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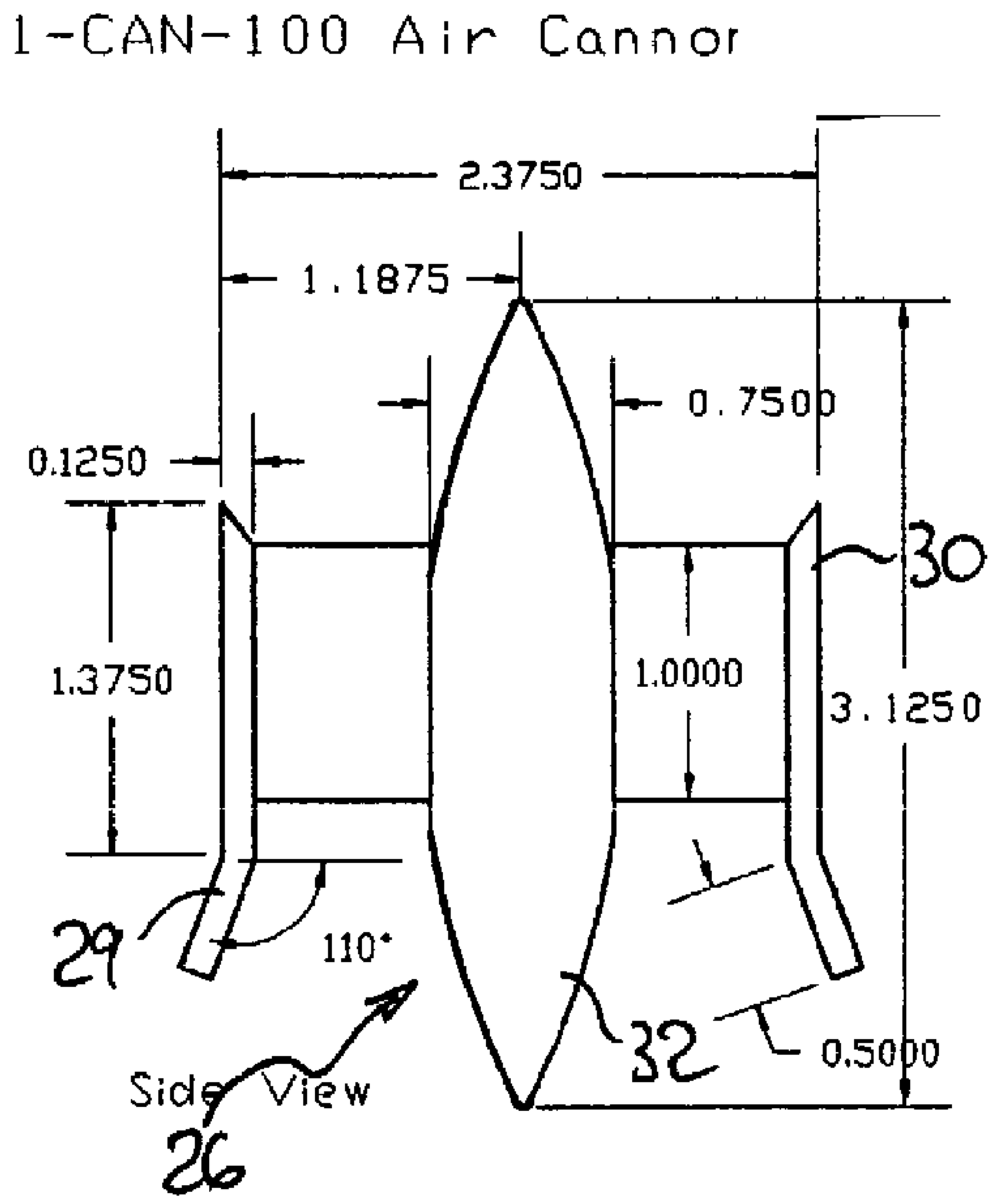
(54) **BUSE D'AERATION POUR PRODUIRE UN JET D'AIR HAUTE INTENSITE ET A GRANDE PORTEE EN UTILISANT DE L'AIR PROPULSE PAR UN VENTILATEUR**

(54) **NOZZLE FOR PRODUCING A HIGH-IMPACT LONG-RANGE JET FROM FAN-BLOWN AIR**




(57) Blow-off nozzles are used for creating a high-energy air blast, for drying metal panels prior to painting. Depth or reach of penetration (in the atmosphere) is important. A bullet is provided in the centre of the nozzle. The bullet is aerodynamically faired, for minimum drag. The effect of the bullet is to create a low pressure area in the jet downstream of the nozzle. The low pressure area serves to hold the jet together, preventing spreading, to a degree that enables a significant increase in penetration distance. The bullet is mounted on faired arms, which are secured to the walls of the nozzle.

