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MODERNIZED MATERIALS HANDLING AND INSTALLATION IMPLEMENTS FOR PLOW-TYPE DRAINAGE EQUIPMENT*

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During the 1970's the plow-in method of installing corrugated plastic drainage tubing gained rapid acceptance and use worldwide. The development of automatic laser grade control in the late 1960's made the high-speed drainage plow practical. However, under many soil conditions the quality of drain installation with plow-type equipment is often poor in comparison with trench-installed drains, primarily because positive blinding and backfilling are not provided with most plow implements. Materials handling problems for coiled plastic drain tubing in shipment and during installation, especially for high-speed plows, continued to receive development attention throughout the 1970's; power feeders or "stuffers" were introduced to reduce stretch of corrugated tubing during installation with plows.

This paper reports on the development of a tractor-mounted reel for a maxi-coil of corrugated tubing, an automatic tubing uncoiler/feeder, and a special tubing installation "boot" for the plow with trailing disc backfillers; these improvements for the plow enhances materials handling operations and significantly improves installation quality for a wide range of soils and installation conditions.

TRACTOR-MOUNTED REEL

The tractor-mounted reel, with vertical spindle (see Fig. 1), is of the same basic design as the up-right stringer trailer developed in the late 1970's, and which is in common use today. The spindle can be hydraulically lowered or swung into a horizontal position to load a maxi-coil of tubing (typically 900 m length for 10-cm diameter tubing), and then lifted again for transport and/or uncoiling. The hydraulic lift control circuit includes a flow regulator/check safety valve so the reel spindle cannot "free-fall" downwards. For the tractor-mounted reel, low-friction, self-aligning bearings are used, and a disc-brake system is provided as a means to stop and/or control speed of uncoiling; the brake can be set to create a slight "drag" during uncoiling if desired.

The separate pre-stringing operation common today is eliminated with the machine-mounted reel. This is particularly important for tubing with synthetic envelope since damage to the wrapping is essentially eliminated because the conduit is installed directly as it is uncoiled from the reel. This direct installation method also significantly reduces tubing stretch during installation, especially on hot, sunny days when tubing pre-strung onto the ground may become very hot (greater than 55° C.), and thus it is more easily stretched by normal feeding through the "boot" for installation.

Some advanced planning by the contractor is needed to effectively use the machine-mounted reel system, for example: Determine the locations in the field to distribute the maxi-coils of tubing to avoid long trips to get the

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next coil; setting up the laser transmitter such that the receiver on the plow is not within the "blind spot" of the vertical coil on the machine; etc. A tine was developed for a backhoe bucket to move the large coils of tubing around the field and to keep the machine-mounted reel supplied with pipe; the original up-right stringer trailer has also been effectively used for this purpose. Pre-stringing the remaining length from the big reel prior to beginning a new drain line with a full coil "on board" is also a technique to increase efficiency under some field conditions. Occasionally a contractor may wish to keep one or two small coils of tubing on the machine to insure he has enough tubing to get to the end of any drain line where the large coil runs out.

TUBING UNCOILER/FEEDER

The hydraulic powered tubing uncoiler/feeder mechanism is designed to positively "pull" on the corrugated tubing to uncoil it from the tractor-mounted reel, and at the same time provide "slack" tubing behind the puller to prevent stretch during the feeding and guiding of tubing into the ground through the plow "boot"; see Figs. 2, 3, and 4. The positive "pull" is provided by a hydraulically-driven cage wheel which engages the corrugations of the tubing. Because of the close distance between the machine-mounted reel and uncoiler mechanism, and the very brief time interval that the corrugated tubing is actually under a tensile force, the stretch of the tubing during the reel uncoiling operation is much less than typically occurs when it is pre-strung in the field. For field stringing, "pull" is exerted on a much larger section of tubing for a considerably longer period of time, thus resulting in more stretch; magnitude of tubing stretch is a time dependent function of tensile force applied. For some plows, a power "stuffer" is mounted on top of the "boot" to further reduce stretch during installation (see Fig. 3); this "stuffer" can be used with the machine-mounted reel, and/or when the tubing is pre-strung onto the ground.

