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16. Abstract

A plow-resistant recessed reflective marker (RRM) delineation system having a linear tapered profile and which uses a reflector base/reflector unit is proposed. A single-operator mechanized vehicle to install the RRM delineation system is described. This vehicle satisfies the design criteria which are given in the report. The apparatus automatically cuts the longitudinal main groove and the transverse drainage groove, cuts the reflective marker recess, removes the cutting debris from the groove, dispenses the adhesive for securing the marker to the pavement, installs the reflective marker unit, and propels the vehicle between adjacent markers. Details of the mechanical, hydraulic, pneumatic and electrical subsystems are designed and presented. It is recommended that this vehicle be built in order (1) to demonstrate the feasibility of the mechanized installation of the RRM delineation system and (2) to obtain generally lacking data on pavement cutting parameters.

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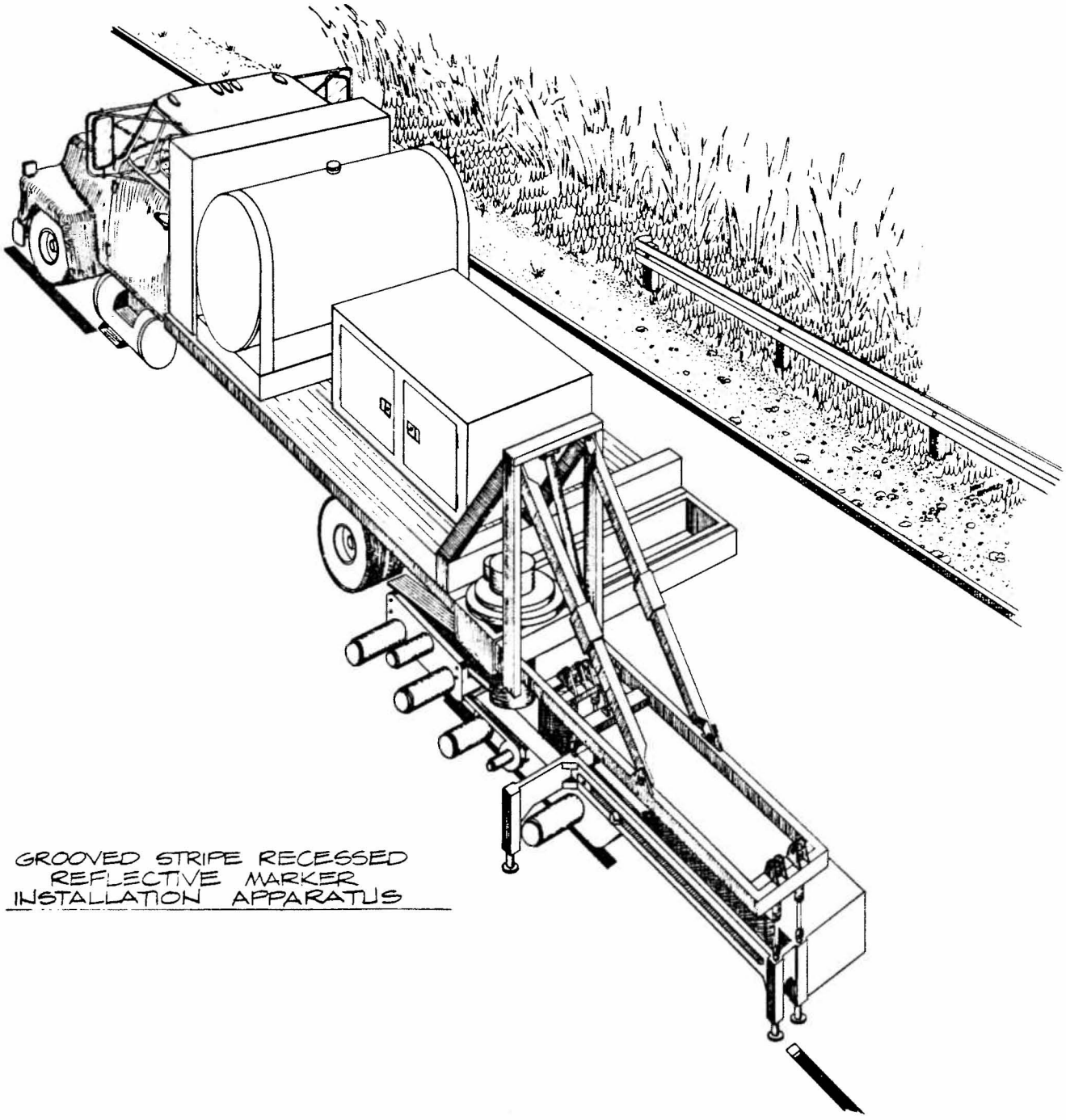