Abstract of the Disclosure

Title: NOZZLE FOR PRODUCING A HIGH-IMPACT LONG-RANGE JET FROM FAN-BLOWN AIR

Blow-off nozzles are used for creating a high-energy air blast, for drying metal panels prior to painting. Depth or reach of penetration (in the atmosphere) is important. A bullet is provided in the centre of the nozzle. The bullet is aerodynamically faired, for minimum drag. The effect of the bullet is to create a low pressure area in the jet downstream of the nozzle. The low pressure area serves to hold the jet together, preventing spreading, to a degree that enables a significant increase in penetration distance. The bullet is mounted on faired arms, which are secured to the walls of the nozzle.

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Agent for the Applicant
Docket: 878-11

Title: NOZZLE FOR PRODUCING A HIGH-IMPACT LONG-RANGE JET FROM FAN-BLOWN AIR

This invention relates to apparatus for producing an intense jet of air from a nozzle. The jet of air is used industrially for such purposes as blowing water, dust, particulate material, etc, from surfaces, to clean and dry the surfaces preparatory to painting, application of adhesives, etc.

## BACKGROUND TO THE INVENTION

Conventionally, in automotive component painting applications, for example, blow-off stations are provided between the workpiece washing station and the paint spray booth. The blow-off station includes several air-nozzles, which are fed from a common fan, driven by an electric motor. Typically, the fan supplies air at a flow rate of 2000 cfm or so, and at a pressure of around 1 psi (27" water gauge). The air travels through flexible hoses or pipes to the nozzles, the hoses being, typically, four inches in diameter. The nozzles are mounted on a frame, and are adjustable as to mounting position and angle.

The present invention is aimed at providing a manner of designing the nozzle that enables the jet or stream of air emanating from the nozzle to penetrate further, downstream of the nozzle, for higher surface impact, without incurring a penalty of increased energy requirements.

## THE PRIOR ART

Patent publication US-5,636,795 (Sedgwick, Jun 1997) shows a spray nozzle of the type with which the invention is generally concerned.

It should be noted that the type of blowing-off to which the invention refers is done by air at low pressures. That is to say, the air-flow is generated by means of a air-fan, rather than by means of an air-compressor.

It is of course possible to produce a vigorous jet of air by blowing high pressure air (i.e air from a compressor, at perhaps 80 psi) out of a nozzle. However, it would be highly uneconomical to create the required huge flow rate needed for air blow-off systems using air at 80 psi.

On the other hand, air at 80 psi is widely available as a utility in factories generally, and there are a number of technologies aimed at entraining atmospheric air into a high pressure (80 psi) jet, to allow some of the energy of the high pressure jet to be transferred to the surrounding air, to give the jet the desired volumetric flow rate. However, such systems are only economical because the high pressure air compressor already exists.

Industrial purpose-designed air blow-off systems use a fan that provides the air at low pressures, i.e at pressures in the 0.5 to 2 psi region. In this case, entraining air from the atmosphere into the jet is to be avoided. The invention is concerned with applying as much as possible of the energy derived from the fan into enabling the jet to penetrate more deeply through the atmosphere, and such entrainment would, in the present case, serve simply to dissipate the energy of the jet, and detract from penetration.

## THE INVENTION IN RELATION TO THE PRIOR ART

The invention provides a bullet, which is mounted in position in the centre of the nozzle. The bullet serves, in operation, to create a low pressure area downstream of the nozzle.