The speed of the uncoiler/feeder is governed by a demand-sensing arm which "lightly" touches the tubing at a position between the cage-wheel and the feeder chute of the "boot" (Fig. 2). As the plow moves forward, the slack in the tubing is taken up, thus lifting the sensing arm which is direct coupled to a hydraulic valve, and the cage-wheel is power rotated to pull more tube from the coil on the reel. When the plow stops, the uncoiler/feeder also stops as slack (or sag) develops in the tubing. The unit will accept 10- to 15-cm diameter tubing (as originally designed, the experimental arch-shaped drainpipe by Hancor, Inc. could also be used in the puller; see Figs. 2(b) and 4). An air shock-absorber is used on the sensing arm to prevent excessive oscillatory motion and surging tube supply (Fig. 2). The maximum speed for the hydraulically driven uncoiler/feeder must equal or exceed the fastest allowable ground speed for plow installation of drains; e.g., 60 m/min. The hydraulic oil supply to the puller motor is "priority flow" so that the speed of pipe feed is not affected by other hydraulic powered operations, such as power steering, "stuffer" brake boosters, etc. A manual control valve is also provided to operate the puller motor during drain starts, pipe coupling, etc.

PLOW "BOOT" DESIGN

The proposed design for the plow "boot" includes the following features or characteristics: (1) A minimum width of 23 cm for installation of standard 10-, 12.5- and 15-cm diameter corrugated plastic tubing; (2) a side-view shape like a 60°-30° right triangle, with the rear surface (hypotenuse) at a 60° angle from horizontal (see Fig. 5); (3) a replaceable friction reducing surface (e.g., high molecular weight polyethylene plastic sheet) on the rear 60°-inclined, 23-cm wide surface of the "boot"; and (4) "wing" like projections at 45° angle from the rear base side-plates of the "boot" (Fig. 5). The width dimension for this proposed design is the same as that presently used with most plows for installing standard 15-cm diameter corrugated tube.

The 23-cm wide "boot", with the 60°-inclined rear surface, maintains an opening in the soil as the plow blade and "boot" move forward, for downward passage (flow) of blinding and soil backfill; the downward flow of soil by sliding on inclined rear surface of the "boot" is enhanced by the low friction covering. Topsoil and backfill soil are positively placed onto the top end of the "sliding-board" type rear surface of the "boot", during forward motion, with the double disc assembly described below. The 60° angle for the rear surface of the "boot" was selected over that of a 45° angle, the only other angle tested. The steeper angle appeared to provide a uniform gravity flow of loosed soil from the ground surface to drain depth, while the 45° angle tended to occasionally cause slowing and surging soil flow, and backfilling of the plow-trench was often not as complete with the 45°-plane. The 45° plane also created a much longer "boot" base.

It was found that an increase in the plow blade width to about 26-28 cm reduced soil drag along the sides of the 23-cm wide "boot", and also allowed proper "flotation" action of the "boot" during grade control corrections. A soil lifting plane style of blade was found to significantly reduce draft requirements compared to even curved-type shanks, and it further provided more loosing of the soil so better backfilling occurred. Thus, with this style blade and with soil shields between the plow blade shank and the "boot" (see Fig. 5), a significant increase did not occur when pulling the 23-cm wide "boot" and wide blade (i.e., 26 cm width); some contractors have claimed a noteworthy reduction in draft for wide blades with a soil lifting plane at a 30°-angle or less.

It is again noted that the proposed "boot" design is used for 10-, 12.5, and 15-cm diameter corrugated plastic drain installation; these are the typical laterals and the small diameter mains. Thus changing of "boots" for the various sizes in this range is eliminated. Most present-day standard plow "boots" for installing 10-cm tubing has an average width of 15 cm. For drain installation of 1.0 to 1.5 meters deep, such a narrow plow-trench will often collapse together at the ground surface as the "boot" passes, without significant soil backfill falling into the void behind the "boot". In wet fine-textured soil conditions, the void at drain depth may not be filled with soil at all, and the polyethylene plastic tubing will float upward off the plow-trench bottom as water infiltrates into the void; subsequent soil settlement sometimes surrounds the tubing at a level above the design drain depth, thus creating grade-line irregularities and potential sedimentation problems. The new "boot" design resolves these problems. In unstable type soils, the small 45° angle "wings" at the rear base of the "boot" (see Fig. 5) insure that topsoil fill is on the tubing before releasing the base of the plow-trench sidewalls.

