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Master Thesis

Airflow in transfer points of conveyor belts for bulk material handling

Modelling the airflow to optimize passive dust control

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Leoben, June 2010

AFFIDAVIT

I declare in lieu of oath, that I wrote this thesis and performed the associated research myself, using only literature cited in this volume.

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Kurzfassung

Luftströmungen in Übergabe Stellen von Förderbändern für den Schüttgut Transport

Modellieren der Luftströmungen zur Optimierung der Passiven Staub Kontrolle

Die Staubentwicklung im Bergbau stellt ein Problem für die Umwelt und die in der Produktion beschäftigten dar. Ein großer Teil des Staubs entsteht im Zuge des Material Transports. Bei Transport von Schüttgut kommt es besonders im Bereich von Förderbandübergaben zu einer erhöhten Staubbelastung.

In Länder mit einem eingeschränkten Wasserangebot muss über alternative Methoden der Staubbekämpfung nachgedacht werden. Das „Dust Project“ beschäftigt sich mit passiver Staubkontrolle. Um diese zu verbessern ist es wichtig die Form der Luftströmungen in einem Übergabe Punkt zu erfassen. Dies wurde mithilfe einer von mir entworfenen Anlage versucht. Die Versuche wurden mit unterschiedlichen Fallhöhen durchgeführt. Außerdem ermöglicht die Anlage den Einbau unterschiedlicher Schuren um Übergaben möglichst realitätsnah darzustellen. Ebenso wurde ein Teil der Versuchsanlage durch eine Schleuse abgetrennt um der Luft die Möglichkeit zu geben sich zu verlangsamen und so das Absetzen der Staubpartikel zu ermöglichen.

Die Versuche haben gezeigt, dass es möglich ist durch die Form der Übergabe die Luftströmungen zu beeinflussen. Dies könnte in Zukunft helfen die Passive Staubbekämpfung bei Förderbandübergaben zu verbessern.

Abstract

Airflow in transfer points of conveyor belts for bulk material handling

Modelling the airflow to optimize passive dust control

Dust created in mining operations poses a threat not only to the environment but also to the labourers engaged in production processes. One of the greatest sources of dust is the material handling process. The transfer points located along conveyer belt systems in the bulk material handling operations are the areas where most of the dust is produced.

In countries where water supplies are limited, engineers must come up with alternative solutions to control the dust created in mining operations. The “Dust Project” focuses on passive dust control. To optimize passive dust control, it is essential to understand the shape of the air currents in the transfer points along the conveyer belt systems. In order to study the air currents within these transfer points, I designed a test rig which models these kinds of transfers. The test rig was designed such that experiments with different drop heights could be conducted. Furthermore, the rig’s design allows one to incorporate different chutes. The material stream can be guided by impact plates and chutes, just like in a real transfer point. Additionally, a part of the test rig can be separated by a gate which allows the air to slow down in order for dust particles to settle.

The experiments illustrated that the shape of the transfer can influence the air currents. This can help optimize the passive dust control in conveyer belt transfer points.

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1 Introduction

The experimental part of this thesis was done in Newcastle, Australia, in the labs of Tunra Bulk Solids. Tunra Bulk Solids Handling Research Associates is a division of Newcastle Innovation Ltd. Newcastle Innovation was established in 1969 and is the commercial arm of the University of Newcastle.

Tunra Bulk Solids was founded in 1975 for consulting activities by a group of researchers from the department on Mechanical Engineering in the field of bulk material handling. The main field of research is the handling of bulk material mostly for the mining industry but also for minerals and chemical processing, food production and pharmaceutical companies. Since the founding of the company over 2000 major projects for over 600 australian and international companies have been completed.

Tunra Bulk Solids is in an association with the Centre for Bulk Solids & Particulate Technologies. Together they undertake research projects in bulk material handling. This center was established as one of the national Centres of Teaching and Research in 1995. [1]

1.1 Problem

The generation of dust in material handling operations causes several problems. On one hand we have the influence on the health of the labourers working in the operation; on the other hand we have the environmental impact. In countries without a lack of water mining companies usually use water sprays to minimise the dust generation. Especially in Australia with its large scale mining operations and the lack of water, engineers have to think about a different way of dust control. Research is done in the field of passive dust control. One of the main sources for dust generation in material handling is the transfer of the material from one conveyor to another. To be able to control the dust it is necessary to understand the airflow within a transfer point.

1.2 Target

As a part of the dust project the goal of this thesis work was to design and build a transfer point of two conveyor belts to show the airflow within the transfer to help understand the generation of dust. The goal was to create a test rig with a circulating material flow. The rig should be flexible in terms of drop height as well as material flow and it should be possible to put in different chutes to guide the material stream.

The results of the tests will be compared with the results of simulations done by Xiao Ling Chen.

2 Basic Information

2.1 General Background

Mining activities are causing a lot of dust. Especially in open pit operations. The first source of dust in the extraction process is drilling and blasting. With the impact of the energy released by the explosives the rock mass gets broken down to small pieces and particles. The turnover of explosives also generates a lot of air volume. The air flow helps particles to become airborne. The mixture of air and particles is well known as dust. This dust can be minimised by watering the rock mass before the blast. Usually this source of dust doesn't cause that many problems. Normally there is no direct contact between the mine and people living nearby. The dust is mainly generated during the blast and there are no workers in the area, so usually the dust settles down before the work goes on and the labourers are protected by the cabin of the equipment used in the mine. To reduce the generation of dust it is also useful to pay attention to the weather. After or during rain the amount of dust created by the blast can be reduced. If we pay attention to the direction and strength of the wind we can also reduce the impact of the dust on the environment.

Another source of dust is the loading of the material on trucks. The dust can also be reduced by watering the blasted material or with less ado by reducing the fall height of the material when the truck gets loaded. One of the biggest origins of dust is the material transport. If the material is transported by truck a lot of dust is generated during driving. Material that falls off the trucks breaks under the heavy load of the truck when the wheels drive over it. There is also a big effect from the air turbulence caused by the motion of the truck. This source can be minimised by watering the street, reducing the speed and sealing off the road surface.

Dust generation in processing can easily be controlled by housing the plant and its equipment. In that case dust extraction systems are used. They try to collect the dust at the source but are very energy intensive. The collected dust requires some treatment as well.

2.2 Dust generation in bulk Material handling

The dust is mainly due to industrial production processes where the greatest part, about 90%, is caused by storage and transfer of bulk solids [2]. During material handling there are many operations which can cause dust. Dust is always generated when particles become airborne. The property of a material to produce dust is called dustility or dustiness [3]. To get particles airborne, the aerodynamic drag force on the particle must be higher than the particle weight and the cohesion force.

[Aerodynamic drag force] > [Particle weight] + [Force of the cohesion of the particle to the bulk powder] [3]

$$\frac{1}{2} c \rho a V^2 \geq mg + F$$

C= the fluid drag force coefficient

ρ= the density of air

a= the area of the particle presenting resistance to air

V= the velocity of the air relative to the particle

m= the mass of the particle

F= the cohesive force holding the particle to its neighbours

The equation shows that the amount of particles that become airborne is a function of the particle size, the air velocity and the cohesive force. The cohesive force of a material is a function of its moisture content. In most applications of bulk material handling we can not affect the particle size and the moisture content. They are given by the material that we have to transport or by the product we have to deliver.

That shows that we can influence the mass of dust particles through changing the air velocity. The speed of the air relative to the speed of the particles depends on the process of material handling. A range of possible processes is shown in figure 1.

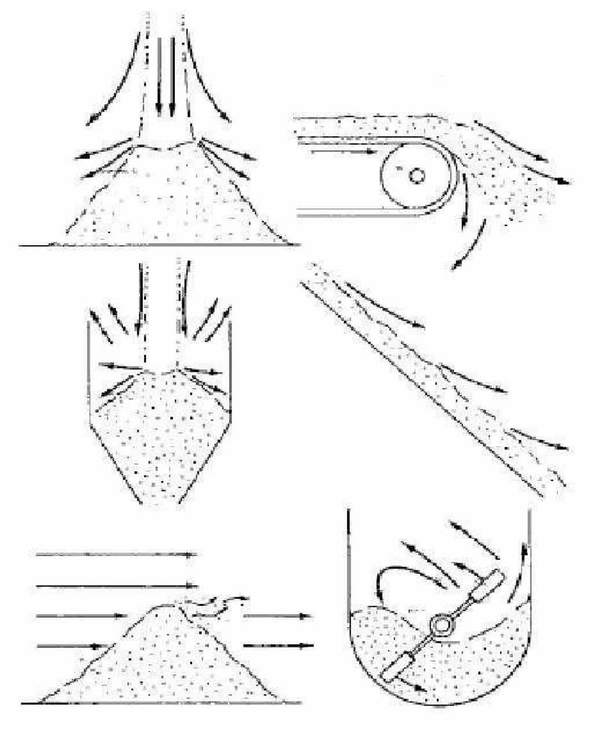


Figure 1: Examples of dust dispersion processes [3]

The Picture shows six different examples of dust dispersion processes. Dust is generated by:

- a falling stream, for example dropping material on a stock pile
- a projected stream, for example a belt tripper

- displacing air, for example filling a hopper
- on chutes
- wind and droughts, for example uncovered stockpiles
- processing, for example mixing

Schofield speaks about several ways of reducing the amount of dust generated during material handling processes. Those are shown in Table 1.

Reducing External (Pulvation) Forces	Increasing Particle Size	Increasing Particle Cohesion
Reduce heights of fall.	Granulate or agglomerate.	Spray water/wetting agent onto stockpiles and flowing systems to increase cohesion at the surface of the bulk.
Shield material from external air.	Sieve out fines and recycle.	
Reduce conveying velocities.	Delay comminution to just before the process requiring it.	Mix water or compatible oil with bulk - may be combined with agglomeration.
Arrange continuous flow rather than dumping.		
Reduce surface area to volume ration of flowing stream.		
Use gentle conveyors or processes to prevent undue crushing of particles or granules.		
Minimise handling.		

Table 1: Methods of reducing dust emissions at source [3]

It is not always possible to change the properties of material in the ways shown in table 1. We have to deliver the material with the characteristics our customers want it with, or how we need it for further processing.

2.3 Dust and labour

Dust will also affect people working in a material handling operation or plant. Most countries have rules and regulations regarding how much dust is allowed at the workplace. In Austria, for example, the law speaks about the “MAK-Wert”, which means maximum workplace concentration. For particles without any other threat to health, this maximum concentration is:

- 10 mg/m³ for breathable particles
- 5 mg/m³ for particles that are alveolar [4]

The law says that companies have to stay under these limits. A special problem for the workers is dust that contains silica. The inhalation of crystalline silica dust can cause Silicoses. This lung disease can cause death.

2.4 Loss of material

To get an overview of the costs for the processing industries caused by dust, a study was conducted in the United Kingdom in the year 1987. For this study eight representative plants operating in the field of large scale bulk material handling were visited. The committee of this study took a survey of the following objectives:

- To take the eight plants as a representative for all U.K. industries

- Determine the cost of the material turned into dust, mess and spillage in the material handling operation as well as the cost for cleaning
- Identify the areas that cause the problems and are typical for industries in bulk material handling
- To find successful solutions to those problems [5]

2.4.1 Properties of bulk material

The problems that we have in bulk material handling arise from the physical properties of the material. With the few on dust generation, we have two categories of material that cause the most problems concerning dust generation, mess and spillage. We have the fine, dry, dusty types of material as well as the wet and sticky ones.

The main problem caused by fine and dry material is that the particles become airborne easily. The air currents around the material handling equipment can cause enough drag force to take the fine particles out of the material stream. Usually these particles are very fine, with means, depending on the strength of the currents, the particles can be carried away from the source very easily. For example, the settling velocity of silica in the air for a 100 µm particle is about 300 mm per second, for a 1 µm particle it is just 1 mm in 30 seconds. This type of dust generation is difficult to handle and usually appears as a dust cloud covering the operation. Depending on the material it can cause health problems for the labourers and people living nearby. In closed areas, special types of material such as coal dust or flour dust can become an explosive mixture.

The second group of material causing big problems is the wet and sticky one. They don´t cause problems with particles becoming airborne, but with material sticking on conveyor belts or chutes. If material starts to build up, this usually ends if the gravity gets bigger than the cohesion force. The built up cake falls down and can cause spillage and mess, in the worst case, damage to the structure or equipment. If material sticks on chutes, it can cause blockage in the transfer points. Material sticking on conveyor belts can block idlers and cause spilling along the belt track.

Both cases will require an extra amount of maintenance work and can reduce the live cycle of the equipment. [5]

2.4.2 Results from the study in the United Kingdom

Plants that were part of the studies

The following table shows the different plants that were part of the studies. The plants provided data to get an overview of the costs caused by dust, mess and spillage.

No.	Plant	Bulk material covered in Survey		Bulk material not covered
		Type	1,000 t/a	
1.	Power Station	Coal	2000	Pulverised fuel ash
2.	China Clay Producer	China clay	2650	Sand
3.	Lead/Zinc smelter	Lead/zinc ores	236	Coke
		sinter	236	
4.	Flour mill	Grain	66	
		Flour	55	
		Bran etc.	11	
5.	Cement works	Limestone & Shale	1155	Coal
		Cement	700	
6.	Fertiliser manufacturer	Phosphate rock	100	Sulphur
		Potash	53	Limestone
		"Nitram"	100	Talc
		"NPK"	200	
7.	Aluminium smelter	Alumina	300	Coke
8.	Coke works	Coal	800	
		Coke	540	

Table 2: Plants that were part of the studies [5]

Loss of Bulk Material

As we can see, the amount of material lost during the process shows that there is a big difference between facilities that are housed and those that are open. With keeping in mind that at the plants 2, 4, 5, 6 and 8 there will be some more loss of material caused by the end user, the study speaks about an average loss of material of 1 % of the throughput.

