DEVELOPMENTS IN FERTILIZER TECHNOLOGY

AND APPLICATION TECHNIQUES*

By

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INTRODUCTION

The Tennessee Valley Authority's (TVA) is a government corporation created in 1933 to help develop the Tennessee Valley region in parts of seven southeastern States to conduct fertilizer research and development for the Nation and to serve as a model of public and private cooperation in developmental programs. The National Fertilizer Development Center (NFDC) at Muscle Shoals, Alabama, is TVA's only national program and is the Nation's only full-scale fertilizer research and development program. NFDC scientists and engineers conduct basic research and developmental activities to generate new technology—including new fertilizer products and processes, fertilizer practices, and nutrient-related environmental technologies. NFDC also conducts a national technology transfer program to introduce new technology into U.S. agriculture.

NFDC has the laboratories, pilot plants, prototype production facilities, and greenhouses to develop and test new technologies. It has the relationships with the fertilizer industry, land-grant universities, and farmers required to get new technology into use for the benefit of the Nation. Major goals are to improve fertilizer use efficiency, efficiently process raw materials and by-products into quality solid and fluid fertilizers, and prevent environmental damage when producing and using fertilizers.

This paper highlights major new product and process developments underway, a new environmental initiative so important to industry and agriculture, and identifies trends in fertilizer application technology.

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*For presentation at "Technology In Agriculture Panel," Terra International, Inc., Management Meeting, Kansas City, Missouri, December 5–7, 1988.

NEW FERTILIZER TECHNOLOGY

The following are examples of recent developments and future advances in fertilizer manufacturing.

Granular Urea-Nitric Phosphate

The high cost of sulfuric acid, the increasing dominance of urea as the nitrogen fertilizer of trade, and the need to develop a cheaper source of soluble phosphate prompted TVA to investigate the properties of solid fertilizers that can be produced by the direct reaction of phosphate rock with nitric acid and urea. The process that evolved resulted in a urea-nitric phosphate (UNP) product of 27-9-0 grade. By adding supplemental wet-process phosphoric acid, products with grades of 24-12-0 and 19-19-0 with good physiochemical properties can also be produced.

Potential advantages of the process are:

- Economics of UNP fertilizer production is independent of sulfuric acid prices.
- Process employs the cheapest source of phosphate—phosphate rock.
- No gypsum by-products are formed and thus no gypsum disposal problems are incurred.
- Can use granular, prilled, or molten urea.
- High citrate- and water-soluble P_2O_5 contents are obtained.
- Calcium and micronutrients present in the phosphate rock are also present in the final products.
- High acidity of the products could reduce nitrogen losses resulting from hydrolysis of urea and subsequent ammonia volatilization.

Possible disadvantages of the process are:

- Product is relatively low in concentration (36 percent total plant food) which increases shipping and handling costs.
- Relatively low critical humidity (50 to 55 percent) when compared with ammonium nitrate (59 percent) and urea (70 percent).

Because of the potential advantages, TVA is continuing to work on the process.

Urea by the Falling-Curtain Process

The TVA falling curtain-evaporative cooling process has proven to be a versatile, economic process for granulation of urea. Prilling is still the lowest cost finishing process, but it cannot provide the larger particle size required to prevent segregation in bulk blends. Favorable features of this process, when compared with other urea granulation processes, include the following:

- Low energy consumption.
- Relatively low equipment costs.
- Superiority of product (hardness and roundness).
- Less pollution abatement needed because of the inherent low dust generation and versatility in making a variety of particle size.

Falling-curtain granular urea products are closely sized and have been produced in sizes ranging from the size of urea prills to larger than 1.25 centimeters (about one-half inch) in diameter. NFDC's normal size, however, is -0.3 +0.01 centimeter which matches the standardized particle size distribution of popular bulk blend materials.

Granular Urea LS™

Urea LS™ is the NFDC trademark for urea produced using calcium lignosulfonate as the conditioning/hardening agent. This product was developed to find a suitable replacement for formaldehyde which is used by a large segment of the urea industry. There is no known direct environmental effect from the presence of formaldehyde reaction products in urea fertilizers. There is concern about its future use, however, because the toxic nature of formaldehyde alone could prompt enactment of protective environmental legislation.

Lignosulfonates are as effective as formaldehyde as conditioning agents for granular urea and have several other advantages:

- They are nontoxic and environmentally safe.
- Their use results in a savings of 50 cents to $1 for each ton of urea produced.
- The granular Urea LS™ remains in better physical condition during bulk storage for longer time periods, and the tan to brown color blends in well with DAP and other fertilizers used in bulk blends resulting in a homogenous appearing mixture.

The product has been successfully used in bulk blends and for direct application. TVA studies show that lignosulfonates modify the crystal structure of urea in the same way that formaldehyde does. Because of this strucutre, granule crushing strength is high.

TVA began producing Urea LS™ in the falling-curtain evaporative cooling plant in October 1986. Since then, about 60,000 tons of Urea LS™ has been produced for demonstration programs in the Tennessee Valley and throughout the United States. Dealer and farmer responses have been favorable. More than 100 dealers in 12 States have used Urea LS™.

Several U.S. and Canadian urea producers are investigating the switch from formaldehyde to calcium lignosulfonate as a conditioning/hardening agent. Agrico became the first commercial producer, when, about six weeks ago, they began use of calcium lignosulfonate at their Blythville, Arkansas, plant. We are pleased that Terra has conducted experimental production runs at Port Neal (Iowa), and we understand you are seriously considering production of this new product.

Sulfur Coated Urea LS™

In the 1970s, TVA developed a process for coating soluble fertilizer granules and prills with sulfur to produce a controlled-release fertilizer. Called sulfur-coated urea, the product has two major advantages: (1) greater plant uptake efficiency and (2) smaller losses from leaching, runoff, or decomposition.

The major advantages of using Urea LS™ instead of urea conditioned with formaldehyde as the substrate for sulfur coating are:

- Less sulfur is required for the same dissolution rate.
- Nitrogen content of the sulfur-coated product is higher.
- Urea LS™ is up to $1 cheaper than urea conditioned with formaldehyde.

Nitrogen-Sulfur Suspension Fertilizers

A recently developed family of nitrogen-sulfur fluid fertilizers appears promising for use on sulfur-deficient soils. These new suspensions are urea-ammonium nitrate-ammonium sulfate (UANAS) and high-sulfur urea-ammonium sulfate (UAS) suspension. They contain only ammonium sulfate crystals which grow very little during long-term storage.