Other design features of the plow "boot" that are important in minimizing stretch of corrugated plastic tubing as it is fed/pulled through the "boot" during installation include: (a) low friction guide path for tubing, e.g., using rollers (an optional power "stuffer" on the "boot" can help to overcome frictional drag in the tube feed path); (b) a "smooth" curved feed path from vertical to horizontal directions of travel for the tubing within the "boot"; and (c) a final horizontal feed path well within the base of the boot, such that the corrugated tubing is straight and level as it emerges from the rear of the "boot" and is covered with soil backfill. Many boots incorporate a final press roller to insure the tubing is in firm contact with the plow-trench bottom as it emerges from the boot; it is very important that the pressure exerted on the tubing at this point is controlled within reasonable limits, otherwise excessive stretch of the tubing will occur independent of most of the other improved design features mentioned above. A "dead-weight" lever-arm-type final press roller is preferred by many engineers and contractors over a spring-loaded roller design. The dead-weight roller unit applies a predetermined "constant" force on the tubing being installed, and different size tubing can be installed without adjusting the roller. The spring-loaded type rollers generally provide satisfactory performance (especially the long leaf-spring type), but they require adjustment for each size tubing, and the chance for improper spring adjustment can result in excessive tubing stretch.

It is noted that the outside diameter of corrugated tubing will vary significantly between manufacturers for the same nominal inside diameter drain. Most dead-weight type rollers do not require a dampening device to prevent oscillatory or bouncing motion along the top of the corrugated tubing. The dead-weight roller unit is also used in many trenching machine "boots" and tube feeder mechanisms.

DISC BLINDER/BACKFILLER

The blinder/backfiller implement is simply a double disc arrangement on two independent control arms which are pivot mounted to the plow blade support frame (see Figs. 3 and 4). The combination of the disc assembly and the improved "boot" with the inclined rear surface provides for more positive blinding and backfilling of plowed-in drains; Fig. 7 clearly shows one example of field performance -- the black topsoil completely fills the void left by passage of the "boot" in the light colored subsoil. Farmers and contractors alike have been pleased with this type performance of the improved equipment.

The disc assembly is not mounted onto the plow "boot" because the desired "floating" linkage action between most "boots" and plow blades would be hindered (see Fig. 5). The control arm for each gang-pair of disc coulters are independently operated with a hydraulic cylinder. An active pressure of about 2,000 kPa on the hydraulic cylinders ensures good cutting action, and a 2,400 kPa pressure release valve permits the discs to roll over a rock or very hard soil clods without damage.

Two styles of disc coulters are used on the blinder/backfiller assembly (Fig. 6); for each gang-pair the larger disc coulter is positioned on the inside (closest to the soil void left by passage of the "boot"), and is a "conical" shaped disc of 60-cm diameter; the outside discs are the more common "dish" shape and of 45-cm diameter. Both disc types have notched edges to ensure more positive rotation and cutting while passing through soil where sod or crop residue is present. The spacing between the inner (larger) and outer (smaller) disc on each gang-pair is at least 30 cm; this protects against soil clogging between the discs on each gang-pair in sticky clay-type soil -- the difference in disc shapes also aids in this regard since the distance between the discs increases from the axle to the outside diameter (cutting edge).