GROOVED STRIPE RECESSED
REFLECTIVE MARKER
INSTALLATION APPARATUS

CONTENTS

SECTION II: GROOVE AND REFLECTOR CONFIGURATIONS

FIGURE 1 shows the groove and reflector configuration employed by the NYDOT research group during its field evaluation of the recessed reflective marker system. The main longitudinal groove was 4 inches wide and 60 inches long. Its cross section consisted of three sinusoidal indentations cut to a nominal depth of 1/2 inch over the full length of the groove using a 4 inch diameter diamond roll cutter. At the downstream end of the main groove a nominally 2 inch long by 4 inch wide by 1/2 inch deep recess was chipped out. Into this recess the 2 inch by 4 inch by 1/2 inch reflector prism was secured using an epoxy adhesive. To prevent the collection of water and debris in the main groove, a transverse drainage groove 1/2 inch wide and 1/2 inch deep extending at 90° towards the lower shoulder of the roadway was cut to join the lower end of the main groove. The length of this drainage groove was varied to accomodate the particular cross slope encountered.

The NYDOT groove configuration, while amenable to construction using "hand" techniques, is not well suited to high speed large-scale automated production. In considering the automation of the grooving and reflector installation operations and procedures, the major features of the NYDOT system were reconsidered and a number of concerns was identified. Among the primary concerns relating to the NYDOT system are the following:

1. The design has a full depth cut over the entire length of the main groove which requires greater energy consumption and greater cutter wear than an alternative system which does not have a full depth cut over the entire length.

2. The full depth cut of the main groove requires a capability of locating the drainage groove at either end of the main groove, depending on roadway grade. (This imposes a substantial design difficulty in automating the installation procedure.)

3. The design requires a drainage groove whose length should be "extended far enough toward the low side of the pavement to remove water from the (main) grooves."[2] (In order to define an automated operation, this drainage requirement must be quantitatively specified.)

4. The use of a drainage groove that is orthogonal to the main groove does not utilize the potential drainage capability of the roadway grade.

5. The rectangular recess for the reflective marker is not amenable to a simple fast mechanical operation without a separate subsystem designed specifically to generate it.

FIGURE 2 shows the proposed alternative groove and recessed marker configuration. The main groove is 4-1/8 inches wide and 60 inches long. Because the proposed equipment employs diamond ganged-saw blades rather than diamond roll cutters, the proposed groove cross section is different from the NYDOT cross section in that the sinusoidal surface is only approximated by steps generated by the individual saw blade diameters.† The proposed groove has a linear tapered profile, varying in depth from 0 inches at the upstream end to 9/16 inches at the downstream end where the reflector is located. On a straight roadway with no grade, this configuration provides full view of the reflector to an observer located approximately 430 feet away with an eye level of 48 inches. Note that appreciable savings (~50%) in cutter wear and energy consumption are obtained when cutting the proposed groove in lieu of the NYDOT groove. (Refer to concern (1) in the second paragraph of this section.)

FIGURE 3 gives details of the NYDOT and the proposed recessed reflective markers. The proposed recess is cut using the same cutters that produce the main groove. At the end of the main groove these cutters index vertically downward to a depth of 1-7/16 inches. A corrugated reflector base is fixed in the recess with an epoxy adhesive and provides support and protection for the reflector. The reflector, which is held

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†In developing a cutter assembly design for automated production it became very desirable to have the cutter bundle mounted on a common shaft with its driving motor. Thus, the diameter of the driving motor established the minimum allowable cutter diameter, in this case about 10 inches. In diameters of this size, economy dictated the use of ganged-saw blades rather than a single diamond impregnated roll.

to the base by a mastic backing, is formed by splitting a 944 Stimsonite reflector lengthwise. The reflector and the reflector base are installed simultaneously as a unit. (Refer to concern (5) in the second paragraph of this section.)