No.	Plant	Estimated Loss as % of Total Quantity of Bulk Material Handled	Bulk material not covered
1.	Power Station	0,25	
2.	China Clay Producer	0,75	an additional 1,25% loss by end user
3.	Lead/Zinc smelter	1,00	
4.	Flour mill	very small*	
5.	Cement works	small*	
6.	Fertiliser manufacturer	small* small*	
7.	Aluminium smelter	1,50	
8.	Coke works	small*	

* Most of the plant enclosed in buildings

Table 3: Loss of Bulk Material [5]

Spillage Clearance

The costs shown in the next table are based on the number of man-years needed for the spillage clearing. The man-year is calculated with the average cost of a year´s worth of labour in the United Kingdom, which is between 10,000£ - 15,000£. To find the average cost in pence/t, the highest and lowest plant, number 4 & 6 are not taken into consideration. This gives us an average of 6,9 pence/t.

No.	Plant	Bulk material Handled	Estimated Cost of Spillage Clearance	
		1,000 t/a	£ 1,000/a	pence/t
1.	Power Station	2000	160	8,0
2.	China Clay Producer	2650	280	10,6
3.	Lead/Zinc smelter	742	20	4,2
4.	Flour mill	132	very small	0,0
5.	Cement works	1855	162	8,7
6.	Fertiliser manufacturer	453	225	49,7
7.	Aluminium smelter	300	4	1,3
8.	Coke works	1340	116	8,7
	Average (excl. The highest and lowest, 4 & 6)			6,9

Table 4: Cost of spillage clearance [5]

Additional Maintenance

The engineer's management in the visited plants estimates the cost of additional maintenance caused by dust, mess and spillage as a percentage of the normal maintenance cost. Into this estimation the extra costs caused by a more rapid wear of bearings, the extra corrosion and the difficult access and blockage are calculated.

No.	Plant	Bulk Material Handled	Estimated Cost of extra maintenance		
		1,000 t/a	% of Budget	£1,000/a	pence/t
1.	Power Station	2000	NA	-	-
2.	China Clay Producer	2650	20	150*	5,7
3.	Lead/Zinc smelter	472	7	35	7,4
4.	Flour mill	132	very small	0	0
5.	Cement works	1855	5	68	3,7
6.	Fertiliser manufacturer	453	20	150	33,1
7.	Aluminium smelter	300	10	16	5,3
8.	Coke works	1340	10	19	1,4
	Average (excl. The highest and lowest, 4 & 6)				4,7

* Covers conveyors only

Table 5: Extra Maintenance [5]

Other Costs

The study also explores other or special costs which are connected to dust, mess and spillage. Those costs are not directly but indirectly connected:

Power station: During the unloading of ships on the jetty, coal gets spilled by the grabs while they are unloading the ship. This coal enters the circulating water pipe and fouls condensers and thus causes reduction of the turbine efficiency. While the coal gets stockpiled, water needs to be spayed to reduce the dust.

China clay producer: The spilled material can´t be returned into the process directly. Because of the quality required of the material, it has to be re-processed before it can be re-circulated.

Lead/Zinc smelter: The staff needs to have regular medical checks due to the toxic nature of the lead ore.

Fertiliser manufacturer: The spillage can reduce the throughput of the plant and this can decrease the profitability.

Aluminium smelter: If there is windy weather, the ships can´t be unloaded. The dust generated during unloading will cause nuisance to the nearby town. This will bring some extra demurrage charges to the company. [5]

The following table shows the extent of these other costs:

No.	Plant	Bulk Material Handled	Estimated amount of other costs	
		1,000 t/a	£1,000/a	pence/t
1.	Power Station	2000	245	12,3
2.	China Clay Producer	2650	180	6,8
3.	Lead/Zinc smelter	472	18	3,8
4.	Flour mill	132	-	-
5.	Cement works	1855	-	-
6.	Fertiliser manufacturer	453	150	33,1
7.	Aluminium smelter	300	60	20,0
8.	Coke works	1340	-	-
	Average (excl. Nos. 4, 5, 6 ,8)			10,7

Table 6: Other costs [5]

Total Cost:

The following information shows us the total costs of dust, mess and spillage:

= 1 %		spillage		
loss	+	clearance	6,9	pence / t
		extra		
		maintenance	4,7	pence / t
		other costs	10,7	pence / t
		Total	22,3	pence / t

Total Cost today:

This data comes from the year 1989. We calculate the worth of that money today, with the inflation rate of the British pound of 1,9 [6]. This is equal to about 42,37 pence/t. This means about 48 €cent/t with an exchange rate of 1,1331 or 73 cent AUS/t with an exchange rate of 1,7280 [7].

The summary of this study from the United Kingdom shows that dust is not just a problem for workers and the environment but also for the cost-effectiveness of companies involved in mining and material handling operations.

2.5 Dust generation in belt conveying

If one conveys bulk material with belts, there are a few cases that can generate dust. One of those is dust generated during the transport of the material. Especially long overland transport can be a big problem. During the transport the material gets dried by the airflow generated through the speed of the belt as well as by wind. With long overland conveyors we also have the problem that during the transport the material is in motion when the belt runs over the idlers. This can cause friction between the particles and between particles and the belt. Depending on the material properties, this can cause breaking of the particles and therefore increase the number of fines. These fines can easily be picked up by the airflow and generate dust. One way to minimise that problem is to house in the belt. This will raise the construction cost and later on make the maintenance more complicated. But on the other hand the covering also secures the material from natural impacts as well as from being stolen.

Another potential source of a problem are the loading points of the belt. If we have high drop heights onto the belt we are generating dust and causing breakage of the particles. The airflow from the falling material stream can pick up small particles and make them airborne. It is also a problem if the material is not loaded in the center of the belt. This can cause spillage and mess. As shown in the study before, this results in higher production costs and lower productivity. One can solve this problem by guiding the material stream with chutes and by reducing the drop height. More details about that will follow later.

Picture 1: Housed Conveyor Belt; Lafarge, Pichcin, Poland

The third case of dust generation in belt conveying is at the discharge point. In this case we have similar situations as shown before with loading the belt. The bigger the drop height at the discharge point, the more particles will become airborne.

Depending on the material, cleaning the belt can also be an important thing. If we have to convey sticky and wet material, one needs to clean our belt after the discharge. If we don´t pay attention to the belt cleaning, we will cause mess and spillage when the returning belt runs over the idlers. This will be another source of extra maintenance and dust. As we can see in the picture, if the belt doesn´t get a good cleaning after the discharge we have mess and spillage when the belt runs over the idlers. To work against that, we need some equipment to clean the belt. There are many different producers on the market. In some cases it is necessary to clean and wash the belt. The material that sticks onto the belt instead of falling off at the head pulley is called carryback [8]. Fred Kissell says in his “Handbook for Dust Control in Mining”, that the amount of carryback material can be reduced by using two or more belt scrapers or even using a combination of scrapers and washing. If we reduce the amount of carryback we reduce the amount of dust generated by material transport and therefore also the maintenance cost of the operation [8].

Picture 2: Bad Belt Cleaning; PGR, Belchatow, Poland

2.6 Ways to prevent dust

There are a few different ways of dust control and they can be separated into two main groups.

2.6.1 Active dust control

If we mean active dust control we are speaking about all the technical solutions that need the input of energy or other material.

Dust Collection:

If we speak about dust collection we speak about how fans are collecting the dust loaded air at the source. There are two main systems on the market, generally described as the integrated and the conventional system.

The conventional system has several components. We have the exhaust system, which is as close to a specific dust source as possible. The exhaust system usually consists of a hood and some ducting that carries the dusty air to the abatement system and of a fan driven by a motor to provide the necessary exhaust volume. The target in the design of the hood is to make sure that all of the dusty air is collected. When pulvation occurs, some particles can be ejected from the source. After expending that energy the airflow will pick up small particles and they will move around in the local air currents [3]. The point where this happens is the null point which is shown in Figure 2. If we have established the position of the hood and the null point of the material, it is necessary to find the face velocity of the hood. For standard hoods we can find iso-velocity curves in literature [3].

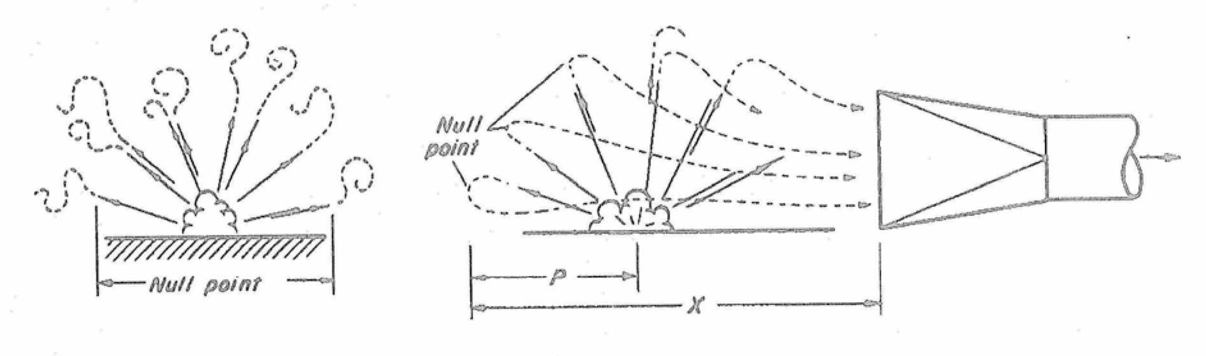


Figure 2: Null point [9]

The next important aspect is the ductwork. It is necessary because the dust collectors and abatement systems are usually too big to be positioned directly next to the source. If we have extensive ductwork we need a high air velocity to transport the dust. If the speed is too low, the particles can settle down in ducts and block them. The amount of pressure loss in the ductwork is dependent on the length, surface, number and types of elbows and transitions. How ducts are designed is also a question of material properties. For example, if we have very abrasive material, the lifetime of the ducts will be shorter unless we use special inlets for the ducts to prevent wear.

The last part of the collection system is the dust collector which should separate the particles from the air. After the separation we have to treat the separated material. In the ideal case we can return this material without treatment back to the process stream. In some cases it has to be processed before this can happen, for example pelletised or in the worst case simply dumped as waste.

These systems have a few problems:

- Large volume of air requires large fans and motors.
- Dust collection equipment usually can´t be located near the source. Additional foundations and structures are required.

- Dusty air needs to be transported to the separation with ducts. Wear of ducts can result in leakage and material settlement can induce blockage.
- The dust-laden air is transported with high velocity which can cause a sandblasting effect. Especially at elbows, extra maintenance is required.
- The dusty air can generate static electricity.
- The dust needs to be disposed of after separation from the air.
- All the equipment needs electrical control and protection [10].

The second principle is the integrated dust collection system. This system contains the dust cloud and allows the particles to settle down and fall back into the material stream. Then it directs and collects the dust which remains in suspension and returns it directly into the material stream. From the idea it is similar to the conventional system, but it separates the dust from the air at the source. We have filters with a lower pressure at the clean side. The dusty air gets sucked through the filter. The dust stays at the inside and starts building up a cake. This cake eventually falls off when it gets too heavy or can be cleaned by shaking for example. Then the cake falls directly back into the material stream. Figure 3 illustrates an integrated dust collection unit.

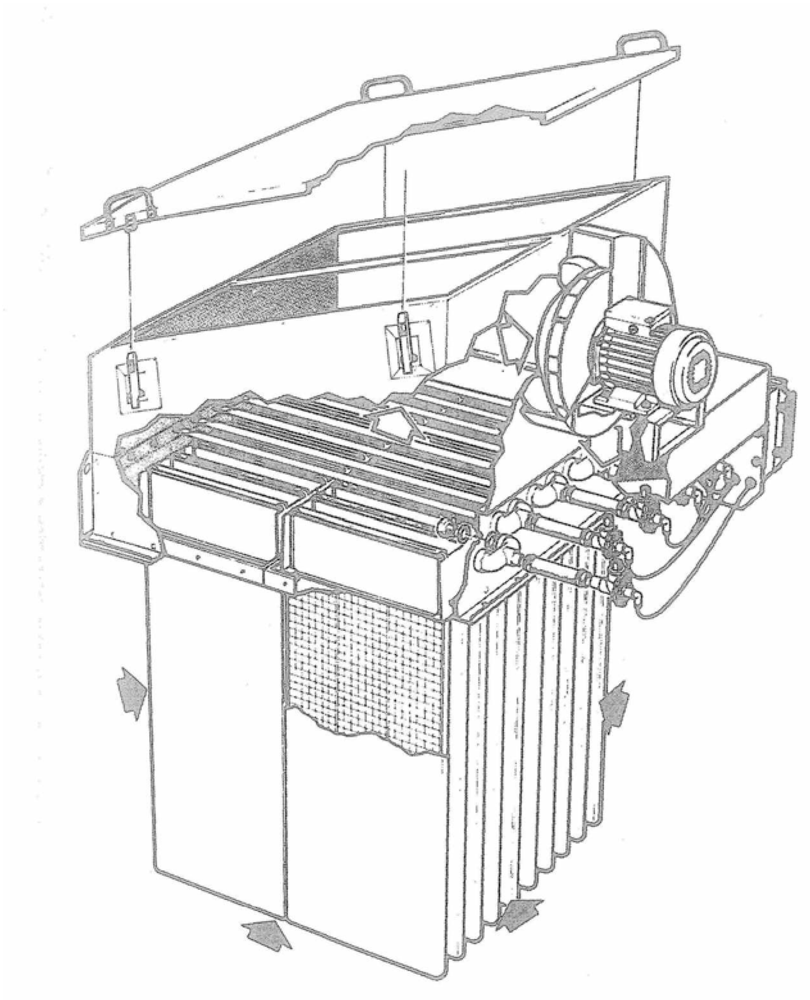


Figure 3: Integrated dust collection system [10]

Wet Dust suppression system:

The idea of this system is to wet the whole material stream to generate less dust. There are three different types in use:

- Plain Water Sprays – In this scenario, plain water gets sprayed onto the material. Depending on the material, it can be difficult to wet the surface of it because of the high surface tension of water.