The proper adjustment and field operation of the disc blinder/backfiller assembly in combination with the new design of plow "boot" involves three main factors: (1) the alignment or position of the disc gang-pairs with respect to each other on opposite sides of the "boot"; (2) the position of each gang-pair with respect to the 60° inclined rear plane on the plow "boot"; and (3) the downward active hydraulic pressure and release pressure settings for the soil conditions. These are accomplished by first adjusting the disc control arm lengths such that one gang-pair of discs trail the other so that soil moved into the "effective trench" left by passage of the "boot" is not "bridged" over at the top because the soil from opposing disc pairs merge. Second, the disc gang-pair running the closest to the rear of the "boot" should be positioned with respect to the inclined rear plane of the "boot", so that the soil movement from this disc pair falls directly onto the plane. This will ensure that topsoil from the ground surface is placed on the sliding-board boot plane first, and this topsoil will travel (slide) down the plane to cover the installed plastic conduit emerging from the "boot". The forward disc pair may need adjustment from time-to-time depending upon the depth of drain installation and soil moisture conditions; the deeper the drain, the further forward the disc pair may need to run (a different linkage system could be designed to maintain the disc-gangs at the same relative position with the inclined plane for a range of plowing depth). The trailing gang-pair should be behind the first pair by 30 cm or more for most soil conditions. The lateral position of the disc gang-pairs should be adjusted for soil conditions to cause all soil movement directly into the "effective trench" void in the case of the leading pair, and into any remaining void for the trailing pair. The resulting ground surface is considerably more level and ready for subsequent cultivation than conventional plowed-in drains -- another added benefit of the modernized implements. And finally, the active hydraulic pressure should be set at a level high enough to ensure good cutting of the discs, but not so high that the discs are "buried" to the axle, thus causing poor backfilling and excessive draft. The release pressure can be set as a rule-of-thumb at about 400-500 kPa above the active pressure. The release pressure should also be at a value high enough to allow the disc assembly to be lifted hydraulically into the transport (non-cutting) position. For safety purposes, the manual hydraulic control lever should be provided with a safety lock to ensure that it cannot be accidently moved from a given position (up or down). As an additional safety measure, to prevent the discs from being lowered (or "free-falling") too fast from the elevated transport position, flow regulator/check valves are placed in the appropriate hydraulic connections for each cylinder. Since the disc coulters are exposed, the plow operator should ensure that other persons are away from the plow-boot area before moving the discs.

COMMENTS AND CONCLUSIONS

(1) The machine-mounted reel for corrugated tubing maxi-coils can notably improve materials handling efficiency for many job sites and conditions, and significantly reduce damage and stretch to tubing materials during installation operations.

(2) The hydraulically driven tubing uncoiler/feeder mechanism provides positive uncoiling of corrugated tubing from the machine-mounted maxi-coil, and significantly reduces tubing stretch in comparison to that often caused by prestringing from poorly designed reels, and/or due to prestringing and subsequent installation on hot sunny days.

(3) Design features of the plow "boot" which minimizes stretch of corrugated tubing during installation are identified; for example, a "dead-weight" type final press roller is better than a spring-loaded roller to ensure the tubing is in contact with the bottom of the plowed-in trench (the dead-weight roller does not require adjustment for different diameter drainage tubing).

(4) The 23-cm wide plow "boot" for installation of 10- to 15-cm diameter corrugated tubing provides and maintains an opening from the ground surface to drain depth, during forward travel, through which topsoil for blinding and backfilling can be effectively transported via a "sliding-board" manner on the 60° inclined rear surface of the "boot".

(5) Operation of double disc gangs on each side and behind the plow "boot" effectively pulls loose topsoil onto the inclined soil transport plane of the "boot" to provide for positive blinding and backfilling of plowed-in drains, and thus the quality of plow installation for tubing is in creased significantly for a wide range of soils and field conditions.

