COST AND EFFECTIVENESS OF ALTERNATIVE TECHNOLOGIES

Research and experience have demonstrated differing degrees of effectiveness of the different technologies used for dust control. There are technical as well as economic advantages and disadvantages of the alternative methods. The three primary forms of dust control (pneumatic suction, water, and oil) can be effectively used depending on elevator design and end-use grain requirements. Good housekeeping practices supplement other strategies by reducing the amount of dust at rest in the elevator. The methods are often integrated for optimum performance. The following paragraphs review the strengths and weaknesses of each of the three techniques.

Pneumatic systems

A Regulatory Impact Analysis performed by OSHA in accordance with the grain facilities rulemaking determined that compliance with the standard was economically feasible. That analysis included a recommendation for the installation of pneumatic control measures. A number of firms have installed pneumatic systems in their flagship facilities, suggesting that they are cost effective. Operating firms have reported that pneumatic technology has been effective in meeting California regulations, requiring lower levels of airborne grain dust, and that these systems are economically feasible. [Mestrich,1993].

Pneumatic suction systems, while generally effective in reducing the amount of dust in the air, possess some shortcomings. In addition to being extremely expensive to install, such complex systems are difficult to properly maintain, consume a great deal of electricity, and may be a focal point of elevator explosions. Although some dust is removed with the pneumatic system, many elevators subsequently recombine that dust with the grain to avoid any weight loss and to provide disposal of the dust. Dust that is not recombined creates it's own handling and storage hazards.

A common misconception is that pneumatic dust control systems remove all dust from grain. They do not; they remove only about 5% of the dust in the grain at a transfer point. They do lower the dust concentration. [Parnell,1993].

Pneumatic systems can be economical for even small grain elevators. A quote from the 1993 House of Representative hearings provides an illustration. "Some of them have been installed in grain elevators like the local one where I live that only had 48,000 bushels of capacity. That elevator was built 50 years ago. It has not had any problems." [Richard,1993].

The pneumatic systems are not without their technical problems. The Westwego export elevator was rebuilt following the 1977 explosion with a radical new design. Instead of using bucket elevators, a series of inclined belts were used to elevate the grain. In addition, a system was designed to eliminate all recirculation of captured dust. Every grain transfer point had an associated dust control system. The system was designed to handle the grain dust so that no dust was recirculated. However, the system did not significantly lower the level of dust in the grain. The goal was to lower the concentration of dust at the transfer point to less than the MEC so an explosion would not occur. Dust content of grain before and after dust control systems was measured and it was found that the level of dust in the grain did not change. The system was later modified to include some recombination of grain dust to provide a technically and economically feasible system for removing and storing dust. The dust control systems were located on the river at the receiving and shipping points, 1/2 mile from the head house. Since dust was not to be recirculated it had to be collected in a bin at the river and conveyed to the head house pneumatically. This system of collecting dust and conveying it to a bin on the river and subsequently to a bin at the head house so that it could be shipped by rail was not reliable. Whenever a technical problem occurred in the dust collection and conveying, the elevator had to cease unloading and/or loading of grain.

FGIS requested a study on the recombination/recirculation (R/R) ruling and the classification of dust according to its location in the handling system, to determine its economic impact on the grain industry, on grain quality, and on safety. The results of this study were as follows: [Parnell et. al, 1992].

1. Disallowing R/R will not significantly reduce the dust content of exported grain. The amount of dust removed from the air is very small relative to the amount of dust in the grain.

2. No measurable quality improvement would be achieved if R/R were to be disallowed.

3. Disallowing R/R would increase the grain dust explosion hazard in export elevators. (This conclusion was based on three factors. Disallowing R/R would: (a) increase the number of locations in the facility that would have Minimum Explosive Concentrations (MECs) as a consequence of the required materials handling systems for captured grain dust; (b) result in an economic incentive to reduce the number and volume-rate-of-flow of dust control systems in order to reduce the volume of bin dust captured; and (c) there would be an incentive to replace pneumatic dust control systems with oil additive systems, although liquid additive systems degrade with time.

Assuming an annual export volume of 4.5 billion bushels of grain:

4. The fixed cost of disallowing R/R would be $29 million (0.6 cents per bushel).

5. The annual cost of disallowing R/R would be $38 million per year (0.8 cents per bushel).

6. If R/R were to be disallowed, approximately 200,000 tons of grain dust (3.2 pounds of grain dust per ton for 4.5 billion bushels of exported grain) would be collected annually, adding to the cost of marketing or disposal by export elevators. The 3.2 pounds per ton of grain dust captured was the estimated total amount of grain dust that would be captured by all of the pneumatic dust control systems operating at an export elevator. One of the export elevators in this study had 52 operating dust control systems.

