UNIVERSITI MALAYSIA PERLIS

OPTIMIZING THE PERFORMANCE OF FILTER BAGHOUSES AT PORTLAND CEMENT RAW MILL

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Technical Report

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PREFACE

This project is made possible through the help and support from everyone, including the team members consisting of the academic staffs and final year students (academic session 2019/2020) of the Faculty of Civil Engineering Technology, Universiti Malaysia Perlis.

Special thanks to the Dean of the Faculty of Civil Engineering Technology, Universiti Malaysia Perlis, Dr. Afizah Ayob for her continuous support and encouragement.

The greatest acknowledgment of gratitude towards the Plant Manager and technical staffs from the Mechanical and Maintenance Department of Negeri Sembilan Cement Industries Sdn. Bhd., Perlis Plant, especially Mr Muzzammil bin Haron (the Senior Engineer) for their assistance in completing this report.

Finally, we sincerely thank to our parents, family and friends, who provide the advice and support. The product of this project would not be possible without them.

1.0 INTRODUCTION

The project proponent is Cement Industries of Malaysia Berhad (CIMA). All the necessary information pertaining to the project to the consultant to facilities for the upgrading the APC system designs are provided by them. The proponent concurred and acknowledges the content of this report including the design criteria.

Negeri Sembilan Cement Industries Sdn. Bhd. (NSCI), Perlis is one of the Portland cement producers in Malaysia, which involves processes such as selecting, grinding, heating, cooling and packaging. Each one of these processes discharges certain amount of particulate matter (PM) and harmful gases. However, when considering budget, only selected processes with higher particulate matter and harmful gases emission will be equipped with Air Pollution Control System (APC). The processes that take place in coal mill, kiln and grinder are the most likely to release high emission of particles, thus suitable air pollution control equipment is needed.

In this study, the problem related to the under-capacity performance of coal mill at Portland cement plant from Negeri Sembilan Cement Industries Sdn. Bhd. (NSCI) company in Perlis will be addressed. The inefficiency of filter bag house at coal mill is viewed as one of the reasons for this under performance. Filter bag house role is to collect and filtrate the coal during combustion at the coal mill. Previously in NSCI, the coal mill was able to produce up to 14 tonnes of pulverized coal in an hour but due to some unknown explanation, the amount of pulverized coal that enter the storage decreases to 12 tonnes per hour. So, any problem-related aspect of filter baghouse such as dimensions for the baghouse system, support designs and filter cloth will be discussed.

For the specification of filter cloth provided or manufactured by manufacturer, NSCI is currently using a woven type fabric filter made up of glass fibre. The strength of fabric filter came into focus since information regarding low magnehelic pressure of the filter bag house has been issued by one of the NSCI staff during the site visit. Magnehelic pressure is used in the industry to measure filter resistance, fan and blower pressure, velocity of air and pressure drop across the fabric. The drop in the magnehelic pressure indicated the presence of hole on the fabric. Hence, it is important to evaluate and compare the characteristics of different types of filter bag media to prevent problem from occurring in the future. The suitable dimension and modification on the support design and parameters such as cleaning mechanism and temperature will be analysed thoroughly. This is to reduce the problem such as choking and fabric tearing of the bag filter at the coal mill that will surely take a toll on the plant performance.

1.1 Environmental Quality (Clean Air) Regulations 2014

Environmental Quality (Clean Air) Regulations 2014 is the substitution to the Environmental Quality (Clean Air) Regulations 1978. Gazetted on 4th June 2014 and started enforced on the 5th June 2014. It is applicable for premises that conducts burning or incineration (of waste, materials etc) activity, premise that discharges air pollutants into the open air any fuel burning equipment any industrial plant. The regulation related to the emission in CIMA cement is Regulation 13 that stated:

"All activities and industries specified in the First Schedule shall comply with the technical standards and limiting values as specified in the Second and Third Schedules, as the case may be".

Since NSCI is a mineral-based industry and uses mega fuel burning equipment, it can be categorized under activities listed in the First Schedule of Non-Metallic (mineral) Industry Cement Production (All-Sizes). Referring to the Second Schedule for liquid and solid fuel type. The control of fuel quality and combustion emission for fuel burning equipment in general is as listed below:

Table 1.1: Fuel quality parameter for fuel burning equipment

Fuel Type	Fuel	Fuel quality parameter
Liquid	All	Sulphur content <500 ppm (per weight)
Solid	Coal	Sulphur content <1% (per weight)
	Biomass	Wood, agricultural waste, etc.: air dry and in its natural composition (e.g., wood without coating, paint or other treatment)
		Residues from wood-based industries: without wood preservatives

Table 1.2: Pollutants limiting values for combustion emission for solid and liquid fuels

Fuel type	Pollutant	Limit value	Monitoring
Liquid	Total particulate matter (PM) Where dust load emitted: *a) >0.33<1.0 kg/hr* *b) ≥1.0 kg/h*	50 mg/m^3	Once/year 2 times/year
Solid	Total particulate matter (PM) Where dust load emitted: *a) >0.44<1.0 kg/hr* *b) ≥1.0<1.5 kg/h* *c) ≥1.5<2.0 kg/h* *d) ≥2.0 <2.5 kg/h* *e) ≥2.5 kh/h*	150 mg/m^3	Once/year 2 times/year 3 times/year 4 times/year Continuous*
	Carbon monoxide (CO)	1000 mg/m^3	Periodic

*Averaging time for continuous monitoring is 30 minutes

Third schedule address the limiting values and technical standard according to the activities in the industries. The proposal for this project will need to comply with the limiting values listed in the Non-Metallic (Mineral) Industry: Cement Production (All Sizes)

Table 1.3: Limiting values for the pollutants of kiln

Source	Pollutant	Limit value	Monitoring
Cement kilns	Sum of NO and NO_2 expressed as NO_2	800 mg/m^3	Continuous*
	Total PM	50 mg/m^3	Continuous*
	Mercury	0.05 mg/m^3	Periodic
	PCDD/PCDF	1.0 ng TEQ/m^3	Periodic

1.2 Objectives

The main purpose of this study is to analyse the best design for baghouse filter to filtrate the coal of Portland cement plant. The baghouse filter will be designed to accommodate the coal mill of the cement plant.

i. To evaluate the performance of filter baghouse to further lower the particulates outlet loading to values less than the stipulated standard (control air pollution).
ii. To provide dimensions for the baghouse system based on the key performance evaluated. The performance factors that are considered are the effects of particle charge, the air-to-cloth ratio, and the inlet particulates loading.
iii. To provide modifications on various supported designs in the baghouse to accommodate the new designed system.

2.0 PROJECT DEVELOPMENT PLAN

One of the top cement suppliers in Malaysia is Cement Industries of Malaysia Berhad (CIMA), which is a subsidiary company of the UEM Company Berhad. It has been well known for manufacturing and supplying high quality cement, ready-mixed concrete and related products from 1975. CIMA's corporate office is situated in Petaling Jaya, Selangor, and has two strategic locations in Bukit Ketri, Perlis and Bahau, Negeri Sembilan, which are known as the Negeri Sembilan Cement Industries Sdn Bhd. Both plants have a gross production capacity of 7.2 million tons of cement per year.

Both plants are supplying an Ordinary Portland Cement/CEM1 (OPC), ASTM Type II Portland Cement, Low Heat Cement, Masonry Cement and Portland Composite Cement (PCC). Commonly consumed materials for cement production are sand (silica), iron oxide, alumina and limestone. These materials contain different properties and each of them each plays a vital role in creating variety of cement. The study was conducted at Negeri Sembilan Cement Industries Sdn Bhd. Perlis plant (Figure 2.1). It is located with latitude 6.511816 and longitude of 100.257870 with a total area almost 4,000,000 ft^2 were completely equipped with technology and machines on cement production.

Figure 2.1: Project Area

Cement production needs four type of materials which are sand, iron oxide, alumina and actually a huge portion of limestone. Most of these raw materials are acquired from the limestone quarry excavation. Limestone quarry is chosen due to the high content of limestone contain in it. Thus, by excavating limestone other than limestone itself, we already have all the raw materials necessary for cement production.

Based on Figure 2.2, our study area is located at stage 2 where the filter baghouse was located. At coal mill, the coal supply will be grinding, dried, classified and transported the product to the kiln by undergo the process of filter first. The finer particle of the product will be penetrated or trap to filter baghouse and due to gravity, the particle will drop as solid to the coal storage while the clean air emits to atmosphere. The under capacity happened at this area where baghouse cannot fully trap the coal supplied.

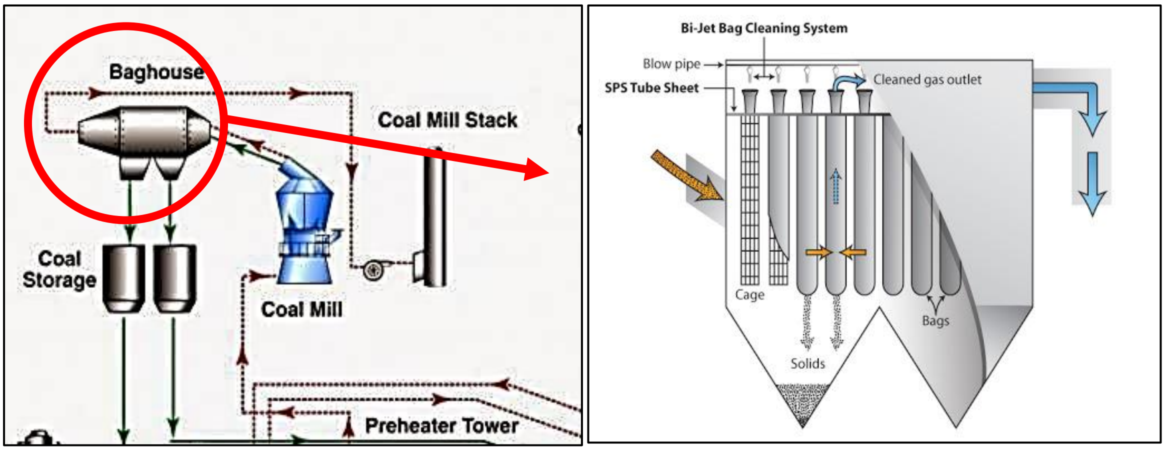


Figure 2.2: Project's Located Point

Nevertheless, the physical process in cement manufacture has a lot of issues especially when it comes to environmental. In general, cement plant contributes to emissions of water, noise quality and air emissions which is the most prominent one. The main pollutants in Portland cement production are particulate matter (PM and PM_{10}), nitrogen oxides (NO_x), SO_2, carbon monoxide (CO) and CO_2. As of the industries needs to follow the regulation to continue their business activity. A lot of control measure have been established to guarantee that the cement plant complies with the standard regulation of Clean Air Act 2014.

