SURVEY OF ENGINEERING CONTROL TECHNOLOGY FOR PESTICIDE APPLICATION

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ABSTRACT

Farmers and custom applicators are under great pressure when applying pesticides. An increasing awareness of environmental pollution, along with worries about pesticide residues on food has resulted in increased legislation concerning pesticide use. Worker protection is extremely important and engineering solutions to reduce worker exposure are coming to the market place. Exposure to substances that are hazardous to health (including pesticides) should either be adequately controlled or even eliminated by using engineering controls. Surveys and a network of professionals were used to determine current engineering control availability, state requirements for engineering control use, status of educational programs and materials about engineering controls, and farm operator adaptation of engineering controls. A description of 14 different engineering controls is provided along with the relative merits of each. A brochure has been designed for regulators, educators and applicators about the various engineering control technologies.
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REPORT OVERVIEW

This report summarizes surveys conducted to determine engineering control availability, regulations, education and use. An interdisciplinary team at Cornell University surveyed a network of 104 application equipment manufacturers and distributors, 50 state level pesticide regulatory officials, 50 pesticide applicator training coordinators and 108 pesticide inspectors/agents. These professionals were selected to help determine the current level of use and understanding of engineering control methods and the relevant merits of design and application of engineering controls. A brochure has been designed to inform regulators, educators and applicators regarding the various engineering controls for pesticide application.

This report is organized into two main sections. Section A provides descriptions and comparisons of the 14 engineering controls included in the study. The descriptions are organized from those controls providing protection for higher-risk pesticide activities to those providing protection for lower-risk activities. Also included is a brief summary of the written survey results for each control. Section B contains a description of the survey procedure used for the four survey groups as well as the detailed results of the surveys.
Section A

Engineering Controls
I - Loading the Sprayer

A - Closed Transfer Systems

A closed transfer system is a method of extracting concentrated pesticide from the original pesticide container and transferring it to the water or mixing tank on the crop sprayer. Closed transfer systems, in combination with protective clothing, can maximize operator safety. Closed transfer systems incorporate some or all of the following features:

1. open the container either by cutting the foil seal or puncturing the container wall or base
2. create a good seal between the container and the transfer device to avoid any pesticide leakage
3. empty all or part of the contents either by suction or gravity
4. measure the quantity of pesticide dispensed
5. rinse out the pesticide container either insitu or as a separate operation

Currently available closed transfer systems consist of either a sheathed probe, as shown in the photo at the right, or as a connector fitted to an inverted container.

Probe-type Systems
The Cherlor Chemprobe® comprises a telescopic probe that can be screwed onto the container opening. Different size caps are available for the Chemprobe® to accommodate different size container openings. The pesticide is drawn out of the pesticide container by means of a vacuum, created by a venturi, into the sprayer or mixing tank. The probe is surrounded by a collapsible rubber sheath that protects the operator from contamination when removing the probe from the container. As the sheath is pushed over the probe, a small O-ring removes excess pesticide from the probe.

The Cherlor Chemeasure® probe is similar to the Chemprobe® but has a transparent measuring cylinder attached to it. Pesticide can be transferred to the sprayer mix tank by a simple hand movement.

The major advantage of the probe system is its simple and compact design. The one drawback is the potential for contamination while removing a contaminated probe from the container, particularly a partially full container.
Container Opening Devices

In the mid-1970s, approximately ten different closed transfer devices were manufactured. This group included probe-type devices and also container opening devices. Container opening devices are currently not manufactured but might still be in use on some farm operations.

One such device is the Goodwin Can Opener. This device has a stainless steel box into which the pesticide container is placed. A handle is pulled forcing knives to slice into the side of the container releasing the pesticide into the box. A sight gauge tells the operator how much pesticide has been released. A rinsing system attached to the puncturing knives allows the operator to let rinse water enter the punctured container and the box, flushing out the pesticide and rinsing the system. The pesticide/water mix is then piped into the sprayer tank.

Another container opening system is the Captain Crunch. This system comprises a hydraulic unit into which the pesticide container is placed. Stainless steel knives cut the base of the container, releasing the pesticide. Rinse water is then introduced into the system to flush out the pesticide. A hydraulic cylinder then crushes the container to one-fifth its original size. The advantage of crushing the container is that it takes up less space for disposal.

A major advantage of container opening devices is that the pesticide container is emptied and rinsed within a sealed box. A major disadvantage of these devices is that the entire container contents must be used, creating problems when only part of a container of pesticide is required.

Container Attached Devices

A number of pesticide manufacturers offer returnable, refillable containers with transfer devices attached to the container opening (i.e., Secura-Link G™ manufactured by Sotera Systems). They are often used on smaller containers that can be inverted and mated to the lid of the spray tank. The empty containers are not rinsed out but are returned to the chemical manufacturer for refilling. Graduations are provided on the side of the container to measure concentrated pesticide as it is dispensed into the sprayer. A small handle attached to the coupling is used to control the amount of liquid flowing from the container into the sprayer.