7. Dust control systems are <u>not</u> grain cleaning systems. They are used to decrease the concentration of dust entrained in air at a grain transfer point. Dust control systems are in reality dust <u>management</u> systems.

Housekeeping Practices

The effectiveness of housekeeping in reducing dust explosions differs between primary and secondary explosions. Primary explosions are always the first explosion in the elevator. When someone refers to the "cause" of the explosion, this is in reference to the cause of ignition of the primary explosion. The pressure wave leaving the primary explosion entrains residual dust into secondary explosive concentrations that are ignited by the relatively slow moving fire front from the primary. Good housekeeping is probably the single most important factor in reducing the risks associated with secondary grain dust explosions. Even with effective airborne dust controls, some dust will escape and settle on floors, equipment, ledges and other surfaces. [Miller, 1983].

The National Academy of Sciences (NAS) in a 1982 report recommended that the most cost effective step to reduce explosions was improved control of grain dust within elevators through concerted housekeeping programs. NAS recommended automatic suction and manual cleaning systems be installed to remove dust from within closed elevator spaces, particularly elevator "legs", the portion of the facility through which grain is transported from ground level to the top of elevator silos. Today, these systems are in place in nearly every facility. [Botos, 1993].

Use of Liquid Additives.

Liquid additive application systems require sophisticated equipment to control application rates and to assure adequate coverage of the grain surface. Not all oil application systems in use today are sufficiently sophisticated to assure adequate coverage. This requires continuous monitoring of grade, quality, and viscosity of the oil used in the application. Water quality and application rates also must be carefully monitored. Inappropriate application or repeated applications may cause detrimental biological or microbial activity in grain [Steele, 1993].

Effectiveness of oil as a dust suppressant. Research results have demonstrated that food grade oil applied to grain reduces grain dust concentrations at grain transfer points [Lai et. al., 1979, 1982, 1984, 1986; Parnell et al, 1989). For example, Lai et al [1986] states that "Oil treatments effectively reduced dust emissions in commercial grain handling facilities. Environmental dust levels were lowered to less than 0.015 g/m^3". FGIS concurred with the conclusion that oil applications are effective. "In terms of its effectiveness, all indications from research and what we have observed are that oil is effective". [Shipman, 1993]. However there exists some disagreement over its effectiveness under various conditions. Parnell reported that the oil dust suppression mechanism can be overwhelmed by extremely dusty grain and is not as effective on milo as it is on corn. In addition, there have been reports that the effectiveness of the oil application degrades with time.

"A 1982 study on additives found that while both water and oil applications result in significant dust reductions, oil application is very slow to develop dust control as it requires extensive mixing in the grain flow. As a result, the impact of oil on dust control is negligible at the most explosive and critical location of the grain elevator transfer process -- the elevator legs. ... Some companies have stated that research shows that the addition of food grade mineral oil at the rate of 0.03% by weight to corn reduces dust accumulation on the gallery floor by 90%. There are three problems with this statement. First, 1982 ARS research found that 0.05% (not 0.03%) reduced dust concentration by 90% on the gallery floor. Second, explosions are most likely to occur in the leg of the elevator, which precedes the gallery, where oil is not as effective.

Third, an application of 0.03% or 0.05% would be illegal since the FDA limit on the application rate of food grade mineral oil is 0.02%. Again, oil is not a full or equal substitute for water-based dust suppression". [Jacobson, 1993].

Another concern with oil additives, from either mineral or vegetable based sources, is the potential residual build-up through repeated additions in the grain distribution channel. Water either evaporates or is absorbed, in which case it can be detected by moisture measurements. Oil additives remain with the grain and go unmonitored in standard grain analysis. However, the high cost of oil is a deterrent to overapplication and FGIS reported that "..we do not see overapplication because of the cost of the oil". [Shipman, 1993]. However, it is not possible to determine total application and whether the 200 ppm (1.5 gallons per 1000 bushels) FDA limit has been exceeded, because there is no method for detecting the level of oil that has been applied to grain. It is possible that oil could be applied to grain at the country, inland terminal and terminal elevators without it being detected by FGIS. The proposal to limit the application rate of water to grain to no more than 0.3% [Parnell, 1993] would, if promulgated, result in an application rate of water of more than 10 times the FDA application rate limit of oil or 22 gallons of water per 1000 bushels.