The main aim of the project is to evaluate the performance of filter baghouse to further lower the particulates outlet loading to values less than the stipulated standard (control air pollution). Appropriate bag house filter media has to be chosen to maximize efficiency, raise filter life, reduce system maintenance, and thus save money. With so many various types of bag house filter fabrics and treatment methods to choose between, we may detect which one is better suited to the application of CIMA. Table 2.1 indicates the four key considerations that will be weighed before the filter media is selected: to evaluate the performance of filter baghouse to further lower the particulates outlet loading to values less than the stipulated standard (control air pollution)

Second objective is to provide dimensions for the baghouse system based on the key performance evaluated. The performance factors that are considered are the effects of particle charge, the air-to-cloth ratio, and the inlet particulates loading. The third objective is to provide modifications on various supported designs in the baghouse to accommodate the new designed system. Taking into consideration a variety of variables for the re-designed baghouses to withstand the pressure drop, filter drag, air-to-cloth ratio, and collection capacity.

a) Pressure drop (Δp), a quite sensitive in the baghouse design feature, defines the resistance to air flow into the baghouse to achieve an optimal performance.
b) Reasonable air-to-cloth ratios are required to prevent high-speed effect of dust particles on the fabric, as this results in earlier time of bag replacement. To evaluate the acceptable filter size, we must analyze air-to-cloth ratio to fabric and the can velocity of the filter.
c) To maximize the can velocity of the bag filter compartment, the distance between the bags in each row as well as between the rows will be measured and specified for each particular

event. This kind of criteria are often used to decide the most acceptable length of the bag and the number of compartments required.

Table 2.1: Factors on Choosing Filter Media

Factors	Explanation
Temperature	Because different media have varied optimum temperature ranges, the working temperature differences will be investigated to avoid filter media from exceeding the filter media’s bearable range.
Moisture Content	Air humidity is proportional to the point of dew. It is easy to create condensation in a filter bag with a high moisture composition and a high dew point that will influence the de-dusting results. We shall consider this most suitable filter media to avoid the filter media from brittle and damage.
Chemical composition	The anti-acid, anti-alkali and anti-organic solvent filter media must be chosen when there is a presence of acid, alkali or organic solvent in the dusty gas.
Combustibility and explosives	Fire retardant and anti-static filter materials should be utilized, if the dusty gas consists highly explosive gas,

3.0 FORMULATION OF ALTERNATIVES SCHEME

In conveying systems processing granular or dusty substances, the most common and popular method of filtration is a bag variety textile filter. These filters are usually named as baghouses. Most of the baghouses are long and tubular, and they are formed of interwoven or felted material as their filter mechanism. When the dust gas or air is penetrating the baghouse through hoppers by power pressure and is immediately led into the baghouse part. The optimized performance of filter baghouse is based on the comparison among all critical parameters, most important collection efficiency of targeted gaseous pollutants and dust particles. To design high-efficiency filter baghouses, based on Environmental Quality Act (Clean Air) Regulations 2013 for non-metallic industry such as cement plants, the minimum gaseous pollutant emission for dust particulates is 50 mg/m^3. This limit value will be used as the main criteria for design as dust is the leading gases pollutant and particulate matter, physical pollution control by using suction pressure, and is immediately directed into the baghouse section.

3.1 Generating design concept

The selection of the best design filter baghouse system is based on the comparison among all suggested essential parameters such as cleaning mechanism, size, pressure drop. Most important is looking at the collection efficiency of target air pollutants, which are able to perform high efficiency with low cost and resources. Moreover, the financial concern is also an essential element to put into the design consideration that the company affords with. The filter baghouse system has been described below.
a) Filter Baghouse
b) Working Principles of filter baghouse
c) Advantages and disadvantages of filter baghouse system

3.2 Advantages and Disadvantages of Filter Baghouse System

Table 3.1 illustrates the advantages and disadvantages of filter baghouse system.

Table 3.1: Advantages and disadvantages of filter baghouse system

Devices	Advantages	Disadvantages
Baghouse	• Provide high efficiency on course and fine particulate • The collected material has been collected in a dry condition for subsequent processing or for disposal • Efficiency and pressure drop are not affected by large changes in inlet dust loadings especially for continuously cleaned filters • Baghouse filter did not require high used of voltage and need a simple maintenance	• There is a limitation on gas temperature to the utilization of fabric because of the restriction of the structure itself • The fabric can thermally degrade, or the protective surfaces can volatilize when used at high temperature • The fabric filter has limit on temperature at 260 °C or 500 °F • Fabric can burn if readily oxidizable dust is being collected • High costing

3.3 Characteristics of Particulate Matter

The fuel and the coal are used to provide the heat required to convert the kiln feed into clinker. Coal will deliver to the coal mill and during the coal mill process, the dust particles matter will be produced. Therefore, it needs a baghouse to filter the dust. Coal is mainly composed of carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus and other elements, it is very essential energy, an important raw material in the cement industry, coal is mainly used in power generation, steel, cement, fertilizer, system of oil fields. It can be divided into lignite coal, bituminous coal, anthracite, semi-anthracite and other types. The below is the characteristics of coal. The ideal size is taken as 74 μm or smaller, but standards allow a range of larger particles, the amount decreasing with size until the maximum size acceptable is reached. In the coal mill process the temperature is maintained between 65 to 90 °C. The strength of coal is between 800 psi and 5000 psi.

3.4 Cleaning Mechanism

After a careful investigation of different cleaning mechanisms, between mechanical shaker, reverse-air and pulse jet types, we have decided to choose the pulse-jet cleaning mechanism. This is due to the pulse-jet baghouses having more significant advantages than other mechanisms. The investigated parameters of different types of cleaning mechanisms along with their advantages and disadvantages are tabulated in Tables 3.2 and 3.3. The advantages of pulse-jet cleaning mechanism are it is simple to operate, clean the dust efficiently, requires less bags and can make it more space-efficient and low cost. Other than that, it is the most suitable method for using in the coal mill process due to the coal characteristics and the coal mill temperature.

Table 3.2: Cleaning parameters of mechanical shaker, reverse air and pulse jet mechanisms

Parameter	Mechanical Shaker Cleaning	Reverse Air Cleaning	Pulse Jet Cleaning
Frequency	Usually several cycles per second; adjustable	Cleaned one compartment at a time, sequencing one compartment after another	Usually, a row of bags at a time, sequenced one row after another; can sequence such that no adjacent rows clean one after another;
Motion	Simple harmonic or sinusoidal	Gentle collapse of bag (concave inward) upon deflation	Shock wave passes down bag
Peak acceleration	4 - 8 g	1 - 2 g	30 - 60 g
Amplitude	Fraction of an inch to few inches	N/A	N/A
Duration	10 - 100 cycles, 30 s - few minutes	1 - 2min. including valve opening and closing and dust settling periods	Compressed air (40 to 100 psi) pulse duration 0.1 sec
Common filter baghouse dimensions	5, 8, 12 diameters (inches); 8 to 10, 22, 30 length (foot)	8, 12 diameters (inches); 22, 30, 40 length (foot)	5 to 6 diameters (inches); 8 to 20 length (foot)

Table 3.3: Advantages and Disadvantages of Cleaning mechanism

Cleaning Mechanism	Advantages	Disadvantages
Mechanical Shaker	• Easy to operate • Low cost • Can be cleaned easily without shutting the whole baghouses	• Cannot operate in high temperature • Takes up a large area to operate • Time and energy sensitive
Reversed-air	• Operate in high temperature • Long baghouses life • Can be cleaned easily without shutting the whole baghouses	• Needs to be cleaned regularly • Difficult to remove dust on the fabric surface • Low air-to-cloth area
Pulse-jet	• Space efficient • Utilized less bags • Can Cleaned Continuously • Low-cost • Simple to operate • Higher air-to-cloth ratio	• Cannot operate in high temperature • Needs dry compressed air • Cannot operate when the surrounding is humidity

4.0 DETAIL DESIGN WORK

4.1 Design Procedure

To design the filter baghouse system, some of the mathematical equations and calculations need to be applied. Baghouses are designed by their size and depend on gas-to-cloth ratio and "can velocity". Other than that, the pressure drop is also an important parameter to consider the efficiency of the filter baghouse. The collection efficiency is the most important to determine the characteristics of the filter baghouse. The following are the procedure established for the calculation of baghouses design.

1. Gas-to-cloth ratio

The gas-to-cloth ratio is the measure of the amount of gas emitted by each square foot in the baghouse. It is given in terms of the number of cubic feet of gas per minute passing through one square foot of cloth. In other words, the G/C ratio is equal to the gas volume rate/cloth area. Also note that this velocity is not the actual velocity through the openings in the fabric, but rather the possible velocity of the gas surrounding the cloth. When the G/C ratio is increased, the pressure drop also will increase. The baghouses that usually have the highest gas-to-cloth ratio is pulse jet baghouses. A high gas-to-cloth ratio means that there is a large volume of dirty air passes through the bags at a given time.

