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ENCLOSURE-BASED SUCTION APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a suction apparatus which utilizes an enclosure to artificially generate a tornado therein for sucking and exhausting contaminated air due to smoke, dust particles, bad odor, poisonous gas and so on by the tornado.

2. Description of the Related Art

As illustrated in Fig. 1, a conventionally known tornado generating method involves blowing out air from a blow-out nozzle b arranged in a substantially completely closed cylinder a to a side wall c of the cylinder a, and simultaneously sucking the air from a suction port d to generate a tornado t directed to the suction port d. This is a so-called in-pipe tornado which has been known for a long time.

In another known method, as illustrated in Fig. 2, a box e which has an open front face used as a hood is provided with suction ports d at two location on the top surface, and with blow-out pipes g on both sides of an opening f. Air is blown out of the two blow-out pipes g to form air curtains h. When the air is sucked simultaneously from the two suction ports d, two tornados t directed to the two suction port d are formed within the box e.



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Then, within the box e for use as a hood, a work is performed under the presence of poisonous gas and a large amount of dust particles.

In a further known method, as illustrated in Fig. 3, four blow-out pipes g, which blow out air to form air curtains h, are positioned in parallel with one another, such that the air blown out of the pipes g rotates in the same direction. A revolving airflow i is formed by a wake action of the air curtains h from the blow-out pipes g. A suction port d is formed at least one of both axial ends of each blow-out pipe g at a position in the axial direction of the revolving air flow i, and a shield plate j is arranged at at least one of the two ends. Then, air is blown out of the blow-out pipes g, while the air is sucked from the suction ports d to generate a tornado t directed to the suction ports d in the space defined within the air curtains h (disclosed in Laid-open Japanese Patent Application No. 62-178826 filed by the present applicant).

In another known method, as illustrated in Fig. 4, shield plates j are arranged on both sides of a spiral plate k, and a suction port d is formed through at least one of the shield plates j. Air is sucked from the suction port d to cause the air to flow along the spiral plate k, forming a revolving airflow i within the spiral plate k, and form a tornado t directed to the suction port d.

Further, as another known method, as illustrated in Fig.

5, a workbench 1 is formed with an air blow-out port m in a rear portion of the workbench 1, a curved air guide wall n on the back of the air blow-out port m, side walls o on both sides of the air guide wall n, and suction ports d through both walls o. In the workbench 1 thus constructed, air is blown out of the air blow-out port m, and the air is sucked from the suction ports d to form a revolving airflow i by a wake action between an air curtain h and the air guide walls n, resulting in the generation of a horizontal artificial tornado directed to the suction ports d. This tornado generating method is disclosed by the present applicant in Laid-open Japanese Patent Application No. 2000-175772. On the workbench 1, the operator is working under the presence of smoke, poisonous gas and a large amount of dust particles.

The foregoing conventional tornado generating methods strategically utilize the shape of wall surfaces and the like as well as blown air to artificially generate rotational motions to forcedly generate a revolving airflow (vortex) within a fixed space. The rotational motions of the vortexes are used as a power source to suck the air from the axial direction of the vortexes, thereby generating a tornado. Stated another way, according to the concept of the Rankine's combined vortex, as illustrated in Fig. 6, vortexes include a free vortex p on the outer side which does not have vorticity and a forced vortex q positioned inside the free vortex p, in which certain vorticity is concentrated. The conventional tornado generating methods utilize the shape of

wall surface and the like as well as blown air to impart rotational energy to the outer free vortex p to drive the inner forced vortex q which is the core of the tornado.

In the following, the respective tornado generating methods described above will be verified from this point of view.

The tornado generating method illustrated in Fig. 1 blows out air from the blow-out nozzle b along the side wall c of the cylinder a, forcedly forms a revolving airflow by the aid of the shape of the cylinder a and the blown air, and sucks the air from the suction port d to generate the tornado t, so that this method drives the inner forced vortex q, which is the core of the tornado, with the outer free vortex p.

