

CIRCUMFERENTIAL AIR KNIFE AND APPLICATIONS

The present invention generally relates to the use of a novel air knife to help prevent solid particulates from blocking the entrance to a vessel. More specifically, the present invention is particularly useful for reducing blockage by solid chlorides removed from a titanium tetrachloride product gas by a cyclone or by some other gas/solids separation device, in processes for producing titanium tetrachloride.

The production of titanium tetrachloride ("TiCl₄") via the chlorination of titanium values in a titanium-containing starting material is generally known in the art. The production of TiCl₄ is useful, for example, in the production of titanium metal or titanium dioxide ("TiO₂").

As is known in the art, TiCl₄ can be produced by reacting chlorine gas with titanium-containing starting materials in a chlorinator. During this process, a solids-laden gas mixture comprised of the desired TiCl₄ gas and residual solid chlorides is removed from the chlorinator, cooled, and conventionally is then transferred to a cyclone separator to remove the solids from the solids-laden gas mixture. The solids are then dumped into a suspension vessel, frequently referred to as a chlorinator sump, where the solids are mixed with water to form a suspension.

These removed solids are typically very warm upon entering the suspension vessel. The mixing of these hot solids with water in the suspension vessel results in a high humidity gas phase in the space above the suspension in the vessel, including the length of pipe that carries the cyclone dust from the cyclone to the suspension vessel. The cyclone dust contains metal chlorides, which are hygroscopic, and as such become sticky when entering the high humidity areas of the pipe that transfers the cyclone dust from the cyclone to the suspension vessel. The sticky solids gradually build up on the walls of the pipe until the pipe is completely plugged, stopping further discharge of solids from the cyclone. Clearing the blockage requires operation downtime to unclog and can be a safety hazard.

The present invention addresses the issues presented above by placing a novel air knife at or near the entrance to the suspension vessel. The cyclone dust passes through the air knife on its way to the suspension vessel. The novel air knife is circumferential. That is, the novel air knife injects a gas stream along the inside walls of the air knife. The gas stream is injected at a rate sufficient to reduce the buildup of hygroscopic cyclone dust on the walls of the air knife (and thus at the entrance to the chlorinator sump), so that the chlorinator sump can continue to receive solids from the cyclone, improving time-on-line and safety.

In one embodiment, the present invention is a novel air knife adapted to reduce hygroscopic solids from building up at the entrance to a suspension vessel enclosing a high-humidity environment. In a second embodiment, the present invention is a method for preventing hygroscopic solids from building up at the entrance to a suspension vessel enclosing a high-humidity environment.

The present invention is illustrated by way of example in the following drawings in which like references indicate similar elements. The following drawings disclose various preferred embodiments of the present invention for purposes of illustration only and are not intended to limit the scope of the invention.

FIG. 1 is a diagram of a TiCl_4 production process.

FIG. 2 illustrates a process utilizing an air knife according to the present invention in conjunction with a cyclone separator and a suspension vessel.

FIG. 3 illustrates a cut-away view of an air knife according to the present invention.

FIG. 4 illustrates a top-down view of the air knife shown in Figure 3.

Figure 1 illustrates a schematic of a typical TiCl_4 production process **100**. The process **100** illustrated in Figure 1 involves chlorination of titanium-bearing ores. Ore **104** and coke **106**, preferably petroleum coke, are conveyed to a chlorinator **102** on a timed basis to maintain a certain bed level **108** and composition. Chlorine gas **110** is fed up to the bed through a distributor in the bottom of the chlorinator **102**. The chlorination reaction occurs as the chlorine gas **110** flows up through the bed. Most of the titanium values in the bed are reacted to form TiCl_4 . Metal oxides in the ore **104** largely are converted into gaseous metal chlorides. Other gases are also formed including carbon dioxide (" CO_2 ") and carbon

monoxide ("CO"). Impurities in the ore are also chlorinated, forming chlorides such as FeCl_2 and MnCl_2 , for example.