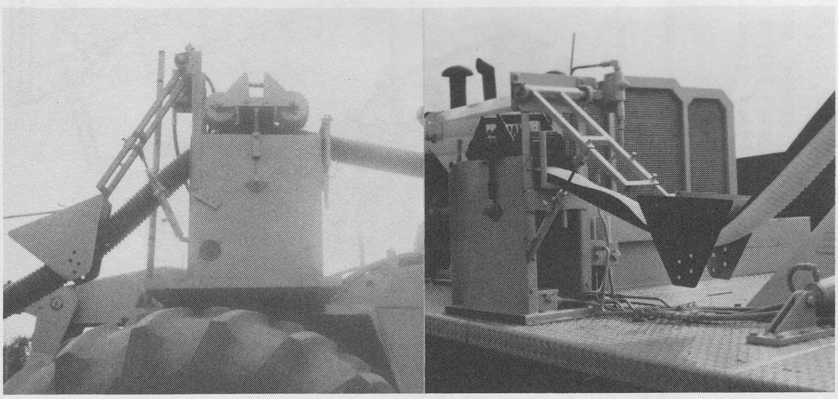
REFERENCES

1. Fouss, J.L. and W.E. Altermatt. 1982. Drainage-plow "boot" design to improve installation of corrugated plastic tubing. Proceeding of the Fourth National Drainage Symposium, December 13-14, 1982, Chicago, IL; ASAE Publication 12-82, pp. 102-104.

2. Darbishire, Peter (Editor). 1982. Additional benefits gained by using new pipe. Drainage Contractor, Agri-Book Magazine, Winter Edition, Vol. 8, No. 1, p. 25.

a. 4WD Tractor-Mounted Plow   b. Track-type Plow

Fig. 1 Machine-Mounted Reel for Maxi-Coil of Corrugated Plastic Drainage Tubing.



a. 4WD Tractor-Mounted Plow   b. Track-type Plow

Fig. 2 Hydraulic Driven Uncoiler/Feeder to Uncoil Corrugated Tubing from Machine-Mounted Reel, and to Feed "Slack" Tube into Plow "Boot".

Fig. 3 Power "Stuffer" on Top of "Boot" to Aid in Feeding Tubing, and Thus Reducing Tube Stretch During Installation.

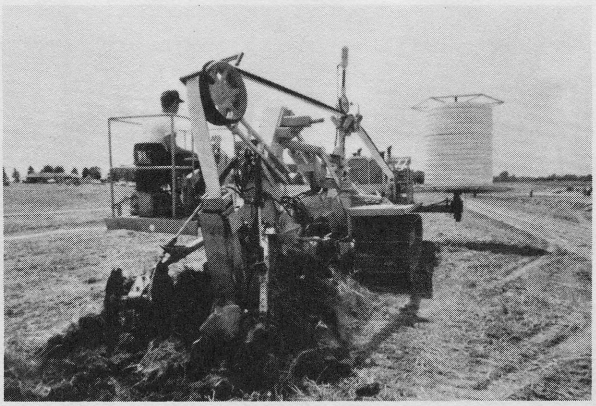


Fig. 4 Machine-Mounted Reel-Uncoiler/Feeder-"Boot"/Disc Backfiller-System was Developed for Both Round Corrugated Plastic Tubing and Experimental Arch-Shaped Drainpipe (by Hancor, Inc.).