It has been found that the low pressure area can be made to extend so far downstream of the nozzle, under the conditions as described herein, as to suck the jet in somewhat, and to hold the jet together. The main reason a jet would fail to penetrate a large distance is that the jet tends to spread or widen, to strike the atmospheric air, and thereby to dissipate its energy. The low pressure area created by the bullet sucks the jet in, and keeps the jet together, for a significantly increased distance. Thus, for example, where a traditional low-pressure air nozzle might enable air to penetrate a maximum of perhaps four feet, the nozzle with the bullet can enable air to penetrate five or even six feet.

Of course, it is always possible to create whatever strength of jet is desired, simply by using a larger power source to pump more air through a nozzle at higher pressure. But the concern in this present case is with the efficiency at which a given strength of jet can be provided. A high pressure jet (as from a conventional factory air compressor) creates such a high velocity in the emerging air as to create a low pressure aura around the jet, which tends to suck in outside air and entrain it in the jet. Thereby, the jet can impart a portion of its energy to the surrounding air. With this entrainment, instead of all the energy of the jet being in the form of high-speed/ low-mass, the energy form of the jet now becomes medium-speed/ medium-mass, which is more useful for doing work. But still, a high-pressure system is inefficient; it is inefficient to create high pressure, then destroy it.

In the Sedgwick patent mentioned above, the emerging jet is given a vigorous spin or rotational velocity. It might be considered that a low pressure area exists on the inside of the emerging jet, because of the cyclone effect arising from the spin. However, it should be noted that a cyclone creates a spinning vortex, with a low pressure area inside, because of the presence of the low pressure; i.e in a cyclone the low pressure core creates the spin, the spin does not create the low pressure core. In Sedgwick, the spin velocity has to be generated, and that takes energy. Also, whatever spin velocity exists will be at its maximum at the outside of the stream, where the stream hits the stationary air. This interaction creates more friction, and wastes more energy. In fact, whatever energy goes into creating the rotation of the cyclone, must take away from the energy available for the forwards penetration of the jet.

It is an aim of the invention that the bullet should create the downstream low pressure area aerodynamically, and thereby cause only a minimum of disruption to the downstream longitudinal penetration energy of the jet.

Nozzles are provided in many types of machine. Placing a bullet in the centre of a nozzle would have a different effect in different types of machine.

In the nozzle system as described herein, lowering the pressure inside the jet has the effect of sucking the jet together. By reaction, the low pressure area creates a force on the bullet tending to draw the bullet downstream, with the jet of air. In a jet engine, for example, the purpose of the nozzle is to convert the energy of the emerging stream of air into thrust for the aircraft, which, it will be understood, is opposite to the purpose of enabling the stream to penetrate as far as possible away from the nozzle.

In a nozzle, air is accelerated up to jet speed by reducing the cross-sectional area through which the air passes. It might be considered that keeping the outside diameter of the nozzle the same as the pipe, and making the bullet so large that the bullet nearly fills the nozzle, would be a way of creating the reduced area which is necessary for accelerating the air. However, the overall or outside dimensions of the jet should be kept small. If the bullet is large, so that the jet becomes a thin annulus, the area of the jet that is exposed to the outside air is correspondingly large, and so, even though the jet might emerge with good energy, the losses associated with the interaction would be also large. Therefore, the bullet should not be so large that the flow through the nozzle came to have a configuration that could be considered annular to a significant degree.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

By way of further explanation of the invention, exemplary embodiments of the invention will now be described with reference to the accompanying drawings, in which:
Fig 1 is a diagrammatic representation of a nozzle under test, in which air passing through the nozzle contains smoke, for visibility;
Fig 2 corresponds to Fig 1, and shows a nozzle that incorporates the invention;
Fig 3 is a cross-section of the nozzle of Fig 2;
Fig 4 is a front elevation of a component of the nozzle of Fig 2;
Fig 5 is a side elevation of the component of Fig 4;

Fig 6 is a pictorial view of the component of Fig 4;
Fig 7 is a pictorial view of the nozzle of Fig 2, in use.

The apparatuses shown in the accompanying drawings and described below are examples which embody the invention. It should be noted that the scope of the invention is defined by the accompanying claims, and not necessarily by specific features of exemplary embodiments.

Figs 1 and 2 illustrate the difference between a conventional air-blow nozzle unit 20 and a nozzle unit 23 that incorporates an internal faired bullet, in accordance with the invention. In both cases the muzzle of the nozzle unit is about 2.5" in diameter and the nozzle unit is supplied from a pipe of about 4" diameter. The difference in the length of forceful penetration of the jets arises because of the presence of the bullet in the nozzle of Fig 2.