- Water Sprays with Surfactant – Surfactants added to spray water lower the surface tension. In effect, the water droplets spread further and can penetrate deeper into the material. That way, material can be wet more efficiently.
- Foam – When water gets mixed with a special type of surfactant it turns into foam. With a higher surface area per unit volume the wetting efficiency can be increased [11].

The next table shows the advantages and disadvantages of the different types of suppression systems:

Advantages	Disadvantages
Plain Water Sprays	
It is probably the least expensive method of dust control.	Water sprays cannot be used for products that cannot tolerate excessive moisture.
The system is simple to design and operate.	Water sprays cannot be used when temperatures fall below freezing.
A limited carryover effect at subsequent transfer points is possible.	Usually, dust control efficiency is low, unless large quantities of water are used.
When good mixing of water and material can be achieved, dust generation can be reduced effectively.	Freeze protection of all hardware is necessary.
Enclosure tightness is not essential.	Careful application at transfer points that precede a screen is required to prevent blinding.

	Water Sprays with Surfactants	
This method is used when surfactants are tolerated but excessive moisture is not acceptable.	Capital and operation costs are higher than water-spray systems.
In some cases, dust control efficiency is higher than plain water sprays.	Careful application at transfer points that precede a screen is required to prevent blinding.
Equivalent efficiency is possible with less water.	Equipment such as the pump and proportioning equipment used to meter the flow of surfactant require maintenance.
	Freeze protection of all hardware is necessary.
Foam	
When good mixing of foam and product stream can be achieved, dust control efficiency is greater than water with surfactants.	Operating costs are higher than with finely atomized water-spray systems.
Moisture addition is usually less than 0,1% of the material weight.	The product is contaminated with surfactants.
	Careful application at transfer points that precede a screen is required to prevent blinding.

Table 7: Advantages and disadvantages of wet suppression systems [11]

One of the main factors affecting the efficiency of wetting is the droplet size. The smaller the droplet, the bigger the surface area and thus a greater amount of material can be wet using the same amount of water. Another way to increase the efficiency is to raise the impact velocity of the water. By increasing the impact velocity, the droplets can penetrate deeper into the material. The easiest way to accomplish this is to make the nozzle smaller while increasing the system pressure.

Airborne dust capture:

This type of system uses water sprayed very finely into the airborne dust particles. The idea behind this system is that the particles and the droplets collide and start to build up agglomerates. These agglomerates get heavier and when they are too heavy to stay airborne, they settle down. Two different types are used. These are finely atomised water sprays and electrostatically charged fogs. Atomised water sprays can be used for applications with a dust velocity below 1 m/s, for example at transfer points. If we have higher velocities, one can charge the water drops by induction or direct charging. This effect will increase the collision efficiency between the water particles and the dust particles in the air. The following table shows the advantages and disadvantages of the two systems.

Advantages	Disadvantages
Finely Atomised Water Sprays	
Water requirements are low, typically 5 to 20 gal/h per nozzle.	Tight enclosures are needed for effective system operation.
Moisture addition to the product is quite low, typically less than 0,1% of the material weight.	Requires good droplet to particle size match for effective control.
The material is not chemical contaminated.	The system may not be effective either in highly turbulent environments or when the dust dispersion rate is more than 1 m/s.
The system can be economical.	
Electrostatically Charged Fogs	
Moisture addition to the product is generally less than 0,5% by weight.	Capital costs are high.
The material does not become chemically contaminated.	These systems require high-voltage equipment.
Electrostatic fogs can be effective if the dust cloud carries predominantly positive or negative charges.	These systems are not recommended for underground coal mines or other gassy applications where explosions can be triggered by sparks.
	Maintenance of electrical insulation is critical for safe working conditions.

Table 8: Advantages and disadvantages of airborne dust capture systems [11]

2.6.2 Passive Dust control

The biggest advantage of passive dust control is that no extra energy or water are required. The simplest type of passive dust control focuses on preventing material from being broken down into small particles that can potentially become airborne before the process requires it. But this is not always possible. However, if we plan a processing plant, we can place all the crushing and grinding processes at the very end of the processing cycle to keep the transport distance of small particles as short as possible. The next step in the planning is to keep the air velocities that act on the material stream as low as possible. We have the belt speed as a function of the amount of material we need to transport. If we make the belts bigger we can reduce the speed of the belt and the drag force acting on the material.

In the stage of planning a new plant one should also consider the main wind direction and the wind strength. We can use natural barriers to shelter our belts, for example by planning them in the windshield of hills and mountains. It is also an option to install transport conveyor belts underground. This covers and secures the belt, but the construction costs are much higher than the costs of an overland conveyor.

In most cases housing in the structures is a typical way to prevent dust. It is of course also possible to improve existing plants. In the case of conveyor belts, it is unusually done with sheet metal covers. The next two pictures show examples of covered conveyor belts.

Picture 3: Covered conveyor belt; Holcim, Merone, Italy

Picture 4: Covered conveyor belt; Omya, Gummern, Austria

What we try to do in the “Dust Project” is to look for alternative types of dust control. Because of the lack of water in Australia the classic active dust control systems can´t be used. One of the ways I looked at the problem is to let the dust settle down by reducing the air velocity. If one can get the dust to settle, the material loss is minimized as the fines stay with the material stream.

2.7 Transfer points

In material handling operations we try to guide the material stream within a transfer point. A guided material stream has a lot of possible ascendancies. One can guide the material just at the loading point and at the discharge point.

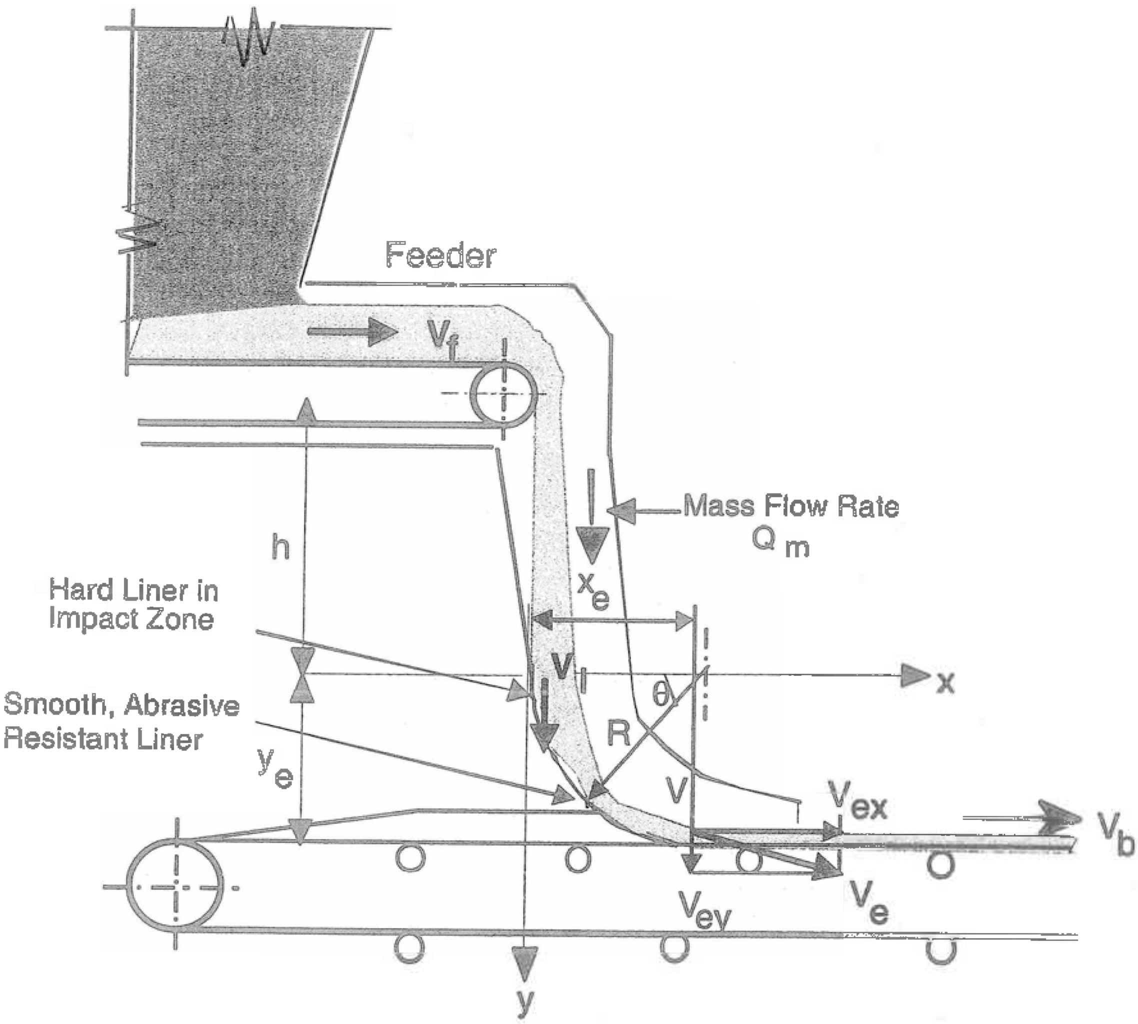


Figure 4: Feed chute configuration [12]

Figure 4 shows a possible setup for feeding from a hopper to a conveyor belt. In such a case we usually don´t need to guide the material at the head pulley. The speed of feeding belts is so slow, that the material falls down vertically after discharging from the belt.

If we have a transfer from one belt to another we usually use two chutes. One chute is situated at the discharge point of the first belt and the other one is positioned at the loading point of the second belt. This situation is illustrated in figure 5.

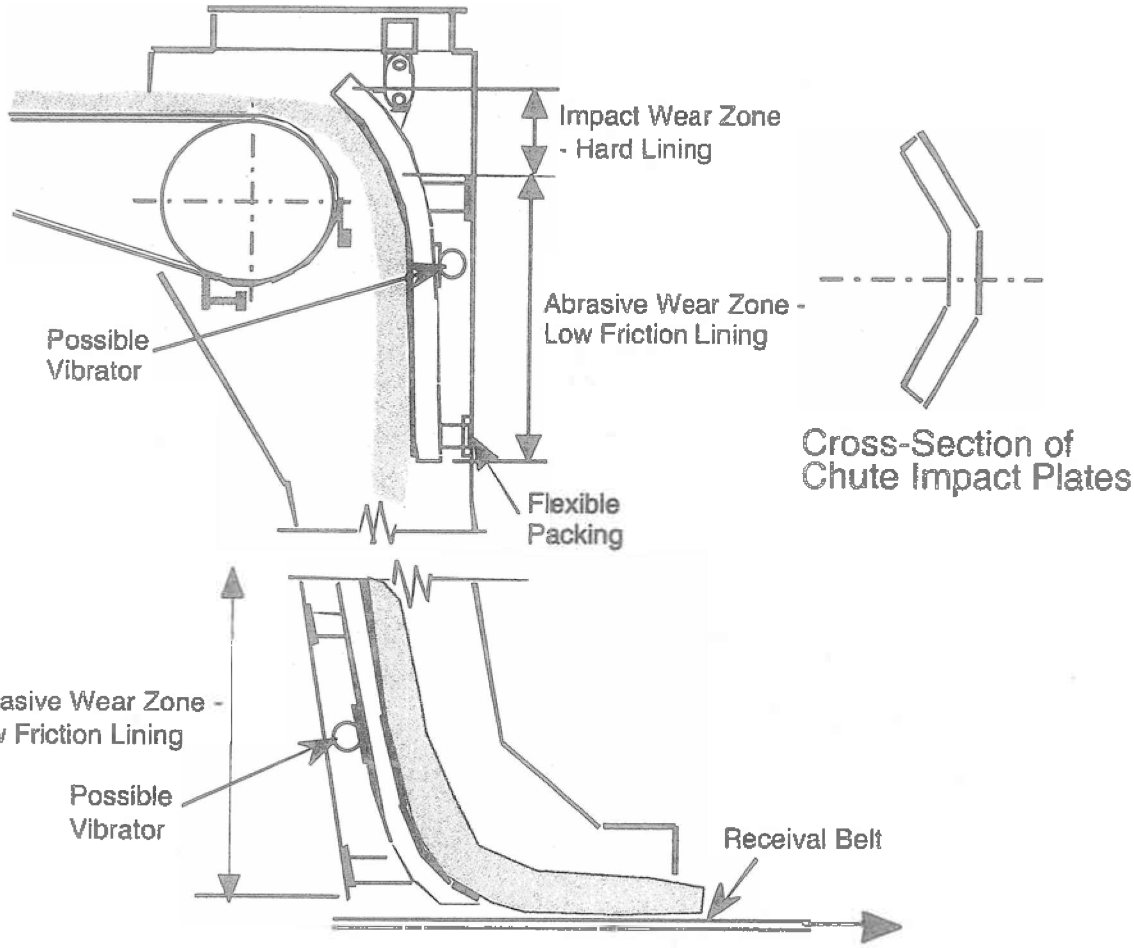


Figure 5: Transfer chute with impact plates [12]

There are a few situations where chutes at transfer points can help us. A chute at the discharge of a belt helps to guide the material stream in the direction we need it. As we can see in figure 5 the chute has two main parts. The area where the material impacts on the chute should be covered with hard lining to reduce the wear. In the lower section of the chute we need an abrasive wear protection. This chute should have a cross section as shown on the right side of figure 5. This shape helps guide the material in the center of the chute and tries to keep the stream narrow. In an application with sticky material vibrators can be used to prevent material from sticking on the chute.

After a free fall zone the material stream enters the lower chute. This chute starts with a smooth angle and the main objective is to guide the material in the direction of the receival belt. In the perfect situation we load a belt in the center and the material that falls onto the belt moves as fast as or slightly faster than the belt itself. Loading the belt in the center is very important to avoid that the belt runs out of its center position. A belt running continuatively out of line can cause wear and damage to itself and other equipment and in most cases it also causes spillage. This will have effects on the operating and maintenance costs. Another effect of feeding in the right way is the reduction of wear on the belt. If the material drops on the belt with the same speed as the belt is running we can reduce the wear on the surface because the friction forces between belt and material are minimised. By guiding the material stream we can use the energy of the falling stream to reduce the energy consumption of the belt conveyor.