Other advantages of these suspensions are:

- A wide variety of grades and ratios can be made.
- Viscosity of products is relatively temperature independent.
- Product quality is not lowered by dilution or blending.
- Dry clay can be gelled effectively without excessive agitation.
- The production process and equipment are simple and economical.
- Inexpensive by-product raw materials can be used.
- Storage properties are good.

NFDC will continue to evaluate these materials in its industry demonstration programs.

12-36-0 Ammonium Polyphosphate Suspension From Merchant-Grade Acid

In the late 1960s and early 1970s, NFDC developed a pipe reactor process that used low-conversion superphosphoric acid to produce a 10-34-0 grade liquid fertilizer. That process was adopted in about 130 plants.

More recently, efforts were undertaken to use less expensive merchant-grade acid in a pipe reactor. The process was designed so that it could be retrofitted into the existing 10-34-0 process with minimal equipment changes or additions.

The product was a 9-32-0 grade suspension fertilizer which contained about 20 percent of the P_2O_5 as polyphosphate.

And most recently, as a part of NFDC's ongoing efforts to produce less expensive, high-quality fertilizers for the U.S. farmer, the 9-32-0 process was modified so that a more concentrated 12-36-0 grade product could be produced from merchant-grade acid. About 15 percent of the total P_2O_5 in this product is present as polyphosphate.

The raw material cost of the 12-36-0 is lower than either 9-32-0 or 10-34-0 on a dollar per unit of plant food basis.

The lower raw material costs and higher concentration of 12-36-0 also make it less expensive to ship and store.

The 12-36-0 APP base suspension can be applied directly to the soil or can be used in preparing mixed suspension products of various grades by blending it with a nitrogen base suspension and potassium chloride.

Granular APP and UAP Fertilizers

Produced with Energy-Efficient Pipe-Cross Reactor

And Drum Granulator Process

About 12 years ago, NFDC developed the pipe-cross reactor that commercial producers used in conjunction with TVA-type drum granulators. Results were energy savings, convenience, and improved product quality. Many grades of MAP-based fertilizers containing some sulfur from sulfuric acid were produced.

TVA recognized that these plants using the pipe-cross reactor also had the potential to produce granular phosphate fertilizers containing useful levels of polyphosphates. This would allow the granular products to be used as intermediates to produce both higher grade and higher quality phosphate suspensions.

Very recent process developments led to production of a variety of products with higher nitrogen ratios by using urea as a supplemental nitrogen source. These included urea-ammonium phosphate (UAP) product grades that contain no added sulfate, such as 28-28-0 and 35-17-0, and those which contain sulfate, such as 25-25-0-4S, 15-15-15-8S, and 17-17-17-4S.

This energy-efficient fertilizer was demonstrated to the fertilizer industry in 1985 as 12-53-0-2S ammonium polyphosphate sulfate. The product is dry, hard, and free flowing. A satisfactory 12-36-0 grade APP suspension can be made from the granular product.

Granular Unpurified Urea Phosphate

NFDC and others have studied the production of pure 17-44-0 grade urea phosphate crystals from impure wet-process acid by a crystallization process. These crystals can be used to made a high quality 15-28-0 urea phosphate liquid fertilizer, but the process is expensive.

Studies indicate that a high degree of purity may not be necessary in certain applications and that a less expensive 16-41-0 grade solid urea phosphate would still have useful agronomic advantages. The acidic nature of the material may reduce nitrogen losses from the urea.

The unpurified urea may offer potential advantages for conversion to suspensions when compared with solid MAP used for suspensions.

Preliminary results are promising and work is continuing.

Granular By-product Ammonium Sulfate

NFDC has developed a granulation process that combines the small crystals of abundant by-product ammonium sulfate into a granular product. The resulting product is in great demand by the bulk blending fertilizer industry. The process was designed so that it can be used with little modification to a conventional granulation plant. Basic modification is to reverse the airflow in the dryer. In most cases, little additional cost is required for the modification.

The granular ammonium sulfate made by this process contains 20 percent nitrogen and 24 percent sulfur, all in water-soluble form.

Potential advantages of granular AS should be in the bulk blend segment of the industry because of its compatibility with other blend materials and its readily available sulfur content.

Nitrogen Suspensions

TVA has developed urea-ammonium nitrate suspension fertilizers which analyze 30 or 31 percent nitrogen and has conducted fairly extensive introduction programs with the materials in the market area served by Terra. The UAN suspensions contain 1-1/2 to 2 percent gelling clay, have good storage and handling characteristics, and help overcome problems of handling dry clay at a dealer location. Terra has produced limited quanitites of this material, and we understand you are considering production of more significant quantites in the future.

Future Technologies

Future developments will involve improvements in existing processes to reduce production costs and increase efficiency. The long-term concerns of the industry today and in the future will be how to comply with strict environmental regulations and how to use lower grade phosphate rock and still produce fertilizers, such as DAP, that are competitive on the world market.

NFDC is in the process of developing a national environmental initiative to help fertilizer dealers comply with rapidly increasing environmental regulations at the regional, State, and Federal levels. We plan to do this through three program areas: containment and compliance, research and development, and information sharing.

Our researchers are also heavily involved in developing processes to use the low-grade phosphate ores.

INNOVATIONS IN FERTILIZER APPLICATION

Significant technical developments in methods of applying fertilizer have been made as a result of research and development by many private organizations, universities, and other public organizations, including NFDC. The following is a discussion of recent advances in fertilizer application.

Custom Application

Innovations to facilitate the task of the applicator operator are common on large custom application equipment. Custom machines are equipped with electric monitors and controls which automatically adjust fertilizer output to compensate for applicator speed changes.

A diagram of an automatic rate controller on a high flotation liquid applicator is shown in figure 1. Custom equipment usually has a radar speed sensor to give signals to a microprocessor which adjusts the flow of fertilizer to compensate for speed changes. Unlike other speed sensors, the accuracy of radar sensors is not affected by wheel slippage.

Automatic rate controllers are also available for dry spreaders. Fuel efficiency has also become a major concern of applicators, and they are being equipped with diesel engines and wider booms. Many of the features discussed here are also available on farm-operated applicators.

Dry Fertilizer Application

The most innovative custom applicator designs have involved dry fertilizer applications. Several boomed spreaders are being promoted as machines that will make spinner spreaders obsolete. One has augers, the others are pneumatic.