Figs 3 and 4 are cross-sections of the nozzle unit 23 of Fig 2. The housing 24 is shaped to converge to a cylindrical nose 25. The housing 24 is formed from aluminum sheet, by spinning the sheet into a tubular form.

The bullet assembly 26 shown in Figs 4,5,6 fits concentrically inside the nose 25, and includes two radial arms 27,28. The arms terminate with bars 29,30. The bullet unit, comprising the bullet 32, the arms 27,28, and the bars 29,30, are formed as a one-piece aluminum casting. The bullet unit is mounted in place in the nose 25 by welding the bars 29,30 to the internal cylindrical wall of the nose 25.

The bullet 32 is of an aerodynamically faired configuration, the shape being so designed as to impart a minimum tendency to cause drag and turbulence in the air flow passing through the nozzle. The designer should take care to cause as little energy as possible to be dissipated in the nozzle; any energy that is dissipated as turbulence in the nozzle takes away from the energy that would otherwise be available for projecting the jet of air toward the work-piece. The designer's aim is to create a low pressure area downstream of the bullet, without creating turbulence.

The radial arms 27,28 are faired also, to minimise any tendency of the arms to create turbulence. However, as shown in Fig 5, the arm 27 is angled in the Fig 5 view. Thus, air passing the arm 27 is given a velocity to the left. The arm 28 is similarly angled, and deflects its stream of air to the right. Thus, the air emerging from the nose 25 has a degree of imparted helical twist or spin. Again, the designer should take care, when imparting the spin to the air flow. not to induce turbulence.

In the type of system as illustrated, air is blasted from the muzzle 33 of the nozzle with a great deal of vigour. Air-flows in the region of 450 cfm are typical. It is the intention that the blast of air should be able to perform useful work four, five, or even six, feet away from the 2.5 inch nozzle.

The presence of the bullet 32 means that the air jet flowing from the nozzle contains a low pressure area 34, downstream of the bullet. (Of course, no such low-pressure area is present in a conventional nozzle, which has no bullet). This low-pressure area gives rise to a suction force tending to draw or hold the jet of air together. The low-pressure area 34 tends to focus the jet, stopping the jet from expanding or spreading; the more the jet can be prevented from spreading, the further the jet can be made to penetrate.

A jet of fast-moving air, as it emerges into, and interacts with, the ambient air, starts to slow down. The outer portions of the jet are retarded first. The molecules of air in the outer portion start to spread out and become dissipated. In other words the molecules of the outer portion start to acquire an outwards or radial component to their velocity. Gradually, as the jet travels further from the nozzle, the whole air stream spreads and becomes dissipated.

The low pressure area 34 provides a force acting on the jet, which tends to stop the jet from spreading laterally. Thus, because of the low-pressure area, the tendency of the outer portions of the jet to acquire an outward velocity is resisted. The air stream is held together by the low-pressure area. Thus the stream remains in focus for a significantly longer distance downstream from the nozzle, and the depth of penetration at which the blast of the air stream can do useful work is thereby increased.

The helical twist imparted to the stream by the angled arms 27,28, tends to make the stream a little more coherent, and is also significant in increasing the depth of penetration of the air stream.

The nozzle unit 23 is provided with a mounting fixture 36, which comprises a short stub-tube 37 welded to the outside of the housing 24. In a typical installation, several of the nozzle units are provided (Fig 7), and directed around the work-piece. Each nozzle unit is adjustable as to the angle at which its jet is directed, and the unit is locked in place by clamping the stub-tube 37 to a fixed frame.

As mentioned, a typical air flow through the nozzle would be around 450 cfm. Such a flow would be supplied in the supply pipe 39 at a pressure of about 1 psi. A one-horsepower electric motor 38 would typically be required to power the fan to supply air at that energy level.