Because the main groove is sloped downward toward the reflector, once the grade is established, the longitudinally low point of the groove is automatically defined. If required at all, the drainage groove for the proposed configuration always intersects the main groove at the downstream (reflector) end. On an uphill longitudinal cut if the magnitude of the roadway grade exceeds the magnitude of the inherent downward slope of the groove (that is, $\frac{9}{16}/60$), the main groove drains itself and the drainage groove is automatically omitted. The drainage groove is 3/4 inch wide and its cross section is concave without corners in order to facilitate self-cleaning. Depending on the availability of utilizable roadway grade for drainage, the drainage groove is cut in any one of six directions with respect to the main groove: 45°, 90°, 135°, 225°, 270°, 315°. The bottom of the drainage groove is always oriented in a horizontal plane with respect to the earth's gravitation and always intersects the main groove at a depth of 9/16 inch. The maximun length of the drainage groove is arbitrarily limited to 60 inches but may be shorter if due to the cross slope and grade, its bottom intersects the road surface. (Refer to concerns (1), (2) and (3) in the second paragraph of this section.)

SECTION III: DESIGN CRITERIA

In commissioning this engineering feasibility and design study, the FHWA recommended a number of design suggestions, and once underway, the study itself identified other important design criteria. The following list is a summary of the equipment design criteria which were observed in conducting this study:

1) The equipment will operate in daylight or darkness during dry or rainy conditions.

2) The equipment will travel from one job site to another at normal highway speeds under its own power.

3) The equipment will operate from a single traffic lane and when operating will allow continual passage of traffic on both sides.

4) During operation, the equipment will always travel in the direction of traffic.

5) The machine will install grooves along either edge line as well as along lane divider lines, though not simultaneously.

6) All phases of the grooving, marker placement, and between marker transit will be fully automated. The equipment will require only one operator whose sole function after initial set-up will be to steer the vehicle using the existing lane markers as a guide.

7) The equipment will perform the entire installation sequence (main and drainage groove cutting and marker installation) in a single pass, the exception being those cases where the drainage groove must extend into the adjacent traffic lane. Such drainage grooves may be cut later when the equipment can operate from the adjacent lane.

8) The equipment will function on old and new asphalt and portland cement roadways though at different rates according to the hardness of the particular surface.

9) On typical fully cured portland cement roadways the per-marker installation cycle time including transit between markers will be approximately three minutes.

10) Spacing of the grooves will be automatically controlled and will be adjustable within the limits 0 to 160 feet.

11) Standard commercially available components will be used wherever possible.

12) All systems will be configured to maximize the safety and health of the operating personnel.

13) Manual overrides will be provided for all systems.

14) A fully automatic cutoff system will be employed to ensure immediate equipment shutdown in the event of cooling water supply failure, unscheduled movement of the vehicle, obstruction of machine components, presence of subsurface metallic objects, excessive cutter feed power requirements, or excessive or inadequate cutter speeds.

15) The equipment will incorporate both transverse and longitudinal grade sensors to determine the direction of cut and the utility of the drainage groove. Where insufficient cross slope and grade, or grade sufficient to drain the groove lengthwise, exist, the drainage groove will be omitted automatically.

16) If for any reason the cutting apparatus fails to retract from the roadway, equipment for manual jacking of the cutters will be provided to allow for the movement of the equipment.

17) Cutter blade assemblies will be replaceable by the single operator, but the operator will not be able to disassemble the ganged-saw cutter bundles.

18) The equipment will have sufficient cooling water storage capacity to allow four hours of continuous operation. Use of trailers for additional water supply will be avoided.

19) Groove and reflector recess depths will conform to a tolerance of $\pm$1/64 inch.

20) Target per-marker installation cost including equipment amortization, labor, and consumables but excluding the cost of marker materials is $5.00.

Early in the Task A analysis it became apparent that no substantial quantitative information is currently available regarding cutting power requirements, cutter tip speed requirements, feed force requirements, cutter life expectancies, or cooling water requirements - in short, any of the information necessary to accurately size the major system components. Thus, this engineering feasibility study has been conducted by adopting a reasoned conservative approach to all equipment power and rate requirements. Therefore, in the analyses of all mechanical and hydraulic systems, the highest probable power requirements were assumed. Though leading to a higher system cost, this oversizing of components does offer some important advantages. First of all, it ensures adequate available power to establish the feasibility of the automated marker installation concept. Secondly, by providing variable controls on the power outputs of all elements and a means for recording system performance, the equipment can be used as a testing vehicle capable of generating the very information presently lacking. Accordingly, the following two design criteria were added to the above list:

21) All power sources will be conservatively sized.

22) All major power transmission systems will be infinitely variable in output over their ranges of operation to facilitate the use of the equipment for data gathering.

SECTION IV: GENERAL DESCRIPTION AND OPERATION SEQUENCE

The frontispiece is an artistic rendering of the proposed grooving and marker installation system. Drawings 703-1, 703-2 and 703-3 contain details of the general arrangement (703-1), and orthographic (703-2) and isometric (703-3) views of the cutter and marker insertion assemblies.

