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# Staged Enclosure Dust Suppression With Induced Air Balance


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## Abstract

This disclosure describes an arrangement for suppressing dust at bulk material transfer points. It employs a staged enclosure around the material drop zone, paired with an induced air balance system. The enclosure design promotes staged particle settling while skirt seals minimize uncontrolled air ingress. An air extraction system maintains a net inward airflow, preventing dust escape. The induced air volume is determined by material flow characteristics and drop height, ensuring efficient capture of airborne particles. Adaptations for sticky materials are also detailed, addressing potential accumulation and flow issues within the system.


## 1. Technical Field

[0001] The technical field is the handling and transfer of bulk materials, specifically concerning the control and suppression of airborne particulate matter generated during material transfer operations between conveyors.

## 2. Technical Context

[0002] When bulk materials are transferred from an upper conveyor (10) to a lower conveyor (14), or into a receiving chute, the falling material entrains air. This entrained air, along with displaced air within the transfer chute (12) and receiving enclosure, is forced out of any available openings. As this air exits, it carries fine particulate matter, commonly referred to as dust, into the surrounding environment. This uncontrolled release of dust presents operational challenges, including potential visibility issues, equipment wear, and material loss. The primary problem addressed is the expulsion of dust from the transfer point due due to air currents generated by the falling material.

## 3. System Overview

[0003] The dust suppression system incorporates a staged settling enclosure (16) integrated with an induced air balance mechanism. As illustrated in FIG. 1, bulk material is transported by an upper conveyor (10) and discharged into a transfer chute (12) where it falls onto a lower conveyor (14). The entire transfer zone is enveloped by the staged enclosure (16). This enclosure is designed to contain the material drop and create zones of reduced air velocity, allowing dust particles to settle. An air extraction fan (18) is connected to the enclosure (16), drawing air and entrained dust particles into a dust collector (20) for separation. The system maintains a net negative pressure or balanced airflow within the enclosure (16) to prevent dust from escaping through the material entry and exit points. Skirt seals (26, 28) are employed at the interface between the enclosure (16) and the conveyors (10, 14) to minimize uncontrolled air ingress and maximize the effectiveness of the induced airflow.

## 4. Components

[0004] The system primarily comprises the following components:

[0005]

- **Upper Conveyor (10):** Transports bulk material to the transfer point.
- **Transfer Chute (12):** Guides the falling material from the upper conveyor (10) to the lower conveyor (14). The chute walls (22) define the primary material flow path.
- **Lower Conveyor (14):** Receives the material from the transfer chute (12) and transports it onward.
- **Staged Enclosure (16):** A multi-chambered structure surrounding the transfer point. It is fabricated from sheet steel or other suitable material, with internal baffles (24) or shelves arranged to create multiple zones. The enclosure defines the volume within which dust is contained and air is managed.
- **Internal Baffles (24):** Plates or structures positioned within the staged enclosure (16). These serve to increase the path length for airborne dust, reduce air velocity in specific zones, and promote gravitational settling of larger dust particles. As shown in FIG. 2, they create a tortuous path for air.
- **Air Extraction Fan (18):** A centrifugal or axial fan sized to draw a specific volume of air from the staged enclosure (16). It creates the negative pressure differential required to induce airflow into the enclosure and direct dusty air towards the dust collector (20).
- **Dust Collector (20):** A filtration unit, such as a baghouse or cyclone separator, designed to remove particulate matter from the air stream drawn by the air extraction fan (18).
- **Primary Skirt Seals (26):** Flexible strips, often made of rubber, polyurethane, or similar elastomer, that are mounted along the edges of the transfer chute (12) or enclosure (16) where it meets the lower conveyor (14) belt. These seals exert light pressure on the belt surface to prevent dust leakage and minimize uncontrolled air ingress.
- **Secondary Skirt Seals (28):** Positioned outboard of the primary skirt seals (26), these provide an additional barrier against dust escape and further reduce air ingress. They are typically made of a softer, more compliant material than the primary seals.
- **Air Inlet Louvers (30):** Strategically placed openings in the enclosure (16) walls, often equipped with adjustable blades, to allow controlled ingress of ambient air. These inlets help balance the internal pressure and direct airflow patterns.
- **Access Panels (32):** Hinged or removable panels in the enclosure (16) walls to permit inspection, maintenance, and clearing of blockages. They are fitted with gaskets to ensure airtightness when closed.
- **Level Sensors (34):** Non-contact sensors, such as ultrasonic or radar types, installed within the chute (12) or enclosure (16) to monitor material accumulation.