Factors affecting the G/C include the cleaning process, filter media, dust capacity, dust quantity, dust loading, and other factors that differ from each situation. Once the gas/cloth ratio (G/C) has been decided, the size of the baghouse is nearly installed. Variations also occur in the number of walkways, hopper slope, and other design problems. These different modifications will influence the total capacity of the baghouse to a limited degree, once G/C has identified the essential requirements.

$$\textbf{Units gas}/\textbf{cloth ratio} = \frac{\textbf{gas volume rate}}{\textbf{total cloth area}} = \frac{\boldsymbol{ft^3/min}}{\boldsymbol{ft^2}} = \boldsymbol{ft/min}$$

For the pulse jet filter baghouse with felted fabric for coal:
G/ C = 3.5 ft/min
= 0.01778 m/s

2. Gas flow rate

Area of filter baghouse

$$A = \pi DL$$

Where, A=bag surface area, m^2
D=bag diameter, m
L=bag length, m

Bag diameter= 0.152 m
Bag length= 3.66 m

$$A = \pi DL = \pi(0.152)(3.66) = 1.75\ m^2$$

Total Area of filter baghouse

Assume number of bags = 240
Compartments of baghouses = 4

$$Area\ baghouse\ \times number\ of\ baghouse \times compartment$$
$$= 1.75 \times 240 \times\ 4 = 1677.82\ m^2$$

Gas flow rate

$$F = \frac{Q}{G/C}$$

Where, F=total fabric area, m^2
Q=gas flow rate, m^3/s
G/C=gas-to-cloth, $(m^3/s)/m^2$

Assume Pulse jet baghouse with felted fabric, so
G/ C = 3.5 ft/min
= 0.01778 m/s

$$Q = \left(\frac{G}{C}\right) \times F = 0.01778 \times 1677.82 = 29.83\ m^3/s$$

Gas-to-cloth ratio increase, the air flow rate will increase.

3. Pressure drops

$$\Delta p = k_1 V_f$$

Where: Δp = pressure drop across the clean fabric (in. H_20)
k_1 = fabric resistance in H_20 / (m/s)
V_f = filtration velocity, m/s

Assumption felted fabric as our fabric, therefore the k_1 = 281.21 m/s
The filtration velocity will be 0.01778 m/s.

Therefore,

$$\Delta p = (281.21) \times 0.01778 = 5\ in.H_2O$$

The pulse-jet baghouse is usually operated with pressure drops of 5 in. H_20.

4. Can velocity

Can Velocity = (ACFM / A_t - (N x (A_b))

Where: A_t= tubesheet area (m^2)
N= number of bags
A_b= area of the bottom of the bag (m^2)

ACFM = 29.83 m_3/s
= 1053.44 ft/s
A_t = 1677.82 m2
N = 240
A_b = 1.75 m^2

$$Can\ Velocity = (2983\ \div (1677.82 - (240\ \times 1.75)) =\ 2.38\ m/s$$

Velocity should not exceed 468 fpm or 2.38 m/s.

5. Filter drags

$$S =\ \Delta\,\mathrm{p}/V_f$$

Where: S = filter drag, in. H_2O

Δp = pressure drop across the clean fabric (in. H_20)

V_f = filtration velocity, m/s

Δp = 5 in

V_f = 0.01778 m/s

Therefore,

$$S = \frac{5}{0.01778} = 281.21\ in\ H_2O$$

Filter drag in pulse jet baghouse would be 281.21 in. H_2O

6. Collection efficiency

Assuming volumetric flow rate (Q) inlet = 29.83m^3/s when using pulse-jet filter baghouse with felted fabric.

Assuming Q outlet is 10% from Q inlet: 2.983 m^3/s

$$E =\ \frac{(Inlet\ loading - outlet\ loading)}{(Inlet\ loading)}\ \times 100\%$$

$$E = \frac{(29.83 - 2.983)}{(29.83)} \times 100\% = 90\%$$

Assuming Q inlet = 29.83 m^3/s

Assuming Q outlet is 7% from Q inlet: 2.09 m^3/s

$$E = \frac{(29.83 - 2.09)}{(29.83)} \times 100\% = 93\%$$

Assuming Q inlet = 29.83 m^3/s

Assuming Q outlet is 5% from Q inlet: 1.50 m^3/s

$$E = \frac{(29.83 - 1.50)}{(1.50)} \times 100\% = 95\%$$

Table 4.1: The collection efficiency of different outlet flow rate

Inlet flow rate (m^3/s)	Outlet flow rate (m^3/s)	Collection efficiency (%)
29.83	2.983	90
29.83	2.09	93
29.83	1.50	95

7. Particulate matter emission from a coal mill

Particulate matter emissions from a coal mill process. The results indicated that an emission of total particulate matter is 121 mg/m^3. The outlet loading is 28.7 mg/m^3. According to Malaysia emission standards, the particulate matter emission limit value should not exceed 50 mg/m^3. Therefore, the design is following the emission standards. The removal efficiency was achieved 76.3 % (Lu, Wu, & Pan, 2010).

$$E = \frac{(121 - 28.7)}{(121)} \times 100\% = 76.3\ \%$$

4.2 AutoCAD Drawing

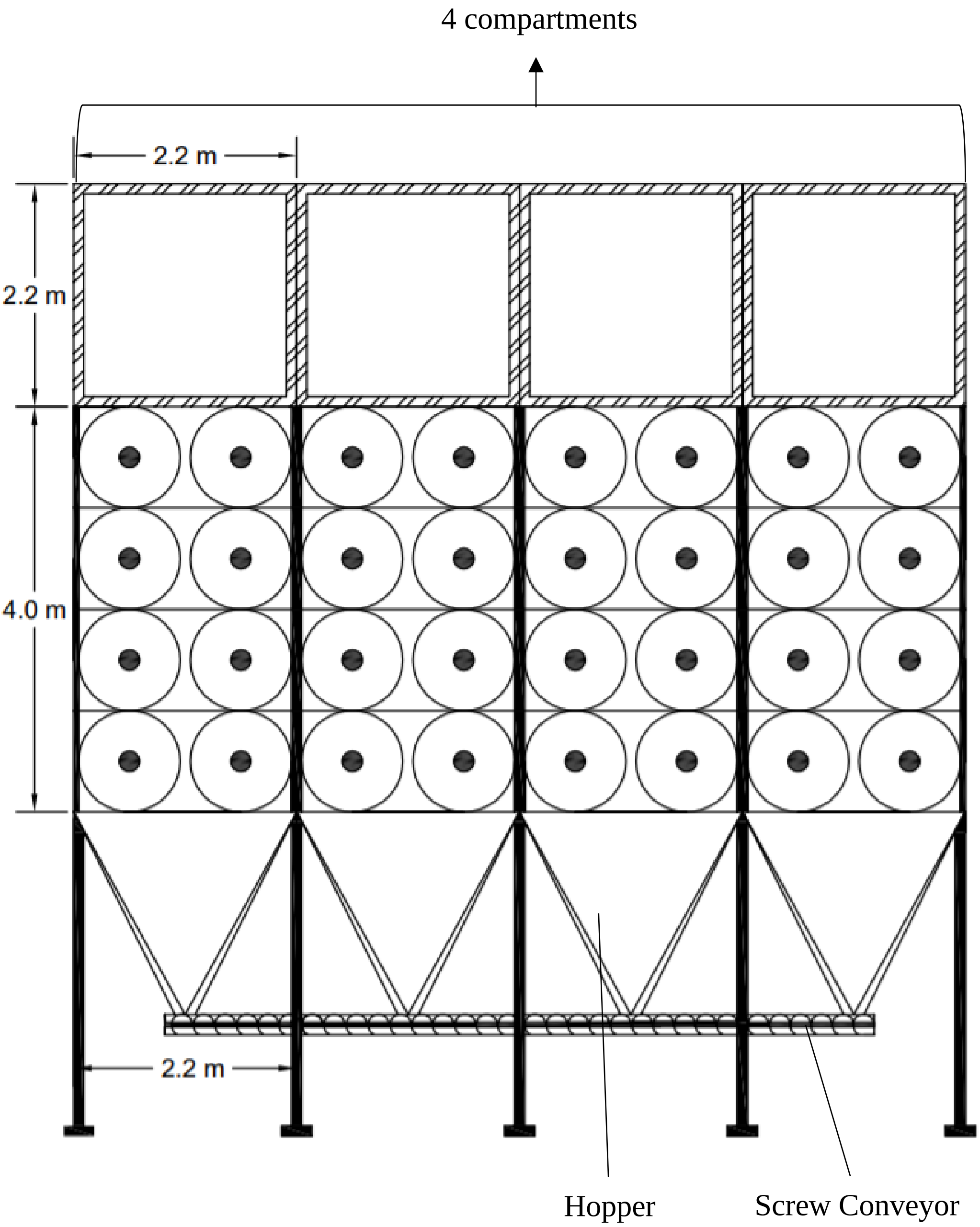


Figure 4.1: Front view of filter baghouse system

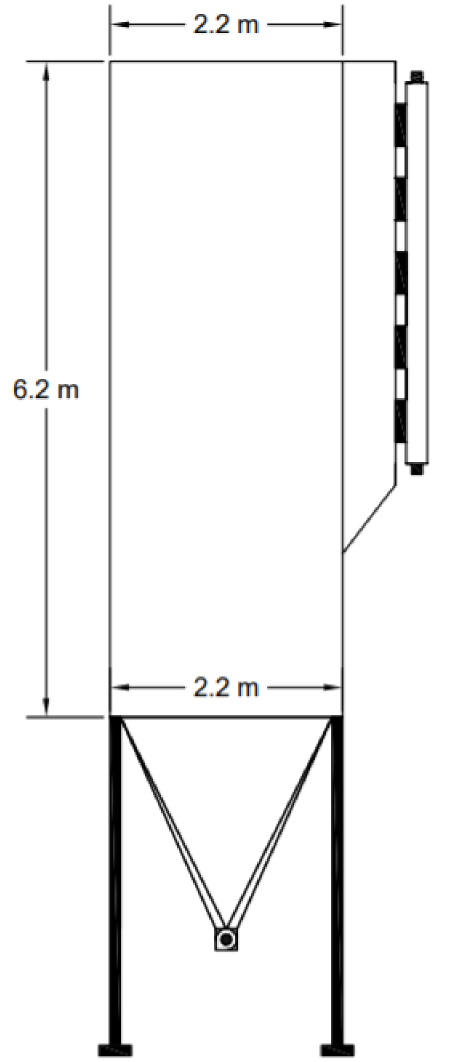
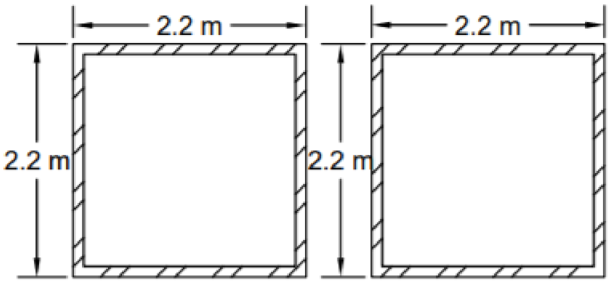