The auger system has been marketed on a truck chassis for several years in the Northwest. It is now marketed on a high flotation chassis by one of the largest manufacturers of high flotation equipment. Figure 2 depicts the latest version which has two lift augers which are gravity fed from the hopper and two 5-inch augers which supply each boom. An agitator and a metering screw are located under each boom supply auger to meter the flow of fertilizer. The metering screw is driven hydraulically from a pump driven from the vehicle drive shaft.

Figure 3 is a sketch of the early version of the most popular pneumatic dry fertilizer spreader. Rate of application is controlled as in conventional spreaders by controlling apron speed. Fertilizer is distributed through 20 outlets by a vertical auger which conveys material from beneath the supply apron to a manifold. A wiper on top of the vertical auger distributes fertilizer to the 20 openings. Vertical tubes transfer fertilizer from the 20 openings downward to lateral tubes which supply 20 nozzles. The 3-inch lateral tubes are fed air at high velocity from two headers.

On newer versions, the diesel engine driving the blower has been replaced with a hydraulic motor. Nozzles consist of deflector shields positioned just below the outlets of the lateral tubes.

Five other pneumatic spreaders are being marketed in the United States. A major reason for the growing popularity of boomed spreaders is the demand for uniform application of impregnated blends.

One of the newest developments in dry fertilizer application is onboard impregnation of herbicides. The system is similar to regular dry fertilizer impregnation with herbicide, except that the impregnation process occurs in the field onboard the applicator rather than in the fertilizer plant.

There are two types of onboard impregnators on pneumatic applicators. One has a single nozzle that sprays pesticide on the fertilizer being augered into the distribution system. The other has a separate pump for each of the 20 outlets. The 20 pumps are ganged in four groups of five and are hydraulically driven. Automatic rate controllers are used for metering both fertilizer and pesticide.

Suspension Fertilizer Application

The adoption of suspension fertilizers has led to the development of flow dividers for row and band application. Before suspensions became popular, liquid fertilizers were row applied by gravity feeding from a tank over each row or by pumping them through manifolds with ground driven piston pumps. But because of crystals, suspensions could not be gravity fed, and they often caused fouling of valves in piston pumps. The squeeze (hose) pump (figure 4) was developed as a less expensive alternative to the piston pump. It moves suspension by pressing rollers against flexible hoses.

As the number of outlets on row equipment increased so did the demand for a flow divider that could be used in a pressure system. The first suspension flow divider designed for large row applicators is shown in figure 5. It has a vented pot into which liquid is distributed by a hollow cone nozzle. The pot is compartmentalized, and each compartment drains into a single hose which supplies an application knife or dribble tube. Since the compartments drain more rapidly than they are filled, equal length lines to each knife are not required. This is a major selling point for this and similar flow dividers.

Another suspension flow divider uses a system of multiple orifices to equalize the pressure drop through the manifold and to produce lower outputs than would be possible through a single orifice (figure 6). Unlike the pot system, one or more outlets on this divider may be plugged to reduce the number of outlets without decreasing uniformity of distribution.

Figure 7 is a sketch of another suspension flow divider. This divider combines different inlet and outlet orifices to produce a range of application rates. The number of outlets on this divider can also be reduced using plugs without altering distribution uniformity.

Agronomic Inspired Innovations

Some innovations in application involve the positioning of fertilizer in the soil and are the result of agronomic research. The shift by farmers to minimum or reduced tillage has precluded the conventional practice of mixing broadcast fertilizer into the soil during tillage. Researchers are improving the efficiency of fertilizer by injecting them below the soil surface or banding them on the soil surface in minimum tillage situations.

A unique application method adopted by farmers in the U.S. wheat belt is dual application. Dual application is the simultaneous injection of nitrogen, usually anhydrous ammonia, and phosphate. Liquid phosphate, 10-34-0 grade ammonium polyphosphate solution, is the most common; however, suspensions and dry sources of phosphate are used.

Starter fertilizer application is a type of precision placement that has been used for many years but is getting more attention for use with reduced tillage corn where it helps offset detrimental effects of colder soil temperatures. Minimum tillage planters have been improved, and corn hybrids bred particularly for minimum tillage have eliminated many problems encountered by those who pioneered minimum tillage.

A unique tillage tool used for dual application is the V-blade chisel plow. A diagram of this implement equipped for dual application is shown in figure 8. Unlike knife systems which usually have liquid phosphate capabilities, many V-blade systems use a pneumatic dry phosphate system. The V-blade plow is popular in arid wheat growing areas because it tills the soil without greatly disturbing the soil surface. This helps preserve soil moisture.

A new experimental machine injects a solid stream of liquid fertilizer at 2,000 psi into the soil without a knife. A high pressure piston pump delivers liquid to solid stream nozzles mounted in shoes that slide along the soil surface or residue surface. This approach was used in the 1960s to inject anhydrous ammonia into soils not well suited for conventional knifing.

Another unique injection system is being developed by a midwestern university. This device, called the spoke injector, resembles a spoked wheel without a rim. The hub has a cavity in which liquid fertilizer is delivered under pressure. The internal design of the hub is such that liquid is forced out of the hub and through a spoke only when the spoke is aimed vertically downward. The outlet hole on each spoke is on the side of the spoke near the end to prevent clogging. Like the high pressure injector, the spoke injector produces no slit that increases the erosion potential of a field. The best knife rigs, on the other hand, create some potential for erosion when operated up and down hills.

Other interesting devices that have been patented but are not yet in common use include radar controlled automatic boom levelers and radar applicator guidance systems. An onboard herbicide injection system can meter chemicals into the output line of a liquid applicator. The most appealing aspects of this device are the conservation of chemicals and elimination of chemical waste disposal. Without the chemical injection system, applicators must be flushed with water after spraying chemicals to avoid contamination.

Future Trends

Emphasis on accurate fertilizer application will aid development of more accurate metering systems, better monitors, and more sensitive sensors. Measurement of fertilizer output from automatic rate controllers has revealed that some controllers cannot respond to rapid changes in applicator speed. Faster acting servomotors are being developed to eliminate these time lags in metering response. An organic matter sensing device has been tested which will be used to adjust application rates of triazine herbicides. These herbicides are organic matter sensitive. This marks the beginning of a technology that some believe will eventually evolve to sensing of soil fertilizer nutrient content.

There is much interest among researchers in site-specific control of nutrient application rates. Preliminary tests have shown that comparable yields can be achieved with less fertilizer using this approach.

A new applicator is available that automatically adjusts the rate of up to six different granular products—on-the-go. Special maps and soil tests are interpreted by an onboard computer which constantly tailors the blend to each area in the field.