With the use of transfer chutes we can optimise the flow of material through transfer points. The chutes also help keep the material stream together which also effects the generation of dust. With a compact material stream we reduce the amount of air entering the falling stream. This will reduce the amount of small particles separated from the stream. This mechanism is shown in figure 6.

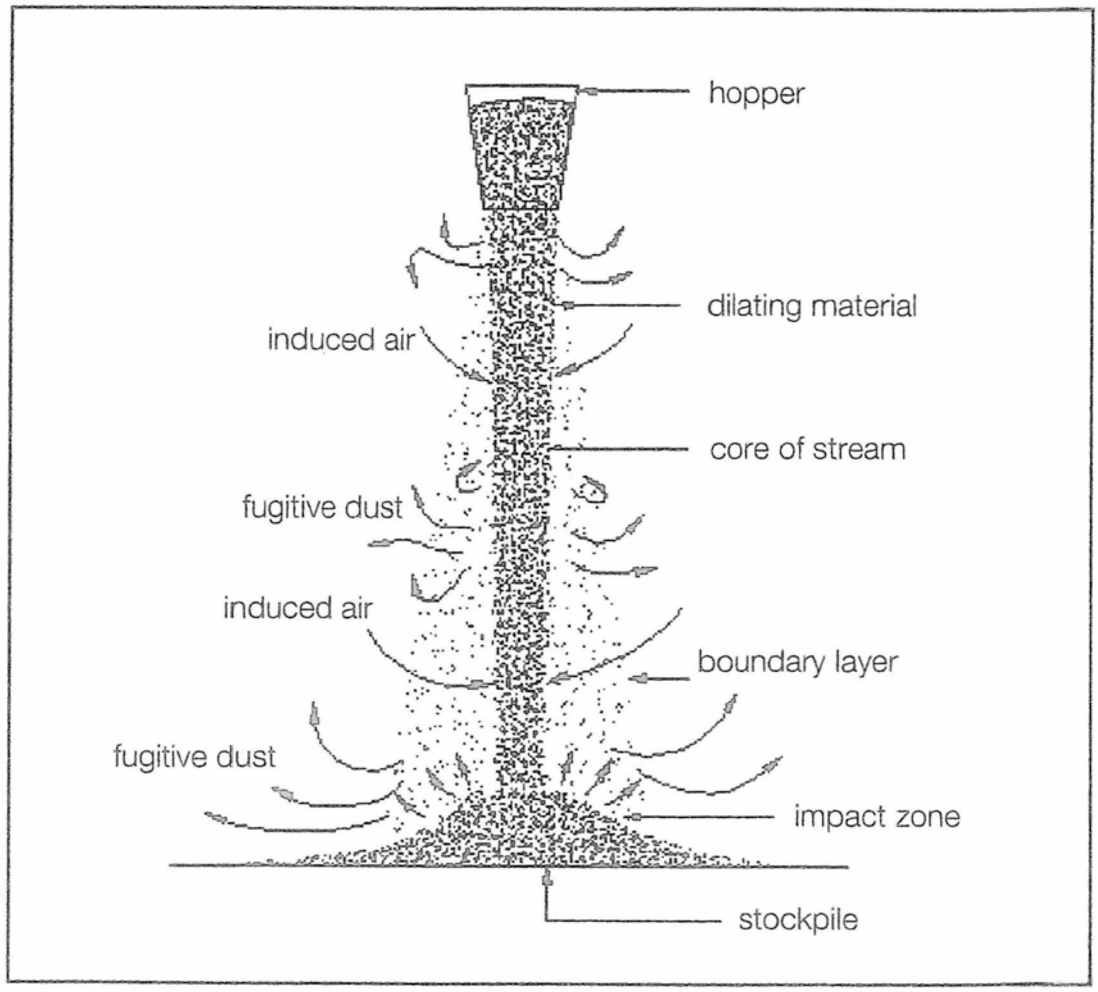


Figure 6: Schematic of dust generation from falling stream of bulk material [11]

3 Test Rig

3.1 Requirements to the test rig

The task for the rig was to replicate the air behaviour in a transfer point of two conveyor belts. The rig should use as much of the available conveyor belts from the workshop as possible. The whole rig should be in perspex to allow monitoring the air and dust flow in the transfer. The material should be in a continuous cycling flow. The feeding rate should be adjustable. The drop height should be variable. For later experiments, the option to incorporate different chutes should stay open.

The next part of the thesis will describe the various parts of the rig.

3.2 Place for the setup

The whole rig was setup in the workshop of TUNRA Bulk Solids. To fulfil the circulating material stream the rig was positioned in an existing test rig used for silo experiments. In this position the existing returning belt has been used. That belt feeds a bucket elevator. From the top of the bucket the material is transported with a screw elevator. This setup had the positive side effect that the existing bin could be used to store of the material.

Picture 5: Returning belt and storage bin

Picture 6: Area where the test rig is setup

In picture 5 we see the returning belt, which feeds into the bucket elevator and the yellow storage bin in the back. In the back of picture 6 we can see the existing bucket elevator. It feeds the material into the screw conveyor that can be seen in the upper part of the picture.

3.3 Used conveyor belts

For the rig two existing belts from the workshop have been used. The short red one is used as the feeding belt under the hopper. This belt will be driven with a converter to allow for adjustment of the feeding speed.

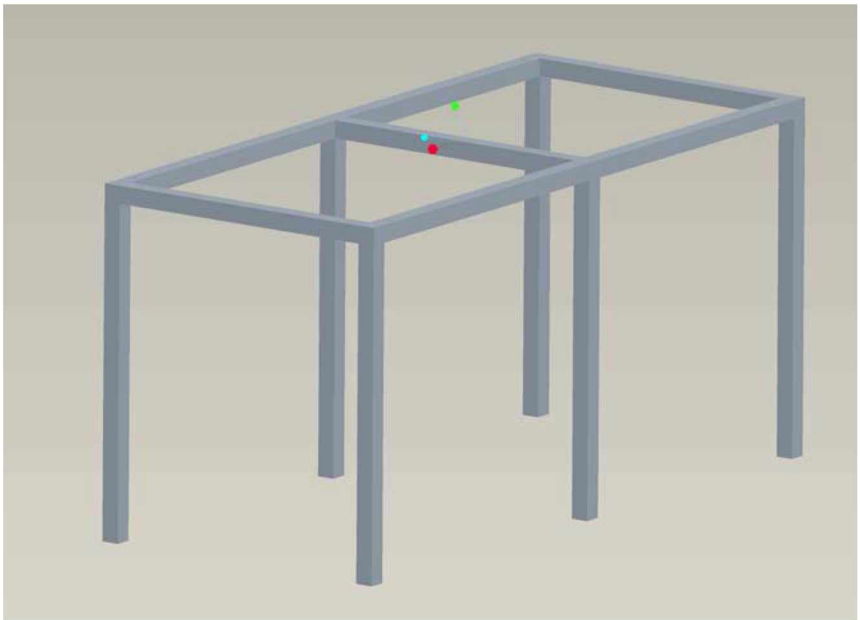
Picture 7: Feeding belt found in the workshop

Picture 8: Feeding belt ready for use

The second belt, the green one, is used to transport the material out of the rig. It was driven with a constant speed which was higher than the feeding speed to make sure that all the material going through the transfer can be returned. The red belt was about 10 cm wider than the green one. That made the shape of the rig as illustrated in pictures 15 & 16 necessary.

3.4 The stand

The stand was needed to elevate the rig high enough to fit over the returning belt. The height of the stand is 1000 mm.

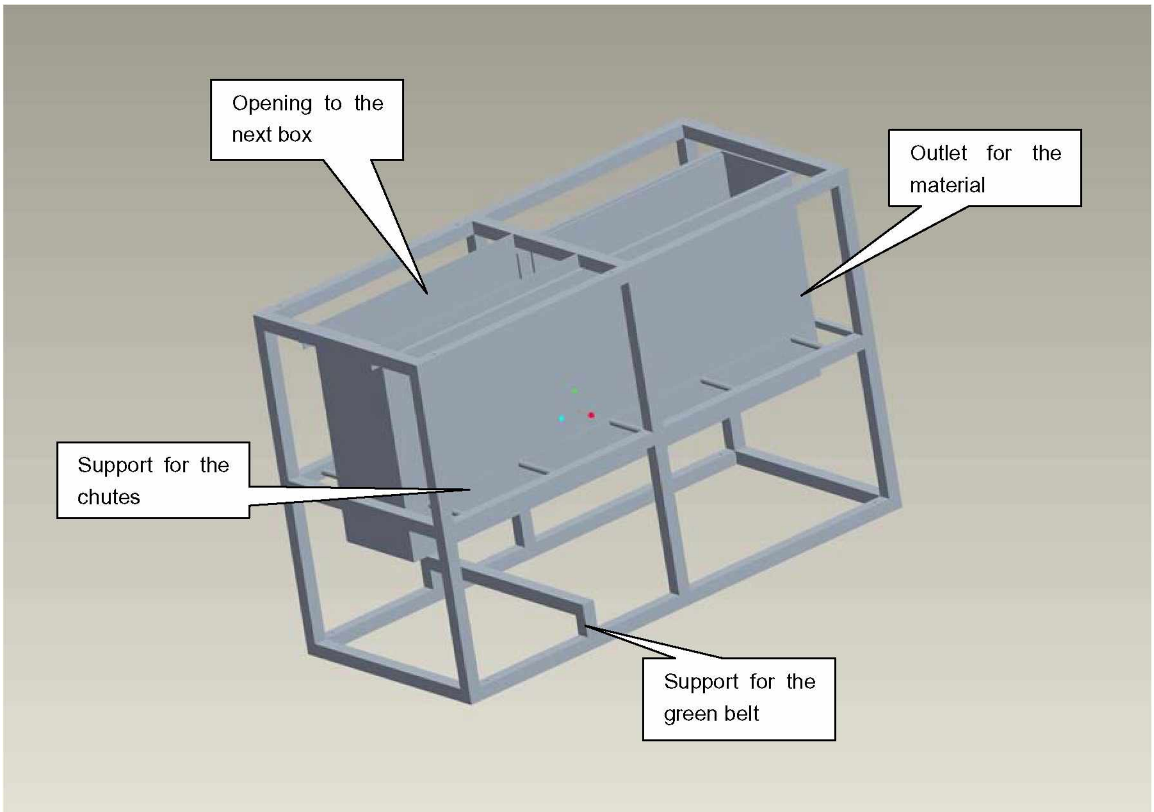


Picture 9: 3D drawing of the stand in Pro Engineer

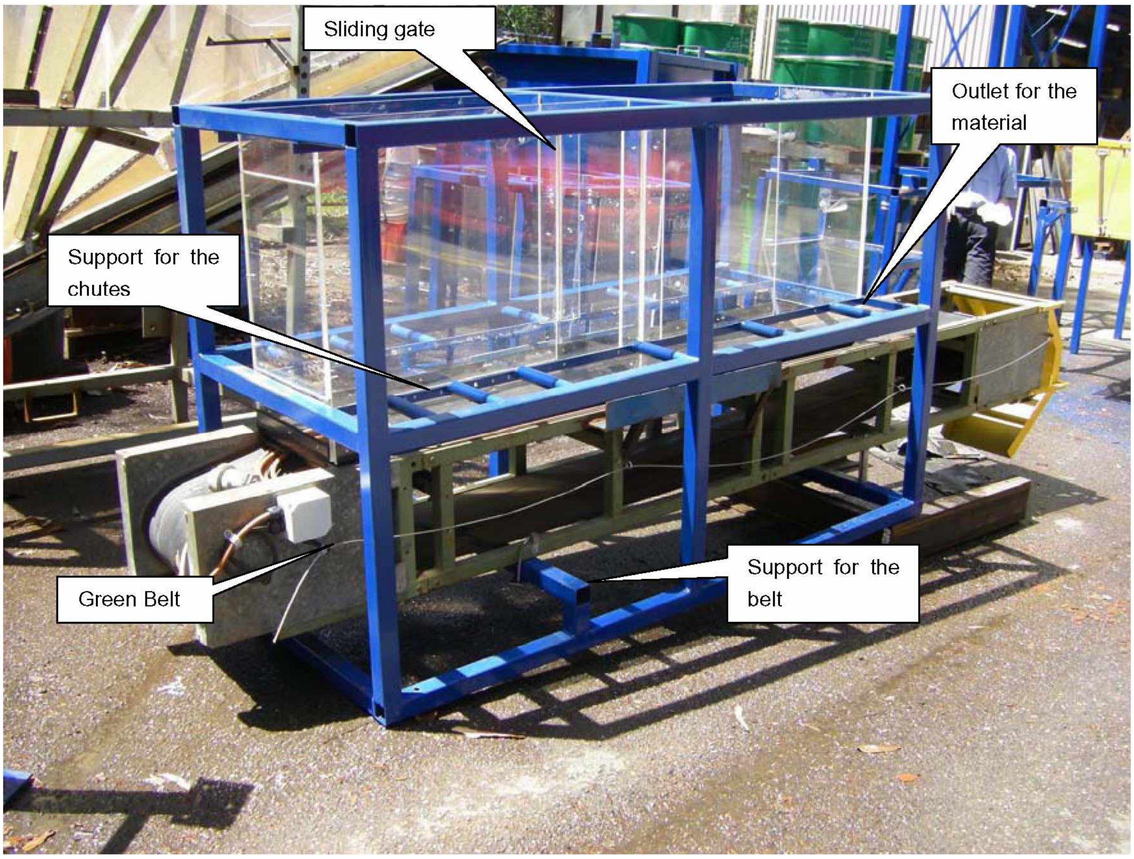
Picture 10: The stand in position

3.5 The main box

The main box is the heart of the rig. This frame supports the green belt which transports the material out of the rig. This box is 2000 mm long and 900 mm wide. The height of this box is 1300 mm. This box and all the others are made from 50x50 mm hollow steel sections welded together. All the boxes have an inner part, which is made from 10 mm perspex to provide the opportunity of watching the material fall and to see where dust is generated. The width of the boxes is given by the red conveyor belt. It is 730 mm wide and that determines the minimum width of the whole rig at 900 mm. The length is 2000 mm and can be split in two areas by a sliding gate made from perspex. This is important for the test I did with the rig later. In the lower half of the rig is a smaller frame to support chutes for later experiments. The box is closed except for the opening where the next box is situated and a small material outlet.