Effectiveness of water as a dust suppressant. There exists some disagreement over water's effectiveness under various conditions. For example, the water dust suppression mechanism can be overwhelmed by extremely dusty grain. The strongest argument for water-based dust control is its proven ability to immediately suppress dust at grain elevator legs, as shown in the research conducted by the USDA Grain Marketing Research Laboratory [Lai et al, 1979, 1982, 1984, 1986] The elevator legs contain the greatest concentration of suspended grain dust during routine operation. Virtually all grain dust explosions are chain-type reactions triggered by primary explosions. Approximately 23% of the known locations of primary explosions is attributed to elevator legs [USDA, 1984].

Lai et. al., [1979, 1982] reported the following conclusions from research using water sprays to control corn dust.

- At least 0.3% of water was required to achieve dust suppression. [Lai et. al., 1982].
- Water spray provided suppression of 60-75% of dust emissions.
- A water spray may help provide fire protection as well as dust explosion protection in a grain elevator.
- A system to add water is inexpensive and easy to install.
- Proper application of water spray (1.0%) will not spoil the grain if the grain contains less than 13 percent moisture." [Lai et. al., 1979].

Lai et. al., were primarily concerned with wheat where moisture content in exported grain is low. However, FGIS showed that 100%
of corn exported in 1991-92 had a moisture content of 13% or greater. [FGIS, 1993].

In 1982, the USDA Grain Marketing Research Laboratory completed a study that had been requested by the NGFA. That study found that additives applied properly and at correct locations can reduce fugitive grain dust [Lai et al., 1982a]. Water addition at the leg dramatically reduced the fine dust particles and increased the moisture content of the dust, thereby lessening the electrostatic activity within the leg, reducing ignition source volatility. Water-based dust suppression was found to decrease the danger of an explosion at this critical point.

U.S. Patent 4439211 by Don E. Anderson, Glenn E. Hall, and Kevin M. Foley of The Andersons describes a method of controlling food dusts using a water spray, a water plus emulsifying agent spray, or a water plus emulsifying agent and oil spray. Applications were made to streams of corn, wheat, and soybeans prior to a loadout point or discharge location. They reported that there is a time delay after the particles are dampened and there needs to be a time during which the particles must remain consolidated before going to the discharge location, if the spray is to effectively reduce opacity. Opacity was defined as a measure of the reduction in light that is transmitted through an environment. In one application, 14% moisture corn exited from a chute to a short free fall drop. In the free fall drop, a nozzle was placed on each side of the stream, then the grain was consolidated on the chute where it was relatively undisturbed for 3 seconds before it exited the second chute. Opacity at the end of the second chute was effectively reduced from 33% down to an acceptable level of 20% when 0.1% water (weight water/weight of grain) was applied. With 0.2% water application, opacity of 43% was reduced to 20%. With 0.05% water application, opacity of 28% was reduced to 20%. The moisture was absorbed into the corn with out spoilage.

In further work done under US Patent 4439211, the effect of grain agitation by mixing after spray application was determined. In all cases the less agitation that occurred after spraying, the more effective the spray was in reducing opacity. Dust is distributed through out the sample and spraying only affects the dust particles near the surface (approximately 5%), which are the same particles that would likely become entrained in the air at the next transfer point; however if considerable mixing occurs after spraying and before the next transfer point, the remaining dust particles (approximately 95%) are untreated and are available to contribute to high opacity and dusty conditions.

In full scale tests with work done under US Patent 4439211, grain was delivered by belt to a garner, sprayed from two sides while in free fall, using the device described in the patent and loaded on to a hold of a ship. Opacity was measured at the loadout spout going into the ship. Data from Figure 14 of US Patent 4439211 shows that 31% opacity was reduced to 6% with 0.35% water applied and to 8% with 0.21% water applied. With 0.01% water applied, the lowest level tested, opacity was 28%. They also tested emulsifying agents with water, and mixtures of oil and water with an emulsifying agent. Water-oil emulsions of 1% oil - 99% water and 10% oil - 90% water were slightly more effective than water alone in controlling dust at the lower application rates. Their results indicated that to reduce opacity at a loadout point, it is critical to have very little grain mixing after the water has been applied. The method described in Patent 4439211 was reported to be able to reduce opacity (visible dust emissions) at a loadout point located outside an elevator; it did not claim to reduce dust explosion hazards.

Peavey reported that their outside insurance underwriters agree that water-based systems, when utilized in combination with pneumatic suction systems, present a preferred approach to controlling dangerous air suspension and accumulations of grain dust. [Jacobson, 1993].

There are potential dangers associated with improper applications. Lai et. al., [1986] also reported that if too much water is added, grain will spoil and lodge in bins requiring manual extraction, a dangerous process. In addition, wet grain often adheres to and cakes enclosures around belts and buckets. This increases static electricity in these enclosed areas, which can become an ignition source for dust explosion.