## 5. Operation

[0006] The system operates to contain and extract dust generated during material transfer.

[0007] **Start-up:** Upon initiation, the air extraction fan (18) is activated, establishing a negative pressure within the staged enclosure (16). This creates an immediate inward airflow at all enclosure openings, including the gaps around the conveyors (10, 14) and any designated air inlets (30). Once the airflow is established, the upper conveyor (10) and lower conveyor (14) are started, and material flow commences. The fan (18) typically operates continuously while material is being transferred.

[0008] **Steady Running:** As material falls from the upper conveyor (10) through the transfer chute (12) to the lower conveyor (14), it displaces air and entrains additional air. This air, now laden with fine dust particles, is contained within the staged enclosure (16). The internal baffles (24) within the enclosure (16) cause the dusty air to follow an extended, tortuous path, reducing its velocity in stages. This velocity reduction allows larger dust particles to settle out of the air stream due to gravity, falling back into the material flow on the lower conveyor (14).

[0009] Simultaneously, the air extraction fan (18) continuously draws a calculated volume of air from the enclosure (16) and directs it to the dust collector (20). The collected dust is then discharged from the collector (20) for disposal or return to the material stream, and cleaned air is exhausted or returned to the environment. The primary skirt seals (26) and secondary skirt seals (28) maintain contact with the lower conveyor (14) belt, preventing dust escape and minimizing uncontrolled ambient air ingress at the discharge end of the transfer. Controlled air ingress occurs through engineered air inlet louvers (30), which are positioned to direct ambient air into the enclosure (16) in a manner that assists dust capture and directs it towards the fan take-off point. The induced air volume drawn by the fan (18) is estimated to be sufficient to overcome the air displaced and entrained by the falling material, plus a safety margin, thereby maintaining a net inward airflow at all openings.

[0010] The induced air volume required is estimated based on several factors. The volume of displaced air is approximately equal to the bulk volume of material passing through the transfer point per unit time. The volume of entrained air is a function of the material's bulk density, particle size distribution, and the drop height ($H$) of the material. For a given material flow rate ($M$ in kg/s) and material bulk density ($\rho$ in kg/m$^3$), the volumetric flow rate of material ($Q_m$ in m$^3$/s) is $M/\rho$. The air displaced is directly related to $Q_m$. The entrained air volume can be estimated as a factor (typically 1 to 3 times) of the material volumetric flow rate multiplied by a function of the square root of the drop height ($H$ in meters) and the gravitational acceleration ($g$ in m/s$^2$), representing the velocity of the falling material. A more detailed estimation considers the cross-sectional area of the falling stream and the relative velocity between the material and the surrounding air. For a typical bulk material with a drop height of 3 meters and a material flow rate of 500 tonnes per hour (approx. 0.16 m$^3$/s volumetric flow), the entrained air volume can be approximated to be between 0.5 to 1.5 m$^3$/s, requiring the fan (18) to draw a minimum of this volume plus any air required to establish inflow through the sealing gaps, often totaling 1 to 3 m$^3$/s or more depending on enclosure leakage and desired capture velocity.

