THE UNIVERSITY OF MANITOBA

DUST CONTROL SYSTEM FOR FARM SEED CLEANING PLANTS

by

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A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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To my parents and wife Yashu

ABSTRACT

Dust control in farm seed cleaning plants is of paramount importance as harmful effects (health hazards and fire explosions) of grain dust are well know. Dust emission levels in eleven seed cleaning plants were measured and several particle size distribution analyses were conducted in order to study the grain dust properties. Approximately 40% of the farm seed cleaning plants that were surveyed in this dust monitoring study had dust levels larger than the acceptable limit of 10 mg/m^3.

Friction head losses in galvanized iron sheet metal pipes and flexible plastic pipes were determined at various air flow rates and then utilized to draw friction loss charts. Friction head losses in plastic flexible pipe bends were also measured and expressed as equivalent length of straight pipe. The frictional head losses in the plastic flexible pipes were 2 to 2.5 times larger than sheet metal pipes, whereas losses in pipe bends were almost equal to that from sheet metal elbows of the same size.

A typical exhaust system was balanced by using the friction head loss data. The fan static pressure, power, and fan rpm were established during operation of the system as well as from fan performance curves.

Two types of dumping hopper hoods were designed, fabricated and tested for their effectiveness in capturing dust. The corresponding pressure drops were also measured. The use of hoods at the dumping hopper reduced the dust concentrations considerably. Thus a partially enclosed side draft type hood was recommended for collecting dust in a dumping hopper in farm seed cleaning plants.

Performance characteristics (collection efficiency and pressure drops) were determined for a cyclone separator and for three types of fabric filter bags. The cyclone separator was 82% efficient in the collection of grain dust while two of the three fabric filter bags tested were 99% efficient in removing grain dust from the work environment. Dust that penetrated through the filter bags followed a log-normal particle size distribution function.

Pressure drop in the cyclone separator varied with the air flow rate and was proportional to the 2.13 power of air flow rate. A linear relationship between bag pressure drop and collection efficiency was obtained in the fabric filter bags.

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1. INTRODUCTION

The seed processing industry is vital to Canadian Agriculture and is important to farmers and consumers. Seed grain should be free of other crop seeds, weed seeds, straw, chaff, and dust. The maximum percentage of pure crop seeds with maximum germination potential may be obtained through proper cleaning and grading of the seed grains. Cleaning seed grains provides a positive method of weed control. In Manitoba, a large percentage of the seed is cleaned in country elevators and on the farm. Most farmer-owned seed-cleaning plants were initially built by the registered seed growers for their own use. This was necessary in order to satisfy the seed quality standards required by Canada's seed regulatory agency - The Canadian Seed Growers Association. These plants may have developed into custom cleaning establishments. In the seed processing industry, the concern over the plant environmental dust levels and potential health hazards of the grain dust being emitted during seed processing has added a new dimension to the seed cleaning and grading operation.

The active handling and treating of seed grains generate dusts which can potentially pollute the work environment in the seed-cleaning plants. Dust is generated each time the grain is handled. The truck unloading station is the largest single source of dust (Sherman, 1973) but, however, dust is also generated at each transfer point such as bucket elevators, belt conveyors, screw conveyors, and bagging operations. Loading and unloading of bins create clouds of fine dust in the environment. During the cleaning process, dockage is removed from the grain and a considerable amount of fine dust is emitted.

The concentration of dust in the seed-cleaning plant environment will vary depending on the type of operation, field source of seed grains, type of seed, harvesting method, weeds present and chemical residual. For instance, the barley kernel generates a long fibre dust while wheat kernel produces a fine dust. Yoshida and Maybank (1974) observed maximum dust concentrations of 892 mg/m^3 and 81.9 mg/m^3 for barley and wheat respectively from a spout-penthouse while handling grains in elevators. Studies on generation of dust by repetative handling of corn indicate that the amount of dust removed per transfer was 0.088% of the corn mass (Norman et al, 1977). The level of emission will also depend on the type and design of the cleaning and grading machines. These machines may be open to the atmosphere or of the enclosed type having a cross-current or counter-current type of air flow. The finer the dust the more severe the atmospheric pollution problem would be because fine particles remain in suspension for a longer period of time. The respirable mass fraction of dust inside the work areas accounted for 50% and 80% of the total dust for wheat and barley, respectively (Yoshida et al, 1978).