The tornado generating method illustrated in Fig. 2 substantially encloses the interior space of the box e with the box e and the air curtains h from the two blow-out pipes g positioned on both sides of the open face of the box e, and sucks air simultaneously from the two suction ports d to forcedly transform the air curtains h into two revolving airflows i, which flow in different rotating directions, to generate two tornados t. Thus, similar to the method of Fig. 1, a free vortex p imparted with rotating energy by the shape of the box e and the air curtains h formed by the blown air to drive a forced vortex q which is the core of the tornado.

The tornado generating method illustrated in Fig. 3 forms a closed space by the four air curtains h from the four blow-out

pipes g, shield plate j, and floor surface, and forcedly forms the revolving airflow i within the closed space simultaneously by the wake action of the air curtains h to generate the tornado t, so that a forced vortex q, which is the core of the tornado, is driven by a free vortex p which is imparted with the rotating energy only by the air curtains h formed by the blown air.

The tornado generating method illustrated in Fig. 4 forcedly forms the revolving airflow i only by the shape of the spiral plate k since the air flow generated by sucking air from the suction port d flows along the spiral plate k to obtain a rotating force, and generates the tornado t by sucking the air from the suction port d, wherein a forced vortex q, which is the core of the tornado, is driven by a free vortex.

The tornado generating method illustrated in Fig. 5 encloses a space by the air guide wall n, side walls o arranged on both sides of the air guide wall n, and the air curtain from the leading end of the air guide wall n, forcedly forms the revolving airflow i by the wake action of the air flow blown out of the air blow-out port m and the air curtain h, and sucks the air from the suction port d to generate the tornado t, so that similarly to the foregoing methods, a forced vortex q, which is the core of the tornado, is driven by a free vortex p that is imparted with rotating energy by the shape of the air guide inner wall n and the air curtain h.

As described above, the prior art examples illustrated in

Figs. 1, 2, 3, 4 and 5 are utilized in accordance with their respective purposes of applications, and sufficiently achieve the purposes. However, since these prior art examples are all configured to enclose a space by wall faces, air curtain, and the like, artificially revolve the outer free vortex p to drive the inner forced vortex q, which is the core of the tornado, it is in some cases difficult to enclose a space making use of wall surfaces, air curtain and the like depending on places. Moreover, for forcedly generating the revolving airflow i within the space, and transforming the revolving airflow i into the persistent tornado t, persons and objects are not basically permitted to exist at least in a region in which the tornado t is being generated.

In addition, if large turbulence or three-dimensional airflow occurs within the space in which the tornado t is being generated due to an internal factor (for example, an object or a person existing within the space) or an external factor (wind or the like blowing into the space), the revolving airflow i, which is driving the tornado t, is disturbed and prevented from imparting the rotating energy to break the tornado t, causing the tornado generating apparatus to fail to demonstrate sufficient performance and end up in an apparatus which simply sucks air from the suction port d.

OBJECT AND SUMMARY OF THE INVENTION

The present invention has been made in view of the situation mentioned above, and it is an object of the invention to provide an enclosure-based suction apparatus which is capable of generating a tornado, even without forced generation of a revolving airflow in a certain space to impart rotating energy, and utilizing the characteristic of the tornado to ensure a wide collecting range and a capturing force to allow for an efficient suction operation.

As a result of diligent studies for achieving the above object, the inventor found that when an enclosure was formed with an opening for working and air was sucked from the enclosure, a discontinuous plane was created in an airflow along peripheral edges of the opening, with a plurality of vortexes generated on the discontinuous plane, so that if air suction positions were appropriately set in the enclosure, tornados were generated near the peripheral edges of the opening and acts to prevent particulate products within the enclosure from leaking out, even if the enclosure was formed with the large opening for working, so that the products could be fully sucked. The completion of the present invention was reached based on this finding.

More specifically, the object of the present invention is achieved by an enclosure-based suction apparatus which includes an enclosure for enclosing a space, an opening formed in the enclosure, and at least one suction port formed in the enclosure near the opening. The suction port is positioned to suck air

thereinto to introduce an airflow into the opening from the outside. The introduced airflow interacts with an airflow within the enclosure to form a discontinuous plane therebetween. A plurality of vortexes generated on the discontinuous plane are connected in an axial direction thereof and converged to generate a tornado which enables a highly efficient sucking operation.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view illustrating a prior art tornado generating method;

Figs. 2 and 3 are perspective views each illustrating a prior art tornado generating method;