Those requesting a prohibition on the use of water on grain to suppress air borne dust identify several limitations and disadvantages. Since water is quickly absorbed by the grain and grain dust, it provides only temporary reduction. As the water evaporates or is absorbed, the dust may again become entrained in the air. However, the argument that water should not be used because it is only a temporary solution, is negated by the way that dust collection systems are used. Dust collection systems too, are temporary because the collected dust is "returned and recirculated" back into the grain stream. This is a permitted method to dispose of dust because it has been effectively argued to be safer than storing dust in bins. [Dust stored in bins eventually has to be removed and disposed of and the handling of this dust may in itself result in an explosion.] Whether very elaborate dust collection systems are used or water spray mist is used, the solution only takes care of one transfer point, because the dust either is put back in the grain or, in case of water, it was never removed and suppression is temporary.

The most significant objection to the use of water for dust suppression has been the potential for abuse. The Office of the Inspector General (OIG) stated that at least a fourth of the elevators investigated by OIG had used a firehose or some crude method for applying water to grain. The abuses were found mostly at the country elevators. [Stang, 1993]. In addition OIG reported that "as a result of water application to grain, we found poor housekeeping practices on many of the facilities that were using water. Excessive buildup of caked material around belt end bearings we feel are creating extra safety hazards in these elevators". "...many elevator employees at houses that have used or have purported to use water for dust-suppressant systems have told us in testimony they did not like the use of water, they did not like the use of water specifically because of safety problems" [Stang, 1993].

Based upon the results of several studies dealing with water spray applications one could conclude that a limitation of 0.3% total application rate of water would be ineffective since 0.3% was needed for each application point and at least five locations would be candidates for dust suppression in a grain elevator. However, these studies by Lai et. al., [1982a, 1986] used water spray systems rather than "fogging" systems that are reported to produce extremely small water droplets (in the 10 micron range). Fogging systems treat the air space around the grain more than the grain itself and consequently place very small amounts of liquid on the grain.

Zalosh [1977] proposed that water spray could "inert" strategic locations such as grain transfer points, elevator legs, receiving and shipping points by reducing MEC below the critical level. His concept is the same concept used to cool hot gases with water sprays. The energy required to change liquid water into vapor can be extracted from hot gases resulting in a more humid cooler gas. If sufficient water were present to absorb the combustion energy of the burning dust, an explosion would not occur. He estimated that 0.24 pounds of water per pound of dust would be needed to inert a grain transfer point. The latent heat of vaporization of water (the amount of heat energy required to change 1 pound of water to 1 pound of water vapor) exceeds 1000 BTUs per pound. Grain dust will typically have an energy content of 7,000 BTUs per pound. If the grain had a typical dust content of 2 lbs/ton, an application rate of 0.24 pounds of water per pound of dust would be equivalent to 0.024% (by weight).

Zalosh's 0.24 lb (water) per pound of dust may be low [Zalosh, 1977]. The process of vaporizing 0.24 pounds of water would absorb the energy of 0.034 pounds of dust (15 grams). If 5% of the dust in grain were to be entrained in air at a grain transfer point, 2 pounds of dust per ton would result in 0.1 lbs of dust per ton of grain entrained in air at a transfer point. A primary explosion would release 700 BTU that could be inverted by 0.7 lbs of water. This 0.7 pounds of water per ton of grain, which is equivalent to an application rate of 0.035% by weight, could result in preventing grain dust explosions irrespective of whether the application resulted in dust suppression. Hence, a low level application of a water spray has the potential for preventing grain dust explosions other than dust suppression. The ability to realize this potential is dependent on meeting the conditions of 3 assumptions: 1) the level of dust in the grain is no more than 0.1% by weight. 2) only 5% of the dust that is present is entrained in the air at any transfer point; and 3) all of the water applied is in liquid form, in order to have the ability to provide the 1000 BTU's per lb required to absorb energy to vaporize the water. Much of the water applied by fogging nozzles is in vapor form.

The use of water fogging to suppress dust is a new technology that appears to be effective under experimental conditions. Allison [1993] reported effective dust suppression using a water "fogging" system at application rates of 0.02% and less. "In my opinion water fogging systems can be designed to apply a limited amount of water to grain. The argument that water spray or fogging is technologically infeasible is not accurate. It is my understanding that systems have been installed [Parnell, 1985]. Matsumora et. al., [1991] tested the effectiveness of the water fogging system for reducing concentrations of less than 10 micrometers of particulate matter (PM10) downwind from an almond hulling plant. His results suggested that "PM-10 concentrations can be reduced up to 50% at an almond huller through the application of water atomizers at their exhaust ducts." Parnell [1994] provided photographs to the Congressional Subcommittee illustrating the apparent coagulation of grain dust in the basement and other locations of a grain elevator where water fogging nozzles were being used. He provided a dramatic visual demonstration of the decrease in the dust concentration. It is likely that an electrostatic attraction of dust and water droplets results in coagulation causing the larger droplets to settle by gravity. Particles of less than 10 micrometers have a settling velocity of 0.6 feet per minute [Cooper and Alley, 1994]. Without significant coagulation, the grain dust particles would not settle out.