Figure 4.2: Side view of filter baghouse system



Inlet Flange Outlet Flange

Figure 4.3: Inlet flange and outlet flange of filter baghouse system

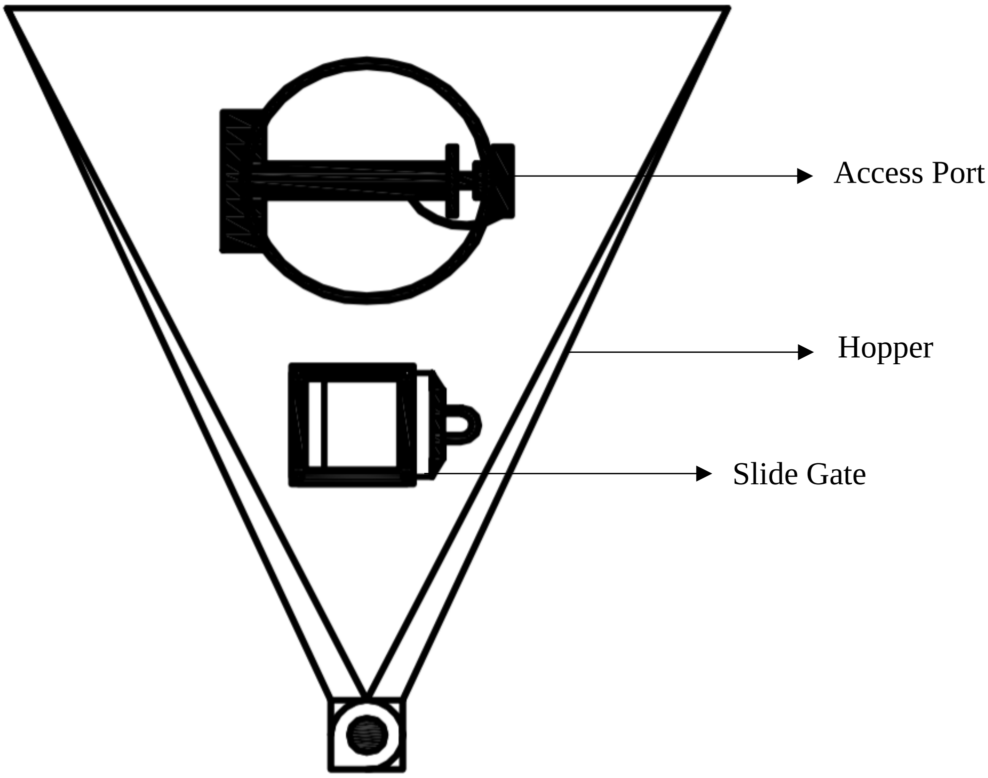


Figure 4.4: Access port and slide gate installed at hopper of filter baghouse system

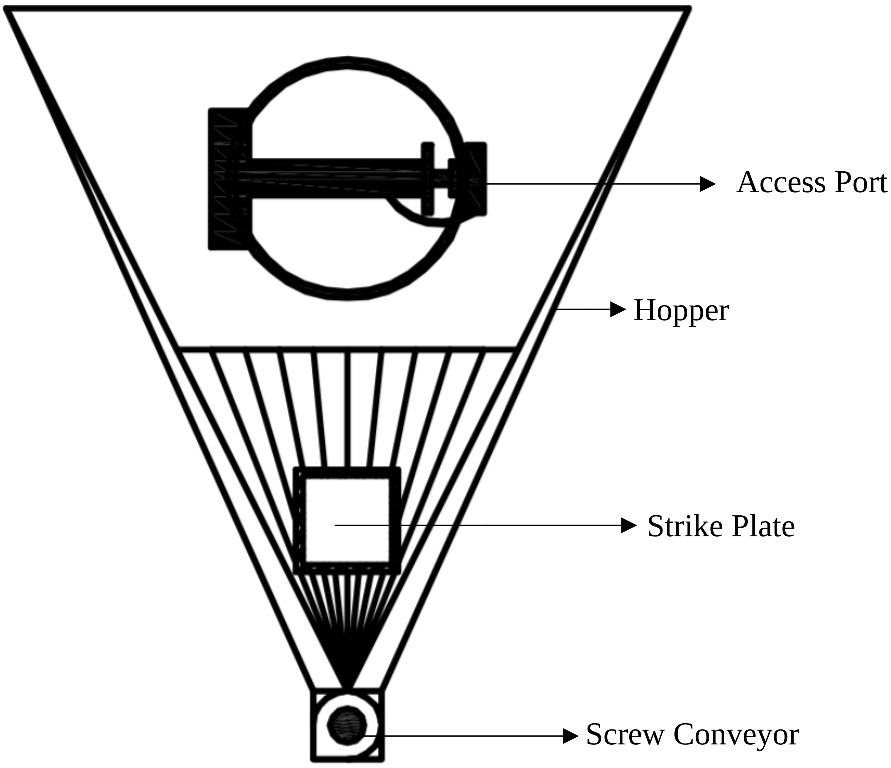


Figure 4.5: Access port and strike plate installed at hopper of filter baghouse system

Figure 4.6 showed a prime example of a near-integrating process would be gas pressure control in large-volume equipment such as baghouses, furnaces, coke ovens, and distillation columns. It was the control of pressure in a closed-loop system consisting of a coal pulverizer, fan, baghouse, and many meters (yards) of ducting. The system recirculated nitrogen gas to carry pulverized coal from the pulverizer to the baghouse. Make-up nitrogen was continuously added to the system. A vent with a control valve, and a pressure transmitter were provided for pressure control.

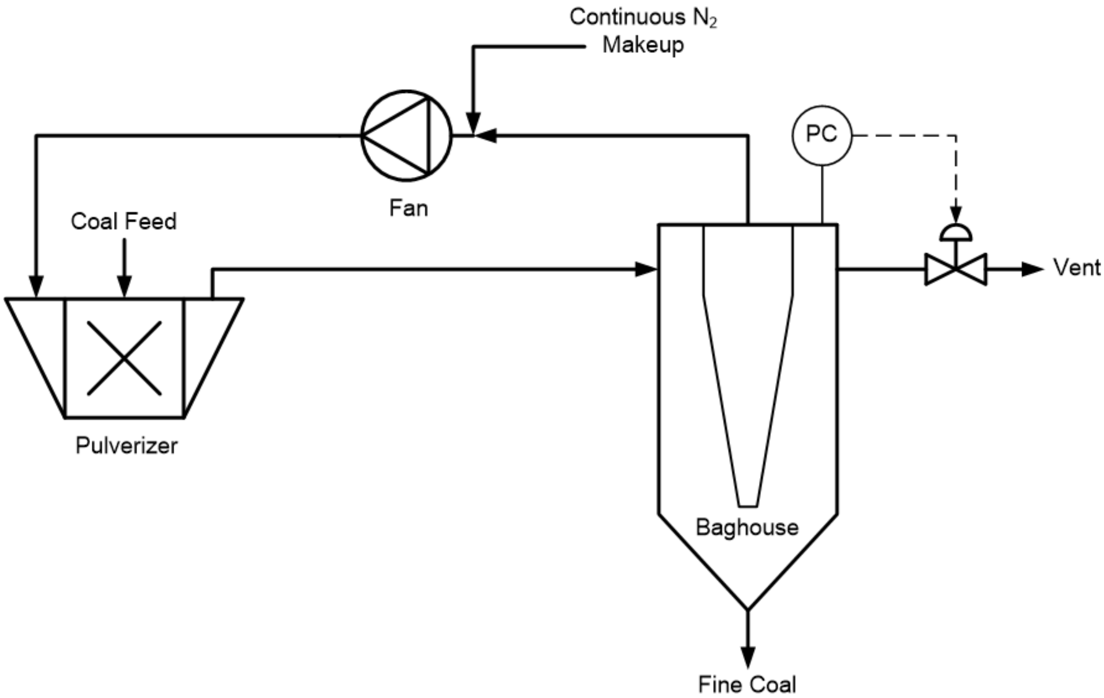


Figure 4.6: Simple diagram of system with a near-integrating process response of baghouse

5.0 SAFETY, HEALTH AND ENVIRONMENTAL CONSIDERRATION

5.1 Hazard Identification, Risk Assessment and Risk Control

Bag failures occur at varying times depending on the operation of the collector. Hence, it is important to schedule monitoring and maintenance activities of the bag houses. The bag house that is maintained properly will ensure the smooth run for filtration process as the possibilities for damaged can be avoided. The hazard identification, risk assessment and risk control is identified as in the following Table 5.1.