The cost of automatic rate controllers—the heart of on-the-go rate adjustment—should decrease, and the reliability and simplicity of these devices should improve in the future. Emphasis on better fertilizer and herbicide application will speed the use of rate sensors and controllers to improve accuracy.

The common practice of batch mixing herbicides and fertilizer will likely be abandoned because of the amount of equipment that must be rinsed—mix tank, nurse equipment, and applicator. Some dealers are already developing systems to limit the volume of rinsate produced.

Fertilizer application is now a far more precise operation than in the past. Yet, much work remains to be done in lowering the cost of application by improving delivery systems to the farm, increasing uniformity of application and refining metering equipment. More efficient application systems and low-cost fertilizers that work with them are keys to success in tomorrow's fertilizer industry.

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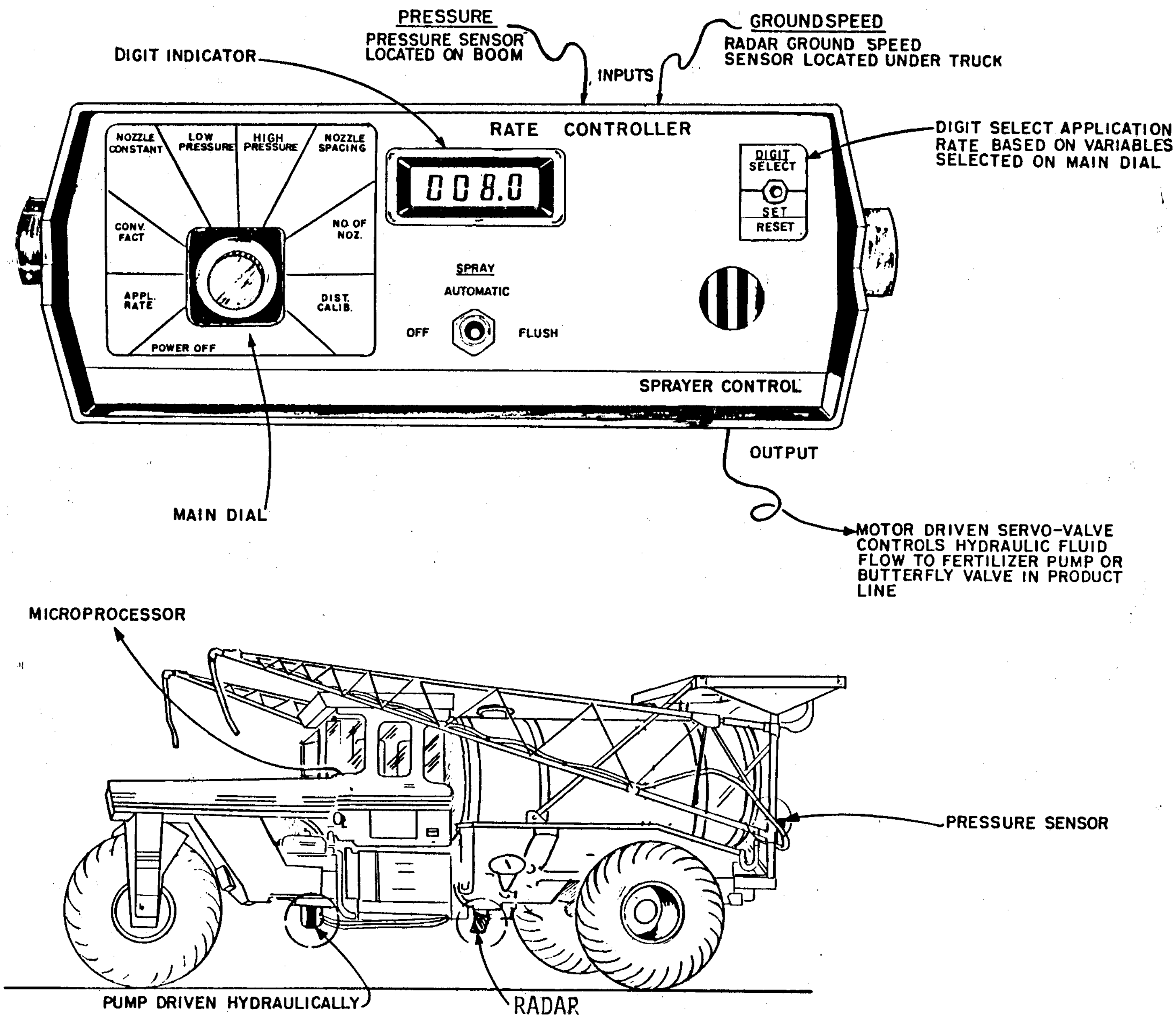