Figs. 4 and 5 are cross-sectional views each illustrating a prior art tornado generating method;

Fig. 6 is a cross-sectional view for explaining the structure of a tornado;

Fig. 7 is a perspective view illustrating an enclosure-based suction apparatus according to one embodiment of the present invention;

Fig. 8 is a cross-sectional view for explaining the principles of the generation of a tornado in the enclosure-based suction apparatus according to the embodiment of the present invention shown in Fig. 7;

Fig. 9 is a perspective view showing how a tornado is generated in the enclosure-based suction apparatus in the

embodiment of the present invention shown in Fig. 7;

Fig. 10 is a cross-sectional view for explaining an end plate angle of the enclosure-based suction apparatus in the embodiment of the present invention shown in Fig. 7;

Figs. 11 and 12 are cross-sectional views each illustrating the structure of another opening in the enclosure-based suction apparatus in the embodiment of the present invention shown in Fig. 7;

Figs. 13 through 15 are cross-sectional views each illustrating the structure of a different opening in the enclosure-based suction apparatus in the embodiment of the present invention shown in Fig. 7;

Figs. 16 and 17 are cross-sectional views for explaining the generation of a tornado in the enclosure-based suction apparatus according to the embodiment of the present invention shown in Fig. 7;

Fig. 18 is a perspective view illustrating an enclosure-based suction apparatus according to another embodiment of the present invention;

Fig. 19 is a cross-sectional view for explaining the principles of the generation of a tornado in the enclosure-based suction apparatus in the embodiment of the present invention shown in Fig. 18;

Fig. 20 is a perspective view illustrating an enclosure-based suction apparatus according to another embodiment of the

present invention;

Fig. 21 is a cross-sectional view for explaining the principles of the generation of a tornado in the enclosure-based suction apparatus in the embodiment of the present invention shown in Fig. 20;

Fig. 22 is a side view of an enclosure-based suction apparatus according to another embodiment of the present invention, when it is incorporated in a working section of a machine tool;

Fig. 23 is a perspective view illustrating the enclosure-based suction apparatus according to the embodiment of the present invention shown in Fig. 22;

Fig. 24 is a vertical sectional view of the enclosure-based suction apparatus according to the embodiment of the present invention shown in Fig. 22 when it is in operation;

Fig. 25 is a horizontal sectional view of the enclosure-based suction apparatus according to the embodiment of the present invention shown in Fig. 22 when it is in operation; and

Fig. 26 is a horizontal sectional view showing the orientation of a nozzle of the enclosure-based suction apparatus according to the embodiment of the present invention shown in Fig. 22.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following, the present invention will be described

in detail in conjunction with preferred embodiments thereof illustrated in the accompanying drawings.

As illustrated in Figs. 7 through 9, an enclosure-based suction apparatus 1 according to one embodiment of the present invention has an enclosure 2 which encloses a certain space, an opening formed in the enclosure 2, and one or more suction ports 4 positioned near the opening 3 within the enclosure 2. As air is sucked from the suction ports 4, an airflow is introduced from the outside into the opening 3 to generate a discontinuous plane 7 between the introduced airflow 5 and an airflow 6 normally stagnated within the enclosure 2. A plurality of vortexes 8 generated on the discontinuous plane 7 are connected in the axial direction thereof and converged to define a position at which a tornado *t* can be generated. Eventually, the generated tornado *t* can act to highly efficiently suck substances (for example, gas, floating liquid and solid particles, and the like, without limitation) possibly existing within the enclosure 2.

In this embodiment, the enclosure 2 may be a rectangular solid having one open side, comprised of a top plate 10, a bottom plate 11, both side plates 12, 13 between the top plate 10 and bottom plate 11, and a back plate 14. It should be noted however that the enclosure is not particularly limited in shape as long as it can enclose a certain space, and may be a cube, a cylinder, a sphere, a polyhedral body or the like. Alternatively, the enclosure 2 may be defined by an entire room or a portion thereof

surrounded by plates or the like. In essence, the enclosure 2 is only required to ensure a fixed space in which an operator can work or to which a person can access. An open side of the enclosure 2 is the opening 3.