5.2 Hazard and Operability (HAZOP) Worksheet

Hazard and Operability (HAZOP) report is a comprehensive approach to recognize hidden dangers in the working system. In this method, the procedure is broken down into stages, and any change in the function parameters is evaluated from each step to see what might go wrong. The report extensively examines the growing aspect of the system. The purpose is to detect possible scenarios that might allow the item to present a danger or to restrict the activity of the system as a whole. The HAZOP report is carried out during the planning stage of the new project. The success of the analysis ensures that all possible sources of failure will be known. The HAZOP report would include an overview of the possible deviations, consequences, causes, safeguard and recommendation. From this stage on, improvements to the program will be made to eliminate issues from happening. In the ongoing facilities, HAZOP has been operating to enhance the procedure without any defined end date. The HAZOP worksheet for this research was developed using Process Hazard Analysis (PHAWorks) software and tabulates in Table 5.2.

Table 5.1: The HIRARC form of the proposed project

Job	Sequence of Job Step	Hazard Identification			Existing control	Risk Assessment			Control						
		Hazard	Effect			L	S	RR	Control measures Recommendation					Recommendation	Status
			Occurrence of a hazardous Event or exposure	Injury or Ill Health					E	SB	EN	A	P		
Maintenance	Visual inspection on system fan, dampers, electrical control etc.	Ergonomic hazard	Wrong working posture	Musculoskeletal disorders (MSDs)	Safety checklist card	3	2	6				✓		Take a break for every 30 minutes	
	Remove inspection door and check conveyor for loose items or obstructions	Physical hazard	Sharp objects	Broken finger and Bruised arm	Signage regarding procedure for inspection	2	2	4			✓	✓	✓	Wear rubber gloves	

	Adjust duct work dampers - open or at proper setting	Electrical hazard	Damage wiring	Electrocution	Safety manual	1	2	2					✓	Double check the on off switch	
	Remove any temporary baffles	Physical hazard	Sharp objects	Bleeding	Wears Personal Protective Equipment	1	2	2				✓	✓	Wear gloves	
	Test horn alarm system, if included, by jumping connected sensors	Physical hazard	Exposure to high noise level	Temporary loss of hearing	Wear hearing protection gear	1	2	2			✓		✓	Administration announcement	
	Check cell plates for dust leaks	Physical hazard	Sharp objects Heavy objects	Bruised arm and Broken leg	Full body harness	2	3	6					✓	Provide standing platform for workers	

	Check to see that dust is being discharged from hopper	Chemical hazard	Exposure to particulate matter	Respiratory problem	Mask	1	1	1				✓	✓	Build up temporary walls	
	Walk through baghouse to check for normal or abnormal visual and audible condition	Physical hazard	Falling objects	Head injuries	Safety helmet	2	4	8				✓	✓	Warning signs	
		Chemical hazard	Dust and particulate matter	Coughing and asthma	Mask	1	1	1					✓	Close the area for outsiders	
	Replace high-wear parts on cleaning system	Physical hazard	Falling from high place	Broken leg and Death	Full body harness	3	4	12					✓	Personnel inspection	
		Ergonomic hazard	Awkward working posture	Stiff neck and Musculoskeletal disorders	Personnel inspection	2	3	6				✓		Scheduled a routine work	

Table 5.2: The HAZOP form for the proposed project

PHA Method: HAZOP (Traditional)
Project Name: Optimizing the Performance of Filter Baghouses at The Portland Cement Raw Mill
Location: Negeri Sembilan Cement Industries, Perlis Plant
Facility: Upgraded design of Filter Baghouses
Purpose: Analyzed the best design for baghouse filter in order to filtrate the coal of Portland cement plant.
Scope: To design the filter bag system selected and to optimize the whole system
Objectives:

i. To evaluate the performance of filter baghouse to further lower the particulates outlet loading to values less than the stipulated standard (control air pollution).
ii. To provide dimensions for the baghouse system based on the key performance evaluated. The performance factors that are considered are the effects of particles charge, the air-to-cloth ratio, and the inlet particulates loading.
iii. To provide modifications on various supported designs in baghouse to accommodate the new designed system.

Guidewords	Deviations	Causes	Consequences	Safeguards	Recommendations	By
No	No Flow	1. dust in hopper	1.1.1. dust become solid	1.1.1.1. clean the dust	1.1.1.1. monitor through flow measurement system	Operation & Maintenance Team
More	More Flow	2. decreased the removal efficiency	2.1.1. unproper capture of particle	2.1.1.1. air to cloth ratio should be 7-10 a/c	2.1.1.1. inspect air pulsing duration and frequency	
			2.1.2. shortened life bag	2.1.2.1. used alarm		
			2.1.3. increased bag abrasion			
Less	Less Flow	3. inadequate air pulsing	3.1.1. bags become blinded			

Guidewords	Deviations	Causes	Consequences	Safeguards	Recommendations	By
More	Higher Temperature	1. bag surface holes	1.1.1. premature bag failure	1.1.1.1. Temperature should not exceed 25 F from baseline	1.1.1.1. Compare differences of inlet and outlet temperature as baseline.	Operation & Maintenance Team
			1.1.2. loss of strength due to melt		1.1.2.1. establish normal optimum range	
Less	Lower Temperature	2. dew point temperature	2.1.1. acid condensation/ acid attack		2.1.1.1. install temperature signals to limit indicator	
			2.1.2. bag surface blinded/ loaded			

Guidewords	Deviations	Causes	Consequences	Safeguards	Recommendations	By
More	Higher Pressure	1. high resistance to flow	1.1.1. fugitive emission	1.1.1.1. clean periodically	1.1.1.1. monitor at static pressure drop gauge	Operation & Maintenance Team
			1.1.2. increases operating cost	1.1.2.1. need cleaning if 5- 6 in WC	1.1.2.1. check cleaning system components	
		2. undercleaning	2.1.1. dust cake build/ establish	2.1.1.1. usually 1-3 in WC		
Less	Lower Pressure	3. overclean	3.1.1. small particle cannot be traped		3.1.1.1. reduce cleaning cycle time	
			3.1.2. dust cake re establish			
			3.1.3. increase stack emission			

6.0 ECONOMIC EVALUATION

Total capital investment includes the baghouse structure costs, bags' initial complement costs, auxiliary equipment costs, usual direct costs and indirect costs correlated with installing or erecting new structures. These costs are introduced below.

6.1 The Equipment Cost

6.1.1 *Bare Baghouse Costs*

Relationship between cost and fabric area for 3 types of baghouses are presented. These three types which are preassembled are listed in Table 6.1. Figures 6.1 and 6.2 show common-housing and modular pulse-jet baghouses, respectively. Common housing units have all bags within one housing; modular units are constructed of separate modules that may be arranged for off-line cleaning. Note that in the single-unit (common-housing) pulse jet, for the range shown, the height and width of the unit are constant and the length increases; thus, for a different reason than that for the modular units discussed above, the cost increases linearly with size. Because the common housing is relatively inexpensive, the stainless-steel add-on is proportionately higher than for modular units. Added material costs and setup and labor charges associated with the less workable stainless-steel account for most of the added expense. Figure 6.3 shows costs for cartridge baghouses cleaned by pulse.

Table 6.1: List of cost curves for three baghouse types

	Baghouse Type	Figure No.
	Preassembled Units	
Continuous	Pulse-jet (common housing)	6.1
Continuous	Pulse-jet (modular)	6.2
Continuous	Pulse-jet (cartridge)	6.3

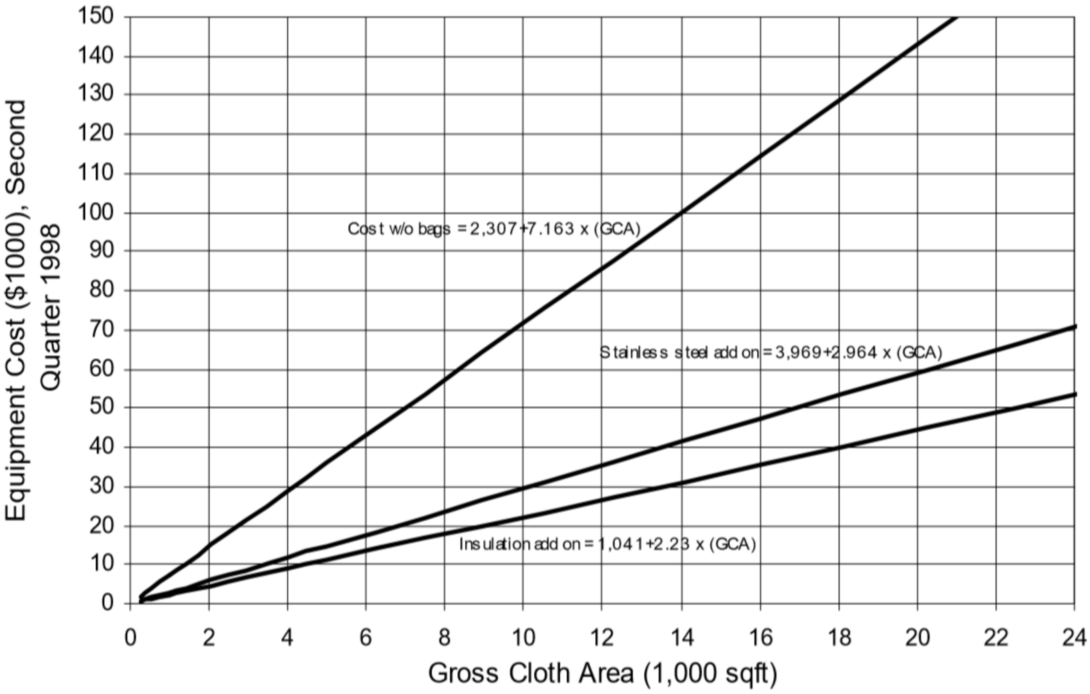


Figure 6.1: Equipment Costs for Pulse-Jet Filters (Common-housing)