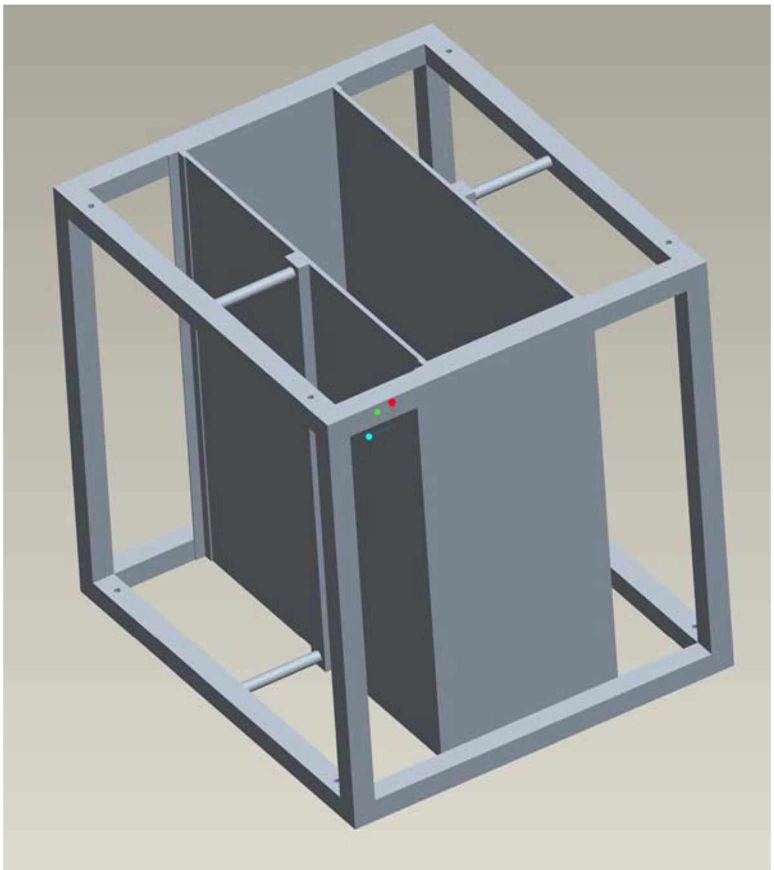
Picture 11: 3D drawing of the main box



Picture 12: Main box complete with the green belt

3.6 Elevation box

This part of the rig is just a simple frame with the perspex box inside. This box is used to elevate the drop height. The dimensions of this object are a width of 900 mm and a length of 1000 mm. The height of the box is 1000 mm, so if it is used in the rig, we can do experiments with a drop height of 2600 mm. But it is also possible to use the rig without this box. The drop height, however, is then 1600 mm.

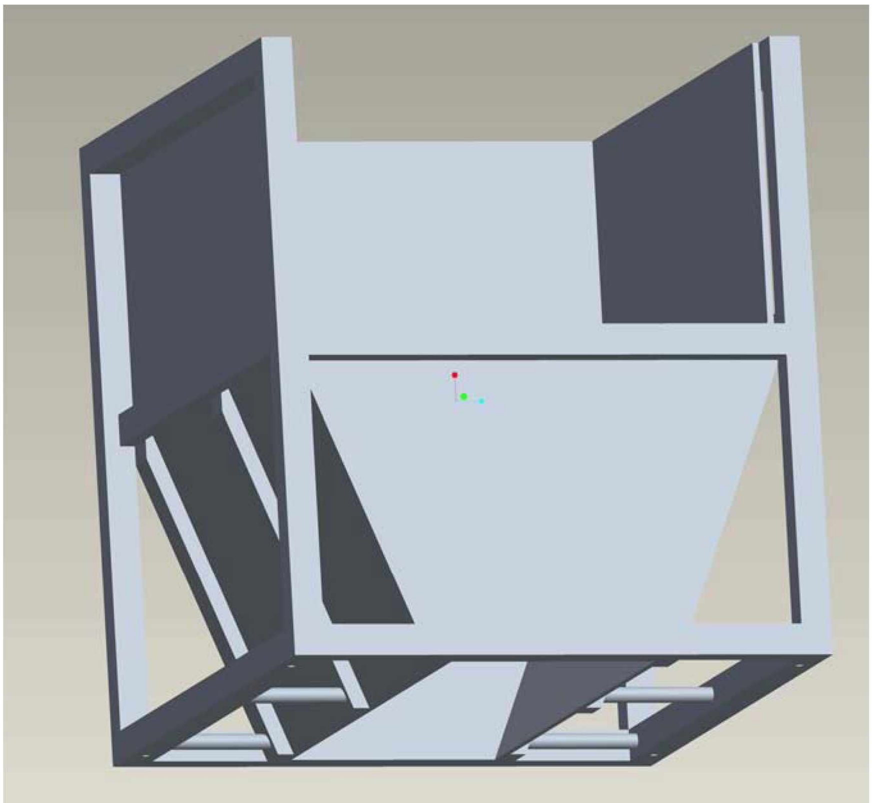


Picture 13: 3D drawing of the elevation box

Picture 14: Elevation box

3.7 Top box

The top box has this particular shape because of the width of the red feeding belt. The dimensions are 1000 mm in length and 900 mm in the width. The height of the box is 1000 mm. The top 440 mm are a perspex frame that is 800 mm wide. In the lower part it narrows to 350 mm inside width. This is necessary because the width of the material stream is limited by the width of the green belt that takes the material out of the rig. This part is also the support for the red feeding belt. The top of the box is covered with a sheet of perspex.



Picture 15: 3D drawing of the top box

Picture 16: Top box

3.8 The support

The support will hold the storage hopper. It consists of two parts. The smaller one is only in use when the rig is set up for the full drop height. The width of the legs is chosen with 1300 mm so that there is enough space to feed material on the returning belt with the workshop´s forklift and the drum lifter. To secure the rig, the stand is bolted to the ground.

Picture 17: Stand

Picture 18: The expansion part for the full drop height

3.9 The storage hopper

The hopper has a capacity of about one cubic meter. The hopper has inside measures of 1300 mm in length and 700 mm in width. The height is 1400 mm and the lower part is convergent to ensure that the material is loaded onto the center of the belt.

Picture 19: Storage hopper

Picture 20: Storage hopper

3.10 Impact plate

To guide the material stream at the head pulley of the red feeding belt, I installed an impact plate. The angle of the plate is variable and can be adjusted with an angle between -10° and +15° from the vertical. It is cont rolled by an air pressure cylinder and fixed by a steel wire. With this plate the material stream can be guided after leaving the belt.

Picture 21: The impact plate

Picture 22: The impact plate in position wired up with air hoses and the steel wire

Picture 23: Crank handle with steel wire to fix the impact plate

The plate can be adjusted from the ground with the air pressure cylinder. Because the cylinder loses pressure after a while, its position is fixed with the steel wire.

3.11 The chutes

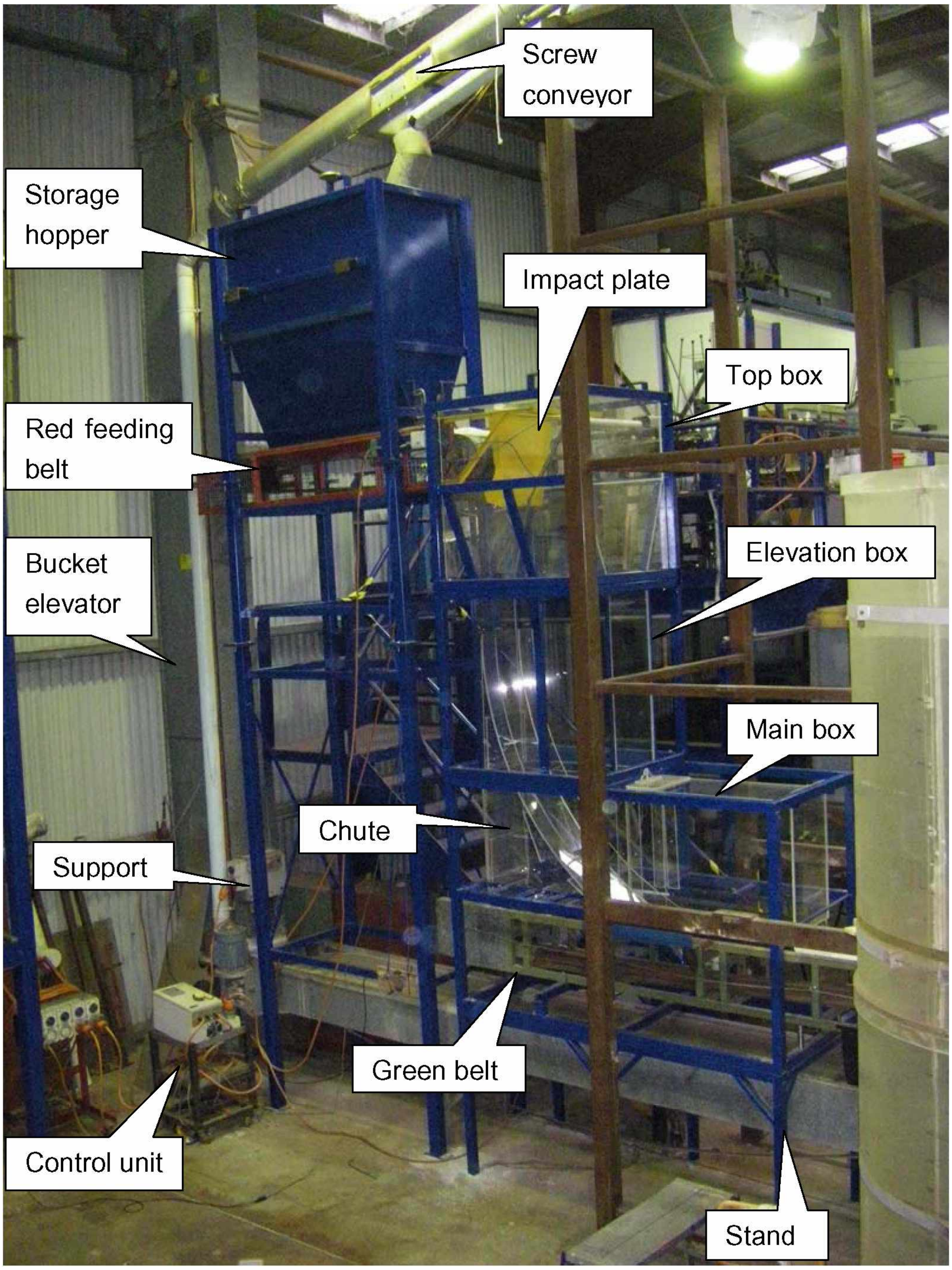
In industrial applications the material stream in a transfer point is guided by chutes. To test the different results between a freefalling stream and a guided stream I built two chutes out of perspex that can be put into the rig. Both chutes have a cut-off angle of 60° to make sure that no material can buil d up on the chute.

Picture 24: Chute for the full drop height

Picture 25: Chute for the reduced drop height

3.12 The rig completely assembled

Picture 26 shows the rig in position, assembled for experiments using the full drop height of about 2500 mm.



Picture 26: Setup with the full drop height

The next picture, number 27, shows the setup for the reduced drop height.

Picture 27: Setup for the reduced drop height without the hopper

4 Experimental part

This part of the thesis will describe the experiments that I conducted with the rig. To represent material I used plastic pallets. The reason for that was that the pallets are clean and don't generate dust. To make the air flow visible, I used a smoke generator. That gave me a chance to observe the airflow in the transfer. Later on the rig will be used by others to do tests with dusty material.

Next to the experiments with the smoke generator I tried to measure the airflow with a thermal camera, a wind meter and with pito tubes.

The amount of material fed into the rig depends on the frequency the red feeding belt is driven with. To measure the speed of the running belt I used a speed meter. The relationship between the frequency and the measured speed is quite linear as shown in Figure 7.

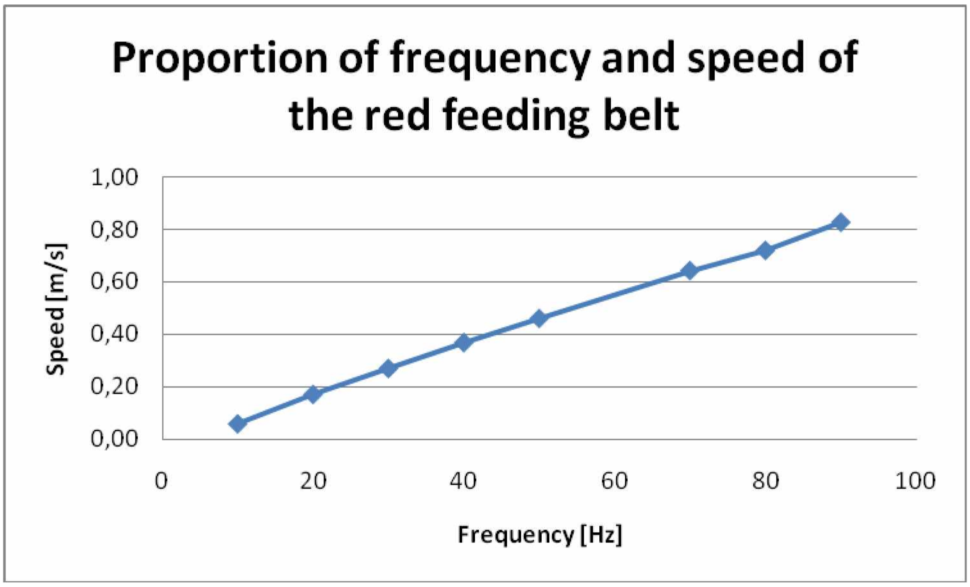


Figure 7: Frequency over Speed

Picture 28 shows the shape of the material stream leaving the outlet of the hopper. The stream has the shape of a trapezoid. It has a bottom length of 340 mm and a top length of 260 mm. The height of the material bed is 25 mm. This means the area of the bed is:

Picture 28: Feed of the material

$$A = \frac{1}{2} h*(a+b)$$

$$A = \frac{1}{2} 25*(260+340) = 7500 \text{ mm}^2 = 0{,}0075 \text{ m}^2$$

To calculate the amount of material fed into the rig we multiply the area of the material bed with the length of conveyor belt moved per time.