The dimensions of the bullet are important. It might be considered that the bullet should have a large cross-sectional area in relation to the nozzle diameter, in order that the low-pressure region 34 downstream of the bullet might indeed be at low-pressure. It might be considered that, the lower the pressure in the region 34, the more marked the effect the low-pressure region has in preventing the jet from spreading and holding the jet together. However, there is a limit to the pressure reduction that can be achieved in the region 34. If the diameter of the bullet were too large, the air flow would be disrupted downstream of the bullet, and turbulence would result, with consequent loss of energy. For a nozzle having a nominal diameter of 2.5 inches, the bullet preferably should be no more than about 1.0 inches in diameter.

On the other hand, the bullet should not be too small, or the effect of the bullet in creating a low-pressure region downstream of the nozzle will be negligible. Thus, the bullet should have a diameter of at least 0.5 inches.

These dimensions can be expressed rather as percentages, i.e the diameter of the bullet should be between 20 percent and 40 percent of the diameter of the nozzle. On a cross-sectional area basis, the area of the bullet should be not less than 4 percent, and not more than 16 percent, of the area of the nozzle.

To minimize the aerodynamic drag caused by the bullet, the downstream end of the bullet preferably should be conically tapered to a point 40.

In some applications, for example in automotive spray painting, it can be advantageous to apply a highlighting liquid to the surface of the workpiece prior to painting. The liquid highlights any surface defects, if present, whereupon the workpiece can be removed from the production line for remediation before paint is applied. In an alternative construction (not shown), the bullet is provided with a tube running down the centre of the bullet, and the highlighting liquid can be applied to the surface of the components by introducing the liquid through the tube, whereby the liquid emerges at the point 40, and is carried with the jet of air to the workpiece.

The location at which the bullet terminates is important. If the bullet were to terminate short of the muzzle 33 of the nozzle, the flow of air will start to conform to the nozzle, rather than to the bullet, and the effect of the bullet might be lost. On the other hand, if the bullet were to protrude too far downstream of the muzzle, the stream might tend to diverge upon emerging from the nozzle, because of the presence of the protruding bullet, and the beneficial effect of the low-pressure area would be lost.

The nozzle itself should be kept short. The reduced diameter nose 25 of the nozzle is where the velocity of the air is at its highest, and therefore also were the fiction is at its highest. Not only does the fiction give rise to direct loss of energy but the friction also causes differential velocities within the jet, in that the radially-outermost portions of the jet are retarded by the friction, and so travel more slowly than the main area of the jet. On the other hand, this tendency to differential velocity, due to friction of the outer regions of the jet against the walls of the nozzle, is offset by the fact that the bullet creates some similar retardation of the centre part of the jet. Both the nozzle and the bullet should be kept short, to minimize aerodynamic friction losses.

The nozzle is most effective when the nose 25 of the nozzle is right-cylindrical. If the nose were convergent, emergence of the jet into the open air would be too abrupt and turbulence might result. If the nose were divergent, part of the energy of the jet would be lost creating back-pressure against the nozzle. A right-cylindrical nozzle enables a minimum energy loss of the jet in emerging from the nozzle.

## Claims

**CLAIM 1.** Apparatus for creating a jet of air, the jet being configured for a long distance of penetration, wherein:

the apparatus includes a means for supplying air at a pressure not more than 2 psi, and at a flow rate not less than 300 cfm;

the apparatus includes a convergent nozzle, and a means for passing the pressurised air therethrough;

the apparatus includes a bullet, and a means for locating the bullet in the nozzle;

the disposition and size of the bullet are such as to create a substantial low pressure area in the jet of air emerging from the nozzle, downstream of the nozzle.

**CLAIM 2.** Apparatus of claim 1, wherein the bullet is aerodynamically faired, for minimum drag and turbulence.

**CLAIM 3.** Apparatus of claim 2, wherein the bullet, on its downstream side, is cone shaped.

**CLAIM 4.** Apparatus of claim 3, wherein the bullet converges to a point on its downstream side.

**CLAIM 5.** Apparatus of claim 1, wherein the overall cross-sectional area of the bullet is no more than 16 percent of the area of the muzzle of the nozzle.

**CLAIM 6.** Apparatus of claim 1, wherein the overall cross-sectional area of the bullet is no less than 4 percent of the area of the muzzle of the nozzle.

**CLAIM 7.** Apparatus of claim 1, wherein the means for locating the bullet in the nozzle is effective to position the bullet so that the downstream extremity of the bullet is substantially in line with the muzzle of the nozzle.