The effect of grain dust on workers subjected to grain dust contaminated conditions is till controversial and is related to a number of contributing factors such as individual resistance and smoking habits. There is now active medical research involving toxic effects of grain dusts. Many individuals experience bronchial or allergic disturbances after exposure to feed and grain processing dust. Operators exposed to grain dust may develop acute symptoms of flu-like high-temperature condition that lasts for a week or more accompanied by shortness of breath, wheezing and coughing. In extreme cases they may suffer from inflamation of eyes, nose, ear and skin. Often, it leads to allergies that become more serious with increased exposure. Grain dust exposure produces discomfort or temporary physiological alteration due to dust accumulation in the bronchial tract prior to the development of chronic disorders. Workers are liable to develop a chronic respiratory condition commonly known as "Farmer's Lung" and is caused by the workers' exposure to spoiled grain dust (Dennis, 1973). A recent report shows that 75% of elevator agents in Manitoba had some respiratory symptoms, chronic cough and dyspnea associated with exposure to grain dust. An estimated 40% of the elevator operators leave the industry because they develop one of the acute conditions. According to Labour Canada (1977), the effects of grain dusts on health is a complicated one, to which definite answers are still being sought.

Extensive property damage and fatal accidents in grain elevator explosions and fires are well known. A few major explosions have occurred in Canadian grain elevators in the past. Grain dusts are capable of forming a mixture of an explosive nature. The major cause of a grain dust explosion is the accumulation of fine, dry dust on processing equipment and pipes which may be ignited by any heat source such as a flame or spark. Clouds of fine dust in the air actually create the greatest hazard. Generally two types of explosions; i.e., primary and secondary explosions occur in grain elevators. Secondary explosions are very severe and occur after the primary shock wave has dispersed dust deposits into the air, creating a massive explosive mixture. In the grain handling industry it is important to prevent any dust accumulation so as to avoid these secondary explosions (Canadian Grain Handling Association, 1979). A somewhat less dramatic but, deleterious effect of grain dust in a plant is the reduction in visibility and a photochemical reaction which produces smog.

Labour Canada and Health and Welfare Canada have adopted a provisional standard which provides an employee exposure to a maximum of 10 mg of total grain dust per m^3 of air averaged over any eight-hour daily period and a 40-hour work week (Labour Canada, 1977). Grain dust is of a complex nature and its characteristics affect the collection efficiency of dust control equipment. Furthermore, little research on dust control equipment specifically for seed cleaning plants has been conducted. However dust emission in seed cleaning plants may be kept within the proposed limits by using different available collectors such as cyclone separators, fabric filters, wet type collectors and electrostatic precipitators. Wet collectors and electrostatic precipitators are expensive and thus are not usually adopted on the other hand, cyclone separators are cheaper but have lower collection efficiencies. The use of fabric filters and/or a combination of cyclone separators and fabric filters seems feasible. A need now exists to develop, test and introduce dust control to grain handling systems on the farm.

The objectives of research reported in this thesis were as follows:

i) To monitor the dust concentration in various seed cleaning plants in Manitoba.

ii) To test and determine the characteristics of various types of pipes and elbows applicable to ducting in seed cleaning systems.

iii) To test and balance the flow rate and static pressure of a typical dust removal system.

iv) To test the characteristics (efficiency and pressure drop) of a cyclone separator and fabric filters.

v) To test the effectiveness of various types of suction hoods for use on truck dumping hoppers.

vi) Recommend suitable modifications to the typical existing systems to meet the threshold limit value of dust emission.

2. REVIEW OF LITERATURE

2.1 Grain Dust Defined

Grain dust is of a complex nature and its composition depends on a variety of factors such as: field source of the grains, type of seed, harvesting methods, weeds present and chemical residual. Thimsen and Aftan (1968), Sherman (1973) and Prosser (1975) defined grain dust as the particulate matter that becomes air-borne and varies in size from 1 to 100 μm. Martin and Sauer (1975) considered dust particles smaller than 125 μm to be of major concern in meeting air pollution standards. Labour Canada (1977) gave a more broad and detailed definition of grain dust as "dust present in the atmosphere during handling or processing of grains which may contain a mixture of many substances including ground up plant matter, insect parts and other containments which may have accumulated with the grain during the growing, harvesting and subsequent processing or storage periods. Any dust present during the handling or processing and dust generated in other operations is considered as grain dust". According to Martin (1978), grain dust is composed of solid particles that become air-borne during handling of grain. This includes all materials collected by the dust control system.