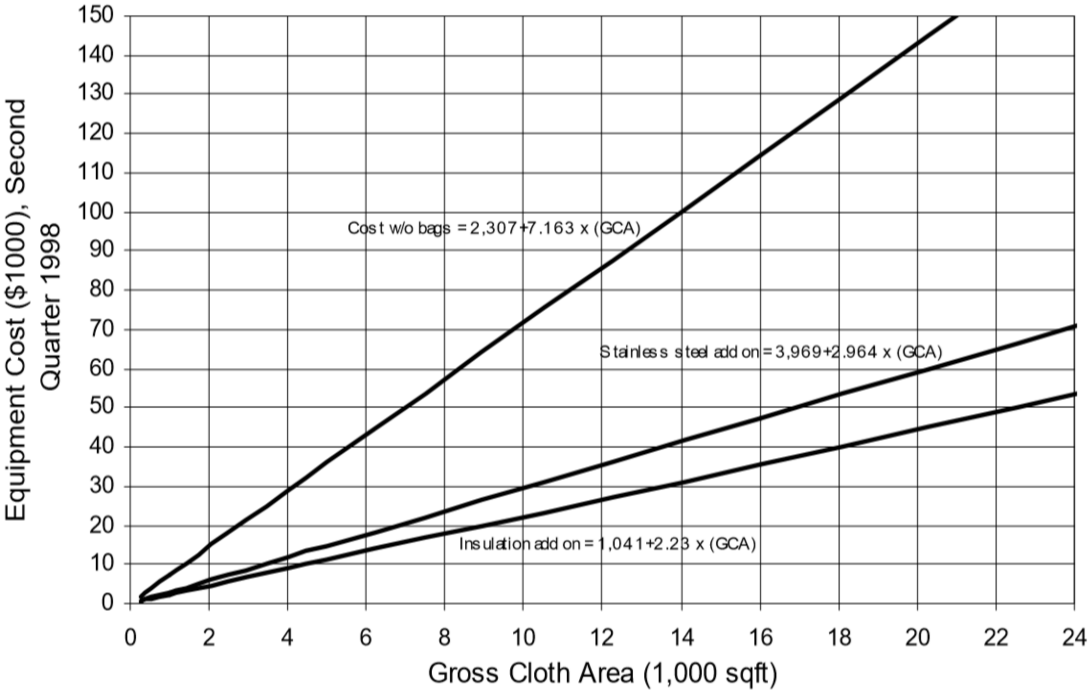


Figure 6.2: Equipment Costs for Pulse-Jet Filters (Modular)

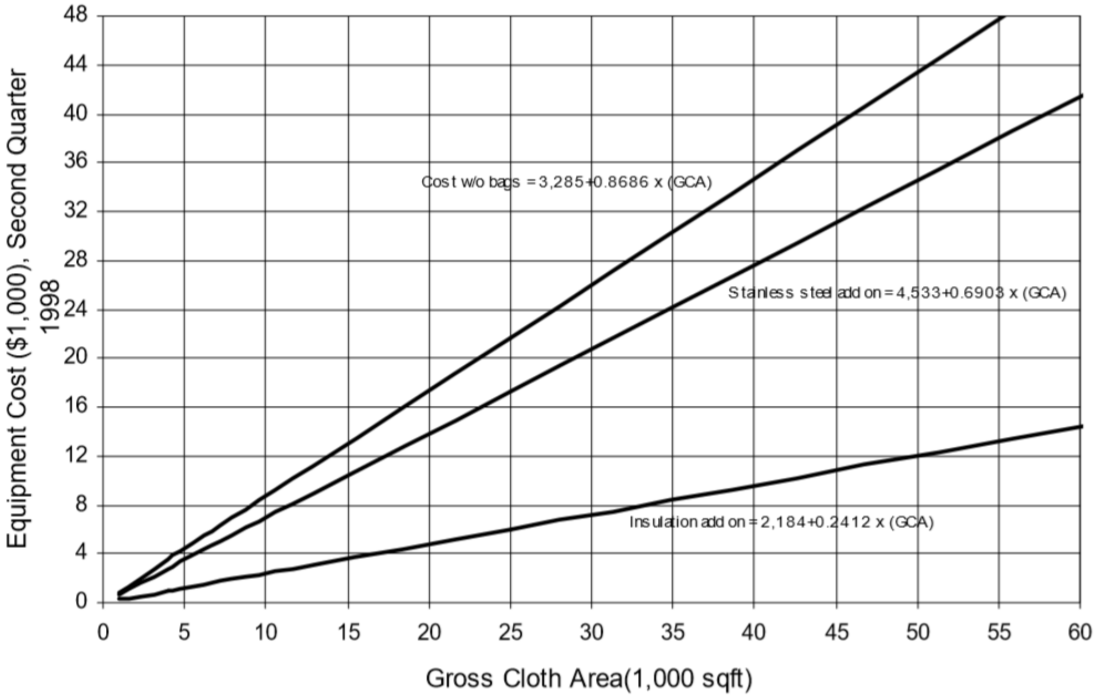


Figure 6.3: Equipment Costs for Cartridge Filters

The capital cost factors are calculated as the following:

Cost Item	Factor (MYR)
<u>**Direct costs**</u>	
Purchased equipment costs	
Fabric filter (EC)	60,000
Bags	28,000
Auxiliary equipment	12,000
Total, A	**100,000**
Instrumentation, 0.10A	10,000
Sales taxes, 0.03A	3,000
Freight, 0.05A	5,000
Purchased Equipment Cost, PEC, B = 1.18 A	**118,000**
Direct installation costs	
Foundations & supports, 0.04 B	4,720
Handling & erection, 0.50 B	59,000
Electrical 0.08 B	9,440
Piping, 0.01 B	1,180
Insulation for ductwork, 0.07 B	8,260
Painting, 0.04 B	2,360
Direct installation costs, 0.74 B	84,960
Total Direct Cost, DC, B+ 0.74B = 1.74 B	**202,960**

Indirect Costs (installation)	
Engineering, 0.10 B	11,800
Construction and field expense, 0.20 B	26,600
Contractor fees, 0.10 B	11,800
B Start-up, 0.01 B	1,180
Performance test, 0.01 B	1,180
Contingencies, 0.03 B	3,540
Total Indirect Cost, IC, 0.45 B	**53,100**
Total Capital Investment = 1.74 B + 0.45 B = 2.19 B	**256,060**

The construction estimation cost of the baghouse filter including equipment costs, installation cost and total capital investments estimated around RM 256,060. The equipment cost including fabric filter with insulation, bag, cages and auxiliary equipment which is RM 118,000 while for total indirect cost is RM 202,960.

6.2 Total Annual Costs Estimation

6.2.1 Direct Annual Costs

Direct annual costs include operating and supervisory labor, operating materials, replacement bags, maintenance, utilities, and dust disposal. Majority costs are talked separately below. They differ with place and time and should be gained to fit the particular baghouse system being costed.

6.2.1.1 Operating and Supervisory Cost

Typical operating labor requirements are 3 hours per 8-hours shift for a wide range of filter sizes. When fabric filters are operated to meet Maximum Achievable Control Technology (MACT) regulations, it is likely that the upper end of the range is suitable. Small or well-performing units may need less time, while very large or troublesome units may need more. Supervisory labor is taken as 15% of operating labor.

Operator cost (OL): requirement of 3 h per 8 h shift = RM56.21/h
Annual cost of OL = (3 h/shift / 8 h/shift) X 6,000 hours/year X RM56.21/h = RM12,472.50
Supervisory cost (SL): 15 % of OL = 0.15 x RM 12,472.50 = RM 1,870.88

6.2.1.2 Operating Materials

Operating materials are usually not essential for baghouses. An exception is the precoat materials used injected on the inlet side of the baghouse to give a layer with protective dust on the bags when adhesive or destructive particles may hurt them. Adsorbents might be injected in the same way while the baghouse is used for simultaneous particle and removal of gas. Materials costs shall be cover on a dollars-per-mass.

6.2.1.3 Maintenance

Maintenance labor differs from 1 to 2 hours per shift. As with operating labor, these values may be minimized or surpass rely on the particular unit's size and operating difficulty. Maintenance materials costs are expected to be equivalent to labor costs of maintenance.

Maintenance Labor (ML) of 1 hour per 8-hour shift = RM 61.85/h Annual cost of ML = (1 hr/shift / 8 hr/shift) x 6,000 days/year x RM61.85/h = RM 46,387.50 Maintenance Materials (MM) is assumed to equal the Maintenance Labor (ML), MM = ML MM = RM 46,387.50

6.2.1.4 Replacement Parts

Replacement parts consist of filter bags, which have a typical operating life of about 2 to 4 years. The following formula is used for computing the bag replacement cost:

CRCB = (CB + CL) x CRFB

CRCB = bag capital recovery cost (RM/year)

CB = initial bag cost including taxes and freight (RM)

CL = bag replacement labor (RM)

CRFB = capital recovery factor whose value is a function of the annual interest rate and the useful life of the bags (For instance, for a 7% interest rate and a 2-year life, CRFB = 0.5531.)

CRCB = (CB + CL) x CRFB

CB = RM 118,000

CL = RM6.57/m^2 net bag area x (1677.82 m^2) = RM 11,023.28

CRFB = 0.5531

CRCB = (CB + CL) x CRFB

CRCB = (RM 118,000 + RM 11,023.28) x 0.5531

CRCB = RM 71,362.78

6.2.1.5 Utilities

Electricity

The cost of electricity depends largely on the fan power requirement. For an estimation of fan power requirement, assuming a 65 % fan motor efficiency and a fluid specific gravity of 1.00:

$$F_p = (0.000181)\ (Q_{e,a})\ (P)\ (HRS)$$

F_p = electricity cost (RM)
$Q_{e,a}$ = emission stream flow rate (acfm)
P = the system pressure drops (in. H_2O)
HRS = the operating hours (h/year)

$F_p = 1.81 \times 10^{-4}\ (Q_{e,a})(P)(HRS)$

F_p = (0.000181) (63,206.19 acfm) (5 in. H_2O) (6,000 h/year) (RM0.26/kWh)

F_p = RM 89234.50

Compressed air

Compressed air (dried and filtered) = (2 scfm/1,000 acfm) (63,206.19 acfm) (RM0.69/1,000 scfm) (60 min/h) (6,000 h/year)

Compressed air (dried and filtered) = RM 31,400.84

Waste Disposal

- Varies with size and location
- Ranging from RM 86.78/ton to RM 130.17/ton for non-hazardous waste,
- Hazardous material 10 times of this amount.