FIGURE 1

ELECTRONIC RATE CONTROLLER FOR LIQUID APPLICATOR

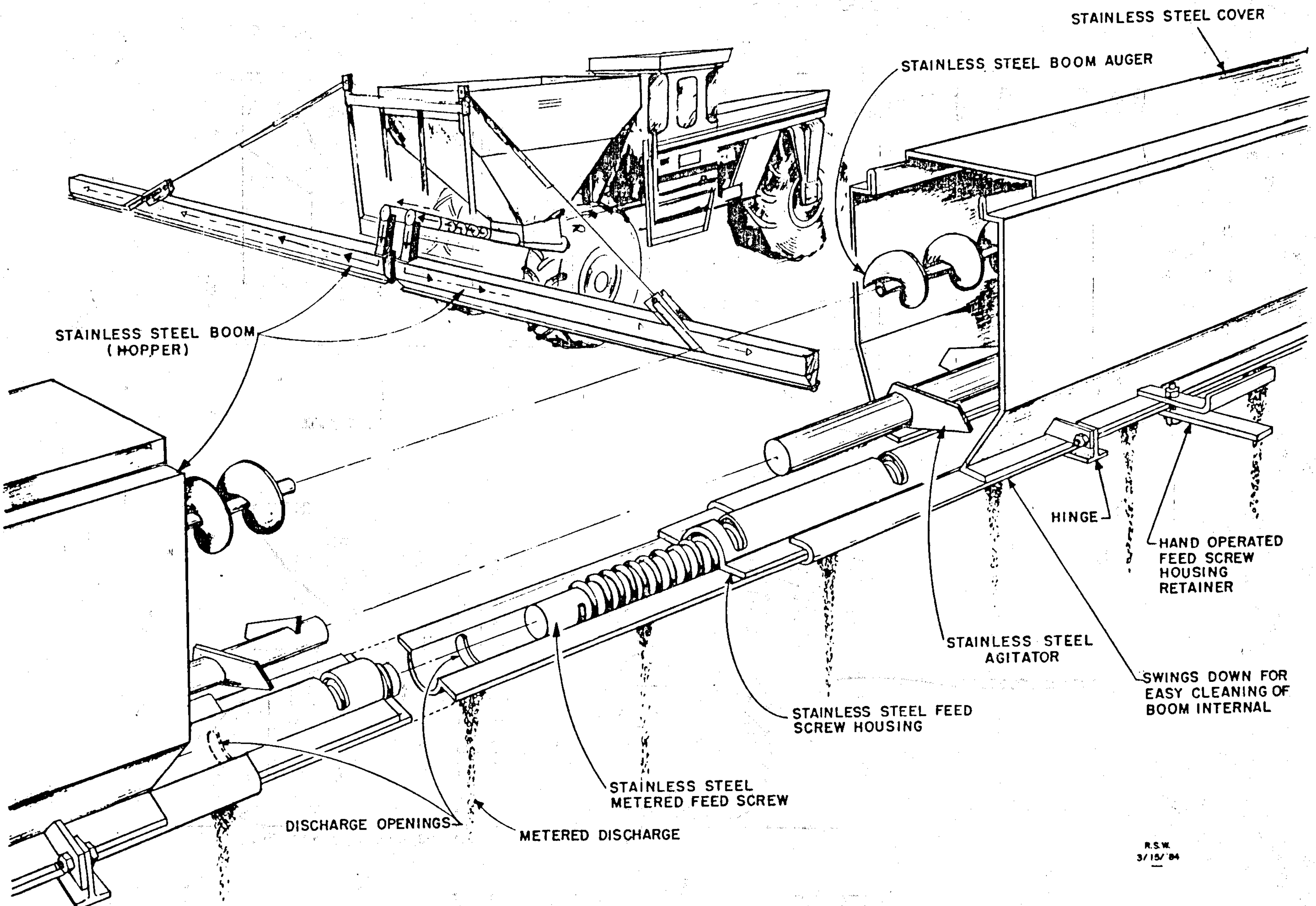

FIGURE 2

AG-CHEM/BARBER AUGER SPREADER

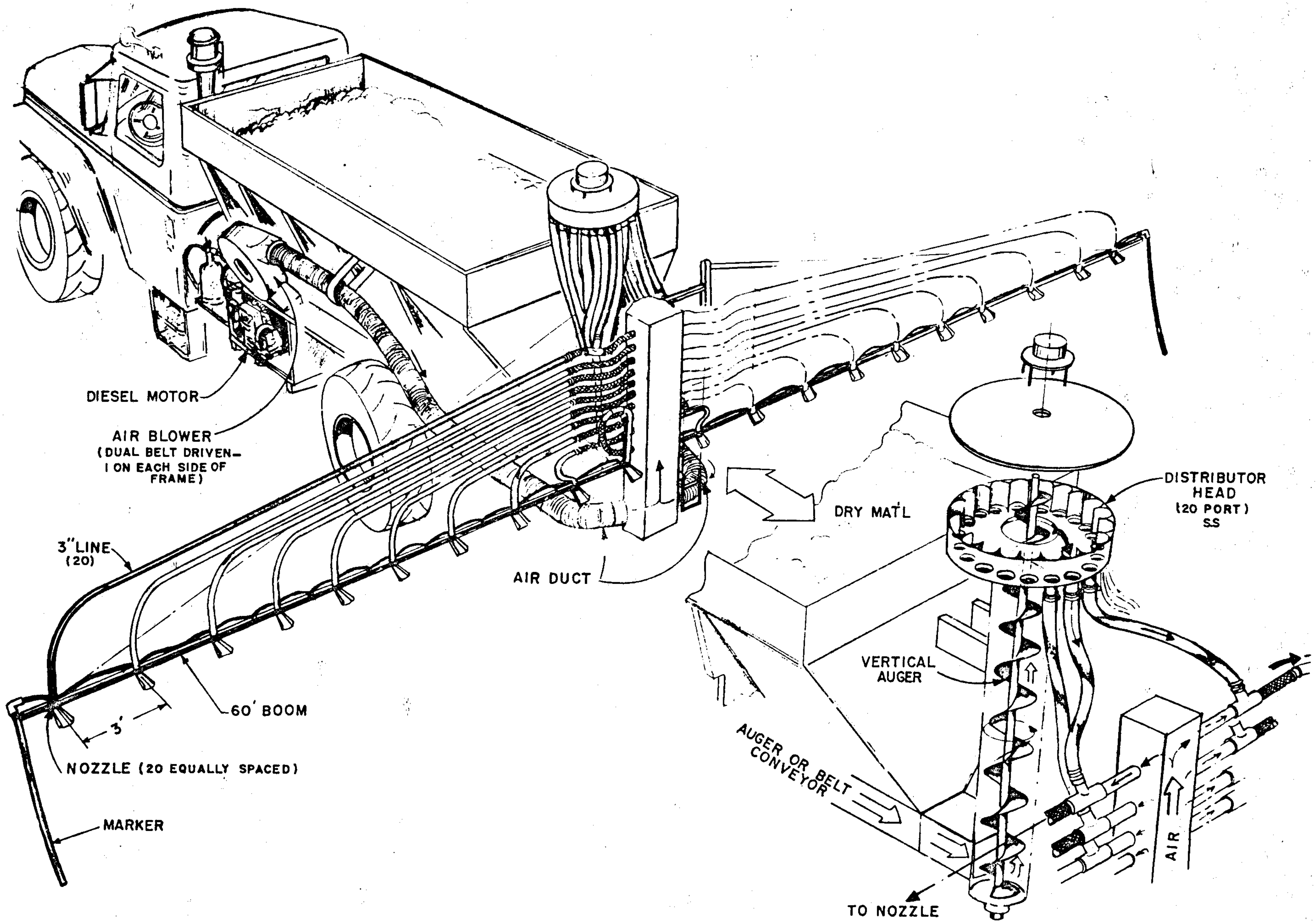