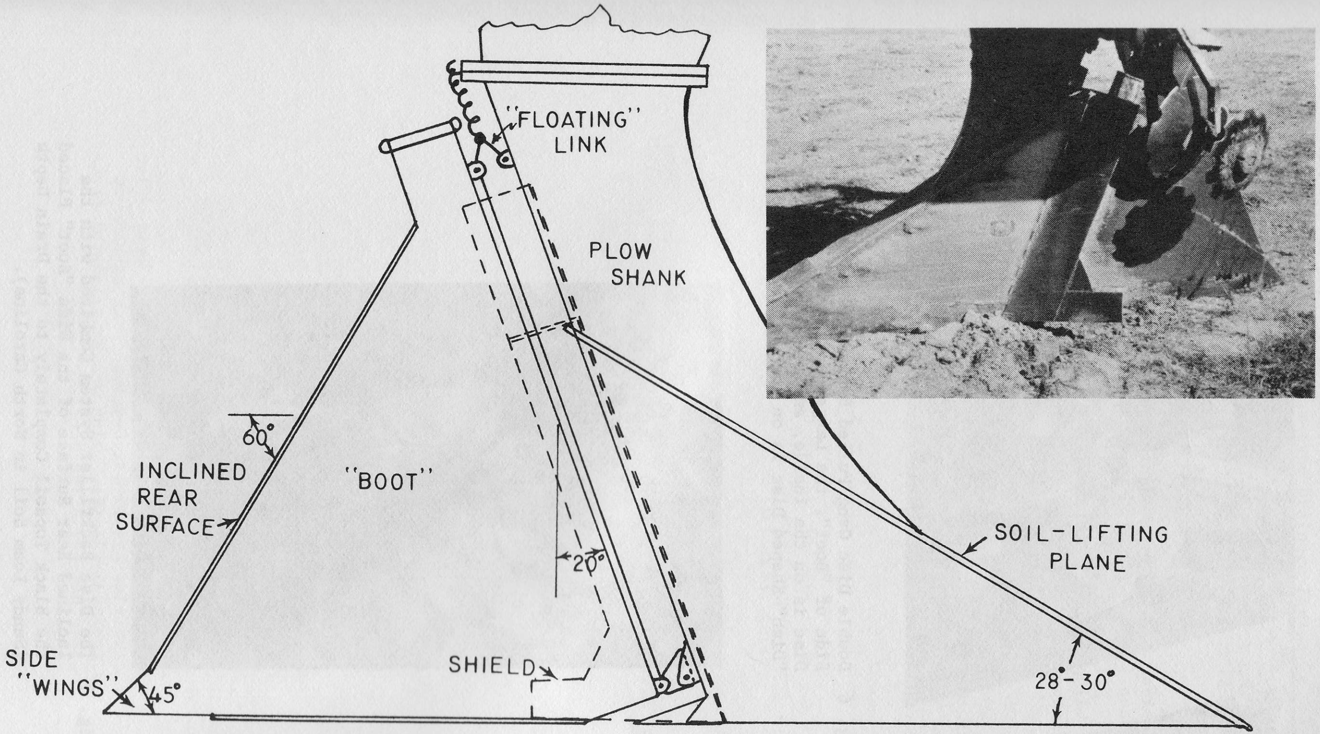


Fig. 5 Proposed "Floating-Boot" Design with 60° Inclined Rear Surface, Pulled Behind Soil-Lifting Type Plow Blade; Soil Shields Between Plow Blade and "Boot".

Fig. 6 Double Disc Gang Pulled Behind and to One Side of "Boot"; the Larger and Conical-Shaped Disc is on the Inside, and the Smaller and "Dish"-Shaped Disc is on the Outside.

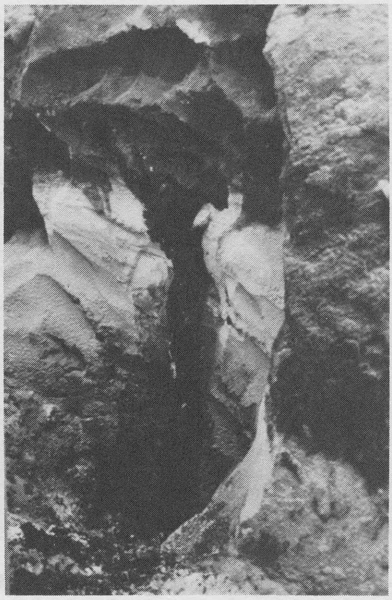


Fig. 7 The Disc Backfiller System Combined with the Inclined Rear Surface of the Wide "Boot" Placed the Black Topsoil Completely to the Drain Depth (Sandy Loam Soil in North Carolina).

Comments on paper entitled "Modernized Materials Handling and Installation Implements for Plow-type Drainage Equipment" by J. L. Fouss

OPINION PARAGRAPH

by Satwat Abdel-Dayem

The material presented during this workshop and the discussions following were very interesting. They handled both the theoretical and practical sides of the subjects considered in the meeting. Referring to the subject of corrugated plastic tubes, there is still a need to specify the acceptable limits for stretching the pipes under manufacturing and installation conditions.