Fig. 3

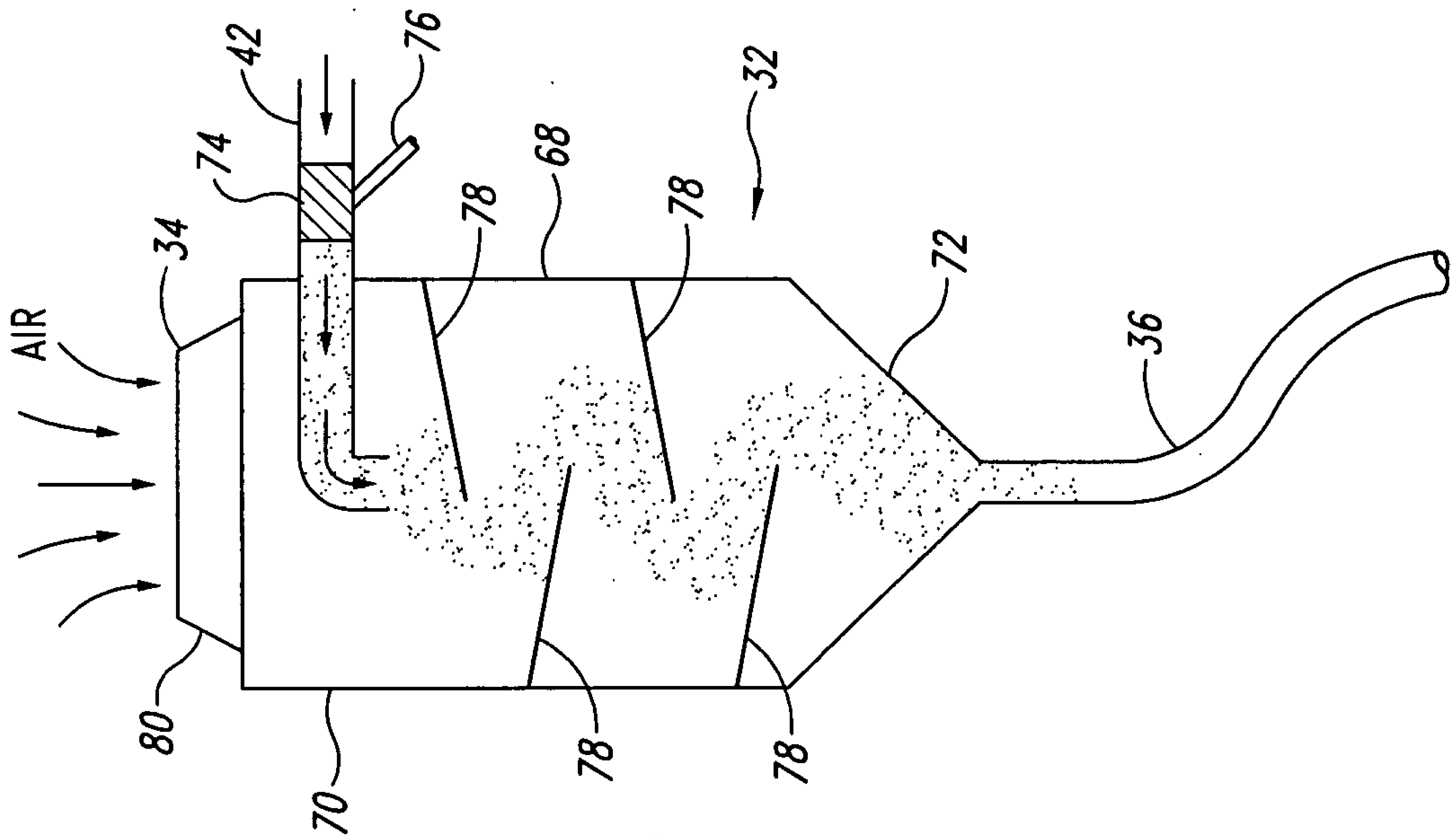

42
76
74
34
AIR
68
78
78
32
72
36
80
70
78
78

Fig. 5

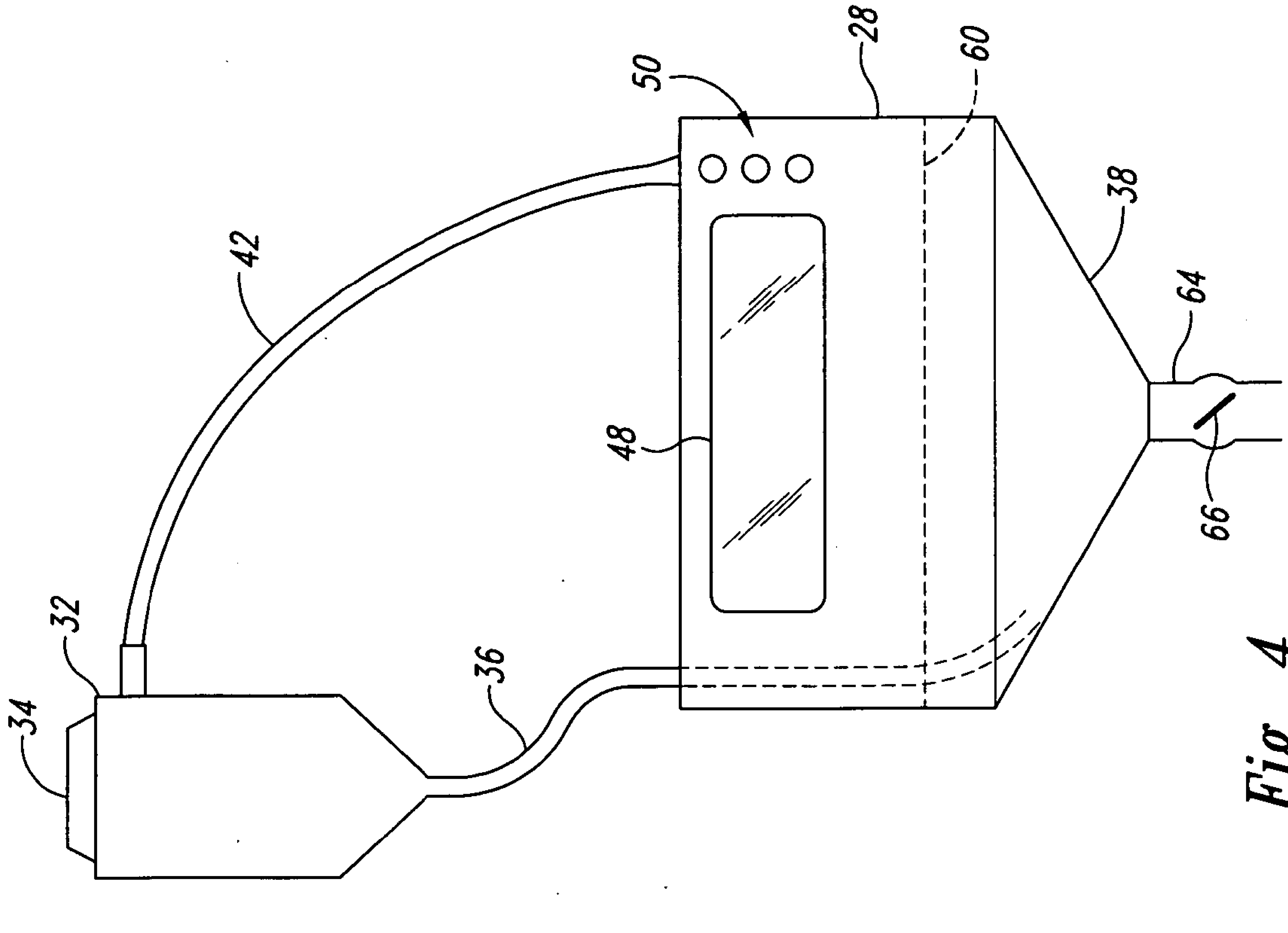

50
28
60
42
38
64
48
66
32
34
36

Fig. 4

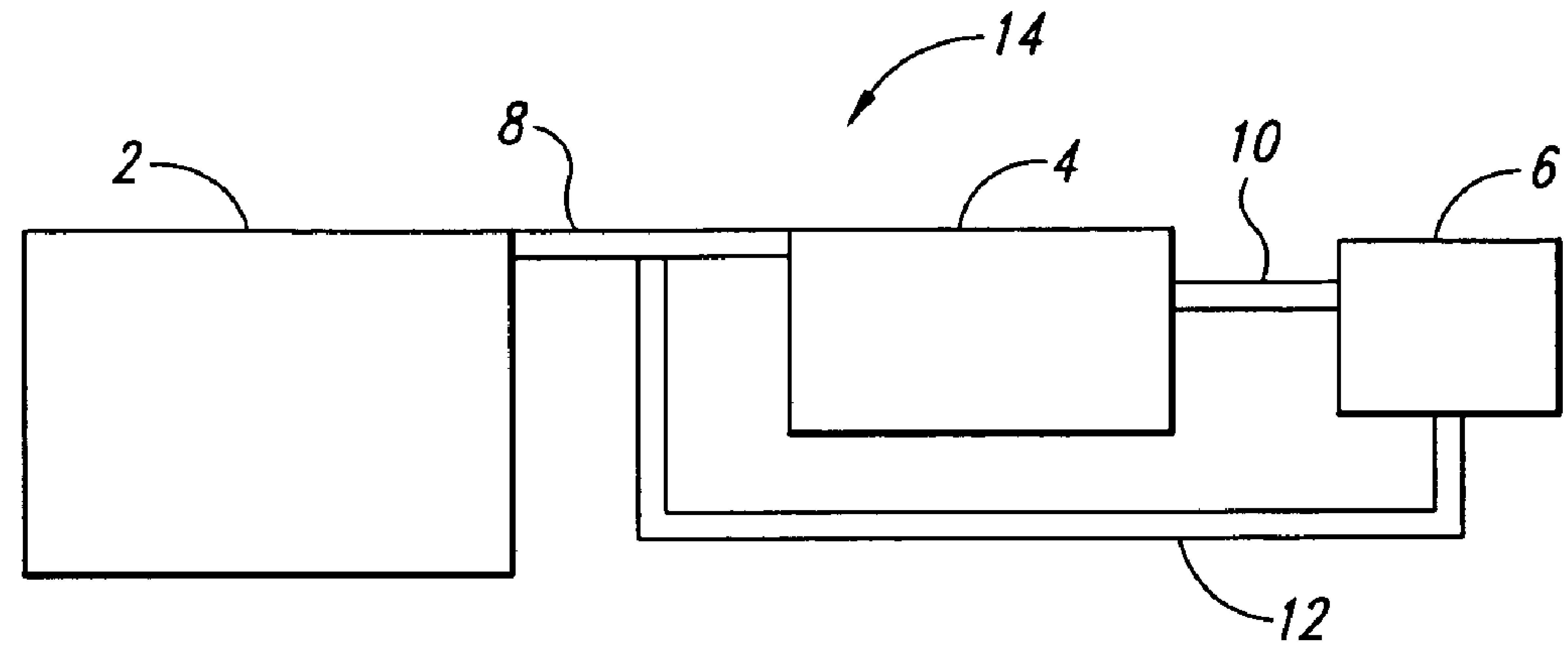


Fig. 6

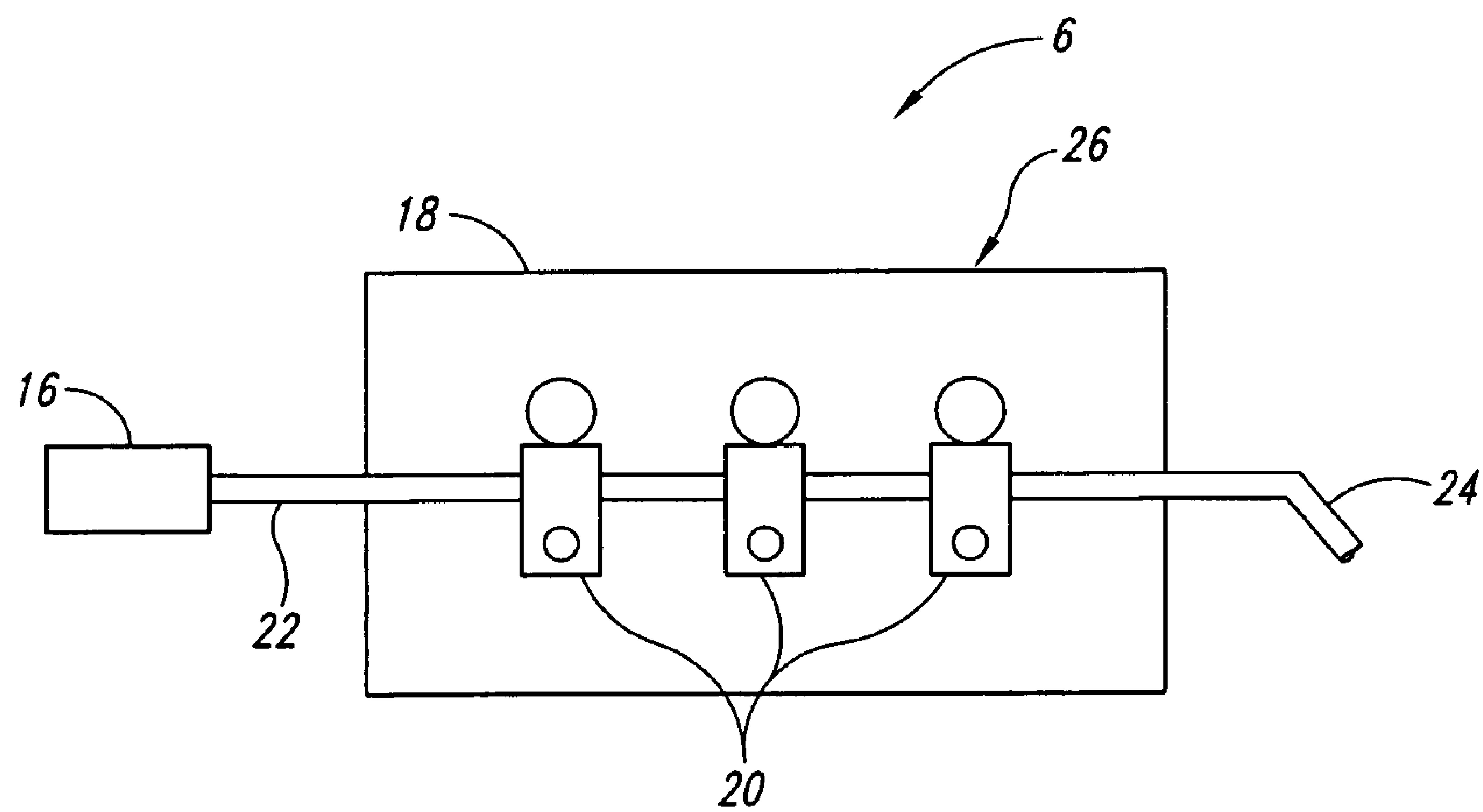


Fig. 7

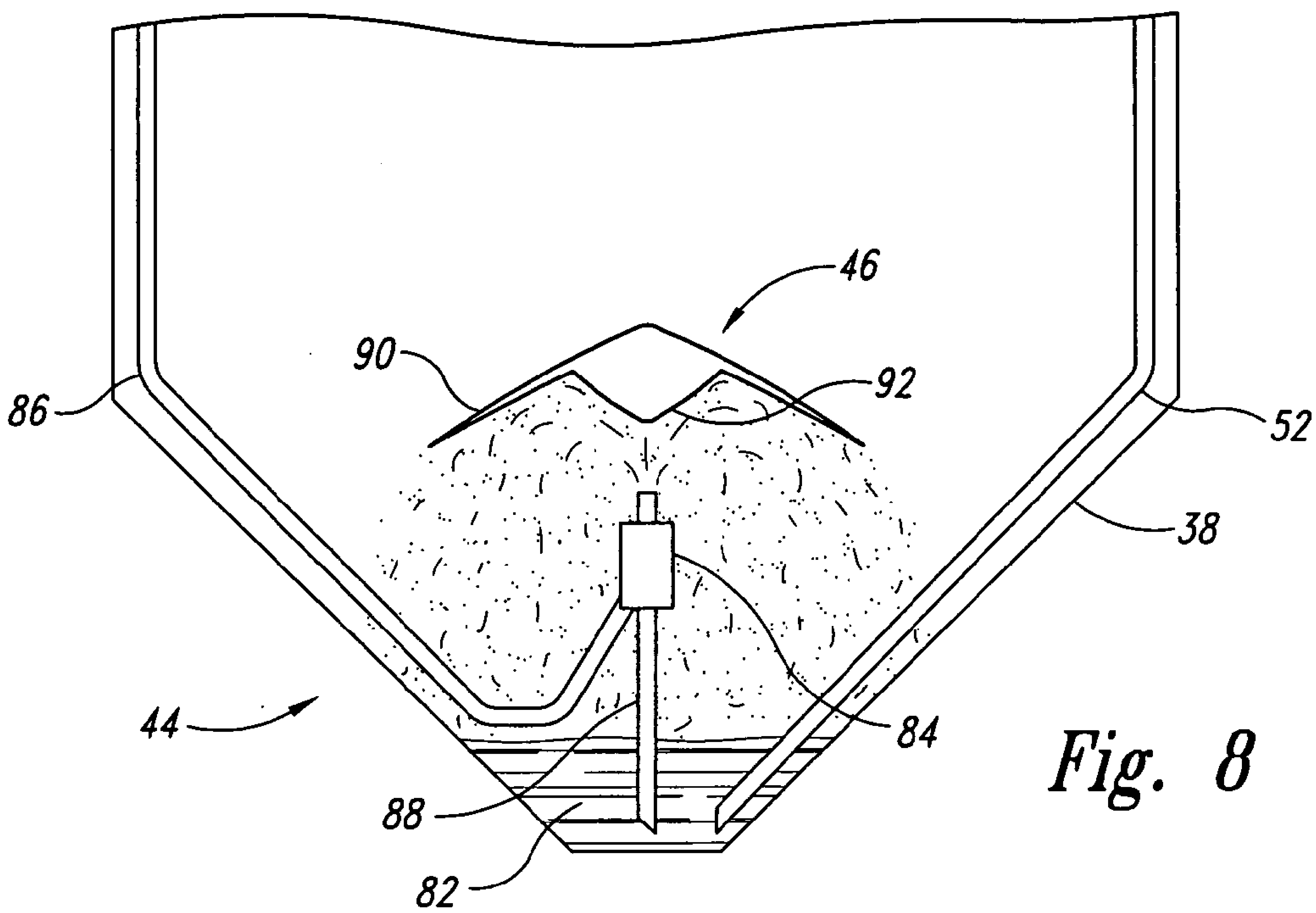


Fig. 8

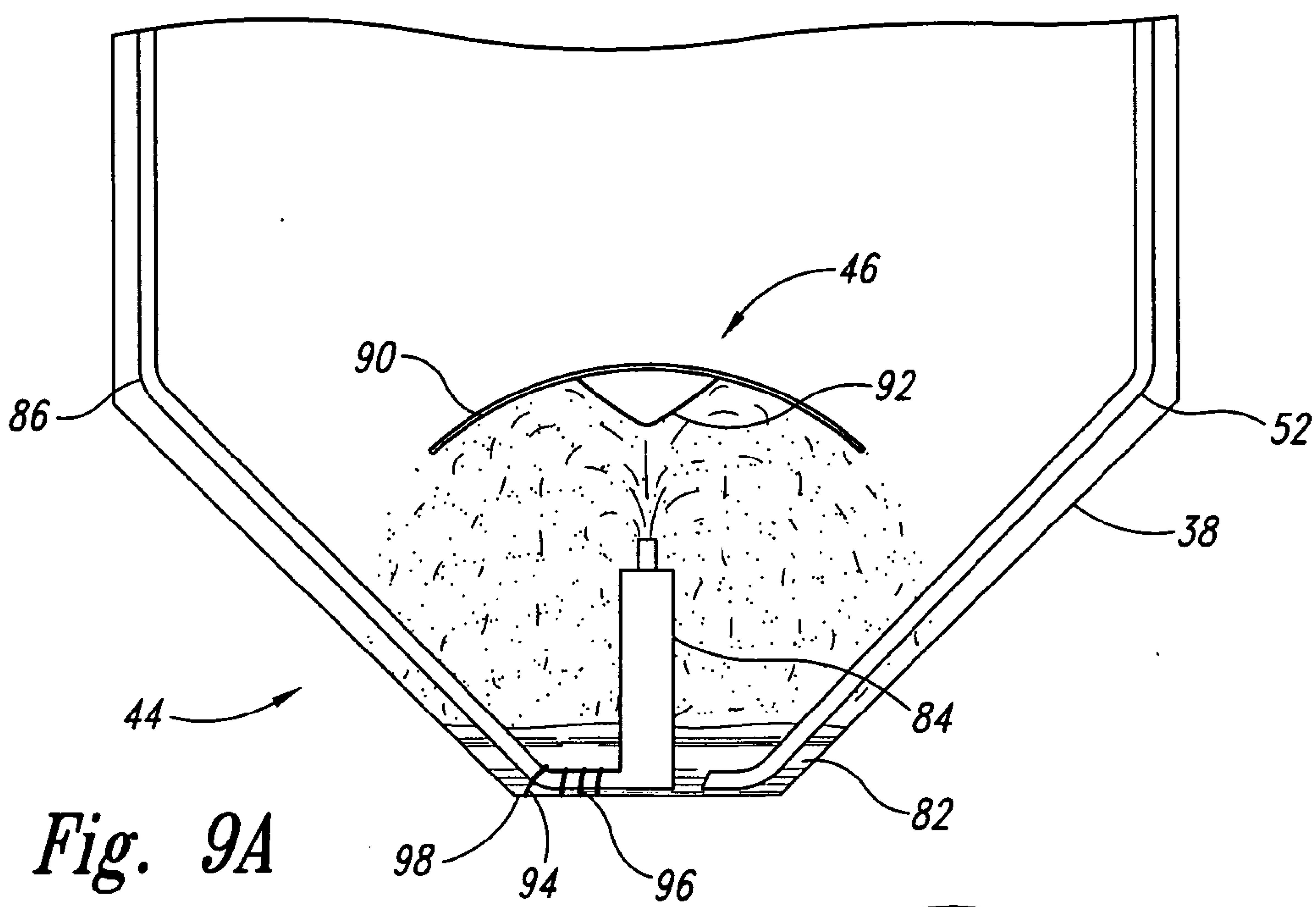


Fig. 9A

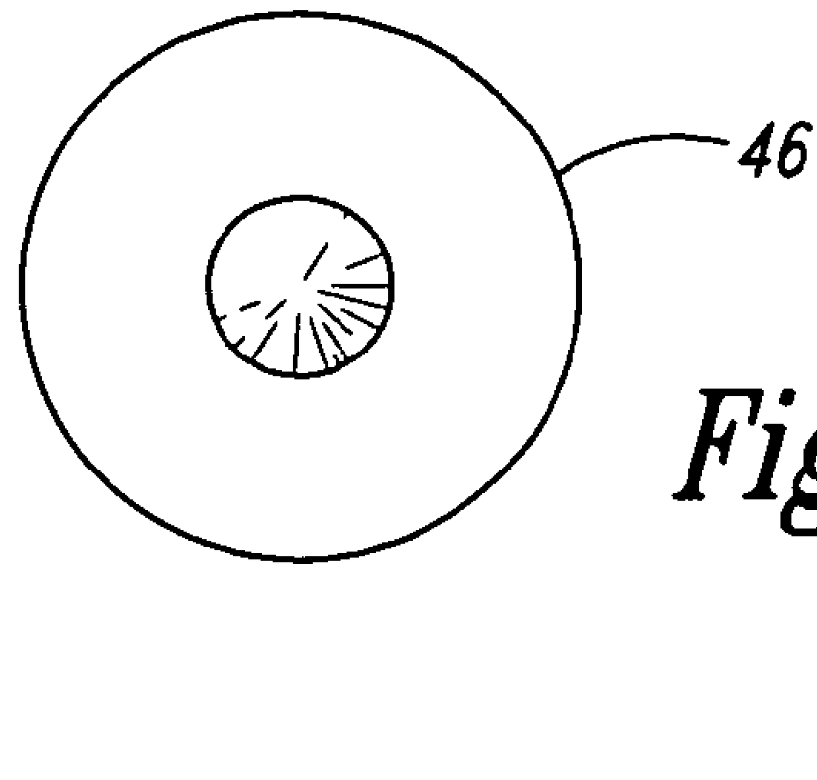


Fig. 9B

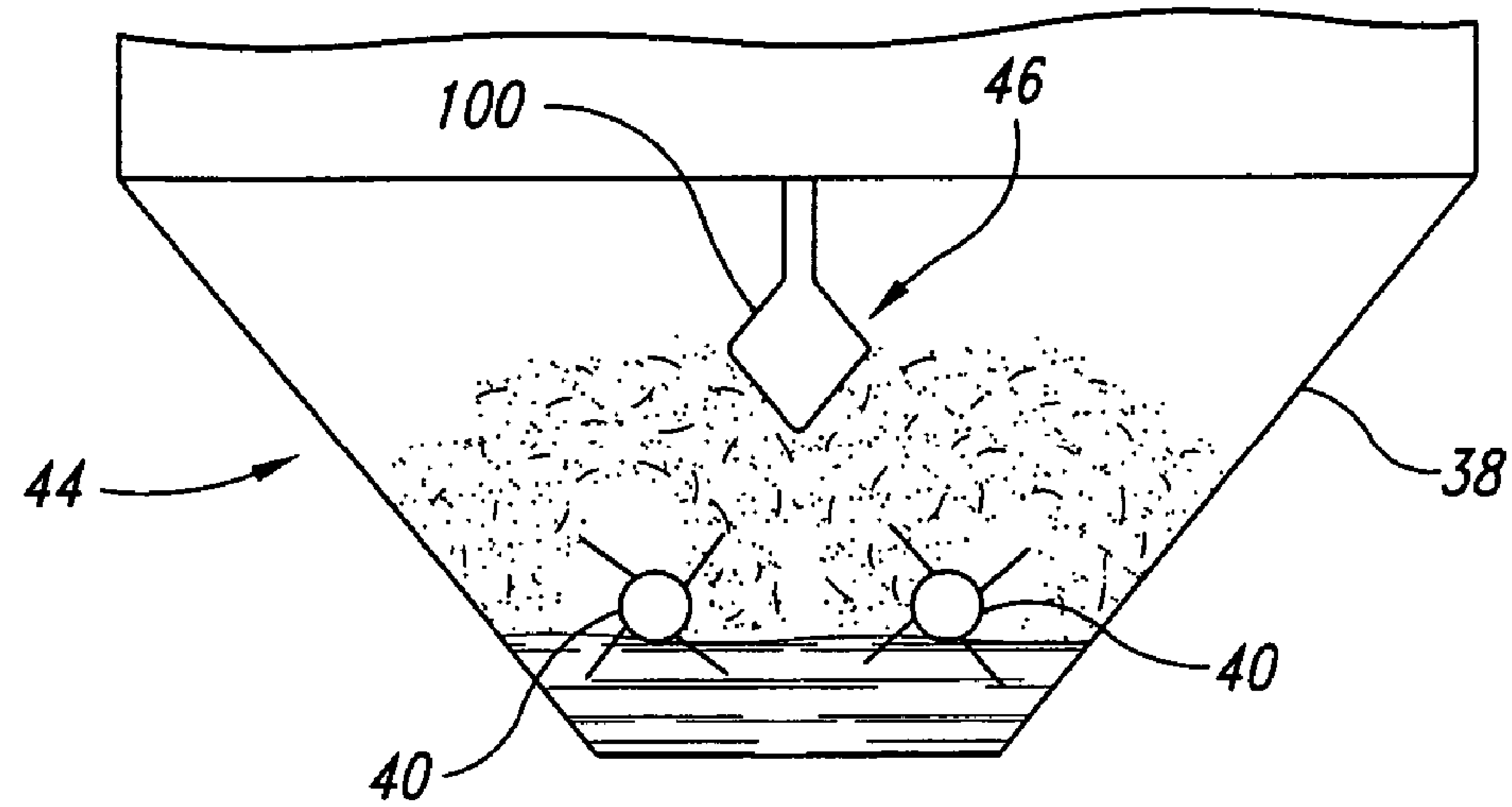


Fig. 10

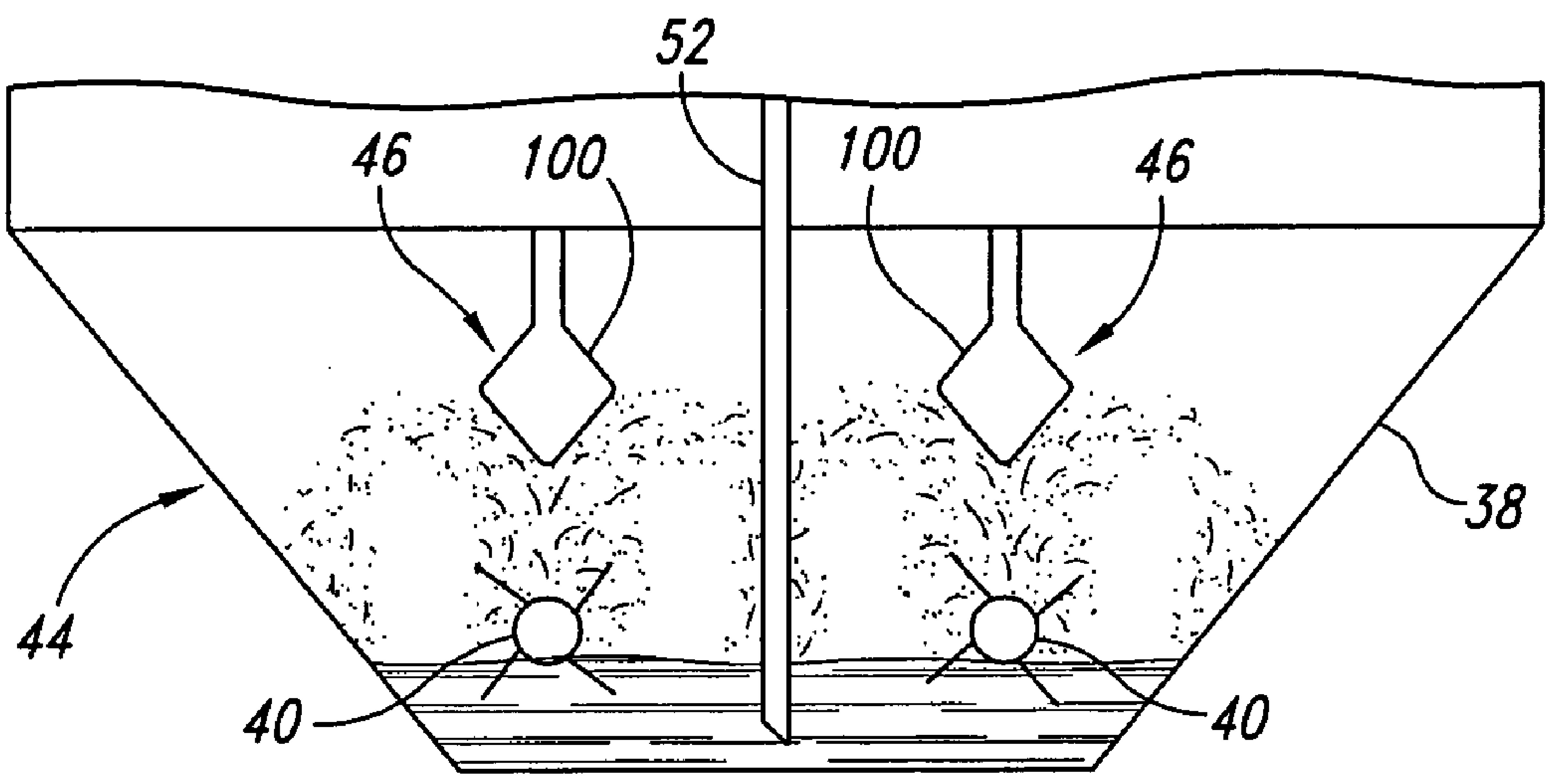


Fig. 11

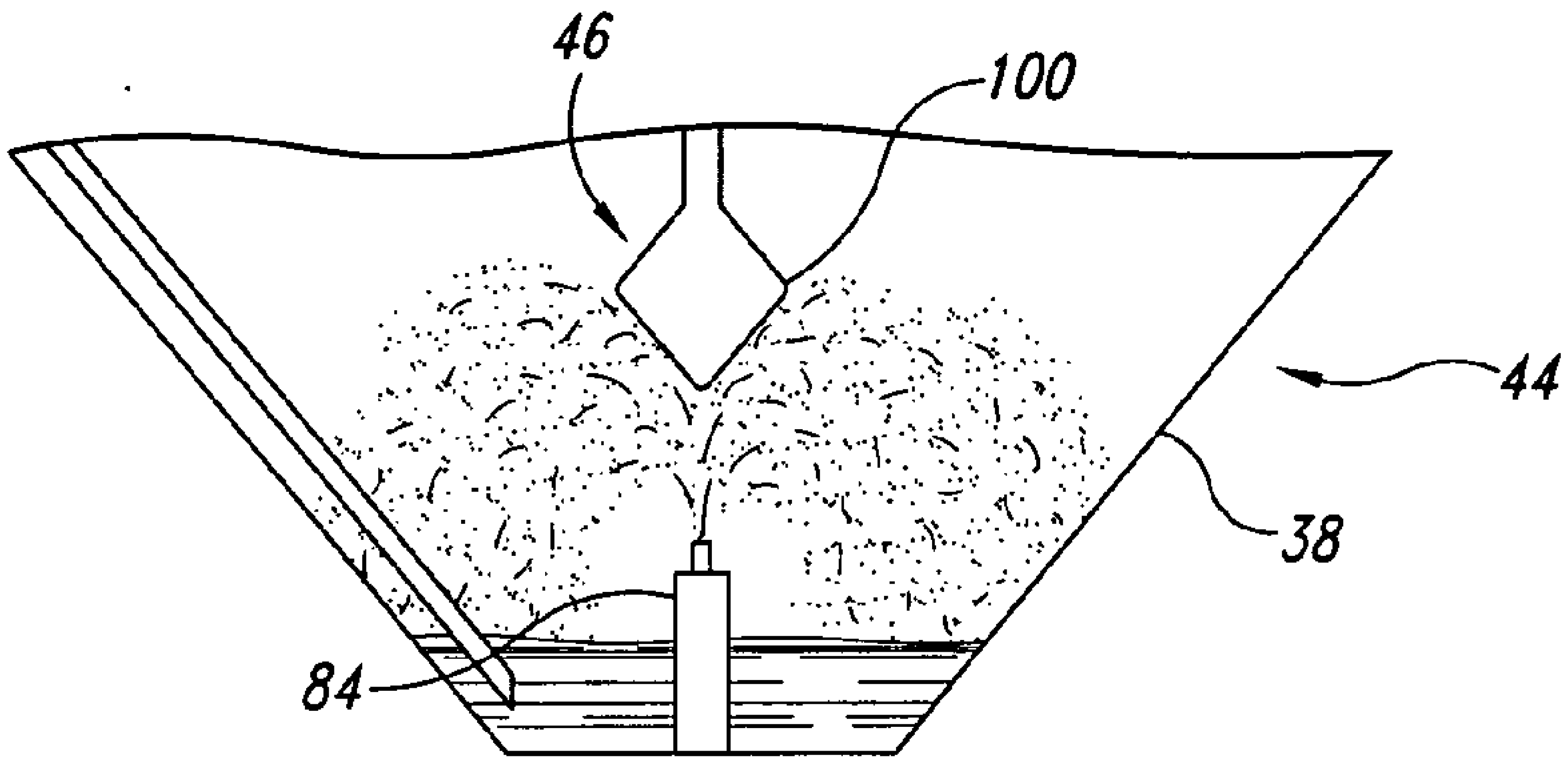


Fig. 12

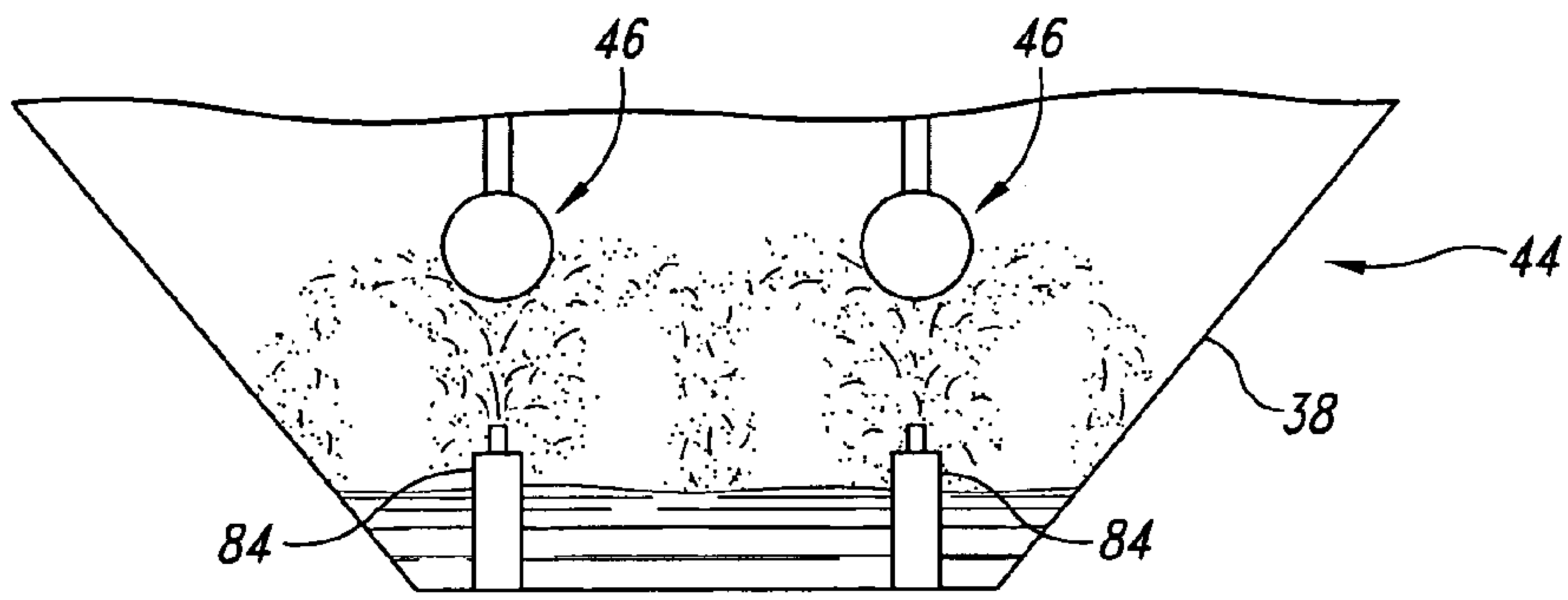


Fig. 13

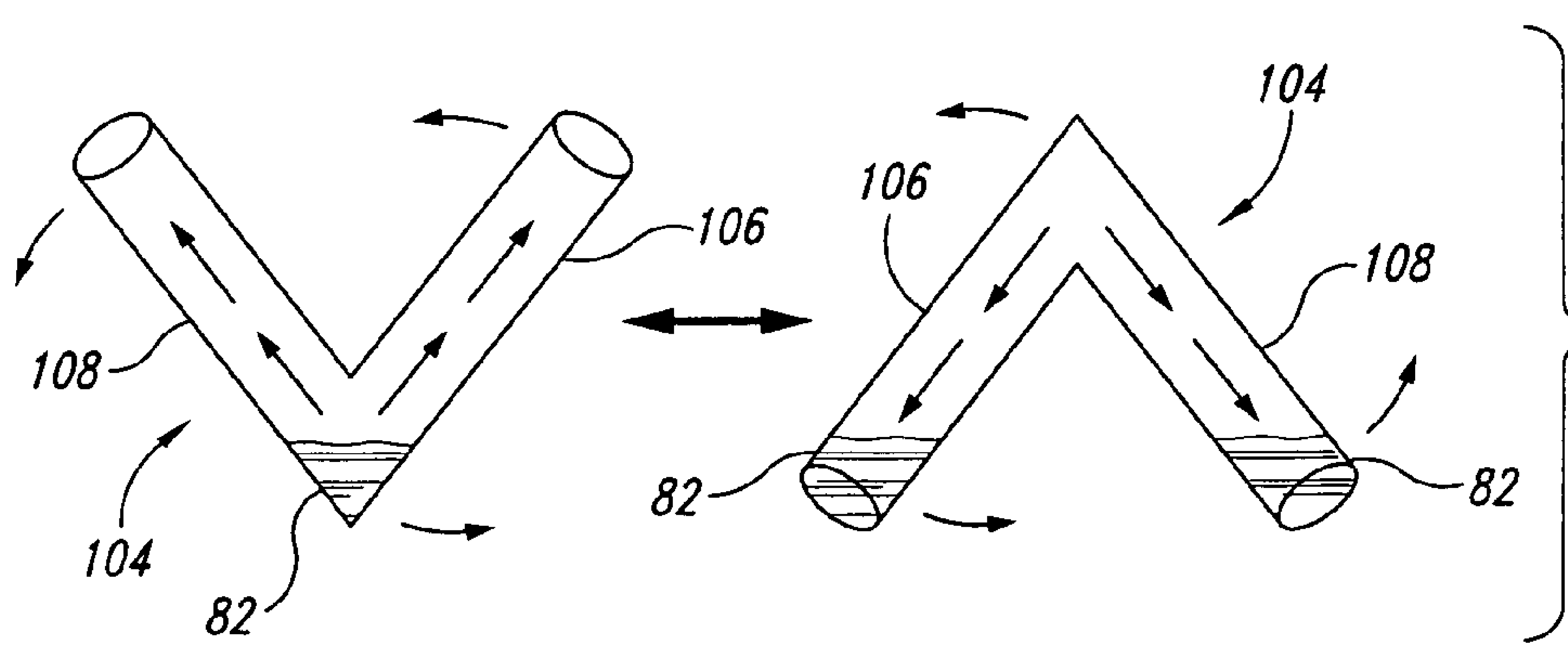


Fig. 14

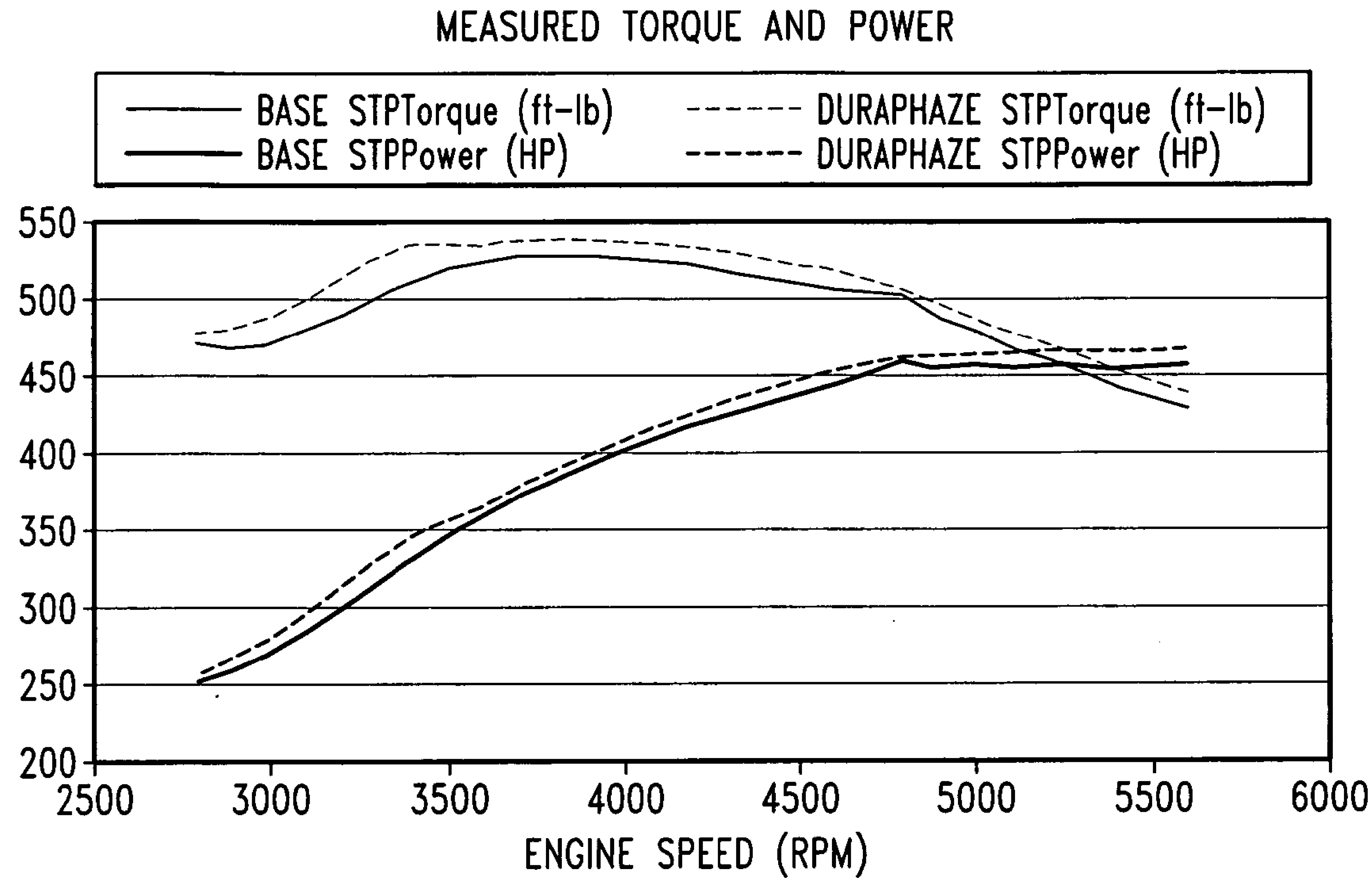

MEASURED TORQUE AND POWER
BASE STPTorque (ft-lb)