In the report by Allison [1993] "Effectiveness of ultra fine water fog as a dust suppressant", nozzles of 0.008 inch and 0.020 inch diameter were used at pressures of 800 to 1200 psi to create a fog-like mist at typical transfer locations in an elevator were dust is generally emitted. The nozzles, creating negatively charged water particles less than 10 microns in diameter, were set to create a fog whereby they would be attracted to positively charged dust particles less than 10 microns in size. As the fog and dust particles come in contact, they coagulate causing the dust to slowly settle out. In many of the transfer point applications, less than 25% of the water applied ever reaches grain surfaces. Because the fog particles are so small, very little water is actually used. In one scenario of operation at the truck dump, boot of bucket elevator, and head of bucket elevator, a total of 0.022% water mist was applied for effective dust control. In a second scenario, water mist was applied at a truck dump, boot of bucket elevator, head of bucket elevator, belt out of a garner bin, and at the tripper into storage bins; for a total of 5 applications with a total of 0.054% water applied. In a third scenario, water mist was applied out of storage bins going onto a belt, at the boot of a bucket elevator, at the head of the elevator, and at rail load out; for a total of 4 locations and a total of 0.015% water applied. If the last two scenarios were combined a total of 0.069% water could have controlled dust for the entire time in the elevator. Even with $3.00/bu corn, the added weight value of 0.069% is about 0.207 cents/bu; with soybeans priced at $6.00/bu, the added weight value is about .41 cents/bu. The mode of operation with a fine-particle spray mist is more of a treatment of the air space where dust accumulates, which is different than using the low pressure, high volume nozzles that coat the surface of grain to help dust particles stick to the grain.

<u>Cost Comparisons.</u>

The operational costs of adding water or oil to grain is a fairly simple calculation. However, the operational cost of operating a dust control system in units of $/1000 bu is complicated. Cost per bushel is a function of the total volume rate of flow of all the dust control systems used at a specific elevator and their respective fan total pressures, maintenance costs and costs of disposing of dust collected and not added back to grain. Data from the study on recombination/recirculation dust [Parnell et. al., 1992] were obtained from an on site study of 7 export elevators that had an average throughput ranging from 40 to 470 million bushels per year. The number of dust control systems ranged from a low of 7 to a high of 52 (average=32). The average volume rate of flow ranged from 11,000 to 25,000 cfm per dust control system. The calculated average air flow per 1000 bu ranged from 1.1 to 6.1 cfm 100 bu. The 6.1 cfm/1000 bu. was found to be the smallest export elevator studied. In the opinion of the author of the study, 5 cfm/1000 bu would be a good estimate of the volume used by all elevators that have a volume exceeding 2 million bushel per year. All smaller elevators will have at least 20 cfm/100 bu.

The operating costs of pneumatic dust control systems are the sum of; 1) electrical energy used; 2) disposal of captured dust; and 3) maintenance costs. Consider the following model: 1) electrical - $4.50/1000 bu. [Parnell, et. al., 1992]. This number is the average of all 7 elevators with electrical costs ranging from $2.92 to $8.34/1000 bu.; 2) disposal cost - $0.50/1000 bu. The average dust captured by elevators in the study if they returned no dust to the grain was 3.2 pounds per ton or 96 lbs/1000 bu.. At $10/ton disposal cost, the disposal cost would be $0.48/1000 bu.; and (3) maintenance cost - $16.50/1000 bu. Assume a 33% capital cost as an estimate of dust control maintenance cost and $10 per cfm as the capital cost of dust control systems with bag filters -- 5 cfm/1000 bu. x $10/cfm x 0.33 = $16.50/1000 bu.

The sum of the three categories of costs described above is $21.50/1000 bu. This number is very close to the number provided by Walker and Associates of $20.20/1000 bu. In the opinion of Parnell et. al., the costs for installation for oil additive systems can range from less than $2,000 to over $30,000. At the extreme one operator reported installing an oil additive system that consisted of pumps, barrels and spray nozzles for a cost of approximately $500.