**CLAIM 8.** Apparatus of claim 1, wherein the means for locating the bullet in the nozzle includes radial arms, and a means for securing the arms to the walls of the nozzle.

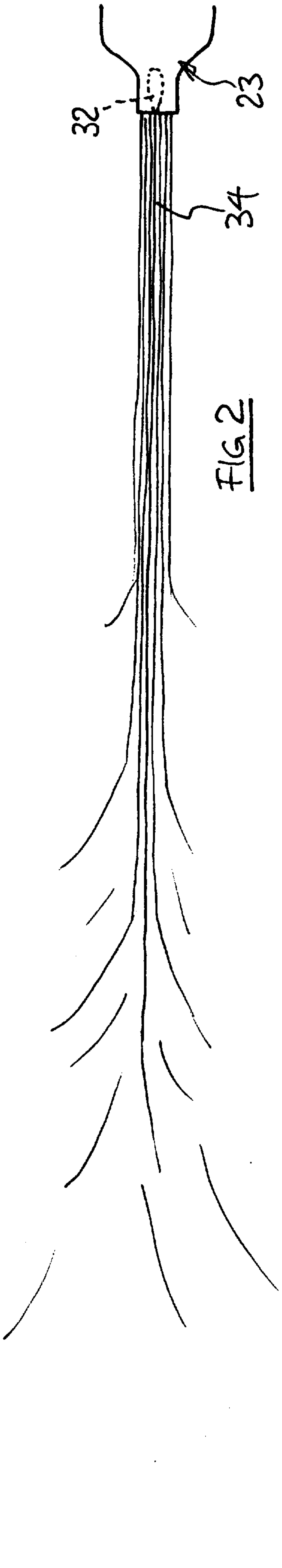



FIG 2

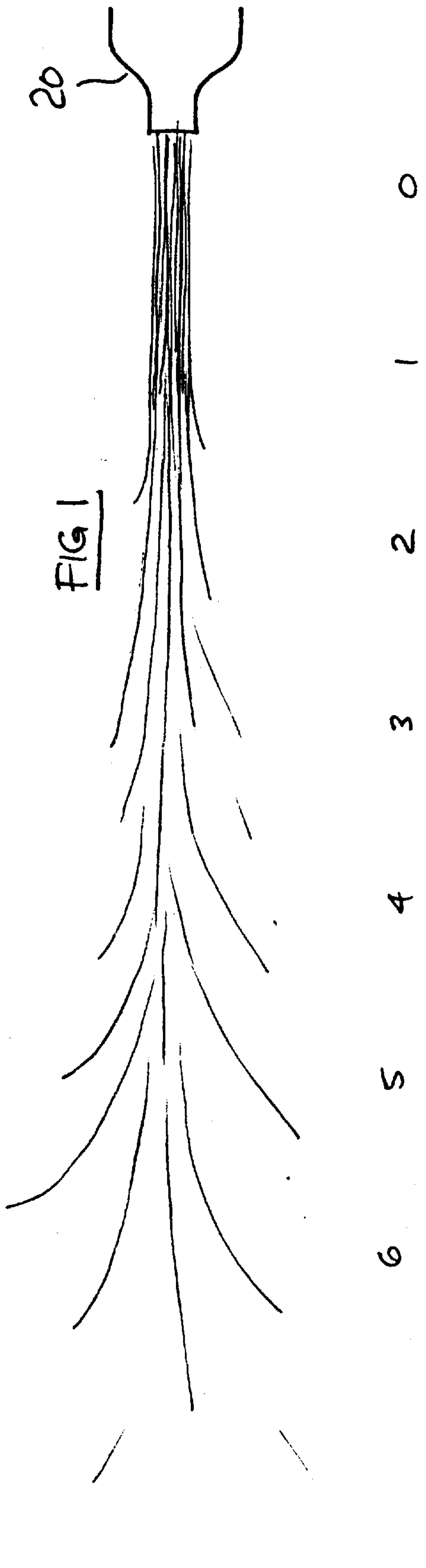
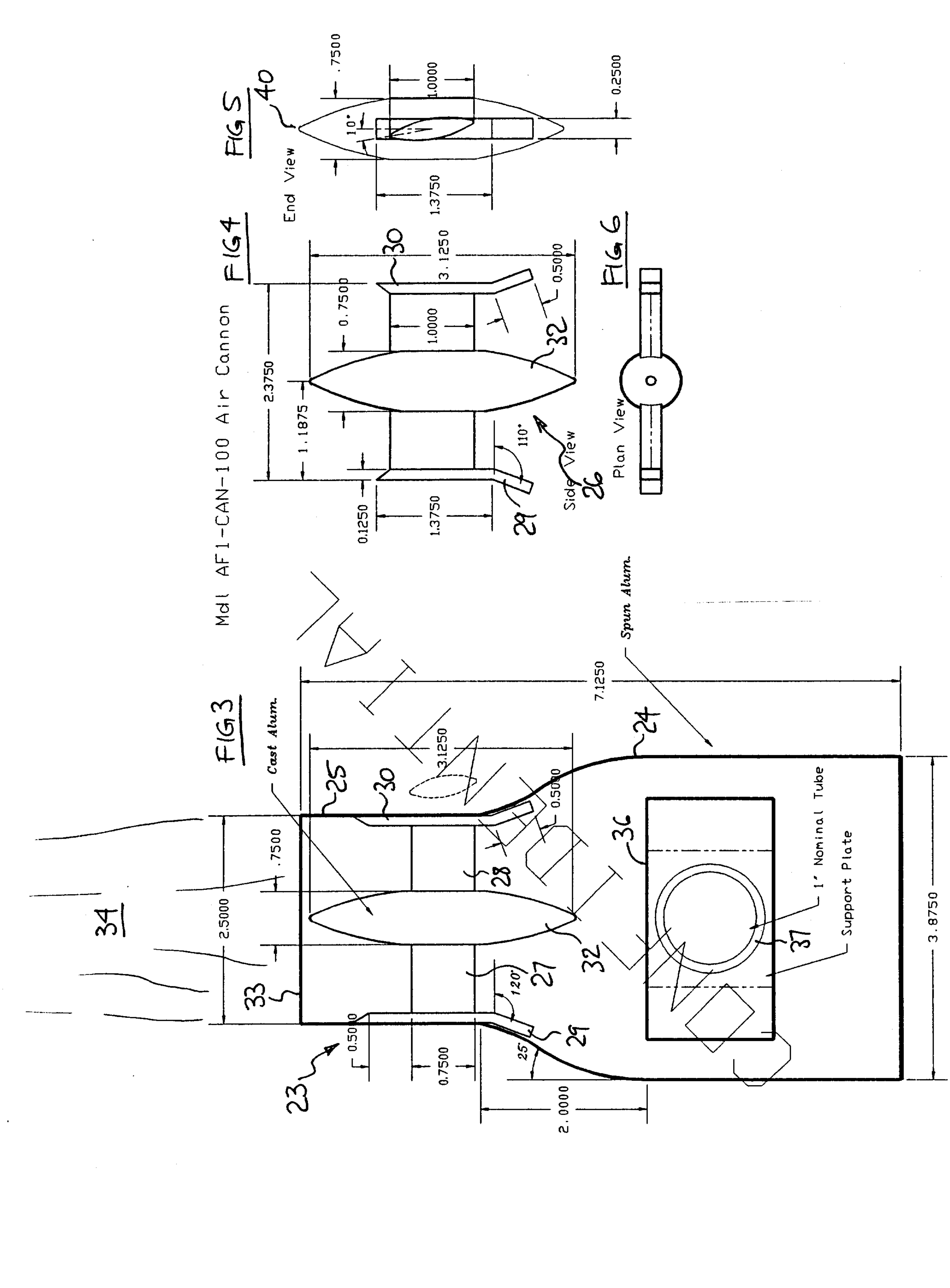



FIG 1


Mdl AF1-CAN-100 Air Cannon
FIG 3
FIG 4
FIG 5
FIG 6
End View
Side View
Plan View
Cast Alum.
Spun Alum.
1" Nominal Tube
Support Plate
7.1250
3.1250
3.8750
2.5000
2.3750
2.0000
1.3750
1.1875
1.0000
0.7500
.7500
0.5000
0.2500
0.1250
1.0°
110°
120°
25°
23
24
25
26
27
28
29
30
32
33
34
36
37
40