One problem with this type of system is the accuracy of measuring the pesticide. Since the pesticide concentrate is dispensed directly from the container to the spray tank, there is no way to re-measure the chemical if too much is dispensed into the sprayer. Extra care must be taken to dispense the exact amount of pesticide. A positive aspect of these systems is that partial containers can be used.
B. Containers and Packaging

Mini-bulk containers are becoming increasingly popular, especially for large-scale farming operations that use great quantities of pesticides. Mini-bulk containers can be emptied using an electric pump, air compressor or suction system to pump pesticides directly into the sprayer tank or mixer wagon. Mini-bulk containers, since they are returnable and refillable, offer the advantage of not needing to be rinsed (saving time and reducing the possibility of operator contamination and environmental pollution) coupled with no unsightly empty pesticide containers to store and dispose of.

One uncertainty is what direction container designs and packaging developments are moving. Effervescent tablets and water soluble bags were developed many years ago but have failed to develop rapidly. The costs of product reformulation and production of tablets and soluble bags may have been overtaken by the development of water-dispersible granules. The marketplace also has plenty of liquid products available in small containers that offer greater flexibility and market share than mini-bulk containers.

Survey Findings

Manufacturers/Distributors
At present, most manufacturers and distributors see a slight demand for closed transfer systems. Closed transfer systems are most often offered as optional equipment in 10 of the study's 18 different sprayer categories. It should be noted that in comparing the description of closed transfer systems given above to those described in the product literature, the survey responses most likely include plumbing systems that allow sprayers to be connected to pumps or bulk containers in order to transfer pesticides. Nevertheless, closed transfer systems are not standard on the majority of sprayers in any category. Trailed airblast sprayers 250 gallons and smaller have the highest percentage of companies (75.0%) offering closed transfer systems as an option. Most trailed boom sprayer manufacturers also offer optional closed transfer systems. Closed transfer systems are not available on 250-gallon and less self-propelled sprayers or on the majority of the other sizes of self-propelled sprayers. For companies reporting closed transfer system prices, the average cost is $395.00 per system.
State Regulatory Officials
Two states require the use of closed transfer systems -- California and Washington. California requires closed systems to transfer only the most toxic (EPA Toxicity Category 1) pesticides. The Washington respondent indicated closed transfer systems are only needed for EPA Toxicity Category 4 (the least toxic) pesticides. No other states are expecting to adopt closed transfer system requirements in the near future.

Pesticide Applicator Training Coordinators
The coordinators indicated that, for the most part, closed transfer systems are generally discussed in their educational literature. Training on closed transfer systems is not provided to the majority of applicators or extension agents, as reported by 42.9% and 61.9% of the coordinators, respectively.

Field Inspectors/Agents
According to the pesticide inspectors/agents surveyed, closed transfer systems are used most often on 0 to 25% of the farms they visit. When asked which farm sizes they felt would be likely to adopt closed transfer systems, inspectors/agents most often indicated farms 1001 acres and larger.

C. Induction Bowls
A low-level induction bowl is fitted to the side of the crop sprayer or the mixing wagon. When attached to the sprayer, the induction bowl can be lowered to a height of approximately three feet from the ground to allow easy pouring of pesticide container contents at knee height. This overcomes concerns associated with lifting heavy containers. The induction bowl can then be raised to allow the sprayer to travel through crops without damage to the bowl or the crop.

The metal, plastic, or fiberglass bowl comprises a nozzle or pipe that rinses or flushes the bowl and disperses the product through an exit port at the base of the bowl. Suction, created by a venturi, removes the liquid via the sprayer hoses to the main tank.

Most products (liquid or dry) can be poured from their container or box into the bowl. Water soluble packages are difficult to disperse in an induction bowl. A rinse nozzle is often included which allows the in situ rinsing of small containers; the washings are used with the spray.

1 In the survey, a general discussion was defined as a paragraph or less. Detailed discussion was defined as a chapter or entire bulletin or fact sheet.
Survey Findings

Manufacturers/Distributors
Most manufacturers and distributors currently see moderate demand for induction bowls. Induction bowls are optional equipment on most of the sprayers included in the survey. The bowls are found as standard equipment on only 8 different sprayers. Induction bowls tend to be unavailable on most smaller sizes (250 gallons and less) of mounted boom, skid mounted, trailed boom and mounted airblast as well as the medium sized (251-to 500-gallon) skid mounted and trailed airblast sprayers. The average cost for induction bowls is $720.00

State Regulatory Officials
Currently, no state requires the use of induction bowls and three-quarters of the states do not expect to require them in the future.

Pesticide Applicator Training Coordinators
Most (66.7%) of the coordinators indicated that they do not discuss induction bowls in their educational materials. Training including induction bowls is also limited. A high percentage (81.0%) of coordinators noted they have not provided training to extension agents/educators and 73.8% indicated they have not provided training to pesticide applicators.

Pesticide Inspectors/Agents
Pesticide inspectors/agents report that they see the most induction bowl use on 25% or less of the farm operations they visit. Much like closed transfer systems, most inspectors feel that only the large farms (1001 acres and larger) would most likely use induction bowls.