FIGURE 3

LOR-AL AIR-FLOW SPREADER

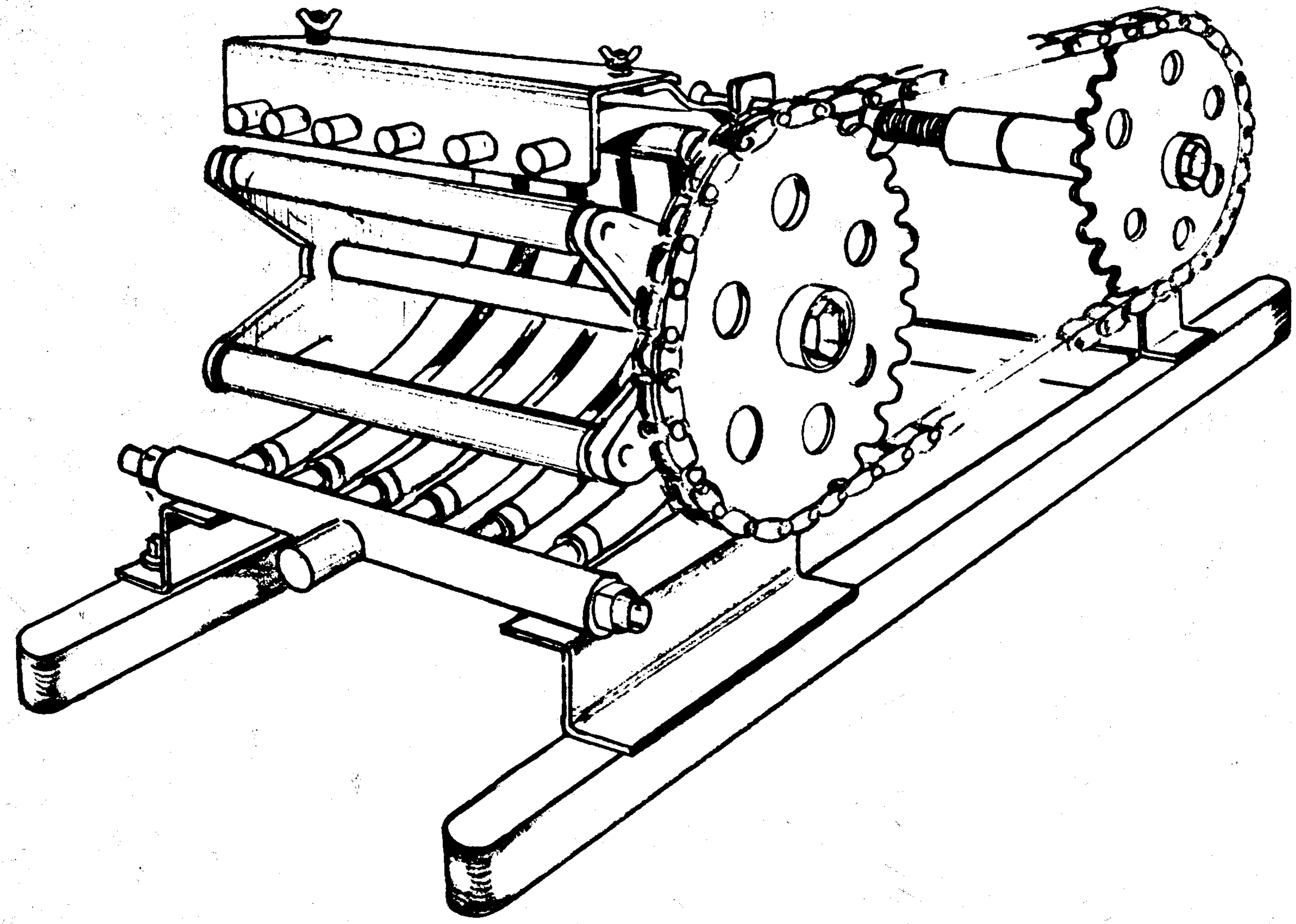

FIGURE 4

SQUEEZE PUMP WITH ROUND HOSES AND BACK PLATE

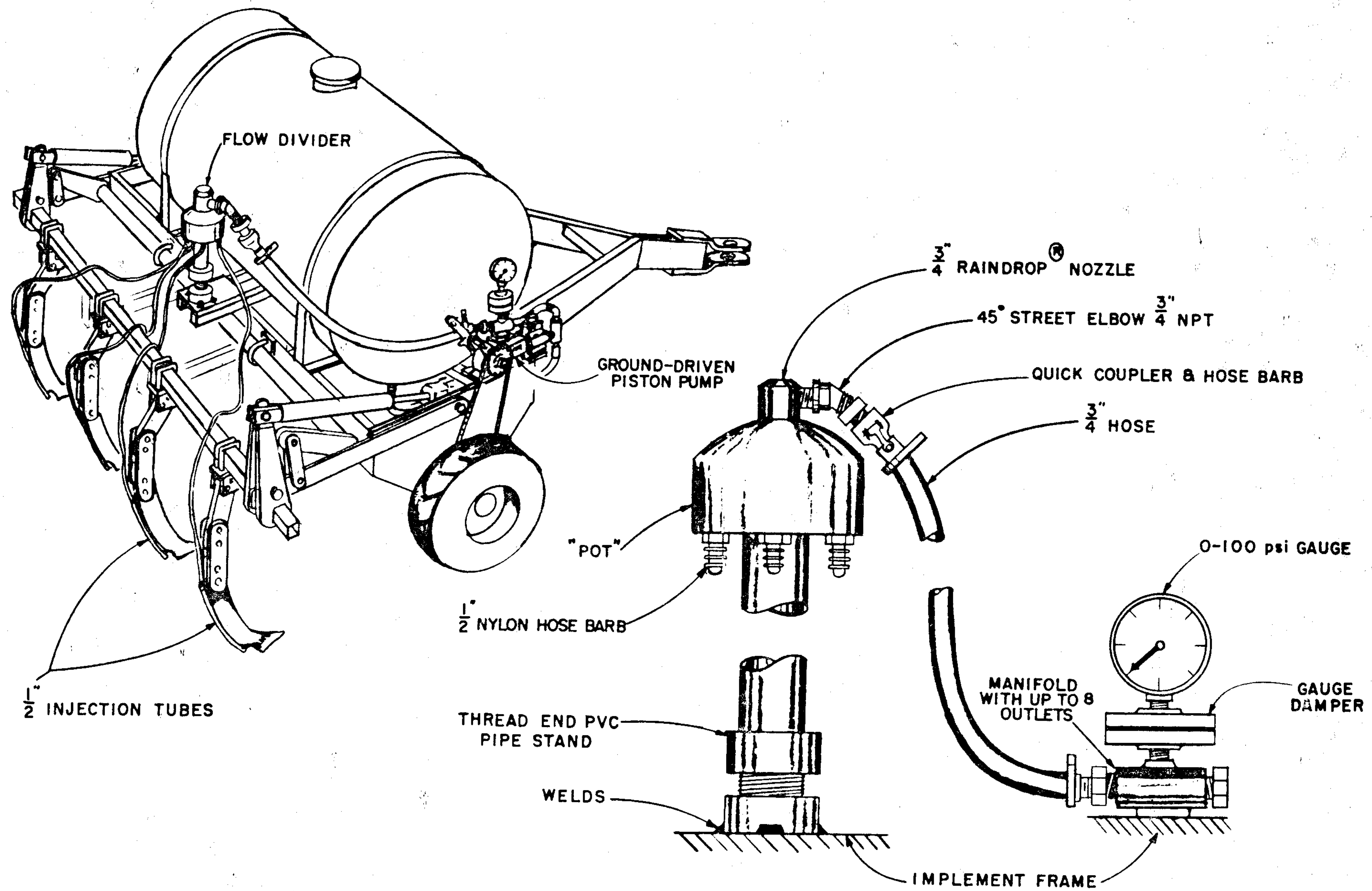