BASE STPPower (HP)
DURAPHAZE STPTorque (ft-lb)
DURAPHAZE STPPower (HP)
550
500
450
400
350
300
250
200
2500
3000
3500
4000
4500
5000
5500
6000
ENGINE SPEED (RPM)

Fig. 15

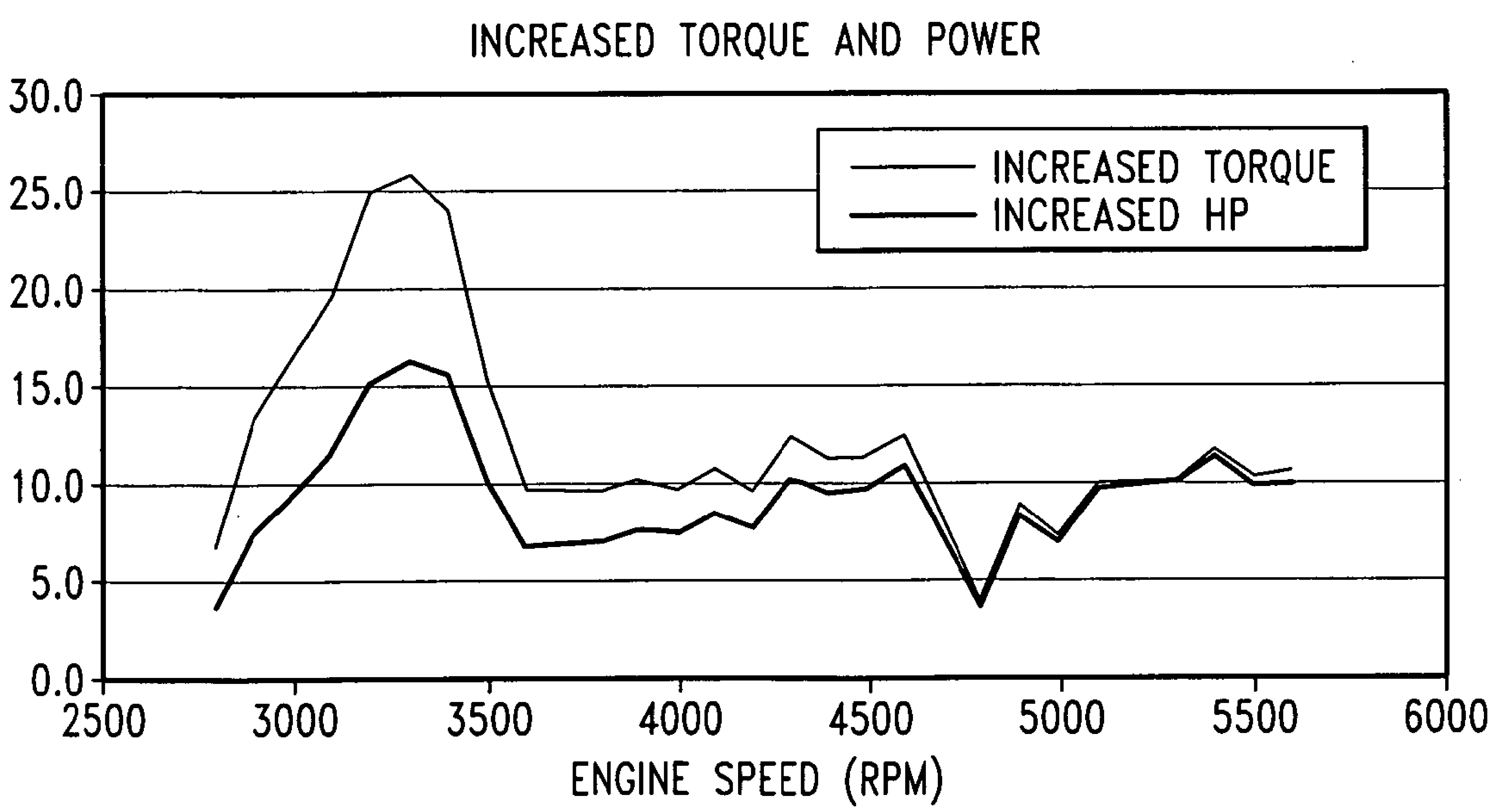

INCREASED TORQUE AND POWER
INCREASED TORQUE
INCREASED HP
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2500
3000
3500
4000
4500
5000
5500
6000
ENGINE SPEED (RPM)

Fig. 16

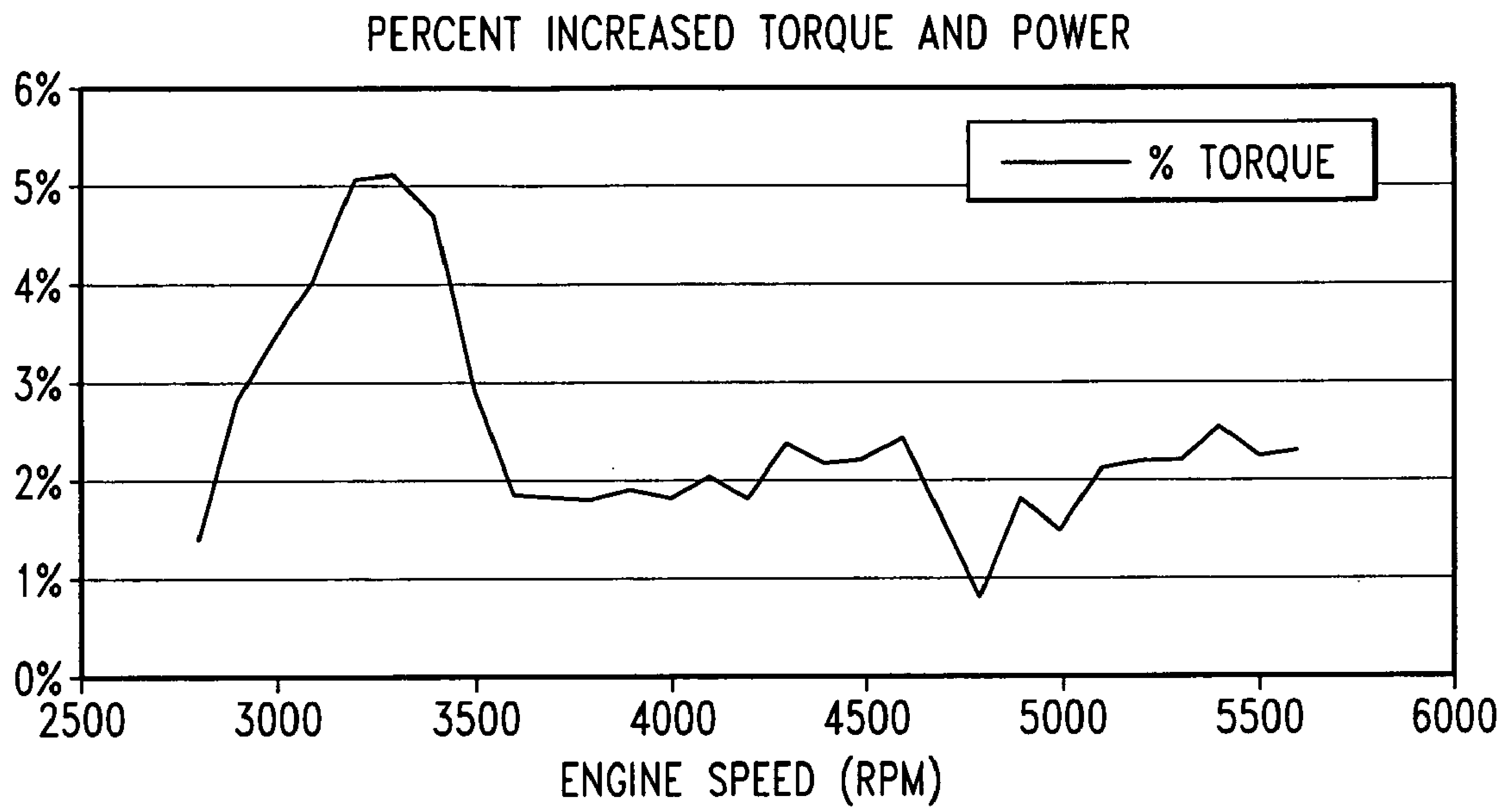

PERCENT INCREASED TORQUE AND POWER
% TORQUE
6%
5%
4%
3%
2%
1%
0%
2500
3000
3500
4000
4500
5000
5500
6000
ENGINE SPEED (RPM)

Fig. 17

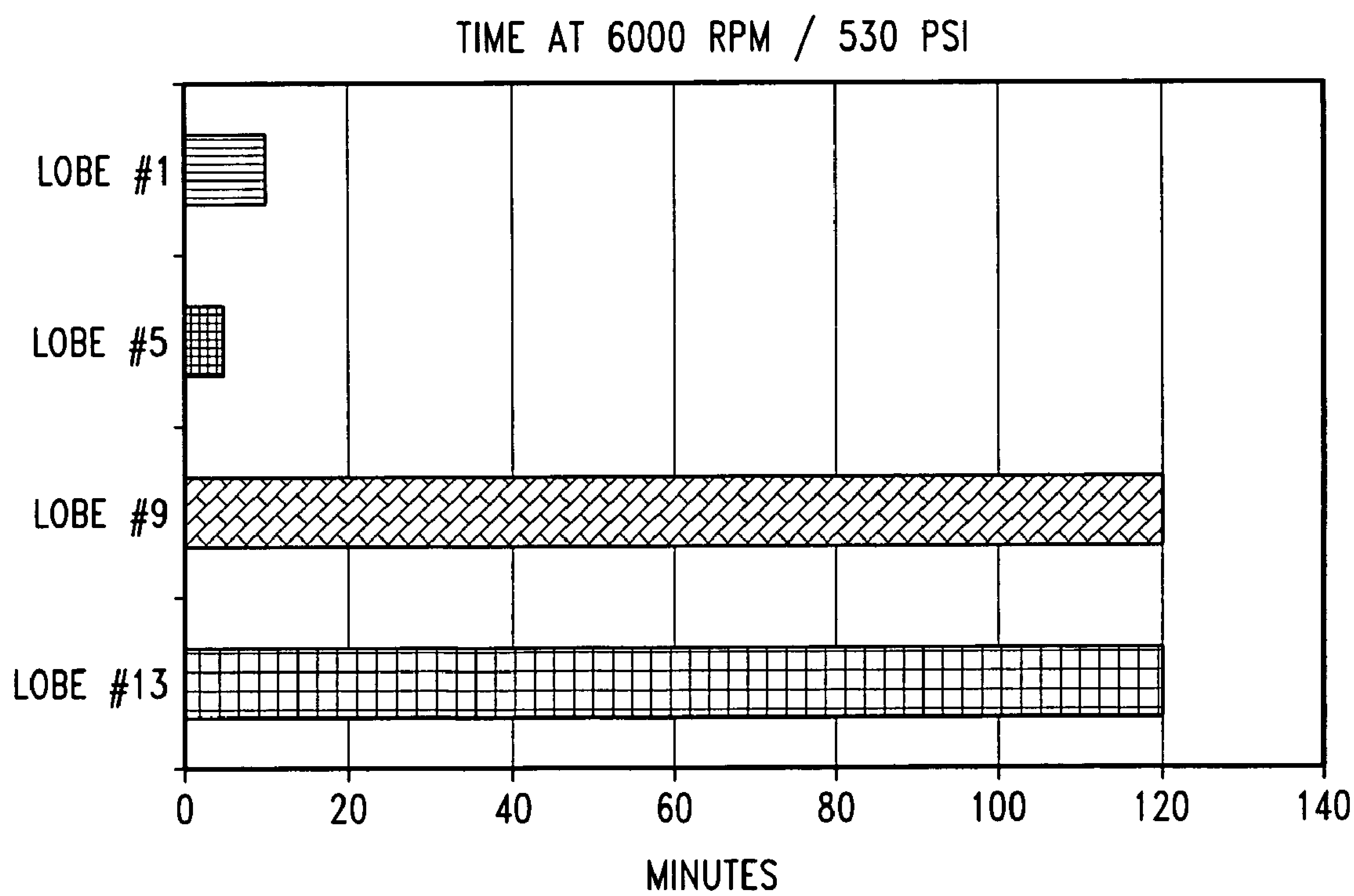

TIME AT 6000 RPM / 530 PSI
LOBE #1
LOBE #5
LOBE #9
LOBE #13
0
20
40
60
80
100
120
140
MINUTES

Fig. 18

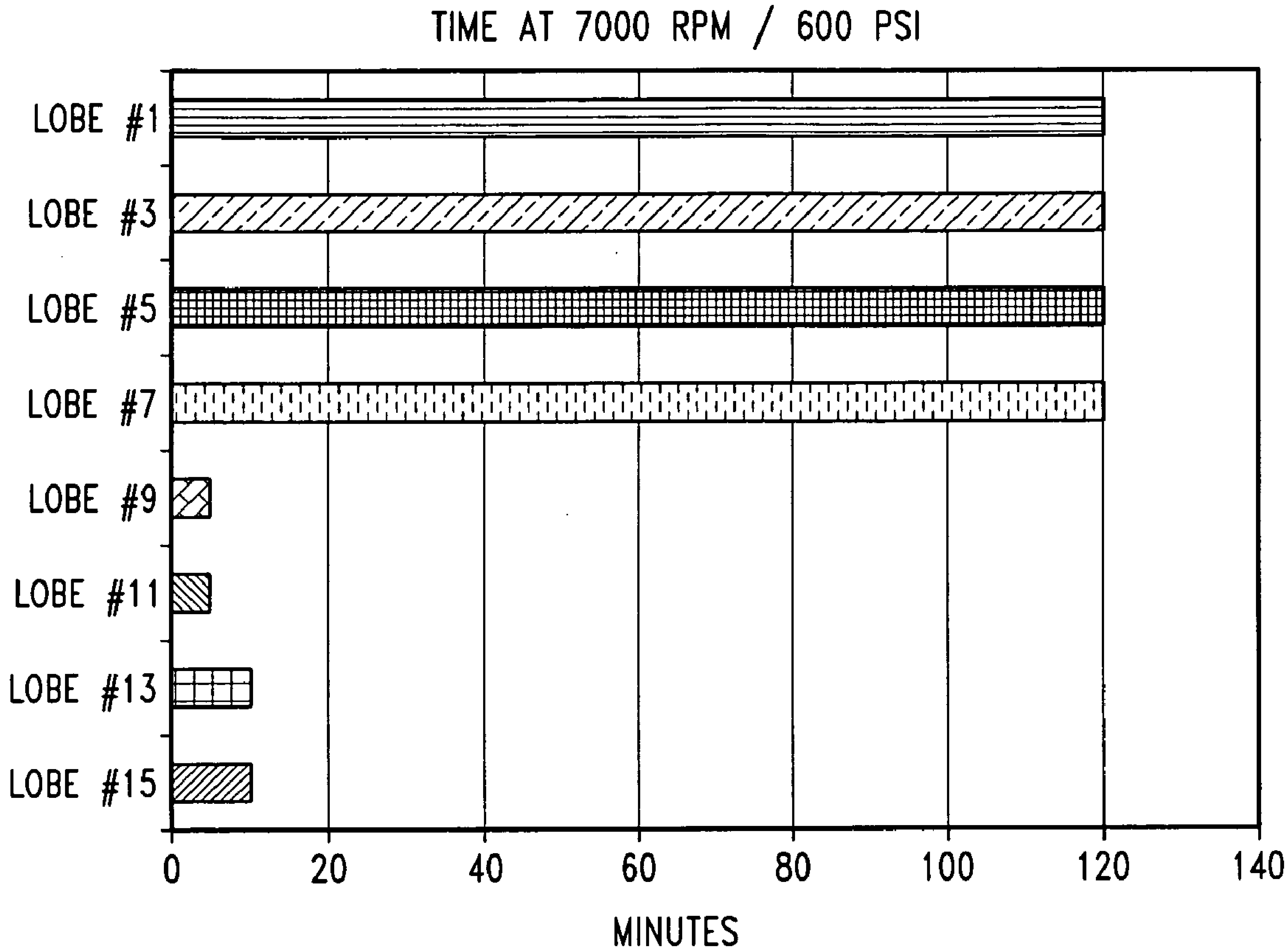

TIME AT 7000 RPM / 600 PSI
LOBE #1
LOBE #3
LOBE #5
LOBE #7
LOBE #9
LOBE #11
LOBE #13
LOBE #15
0
20
40
60
80
100
120
140
MINUTES

Fig. 19

Pin-on-Disk Tribo Measure -- Non-Treated Samples

Tribo parameters

Acquisition: Pin-on-Disk
Radius: 4.99 [mm]
Lin. Speed: 25.00 [cm/s]
Normal load: 5.00 [N]
Test load: 35.00 [N]
Stop condit: 2502 [lap]
Effective Stop: Laps
Acquisition rate: 50.0 [Hz]

Static Partner
Substrate: 316 SS
cleaning: alcohol
Dimension: 6.00 [mm]
Geometry: Ball

Environment
Temperature: 20.00 [°C]
Humidity: 50.00 [%]

Sample
Worn Track Section: 0.0 μm2
Young's Modulus: 0.0 GPa
Poisson Coef.: 0.000

Static Partner
Worn Cap Diameter: 0.0 μm
Young's Modulus: 0.0 GPa
Poisson Coef.: 0.000

Calculations
Sample Wear Rate: 0 mm3/N/m
Partner Wear Rate: 0 mm3/N/m
Max Herzian Stress: 0 GPa