D. Direct Injection Sprayers

A conventional crop sprayer is fitted with an injection system comprising one to four pumps that dispense pesticide at a known rate into the water stream within the sprayer pipeline. The main tank of the sprayer holds clean water only. The pesticide is mixed with the water either in a manifold or at the main water pump and the resultant mix flows to the booms and nozzles.

An electronic controller adjusts the pesticide injection pump according to changes in operating requirements such as changes in application rates and the type of pesticide needed. The major advantages of injection sprayers include:

1. reduction in environmental pollution due to the elimination of tank and pipeline washing.
2. reduction in operator contamination which occurs with conventional sprayers. Ideally the pesticide would arrive on the farm in large returnable and refillable containers and be connected directly to the pesticide injection pumps. The resulting closed system reduces operator contamination.

3. the use of an electronic controller that allows each pesticide pump to deliver a specific product. The injection pumps can be switched on or off as required to spray various patches of weeds or diseases.

4. the amount of pesticide applied (dose rate) can be adjusted on the move. This allows higher or lower dose rates to be applied depending on the amount of weed or disease infestation in the field.

The disadvantages of direct injection systems include high capital costs (approximately $10,000 for a three-pump system) and the need for fairly sophisticated electronics.

**Survey Findings**

*Manufacturers/Distributors*
Most manufacturers and distributors indicate there is slight demand for direct injection systems. Direct injection is most often offered as an option for all sprayers except 250-gallon and less mounted boom and mounted airblast sprayers and 251- to 500-gallon trailed airblast sprayers. Direct injection is unavailable from most companies in these sizes and types of sprayers.

*State Regulatory Officials*
Most states do not require direct injection system use and 70.5% of the states do not anticipate requiring them in the future. One state anticipates requiring their use in the next 2 years.

*Pesticide Applicator Training Coordinators*
Injection system discussion in educational materials is split almost in half with 50.0% of the coordinators providing a general discussion and 47.7% not providing any discussion at all. Training is not widespread, especially for extension agents/educators. Most respondents (78.6%) indicated they have not provided training to extension agents/educators that includes direct injection. Similarly, 61.9% of the coordinators said they have not provided training to applicators.

*Pesticide Inspectors/Agents*
About 42% of the inspectors indicated less than 25% of the farms they visit use direct injection systems. Inspectors also indicated that they felt farm operations 1001 acres and larger would be more likely to use direct injection systems.
E. Container Rinsing

Rinsing containers after use also leads to possible operator contamination. Traditionally, container washing is done near the filling hole at the top of the sprayer, leading to potential pesticide exposure from splashes, spills to the environment and incomplete container washing. Triple rinsing is a must.

Many low-level induction bowls have a rinsing nozzle fitted near the hopper opening which allows the rinsing of small containers. The rinsate drains into the bowl and is then pumped into the sprayer tank.

The Cherlor probe-type closed transfer system, discussed earlier, uses a separate rinsing device called the Chemrinse®. Inverted containers are placed in a polyethylene basin over a water nozzle. A jet of water rinses the container as it revolves inside the container. The rinsate drains by gravity into the basin and is removed to the sprayer or mixing tank via suction.
Survey Findings

Manufacturers/Distributors
Container rinse systems are offered as standard equipment on only 6 different sprayers. In 15 of the 18 sprayer groups, they are optionally available from most companies. One sprayer group - 250-gallon and less trailed boom sprayers - has the most companies not offering container rinse systems.

State Regulatory Officials
Michigan indicated they require container rinse systems only for aerial applicators. As for future container rinse system requirements, 75.5% of the states noted that they most likely will not be required.

Pesticide Applicator Training Coordinators
A high percentage (64.3%) of coordinators indicated there is general discussion about container rinse systems in their educational materials. The high percentage could be attributed to coordinators also including container rinse devices that attach to the end of a garden hose. As for training sessions on container rinsing, 42.9% of the coordinators have provided more than one session to extension agents/educators and 54.8% have provided more than one training session to applicators.

Pesticide Inspectors/Agents
Keeping with our trend, most inspectors (35.1%) see less than 25% of the farms they visit using container rinse systems. There are 24.7% of the inspectors who see 26% to 50% of the farms using rinse systems. Inspectors see these systems as being adopted by somewhat smaller farms than the previous categories, typically those 501 to 1000 acres in size.

II. Preventing Operator Contamination at the Boom

There are two major areas of potential operator contamination to consider: manually folding sprayer booms into the transport mode and making adjustments around the nozzle.

Manual boom folding occurs when spraying a field is finished, when the equipment needs to be taken through a narrow opening such as a field gate or transporting the sprayer back to the farm along the highway. Research indicates the operator is at high risk. The boom maybe covered in pesticide as a result of drift from the nozzles or from dripping nozzles. Folding mechanisms are usually found on wide spray booms but small, mounted sprayers still tend to rely on manual folding systems. Folding mechanisms may be:

- mechanical - using steel cables and pulleys to pull and lift spray booms into field or transport position
- hydraulic - using oil from the tractor or truck hydraulic system and hydraulic rams to move spray booms into field or transport position
- pneumatic - using air from a compressor mounted on the engine to actuate rams that move the booms into field or transport position.
When a sprayer is switched off, system pressure drops resulting in no spray being emitted from the nozzles. Often any liquid remaining in the boom pipes drips from the nozzles, scorching plants, causing environmental pollution and dripping onto the booms (or operator) when they are folded. Anti-drip diaphragm check valves can be installed between the boom pipe and the nozzle to prevent leakage.