FIGURE 5

FLOW DIVIDER FOR SUSPENSION INJECTION

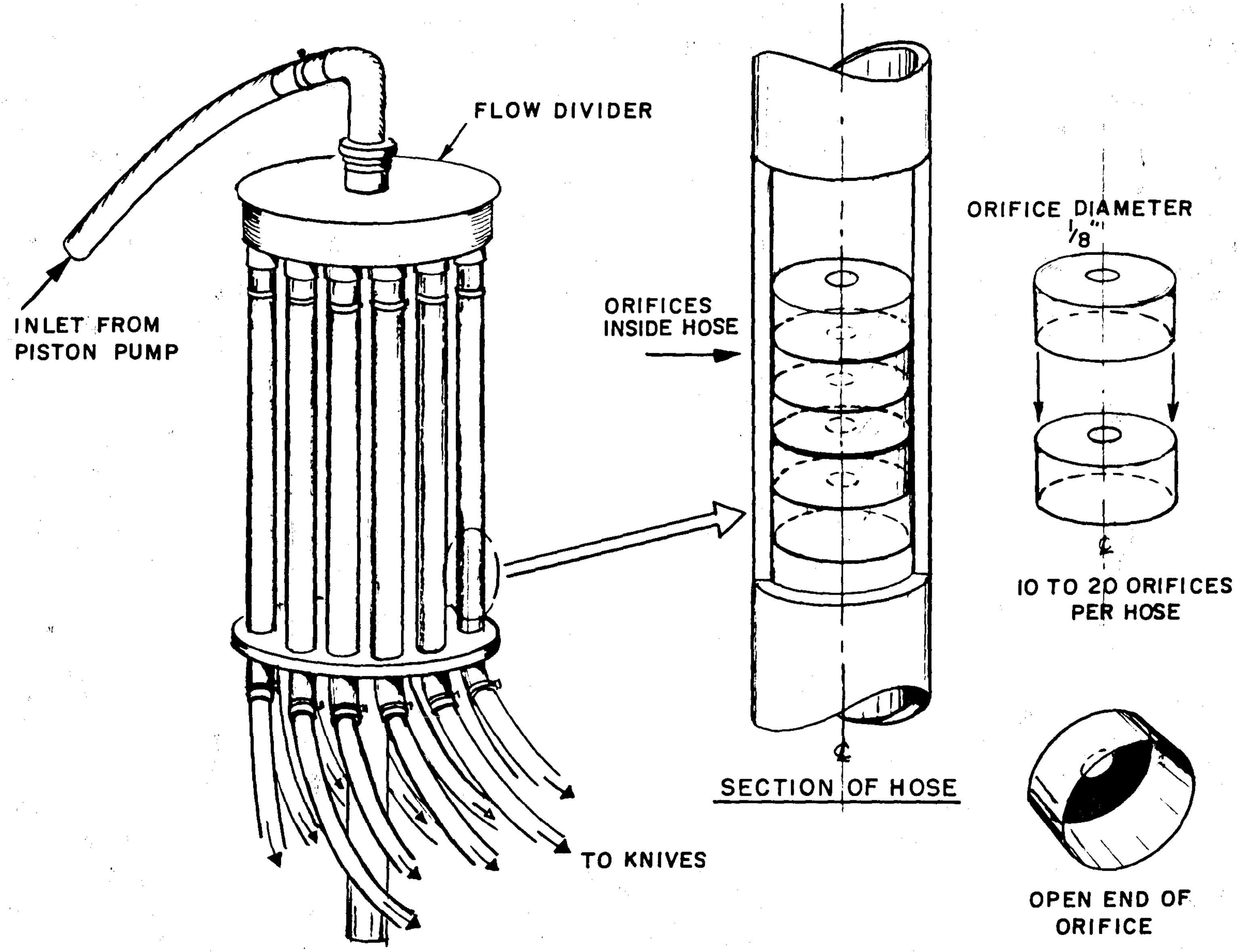

FIGURE 6

JOHN BLUE FLOW DIVIDER FOR ROW APPLICATION OF LIQUIDS

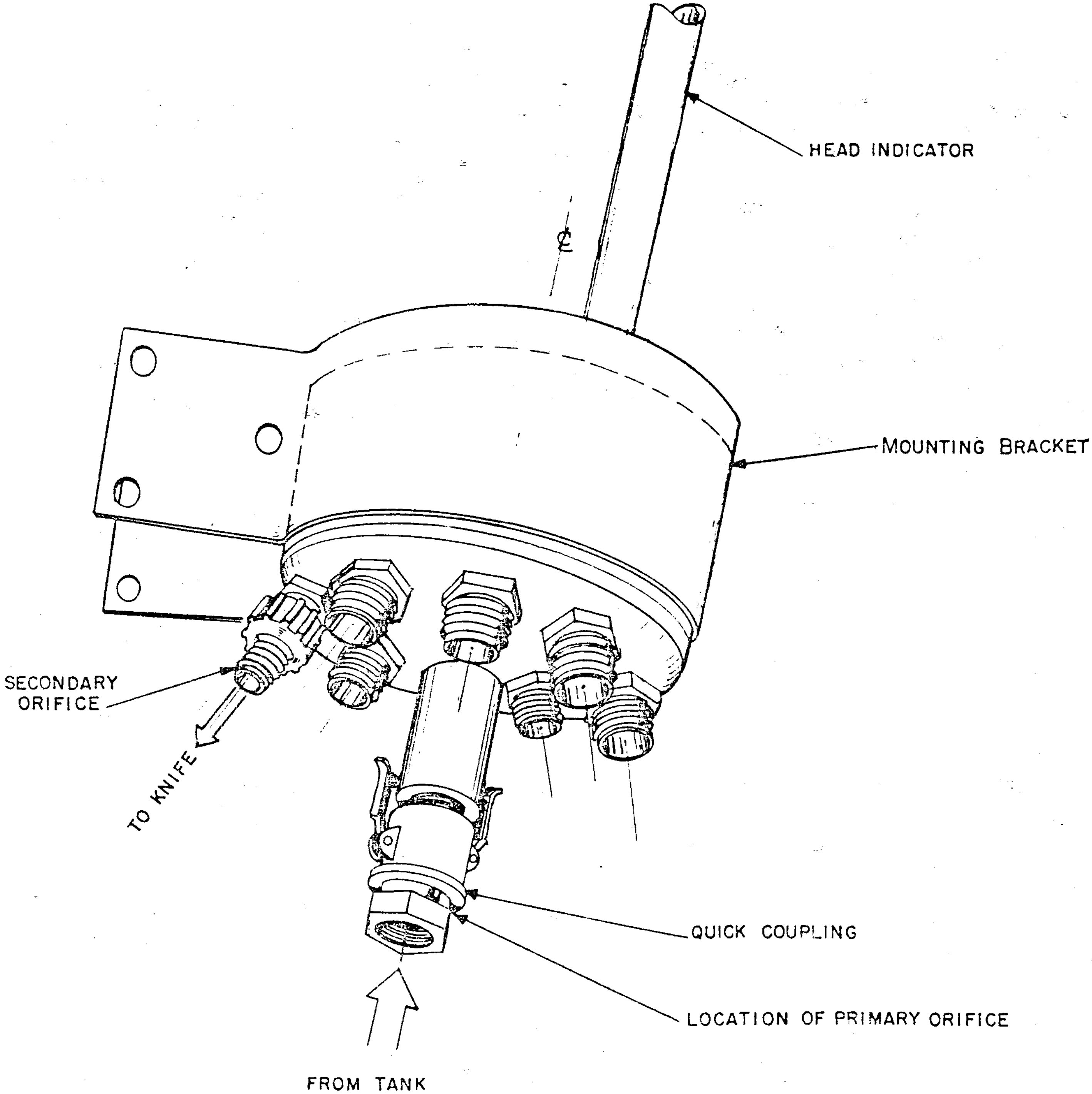