Curve

Start: 0.089 Min: -0.168 Max: 1.197 Mean: 0.491 Std. Dev.: 0.206

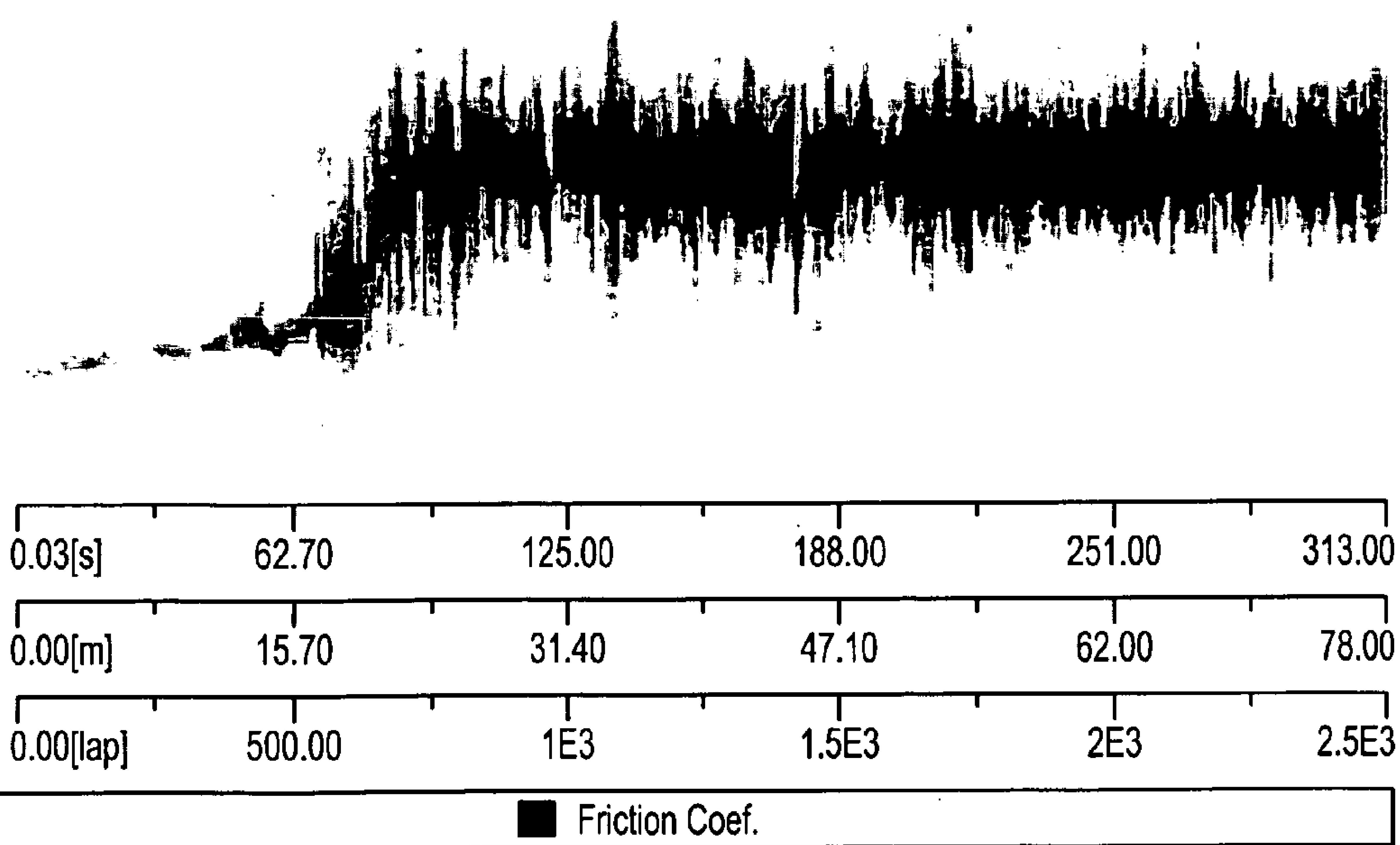


Fig. 20

Pin-on-Disk Tribo Measure -- Treated Samples

Tribo parameters

Acquisition: Pin-on-Disk
Radius: 4.99 [mm]
Lin. Speed: 25.00 [cm/s]
Normal load: 5.00 [N]
Test load: 35.00 [N]
Stop condit: 2500 [lap]
Effective Stop: Laps
Acquisition rate: 50.0 [Hz]

Static Partner
Substrate: 316 SS
cleaning: alcohol
Dimension: 6.00 [mm]
Geometry: Ball

Environment
Temperature: 20.00 [°C]
Humidity: 50.00 [%]

Sample
Worn Track Section: 0.0 μm2
Young's Modulus: 0.0 GPa
Poisson Coef.: 0.000

Static Partner
Worn Cap Diameter: 0.0 μm
Young's Modulus: 0.0 GPa
Poisson Coef.: 0.000

Calculations
Sample Wear Rate: 0 mm3/N/m
Partner Wear Rate: 0 mm3/N/m
Max Herzian Stress: 0 GPa

Curve

Start: 0.107 Min: -0.032 Max: 1.220 Mean: 0.294 Std. Dev.: 0.199

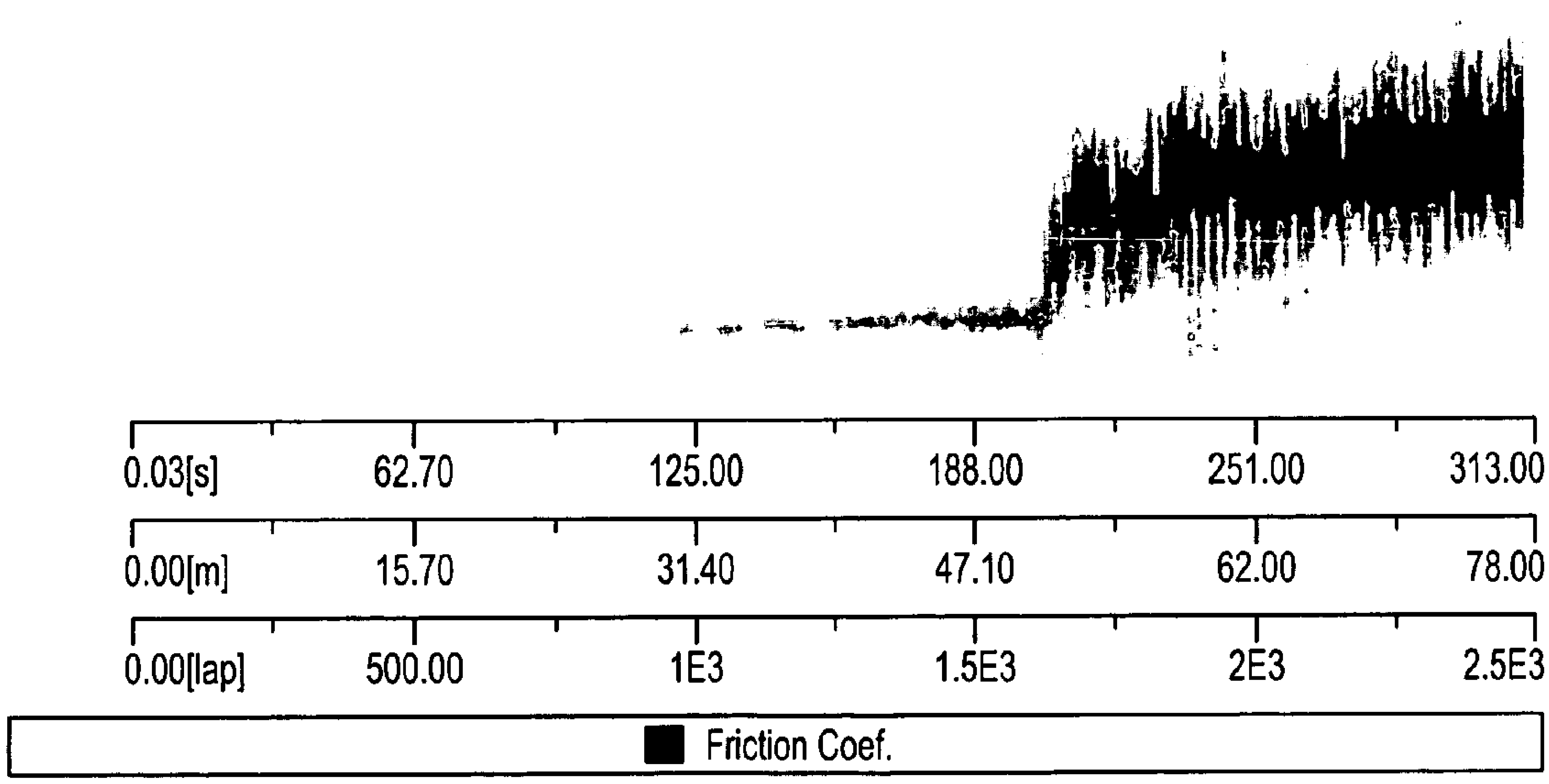


Fig. 21

Tribo Measure -- Treated Samples

Tribo parameters

Acquisition: Linear mode
1/2 Amplitude: 4.99 [mm]
Max Lin. Speed: 15.00 [cm/s]
Normal load: 0.50 [N]
Test load: 35.00 [N]
Stop condit: 4000 [cycles]
Effective Stop: Cycles
Acquisition rate: 50.0 [Hz]

Static Partner
Substrate: 316 SS
cleaning: alcohol
Dimension: 20.00 [mm]
Geometry: Ball

Environment
Temperature: 20.00 [°C]
Humidity: 50.00 [%]

Sample
Worn Track Section: 0.0 μm2
Young's Modulus: 0.0 GPa
Poisson Coef.: 0.000

Static Partner
Worn Cap Diameter: 0.0 μm
Young's Modulus: 0.0 GPa
Poisson Coef.: 0.000

Calculations
Sample Wear Rate: 0 mm3/N/m
Partner Wear Rate: 0 mm3/N/m
Max Herzian Stress: 0 GPa

Curve

Start: -0.059 Min: -1.156 Max: 1.140 Mean: 0.041 Std. Dev.: 0.313

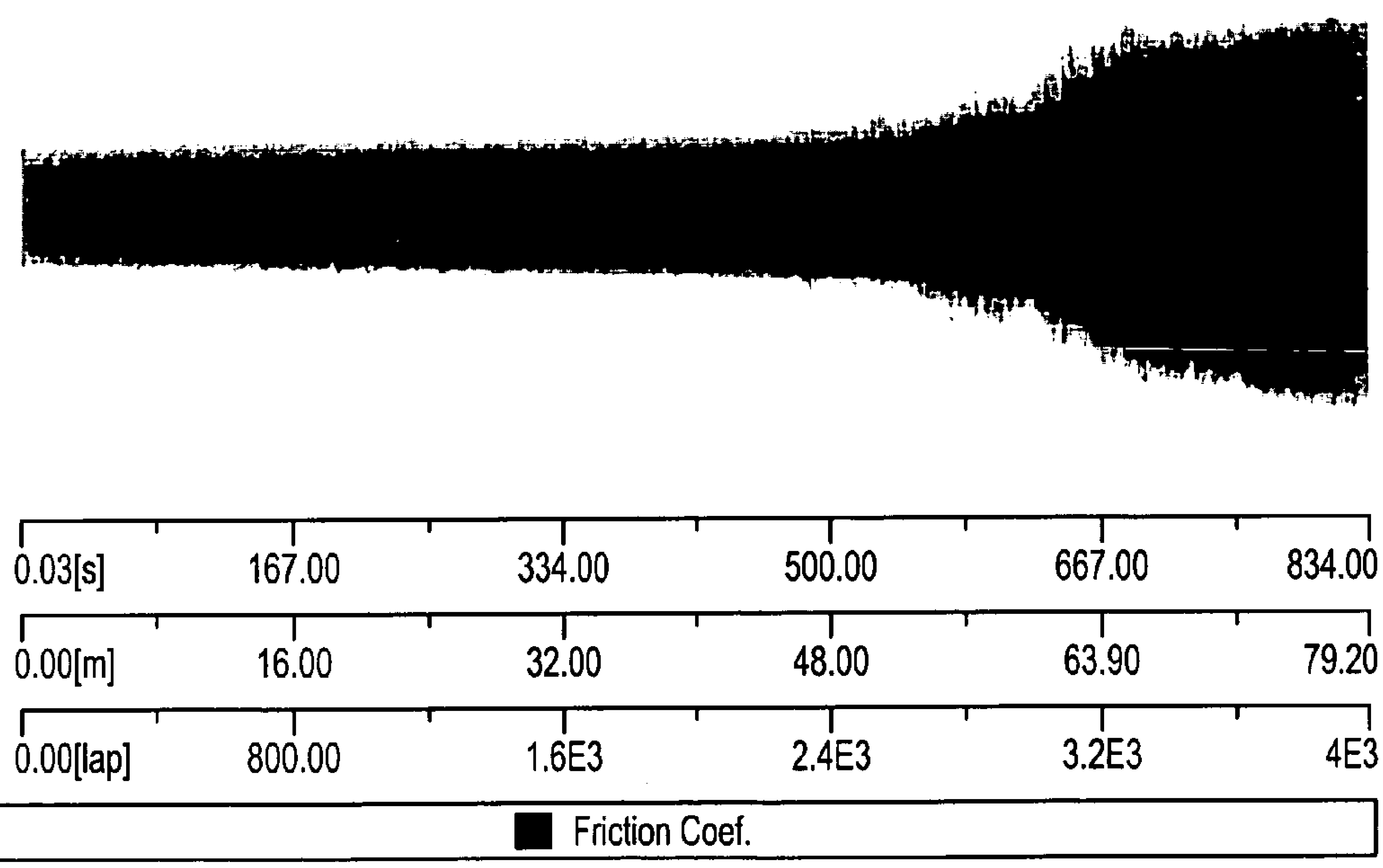


Fig. 22

Tribo Measure -- Non-Treated Samples

Tribo parameters

Acquisition: Linear mode
1/2 Amplitude: 4.99 [mm]
Max Lin. Speed: 15.00 [cm/s]
Normal load: 0.50 [N]
Test load: 35.00 [N]
Stop condit: 4000 [cycles]
Effective Stop: Cycles
Acquisition rate: 50.0 [Hz]

Static Partner
Substrate: 316 SS
cleaning: alcohol
Dimension: 20.00 [mm]
Geometry: Ball

Environment
Temperature: 20.00 [°C]
Humidity: 50.00 [%]

Sample
Worn Track Section: 0.0 μm2
Young's Modulus: 0.0 GPa
Poisson Coef.: 0.000

Static Partner
Worn Cap Diameter: 0.0 μm
Young's Modulus: 0.0 GPa
Poisson Coef.: 0.000

Calculations
Sample Wear Rate: 0 mm3/N/m
Partner Wear Rate: 0 mm3/N/m
Max Herzian Stress: 0 GPa

Curve

Start: 0.054 Min: -1.217 Max: 1.345 Mean: 0.003 Std. Dev.: 0.439

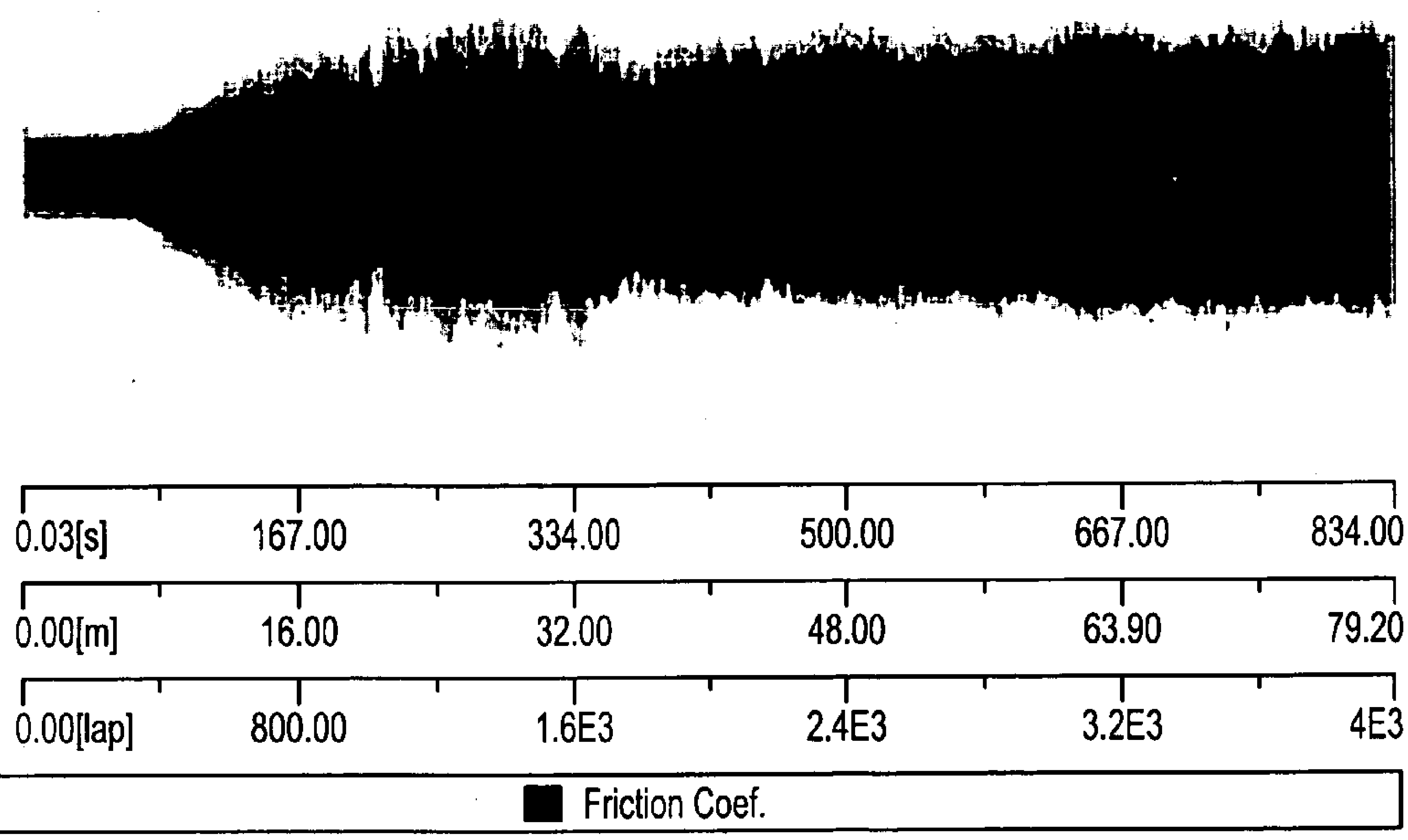


Fig. 23

Micro Scratch n° 1 -- Treated Sample

Scratch parameters

Linear Scratch
Type: Progressive
Begin Load (mN): 30
End Load (mN): 20,000
Loading rate (mN / min): 40054.44
AESensitivity: 9
Speed (mm/min): 5.22
Length (mm):5
Position X (mm): 19.569
Position Y (mm): 13.969
+ Hardware settings

Instrument: MCT S/N: 06-0181
Fn contact: 30 mN
Fn Speed: 5000mN/s
Fn Remove speed: 10,000 mN/s

Approach speed: 0.5% / s
Dz sensor in standard range
Dz range adjusted before measure