The opening 3 is provided on one side of the box which is a hexahedron in this embodiment, and shaped in a rectangle. The opening 3 is not either limited in shape, and may be in the shape of a square, a triangle, another polygon, a circle, an oval, an ellipse, or the like. The opening 3 is provided with end plates 16, along two side edges, which have an angle α less than 90 degrees with respect to an opening plane 15 of the opening 3 (the angle α is 0° in this embodiment, i.e., the end plates 16 are in parallel with the opening plane 15), as illustrated in Fig. 10. However, the shape of the edges of the opening 3 is not particularly limited, and end plates 16A may be arranged in the opposite direction as illustrated in Fig. 11, or the end plates 16 may be removed as illustrated in Fig. 12. Nevertheless, the end plates 16 having the angle α less than 90 degrees with respect to the opening plane 15 is preferably arranged for stably generating the discontinuous plane 7 at all times with the airflow 5 introduced from the opening 3 into the enclosure 2 and the airflow 6 within the enclosure 2. Specifically, the introduced airflow 5 is generated by sucking air from the suction ports 4 with substantially no directivity, so that the discontinuous plane 7

can be readily formed between the introduced airflow 5 and the airflow 6 within the enclosure 2 which is readily captured by the existence of the end plates 16. Therefore, the most preferable angle α of the end plates 16 with respect to the substantially non-directive introduced airflow 5 is 0° with respect to the opening plane 15 (parallel).

The shapes illustrated in Figs. 11, 12 act to create the discontinuous plane 7 when the introduced airflow 5 is in substantially parallel contact with the a plate face 20 of the enclosure 2, or when the introduced airflow 5 comes from a direction indicted by an arrow A, so that a plurality of vortexes 8 can be generated to result in the generation of a tornado t. However, if the introduced airflow 5 comes from a direction indicated by an arrow B, the discontinuous plane 7 becomes instable to break the tornado t in the worst case. Thus, the shapes illustrated in Figs. 11, 12 should be employed when the introduced airflow 5 mainly comes from the direction indicated by the arrow A at all times.

The suction ports 4 are formed through the top plate 10 of the enclosure 2, which is a hexahedron in this embodiment, at end locations near the opening 3, and are connected to a suction side of a suction fan, not shown. For the enclosure-based suction apparatus 1 according to the present invention, it is critical where to position the suction ports 4. When air is sucked from

the suction ports 4 provided in the enclosure 2, the introduced air 5 is generated along the end plates 16 of the opening 3, resulting in the generation of the discontinuous plane 7 and a plurality of vortexes 8. However, the plurality of vortexes 8 thus generated would not always connect one another and converge to end up in the generation of the tornado t. Therefore, the suction ports 4 should be arranged at positions at which the plurality of vortexes 8 generated on the discontinuous plane 7 can be connected in the axial direction thereof and converge to generate the tornado t. The positions of the suction ports 4 depend on the shape and structure of the enclosure 2, the shape and structure of the opening 3, the presence or absence of the end plates 16, and the like, and it is difficult to generally identify the positions. For this reason, the suction apparatus 1 must be prototyped for an enclosure intended for use therewith to make final confirmation through visual experiments as to whether the tornado t can be generated.

In the embodiment illustrated in Fig. 7, when the enclosure 2 is 1000 mm wide, 600 mm deep and 650 mm high, the opening 3 is 800 mm width and 450 mm high, and the suction ports 4 has a diameter of 100 mm, the vertical distance from the opening plane 15 to the center of the suction port 4 is most preferably in a range of 125 mm $\pm$ 25 mm, and the vertical distance from the two side plates 12, 13 of the enclosure 2 to the center of the suction ports 4 is in a range of 50 mm to 125 mm. Although a slight

deviation from these ranges would not prevent the plurality of vortexes 8 from connecting one another and converging to generate the tornado t, it is often the case that the resulting tornado t is not strong enough. A large deviation from these ranges would result in a failure in connecting the plurality of vortexes 8 in the axial direction, so that the vortex t will not be generated.