FIGURE 7
DISTRIBUTOR FOR SUBSURFACE PLACEMENT OF LIQUIDS

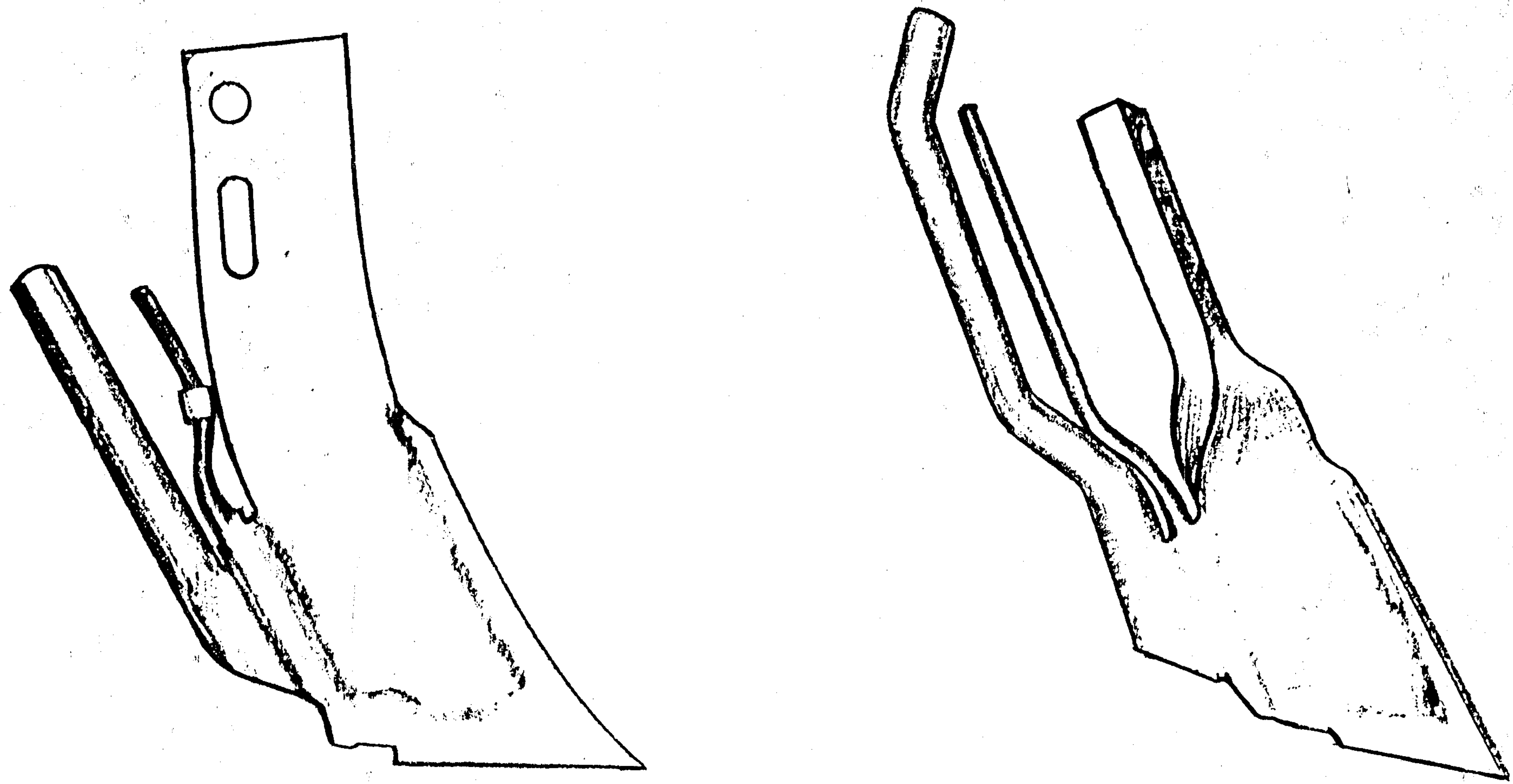

FIGURE 8

DUAL APPLICATION KNIVES FOR DRY PHOSPHATE AND AMMONIA