Date: 6/29/2004
Time: 11:02:59 AM

Indentors

Type: Rockwell
Serial number: S/A-021

Material: Diamond
Radius (μm): 20

Fig. 24

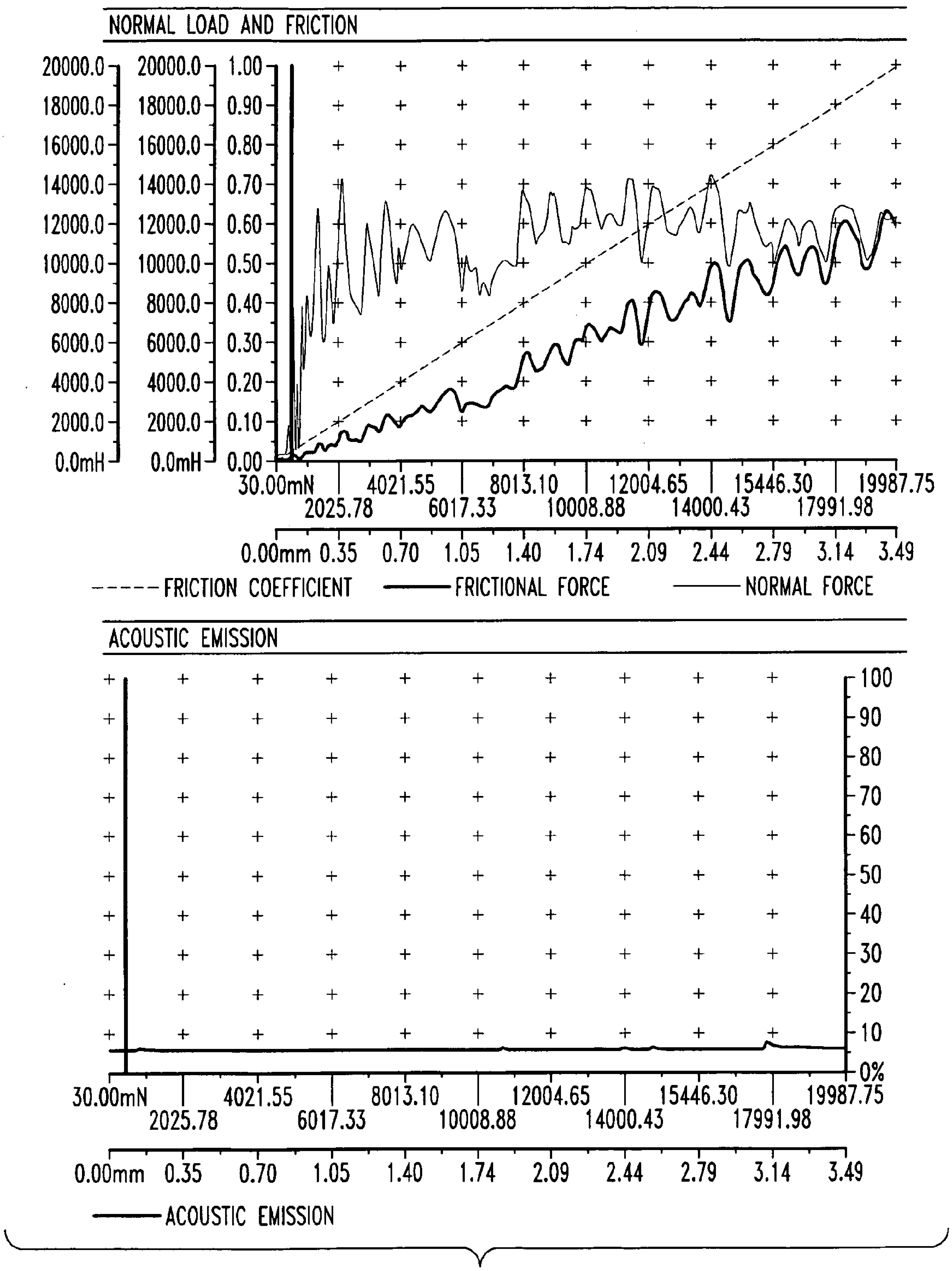
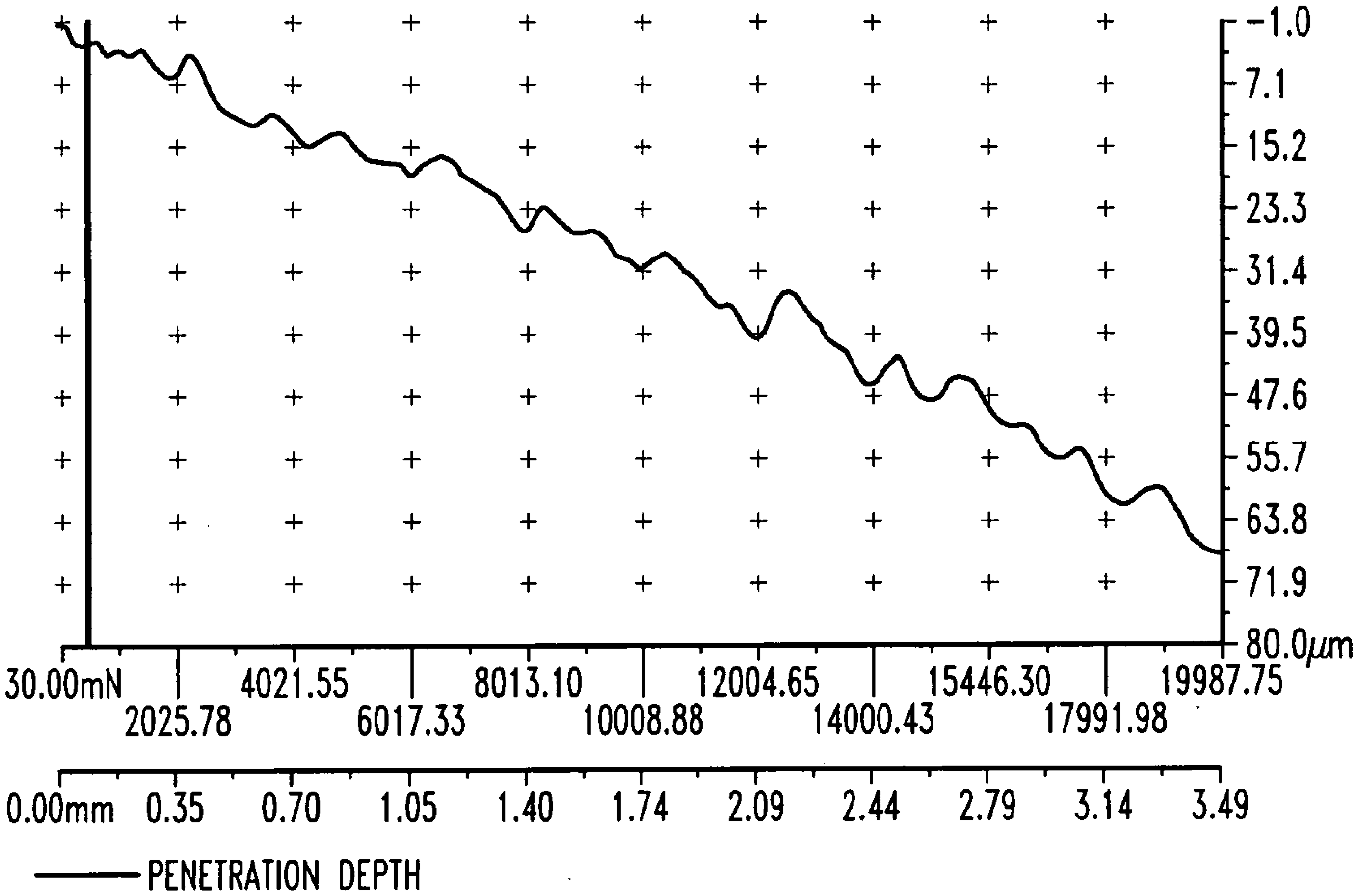
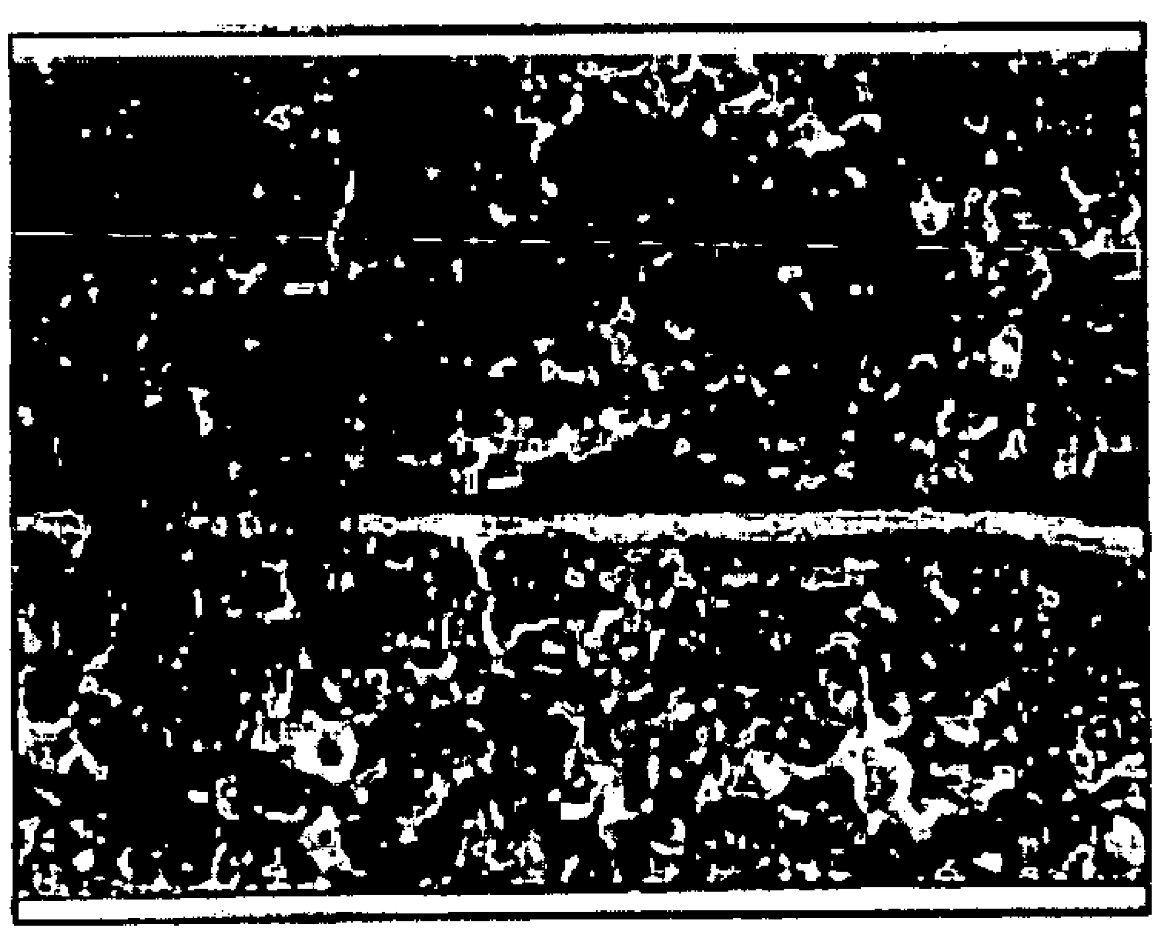

NORMAL LOAD AND FRICTION
20000.0
18000.0
16000.0
14000.0
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0mH
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
30.00mN 4021.55 8013.10 12004.65 15446.30 19987.75
2025.78 6017.33 10008.88 14000.43 17991.98
0.00mm 0.35 0.70 1.05 1.40 1.74 2.09 2.44 2.79 3.14 3.49
FRICTION COEFFICIENT
FRICTIONAL FORCE
NORMAL FORCE
ACOUSTIC EMISSION
100
90
80
70
60
50
40
30
20
10
0%
30.00mN 4021.55 8013.10 12004.65 15446.30 19987.75
2025.78 6017.33 10008.88 14000.43 17991.98
0.00mm 0.35 0.70 1.05 1.40 1.74 2.09 2.44 2.79 3.14 3.49
ACOUSTIC EMISSION

Fig. 25

PENETRATION DEPTH



SCRATCH IMAGES



COMPLETE DELAMINATION

Fig. 26

Micro Scratch n° 1 -- Treated Sample

Scratch parameters

Linear Scratch
Type: Constant
Load (mN): 2000

AESensitivity: 9
Speed (mm/min): 5.22
Length (mm):5
Position X (mm): 19.568
Position Y (mm): 12.205
+ Hardware settings

Instrument: MCT S/N: 06-0181
Fn contact: 30 mN
Fn Speed: 5000mN/s
Fn Remove speed: 10,000 mN/s
Approach speed: 0.5% / s
Dz sensor in standard range
Dz range adjusted before measure

Date: 6/29/2004
Time: 11:20:32 AM

Indentors

Type: Rockwell
Serial number: S/A-021

Material: Diamond
Radius (μm): 20

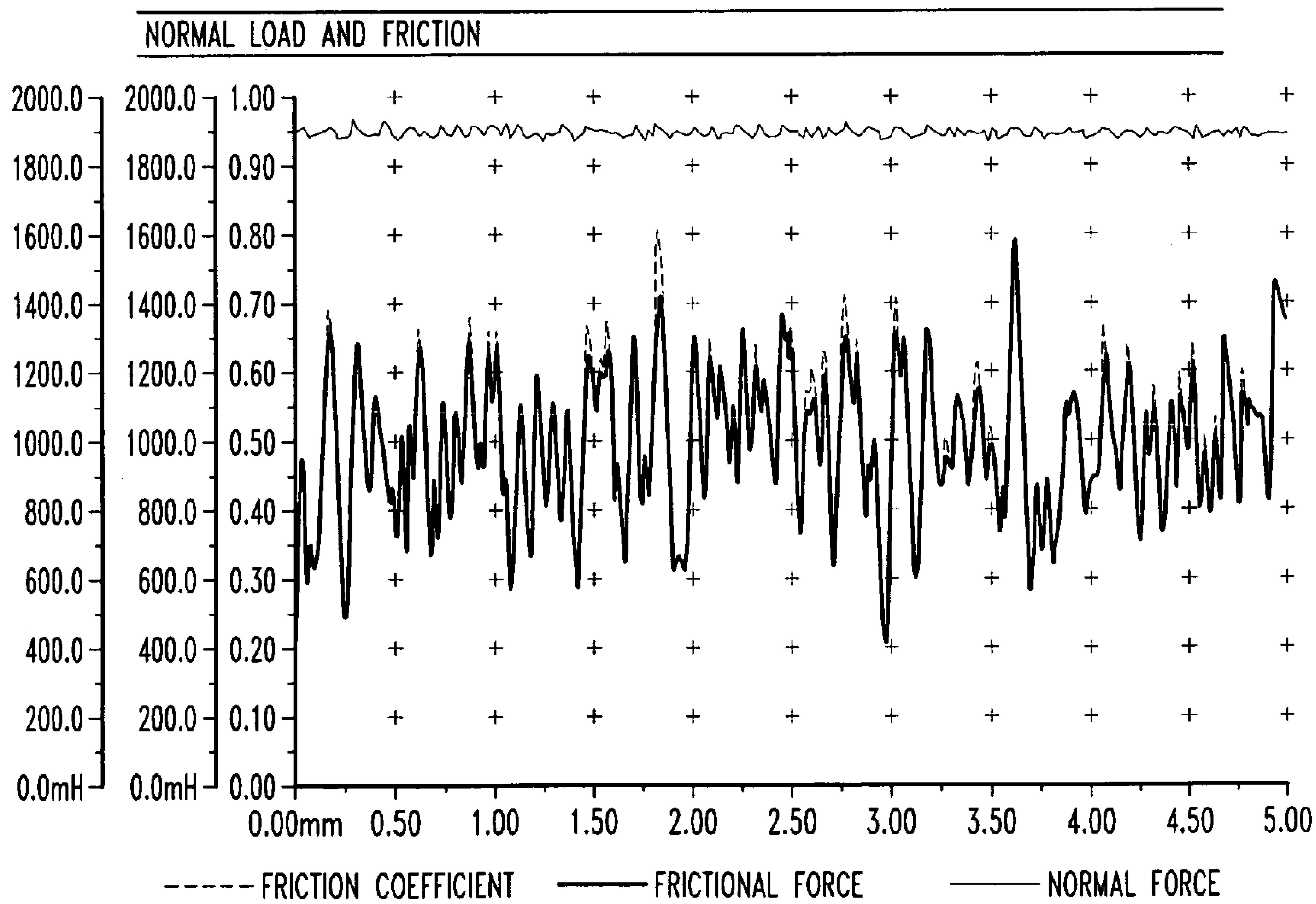


Fig. 27

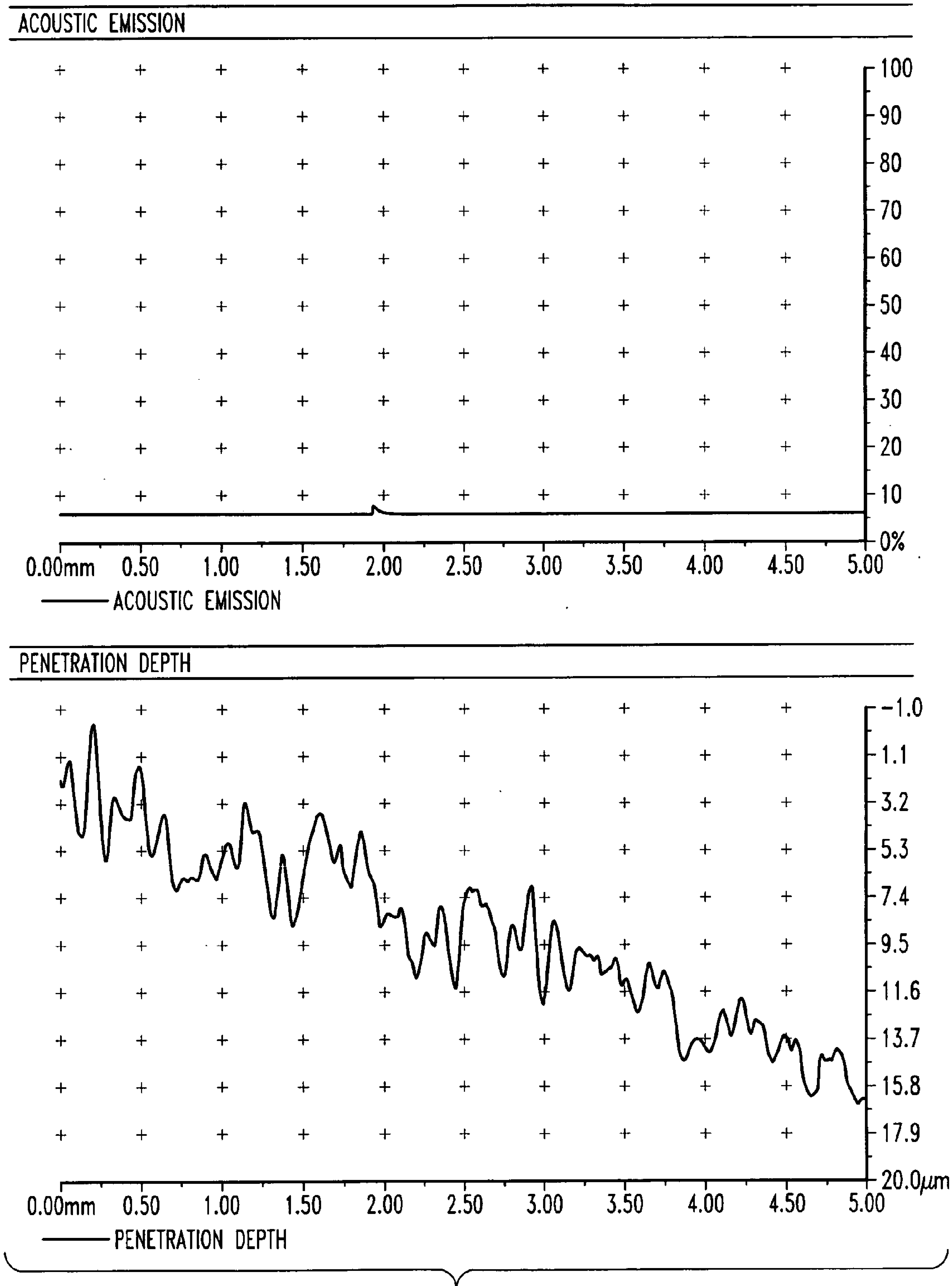
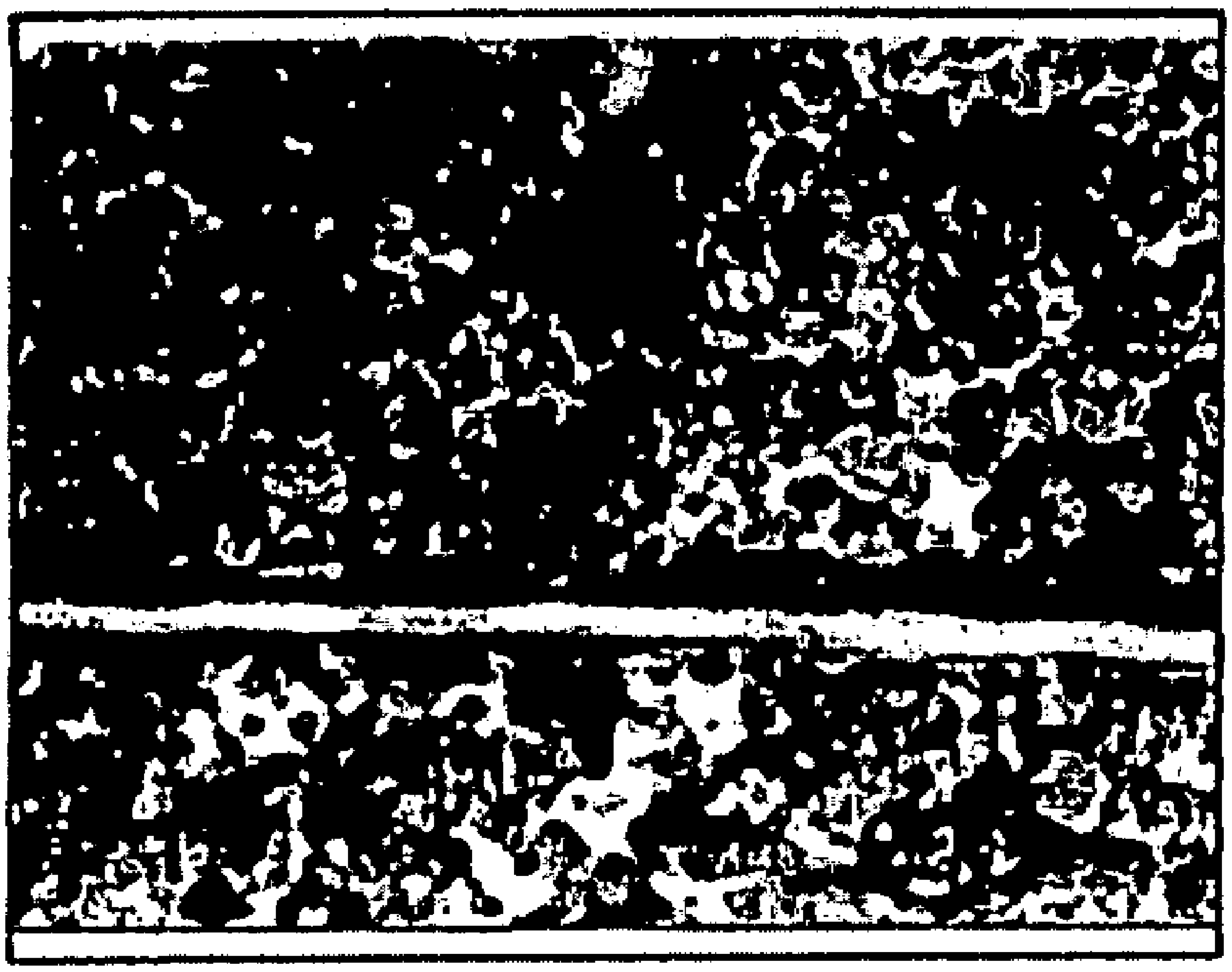

ACOUSTIC EMISSION
100
90
80
70
60
50
40
30
20
10
0%
0.00mm
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
ACOUSTIC EMISSION
PENETRATION DEPTH
-1.0
1.1
3.2
5.3
7.4
9.5
11.6
13.7
15.8
17.9
20.0μm
0.00mm
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
PENETRATION DEPTH

Fig. 28

SCRATCH IMAGES



CONSTANT LOAD - 2N

Fig. 29

COMPOSITIONS AND METHODS RELATING TO TRIBOLOGY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority from U.S. provisional patent application No. 60/618,285, filed Oct. 12, 2004, and U.S. provisional patent application No. 60/637,323, filed Dec. 16, 2004, which are incorporated herein by reference in their entirety and for all their teachings and disclosures.