Diaphragm check valves consist of a spring-loaded rubber diaphragm that closes off liquid flow when pressure drops below approximately 10 pounds per square inch. When the sprayer is switched on, system pressure increases and causes the valve to open and allow spray to be emitted from the nozzle.

Contamination may also occur when an operator changes nozzles for a different application rate or to use low-drift nozzles. Operators who change nozzles frequently should consider using a multiple nozzle body assembly or turret system. The desired nozzles are selected by a turn of the turret rather than unscrewing a threaded or bayonet fitting.

An aid to operator safety and hygiene is the fitting of a hand wash water supply to the sprayer. The hand wash water supply is simply a container with a hand-operated valve that is mounted to the side of the sprayer.

Survey Findings

Manufacturers/Distributors
Manufacturers and distributors indicated there is a high demand for hydraulic boom fold/extend. Hydraulic boom fold/extend systems tend to be standard equipment on self-propelled sprayers. Just over 83% of 501-gallon and larger and over 71% of 251- to 500-gallon self-propelled sprayer manufacturers indicated offering standard hydraulic boom systems. The majority of skid mounted and mounted boom manufacturers and distributors indicated offering optional hydraulic boom fold/extend. The average cost for hydraulic boom fold/extend is $4700.03.

Manufacturers and distributors also indicated a high demand for diaphragm check valves. Diaphragm check valves tend to be standard on 251-gallon and larger self-propelled sprayers. Most all mounted boom sprayers are built with standard diaphragm check valves. All skid mounted sprayers have most companies providing optional diaphragm check valves; 501-gallon and larger skid mounted sprayers having the highest percentage at 71.4%. The average cost of a diaphragm check valve is $10.55 each.

Current demand for multiple nozzle bodies is seen as high by 37.2% of the manufacturers and distributors. Moderate demand is indicated by a close 34.9% of the companies. Most companies in 15 of the 18 sprayer groups in the study offer multiple nozzle bodies as optional equipment. Three-quarters of 501-gallon and larger trailed airblast sprayers have this style of nozzle body as a standard feature. The average cost for multiple nozzle bodies is $16.45 each.
Hand wash water supplies are seen by 53.5% of the companies as having a high demand. Most companies offer them as an optional feature on their sprayers. Hand wash water supplies are standard on the majority of both self-propelled and trailed boom sprayers 251 gallons and larger. The average cost of a hand wash water supply is $142.52.

State Regulatory Officials
No state requires the use of hydraulic boom fold/extend systems or multiple nozzle bodies. Most states also do not expect to require their use in the near future.

Diaphragm check valve use is currently required for all chemicals in Illinois, Michigan, Mississippi, New Hampshire, and Washington. Michigan's requirements only pertain to all chemicals used in aerial application and Mississippi's requirements pertain to all chemicals used in aerial application as well as when any hormone-based herbicides are used, regardless of application method. Washington requires diaphragm check valve use for EPA Toxicity Category 3 chemicals. For states not requiring diaphragm check valve use, 65.9% of them are not planning to require their use anytime soon.

Alaska, Arizona, California, Illinois, Michigan, New Hampshire, New Jersey and Washington require hand wash water supplies for all pesticide categories. Over half the states that don't currently require them are not planning to require them in the future. One state anticipates requiring hand wash water supplies in the next two years.

Pesticide Applicator Training Coordinators
Over half the coordinators indicate they do not discuss hydraulic boom fold/extend or multiple nozzle bodies in their educational materials. The majority of the coordinators indicated they generally discuss diaphragm check valves (66.7% of the coordinators) and hand wash water supplies (69.0% of the coordinators).

Training on hydraulic boom fold/extend and multiple nozzle bodies have not been made readily available to either extension agents/educators or applicators. The survey results show that 25.8% of the coordinators have provided 1 or more training sessions to extension agents/educators on hydraulic boom fold/extend and 23.8% have provided the same number of training sessions to applicators. Multiple nozzle body training is similar with 23.8% of the coordinators providing 1 or more sessions to extension agents/educators and 28.6% holding the same number of sessions for applicators.

Diaphragm check valve training is significantly better. Over 40% of the coordinators have provided educational sessions to extension personnel on these valves and 54.7% of the coordinators have provided training to applicators. Educational sessions on hand wash water supplies have been fairly available with 57.2% of coordinators providing extension agents/educators 1 or more training sessions and 64.3% providing applicators 1 or more training sessions.