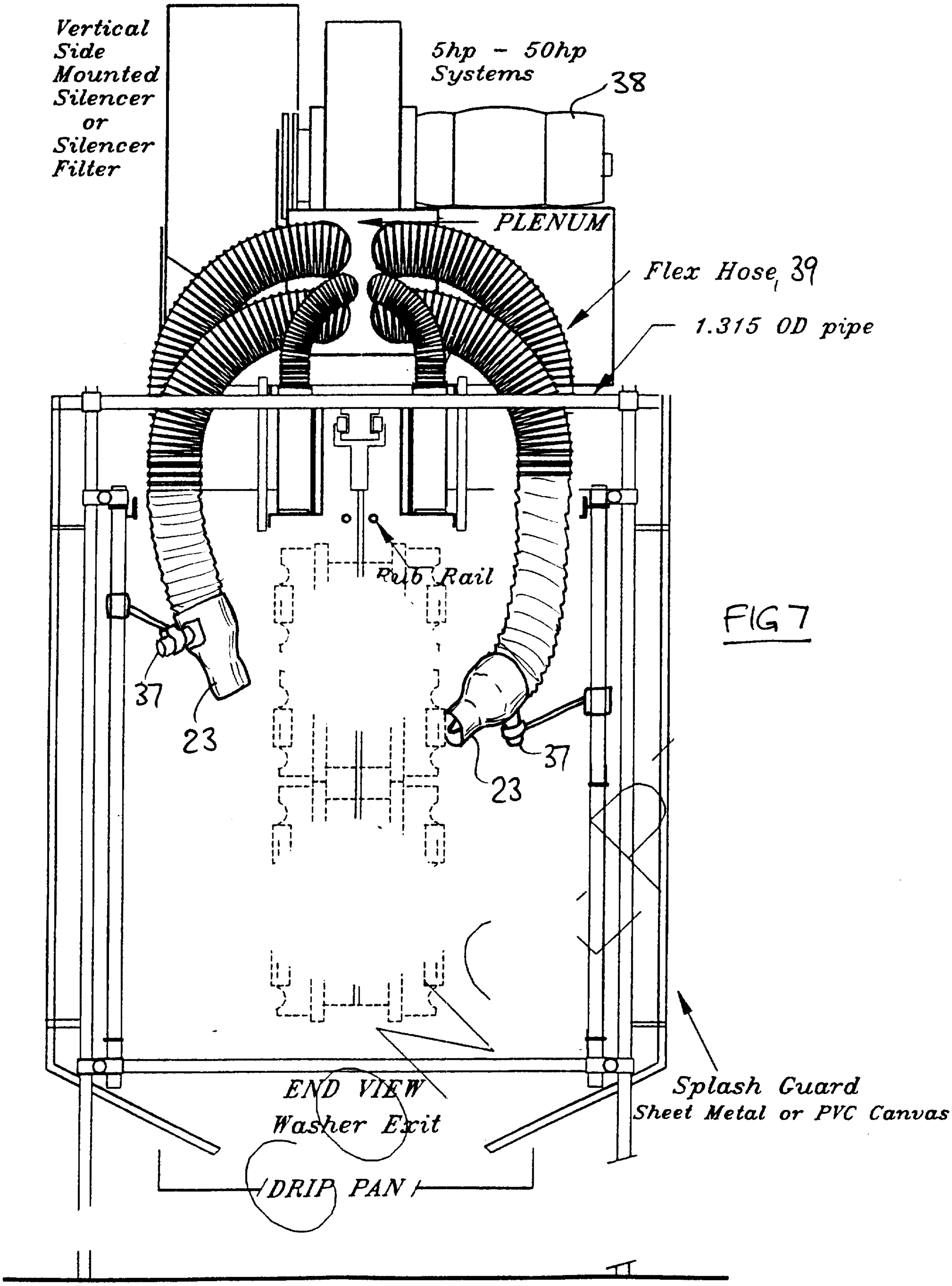

Vertical Side Mounted Silencer or Silencer Filter
5hp - 50hp Systems
38
PLENUM
Flex Hose 39
1.315 OD pipe
Rub Rail
37
23
23
37
Splash Guard
Sheet Metal or PVC Canvas
END VIEW
Washer Exit
DRIP PAN

FIG 7