2.1.1 Dust Levels in the Seed Cleaning Plants

Dust is the most important problem of the work environment in farm seed cleaning plants. Unfortunately, no specific information is available on dust emissions in the work environment of farm seed cleaning plants. However, many researchers measured dust emissions from various operations during grain handling in the grain elevators. It was found that a considerable amount of dust is generated during the unloading of grains from trucks at the receiving hopper at grain elevators. According to Thimsen and Aften (1968), the amount of dust generated while unloading at the receiving hopper was 0.10% of the grain mass. Sherman (1973) noted that the grain unloading station was the largest single source of dust in the grain elevator handling system. In Saskatchewan, Yoshida and Maybank (1974) found that at the receiving hopper, the dust concentration varied from 20-40 mg/m^3 of air handled.

The mass concentration level of dust in the working environment depends on type of grain handled, according to a nationwide inventory of air pollutant emissions, where the dust emission from grain handling is estimated to be 8% of the total emission from industrial processing (Marier et al, 1974). Yoshida and Maybank (1974), in one of their studies on grain dust emission in elevators, found dust concentrations of 892 mg/m^3 and 81.9 mg/m^3 of air handled from the spout-penthouse for barley and wheat, respectively. Getchell et al (1977), while conducting tests on the use of additives for grain dust reduction during handling, observed dust concentrations as high as 2558 mg/m^3 in handling combine-harvested wheat. Studies by Norman et al (1977) on repetative handling of corn indicate that the amount of dust removal per transfer was 0.088% of the corn mass. The handling treatment affected the total amount of dust more than kernel breakage content (Martin and Stephens, 1977).

In order to limit the atmospheric pollution levels in the work environment in the grain industry, Labour Canada together with Health and Welfare Canada has adopted a threshold limit value of 10 mg/m^3 total dust for any eight-hour daily period (Labour Canada, 1977).

2.1.2 Dust Generation in Seed Cleaning

Dust is generated each time the grain is handled. The main sources of dust generation in seed cleaning plants are: grain receiving hoppers, transfer points such as bucket elevators, belt conveyors, screw conveyors, loading and unloading of bins and cleaning and grading machines. Thimsen and Aften (1968), William (1973), Martin and Sauer (1975), Norman et al (1977), and Yoshida et al (1978) discussed various sources of dust generation in the grain industry especially in grain elevators. They reported that the major dust emission problems in grain elevators were from the receiving hoppers, transfer points, loading and unloading of bins, and loading of cars.

2.1.3 Hygienic Significance of Grain Dusts

Significance of dust in respiratory disorders of humans has long been recognized. For instance, many aspects of industrial dust have been studied quite extensively. The effect of grain dust on workers' health, however, is still controversial as it is related to many contributing factors such as composition of grain dust, particle size distribution, individual resistance and smoking habits. Many researchers in the past have reported the allergic disturbances and discomforts caused by the grain dusts. According to Andersen (1966), air-borne dust is a hazard to health with respect to respiratory disorder, only to the extent that it is deposited in the respiratory system.

Henry and Zoerb (1967) reported that irritation to nose, throat and lungs results from breathing of an excess quantity of dust. This may cause inflamation of membranes which become vulnerable to infection and often lead to allergies that become more serious with increased exposure. Another common effect of grain dust exposure is irritation of the skin, especially around the wrists and back of the neck where clothing rubs the skin. This condition is known as "dermatitis" and may cause serious skin infections in extreme conditions.

A recent report shows that 75% of the elevator agents in Manitoba had some respiratory symptoms, chronic cough and sputum and dyspnea (shortness of breath) associated with grain dust exposure (Tse et al, 1973). Dennis (1973) described health problems from inhaling grain dust which usually resulted from handling moldy or heating grains. Workers are liable to develop a chronic respiratory condition commonly known as 'Farmers' Lung'. Martin and Sauer (1975) found that mold spores were concentrated in dust more than in grain, and the higher concentrations were in the dust that escaped from dust control cyclones into the atmosphere. Synnoniums (1976) studied the microbiological characteristics of grain dusts and analysed the concentrations of micro-organisms in the dust which may contribute to health hazards. Norman et al (1977) reported that the health effects of fungi and spores in the grain dust are still under investigation.