Waste disposal, at RM86.78/ton onsite for essentially 100% collection efficiency:

(4 g/ft^3) (1 lb/7,000 g) x 63,206.19 ft^3/min x 60 min/h x 6,000 h/year x (1 ton/2000 lb) x (RM 86.78/ton) = RM 564,174.84

6.2.2 Indirect Annual Costs

Indirect annual costs such as property taxes, capital recovery, administrative costs, insurance and overhead. The capital recovery cost is based on the lifetime of equipment and the annual interest rate adopted. The system lifetime differs from 5 to 40 years, with 20 years being typical for fabric filters. Nevertheless, this does not apply to the bags that generally have shorter lifetime. Therefore, one should base system capital recovery cost predicts on the installed capital cost, reduce the bags replacement cost.

Property Tax = 0.01TCI = 0.01 (RM 256,060) = RM 2560.60
*Capital recovery factor is assumed as 10% interest rate for estimated 20 years equipment life.

*Capital Recovery = 0.1175 (TCI – 0.05 CL – 1.08 CB) = 0.1175 {RM 256,060 – 0.05 (RM 11,023.28) – 1.08 (RM 118,000)} = RM 15,048.09

Administrative = 0.02TCI = 0.01 (RM 256,060) = RM 5121.20

Insurance = 0.01 TCI = 0.01 (RM 256,060) = RM 2560.60

Overhead = 0.6 (OL + ML) = 0.6 (RM 12,472.50+ RM 46,387.50) = RM 58,860

Thus, the total summary of annual costs is listed as follows (Section 6.2):

Cost Items	**Factor (MYR)**
Direct Annual Cost	
Operating Cost	12,472.50
Supervisory Cost	1,870.88
Operating Materials	-
Maintenance	
Material Labor	46,387.50
Material Materials	46,387.50
Replacement Parts	71,362.78
Utilities	
Fan Power Requirement	89,234.50
Compressed Air	31,400.84
Waste Disposal	564,174.84
Total Direct Annual Costs	**863,291.34**
Indirect Annual Costs	
Property Taxes	2,560.60
Capital Recovery	15,048.09
Administrative Costs	5,121.20
Insurance	2,560.60
Overhead	58,860
Total Indirect Annual Costs	**84,150.49**
Total Annual Cost	**947,441.83**

The total direct annual cost of the baghouse filter including operating cost, supervisory cost, operating materials, maintenance, replacement parts and utilities is estimated around RM 863,291.34 while for total indirect annual cost including property taxes, capital recovery, administrative, costs insurance and overhead is RM 88,150.49. The total annual cost including total direct annual costs and total indirect annual costs is RM 947,441.83.

CONCLUSION

Negeri Sembilan Cement Industres Sdn. Bhd. (CIMA, Perlis Plant) has mentioned their needs of reducing emission of particulate matter from the coal mill process and increase the efficiency production of cement by solving the problem of inefficiency baghouses. An air pollution control device has been upgraded to accommodate the new designed system and introduce to the client to fulfil the needs of customer by installing the baghouses system. By modifying the new baghouse system, the cleaning mechanism of pulse-jet method was chosen in this project and the fabric material is felted fabric. This is due to this method being the most suitable for the coal mill process. The advantages of the pulse-jet method are it is simple to operate, clean the dust efficiently, requires less bags and can make more space-efficient and low cost. Besides that, the design is evaluated with the concern of health and safety and economic consideration. This is since the design must be sustainable and environmentally friendly. The design formulation and calculation will be provided with drawing and visualization through the simulation. Thus, the parameters of air-to-cloth ratio, pressure drop, can velocity, airflow rate and the removal efficiency are important in our design project. Therefore, the problem of particulate matter emission from the coal mill process and under-capacity of cement can be solved. The proposed technology considered the environmental and sustainability concern, which will be able to reduce the impact to the environment.

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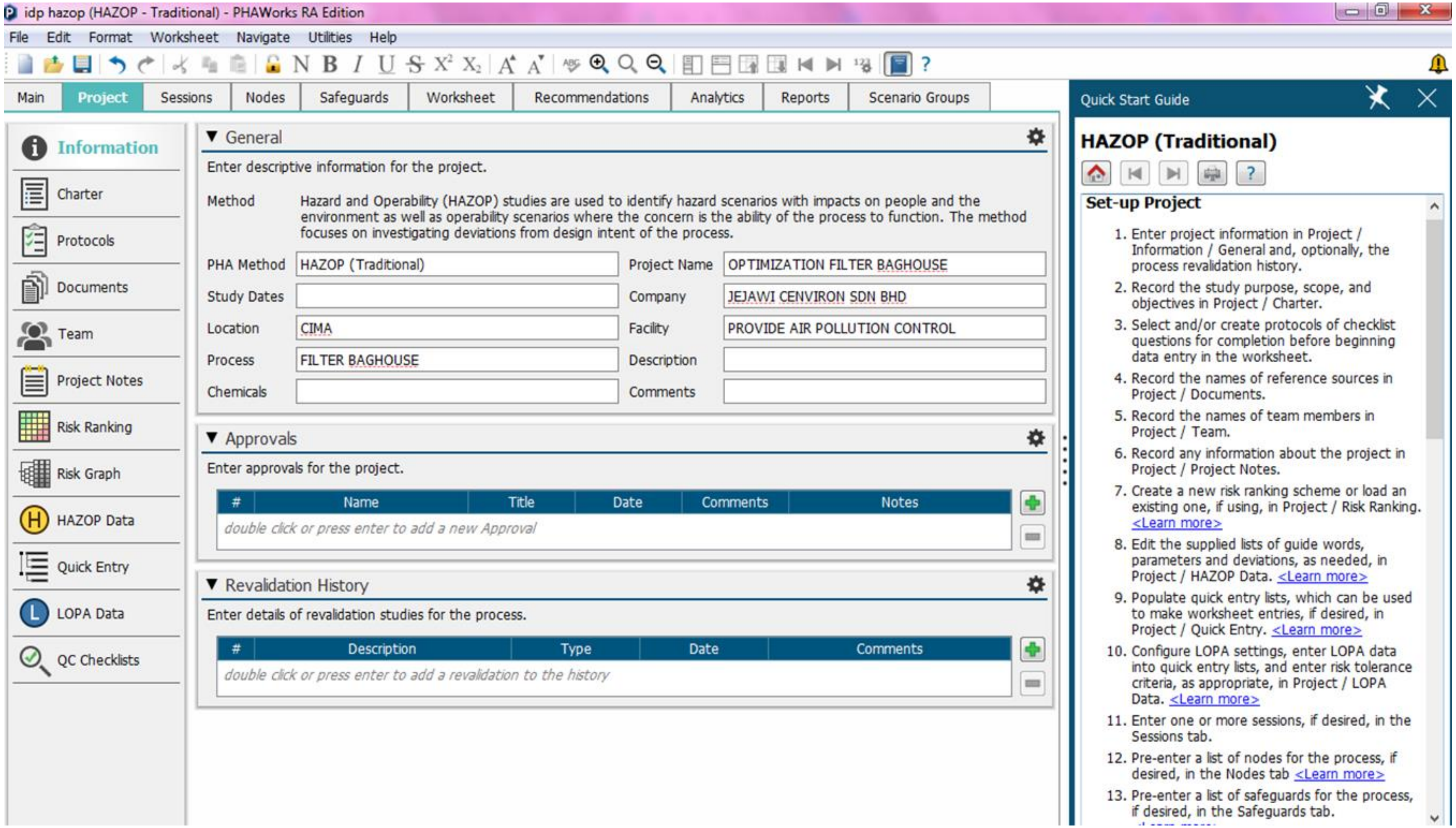
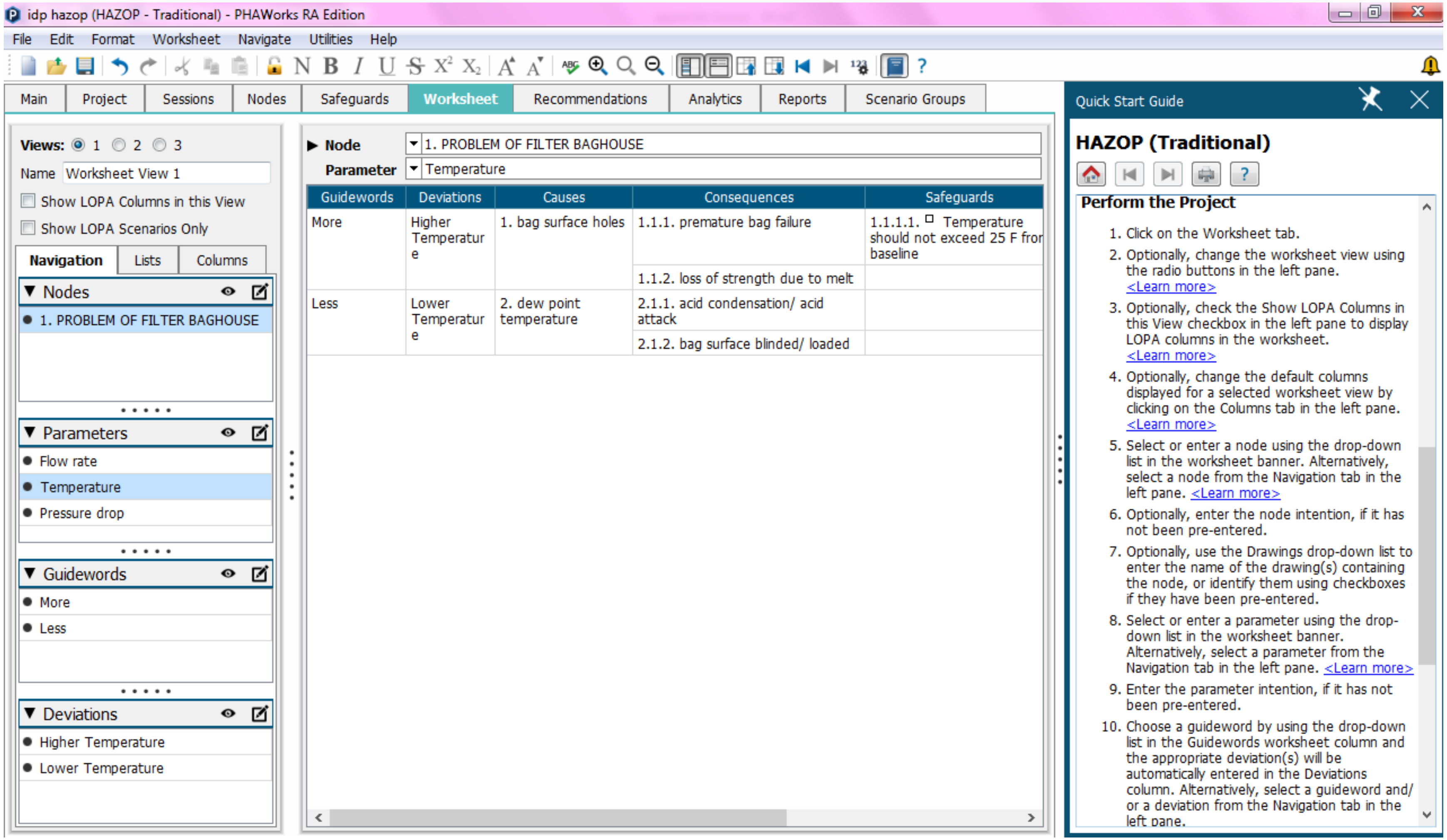
APPENDIX