Pesticide Inspectors/Agents
Hydraulic booms are observed by 29.9% of the inspectors as being used on up to 25% of the farms they visit. There are a fair number of inspectors (26.0%) who see 26% to 50% of the farms they visit using them. Just over 1% of the inspectors said all the farms they visit use hydraulic boom fold/extend. Farms 501 to 1000 acres in size were seen by the inspectors as most likely to use hydraulic boom fold/extend.
Observation of diaphragm check valve use is fairly evenly distributed between three percentage groups. Just over a quarter of the inspectors indicated 26% to 50% of farms they visit use them. Similarly, 22.1% of the inspectors see 25% or less of the farms using diaphragm check valves while another 22.1% see 51% to 75% of the farms using them. A little over 1% of the inspectors reported all the farms they visit use these valves. Inspectors are split as to which farm size would be more inclined to use diaphragm check valves. Farms 251 to 500 acres and 501 to 1000 acres in size both received the same number of responses (35 inspectors each). Not far behind are farms 1001 acres and larger with 34 inspectors.

Nearly 30% of the inspectors see multiple nozzle bodies used on 25% or less of the farms. There are a number of inspectors (24.7%) who don't see multiple nozzle bodies used at all. Most inspectors feel that farms 501 acres and larger would most likely use multiple nozzle bodies.

Hand wash water supplies have the largest number of farms utilizing them. This could be a result of federal WPS requirements to provide hand wash water in the field. Most (31.2%) of the inspectors reported that 76% to 99% of the farms they call on use hand wash water supplies. Compared to the other controls in the study, a sizeable number of inspectors (11.7%) noted all farms they visit use hand wash water supplies. As for farms most likely to use hand wash water supplies, responses are distributed fairly evenly across all farm sizes. Two farm size ranges - 251 to 500 acres and 1001 acres and larger - each have 34 inspectors indicating them as most likely to use hand wash water supplies. Similarly, 32 inspectors said 501-to 1000-acre farms would use them. In both the less than 100-acre and 101-to 250-acre categories, 28 inspectors indicated these farm sizes would use them.

### III. Spray Drift or Contaminated Clothing in Cab

Charcoal cab filtration systems are standard on many self-propelled sprayers and now on a number of John Deere brand tractors. Carbon filters are optionally available for many tractors and can be purchased as a separate filter box to mount on the cab (i.e., the Spray-Safe® system) or as filters that fit inside existing air filtration systems (i.e., the Clean Air Filter available through Gempler's).

John Deere markets what they refer to as a Spray-Ready® cab on their 65 to 150 horsepower tractors and on their model 4710 self-propelled sprayer. These cabs meet the fairly stringent ASAE cab filtration standards described on the next page. Deere is the first farm implement manufacturer to provide such a high standard of air filtration on their equipment.
The American Society of Agricultural Engineers (ASAE) has adopted testing standards (standard number S525, parts 1 and 2) to test filters and cabs used in pesticide application. Development of this test standard involved many people and organizations affiliated with operator safety, filter manufacturing and cab manufacturing. A cab designed to meet this standard allows the operator to apply pesticides without wearing personal protective equipment when operating the sprayer. This then begs the question where should the operator store personal protective equipment needed for filling and maintaining the sprayer? A few manufacturers offer a small clothing locker fitted onto the side of the sprayer.

Survey Findings

Manufacturers/Distributors
Manufacturers and distributors indicated they see a high demand for operator cabs with carbon filters. By far, most all self-propelled sprayer manufacturers offer cabs with carbon filtration as standard. One company who manufactures 501-gallon and larger self-propelled sprayers offers cabs as an option and another company building 250-gallon and less self-propelled sprayers does not offer cabs at all. Manufacturers and distributors were asked if their cabs meet the ASAE S525 standard. Nearly two-thirds of the manufacturers and distributors indicate their cab systems meet this standard.

Most manufacturers (86.1%) see slight or no demand for protective clothing lockers. Similarly, protective clothing lockers are not readily available on most sprayers. Three-quarters of the manufacturers making 250-gallon and less sized trailed airblast sprayers offer them as optional. The skid mounted sprayer 501 gallons and larger category is the only other sprayer group with most companies offering optional protective clothing lockers. Three companies have the lockers as standard on their rigs.

State Regulatory Officials
No state currently requires cabs with carbon filtration. California has taken the lead, in cooperation with the EPA, in allowing applicators to use ASAE certified cabs in place of label required respirators. The California Department of Pesticide Regulation has developed a listing of cabs meeting this requirement. As for future requirements, nearly three-quarters of the remaining states are not planning any. Minnesota noted that at the time of survey completion, they were working on a policy related to cabs and might have it completed within 6 months.

Illinois reported that they require protective clothing locker use for all categories of pesticides. All other states responding do not require protective clothing locker use, at least sprayer-mounted types. Just over 70% of the states do not anticipate requiring their use.
Pesticide Applicator Training Coordinators
Coordinators are nearly divided in the level of cab with carbon filter discussion they provide in their educational materials - 47.6% say they don't provide any discussion while 45.2% say they provide only a general discussion. Only 28.6% of the coordinators have offered 1 or more training sessions to extension personnel. Applicators have received slightly more training with 31.0% of the coordinators providing one or more sessions to them.