A hot reaction solids-laden gas mixture exits **112** from the chlorinator **102** and typically may comprise CO, CO_2 , COS, HCl, N_2 , low-boiling and high-boiling chlorides such as TiCl_4 , FeCl_3 , FeCl_2 , MnCl_2 , SnCl_4 , SiCl_4 , VOCl_3 , NaAlCl_4 , and unreacted solids such as TiO_2 , SiO_2 as well as unburned coke. The solids-laden gas mixture is cooled in a cooling conduit **114**, sometimes referred to as a chlorinator crossover, and then sent to a cyclone separator **116** where the gases and solids are separated.

Cyclone separators comprise well known means for separating gases and solids.

Cyclone separators generally are constructed of the tubular or cylindrical-shaped main body connected to a lower tapered conical portion. A tangential side inlet is provided near the top of the cylindrical main body. A gas outlet tube is provided and generally extends downwardly through the cyclone top into the main body of the cyclone. The tube usually must extend down to a level slightly below the lowest portion of the inlet to assure efficient separation of solids and gases.

In operation, the solids-laden gases are introduced at high velocity through the tangential inlet. They follow a vortex-shaped path around the outside of the gas outlet pipe downwardly towards the bottom of the separator. The solids, which are heavier than the gases, are thrown against the walls of the cyclone by centrifugal force. Gravity then causes the solids to fall to the bottom of the cyclone. The separated gas follows a vortex path upwardly and passes out of the top of the cyclone separator through the gas outlet tube. The separated solids flow through a solids outlet at the base of the tapered conical section. These separated solids are typically referred to as cyclone dust or waste solids.

To minimize the amount of gas that is dumped along with the cyclone dust, a two-valve dump spool leg is typically used on the bottom of the cyclone. The opening and closing of these valves is interlocked so only one valve can possibly be open at any given time. When the top valve is opened, the bottom is closed. This allows cyclone dust to fall through the top valve and fill the dump spool leg. When the top valve closes, the bottom valve is opened to empty the dump spool leg to the suspension vessel. The valves continuously operate on a timer.

In Figure 1, the solids-laden gas mixture flows from the chlorinator crossover 114 into the cyclone 116 through a tangential inlet 118. The gases from the solids-laden gas mixture exit cyclone 116 through the gas outlet tube 120 at the top of the cyclone 116 and the solids exit the cyclone 116 through the dump spool leg 122 at the base of the cyclone 116.

5 The cyclone dust collected at the bottom of the cyclone exits the bottom of the cyclone, is transported through a tube or pipe by force of gravity, and is deposited into a suspension vessel. The section of pipe connecting the cyclone and the suspension vessel can vary in length, typically being from about 20 feet to about 50 feet in length.

10 The suspension vessel is frequently referred to as a chlorinator sump. Once deposited into the suspension vessel, the cyclone dust is mixed with water to form a suspension. Typically, any gas in the suspension vessel is removed through a vent in the top of the vessel and the suspension is pumped out of the vessel as waste or for further processing. Figure 1 shows the cyclone dust 124 entering the suspension vessel 132, water 126 being added to the suspension vessel 132, gas 128 being removed from the suspension
15 vessel 132, and suspension 130 being pumped out of the suspension vessel 132.

20 The cyclone dust is typically very warm upon entering the suspension vessel. The mixing of these hot solids with water in the suspension vessel results in a high humidity gas phase in the space above the suspension in the vessel. This high-humidity environment can extend into the length of pipe that carries the cyclone dust from the cyclone to the suspension vessel. The cyclone dust contains metal chlorides, which are hygroscopic, and as such become sticky when entering the high humidity areas of the pipe that transfers the cyclone dust from the cyclone to the suspension vessel. The sticky solids gradually build up at the opening of the pipe into the suspension vessel or on the walls of the pipe until the pipe is completely plugged, stopping further discharge of solids from the cyclone.

25 Clearing the blockage requires operation downtime to unclog and can be a safety hazard. Stopping the production process to clear a blockage is not only an economic disadvantage, allowing an operator access to the inside of the pipe to clear the blockage creates a risk of gas emissions. The blockage can also result in condensed TiCl_4 being present, which can hydrolyze explosively should an operator try clearing the line with water.