The HAZOP planning via PHAWorks




idp hazop (HAZOP - Traditional) - PHAWorks RA Edition
File Edit Format Worksheet Navigate Utilities Help
Main Project Sessions Nodes Safeguards Worksheet Recommendations Analytics Reports Scenario Groups
Views: 1 2 3
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Nodes
1. PROBLEM OF FILTER BAGHOUSE
Parameters
Flow rate
Temperature
Pressure drop
Guidewords
More
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Deviations
Higher Temperature
Lower Temperature
Node 1. PROBLEM OF FILTER BAGHOUSE
Parameter Temperature
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Higher Temperatur e
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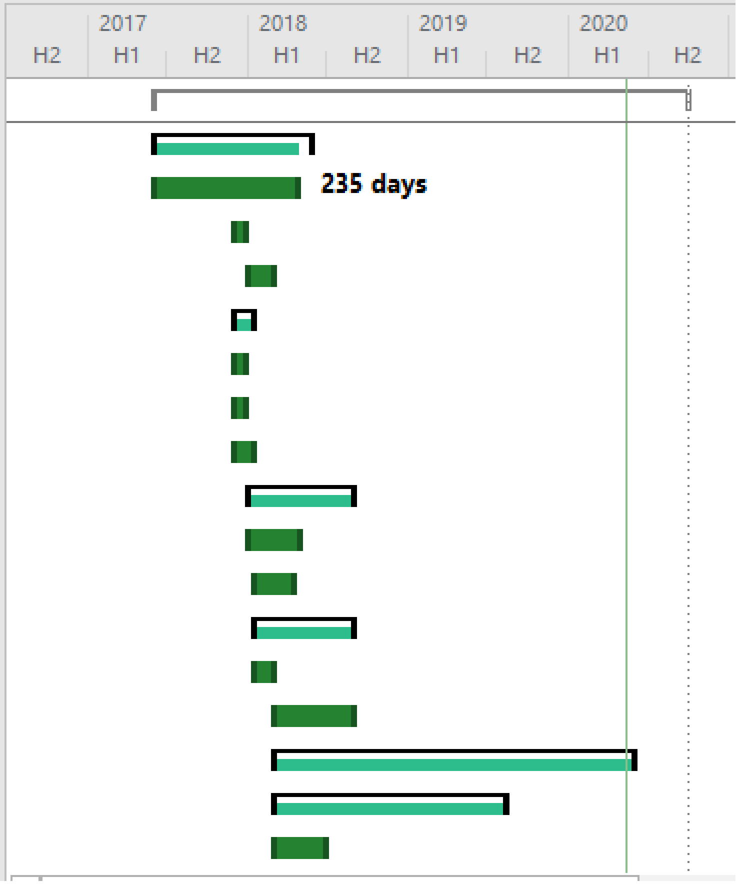
1.1.1. premature bag failure
1.1.1.1. Temperature should not exceed 25 F fror baseline
1.1.2. loss of strength due to melt
Less
Lower Temperatur e
2. dew point temperature
2.1.1. acid condensation/ acid attack
2.1.2. bag surface blinded/ loaded
Quick Start Guide
HAZOP (Traditional)
Perform the Project
1. Click on the Worksheet tab.
2. Optionally, change the worksheet view using the radio buttons in the left pane. <Learn more>
3. Optionally, check the Show LOPA Columns in this View checkbox in the left pane to display LOPA columns in the worksheet. <Learn more>
4. Optionally, change the default columns displayed for a selected worksheet view by clicking on the Columns tab in the left pane. <Learn more>
5. Select or enter a node using the drop-down list in the worksheet banner. Alternatively, select a node from the Navigation tab in the left pane. <Learn more>
6. Optionally, enter the node intention, if it has not been pre-entered.
7. Optionally, use the Drawings drop-down list to enter the name of the drawing(s) containing the node, or identify them using checkboxes if they have been pre-entered.
8. Select or enter a parameter using the drop-down list in the worksheet banner. Alternatively, select a parameter from the Navigation tab in the left pane. <Learn more>
9. Enter the parameter intention, if it has not been pre-entered.
10. Choose a guideword by using the drop-down list in the Guidewords worksheet column and the appropriate deviation(s) will be automatically entered in the Deviations column. Alternatively, select a guideword and/ or a deviation from the Navigation tab in the left pane.

Proposed Project Scheduling

Task Name	Start	Finish
Cement Plant	**Thu 6/1/17**	**Tue 9/29/20**
1 Intial Proceedings	**Thu 6/1/17**	**Tue 5/29/18**
1.1 Getting Industrial Permits	Thu 6/1/17	Wed 4/25/18
1.2 Soil Mechanic Studies & Topographi Maps	Fri 12/1/17	Sat 12/30/17
1.3 Land Preparation	Mon 1/1/18	Thu 3/1/18
2 Design and Engineering	**Fri 12/1/17**	**Mon 1/15/18**
2.1 Civil and Structural Design	Fri 12/1/17	Sat 12/30/17
2.2 Technological Design	Fri 12/1/17	Sat 12/30/17
2.3 Select Machinery and Equipment	Fri 12/1/17	Mon 1/15/18
3 Contracting	**Mon 1/1/18**	**Thu 8/30/18**
3.1 Subcontract Civil Construction	Mon 1/1/18	Mon 4/30/18
3.2 Subcontract Technological Constructions	Tue 1/16/18	Sun 4/15/18
3.3 Procure Foreign Machinery and Equipment	**Tue 1/16/18**	**Thu 8/30/18**
3.3.1 Bidding and Contract	Tue 1/16/18	Thu 3/1/18
3.3.2 Transportation and Customs Clearance	Fri 3/2/18	Thu 8/30/18
4 Construction and Installation	**Fri 3/2/18**	**Fri 5/29/20**
4.1 Primary Crushing	**Fri 3/2/18**	**Wed 8/14/19**
4.1.1 1 Construction	Fri 3/2/18	Sat 6/30/18



Task Name	Start	Finish
4.1.2 Metal Structure (Platform & Pillars)	Sun 7/1/18	Sun 9/30/18
4.1.3 Primary Rotary Hammer Crusher	Mon 10/1/18	Fri 3/15/19
4.1.4 Secondary Roll Crusher	Tue 10/2/18	Sun 4/14/19
4.1.5 Installing Equipment of Department 1	Mon 4/15/19	Wed 8/14/19
4.2 Raw Material Preparation	**Mon 4/16/18**	**Sat 9/14/19**
4.2.1 Proportioning Equipment 2	Mon 4/16/18	Fri 6/14/19
4.2.2 Grinding Mill (Rawmill)	Mon 4/16/18	Sun 4/29/18
4.2.3 Installing Equipment of Department 2	Tue 5/15/18	Fri 9/14/18
4.3 Clinker Production	**Mon 4/16/18**	**Tue 1/14/20**
4.3.1 Pre-heater Tower	Mon 4/16/18	Fri 11/30/18
4.3.2 Kiln	Mon 4/16/18	Sun 7/14/19
4.3.3 Clinker Cooler	Mon 4/16/18	Mon 7/30/18
4.3.4 Installing Equipment of Department 3	Mon 7/15/19	Tue 1/14/20
4.4 Cement Production	**Fri 3/2/18**	**Fri 5/29/20**
4.4.1 4 Construction	Fri 3/2/18	Sat 6/30/18
4.4.2 Proportioning Equipment 4	Sun 7/1/18	Thu 2/14/19
4.4.3 Finish Mill	Sun 7/1/18	Sun 9/29/19
4.4.4 Cement Storage Silos	Sun 7/1/18	Fri 11/30/18