As indicated by these drawings, the machine is constructed on a standard Ford F-700 truck chassis having a wheelbase of 202 inches. Clearance restrictions under drive shafts and cutter changing requirements dictated that the structural assemblies for cutting the grooves and installing the reflector be mounted at the rear of the truck bed. The alternative arrangement - that is, mounting the device between front and rear axles - would require that the truck have front wheel drive, which in consideration of design criterion number 11 is an unacceptable choice. Further, having the device overhang the rear of the truck bed allows for elevation of the cutters to facilitate changing the ganged-saw assemblies. The Ford F-700 was chosen because of the various combinations of wheel bases, cab dimensions, engines, transmissions, rear axle ratios, power takeoff options, load capacities, and bed dimensions which are standard.

It was originally identified as desirable to have the unit dismountable from the truck bed to allow the truck to be used for other road maintenance operations (for example, snowplowing). For this test model, however, the complexities of control and power transmission circuitry effectively require that the unit be made an integral part of the vehicle. It is foreseen, however, that the development of a readily dismountable production system can be easily achieved, given the design information that will be generated by the test vehicle described here.

As noted above, the system is designed to automatically perform all of the functions required to cut the main and drainage grooves, dispense the adhesive, and install the reflective marker. During operation, no commands or decisions are required of the operator. Once automatic sequencing has begun, the operator must only steer the vehicle and monitor the control panel for shutdown alarms. On occasion as needed, the operator will also refill the water tank and the reflective marker supply hopper. Both water and marker supplies are sufficient for four hours of continuous operation.

The following major components are mounted on the truck:

1) A Main Groove Cutting (MC) Mechanism consisting generally of a structure capable of transverse and vertical movement which supports an extensible sliding structure on which are mounted two main cutter diamond ganged-saw bundles driven by hydraulic motors.

2) A Drainage Groove Cutting (DC) Mechanism consisting generally of a structure capable of transverse movement which supports another structure capable of vertical and rotational (yaw) movement which in turn supports an extensible trolley on which are mounted two drain cutter diamond ganged-saw bundles driven by hydraulic motors.

3) An Adhesive Injection System consisting generally of pumps, hoses, valves, a metering device, two 5-gallon component tanks, and a 5-gallon solvent tank.

4) An Automatic Reflector Placement (ARP) Mechanism consisting generally of a reflector base/reflector feed hopper and an air actuated extensible and elevatable arm assembly mounted on the side of the main groove cutting mechanism.

5) An Electrical Control System consisting generally of sensors, switches, and logic circuitry to direct and monitor all phases of the groove cutting, marker placement, and vehicle movement operations. (Key elements within the electrical control system include the DC Director which senses both roadway grade and cross slope, and directs the orientation of the DC mechanism; the Cab Control Panel which enables the operator to monitor all operations and to insert switching commands and overrides; and the Rear Control Station which allows operator positioning of the unit from the rear of the vehicle.)

6) An Auxiliary Power Unit consisting generally of a 175 hp diesel engine driving three hydraulic pumps, an air compressor, a vacuum pump and a water pump.

7) A Hydaulic System consisting generally of motors, pumps, cylinders, valves and a 400-gallon reservoir tank.

8) A Cooling Water Supply System consisting generally of a 1500-gallon supply tank with associated hoses and valves.

9) A Debris Blower consisting generally of a high speed fan driven by a common shaft-mounted hydraulic motor.

10) A Driver Guidance System consisting generally of a protractile arm mounted on the front of the vehicle.

The vehicle will be driven to the site of operations using the truck's own engine and transmission. At the site, the operator will extend the driver guidance arm and align it and the vehicle with the line along which the markers are to be installed. The truck engine will then be turned off and the brakes set with the transmission in neutral, and the rear axle ratio and power takeoff set to "Automatic Operation". (The truck engine will not be started again until it is required to move the vehicle from the site of operations at highway speeds.) From this point in time, all movement of the vehicle will be powered by the auxiliary power unit driving a hydraulic motor attached to the transmission via the power take-off.

After engaging the "Power to Pendant" switch, the operator will leave the cab and start the auxiliary power unit. The operator will then attach an umbilical pendant to the Rear Control Station. This pendant will contain pushbuttons which will control the forward and reverse movement of the vehicle, the transverse movement of the MC and DC support carriages, and the vertical movement of the frame from which the MC mechanism is suspended.