[0011] **Fault or Interruption:** In the event of a material flow interruption or conveyor stoppage, the air extraction fan (18) typically continues to operate for a predefined period (e.g., 5-10 minutes) to clear any residual dust from the enclosure (16) and ducting before shutting down. This prevents dust settling in the ductwork. If a blockage occurs within the transfer chute (12), as detected by level sensors (34), the material feed from the upper conveyor (10) may be automatically stopped, and an alarm activated. The fan (18) continues to run to clear dust. Access panels (32) can then be opened for inspection and clearing.

## 6. Example Embodiments

[0012] **Embodiment 1: Standard Duty Aggregate Transfer** This embodiment is configured for dry, granular materials such as crushed aggregate or sand, with a maximum particle size of 50 mm. The staged enclosure (16) features three internal baffles (24) spaced vertically, creating four distinct settling zones. The primary skirt seals (26) are made of 70 Shore A durometer rubber, approximately 10 mm thick and 200 mm tall, with an initial compression of 10 mm against the conveyor belt (14). The secondary skirt seals (28) are softer 50 Shore A rubber, 6 mm thick, installed with an overlap of 50 mm over the primary seals (26). Air inlet louvers (30) are positioned on both sides of the enclosure (16) at the upper conveyor (10) entry point, totaling an open area equal to 1.5 times the cross-sectional area of the main dust extraction duct. The air extraction fan (18) is sized to provide a minimum capture velocity of 0.5 m/s at the largest uncontrolled opening, calculated to be approximately 3000 $m^3$/hr for a typical transfer point handling 1000 tonnes per hour of material.

[0013] **Embodiment 2: Fine Powder Transfer with High Dust Generation** For fine, dry powders like cement or flour, where dust generation is significant, the enclosure (16) is designed with additional internal baffling (24) and a longer air path, creating five or six settling stages. The internal surfaces of the enclosure (16) are coated with a low-friction polymer to reduce dust adhesion. Both primary (26) and secondary (28) skirt seals are fabricated from a high-wear, low-friction polyurethane material, each with individual spring-loaded mechanisms to maintain consistent, low-pressure contact with the belt (14) despite belt undulations. The air extraction fan (18) is sized for a higher induced air volume, often 2.5 to 4 times the volumetric material flow rate, to ensure a strong inward draft and high capture efficiency. Air inlet louvers (30) are designed with a labyrinthine structure to minimize uncontrolled air velocity while allowing sufficient flow.

[0014] **Embodiment 3: Wet or Sticky Material Transfer** For materials with high moisture content or inherent stickiness, such as clay, iron ore fines, or wet coal, the design requires modifications to prevent material buildup within the transfer chute (12) and enclosure (16). The internal surfaces of the chute (12) and enclosure (16), especially the baffles (24), are constructed from stainless steel or lined with ultra-high molecular weight polyethylene (UHMW-PE) to promote material flow and resist adhesion. The angles of the internal baffles (24) are steeper, typically 60 to 70 degrees from horizontal, to encourage self-cleaning. Instead of multiple settling stages, a single, larger plenum may be used to minimize surfaces for material accumulation. Optionally, vibrators (36) or external heating elements (38) may be affixed to the chute (12) and enclosure (16) walls to prevent material buildup. The skirt seals (26, 28) are designed to be easily accessible for cleaning and may incorporate a scraping element. The induced air volume may be slightly reduced compared to dry materials, as the moisture content naturally agglomerates some dust, but sufficient airflow is maintained to prevent moisture condensation and subsequent dust adherence to internal surfaces.

## 7. Alternative Configurations

[0015] The induced air system can be configured with a variable frequency drive (VFD) controlling the air extraction fan (18) speed. This allows adjustment of the induced air volume and static pressure within the enclosure (16) to optimize performance for varying material flow rates or material types, for instance, reducing airflow when handling coarse, low-dust material and increasing it for fine, dusty material. Alternatively, the dust collector (20) may be replaced by a wet scrubber for applications where the dust is particularly fine or requires conditioning with moisture for disposal. The primary and secondary skirt seals (26, 28) can be designed with a shingled arrangement of multiple thinner strips instead of single thick strips, which can improve sealing effectiveness on uneven belt surfaces. The air inlet louvers (30) can be replaced with baffled openings that draw air from a less dusty location or through a pre-filter to reduce the load on the main dust collector (20).