BACKGROUND

[0002] Generally speaking, "tribology" is the study of how to make things slippery and how to keep them that way for as long as possible. In technical terms, tribology is often referred to as the study of design, friction, lubrication and wear of interactive surfaces in relative motion. Some of the problems that people studying tribology are facing include parasitic power loss, friction, wear and corrosion of mechanisms with direct surface-to-surface contact (e.g., metal-to-metal contact), particularly when such contact suffers from a lack of lubrication or otherwise has undesirable friction. Previous attempts at addressing such concerns have included a process known as "shot peening", for example as discussed in U.S. Pat. Nos. 3,574,658; 3,754,976; 4,312,900; 4,753,094; 6,658,907; 6,694,798 and 6,790,295. (These and all other references set forth herein discuss certain systems, apparatus, methods and other information; all such references are incorporated herein by reference in their entirety and for all their teachings and disclosures, regardless of whether references may appear in this application.)

[0003] These prior systems, methods, etc., still leave open the need for improved methods, compositions, systems, etc., that reduce tribology-related concerns such as power loss, friction, lubrication, wear or corrosion. The present compositions, methods, systems, etc., reduce at least one of these concerns and provide other advantages.

SUMMARY

[0004] In certain aspects, the systems, compositions, methods, etc., herein provide significantly enhanced tribological properties to a target substrate such as metal, plastic, ceramic, wood, glass, etc., by bombarding or showering the target material with bombardment particles substantially saturated with a desirable lubricant composition comprising at least one primary lubricant such as a molybdenum disulphide (MoS_2) and at least one polymeric lubricant, such as polytetrafluoroethylene (PTFE), such that the lubricant composition imbeds into the surface of the target material (also called a target substrate). "Composition" indicates a combination of multiple substances into an mixture.

[0005] In other embodiments, the lubricant composition does not comprise a polymeric lubricant. For example, the lubricant composition can also be comprised of zinc sulfate heptahydrate, $O_4SZn.7H_2O$, which can be used in combination with another compound such as chromium metal powder. If desired, the composition can also include a polymeric component such as PTFE, either in an amount adequate to provide lubricity to the ultimate embedment composition and/or in an amount to help provide an anti-clumping property to the embedding composition prior to administration ot the substrate, which may be less than an optimal lubricity amount. Such compositions may if desired primarily provide properties other than lubricity, such improved anticorrosive or antiwear properties, to the substrate.

[0006] It appears that this embedment process changes the molecular structure of the target material and creates a new, unique embedment composition in the surface of the target material. The embedment composition is not merely a layer of lubricant deposited on the surface of the target substrate but is rather the creation of a new composition, typically at least about 1 to 3, 4, 5, 6, 7, 8-10, 15 or more microns (μm) thick, having exceptionally good lubricity, corrosion resistance and/or other enhanced tribological properties.

[0007] Accordingly, in certain embodiments the embedment composition comprises the solid substrate and a suitable lubricant, such as the primary lubricant and the polymeric lubricant discussed below, mixed together. If desired, a layer of lubricant atop the substrate can be also deposited either during the embedment process or as a separate application of lubricant (in some embodiments, the embedding compositions can be used to make a surface layer of lubricant that does not involve making any embedment composition, including that such can be applied to materials with no embedment portion). Such additional lubricant layer made with lubricant plus bombardment particles may or may not be created with the same lubricant composition used to create the embedment composition.

[0008] The bombardment process typically comprises the use of bombardment particles such as stainless steel shot, aluminum shot, glass beads, conch shell or steel or diamond grit that typically have been substantially completely coated (typically preferably at least about 90%, 95%, 98%, 99% or more, up to 100%, although less coverage can be provided if desired) with the lubricant composition that is suitable for embedding into the substrate to create the embedment composition.

[0009] Accordingly, in some aspects the present invention comprises the lubricant composition itself, wherein the composition comprises at least about 55% (w/w) to about 99% (w/w) of at least one of primary lubricant, and about 3% (w/w) to about 55% (w/w) of at least one polymeric lubricant. Exemplary primary lubricants include metallic lubricants (typically dry although other matter states are also acceptable in some embodiments), graphite or boron nitride, for example molybdenum (IV) sulphide, molybdenum disulphide, molybdenum sulphide, molybdenum sulphide, molybdenum (IV) selenide, molybdenum selenide, tungsten (IV) sulphide, tungsten disulphide, tungsten sulphide, graphite, and boron nitride. Exemplary polymeric lubricants include PTFE (polytetrafluoroethylene), PFA (perfluoroalkoxy), ETFE (copolymer of ethylene and tetrafluoroethylene), FEP (fluorinated ethylene propylene copolymer), PTFE-S dry lubricant, PCTFE (polychlorotrifluoroethylene), and polyethylene.

[0010] In another aspect, the present innovations provide embedding compositions comprising bombardment particles in combination with the primary lubricant and the polymeric lubricant mixed together, such as the metallic dry lubricant, graphite or boron nitride, and/or the polymeric lubricants discussed elsewhere herein. Shot peening-type media are typically suitable for use as the bombardment particles. An exemplary list of suitable bombardment particles includes stainless steel shot, aluminum shot, corn cob, steel cut wire, ceramic, glass bead, aluminum oxide, silicon carbide, walnut shell, pecan shell, steel grit, soda bicarbonate, crushed glass, plastic, iron grit, slag and diamond grit. The type and size, etc., of the particle can be selected to enhance the embedding composition. For example, in some embodiments, increases in density of the chemical composition can be matched with increases in the mass and/or density of the particle.

[0011] In other aspects, the present innovations provide systems, methods and the like for mixing suitable lubricants, not limited to those expressly discussed herein, with the bombardment particles and/or for bombarding the substrate material with such lubricants in a manner suitable to create an embedment layer. In certain embodiments, the embedment process is somewhat similar to shot peening processes and thus certain mixers, delivery systems, bombardment cabinets, etc., from the shot peening fields can be adapted for use in accordance with the innovations discussed herein, given the disclosure herein, but in certain preferred aspects the methods, etc., are performed using unique mixers, delivery systems, bombardment cabinets, etc., configured especially for the embedment processes herein.

[0012] In certain embodiments, the innovations discussed herein are conducted at different (typically lower) velocities than shot peening, for example from about 40-90 psi, and often for substantially shorter periods of time than the typical shot peening process, for example about 15 seconds to create an embedment composition in the surface of a 1.5 inch×1.5 inch steel sample compared to up to about 8 hours for other lubrication technologies. **FIG. 1** depicts an example of an embedment process-treated steel sample next to an untreated sample.

[0013] These and other aspects, features and embodiments are set forth within this application, including the following Detailed Description and drawings. Unless expressly stated otherwise or clear from the context, all embodiments, aspects, features, etc., can be mixed and matched, combined and permuted in any desired manner. In addition, various references are set forth herein that discuss certain systems, apparatus, methods and other information; all such references are incorporated herein by reference in their entirety and for all their teachings and disclosures, regardless of where the references may appear in this application.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] **FIG. 1** depicts an example of an embedment process-treated steel sample next to an untreated sample.

[0015] **FIG. 2** schematically depicts an exemplary air supply system suitable for use with a bombardment system discussed herein.

[0016] **FIG. 3** schematically depicts an embodiment comprising a blast cabinet with a recycleatory collection systems (RCS) attached to the right side.

[0017] **FIG. 4** schematically depicts another embodiment of an RCS attached to a blast cabinet.

[0018] **FIG. 5** schematically depicts a cutaway side view of a funnel-shaped container portion of an RCS.

[0019] **FIG. 6** schematically depicts a part of a bombardment system set up to deliver embedment composition to a substrate

[0020] **FIG. 7** schematically depicts a part of the air supply system discussed above comprising a wall manifold.

[0021] **FIG. 8** schematically depicts a cutaway side view of one embodiment of a particle kinematic system.

[0022] **FIG. 9** schematically depicts a cutaway side view of another embodiment of a particle kinematic system.

[0023] **FIG. 10** schematically depicts a further particle kinematic system embodiment.

[0024] **FIG. 11** schematically depicts a further particle kinematic system embodiment.

[0025] **FIG. 12** schematically depicts a further particle kinematic system embodiment.

[0026] **FIG. 13** schematically depicts a further particle kinematic system embodiment.

[0027] **FIG. 14** schematically depicts a "V" mixer, which is one embodiment of a suitable mixer for substantially constantly mixing or agitating mixtures herein.

[0028] **FIGS. 15-17** depict graphs and information relating to results discussed in Example 1.

[0029] **FIG. 18-19** depict graphs relating to results discussed in Example 2.

[0030] **FIGS. 20-21** depict graphs and information relating to results discussed in Example 3.

[0031] **FIGS. 22-23** depict graphs and information relating to results discussed in Example 4.

[0032] **FIGS. 24-29** depicts graphs, information and pictures relating to results discussed in Example 5.

DETAILED DESCRIPTION

[0033] In certain aspects the present discussion is directed to compositions, methods, etc., that substantially improve the lubricity of target materials. The present innovations include creating an embedment composition within the surface of a target material, typically a solid material such as metal, plastic, ceramic, wood, glass, etc. The resulting surface, typically up to about 1-15 μm thick or more, has outstanding lubricating and corrosive resistance and/or other properties. In preferred embodiments, the compositions, etc., herein are environmentally safe, require no dangerous materials and are suitable for high-volume continual motion production.

[0034] Rather than simply coating metal or other target surfaces (although, as noted above, making or applying such coatings can be effected if desired) the innovations herein create an entirely new embedment composition within the surface of the substrate, apparently by altering the molecular structure of the surface. Although not critical to the innovations, it is believed that the bombardment uses a form of energy to close exposed boundaries, actually changing the atomic structure of the surface while dispersing the chemical lubricant compound(s) (which can be dry, resinous, liquid or otherwise as desired) into the substrate of the metal, typically also without destroying or losing the properties of those chemicals or the base (substrate) material. The bombardment compositions can have adequate kinetic energy to create elastic or inelastic collections with the substrate to provide a kneading of the substrate surface but preferably without disrupting the dimensional tolerances of the substrate. The impact can be enough to create a slight indentation, which can be smoothed by subsequent impacts by other particles. The bombardment particle may deposit the lubricating, etc., material before rebounding.

[0035] Typical substrate materials are suitable for use in engines and engine components, ball bearings, high pressure fittings, tool and die, heavy duty automotive and truck products, chain and gear products, automobile and other mechanized racing, aerospace and military uses.

[0036] The processes herein are suitable for use to make multiple substrate product combinations simultaneously or sequentially (e.g., treating gears and high pressure fittings at the same time) and can be adapted for different situations, for example by adapting the embedding composition by selecting specific embedding composition ratios or components, by selecting larger or smaller and more rounded or more angular bombardment particles, etc. The systems are highly suitable to provide uniform results for a variety of different parts and substrates over the course of extended periods of manufacturing time.

[0037] It is a particular feature of certain embodiments that, unless desired to perform the processes otherwise, the dimensions of the substrate remain uniform during and after the embedment process: the process does not create any dimensional changes in the substrate, there is no build-up of surface material and the substrate's thickness does not vary significantly at edges, corners or bending points. The embedment compositions created using the innovations herein can be created to show no unstable movement due to heat (thermal migration), surface peeling (delamination) or chemical breakdown (decomposition).

[0038] The methods, etc., herein do not typically require (although such can be provided if desired for particular purpose) ultra high vacuum or evacuated chambers, emersion in inert gasses nor the use of toxic chemicals or high voltage equipment or clean rooms. The methods, etc., can be used with high-speed continuous motion production as well as batch or in-line processing or even one-by-one production such as for just-in-time inventory management. In some aspects the methods, etc., can be implemented within health and safety laws, without the use of toxic materials and can be managed without producing dangerous emissions or hazardous waste. The lubricant and bombardment particles, etc., that are used in the embedding process but are not actually incorporated into the embedment composition can be reclaimed or recycled. In certain embodiments, the methods, etc., can be incorporated into virtually any manufacturing process. This can be particularly useful where substrates are designed and/or manufactured having certain specific shapes and tolerances, then subjected to the innovative embedment processes, and then continued into further manufacturing processes, or into actual use, without any dimensional modifications to the substrates since the dimensions of the substrate have not been changed by the embedding process.

[0039] In certain embodiments, the embedding processes can be run in simple blast cabinets using suction methods. Other bombardment methods and other cabinets or processing rooms (or lack thereof) can also be used as desired.

[0040] Turning to a brief discussion of some of the figures that depict certain embodiments and parts of bombardment/embedment systems, **FIG. 2** depicts an air supply system **14** suitable for use with a bombardment system discussed herein. The system comprises a compressor **2** operably linked to a dryer **4** via a first conduit **8**. The dryer **4** dries the air and/or the embedding compositions, and is operably linked via a second conduit **10** to a manifold **6**. The manifold **6** is in turn linked via a second conduit **10** to a third conduit **30** to a blast or processing cabinet **28**, where the embedding composition is applied to the substrate. The blast cabinet can be a small cabinet as in some of the drawings, and can comprise one or more nozzles to spray the embedding composition. The blast cabinet can also be a large cabinet, or even a room that forms the "cabinet", or otherwise be any suitable staging area for the embedment process to occur. The nozzle(s) can be fixed or moveable, for example via a control knob or the like for a small cabinet, or can be hand held in large cabinet, hand held in a large room wherein the room itself forms the "cabinet", etc. The nozzles can also be focused to provide a concentrated spray, or dispersive to provide a wide spray, or otherwise as desired.

[0041] Certain embodiments herein provide a particle kinematics system (PKS). The PKS is used to minimize settling of the bombardment particle composition or embedding composition while it is retained in a storage hopper or bin prior to delivery to a substrate in a blast cabinet for processing or bombardment. Such PKS reduces conglomeration of the bombardment materials and/or the coatings on the bombardment materials. Further, the PKS can act as a mixing phase, whether primary or secondary, for the delivery system. Further embodiments comprise recycleatory collection systems (RCS). The RCS can be used to reclaim residual bombardment particle mixtures that have been sprayed or otherwise delivered against a substrate in a processing cabinet. The systems preferably reclaim the bombardment particle mixtures without separating the elements of the mixture from each other (i.e., without separating the bombardment particles from the lubricant coating). The RCS typically further provides a stage, which can be an initial stage, of internal mixing for the delivery system. The RCS preferably captures and reclaims fine chemical particles in the air, and can if desired reclaim excess particles at the bottom of the processing cabinet. The RCS further provides advantages because it can reduce the amount of waste ultimately expelled or extracted from the system. The dried air can also be introduced into the RCS or other locations in the system.

[0042] **FIG. 3** depicts an embodiment comprising a blast cabinet **28** with a RCS **32** attached to the right side. The RCS **32** is operably connected to the blast cabinet **28** by a connecting conduit **42** and includes a fan **34** located at the top to assist in the movement and processing of various materials. The RCS **32** feeds recaptured composition via a gravity feed tube **36** down to a hopper **38** containing a PKS **44** (shown in dotted line and discussed in more detail in other figures) comprising a spinning flanged wheel **40** and a deflector **46**. In the embodiment shown, the blast cabinet **28** comprises a window **48** so that a user can view the process taking place, a plurality of control knobs to control, as desired, the positioning of sprayer **54**, substrate **56** or stage **58**. The sprayer **54** is fed by a pick up tube **52**. The bombardment area **62** where embedment takes place is separated from hopper **38** by a divider **60**. Of course, other combinations of the various elements can also be pursued if desired. For example, the fan can be omitted or located in other positions, the RCS **32** can be located in other positions including positions that do not use a gravity feed to the hopper, the sprayer, which may be a nozzle that provides a focused concentration spray, a wide-dispersion sprayer, or a plurality of sprayers or jets, can be fixed, movable by remote control, moveable by hand control, or even hand-held via a port in the side of the spray cabinet, etc.

[0043] **FIG. 4** depicts another embodiment of an RCS **32** attached to a blast cabinet **28**. The RCS **32** is located up and to the left of the blast cabinet **28**. The system also comprises a drain tube **64** comprising a valve **66** so that unused embedding composition can be easily removed from the hopper **38**. If desired, a counterpressure mechanism can be provided so that the drain tube **64** can also function as a pick up tube to accept embedding composition from an external source(s), such as a pre-mixer, or a plurality of different component sources such as a reservoir of primary lubricant, a reservoir of polymeric lubricant, and a reservoir of bombardment particles. In such an embodiment, if desired, the system can further comprise one or more metering valves that control how much of each of the different components of the embedding composition are fed into the hopper **38**. Of course, the embedding composition can also be fed into the system via one or more separate inlet ports if desired.

[0044] **FIG. 5** depicts a cutaway side view of a funnel-shaped container portion **68** of the RCS **32**. Initially, dust and other desired elements from the blast cabinet **28** are transmitted to the conductive container portion **68** having a side wall **70** and a conical bottom **72** via a connecting conduit **42** which, in certain embodiments, includes a joint **74** comprising a venturi valve **76** to intake air or other desired elements that can enhance the process. The collected dust is then sprayed into the interior of the container **68** and past one or more defusing/mixing fins **78** maintained inside the conductive RCS container **68**. The container conducts the bombardment particle mixture dust and other elements from the dust connecting conduit **42** to a gravity feed tube **36** that transmits the material to the cabinet hopper or other desired location. In the embodiment shown, the RCS **32** also comprises an air intake filter housing **80** containing an air intake with a filter and a fan **34** that takes in air and mixes it with the collection mixture. If desired, the filter can also comprise a filtration mesh over the intake air filter.

[0045] **FIG. 6** depicts a part of a bombardment system set up to deliver embedment composition to a substrate The system comprises a compressor **2** operably linked to a dryer **4** via a first conduit **8**. The dryer **4** dries the embedding compositions, and is operably linked via a second conduit **10** to a manifold **6**. The manifold **6** is in turn linked via a return conduit **12**, such as a hose, to the first conduit **8** between the compressor **2** and the dryer **4**. This return connection permits constant pressurization and movement of the embedding composition before it is transmitted via a further conduit, an example of which is shown in **FIG. 2**, conducts the embedding composition from these components to the blast cabinet or other desired staging area where the embedding composition is applied to the substrate.

[0046] **FIG. 7** depicts a part of the air supply system **14** discussed above, and comprises a wall manifold **26** comprising a housing **18** so that the air can be controlled and regulated via regulators **20** when it is supplied to one or more blast cabinet(s) (not shown) connected to the air supply system **14**. Air can be taken into the regulator via valve **16**, then transmitted via pipe **22** to regulators **20**, when transmitted further the quick connect air port **24**. In one embodiment, air compressor and dryer support 50 cfm @ 100 psi, and the system has a 120 gal tank for storage.

[0047] **FIG. 8** depicts a cutaway side view of one embodiment of a particle kinematic system **44** wherein a hopper **38** contains the bombardment or embedding composition **82**, which in the embodiment shown is maintained at the bottom due to gravity. A low PSI mixing nozzle **84** sprays the embedding composition (the PSI can be varied as desired depending upon the bombardment particle composition). Nozzle **84** is fed by a feed tube **86** which functions as an air pressure input tube, and is also fed by a bombardment particle composition tube **88**, which functions to uptake the bombardment particle composition from the bottom of the hopper. The nozzle **84** then sprays the composition against the underside of a concave plate **90**. In the embodiment depicted, a conical impact unit **92** is substantially centrally located in the concave plate **90**, which conical impact unit **92** serves to spread out and separate the bombardment particle mixture before it returns to the bottom of the hopper **38**. When the embedding composition **82** is needed for actual bombardment, the embedding composition **82** is taken through the pick up tube **52** shown at the right of the Figure.

[0048] **FIG. 9** depicts a cutaway side view of a similar embodiment as in **FIG. 8**, wherein the feed tube **82** comprises an intake port **94** to take up the composition **82**, and the feed tube **82** is held to the bottom **98** of the hopper **38**. In both **FIGS. 8 and 9**, the spray apparatus can in some embodiments function like a bubbler.

[0049] **FIGS. 10-13** depict some further PKS embodiments comprising one or more flanged paddle wheels **40** or low PSI nozzles provided at the bottom of the hopper **38**. For the flanged paddle wheels **40**, the wheels spin and the paddles or flanges contact and throw or otherwise move the embedding composition **82** toward a deflector **46**. If desired, the deflector can be an angled splitter **100** or a substantially spherical splitter **102**, which splits and separates the mixture before it returns to the bottom of the hopper. As with the conical plates discussed earlier, one or more of each of the different particle kinematic system elements can be provided in the hopper(s), including mixing and matching different elements of the particle kinematic devices as desired.

[0050] The chemicals are typically mixed prior to embedment, or after recapture from the blast cabinet. **FIG. 14** depicts a "V" mixer **104**, which is one embodiment of a suitable mixer for substantially constantly mixing or agitating mixtures herein. As depicted, the "V" mixer **104** has a first arm **106** and a second arm **108**, which contain the embedding composition **82**. As can be seen, the "V" mixer **104** is rotated such that the embedding composition is split apart and mixed and re-combined. The mixture is mixed for any desired amount of time, typically until substantial saturation. Generally speaking, saturation is substantially complete coverage by the 2 or more chemicals of the lubricating composition over the bombardment particles, which can be verified by viewing samples under a microscope at different periods of time. Typically, at least 90%, 95%, 98%, 99% or better coverage of the bombardment particles is desired.