Operational costs for each of three alternative systems for an elevator handling 1 million bu./month are approximately:

pneumatic:	$20.20 per 1,000 bu
oil:	$ 3.58 per 1,000 bu
water:	$ 0.04 per 1,000 bu

Installation costs for an elevator handling 1 million bu per month are in the range of $30,000 for either oil or water systems; $44,000 for a combination oil or water system; and $250,000 - $300,000 for an aspiration system. [Walker and Associates, 1993].

The application rate of food grade mineral oil to grain is limited by FDA to less than 200 ppm (1.5 gallons per 1000 bushels [Food and Drug Administration, 1982]. The cost of mineral oil is $2 to $3 per gallon. The relative price of soybean and mineral oil change with market conditions.

Analyses on the Financial Impact of Water and Oil Dust Suppressants on Soybeans has been documented as supplementary information regarding the FGIS final rule prohibiting the addition of water to grain. Table 5 presents these data.

Industry representatives have presented the results of studies completed by the American Feed Industry Association (AFIA) and the Grain Elevator and Processing Society (GEAPS) concerning feasibility of meeting the permissible exposure limit (PEL) for oat, wheat, and barley grain dust set by the California Occupational Safety and Health Standards Board. Evaluation of the results of these studies by industry representatives concludes that compliance with the PEL standard of 4 milligram per cubic meter would represent economic hardship for members of their industry. Food and Allied Service Trades provided the following analysis of the costs associated with meeting these standards in one of their facilities [Mestrich, 1993].

"Following our review of the industry supplied cost studies we contacted Airtech Industries for an independent cost estimate. Airtech told us that they could fit the said facility with a comprehensive dust collection system that would enable the facility to comply with the 4 mg/m^3 PEL. We were quoted a total price of $64,398 ($53,052 in 1988 inflation adjusted dollars) to install the system. We note that this is almost $10,000 less than the 1988 AFIA estimate of $73,500. Moreover, our estimate is almost $20,000 less in constant 1988 dollars. Finally, our cost estimate assumes that no other existing dust control mechanisms exist in the facility. Since all facilities currently have to control dust levels to comply with other OSHA standards, we assume that facilities have implemented control systems that will obviate the installation of a complete system overhaul." [Mestrich, 1993]

Dust emission standards set by EPA and Department of Environmental Quality (DEQ) also impact vessels during loading or discharge at U.S. ports. When these standards were implemented all of the export elevators in the Pacific Northwest put in evacuation systems to take the dust particulates out of the air. The cost is borne by the vessel that receives the cargo. The secretary-treasurer of the Supercargoes and Clerks, Local 40 explained the charges. "... the owner or the charter, whoever it may be, that receives that cargo pays, in effect, 35 cents per short ton, 35 cents per 2,000 pounds for that equipment. That is an elevator charge to the vessel that is loading there. That equates to $21,000 to a ship loading 55,000 tons of grain. At 100 ships a year, $2.1 million. Ten years equals $21.2 million that the elevator receives back from the vessel for that dust control system. It isn't water. It is a dust system that vacuums up the dust particulates in the air, puts them in a silo. Then trucks come to the silo. Hog ranchers receive that dust to feed their hogs with. So the elevator operators are getting money at both ends of that system." [Clark, 1993]. "However, the New Orleans Gulf (from where most of the grain is exported) does include a separate charge in their tariff. They have a total facilities use charge of 25 cents per ton." [Hawk, 1995].

It has been estimated that prohibiting the use of water for dust control would result in an increase in insurance costs of $6000 per year at an elevator handling an average of 1,000,000 bu/month. [Personal communication with Walker & Assoc.] In addition, the alternative of pneumatic dust control has been estimated to cost $5 to $10 per c.f.m. under the assumption that it would require from 10,000 to 20,000 cfm per grain transfer point. The cost of installing bag filters to comply with air pollution regulations could be as high as $100,000 to $300,000 per application point. Elevators with pneumatic systems already installed would not incur the entire cost.

<u>Economic Impacts</u>.

The economic impact of a prohibition on the use of water for dust suppression in grain handling facilities will depend on many factors -- current practices at these facilities, volume of grain, and the direct and indirect costs of each alternative system that have been described in the previous section. Most of these costs can only be estimated and aggregating across all firms in the industry would require extensive and detailed data that are not available.

One piece of information needed for estimating impact is the current use of the different technologies including water application. A survey conducted by the University of Illinois provided estimates of the frequency of the different technologies and the motivation for their use. A survey was mailed to approximately 2500 grain handling firms throughout the United States asking for answers to the following questions: (1) What methods are currently being used by grain handling firms to control dust? and (2) What is the primary motivation for implementing dust control strategies? (3) What are the marketing practices that encourage or discourage the application of water to grain? A survey form was mailed to approximately 2500 grain marketing firms. Thirty-eight of the 2500 were returned as undeliverable or were not handling grain. Six hundred and seventy-one responses were received from the remaining firms. However, not all respondents answered all questions. The number of responses for each question was used in calculating percentages. Also, some respondents answered for multiple firms and firm types in the company. Multiple firm types on one survey were included as one answer in calculating percentages for all firm types. They were counted as multiple responses when analyzing the data by firm type. The sum of responses by type of firm will, therefore, exceed the total.