According to the present invention, a novel air knife is advantageously utilized to reduce or eliminate the buildup of hygroscopic materials on the inside of the pipe that transports the cyclone dust from the cyclone separator to the suspension vessel. The novel air knife is connected to the cyclone separator in the sense that the novel air knife is attached to the tube or pipe that transports cyclone dust from the cyclone to the suspension vessel in a manner that requires the cyclone dust to pass through the air knife either before the dust enters the suspension vessel or as the dust enters the suspension vessel. Preferably, the air knife is placed at or near the entrance to the suspension vessel.

Air knives according to the present invention are circumferential. By circumferential it is meant that the air knife creates a stream of gas inside the air knife along the circumference of the passage in the air knife through which the cyclone dust passes. Typically, the pipe carrying the cyclone dust from the cyclone to the suspension vessel is circular and the inside of the air knife will have a circular passage through which the cyclone dust passes. However, the present invention is not so limited. Other geometric shapes are within the scope of the present invention. For example, the pipe transporting the cyclone dust and the inside passage of the air knife could be oval shaped or even rectangular.

The gas stream created by air knives of the present invention has a velocity sufficient to blow most or all hygroscopic material from the inside wall of the air knife. In this manner, the air knife reduces the amount of hygroscopic material that can accumulate, significantly reducing the chance that the entrance to the suspension vessel can be blocked by accumulated hygroscopic material. When used in a TiCl_4 production process to reduce cyclone dust accumulation, the gas stream will preferably have a velocity of at least 30 meters/second (100 feet per second), and more preferably, at least 60 meters per second (200 feet per second). Still more preferably, the gas stream will have a velocity of at least 120 meters/second (400 feet per second). While some applications of the present invention may require a gas stream velocity of greater than 150 meters/second (500 feet per second), preferably the gas stream velocity is no more than 150 meters/second (500 feet per second).

The gas stream created by the air knife generally travels in the same direction as the direction in which the hygroscopic material moves through the air knife. In one embodiment, the gas stream travels parallel to the direction of the hygroscopic material. However, it is

within the scope of the present invention to adapt the air knife to create a gas stream that travels at an angle to the direction of the hygroscopic material, causing the gas stream to travel in a spiral motion when the air knife passage is circular.

Figure 2 illustrates a process **200** utilizing an air knife **202** according to the present invention in conjunction with a cyclone separator **206** and a suspension vessel **204**. The solids-laden gases are introduced into the cyclone separator **206** at the tangential inlet **208**. Inside the cyclone separator **206** the solids and gases are separated. The gases exit the cyclone separator through a gas outlet tube **210** and gravity causes the solids to collect at the bottom **212** of the cyclone separator **206**. A two-valve dump spool leg **214** minimizes the amount of gas that is dumped along with the cyclone dust. A pipe **216** connects the dump spool leg **214** with the air knife **202**. Cyclone dust that is dumped from the two-valve dump spool leg **214** falls through the pipe **216** and through the air knife **202** into the suspension vessel **204**.

Figure 3 illustrates a cut away view of an air knife **300** according to the present invention. Hygroscopic material **302** enters the air knife **300** via a pipe **304** such as the pipe **216** shown in Figure 2 and travels down through the air knife **300** in the direction indicated by the arrow **306**.

The air knife **300** comprises three overlapping wall sections **308**, **310**, and **312**. The overlapping portions of the wall sections form gaps through which gas is forced. The gaps face in the same direction in which the cyclone dust moves. By facing in the same direction it is meant that the gas forced through the gaps moves through the air knife in the same direction as the cyclone dust. Preferably, air knives of the present invention will comprise at least two different circumferential gaps through which gas is forced. Generally, the size of the gap (that is, the distance between two wall sections) is no more than 0.18 cm (0.07 inches), and preferably no more than 0.13 cm (0.05 inches). In one embodiment, air knives having a gap size of 0.09 cm (0.036 inches) have been advantageously utilized in a TiCl_4 production process to keep hygroscopic cyclone dust from accumulating on the walls of the air knife.

Air knives according to the present invention have at least one gas intake. Typically, air knives of the present invention will have between two and four gas intakes. In Figure 2,

gas flows into the gas intake **314** and travels in the direction indicated by the arrows. The gas is forced through the gaps between the wall sections **308**, **310**, and **312** at a velocity sufficient to blow most or all hygroscopic material from the inside part of the wall sections **308**, **310**, and **312** of the air knife. The gas velocity is calculated in a conventional manner, by dividing
5 the gas flow into the gas intakes by the cross-sectional area of the circumferential gap.