Frequency	Speed		Amount of material fed		
HZ	m/min	m/s	m^3/s	m^3/min	m^3/h
10	3,6	0,06	0,0005	0,0270	1,62
20	10,3	0,17	0,0013	0,0773	4,64
30	16,2	0,27	0,0020	0,1215	7,29
40	22,1	0,37	0,0028	0,1658	9,95
50	27,6	0,46	0,0035	0,2070	12,42
70	38,5	0,64	0,0048	0,2888	17,33
80	43,1	0,72	0,0054	0,3233	19,40
90	49,5	0,83	0,0062	0,3713	22,28

Table 9: Material fed

I did experiments with different setups of the rig. They are described in the next chapters.

4.1 Full drop height and free fall with open gate

The first series of experiments were done with the full drop height and freefall of the material. That means the drop height was 2640 mm and the material is discharged from the red feeding belt without guidance and falls straight onto the green belt. The amount of material fed was controlled by the speed of the feeding belt. As I stated earlier, the material used was white plastic pallets with a diameter of about 2 mm.

The experiment was started with a frequency of 10 Hz. Then the frequency was raised to 60 Hz in steps of 10 Hz. While the experiment was running, smoke from a smoke generator was induced to show the air currents in the test rig. The basic setup: free fall of the material and the gate to split the main box into two parts open completely. This way I was able to see the main currents in the transfer. The first tests showed that increasing the amount of material falling through the rig just makes the currents stronger, but doesn´t change their shape. During the experiments the top box is covered with a sheet of perspex but the area where the belt reaches into the box is open. Before the experiments I thought that these facts might be a problem, because the air and the smoke will leave the rig through these openings. During the experiment, I noticed that if no material is falling, smoke escapes the rig at the top. As soon as the material starts falling through the rig, the drag force of the material acting on the air with the falling stream and the currents occurred.

Picture 29: Smoke inside the rig before the material starts falling

Picture 29 shows the smoke standing still inside the rig. After a few seconds the smoke starts to leave the rig through the opening next to the feeding belt, because of the temperature difference between the air and the smoke. The smoke is made by heating up oil in the smoke generator, so it has a slightly higher temperature than the surrounding air.

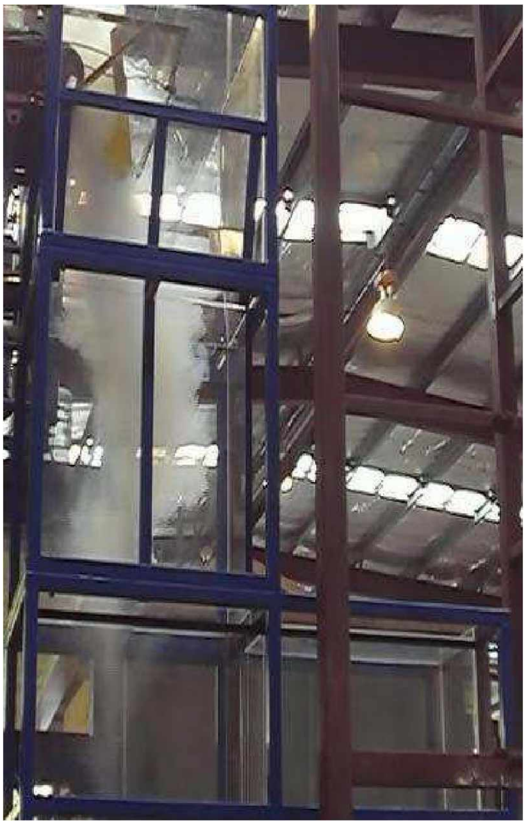
Picture 30: Before material flow

Picture 31: Start of the experiment

Picture 32: Start of the turbulence

As soon as the material fell through the smoke I could see the currents in the transfer. With this setup three main turbulences occurred. Two are in the vertical part of the rig as seen in picture 33 and 34. The third one is in the horizontal part of the rig as shown in picture 35.

Picture 33: Injection of the smoke



Picture 34: Start of the turbulence in the vertical part

Picture 35: Start of the turbulence in the horizontal part

In this experiment the material feed is very low to show how the currents occur. We can see the smoke dragged down by the material and the two turbulences starting in the vertical part. As soon as the smoke hits the green belt we can see that turbulence develops on the left side of the stream and an even bigger one in the horizontal section of the transfer.

The experiment showed that most of the air leaves the rig directly with the material stream. Only a portion of the air stays in the rig feeding the horizontal turbulence.

Picture 36: All main turbulences in that experiment

All three turbulences only appear if the air gets the chance to leave the rig at the bottom. I also did an experiment where I closed the outlet of the stream with some rubber sheets. That experiment showed that if the air doesn´t get the chance to leave the rig in the direction of the material flow, all the smoke will leave the rig trough the top. In that case, as soon as the box is filled with smoke, it leaves the rig at the top and through every gap that is open. This shows that if we want to control and guide the airflow and later on the dust loaded air, we need to give it a chance to flow through the transfer with the material.

4.2 Full drop height and free fall with the gate closed

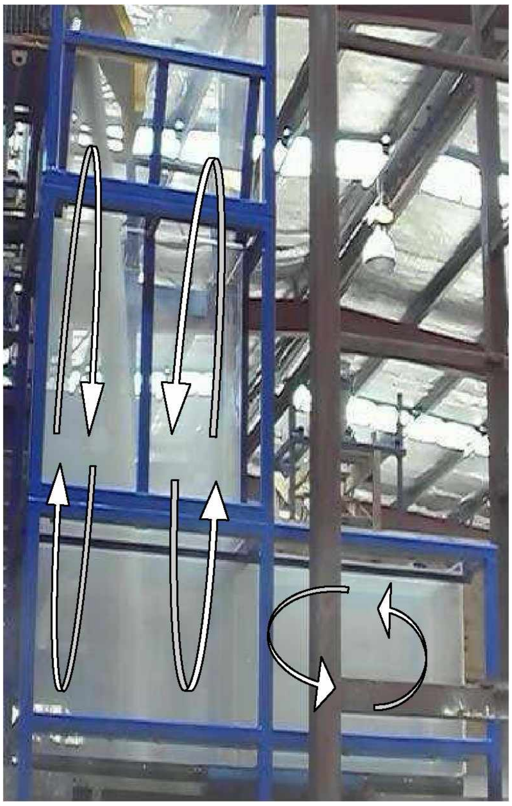
In this setup, the material is also in a free fall with a drop height of 2640 mm, but the gate that can split the horizontal main box in two parts is closed. The idea behind this setup is to give the dust loaded air an area to slow down. After passing the narrow gate, the air has the chance to slow down in the left part of the box. With reducing the air speed we can reduce the drag force on the dust particles carried by the air which should cause them to fall back into the material stream leaving the transfer. The experiment showed that the smoke initially stays on the left part of the rig before filling the right part of it. Eventually the smoke leaves the rig through the material outlet. This is illustrated in the following pictures.

Picture 37: Main turbulence in the left side of the vertical part of the rig

Picture 38: Turbulence starting on both sides of the vertical section

This experiment showed that the air stays in the separated part of the box for a while. Even thought I didn´t introduce more smoke into the System, it took a while for the smoke to clear the separated right area of the rig.

Picture 39: Turbulence in the right part of the box



Picture 40: The main turbulence with the closed gate

4.3 Full drop height and a guided material stream with the gate open

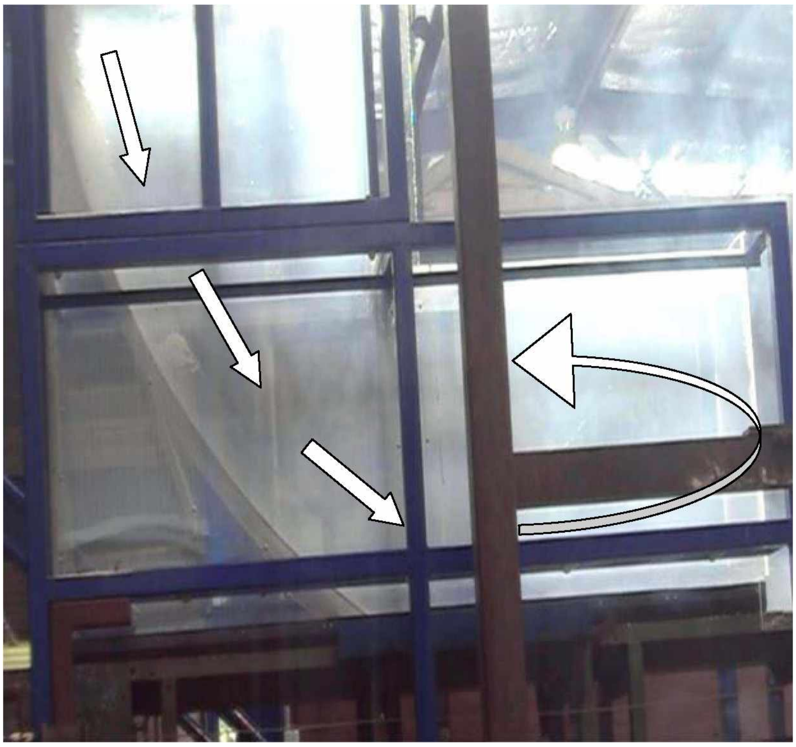
In material handling plants we generally try to guide the material stream. As described in chapter 2.7, a guided material stream can help reduce dust.

For this experiment the rig was set up with the full drop height of 2600 mm. The impact plate was used to guide the material stream to the back side of the top box. This directed the material straight onto the chute seen in picture 24. This setup is a simulation of the material stream in a transfer point application in the material handling process.

The first experiment was conducted with the gate open. The feed of the belt started with 10 Hz and was raised to 60 Hz in steps of 10 Hz.

Picture 41: Introducing the smoke

Picture 42: Start of the turbulence



Picture 43: The various turbulence in this setup

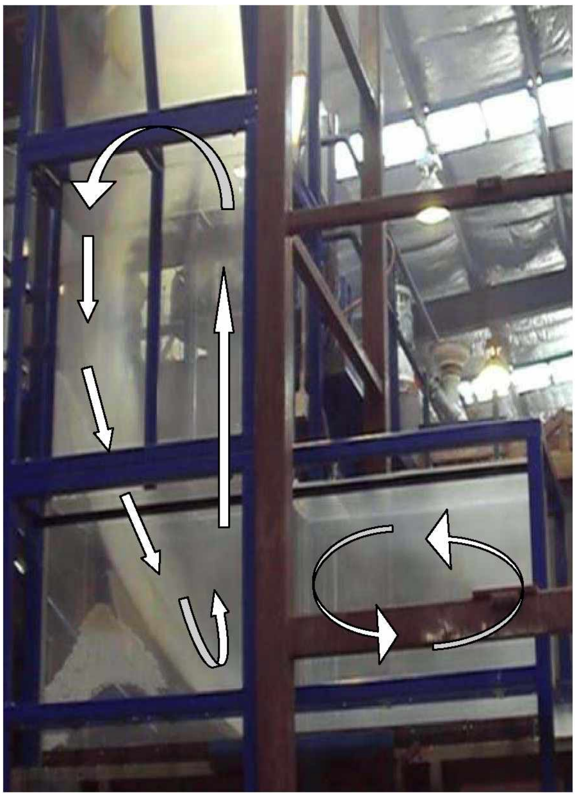
As shown in pictures 41 and 42, the smoke follows the material stream. After sliding down the chute, it starts an eddy at the end of the horizontal part of the rig. In picture 43 we can observe the shape of the current. This setup showed that there is only one main current and that a lot of the smoke leaves the rig directly along with the material through the outlet.

4.4 Full drop height and a guided material stream with the gate closed

The setup is identical to the one described in chapter 4.3 except for the fact that the gate is now closed.

Picture 44: Introducing the smoke

Picture 45: Start of the turbulence



Picture 46: The various turbulence in this setup

As we can see, the turbulence here appears slightly different to what we observed earlier. When the smoke hits the gate, only a portion of it enters the right part of the rig. The other part remains on the left side and starts a current there. The smoke and air entering the right part of the rig gets trapped there in currents for a while before leaving the rig through the outlet. This gives us an idea of how dust loaded air can appear. If we don´t split the box, the dust leaves the transfer along with the material stream and we can´t achieve the effect of slowing down the air stream. On the other hand, if we do split the box, we get an area with lower air speed on the right side of the rig.

4.5 Reduced drop height and free fall with open gate

Similar to the first set of tests, I carried out some experiments with the reduced drop height of 1600 mm. In this setup I only used the top box and the main box. Like in the other experiments plastic pallets were used to represent the material in the tests. The feeding speed started with a frequency of 10 Hz and increased steadily until it reached 60 Hz. In the first test, the material was allowed to free fall and the gate was open.