## 8. Parameter Variations

| Parameter | Realistic Range | Effect of Increasing Value | Effect of Decreasing Value |
|---|---|---|---|
| **Material Drop Height (H)** | 0.5 to 5.0 meters | Increases air entrainment and displacement; requires higher induced air volume and potentially more vigorous baffling. | Reduces air entrainment and displacement; lowers required induced air volume and less aggressive baffling. |
| **Material Flow Rate (M)** | 50 to 5000 tonnes/hour | Increases material volume, leading to greater air displacement; higher induced air volume and fan capacity required. | Decreases material volume, reducing air displacement; lower induced air volume and fan capacity may be sufficient. |
| **Number of Internal Baffles** | 2 to 6 | Increases settling stages, improving dust capture at lower air velocities; may increase risk of material buildup. | Reduces settling stages, requiring higher induced air volume for effective capture; less resistance to material flow. |
| **Skirt Seal Compression** | 5 to 20 mm | Improves sealing effectiveness; increases friction and wear on conveyor belt; higher power consumption for conveyor drive. | Reduces friction and wear; increases potential for dust leakage and uncontrolled air ingress. |
| **Induced Air Volume (Q_air)** | 1 to 5 $m^3/s$ | Enhances dust capture and containment; higher energy consumption for fan; potentially draws in more ambient air, cooling material. | Reduces dust capture effectiveness; increased risk of dust escaping; lower energy consumption for fan. |
| **Enclosure Internal Velocity** | 0.2 to 1.5 m/s | Better capture of fine particles; higher energy consumption; increased potential for re-entrainment if too high. | Allows heavier particles to settle; reduced capture of fine particles; potential for dust accumulation on surfaces if too low. |
| **Internal Surface Friction Coeff.** | 0.05 to 0.4 (UHMW-PE to Steel) | Reduces material buildup on internal surfaces; promotes self-cleaning. | Increases material buildup, especially with sticky materials; requires more frequent cleaning or auxiliary vibrators. |

## 9. Additional Implementations

[0017] The system can incorporate a pre-separator cyclone upstream of the main dust collector (20) to remove larger entrained particles, reducing the load on the final filtration stage and potentially extending the life of filter media. For applications where the bulk material is particularly abrasive, the internal surfaces of the transfer chute (12) and key areas of the enclosure (16) can be lined with wear-resistant materials such as ceramic tiles, basalt, or abrasion-resistant steel alloys. An automated cleaning system, such as pulsed air cannons or vibrating panels, can be integrated into the staged enclosure (16) and transfer chute (12) walls, particularly when handling sticky or cohesive materials. These systems would operate intermittently to dislodge accumulated material. For very fine or health-critical dusts, the air extraction system may incorporate a safety interlock that prevents conveyor operation if the air extraction fan (18) is not running or if flow sensors detect insufficient airflow. The control system can include differential pressure sensors across the skirt seals (26, 28) and across the internal baffles (24) to monitor airflow distribution and potential blockages within the enclosure (16). The system can be designed with a positive pressure zone at the bottom of the enclosure (16) using a small auxiliary fan and controlled air inlets to create an air curtain effect, further preventing dust from escaping downwards along the conveyor belt (14).