Figure 4 illustrates a top-down view of the air knife **300** shown in Figure 3. As seen in Figure 4, the air knife **300** has four gas intakes. The air knife **300** also comprises a series of bolts **316**. The bolts **316** on this embodiment of the present invention are used to fasten the air knife **300** to a suspension vessel. However, other methods for attaching air knives to
10 suspension vessels are within the scope of the present invention. Figure 4 also shows the opening **318** at the center of the air knife **300** through which the cyclone dust passes on its way to the suspension vessel. Air knives according to the present invention have been advantageously utilized at the entrance to a suspension vessel in a TiCl_4 production process without requiring additional ventilation in the suspension vessel.

As shown in Figure 4, the wall sections of the air knife **300** can be attached to each other by small spot welds **320** placed between the wall sections of the air knife **300**. That is, these spot welds **320** are in the gaps between the wall sections. The size of the spots welds **320** is not particularly critical so long as they are not so large as to interfere with the flow of
15 gas through the gaps.

Air knives of the present invention can be manufactured using any material suitable for the intended application. An appropriate material can be determined without undue experimentation. Typically, air knives utilized in a TiCl_4 production process will be manufactured from a corrosion resistant alloy such as Inconel 600 or Inconel 601
20 (commercially available from various steel and alloy distributors).

Gases suitable for use with air knives of the present invention may depend on the particular application in which the air knife is used. However, appropriate gases can be determined without undue experimentation. Gases preferred for use with air knives in a TiCl_4 production process include air, nitrogen, argon, carbon dioxide or any other gas that
25 will not appreciably react under the conditions prevailing in the air knife.

While the present invention has been described in detail with respect to specific embodiments thereof, it will be appreciated that those skilled in the art, upon attaining an understanding of the foregoing, may readily conceive of alterations to, variations of, and equivalents to these embodiments. For example, air knives of the present invention can be advantageously utilized in applications in addition to the production of TiCl_4 . It is within the scope of the present invention to utilize the novel air knives of the present invention in many applications benefiting from the present invention's ability to reduce buildup of materials during transport from one vessel to another, such as through a tube or pipe. Accordingly, the scope of the present invention should be assessed as that of the appended claims and any equivalents thereto.

What is claimed is:

1. An air knife, comprising:
a plurality of overlapping wall sections defining a passage having a
5 circumference, the passage being adapted to allow solid materials to pass through the air
knife in a first direction;
at least two overlapping wall sections forming a gap between them; the gap
facing in the first direction; and
at least one gas intake connected to the gap in a manner causing gas entering the
10 intake to pass through the gap and into the passage along the circumference of the passage.
2. The air knife of Claim 1, wherein the circumference is circular.
3. The air knife of Claim 1, wherein the gap is no more than 0.18 centimeters.
4. The air knife of Claim 1, wherein the gap is no more than 0.13 centimeters.
5. The air knife of Claim 1, wherein the air knife is connected to a cyclone
15 separator.
6. The air knife of Claim 5, wherein the cyclone separator separates hygroscopic
solids from gases.
7. The air knife of Claim 1, wherein the air knife is attached to a suspension vessel
adapted to receive solids including hygroscopic solids from a cyclone separator.
8. The air knife of Claim 7, wherein the suspension vessel encloses a high-humidity
20 environment.
9. A method for reducing buildup of solid material on the inside surface of a
passage as the solid material passes through the passage, comprising:
injecting a gas stream along the inside surface of the passage in the direction the
25 solid material is passing through the passage.
10. The method of Claim 9, wherein the solid material is hygroscopic.
11. The method of Claim 9, wherein the solid material is cyclone dust from a cyclone
separator.

12. The method of Claim 9, wherein passage is exposed to a high-humidity environment.

13. The method of Claim 9, wherein the gas stream is injected at a velocity of at least 30 meters per second.

5 14. The method of Claim 9, wherein the gas stream is injected at a velocity of at least 60 meters per second.

15. The method of Claim 9, wherein the gas stream is injected at a velocity of at least 120 meters per second.