Picture 47: Start of the experiment

Picture 48: Start of the turbulence

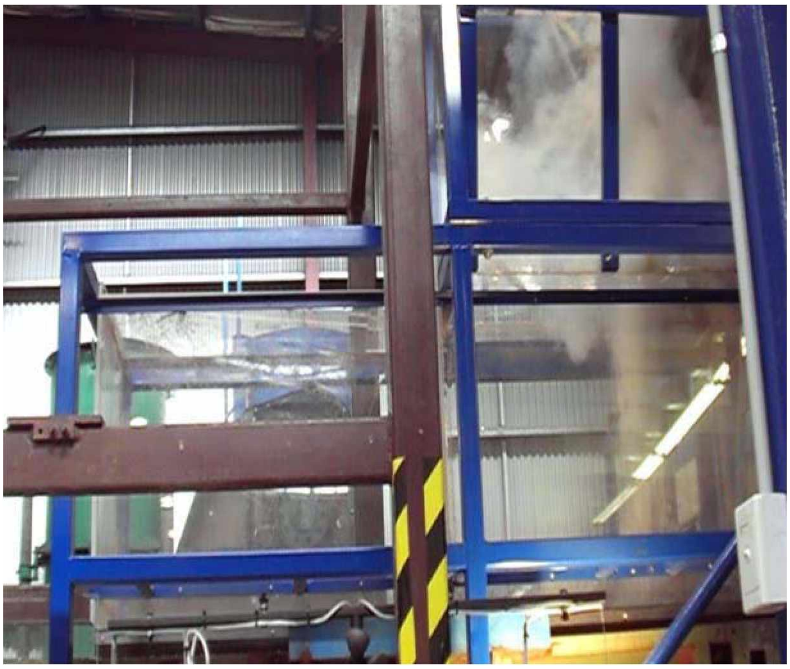
Picture 49: Main currents in the experiment

The main difference between the experiments with the full drop height and the reduced drop height is that there is not such a strong turbulence in the vertical section of the rig when the drop height is reduced. In this experiment, most of the smoke is dragged down with the material stream. The free fall distance is too short for a strong turbulence to occur. In the horizontal box, a curl develops. The majority of the smoke gets caught in this curl for a while before leaving the rig.

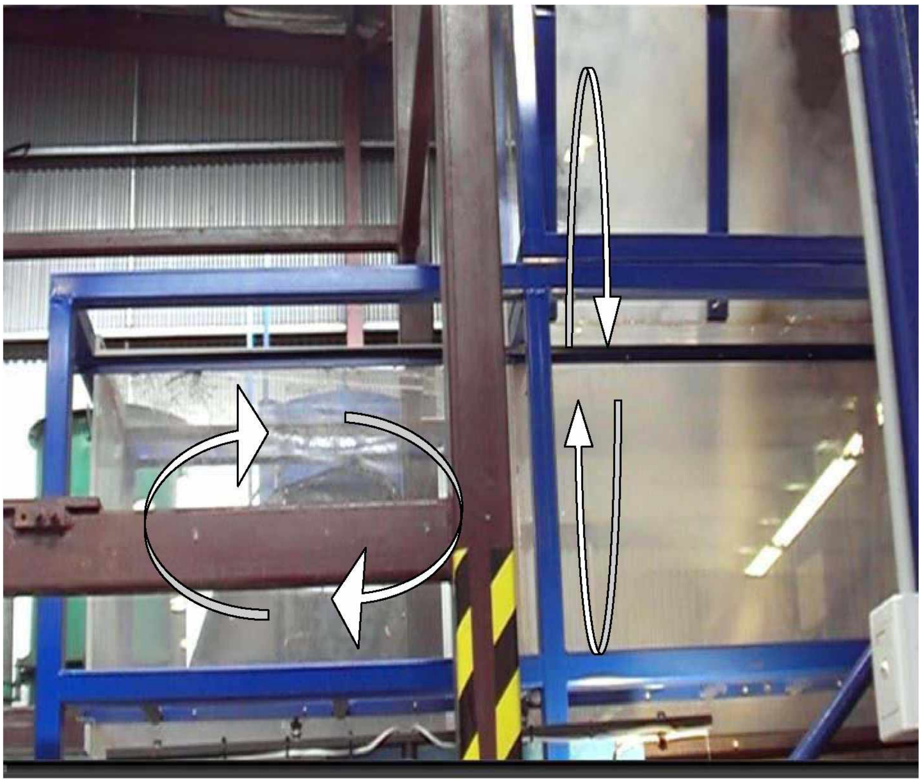
4.6 Reduced drop height and free fall with the gate closed

The setup is the same as described in chapter 4.5 but this time the gate is closed.

Picture 50: Start of the experiment



Picture 51: Start of the turbulence



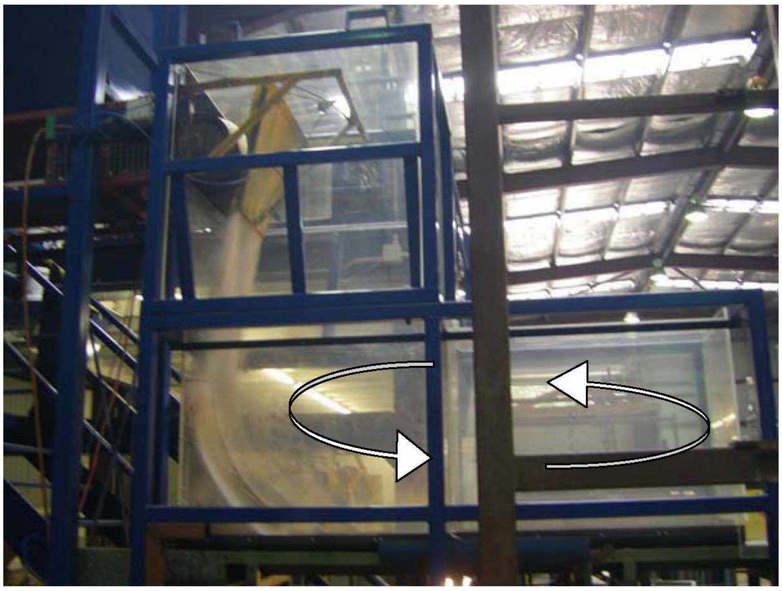
Picture 52: Main currents in this experiment

As we can see in picture 52, closing the gate causes the occurrence of two main currents similar to the ones observed in experiment 4.2. As in the earlier experiments with the gate closed, the smoke remains in the horizontal part of the rig for some time.

4.7 Reduced drop height and a guided material stream with the gate open

In this experiment I used the chute illustrated in picture 25 to guide the material stream in the direction of the green belt. Reminiscent of experiment 4.3 the material is guided to the right side of the rig and onto the chute.

Picture 53: Setup for the experiment



Picture 54: Main currents in the experiment

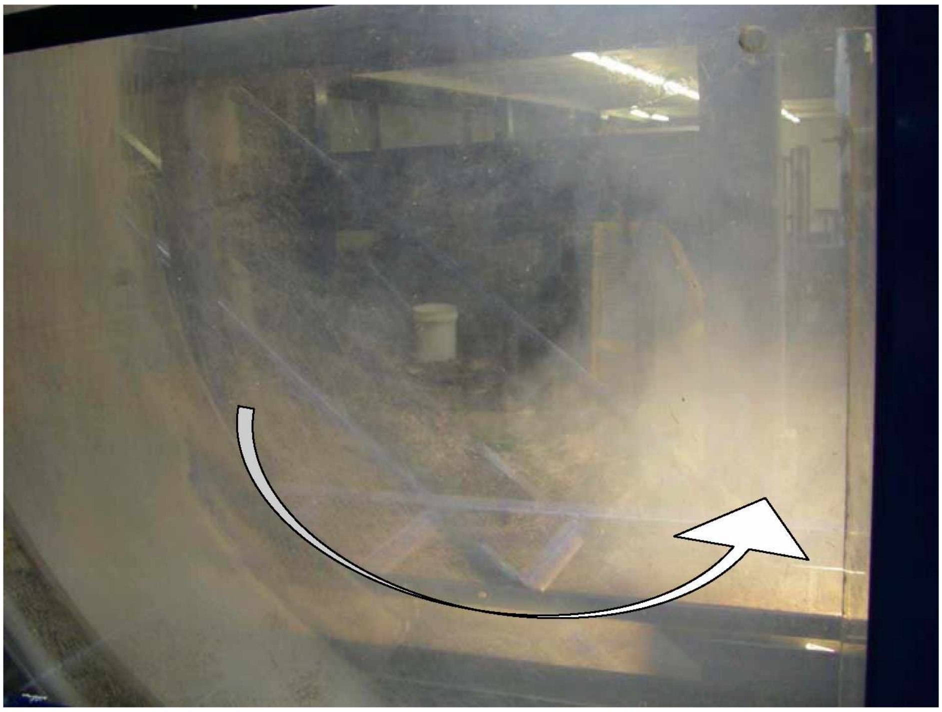
Like in the experiment with the greater drop height and the guided stream, only one current develops. Most of the smoke leaves the rig directly with the material stream. Some of the smoke stays in the rig and builds up a current in the horizontal portion.

4.8 Reduced drop height and a guided material stream with the gate closed

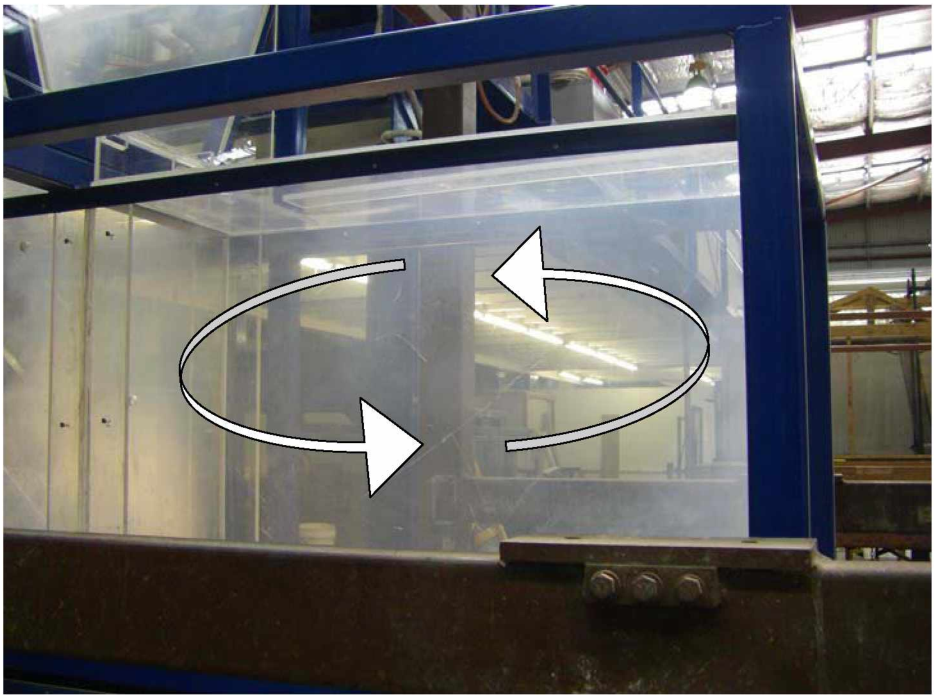
In this experiment the setup was identical to the one in experiment 4.7, except this time the gate was closed. Similar tho the experiment with the full drop height I was able to observe two main currents in the rig. As the experiment commences, the smoke is dragged down by the material and a turbulence develops in the left part of the rig. Some of the smoke enters the right section and starts a separate turbulence there. Similar to the experiments carried out earlier, most of the smoke stays in the right part for a while before leaving the rig through the outlet.

Picture 55: Development of turbulence

Picture 56: Detailed of the current in the left part of the rig



Picture 57: Detailed illustration of the current in the left part of the rig



Picture 58: Current in the right part of the rig

4.9 Other experiments

Aside from the experiments described above I also attempted to accumulate some other data and measurements.

Infrared camera:

I tried to take some useful pictures with an infrared camera. The camera I used was a "Fluke IR FlexCam Thermal Imager Ti 40". For that experiment I removed the perspex from one side of the rig and replaced it with a very fine plastic foil. I removed the perspex to make it easier for the camera to measure the expected temperature difference. After carrying out the above described setup I noticed that the temperature difference between the air and the smoke was too small to make the currents visible through the infrared camera. It worked solely at very small distances and therefore gave me no chance to capture an image of the experiment as a whole. After a few trials with different covers for the rig I concluded this test as I was not able to obtain the data that I expected the infrared camera could provide.

Picture 59: Infrared Camera

Pito tubes:

In an attempt to measure the airspeed I utilized pito tubes. I drilled holes into the perspex to make measurements at different points of the rig. The problem I came across while using the pito tubes is that they only function correctly if they are positioned directly in the stream. This was not possible in this experiment because air trapped in various areas of turbulence inside the rig resulted in a very wide range of measurements. As the results obtained with the equipment available were not useful I decided to terminate the pito tubes experiment.

Wind meter:

My last effort to try to measure the air speed inside the rig was with a wind meter. The one I used was working with two electrodes that were heated up. The air passing the tip cools down the wires, thus changing the electrical resistance. The resulting difference in resistance was then converted into temperature. The dust inside the rig created a problem for this test. From other ongoing experiments in the workshop a lot of dust was brought onto the pallets and the rig, so the contact wires stopped working properly after just a few seconds. Unfortunately I was not able to get useful measurements with the wind meter provided by the workshop.

4.10 Simulation results

All of the described experiments should be compared to the results of the simulations done by Xiao Ling Chen. She is working on her PhD as a part of the dust project. In this chapter I will explain some of the results of her simulations.

The simulations where done using the “AnSys” Simulation software.