[0051] The "V" mixer **104** can be rotated at any desired rate, for example about 0.3-3 revolutions per second. In one embodiment, the "V" mixer **104** can operate at 30 rpm with a ¼ hp motor. The overall dimensions of the "V" mixer **104** can be: 46" long by 34" wide by 20" tall. The V chamber dimensions can be, for example, such that one side of the V is about 16½" deep and the other side is 19" deep with an 80 degree separation angle between the sides, with each side having a diameter of 10" O.D. The size and dimensions can be modified as desired to suit the preferences of a given user and given system, composition, etc. A constant mixer such as the "V" mixer **104** in **FIG. 14** or a vortex mixer operating, for example, at 40-60 hertz, can be incorporated to provide new embedding composition to a blast cabinet, and/or it can be incorporated with a recirculation unit such as those discussed herein to transmit the mixture back into the cabinet. Once the mixture has entered/reentered the cabinet it can if desired then be re-mixed inside the bottom of the cabinet to improve the mixture.

[0052] As noted above, the various embodiments and elements, etc., herein can be combined and permuted as desired and variations on the elements can be also provided as desired. For example, the paddles on the rotating flanged mixers can be straight, can be curved to scoop material or otherwise configured as desired. Additionally, the splitters, if any, can be cone shaped, or pyramid shaped, spherical, or otherwise shaped to provide desired deflection and/or mixing, and the shape, composition, etc., of the various tubes, mixing or spraying nozzle(s), PSI, concave deflection plate(s), etc. can be varied.

[0053] In some embodiments, a great deal of static electricity is created during prep and process, which creates a desire to insulate users from the static. In one embodiment, a grounding strap can be attached to the cabinet and to the wrist of the user, to help reduce the discharge. A possible theory for the grounding strap is that it connects the user "in line" with the air supply so that the static is not jumping from the source to the user. In some embodiments, the equipment is all linked together to obtain continuity to reduce static electricity.

[0054] In certain embodiments, the lubricating composition and the bombardment material are mixed outside the actual bombardment cabinet in a premixing step. Generally speaking, dumping the material into the blast cabinet without adequate mixing will not achieve the desired embedment composition. In other embodiments, for example where the blast cabinet has a mixing chamber (either separate from or combined with the bombardment chamber of the mixing cabinet), the individual components of the embedding composition can be provided separately to the blast cabinet. In such embodiments, it may be preferred to run a mixer such as the bubblers and/or spinning wheels discussed herein before the composition is actually used for embedding.

[0055] Once the lubricating composition and the bombardment particles are mixed together, the mixture can be put into a cabinet hopper or a storage bin. The mixture can then be drawn out of the hopper (or other device for providing the embedding composition for bombardment) through a hose, duct or other channel and then sprayed out of a nozzle or other outlet port where it is sprayed on to the target part where the embedment takes place.

[0056] Embedding mixture that is not actually embedded (e.g., overspray) can then be collected, for example by allowing it to fall though a mesh grate (sifted) and then returned back to the storage hopper to be drawn through the system again. Airborne particles that are not incorporated into the embedment composition in the surface of the target can be collected by suitable methods, for example by force of air pressure being drawn upwards by vacuum into a secondary hopper with a filtration system, which filtered embedding composition can then be returned to the main hopper or other storage.

[0057] Turning to a further discussion of certain lubricant compositions suitable for creating the embedding compositions and ultimately the embedment compositions discussed herein, in certain embodiments the lubricant compositions comprise a) about 55% (w/w) to about 99% (w/w) of at least one of molybdenum (IV) sulphide, molybdenum disulphide (MoS_2), molybdenum sulphide, molybdenum (IV) selenide, molybdenum selenide, tungsten (IV) sulphide, tungsten disulphide, tungsten sulphide, graphite, or boron nitride; and b) about 3% (w/w) to about 55% (w/w) of at least one of polytetrafluoroethylene (PTFE), perfluoroalkoxy (PFA), ethylene-tetrafluoroethylene copolymers (ETFE), fluorinated ethylene propylene copolymer (FEP), PTFE-S dry lubricant, polychlorotrifluoroethylene (PCTFE), or polyethylene.

[0058] In other embodiments, the compositions can comprise about 62% (w/w) to about 94% (w/w) of the compounds of a) and about 6% (w/w) to about 38% (w/w) of the compounds of b); about 75% (w/w) to about 85% (w/w) of the compounds of a) and about 15% (w/w) to about 25% (w/w) of the compounds of b).

[0059] In certain embodiments, the compositions can comprise molybdenum disulfide (MoS_2) and polytetrafluroralethylene (PTFE), for example about 62% (w/w) to about 85% (w/w) MoS_2 and about 15% (w/w) to about 38% (w/w) of PTFE, or consist essentially of about 75% (w/w) to about 78% (w/w) MoS_2 and about 22% (w/w) to about 25% (w/w) of PTFE, or about 76.92% (w/w) MoS_2 and about 23.08% (w/w) PTFE. The MoS_2 can be technical grade MoS_2 and the PTFE can be in resin form. In certain embodiments, the lubricating composition has a melting point of about 342° F. to 345° F., a specific gravity of about 2.1 to 2.3, and a density of about 5000-6000 kg/m^{-3}.

[0060] The compositions can also comprise tungsten disulfide (WS_2) and polytetrafluroralethylene (PTFE), for example about 69% (w/w) to about 94% (w/w) WS_2 and about 6% (w/w) to about 31% (w/w) of PTFE, and can consist essentially of about 82% (w/w) to about 85% (w/w) WS_2 and about 15% (w/w) to about 18% (w/w) of PTFE, to about 83.25% (w/w) WS_2 and about 16.75% (w/w) PTFE. Such compositions can, for example, have a melting point of about 1200-1300° F., a specific gravity of about 2.1 to 2.3, and a density of about 7000-8000 kg/m^{-3}.

[0061] In another aspect, the embedding compositions can comprise components particularly suited for anticorrosion and/or anti-wear, such as zinc sulfate heptahydrate, chromium metal powder, tungsten sulfide (WS_2) and zinc sulfide heptahydrate. As can be seen, such compounds can also have good lubricity properties as well.

[0062] In certain embodiments, such compositions comprise zinc sulfate heptahydrate in powder form and chromium metal in powder form. The zinc sulfate can be from about 48% to about 95% (w/w), generally from about 60%

to about 92%, typically from about 75% to about 85%, and in certain embodiments, about 80% or even about 82.48%. The chromium can be from about 5% to about 92% (w/w), generally from about 8% to about 52%, typically from about 15% to about 25%, and in certain embodiments, about 17-18% or even about 17.52%. In some embodiments, the zinc sulfate/chromium composition has a melting point of about 212° F. and a density of about 1.957 g/c^{-3}.

[0063] In other embodiments, such compositions comprise tungsten sulfide (WS_2) and zinc sulfide heptahydrate, and a small amount of PTFE resin, which appears to reduce clumping. The WS_2 can be from about 60% to about 98% (w/w), generally from about 62% to about 91%, typically from about 75% to about 88%, and in certain embodiments, about 80% to about 88% or even about 85%. The zinc sulfide heptahydrate can be from about 2% to about 40% (w/w), generally from about 5% to about 30%, typically from about 10% to about 20%, and in certain embodiments, about 13-18% or even about 15%. In some embodiments, the WS_2/zinc sulfide heptahydrate composition has a melting point of about 212° F. and a density of about 1.957 g/c^{-3}.

[0064] Other forms of PTFE, MoS_2, PFA, etc., such as dry, powder, liquid, etc., can also be used.

[0065] The lubricating, etc., compositions, such as but not limited to those above, can be combined into embedding compositions suitable for embedding a lubricant into a substrate. Such embedding compositions can comprise a) bombardment particles, b) at least one of a suitable primary lubricant such as a metallic dry lubricant, graphite or boron nitride, and c) a suitable secondary lubricant such as a polymeric lubricant. In some embodiments, individual lubricants can be embedded into the substrate.

[0066] In some embodiments, the composition comprises a) at least about 75% (w/w) of the shot peening media, b) at least about 1% (w/w) of the at least one metallic dry lubricant, graphite or boron nitride, and c) at least about 0.3% (w/w) of the polymeric lubricant. In other embodiments, the composition comprises a) about 80% (w/w) to about 98% (w/w) of the shot peening media, b) about 1% (w/w) to about 15% (w/w) of the at least one metallic dry lubricant, graphite or boron nitride, and c) about 0.4% (w/w) to about 5% (w/w) of the polymeric lubricant, and in still some further embodiment, the composition consists essentially of a) about 85% (w/w) to about 98% (w/w) of the shot peening media, b) about 1.5% (w/w) to about 13% (w/w) of the at least one metallic dry lubricant, graphite or boron nitride, and c) about 0.4% (w/w) to about 4% (w/w) of the polymeric lubricant.

[0067] The bombardment particles can be at least one of stainless steel shot, aluminum shot, corn cob, steel cut wire, ceramic, glass bead, aluminum oxide, silicon carbide, walnut shell, pecan shell, steel grit, soda bicarbonate, crushed glass, plastic, iron grit, slag, or diamond grit; in some embodiments, fine glass beads are preferred. In some embodiments, the bombardment particles consist essentially of substantially spherical fine glass beads having a hardness of about 500-550 (Knoop), a compressive strength of about 33,000-39,000 psi (avg.), a density of about 2-3 gm/cc, a specific gravity of about 2.3 to 2.6, a US sieve of about 10 to 400, and a diameter of about 20-1000 μm, while in other embodiments the bombardment particles consist essentially of substantially spherical fine glass beads having a hardness of about 515 (Knoop), a compressive strength of about 36,000 psi (avg.), a density of about 2.5 gm/cc, a specific gravity of about 2.45 to 2.50, a US sieve of about 20 to 325, and a diameter of about 45-850 μm.

[0068] In still further embodiments, the present innovation provides embedment compositions comprising a solid substrate, combined with the lubricants, etc., discussed herein wherein the lubricant composition is embedded in the solid substrate. In these embodiments, the solid substrate is selected from the group consisting of metal, ceramic, glass, plastic and wood. The metal can be alloy steel, aluminum, carbon steel, stainless steel, titanium, tool steel, brass and brass alloy.

[0069] Some exemplary metals include the following:

[0070] Alloy Steels

[0071] 4130 Chrome Moly Carbon content 0.30%

[0072] 4140 Carbon content 0.30%

[0073] 4330 Cr, Ni, Mo Carbon content 0.30%

[0074] 4340 Carbon content 0.30%

[0075] 5160

[0076] 52100

[0077] 6150

[0078] 8620

[0079] D6AC Carbon content 0.42-0.48% Low alloy

[0080] HY80

[0081] Maraging 300/Vasco Max 300™

[0082] Aluminum

[0083] 1060-H 16 or H 18

[0084] 2011

[0085] 2014

[0086] 2017 T4 temper

[0087] 2018 T4 temper

[0088] 2024

[0089] 2036

[0090] 2117

[0091] 2219

[0092] 2618

[0093] 3003. AKA: Tread-Brite™

[0094] 3004

[0095] 3105

[0096] 4032

[0097] 5005

[0098] 5052

[0099] 5086. H34

[0100] 5086. H36

[0101] 5086. H38

[0102] 5657

[0103] 6061. T6 and T4 tempers

[0104] 6262

[0105] 7050

[0106] 7178

[0107] AL 850

[0108] 6020. AKA: Ultra Alloy X6062™

[0109] Carbon Steels

[0110] 1010

[0111] 1018

[0112] 1020

[0113] 1022

[0114] 1030

[0115] 1040

[0116] 1045

[0117] 1075

[0118] 1118

[0119] 1140

[0120] A105

[0121] A283

[0122] A333. Grade 3

[0123] A512. AKA: Rystar 512

[0124] Stainless Steels

[0125] 13-8

[0126] 15-5

[0127] 15-7

[0128] 17-4

[0129] 17-7

[0130] 201

[0131] 203 EZ

[0132] 2304

[0133] 301

[0134] 302

[0135] 303

[0136] 303 YM

[0137] 304

[0138] 309

[0139] 309 S

[0140] 310

[0141] 310 S

[0142] 316

[0143] 316 L

[0144] 317

[0145] 317 L

[0146] 317 CM

[0147] 3R12

[0148] 409

[0149] 410

[0150] 416

[0151] 420

[0152] 420 F

[0153] 440 A

[0154] 440 B

[0155] 440 C

[0156] 440 F

[0157] Titanium

[0158] 15-3

[0159] 3-2.5

[0160] 6-4

[0161] T-1

[0162] T-2

[0163] T-4

[0164] Tool Steels

[0165] L6 tool steel

[0166] M41

[0167] M4

[0168] M7

[0169] Brass and Brass Alloys

[0170] Red Brass C230

[0171] Yellow Brass C286

[0172] Tellurium Copper C145

[0173] C 745

[0174] C 67400

[0175] Mg Alloy AZ31B

[0176] The methods, systems, etc., herein can be performed manually or automatically or combinations thereof. Accordingly, the present innovations include computer implemented programming that controls and directs such methods, systems, etc., and can include sensors, detectors, imaging systems, etc., to confirm the operability of the various components of the systems, such as the fullness level and operation of the storage hopper, the feed lines, the spray nozzle or other ports, as well as the effectiveness, completeness, etc., of the actual creation of the embedding and/or embedment compositions, the thoroughness with which a substrate has been converted to the embedment composition, etc.

[0177] In other aspects, the present discussion includes methods of making the various compositions, devices, systems, etc., herein, including putting together the various pieces of the systems, embedding the embedding compositions into the substrates, etc. In other aspects, the present discussion includes methods of using the various compositions, devices, systems, etc., herein, including using the various pieces of the systems, or the put-together systems to make the embedment compositions. Methods of using can also comprise using the embedment compositions in working situations such as using substrates comprising the embedment compositions to make further products, such as using embedment-composition-containing substrate to make engines or axles, or using such embedment compositions to reduce friction or improve corrosion resistance, etc.

[0178] The present innovations also include computers containing such computer-implemented programming, and related automated components. A "computer" is a device that is capable of controlling a mixer, bombardment device or cabinet, processor or the like, or other elements of the apparatus and methods discussed herein. For example, the computer can control the software discussed herein that determines the length of time a target part is bombarded or the type of lubricant or embedding composition, the psi of the bombardment, etc. Typically, a computer comprises a central processing unit (CPU) or other logic-implementation device, for example a stand alone computer such as a desk top or laptop computer, a computer with peripherals, a handheld, a local or internet network, etc. Computers are well known and selection of a desirable computer for a particular aspect or feature is within the scope of a skilled person in view of the present disclosure.

[0179] All terms used herein are used in accordance with their ordinary meanings unless the context or definition clearly indicates otherwise. Also unless expressly indicated otherwise, the use of "or" includes "and" and vice-versa. Non-limiting terms are not to be construed as limiting unless expressly stated, or the context clearly indicates, otherwise (for example, "including,""having," and "comprising" typically indicate "including without limitation"). Singular forms, including in the claims, such as "a,""an," and "the" include the plural reference unless expressly stated, or the context clearly indicates, otherwise.

[0180] The scope of the present systems and methods, etc., includes both means plus function and step plus function concepts. However, the terms set forth in this application are not to be interpreted in the claims as indicating a "means plus function" relationship unless the word "means" is specifically recited in a claim, and are to be interpreted in the claims as indicating a "means plus function" relationship where the word "means" is specifically recited in a claim. Similarly, the terms set forth in this application are not to be interpreted in method or process claims as indicating a "step plus function" relationship unless the word "step" is specifically recited in the claims, and are to be interpreted in the claims as indicating a "step plus function" relationship where the word "step" is specifically recited in a claim.

EXAMPLES

Example 1

[0181] Summary:

[0182] A dynamometer test was performed on a Chevy 454 engine. The following particular components were treated with the embedment processes discussed herein: cam shaft, wrist pin, rocker arms, lifters, piston rings, and oil pump. The parts were treated with an embedding composition of 65% MoS_2 and 35% PTFE combined with a cast stainless steel shot SS120 specification. Each piece was processed at a 70 to 90 degree angle and an about 3 inch distance from the spray nozzle at 90 PSI. Process time was 30 to 45 seconds for each surface area. A secondary sweep of the parts was performed at a 45 degree angle for 15 sec at 90 PSI for finishing effects. The primary metric for the test was engine torque (ft-lbs.). Horse power is a calculation based on torque output. Hp=(torque×rpm)/5250.

[0183] Engine torque was 5% higher than the baseline. Some observations during the test were cooler oil operating temperature, cool to the touch rocker arms, and higher torque.

[0184] Results:

[0185] After an initial warm up break-in period, which had numerous full throttle cycles to seat the piston rings to the cylinder wall, the valve covers were removed for internal rocker arm inspection. The warm up or "break in period" was part of the testing procedure and lasted approx. 20 mins. The remainder of the test comprised approx. 2 hours of constant running with various rpm ranges, from 2500 to 5500 rpm. The rocker arms were cool enough to touch, which was highly unusual and never previously experienced by the particular testers during such a test procedure. Valve covers were reinstalled and test was resumed. During the test cycle the engine oil temperature did not exceed 138° F. as compared to a normal baseline (control) of 150° F. The engine was also generating more power than baseline (control) results.

[0186] Numerous data sweep collections were performed during the test for accurate and consistent data recovery. It is believed that the results would have been even more significant had oil with a lower viscosity been used. The fact that the oil temperature was running much lower than baseline caused it to be more viscous leading to more drag losses. Therefore the use of lower weight oil would have produced more torque and horsepower. However even with these factors there was a total increase in torque/horsepower of 5%. The engine was running at a cooler temperature than normal baseline, which indicates that there are less friction conditions, and it was generating more power and the cooler running condition would lend itself to less fuel consumption and greater longevity. **FIGS. 15-17** depict graphs containing the results discussed in this Example.

Example 2

[0187] Summary:

[0188] A camshaft and lifter components were embedment treated in the same manner as the parts in Example 1. The test included a comparison of standard non-treated cam lobes and lifters in various combinations with treated cam lobes and lifters. The treated and non-treated parts were subjected to a consistent simulated engine speed with a significant pressure applied to the lifter in contact with the cam lobe. After a designated warm up period with standard pressures applied to each lifter, a predetermined extreme load was placed on the lifter. The cam lobe and lifter were run to failure. It was found that when at least the cam lobe, or both the cam lobe and lifter, were treated with the embedment process they lasted until the end of the test, which was about 90% longer than other combinations of treated or non-treated components.

[0189] Test Methods:

[0190] There were two series of test runs for the purpose of comparison. The first series included a 16 lobe camshaft and four lifters in contact with lobes numbers 1, 5, 9, and 13. The camshaft was exposed to a standard shot peening preparation just prior to being treated with the embedment process. It should be noted that this shot peening preparation is standard to the industry and was consistent with those cam shafts currently sold in the market. Lobes 1 through 8 were left untreated. Lobes 9 through 16 were treated with the embedment process. Lifters numbered 1 and 13 were left untreated. Lifters numbered 5 and 9 were treated with the embedment process. Lifters numbered 1 and 5 were paired with untreated cam lobes. Lifters numbered 9 and 13 were paired with a embedment treated lobe.

[0191] The test began with a warm up period. The cam/lifter set up was run at 6000 RPM for approximately 30 minutes with 270 pounds of pressure applied to the lifters. Immediately after the initial 30 minute break in period the apparatus was run an additional 30 minutes with 400 pounds of pressure applied to the lifters. This warm up phase is considered a standard in the industry with regard to cam shaft and lifter analysis.

[0192] After the initial warm up period the apparatus was maintained at 6000 RPM, and 530 pounds of pressure was applied to each of the four lifters against the cam lobes. Position number one, which had an untreated cam lobe and an untreated lifter, ran 10 minutes before failure. Position number five, which had an untreated cam lobe and a treated lifter, ran 5 minutes before failure. Position number nine, which had a treated cam lobe and a treated lifter, ran 120 minutes without failure. Position number thirteen, which had a treated cam lobe and an untreated lifter, ran 120 minutes without failure. Table 1 below shows some results of this testing:

TABLE 1

Test Series 1 ("UT" = untreated; "TR" = treated)								
Break In 600	30 Minutes at 270 pressure 30 Minutes at 400 pressure Lobe UT							
rpm:	#1	#2	#3	#4	#5	#6	#7	#8
Lifter UT	X							
Lifter TR					X			
R.P.M.	6000				6000			
Time at failu?	10 min.				5 min.			
Lbs. Pres	530				530			
	Lobe TR							
	#9	#10	#11	#12	#13	#14	#15	#16
Lifter UT					X			
Lifter TR	X							
R.P.M.	6000				6000			
Time at failu?	120 min.				120 min.			
Lbs. Pres	530				530			

? indicates text missing or illegible when filed

[0193] **FIG. 18** is a graph containing results discussed above in this Example.

[0194] A second series of tests included a 16 lobe cam shaft and eight lifters in contact with lobes numbers 1, 3, 5, 7, 9, 11, 13, and 15. The cam shaft was exposed to a standard shot peening preparation just prior to being treated with the embedment process. It should be noted that this shot peening preparation is standard to the industry and was consistent with those cam shafts currently sold in the market. Lobes 1 through 8 were left untreated. Lobes 9 through 16 were treated with the embedment process. Lifters numbered 1, 3, 13, and fifteen were left untreated. Lifters numbered 5, 7, 9, and 11 were treated with the embedment process. Lifters numbered 1, 3, 5, and 7 were paired with untreated cam lobes. Lifters numbered 9, 11, 13, and 15 were paired with a embedment treated lobe.