The coordinators also indicated that protective clothing locker discussions are mostly general in nature. From the relatively high number of respondents (71.4%) answering so, it's quite possible that the responses include lockers that might be in a break room or a changing area as well as mounted on the sprayer. With this in mind, half of the coordinators have provided 1 or more trainings to extension personnel and 52.4% have provided the same number of trainings to applicators.

Pesticide Inspectors/Agents
Nearly half of the inspectors noted that up to 25% of the farms they visit use operator cabs with carbon filters. Only about 1.5% of the inspectors said 75% to 99% of the farms they call on use cabs with carbon filters. Like many of the other controls in the study, the inspectors feel that 1001-acre and larger farms would be more likely to use these types of cabs.

Inspectors see quite a number of farms using protective clothing lockers, although many may not be sprayer mounted. A little over 22% of the inspectors see 51% to 75% of the farms using protective clothing lockers. Even so, the majority of inspectors only see up to 25% of the farms using them. The inspectors feel that most farms 501 to 1000 acres would adopt clothing locker use.

IV. Controlling Drift

A. Low-Drift Nozzles

Nozzle Selection
Correct nozzle selection is one of the most important yet inexpensive aspects of pesticide application. A nozzle’s droplet size spectrum determines deposition and drift. Conventional flat fan nozzles on a crop sprayer produce droplets in the range of 10 to 450 microns. (There are 25,000 microns in one inch.) Drift is a major problem with droplet sizes less than 100 microns.

Drift has been a major concern for some years. Off target application wastes money, reduces deposition on the target plant, may pollute watercourses and may cause distress to other people. Increasing the Volume Median Diameter (VMD) will certainly reduce drift, but too large a droplet will bounce off the leaves to the ground, thus causing pollution, wasting money and resulting in less product on the target.
Conventional flat fan nozzles
Nozzles with an 80° angle produce coarser droplets than nozzles with a 110° angle at the same flow rate. The 80° nozzles require the boom to be set 17 to 19 inches above the ground whereas 110° nozzles can be set lower at 15 to 18 inches above the target. (The lower the boom, the less chance of drift.) Spray quality is fine to medium at 15 to 60 pounds per square inch (psi).

Low-drift flat fan nozzles
Advantages of low-drift flat fan nozzles include less drift and better timing. Their disadvantages include poor coverage on the leaves and poor distribution at low pressure. The internal design of this nozzle reduces internal operating pressure when compared to conventional flat fan nozzles. This results in coarser droplets being made. (High pressure creates fine droplets; low pressure creates coarser droplets.) These nozzles are available as 80° or 110° nozzles. Spray quality is medium to coarse at 30 to 60 psi. Drift-guard® is a well-known trade name of low-drift flat fan type nozzle.

Turbo-TeeJet® Nozzles
A turbulence chamber produces a wide angle, flat spray pattern of 150°. Spray quality is medium to coarse at 15 to 90 psi. Nozzles can be set at 15 to 18 inches above the target.

Survey Findings

Manufacturers/Distributors
Nearly half the manufacturers and distributors indicated that current demand for low-drift nozzles is high. Despite the high demand, low-drift nozzles are only optionally available from most sprayer manufacturers. Respondents indicated an average low-drift nozzle price of $4.38 each.

State Regulatory Officials
Two states noted they require low-drift nozzle use. Mississippi requires them for aerial applications and any application of hormone-based herbicides. The state of Washington requires them for all EPA toxicity category 3 pesticides. Most states are not expecting to require low-drift nozzle use in the future though one state indicated they probably will require their use in the next 2 years.

Pesticide Applicator Training Coordinators
Almost 60% of the coordinators indicated they provide a general discussion on low-drift nozzles in their educational materials. About a third of the coordinators provide detailed discussions. Responses about extension agent/educator training show a split between no training at all and more than one training session with 40.5% of the coordinators each. More than one training session has been offered to applicators by 45.2% of the coordinators.

Pesticide Inspectors/Agents
Most pesticide inspectors (26.0%) noted that they see low-drift nozzle use on 26 to 50% of the farms they visit. The inspectors indicated they felt that low-drift nozzle adoption was more likely to be on farms 501 to 1000 acres in size.
B. Air Induction Nozzles (Twin-Fluid Nozzles)

Air induction nozzles (also known as twin-fluid, air inclusion or venturi nozzles) are flat fan nozzles where an internal venturi creates negative pressure inside the nozzle body. Air is drawn into the nozzle through two holes in the nozzle side, mixing the air with the spray liquid. The emitted spray contains large droplets filled with air bubbles (similar to a candy malt ball) and virtually no fine, drift-prone droplets. The droplets explode on impact with leaves and produce similar coverage to conventional, finer sprays.

Air induction nozzles reduce drift even at higher pressures of 80 to 90 psi. They are only available at 110º fan angles so boom height may need to be adjusted to 15 to 18 inches. Trials in Europe confirm that the use of adjuvants can help create bubbles. Air induction nozzles are regarded as expensive since their list price is typically about three times that of a conventional flat fan nozzle.