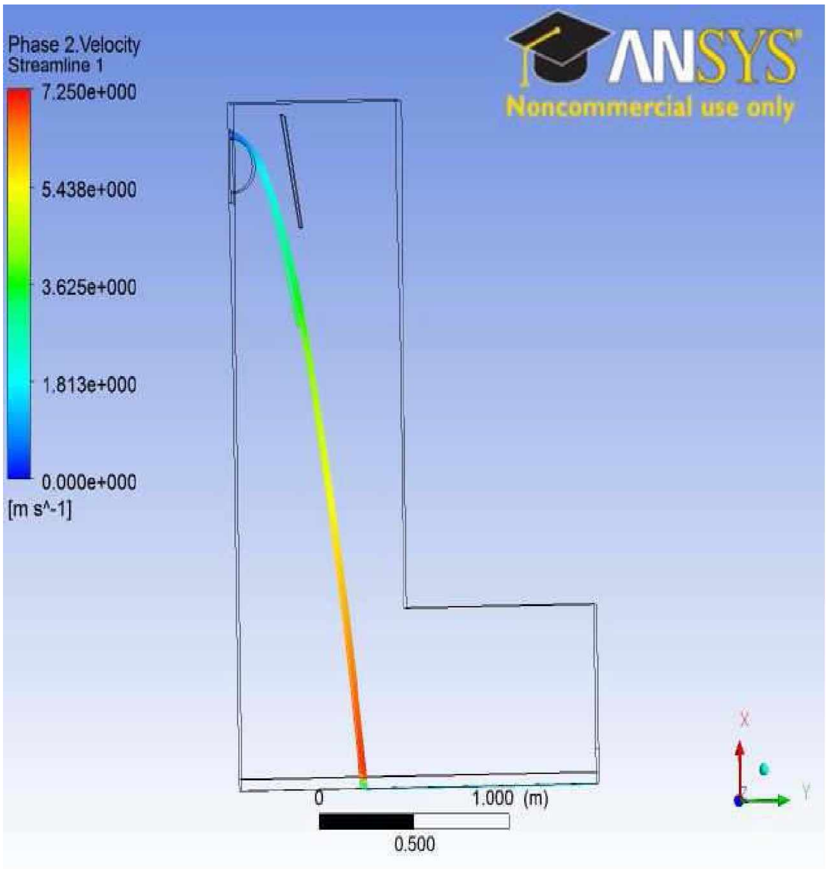


Figure 8: Particle velocity streamlines [14]

Figure 8 shows the particle velocity streamline. This first simulation replicates the setup for the full drop height and an unguided material stream. The shape of the model is given by the inside measures of the perspex frame.

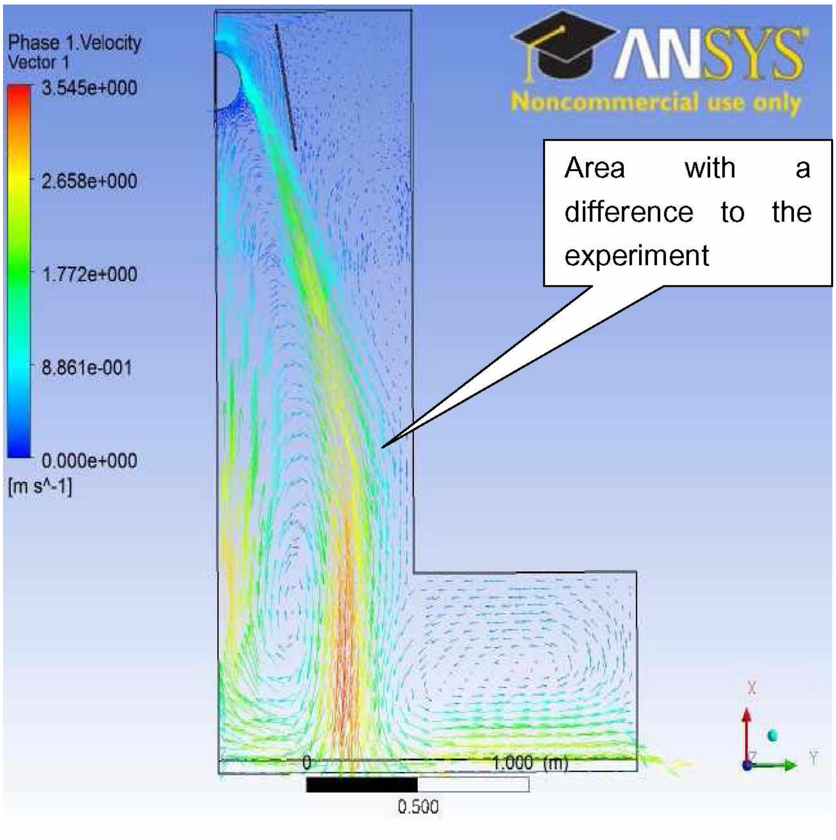


Figure 9: Air velocity vectors [14]

Figure 9 shows the air velocity vectors with the setup of experiment 4.1. This is the full drop height with free fall of the material and the gate open. Clearly illustrated here, we can observe a similarity to the results of the practical experiments. We can see that the turbulence in the right horizontal section of the simulation has the same shape as in the experiment. Additionally, the left vertical section has the same shape as the experimental results shown in picture 60. We can, however, see an aberration on the right side of the stream. The picture of the experiment is shown on the next page again. If we compare them we can see the shape of the turbulence is quite similar to the simulations.

Picture 60: Turbulence in the setup with the full drop height and the gate open

The second simulation done by Mrs. Chen takes into account the reduced drop height.

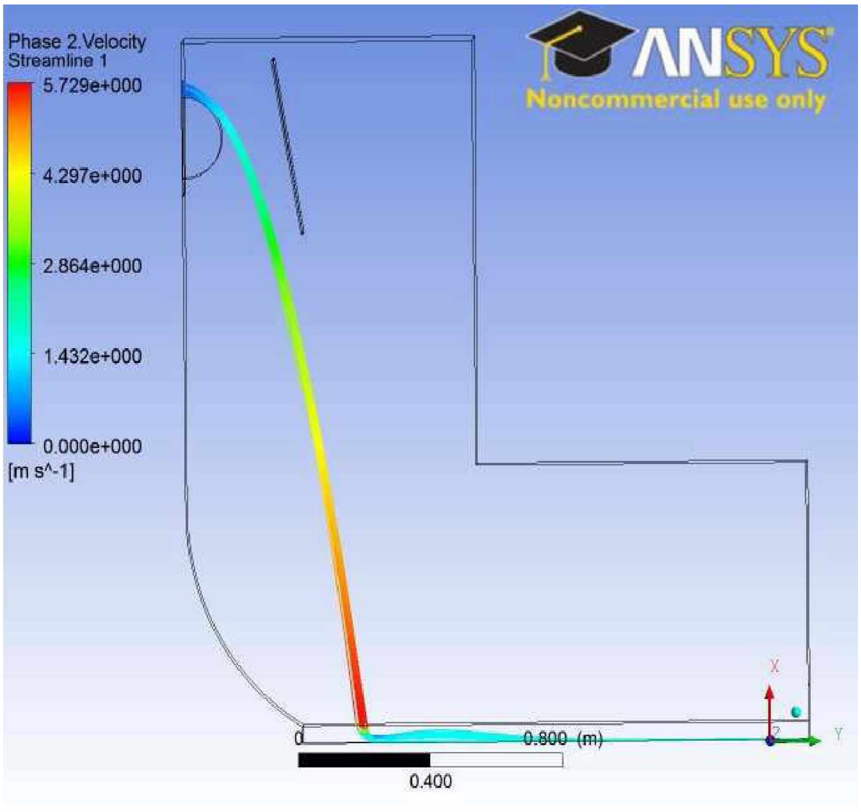


Figure 10: Particle velocity streamlines [14]

As shown in the picture, the shape of the simulation is identical to the inside of the perspex box with the reduced drop height. In the lower left corner we can see the chute. The difference between the setup and the experiment is that the material stream is not guided. That means that this simulation is similar to the setup with the reduced drop height, the unguided stream and the gate open.

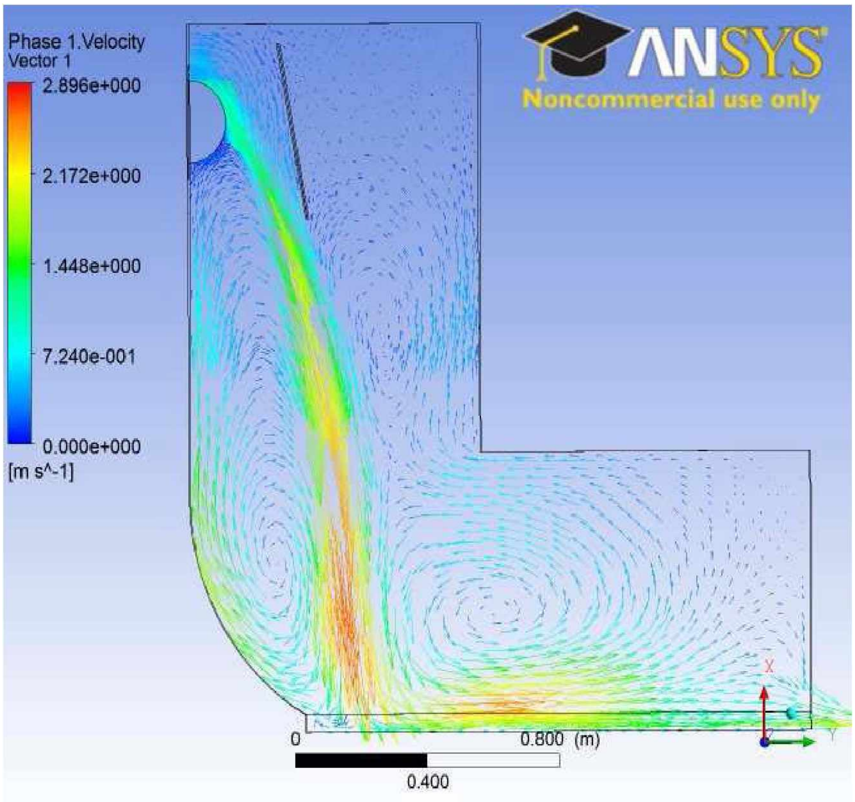


Figure 11: Air velocity vectors [14]

The simulation of the airflow as shown in figure 11 appears quite similar to the results of the experiment shown in picture 61. Similar to the practical experiment we can see that some air stays in the horizontal part of the rig and doesn´t leave the box directly. It starts building up the turbulence as seen in the right part of figure 11. In the experiment the turbulence on the left side of the material stream was not as strong as shown in the simulation. The shape, however, was similar.

Picture 61: Turbulence in the setup with the reduced drop height and the gate open

The two simulations showed that there is no significant difference between the theoretical and practical results for the shape of the air currents.

By the time this thesis was written there were no more results from the simulations available.

5 Results

The target of this project was to design and build a test rig to verify the results of the simulations.

The experiments showed that the results are quite similar to the simulations. This achievement can help optimise the passive dust control.

Four different experiments were conducted with two different drop heights. The basic setup was with free falling material and the gate open. Basically the test showed that we only have airflow if the material is falling and the air has the chance to leave the transfer with the material stream. With the first setup I found out that there are three main currents that affect each other. The difference between the full drop height and the reduced one was that the currents in the vertical section are not that distinct with the lower height. The strength of the current is related to the speed at which the material falls. This is a function of the drop height. We can see this speed difference in the simulations shown in figures 8 and 10. The simulations as seen in figure 9 and 11 show how the currents affect each other especially in the inner corner between the horizontal and the vertical section of the rig. In the experiment I saw that part of the smoke leaves the rig with the material stream while the rest is caught in the currents. The smoke injection causes the entire rig to fog up completely. Even without introducing more smoke into the system, it takes a while for all the smoke to make its way out of the rig along with the material stream until the rig is clear again.

The next setup, freefall without guidance and the gate closed shows that the gate splitting the horizontal part of the rig in two reduces the effect the different areas of turbulence have on one another. The current in the right part of the rig is almost independent from the currents in the vertical section. The experiments showed that the smoke initially stays in the vertical part of the rig before entering the separated horizontal section. In the experiments I observed that the amount of smoke in the two sections after the injection is different. It takes a while until the first section is filled with smoke and the second one follows. It is the same without injecting more smoke. While the first section is already clear, smoke still remains in the second one. The smoke eventually leaves the rig through the outlet.

In the setup with the guided stream and the open gate I found out that most of the injected smoke leaves the rig directly with the material stream. The air is guided in the direction of the material too. As opposed to the unguided stream where the currents are starting in the impact area of the material onto the belt which is illustrated by figure 6, with the guided stream a major part of the air stays with the material stream and currents are not as strong. Just a part of the smoke starts the turbulence shown in picture 42 and 54 when it hits the back perspex wall of the rig above the outlet.

The fourth setup with the guided material stream and the closed gate showed that the escape of the smoke caused directly by the rig can be reduced. The smoke is dragged down with the material stream following the chute. When the smoke hits the gate, a turbulence develops as shown in pictures 46, 56 and 57. Like in the other experiments with the gate closed, some smoke remains in the vertical part of the rig. The smoke entering the horizontal part of the rig starts a current in the separated box where it gets trapped for a while before being able to leave the rig.

The experiment with the reduced drop height best illustrates the behaviour of the smoke. At the full drop height, the chute ranges into the separated box. If we use a chute as big as the one I used, the gate should be behind the end of the chute. Pictures 56 and 57 are ideal in illustrating that when there is a gap between the discharge of the chute and the gate, a turbulence will develop in front of the gate. With the second one in the separated part of the box we can give the air time to stay within the transfer and slow down. That allows airborne particles to settle down.

5.1 Prospect

For future work we should consider how we can use the results from the experiments for a superior design of transfer points. The results from the experiments lead us to conclude that with splitting the transfer into two parts we can generate separate air currents. Another important aspect to regard is that when we use a chute to guide the material there should be some distance between the discharge of the chute and the gate. For future experiments with dusty material we can perhaps improve the results of passive dust control by building the horizontal part of the transfer longer and higher or even by adding a third box. If the dust loaded air is able to slow down, the amount of airborne particles leaving the transfer point may be reduced.

6 Register

6.1 Literature

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6.2 Tables

6.3 Figures

6.4 Pictures

6.5 Units

m	meter
mm	millimetre
µm	micrometer
g	gram
mg	milligram
£	British Pound
€	Euro

6.6 Acronyms

U.K.	United Kingdom
3D	three dimensional
AUS	Australia