Alternatively, the suction ports 4 illustrated in Figs. 7 through 9 may have structures as illustrated in Figs. 13 through 15. A set of suction ports 40 illustrated in Fig. 13 is comprised of a combination of a suction port 4a arranged on the top plate 10 of the enclosure 2 and suction ports 4b arranged on the two side plates 12, 13. A suction port 44 illustrated in Fig. 14 is comprised only of the suction ports 4b illustrated in Fig. 13. A suction port 44a illustrated in Fig. 15 is comprised of a suction port 4a on the top plate 10 or suction ports 4b on the two side plates 12, 13, the suction ports 4a, 4b communicating with a suction hole arranged in chambers 21 defined in corner portions of the enclosure 2. The suction ports 4, 40, 44, 44a are similar in function and substantially similar in performance as well. It should be noted that the suction ports 4, 40, 44, 44a may be applied to the enclosure 2 having the shape illustrated in Figs. 7 through 9, and the suction ports will vary in position and structure when an alternative enclosure 2 having a different shape is employed instead. Assume for convenience of explanation that the respective components in Figs. 13 through 15 are all made of

transparent materials.

Next, detained description will be made on a mechanism of the enclosure-based suction apparatus 1 in the foregoing structure for generating the tornado t, and a method of utilizing the enclosure-based suction apparatus 1.

First, as a suction fan, not shown, is operated, air within the enclosure 2 is sucked from the suction ports 4 to generate a negative pressure within the enclosure 2, causing an introduced airflow 5 to come into the opening 3 from the outside. This introduced airflow 5 impinges on the leading ends 16a of the end plates 16, causing the introduced airflow 5 to peel off. This peeling results in creation of a shear layer, in other words, the discontinuous plane 7 in the space, as illustrated in Fig. 16. Along the discontinuous plane 7, an infinity of vortexes 8 generated by the leading end 16a of the end plate 16, i.e., vorticity 23 is diffused. This results in the formation of a vortex layer 25 which appears to be filled with an infinity of sequential vortex lines on the discontinuous plane 7. The vortex layer 25 maintains the state as illustrated in Fig. 16 as long as the space is not disturbed. However, a space generally includes disturbance which can act as a variety of instable factors, so that the vortex layer 25 is transformed into a large and strong single spiral vortex 26, which has a concentrated core of the vorticity 23, to generate vertical and horizontal tornados t towards the suction ports 4 along the vicinities of the end plates

16 arranged on the peripheral edges of the opening 3 of the enclosure 2, as illustrated in Figs. 8, 9.

Then, as described above, the vertical and horizontal tornados t generated by the enclosure-based suction apparatus 1 roll up substances (all of gas, liquid, solid and the like) which are about to go out of the opening 3 of the enclosure 2, with the vortex convergence, because the tornados t exist along the peripheral edges except for lower ends of the opening 3 of the enclosure 2, and suck such substances into the suction ports 4 to prevent them from leaking from the enclosure 2. On the other hand, if a strong airflow 5 is introduced into the enclosure 2 by disturbance outside the enclosure 2, the introduced airflow 5 impinges the inner wall of the enclosure 2 (for example, the back plate 14), and attempts to go out of the leading ends 16a of the end plates 16 along the inner walls (back plate 14, side plates 12, 13, top plate 10) as an internal flow 6a. However, the internal flow 6a is opposite in direction to the introduced airflow 5 sucked into the suction port 4, so that a speed gradient increases on the discontinuous plane 7, resulting in correspondingly stronger vorticity 23 and tornados t generated thereby. Thus, even with the strong introduced airflow 5, substances attempting to go out of the opening 3 of the enclosure 2 are rolled up and sucked into the suction ports 4, so that the substances are prevented from going out of the enclosure 2.

It should be noted that the tornados t have common

characteristics irrespective of whether they are naturally generated or artificially generated in any method. The characteristics of the tornados will be described below.

(1) Suction Directivity:

A flow rate is hardly changed even far from the suction ports 4. This means that the suction has directivity and contaminated air and the like far from the suction ports 4 can be directly sucked and collected.

(2) Flow Rate Accelerability:

The contaminated air sucked and collected in tornado is converged toward its center and the flow rate is accelerated. This means that the contaminated air can be collected without spattering.

(3) Flexibility:

The core q extends uniformly substantially along the center of tornado t. This means that a tornado can be freely formed not only in the cross direction but also in the longitudinal, diagonal and curved directions.