Prosser (1975) indicated that a health hazard to the lungs exists where particle size is between 0.5 μm and 6 μm but the pollen and other materials can give rise to allergic complaints in the range of 20 μm to 60 μm. The Andersen sampler's instruction manual indicates that dust particles between 3.3 μm to 7.0 μm are retained in the trachea and primary bronchi, 2 μm to 3.3 μm in the secondary bronchi, 1.1 μm to 2 μm in the terminal bronchi and less than 1.1 μm in the alveoli. Thus, particles below 7 μm in diameter are more dangerous to the health.

Khane (1977) reported that for those who work in grain elevators, the chances of developing chronic respiratory disorder are about two times as great as those of the general population. They are also liable to develop a chronic respiratory condition with symptoms of chronic cough and phlegm, obstruction of airways, emphysema and chronic bronchitis. According to Labour Canada (1977), an X-ray program for personnel having 15 or more years of employment in grain elevators was commenced in 1973 and their examination indicated that 19% of workers showed a higher than normal incidence of increased lung markings, a condition not necessarily associated with a person's occupation. A correlation between grain dust concentration and prevalence of health effects has been found by most investigators who have studied the effect of worker's exposure to grain dust. In fact, the effects of grain dust is a complicated one to which definite answers are still being sought.

Atliemo et al (1978) reported similar health effects of grain dust as reported by Dennis (1973). According to them the disease resulting from hypersensitivity appears to have caused most of the damage. Symptoms start with congestion in the throat and proceed to coughing accompanied by tightness in the chest. In some serious cases workers often awake breathless and wheezing with bursts of coughing.

2.1.4 Grain Dust Explosions

In the past forty years in Canada, there have been five major explosions at terminal elevators. Since 1925, grain elevators in the U.S.A. also assume the number one position in terms of deaths resulting from dust explosions. Thimsen and Aften (1968), Stevens and Schoeff

(1973), Canadian Grain Handling Association (1979) and many others explained that the major cause of grain dust explosion is the accumulation of fine dry dust on processing equipment and pipes to explosive concentrations, which may be ignited by any heat source such as a flame or a spark.

The two general types of explosions that occur in the grain industry are primary explosions and secondary explosions. Secondary explosions are more disasterous. Among the plant equipment items, the bucket elevator legs present the greatest hazard. It is therefore of paramount importance that secondary explosions should be prevented and limited (Stevens and Schoeff, 1973; CGHA, 1979). The most significant fuel for secondary explosions is the accumulation of dust in layers. Secondary explosions occur after the primary shock wave has lifted (primary explosion) and mixed heavy dust deposits with air creating a massive explosive mixture.

Fine dust particles that are suspended in the air will form a mixture of a highly explosive nature (Getchell et al, 1977). Gibson et al (1977) estimated the concentration of aerosol particles to be a function of temperature and dust layer thickness. This approach enabled him to study the response of ionization and combustible gas detectors to invisible aerosols and gases evolved from heated grain dusts at a temperature below the ignition temperature.

Stevens and Schoeff (1973), Honey and Mcquity (1976) and CGHA (1979) described that ignition temperature of grain dust, whether in the form of an aerosol or an aerogel, could be attained from heat sources such as exhaust systems, bearings or severely slipping V-belts. Static electricity was shown not to be normally present.

CGHA (1979) reported the explosive limits of suspended grain dusts. While upper limits are not always definite, there is a general agreement that the lower explosibility limit is 40000 to 55000 mg/m^3 with the lowest reported figure being 20000 mg/m^3. In addition to these limits, some grain dust properties such as minimum ignition temperature, minimum ignition energy, ignition sensitivity, explosive sensitivity, and explosibility index were also reported by CHGA (1979).

2.2 Dust Sampling

Two commonly used methods that are employed for determining the total dust concentrations in the work environment are the sampling jar and the high volume air sampler. Yoshida and Maybank (1974) used sampling jars to measure dust falls in the vicinity of grain elevators in the western Canadian prairies. However, the high volume air sampler is a more accurate and quicker method for sampling dusts. This sampler was used extensively in the past. For example, Annis (1972), Morrow et al (1972), Martin and Sauer (1975), Avant et al (1976), Kirk et al (1977), Norman et al (1977) and Parnell et al (1977) used the high volume air sampler for determining total mass concentrations of grain dusts in the working environment.

Environment Canada (1974) and Norman et al (1977) described the procedure for the determination of mass concentrations of suspended particles in the environment. Dust concentration levels are determined by obtaining the net mass of dust taken from the fibreglass filter after sampling with a high volume sampler. This is achieved by pre- and post-