Brands of air induction nozzles include:

- **Greenleaf TurboDrop®**
  - Nozzle consists of two primary components: the venturi air aspirator and the exit pattern tip. A ceramic orifice in the venturi determines the flow rate of the complete assembly. The venturi is ISO color coded to designate nozzle flow rate. The exit pattern tip does not affect flow rate; it is only used to form the desired spray pattern. Pressure range is 40 to 90 psi.

- **Spraying Systems TeeJet® Air Induction (AI)**
  - Nozzle has a plastic body with a steel tip, rated for 30 to 100 psi. They are plastic, single-piece construction.

- **Hardi Air Induction**
  - A one-piece plastic nozzle similar in construction to the Spraying Systems AI nozzle.

- **Albuz**
  - Also similar in construction to Spraying Systems AI nozzle. It is a one-piece plastic nozzle with a ceramic tip.

Survey Findings

**Manufacturer/Distributors**

Most companies indicate a slight demand for twin fluid nozzles. In general, these nozzles are optionally available from most companies in 7 of 12 sprayer categories that could offer these nozzles. No manufacturer offers them as standard equipment. Smaller sized self-propelled sprayers do not offer them at all. The average cost for this type of nozzle is $7.98 each.
State Regulatory Officials
No state currently requires use of twin fluid nozzles. Three-quarters of the states indicated they have no future plans to require them.

Pesticide Applicator Training Coordinators
Just over 52% of the coordinators indicated they do not discuss twin-fluid nozzles in their educational materials. Only 38.1% said they provide a general discussion. Almost 80% of the coordinators have not offered any training to extension agents/educators about these nozzles. Applicator training is slightly better with 61.9% of coordinators not offering educational sessions to them. Nearly one-fourth of the coordinators said they have offered more than one session to applicators.

Pesticide Inspectors/Agents
Most inspectors observe that 25% or less of the farms they visit use twin fluid nozzles. The majority of inspectors feel larger size farms are more likely to use twin fluid nozzles. Thirty-three inspectors indicated that farms over 1001 acres and 32 inspectors indicated that farms 501 to 1000 acres in size would likely use them.

C. Air-Assisted Booms
The basic principle behind air-assisted booms is the addition of an air supply near the nozzle. The boom structure may comprise a standard sprayer boom with conventional nozzles and a means of distributing air mounted onto the boom or surrounding the individual nozzles. The air distribution may be via an inflatable plastic sleeve, a rigid stainless steel or plastic sleeve, or a flexible corrugated plastic sleeve. The air curtain produced helps push the spray droplets into the canopy.

The air stream or the nozzles can often be angled to improve distribution onto the target. When there is plenty of canopy (e.g. a tall wheat crop), drift can be reduced considerably, deposition improved and often application rates reduced. In vine crops, for example, nozzles and airflow may be adjusted to reduce leaf shingle and improve penetration into the mature canopy.

Air-assisted booms also improve sprayer output. They can be used in slightly windier conditions than conventional sprayer booms increasing the number of opportunities to make pesticide applications. Air-assisted booms also use less spray mix, helping speed up applications by keeping the sprayer in the field longer due to fewer trips to the loading site for refilling.
Survey Findings

Manufacturers/Distributors
Manufacturers and distributors observe that, for the most part, current demand for air-assisted booms is slight. In the majority of sprayer categories, air-assisted booms are not available from most companies. Only three companies offer them as standard on their sprayers. The respondents did not provide air-assisted boom prices.

State Regulatory Officials
No state currently requires the use of air-assisted booms. Nearly 73% of the states are not planning to require their use in the foreseeable future. Almost 16% of the states indicated they have some other timeline to adopting air-assisted boom use regulations but none offered any specific numbers. The balance of the officials did not respond to the question.

Pesticide Applicator Training Coordinators
Almost 60% of the coordinators report they do not discuss air-assisted booms in their educational materials. Only 31% of them provide a general discussion of these booms. About 14% of the coordinators have conducted one or more training sessions for extension agents/educators that included air-assisted booms. Applicators have received slightly more training with nearly 30% of the coordinators providing one or more training sessions to them.

Pesticide Inspectors/Agents
The majority of inspectors noted that up to 25% of the farms they visit use air-assisted booms. When asked, most inspectors (34) feel that 1001-acre and larger farms would be more willing to use them. The next most popular farm size is 501 to 1000 acres.

V. Cleaning Spray Equipment

A. Tank Rinse Systems
Tank washing offers an opportunity for operators to be splashed by pesticide residues while cleaning the sprayer tank. On mixed cropping farms, tank washing is often carried out frequently to minimize the risk of crop damage due to the incorrect application of pesticides. Commonly, operators climb up onto the sprayer and reach through a small tank opening with a hose to wash out the inside of the tank. Good sprayer management practice recommends that the operator drive the sprayer back to the field to discharge the tank rinsate. The time taken to wash out the sprayer and to return to the field is of concern. Some growers, rather than applying the tank rinsate to the field, have been known to pull the tank drain plug at the wash site creating a potential source of pollution.
Tests have shown that triple rinsing is better than using just one single rinse. For example, using 100 gallons of clean water in one single rinse to clean a 100 gallon sprayer tank reduced the concentration of the original spray solution from 100% to 5% both in the tank and at the nozzle. When triple rinsing was performed using 33 gallons of clean water per rinse, a concentration of 0.2% to 0.5% was obtained. The aim is for maximum dilution with minimal water use. The use of rinsing devices fitted in the sprayer tank allows in-field rinsing and rinsate disposal.