Results of the Survey

Responses were received from 36 of the 48 continental States. The majority of responses were geographically concentrated in the corn and wheat belts. Respondents were asked to classify their firms as country elevator, river elevator, inland subterminal, feed manufacturer, grain processor, or flour miller. the majority of the respondents were country elevators (Table 6).

Dust Control Techniques. Respondents were asked to indicate the methods used to control dust in their facility. Regular housekeeping, sweeping, etc. was reported most often (89.9%) (Table 7). Over half used aspiration or pneumatic devices to control the dust (53.8%). Other technologies included oil application (42.9%) mechanical devices (37.9%), and water application (7.6%). Dust control differed among firm types. The use of water was reported most frequently by flour millers (17.6%) and the inland subterminals (11.8%). Aspiration, used by 5.3% of all respondents, was reported more often by flour millers, river elevators, and export elevators than by country elevators. The use of oil was reported by 60.7% of the export elevators but by 23.5% of the flour millers who have often reported potential carryover of oil additives into the flour.

Motivation for Implementing Dust Control Strategies. Dust control methods are used to achieve multiple objectives. Respondents were asked to indicate the relative importance of various possible motives for implementing dust control strategies. A value of "1" indicated "very important", "2" indicated some importance and "3" indicated "minor importance". Respondents were asked to rate, not rank, the motives so the same score was often given to more than one motive and the percentages sum to more than 100 percent. Blanks were not counted in the scoring. The primary motive for using dust control strategies reported by all respondents was to reduce the danger of dust explosion (84.7%) (Table 8). A number "1" rating was also given to meeting OSHA standards by (54.7%) of respondents; meeting EPA standards by (53.7%); meeting company housekeeping standards by (52.3%). Thirty-two percent stated their primary motive was lowering their insurance rates. There was no consistent pattern among the firm types. Dust explosions were given as the primary motive more frequently by export elevators (95.8%) and inland subterminals (93.1%). The export elevators were less influenced by insurance rates associated with dust control than any other firm types (10.5%).

Base Moisture Levels Used in Buying Grain. The economic incentive for using water to increase the weight and moisture content of grain originates with grain whose moisture content is below the base. Since moisture content is no longer a grade determining factor the market is free to select the base moisture content for quoting prices. The base varies among the four major grains, but also varies among firms.

Three fourths of the respondents reported a using base of 15.0% moisture for corn (Table 9); 16.9% of the respondents used 15.5%. The most common base moisture for firms purchasing wheat was 13.5% (69.4% of respondents); 20.1% of the respondents reported a base of 13.0% moisture. Over 90% of the respondents used 13% as the base moisture for soybeans. A base moisture of 14% for sorghum was reported by over 80% of the respondents.

The base moisture used for soybeans is similar across all the firm types except for the export elevator. The export elevator reported a higher base moisture for soybeans (14%) than the other firm types (13.5%). [Hill and Caponigri, 1995]. For corn, a base moisture of 15% was reported by three-fourths or more of all firm types except four millers (33.3% and river elevators (72.2%). River elevators tended toward higher base moisture -- 20.3% reported a base moisture of 15.5%. Only 10.5% of export elevators reported 15.5% as the base -- 5.3% reported a base of 14.5%. The moisture content used as a base for wheat was similar for all firm types, although the river elevators tended to quote a lower base more often than the other firms. The base quoted for sorghum is similar for all the firm types.

These data indicate that prohibiting the use of water for grain dust suppression would affect a relatively small proportion (7.6%) of the firms handling grain. The impact will be greatest at the export and subterminal elevators and least at the country elevator. The examples of costs of alternative methods provided in this report can not be generalized to all of the firms that reported use of water for dust control, but only indicate the range of values for the alternatives currently being used in the industry.

<u>Regulation of Alternative Technologies</u>.

There are two major obstacles to the enforcement of a prohibition on the use of water whether based on the FDA ruling or the FGIS ruling. (1) The prohibition is based on motive. (2) The prohibition is tied to the process not to the effect on end product.