(4) Flow Rate Selectability:

When a centrifugal force is balanced with a centripetal force, a tornado can be generated at a low rate of about 0.5 m/sec to a high rate of about 20 m/sec and this means that dust with a low specific gravity can be sucked and collected.

Figs. 18 and 19 illustrate an enclosure-based suction apparatus 1a according to another embodiment of the present

invention. The enclosure-based suction apparatus 1a differs from the embodiment illustrated in Figs. 7 through 9 in that an oblique end plate 30 is attached to a top plate 10a of an enclosure 2a, and the end plates 16 are removed from both side plates 12a, 13a of the enclosure 2a. Thus, the enclosure-based suction apparatus 1a is intended to generate a horizontal tornado t toward both suction ports 4a along the oblique end plate 30 in a top portion of the enclosure 2a. This enclosure-based suction apparatus 1a can be applied to a situation in which the space inside and outside the enclosure 2a generally includes little disturbance, and disturbance, if any, is mainly in the vertical direction. Since the remaining structure and actions made thereby are similar to those of the embodiment illustrated in Figs. 7 through 9, corresponding components are designated the same reference numerals in the figures, and description thereon is omitted.

Figs. 20, 21 illustrate an enclosure-based suction apparatus 1b according to another embodiment of the present invention. The enclosure-based suction apparatus 1b differs from the embodiment illustrated in Figs. 7 through 9 in that an oblique end plate 31 is attached to each of side plates 12b, 13b of an enclosure 2b, and the end plate 16 is removed from a top plate 10b of the enclosure 2b. Thus, the enclosure-based suction apparatus 1b generates a tornado t in the vertical direction toward both suction ports 4b along the two side plates 12b, 13b, and can be applied to a situation in which the space inside and outside the

enclosure 2a generally includes little disturbance, and disturbance, if any, is mainly in the horizontal direction. Since the remaining structure and actions made thereby are similar to those of the embodiment illustrated in Figs. 7 through 9, corresponding components are designated the same reference numerals in the figures, and description thereon is omitted.

Figs. 22 through 26 illustrate an enclosure-based suction apparatus 1c according to another embodiment of the present invention which is incorporated in a working section of a machine tool. The enclosure-based suction apparatus 1c differs from the embodiment illustrated in Figs. 7 through 9 in that a top plate 10c is formed with a trapezoidal recess 34 such that a working section 33 of the machine tool 32 can be inserted into an enclosure 2c from above, an end plate 35 is attached along the recess 34, and a spray nozzle 37 is additionally provided for spraying oil mist between the working section 33 and a material 36 which is machined thereby. The spray nozzle 37 is oriented toward a back surface 14 of the enclosure 2c from an opening 3. Therefore, as a suction fan, not shown, is operated, a tornado t is generated in the horizontal direction along the end plate 35 as illustrated in Fig. 24, and other tornados t are generated in the vertical direction along the side plates 16 as illustrated in Figs. 25, 26. In this state, oil mist is sprayed from the spray nozzle 37 to between the working section 33 and material 36 together with air. Subsequently, the machine tool 32 is operated

to work the material 36 with the working section 33. While a portion of oil mist attaches on the working section 33 and material 36, another portion of oil mist impinges on the back plate 14 of the enclosure 2c together with sprayed air, separates in opposite directions, and attempts to go out of the enclosure 2c around the side plates 12, 13 from the end plates 16. However, the oil mist is captured by the vertical tornados t generated in both side regions, and sucked into the suction ports 4. On the other hand, the remaining oil mist attempts to go out of the enclosure 2c along the top plate 10c from the end plate 35, but is captured by the horizontal tornado t and sucked into the suction port 4. The oil mist sucked by the suction port 4 is sent to a recovering machine through a flexible hose 38 for recovery.

In this event, since the oil mist is generally sprayed from the spray nozzle 37 together with air at a high rate of 50 to 100 m/sec, the oil mist is likely to go out of the enclosure 2c from the opening 3. However, the oil mist helps increase the relative speed to the introduced airflow 5 due to the suction into the suction ports 4 to enhance the tornado t which strongly captures and sucks substances attempting to go out over the airflow generated by the spray nozzle 37, so that such substances are prevented from going out of the enclosure 2c. While the spray nozzle 37 should be oriented generally within an angle β , it may be oriented within a wider angle γ when a large negative pressure

is generated within the enclosure 2c due to a large amount of airflow sucked into the suction ports 4. This increase in angle from β to γ is permitted because a larger negative pressure results in a higher speed of the introduced airflow 5, so that the airflow generated by the spray nozzle 37 is deflected to the back plate 14.