Tank rinsing systems can be mounted to address the problems of large volumes of rinse water, time and operator contamination. A small rotating disc or nozzle(s) is mounted in the top of the spray tank. A 50 gallon tank of clean water is mounted above the main tank. Clean water is pumped to the spinning disc or nozzles and water cascades down the inside walls of the tank. Tank rinsing may take place in the field immediately following spraying saving time and reducing potential groundwater pollution and operator contamination.

**Survey Findings**

*Manufacturers/Distributors*
Most sprayer manufacturers and distributors say they see moderate demand for tank rinse systems. Rinse systems are found standard on half of the 501-gallon and larger self-propelled sprayers and on the majority of 251- to 500-gallon self-propelled sprayers. Most all the remaining sprayer types offer optional rinse systems. The cost of a tank rinse system averages $718.60 per system.

*State Regulatory Officials*
None of the states responding require tank rinse system use. Just over 70% of the states noted they do not plan to require these systems in the near future. Nearly 16% of the officials indicated their state has some other timeline until tank rinse systems may become required. Specific numbers were not given by any of the respondents. The balance of the officials did not respond to the question.
**Pesticide Applicator Training Coordinators**

A little over half (54.8%) of the training coordinators noted they give a general discussion of tank rinse systems in educational materials. Only 14.3% provide detailed information. Half of the coordinators indicated they have provided 1 or more training sessions to extension agents/educators on tank rinse systems. Applicator training is slightly better with 54.8% of the coordinators offering them 1 or more session.

**Pesticide Inspectors/Agents**

A little over 40% of the inspectors note tank rinse system use on up to 25% of the farms they visit. Slightly less than 3% of the inspectors reported that all farms they visit use these systems. Most inspectors (36) feel that tank rinse systems would more likely be used by farms 501 to 1000 acres in size.

**VI. Conclusion**

As the results of this report show (with a few exceptions), spray equipment manufacturers need to be encouraged to provide engineering controls as standard equipment. Manufacturers also need to recognize the need to supply engineering controls for smaller sprayer sizes, especially those less than 250 gallons. Manufacturers also need to do a better job promoting engineering controls and their use in their equipment promotional literature.

Most states do not require the use of engineering controls any stricter than federal government requirements. A few states do have unique requirements. California requires closed transfer system use for the most toxic pesticides (EPA Toxicity Category 1). Mississippi requires diaphragm check valve and low-drift nozzle use for hormone-based pesticides. New Hampshire requires diaphragm check valve use for all pesticides. Three states indicated they are considering future engineering control use requirements. New Mexico might require diaphragm check valve use in about 4 years. Illinois indicated they might require low-drift nozzle use in 10 years and Minnesota noted that at the time of survey completion, they are developing a policy on operator cab with carbon filters.

Engineering control training for applicators, extension agents/educators and pesticide enforcement officers is somewhat limited. Most state regulatory officials indicated engineering control training is not provided to their field staff. States that provide training for field inspectors/agents noted the training is provided "as needed" or as part of certification or recertification programs. The majority of PAT coordinators also indicated they do not provide training sessions to extension agents/educators and pesticide applicators for most engineering controls in the study. In order to develop a better understanding of the application and use of engineering controls, more educational programs for these three groups should be conducted.

Written materials about engineering controls are more readily available than training programs. There are some discrepancies between survey groups about written material availability, particularly between state regulators and field inspection staff. Regulatory officials indicated that educational materials are made available to field staff but most field staff noted they do not have educational materials. PAT coordinators have developed written materials that include engineering control discussions, but the discussions tend to be general in nature. Very few states
have detailed engineering control educational materials. Several PATs recommended that educational materials (i.e., video tapes, web sites, fact sheets, etc.) be developed on a national level so detailed engineering control information can be included in training manuals and other materials they use.

In the field, engineering control use is relatively low. Most engineering controls, as viewed by state pesticide inspectors/agents, are used on 25% or less of the farms they visit. Inspectors remarked that farm operators might use engineering control cost as the most important factor in selecting a control. The level of safety a control provides is most likely the last consideration. Inspectors indicated that farm operators they visit with would most likely be willing to pay up to $1000 for an engineering control. Manufacturers should be encouraged to supply a wide array of basic engineering controls for their spray equipment and be encouraged to promote them on economic and safety grounds. The development of nationwide extension educational materials will improve awareness of engineering controls among educators and growers alike, helping to create a demand to satisfy market developments offered by manufacturers. A reduction in operator exposure should result from these efforts.