Motive is extremely difficult to establish except in extreme cases. Farmers and elevator operators may have multiple motives. Aeration and blending are good strategies for storing and marketing grain. However, both alter the moisture content of the grain and thus change its weight and value. Grain is hygroscopic and will naturally gain moisture with increases in relative humidity and lose moisture with decreases in relative humidity. For example, the equilibrium moisture content (EMC) of shelled corn at 50 ^{o}F and 50% RH is 12.2% wet basis (wb). The EMC at 50 ^{o}F and 90% RH for this same shelled corn is 21.8% wb [ASAE, 1994]. Moisture contents of grain in equilibrium with these two diverse environments could differ by 9.6 percentage points. The principles that control weight gain due to changes in moisture are the same whether achieved by grain elevator operators or producers trying to manipulate weight and value, or a phenomenon occurring naturally during the transfer of grain from one point in the market channel to another. There are no tests capable of differentiating between shipments in which the shipper has added water and shipments where environmental conditions altered the moisture content and weight. However under the previous allowance by FGIS, the customer receiving grain at higher than expected moisture contents, or grain that has gained weight during shipment, would be inclined to believe that water had been intentionally added.

The potential weight gain from the addition of water is small if the application rate is limited to 0.3%. In a 50,000 mt shiplot of wheat, the application for dust control would add 150 mt. At a price of $128 per mt the water would add $19,200 to total receipts -- $0.38 per ton or $0.01 per bushel. Total increase in value would be $33,066 -- $0.018 per bushel for $6.00/bu soybeans. Given the low profit margins in the grain export industry this is still a significant incentive.

The potential economic benefit to an elevator from the addition of oil is much less. For example, by applying mineral oil at a 0.02% rate to a 50,000 mt shiplot of wheat, an exporter could add 10 mt of oil (2,857 gallons) to the shipment. If the wheat was sold for $128 per mt, the oil could generate over $1,280 in additional profit for the shipper. However, the 10 mt of oil (at $2.00 per gallon) would cost the shipper $5,714. As a result, the shipper in this example would lose over $4,434 by applying oil at its recommended rate. [Galliart, 1993].

Total application rates of 0.3% will be difficult to monitor by FGIS. Wide fluctuations in grain moisture content as a consequence of absorption of water from ambient air could incorrectly suggest that an elevator had exceeded the water-added allowance when in fact it had not.

It has been suggested that FGIS could establish a permit or licensing program to monitor and control water applications. FGIS concluded the process would not effectively prevent misuse and would create economic incentive for all companies to apply water whether or not it was needed for dust suppression. Effectiveness of a permit system is compromised because FGIS cannot rely on after-the-fact testing to verify proper application. It is technologically impossible to test and distinguish naturally occurring moisture from applied or added moisture. While FGIS could evaluate and license the initial system and approve installation, opportunities to override computer monitoring would exist with increased incentives to exploit any loopholes. Follow-up audits of systems would be time-consuming, expensive and minimally effective. Monitoring would require that FGIS shift from the current philosophy of proving intent to increase weight, to a philosophy of proving intent to alter an approved system. [Galliart, 1993] FGIS has estimated that the annual cost of a permit system would quickly exceed $1.5 million as more and more elevators are economically forced to apply water under the premise of dust suppression.

The Office of Inspector General also discouraged the use of a permit or license system. "Our investigations have disclosed that normal and routine monitoring of water-based systems, as would be done by FGIS, the Agricultural Stabilization and Conservation Service, or other Government agencies as designated, is not sufficient to protect the Government or grain purchasers from those elevators determined to use water to artificially increase moisture and grain weight. Some elevators have taken measures to conceal the water system, which leaves it undetectable by normal procedures and observation. .. As for the sophisticated, computer-controlled water systems, they are also vulnerable to deliberate misuse. Indeed, the intentional misuse of water by way of the computer-controlled systems is even more difficult to detect. Investigation has disclosed that computerized water control programs are being overridden. The amount of water showing on the monitor may not be the same as is actually being applied. .. Furthermore, grain belt sensors may be adjusted to provide a false reading of grain depth on the belt, which allows for the addition of more water than normally would be required for dust suppression. ..Investigation has disclosed that water applied to grain in layers on belts results in grain not going through the diverter sampler as intended by the manufacturer upon installing the sampler, and the samples taken do not reflect the actual quality of the grain. With the use of water, foreign material adheres to the grain and does not go through the separation devices;

therefore, it is not being read as foreign material. Manufacturers of diverter samplers have informed us their samplers are designed for used with free-flowing dry grain. The samplers are not guaranteed to give accurate measurements for wet grain." [Gillum, 1993].

The effect of rewetting on the accuracy of the moisture meter reading has also generated controversy. Most research shows that the meter reading is temporarily biased upward during a period of water absorption. However, the dielectric response returns to normal within a few hours, depending on temperature, environmental humidity, and average moisture content. [Bloome et al., 1982]