## 10. Figures

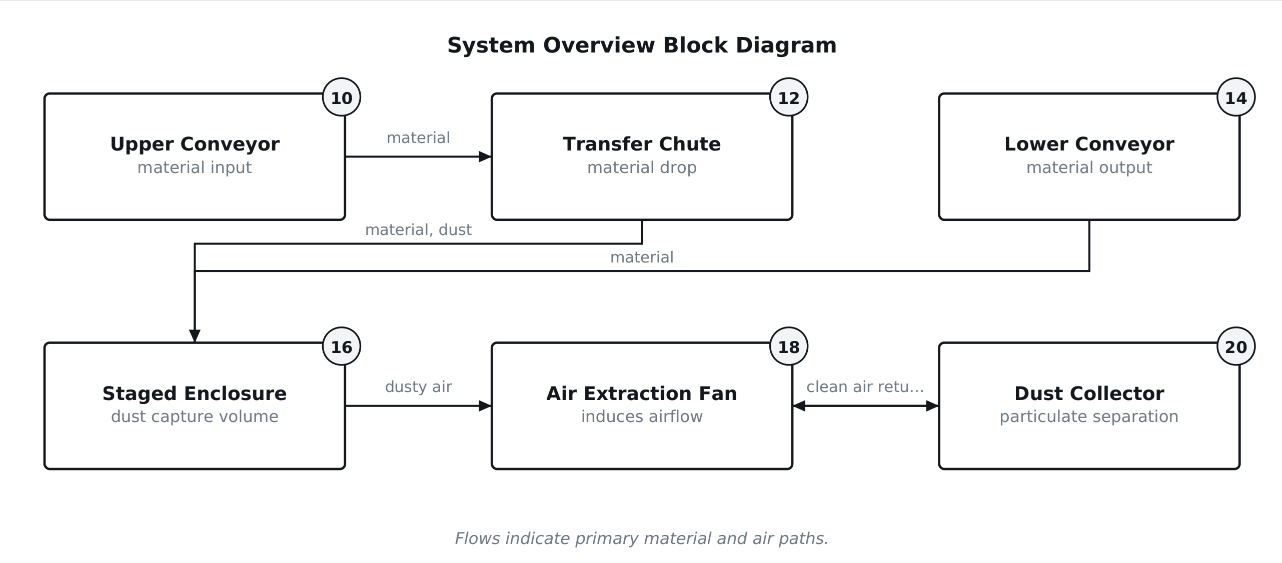


**FIG. 1** A block diagram illustrating the primary functional components of the dust suppression system. PNG

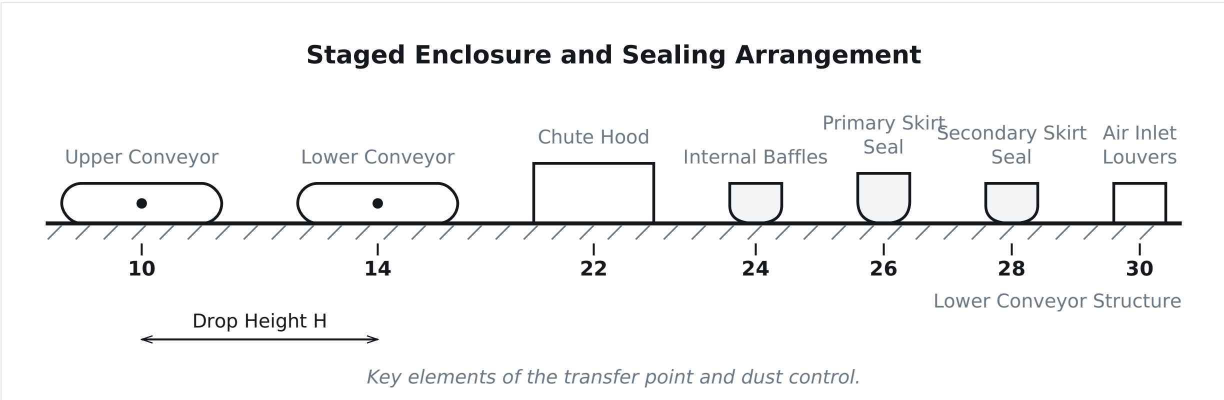


**FIG. 2** An elevation view detailing the staged enclosure, material flow, and skirt sealing elements. PNG

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