In this way, when the working section 33 is covered with the enclosure 2c having the large opening 3 so as not to interfere with the operator who manipulates the working section 33 of the machine tool 32, it is possible to readily and securely recover oil mist, which is prone to diffusion, not to mention sludge associated with the operation of the working section 33. Since the remaining structure and actions made thereby are similar to those of the embodiment illustrated in Figs. 7 through 9, corresponding components are designated the same reference numerals in the figures, and description thereon is omitted.

The enclosure-based suction apparatus described in connection with the embodiments illustrated in Figs. 7 through 26 can be used to recover spray mist generated during a painting process of high technology devices such as portable telephones, and to suck contaminated air such as smoke, other than an application to a hood for recovering oil mist. The contaminated air sucked by the apparatus can be cleaned and recycled by sending the contaminated air to an air cleaner.

As described above, the enclosure-based suction apparatus has an enclosure for enclosing a space, an opening formed in the enclosure, and a suction port, at a position at which a tornado can be generated, to suck air thereinto to introduce an airflow into the opening from the outside. The introduced airflow interacts with an airflow within the enclosure to form a discontinuous plane therebetween. A plurality of vortexes generated on the discontinuous plane are connected in an axial direction thereof and converged to generate a tornado. The tornado is directed to the suction port to capture and suck products within the enclosure. Thus, a plurality of vortexes generated on the discontinuous plane, which have been so far regarded as a burden, can be generated as a beneficial tornado near the opening, through diversion of idea. For this reason, a tornado can be generated without using a wide range within a space to forcibly generate a revolving airflow to impart rotating energy, so that a tornado can be generated and maintained within a space, even if objects such as a machine tool and the like are placed in the space, to ensure a wide capture range and a strong capturing force provided by the tornado, thereby making it possible to perform a highly efficient capturing operation within the space.

The enclosure-based suction apparatus may include an end plate attached to each end of the opening. The end plate acts to increase the relative speed of an airflow introduced from the

opening to the air flow existing in the enclosure to correspondingly increase the energy of the plurality of vortexes generated on the discontinuous plane, so that a correspondingly stronger tornado is generated. Therefore, the benefit of the present invention described above is further increased.

The enclosure-based suction apparatus may further include a spray nozzle positioned near the opening and directed to the inside of the enclosure. As the spray nozzle is operated for working within the enclosure, an airflow generated by the spray nozzle, once introduced into the enclosure, goes out from the opening along the inner faces of the enclosure, but the airflow helps increase the relative speed to the introduced airflow due to the suction into the suction port to enhance the tornado which strongly captures and sucks substances that attempt to go out over the airflow generated by the spray nozzle, so that such substances are prevented from going out of the enclosure. As appreciated, in addition to the foregoing benefit, a stronger tornado can be generated by the airflow from the spray nozzle, so that substances within the enclosure can be more efficiently sucked by the tornado.

What is claimed is:

1. An enclosure-based suction apparatus comprising:
an enclosure for enclosing a space;
an opening formed in said enclosure; and
at least one suction port formed in said enclosure near said opening, said suction port being positioned to suck air thereinto to introduce an airflow into said opening from the outside, said introduced airflow interacting with an airflow within said enclosure to form a discontinuous plane therebetween, a plurality of vortexes generated on said discontinuous plane being connected in an axial direction thereof and converged to generate a tornado, said tornado being directed to said suction port to produce a sucking action into said suction port.
2. An enclosure-based suction apparatus according to claim 1, further comprising an end plate attached to each end of said opening, said end plate having an angle less than 90 degrees with respect to an opening plane of said opening.
3. An enclosure-based suction apparatus according to claim 1 or 2, further comprising a spray nozzle positioned near said opening and directed to the inside of said enclosure, said spray nozzle configured to generate an air flow to increase a relative speed between the air flow generated thereby and the introduced

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airflow to enhance the plurality of vortexes generated on said discontinuous plane to generate a stronger tornado.