[0195] The test began with a warm up period. The cam/lifter set up was run at 7000 RPM for approximately 30 minutes with 270 pounds of pressure applied to the lifters. Immediately after the initial 30 minute break in period the apparatus was run an additional 30 minutes with 400 pounds of pressure applied to the lifters. This warm up phase is considered a standard in the industry with regard to cam shaft and lifter analysis.

[0196] After the initial warm up period the apparatus maintained 7000 RPM and 600 pounds of pressure was applied to each of the eight lifters against the cam lobes. Position number 1, which had an untreated cam lobe and an untreated lifter, ran 10 minutes before failure. Position number 3, which had an untreated cam lobe and an untreated lifter, ran 10 minutes before failure. Position number 5, which had an untreated cam lobe and a treated lifter, ran 5 minutes before failure. Position number 7, which had an untreated cam lobe and a treated lifter, ran 5 minutes before failure. This is also consistent with pin on disk data.

[0197] Position number 9, which had a treated cam lobe and a treated lifter, ran 120 minutes without failure. Position number 11, which had a treated cam lobe and a treated lifter, ran 120 minutes without failure. Position number 13, which had a treated cam lobe and an untreated lifter, ran 120 minutes without failure. Position number 15, which had a treated cam lobe and an untreated lifter, ran 120 minutes without failure. Table 2 below shows some results of this testing:

TABLE 2

Test Series 2 ("UT" = untreated; "TR" = treated)

Break In 700	30 Minutes at 270 pressure 30 Minutes at 400 pressure Lobe UT							
rpm:	#1	#2	#3	#4	#5	#6	#7	#8
Lifter UT	X		X					
Lifter TR					X		X	
R.P.M.	7000		7000		7000		7000	
Time at failu(?)	10 min.		10 min		5 min.		5 min	
Lbs. Pres	600		600		600		600	
	Lobe TR							
	#9	#10	#11	#12	#13	#14	#15	#16
Lifter UT					X		X	
Lifter TR	X		X					
R.P.M.	7000		7000		7000		7000	
Time at failu(?)	120 min.		120 min		120 min.		120 mi	
Lbs. Pres	600		600		600		(?)00	

(?) indicates text missing or illegible when filed

[0198] **FIG. 19** is a graph containing results discussed above in this Example.

[0199] Discussion:

[0200] The embedment process applied to the cam shaft and lifters comprises a chemical mixture applied to the surface of the metal via a pressurized stream of particulate which acts as a catalyst to create the chemical reaction used in the treatment of the metal. The embedment process alters the surface of the substrate creating an amorphous surface with increased lubricating properties. It should also be noted that prior to treatment with the embedment process, the cam shafts were subjected to shot peening treatment. This is considered a standard process in the industry. While bombardment is part of the delivery system for the embedment process, the prompt failure of the untreated cam lobes and lifters indicate superior results of the embedment process versus normal shot peening.

[0201] This test is considered to be a good measure of durability for the cam shaft and lifter mechanism. Typically the amount of pressure applied on the lifter to the cam lobe in the average engine is between 100 and 150 pounds. The application of 530 to 600 pounds of pressure run at a high RPM will exceed the typical real world scenario.

[0202] As outlined in the test methodology, it was noted that when the cam lobe was treated with the embedment process the cam and lifter combination would last significantly longer than that of the untreated cam lobe. It should be noted that this test was run only 120 minutes prior to being discontinued. The treated components may have run longer.

[0203] While the untreated cam lobe and lifter combination failed rapidly it is noted that a similar result was found with the treated lifter combined with an untreated cam lobe. Contrary to this was the findings that an untreated lifter with a treated cam lobe gave the same results as that of a treated cam lobe and treated lifter combination. The results indicate that the treatment of the larger surface area of the cam lobe versus the smaller contact area of the lifter enhances durability and performance.

Example 3

[0204] Several metallurgical samples were run utilizing a Pin-on-Disk tribo apparatus. Each sample was prepared according to ASTM standards. In pin-on-disk tribometry, a flat, a pin or a sphere is loaded onto the test sample with a precisely known weight. The pin is mounted on a stiff lever, designed as a frictionless force transducer. The deflection of the highly stiff elastic arm, without parasitic friction, insures a nearly fixed contact point and thus a stable position in the friction track. The friction coefficient is determined during the test by measuring the deflection of the elastic arm. Wear coefficients for the pin and disk material are calculated from the volume of material lost during the test. This simple method facilitates the study of friction and wear behavior of almost every solid state material combination with or without lubricant. Furthermore, the control of the test parameters such as speed, frequency, contact pressure and varying time, and the environmental parameters, temperature, humidity and lubrication allow a close reproduction to the real life conditions of practical wear situations.

[0205] This test was set up to compare data from metallurgical samples of 316 stainless steel with and without embedment treatment that was the same as in Example 1. The data compared deflection of the elastic arm and over a period of time and the volume of material from the pin and disk lost during the test. Each test was set up with a substantial load of 35 N on the pin point tip. The tip was set at a fixed position while the sample was set into rotation at a speed of 25.00 cm/s with a radius of 4.99 mm.

[0206] The first set of samples was run without the embedment application to establish a base parameter of readings. These samples exhibited a minimum coefficient of friction of −0.168 and a maximum coefficient of friction of 1.197. The mean average coefficient of friction was 0.491.

[0207] The second set of samples was run with the embedment application incorporated into the substrate material. These samples exhibited a minimum coefficient of friction of −0.032 and a maximum coefficient of friction of 1.220. The mean average coefficient of friction was 0.294.

[0208] A comparison of the data indicates that under similar conditions the embedment application when applied to the substrate surface lowered the coefficient of friction by 59.877% when compared to the base readings taken on the samples without the embedment application under similar conditions.

[0209] **FIGS. 20-21** are graphs depicting results discussed above in this Example.

Example 4

[0210] Several metallurgical samples were run utilizing a linear tribo apparatus. Each sample was prepared according to ASTM standards. The Linear Tribometer reproduces the reciprocating motion typical of many real world mechanisms. Including calculating a friction coefficient for both forward and backward movements of the stroke, generating data on Hertzian pressure via its software package, and static partner and sample wear rates. The reciprocating technique is also very useful for studying the variation over time of the static coefficient of friction—as opposed to the kinetic coefficient measured with the Pin-on-Disk geometry. The maximum load is 46 N at frequencies up to 8 Hz (25 Hz optional) with a stroke range up to 60 mm.

[0211] This test was set up to compare data from metallurgical samples of 316 stainless steel with the embedment application, against samples without treatment. The data compares wear rates over a period of time. Each test was set up with a substantial load of 35 N on a pin point tip in order to maximize ware rates over time. The tip was set into a linear motion with an amplitude of 9.98 mm with a maximum linear speed of 15 cm/s.

[0212] The first set of samples was treated with the embedding application that was the same as in Example 1, and run under the fore-mentioned parameters. These samples showed an average failure rate of 573 sec under a 15 minute run duration.

[0213] The second set of samples without the embedding application was run under the same parameters. These samples showed an average failure rate of 145.8 sec under a 15 minute run duration.

[0214] A comparison of samples shows that the embedment application when applied to the surface ran 0.77.554% longer than the samples without the embedment application under simulated conditions.

[0215] **FIGS. 22-23** are graphs depicting results discussed above in this Example.

Example 1

[0216] Scratch-testing with a Micro Scratch Test apparatus is a comprehensive method of quantifying the adhesion properties of a wide range of coatings. The technique involves generating a controlled scratch with a diamond tip on the sample under test. The tip, for example a Rockwell C diamond or a sharp metal tip, is drawn across the coated surface under either a constant or progressive load. At a certain critical load the coating will start to fail. The critical loads are detected very precisely by means of an acoustic sensor attached to the indenter holder, the frictional force, penetration depth and by optical microscopy. Once known, the critical loads are used to quantify the adhesive properties of different film—substrate combinations. These parameters constitute a unique signature of the coating system under test. The data is acquired by a Pentium with real-time display of all the information.

[0217] An initial sample with the embedment application was set up for a progressive linear scratch. The test started with a beginning load of 30 mN increasing to an end load of 20,000 mN. The load rate was set at 40054.44 mN/min. The indenter consisted of a Rockwell diamond with a radius of 20 μm. Complete delamination of the embedment application was found at a penetration depth of 67.85 μm and a load of 19,987.75 mN. This indicates very good adhesion properties of the embedment application.

[0218] The same sample was subjected to a constant scratch test at a load maintained at 2,000 mN. The "Y" coordinates were adjusted to 12.205 mm. The AESensitivity was set at level 9 with a drag speed of 5.22 mm/min. A similar indenter was utilized, consisting of a Rockwell diamond with a radius of 20 (1J.In). The coefficient of friction measured between 0.20 and 0.78 with a mean of 0.58. The normal force of 2.000 mN remained constant throughout the duration of the test. While surface roughness was a factor in coefficient of friction variations, the overall procedure showed consistent uniformity of the substrate surface.

[0219] **FIGS. 24-29** are graphs and pictures depicting testing parameters and results discussed above in this Example.

[0220] From the foregoing, it will be appreciated that, although specific embodiments have been discussed herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the discussion herein. Accordingly, the systems and methods, etc., include such modifications as well as all permutations and combinations of the subject matter set forth herein and are not limited except as by the appended claims.

1. A lubricant composition suitable for embedding into a substrate, the composition comprising a) about 55% (w/w) to about 99% (w/w) of at least one of molybdenum (IV) sulphide, molybdenum disulphide (MoS_2), molybdenum sulphide, molybdenum (IV) selenide, molybdenum selenide, tungsten (IV) sulphide, tungsten disulphide, tungsten sulphide, graphite, or boron nitride; and b) about 3% (w/w) to about 55% (w/w) of at least one of polytetrafluoroethylene (PTFE), perfluoroalkoxy (PFA), ethylene-tetrafluoroethylene copolymers (ETFE), fluorinated ethylene propylene copolymer (FEP), PTFE-S dry lubricant, polychlorotrifluoroethylene (PCTFE), or polyethylene.

2. The composition of claim 1 wherein the composition comprises about 62% (w/w) to about 94% (w/w) of at least one of the compounds of a) and about 6% (w/w) to about 38% (w/w) of at least one of the compounds of b).

3. The composition of claim 1 wherein the composition comprises about 75% (w/w) to about 85% (w/w) of at least one of the compounds of a) and about 15% (w/w) to about 25% (w/w) of at least one of the compounds of b).

4. The composition of claim 1 wherein the composition comprises molybdenum disulfide (MoS_2) and polytetrafluroralethylene (PTFE).

5. The composition of claim 4 wherein the composition comprises about 62% (w/w) to about 85% (w/w) MoS_2 and about 15% (w/w) to about 38% (w/w) of PTFE.

6-8. (canceled)

9. The composition of wherein the composition has a melting point of about 342° F. to 345° F., a specific gravity of about 2.1 to 2.3, and a density of about 5000-6000 kg/m^{-3}.

10. The composition of claim 1 wherein the composition comprises tungsten disulfide (WS_2) and polytetrafluroralethylene (PTFE).

11. The composition of claim 10 wherein the composition comprises about 69% (w/w) to about 94% (w/w) WS_2 and about 6% (w/w) to about 31% (w/w) of PTFE.

12-13. (canceled)

14. The composition of claim 10 wherein the PTFE is in resin form.

15. The composition of claim 10 wherein the composition has a melting point of about 1200-1300° F., a specific gravity of about 2.1 to 2.3, and a density of about 7000-8000 kg/m^{-3}.

16. An embedding composition suitable for embedding a lubricant into a substrate, the composition comprising a) a bombardment particles, b) at least one of a metallic dry lubricant, graphite or boron nitride, and c) a polymeric lubricant.

17. The composition of claim 16 wherein the composition comprises a) at least about 75% (w/w) of the shot peening media, b) at least about 1% (w/w) of the at least one metallic dry lubricant, graphite or boron nitride, and c) at least about 0.3% (w/w) of the polymeric lubricant.

18. The composition of claim 16 wherein the composition comprises a) about 80% (w/w) to about 98% (w/w) of the shot peening media, b) about 1% (w/w) to about 15% (w/w) of the at least one metallic dry lubricant, graphite or boron nitride, and c) about 0.4% (w/w) to about 5% (w/w) of the polymeric lubricant.

19. The composition of claim 16 wherein the composition consists essentially of a) about 85% (w/w) to about 98% (w/w) of the shot peening media, b) about 1.5% (w/w) to about 13% (w/w) of the at least one metallic dry lubricant, graphite or boron nitride, and c) about 0.4% (w/w) to about 4% (w/w) of the polymeric lubricant.

20. The composition of claim 16 wherein the relative ratio of the b) at least one of metallic dry lubricant, graphite or boron nitride to the c) polymeric lubricant comprises:

b) about 55% (w/w) to about 99% (w/w) of at least one of molybdenum (IV) sulphide, molybdenum disulphide (MoS_2), molybdenum sulphide, MoSe, tungsten (IV) sulphide, tungsten disulphide, tungsten sulphide, graphite, or boron nitride; to

c) about 3% (w/w) to about 55% (w/w) of at least one of polytetrafluoroethylene (PTFE), perfluoroalkoxy (PFA), ethylene-tetrafluoroethylene copolymers (ETFE), fluorinated ethylene propylene copolymer (FEP), Teflon®-S Dry Lubricant, polychlorotrifluoroethylene (PCTFE), or polyethylene.

21. The composition of claim 20 wherein the composition comprises about 62% (w/w) to about 94% (w/w) of at least one of the compounds of b) and about 6% (w/w) to about 38% (w/w) of at least one of the compounds of c).

22. (canceled)

23. The composition of claim 20 wherein the composition comprises molybdenum disulfide (MoS_2) and polytetrafluroralethylene (PTFE).

24. The composition of claim 23 wherein the composition comprises about 62% (w/w) to about 85% (w/w) MoS_2 and about 15% (w/w) to about 38% (w/w) of PTFE.

25-26. (canceled)

27. The composition of claim 23 wherein the MoS_2 is technical grade MoS_2 and the PTFE is in resin form.

28. The composition of claim 23 wherein the b) and c) portions of the composition have a composition melting point of about 342° F. to 345° F., a specific gravity of about 2.1 to 2.3, and a density of about 5000-6000 kg/m^{-3}.

29. The composition of claim 20 wherein the composition comprises tungsten disulfide (WS_2) and polytetrafluroralethylene (PTFE).

30. The composition of claim 29 wherein the composition comprises about 69% (w/w) to about 94% (w/w) WS_2 and about 6% (w/w) to about 31% (w/w) of PTFE.

31-32. (canceled)

33. The composition of claim 29 wherein the PTFE is in resin form.

34. The composition of claim 29 the b) and c) portions of the composition have a composition melting point of about 1200-1300° F., a specific gravity of about 2.1 to 2.3, and a density of about 7000-8000 kg/m^{-3}.

35. The composition of claim 16 wherein the bombardment particles comprises at least one of stainless steel shot, aluminum shot, corn cob, steel cut wire, ceramic, glass bead, aluminum oxide, silicon carbide, walnut shell, pecan shell, steel grit, soda bicarbonate, crushed glass, plastic, iron grit, slag, or diamond grit.

36. The composition of claim 35 wherein the bombardment particles comprises fine glass beads.

37-38. (canceled)

39. An embedment composition comprising a) a solid substrate, b) at least one of a metallic dry lubricant, graphite or boron nitride, and c) a polymeric lubricant, wherein the b) at least one metallic dry lubricant, graphite or boron nitride, and the c) polymeric lubricant are configured together as a lubricant composition and the lubricant composition is embedded in the a) solid substrate.

40. The composition of claim 39 wherein the solid substrate is selected from the group consisting of metal, ceramic, glass, plastic and wood.

41. The composition of claim 40 wherein the substrate is metal selected from the group consisting of alloy steel, aluminum, carbon steel, stainless steel, titanium, tool steel, brass and brass alloy.

42. The composition of claim 41 wherein the metal comprises at least one of Alloy Steels: 4130 Chrome Moly

Carbon content 0.30%, 4140 Carbon content 0.30%, 4330 Cr, Ni, Mo Carbon content 0.30%, 4340 Carbon content 0.30%, 5160, 52100, 6150, 8620, D6AC Carbon content 0.42-0.48% Low alloy, HY80, Maraging 300/Vasco Max 300™, Aluminum: 1060-H 16 or H 18, 2011, 2014, 2017 T4 temper, 2018 T4 temper, 2024, 2036, 2117, 2219, 2618, 3003, AKA: Tread-Brite™, 3004, 3105, 4032, 5005, 5052, 5086, H34, 5086, H36, 5086, H38, 5657, 6061, T6 and T4 tempers, 6262, 7050, 7178, AL 850, 6020, AKA: Ultra Alloy X6062™, Carbon Steels: 1010, 1018, 1020, 1022, 1030, 1040, 1045, 1075, 1118, 1140, A105, A283, A333, Grade 3, A512, AKA: Rystar 512, Stainless Steels: 13-8, 15-5, 15-7, 17-4, 17-7, 201, 203 EZ, 2304, 301, 302, 303, 303 YM, 304, 309, 309 S, 310, 310 S, 316, 316 L, 317, 317 L, 317 CM, 3R12, 409, 410, 416, 420, 420 F, 440 A, 440 B, 440 C, 440 F, Titanium: 15-3, 3-2.5, 6-4, T-1, T-2, T-4, Tool Steels: L6 tool steel, M41, M4, M7, Brass and Brass Alloys: Red Brass C230, Yellow Brass C286, Tellurium Copper 535, C 745, C 67400, or Mg Alloy AZ31B.

43. The composition of claim 40 wherein the relative ratio of the b) at least one of metallic dry lubricant, graphite or boron nitride to the c) polymeric lubricant comprises:

b) about 55% (w/w) to about 99% (w/w) of at least one of molybdenum (IV) sulphide, molybdenum disulphide (MoS_2), molybdenum sulphide, MoSe, tungsten (IV) sulphide, tungsten disulphide, tungsten sulphide, graphite, or boron nitride; to

c) about 3% (w/w) to about 55% (w/w) of at least one of polytetrafluoroethylene (PTFE), perfluoroalkoxy (PFA), ethylene-tetrafluoroethylene copolymers (ETFE), fluorinated ethylene propylene copolymer (FEP), Teflon®-S Dry Lubricant, polychlorotrifluoroethylene (PCTFE), or polyethylene.

44. The composition of claim 43 wherein the composition comprises about 62% (w/w) to about 94% (w/w) of at least one of the compounds of b) and about 6% (w/w) to about 38% (w/w) of at least one of the compounds of c).

45. The composition of claim 43 wherein the composition comprises about 75% (w/w) to about 85% (w/w) of at least one of the compounds of b) and about 15% (w/w) to about 25% (w/w) of at least one of the compounds of c).

46. The composition of claim 43 wherein the composition comprises molybdenum disulfide (MoS_2) and polytetrafluroralethylene (PTFE).

47. The composition of claim 46 wherein the composition comprises about 62% (w/w) to about 85% (w/w) MoS_2 and about 15% (w/w) to about 38% (w/w) of PTFE.

48. (canceled)

49. The composition of claim 47 wherein the composition consists essentially of about 76.92% (w/w) MoS_2 and about 23.08% (w/w) PTFE.

50. The composition of claim 46 wherein the MoS_2 is technical grade MoS_2 and the PTFE is in resin form.

51. The composition of claim 46 wherein the b) and c) portions of the composition have a composition melting point of about 342° F. to 345° F., a specific gravity of about 2.1 to 2.3, and a density of about 5000-6000 kg/m^{-3}.

52. The composition of claim 43 wherein the composition comprises tungsten sulfide (WS_2) and polytetrafluroralethylene (PTFE).

53. The composition of claim 52 wherein the composition comprises about 69% (w/w) to about 94% (w/w) WS_2 and about 6% (w/w) to about 31% (w/w) of PTFE.

54-55. (canceled)

56. The composition of claim 52 wherein the PTFE is in resin form.

57. The composition of claim 52 the b) and c) portions of the composition have a composition melting point of about 1200-1300° F., a specific gravity of about 2.1 to 2.3, and a density of about 7000-8000 kg/m^{-3}.

58. A composition suitable for embedding into a substrate, the composition comprising a) zinc sulfate heptahydrate from about 48% to about 95% (w/w); and b) chromium from about 5% to about 92% (w/w).

59. A composition suitable for embedding into a substrate, the composition comprising a) tungsten sulfide (WS_2) from about 60% to about 98% (w/w); and b) zinc sulfide heptahydrate from about 2% to about 40% (w/w).

60. The composition of claim 59 wherein the composition further comprises a small amount of PTFE resin.

61. An embedding composition suitable for embedding a lubricant into a substrate, the composition comprising a) a bombardment particles, and b) a lubricant embedding composition configured to provide a lubricating embedment composition in a metal, plastic, ceramic, wood, or glass.

62. An embedding composition suitable for embedding a lubricant into a substrate, the composition comprising a) a bombardment particles, and b) a corrosion-resistant embedding composition configured to provide a corrosion-resistant embedment composition in a metal, plastic, ceramic, wood, or glass.

63. An embedding composition suitable for embedding a lubricant into a substrate, the composition comprising a) a bombardment particles, and b) a wear-resistant embedding composition configured to provide a wear-resistant embedment composition in a metal, plastic, ceramic, wood, or glass.

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