Using this pendant, the operator will lower the MC support frame to its normal operating position and then lower the MC and DC mechanism to their "intermarker transit" positions. (See next paragraph.) The operator will then make final adjustments to the longitudinal location of the vehicle and the transverse location of the MC and DC support carriages, thus establishing precisely the position of the first groove and marker. Next, the operator will start the MC and DC cutter motors and the debris blower motor. The umbilical pendant will then be disconnected, and the operator will return to the cab and disengage the "Power to Pendant" switch. Once the umbilical pendant is disconnected, transverse movement of the MC and DC support carriages or vertical movement of the MC support frame is not possible. The operator will place all appropriate switches on the Cab

Control Panel in the "Automatic Operation" mode and after setting the "Groove Spacing" and "Road Material" selector switches as required, will initiate automatic groove cutting and marker placement operations by pushing the "Start Auto Operations" button. Figure 4 shows a bar chart sequence and schedule of the significant machine operations and maneuvers that will take place automatically following depression of the "Start Auto Operation" button. The times shown on this chart are those anticipated for operations on concrete roadways; asphalt roadway operations will be significantly faster.

At all times, the MC and DC mechanisms will occupy (or will be moving between) three distinct vertical positions. Position 1, "Highway Transit", is the position of full retraction where both the MC and DC mechanisms are at their position of maximum road clearance, about 10 inches. High speed vehicle travel using the truck engine can occur only when both the MC and DC mechanisms are in Position 1. (Movement of the MC and DC mechanisms to and from Position 1 can be accomplished only by using the manually operated umbilical pendant.) Position 2, "Intermarker Transit", is the position of partial extension where the MC and DC mechanisms are extended down into close proximity with the roadway. In Position 2, however, sufficient road clearance (approximately 3 inches) is maintained to allow the vehicle to move at low speeds between individual marker locations without risking damage to the cutters through inadvertent contact with the road surface as a result of vertical motion due to compliance in the vehicle's tires and suspension. In fact, the vehicle will transit to the next marker location (that is, the hydraulic motor driving the truck transmission power takeoff unit will engage) only if both the MC and DC mechanisms are in Position 2. Position 2 saves the time that would otherwise be spent having the mechanisms descend from and ascend to Position 1 during each operation cycle. This amounts to about 10 seconds per cycle or a 5 percent reduction in the total cycle time on concrete and a correspondingly greater percentage saving on asphalt. Position 3, "Road Contact", is the position of full extension where the MC and DC mechanisms are brought into contact with the road surface. Cutting and marker placement operations can only occur when the MC and DC mechanisms are in Position 3.

As indicated by the bar chart, at t=0 seconds the MC mechanism starts descending from Position 2 to Position 3, and the MC cooling water is turned on. At t=5 seconds the MC mechanism has reached Position 3, and MC grocve cutting begins. Simultaneously, as directed by sensors within the DC director mounted on the MC mechanism, rotation and plumbing of the DC mechanisms begin. Also at this time, the ARP arm reloads with a marker from the supply hopper and returns to its "hold" position. At t=15 seconds, rotation and plumbing of the DC mechanism are complete, and the DC mechanism starts decending from Position 2 to Position 3. In addition, DC cooling water is turned on at this time. By t=20 seconds the DC mechanism has reached Position 3, and DC groove cutting begins. The DC groove will require 100 seconds to cut and, therefore, at t=120 seconds the DC mechanism halts traverse and begins ascending back to Position 2. A second later the DC cooling water is shut off. At t=125 seconds the MC groove cutting operation is complete. A second later, the MC cooling water is shut off and retraction of the MC carriage along the length of the groove begins. During the retraction of the MC cutters, the debris blower clears the groove of water and sediment. By this time the DC mechanism has reached Position 2, and the DC arm starts to rotate back to its "zero" position. At t=130 seconds the MC carriage is fully retracted. During the period t=130 to t=140 seconds, the ARP arm extends, inserts the adhesive, places the marker, maintains pressure on the marker (for about 3 seconds), and retracts to its "hold" position. By t=135 seconds the DC mechanism is completely rotated back to "zero", and retraction of the DC cutters begins. At t=140 seconds the MC mechanism begins to ascend back to Position 2. At t=145 seconds the MC mechanism is back to Position 2, the DC cutters are fully retracted, and the hydraulic propulsion motor engages, thus driving the truck to the next marker location. By t=180 seconds the truck is repositioned, and the cycle repeats.

To cease automatic operations and to prepare the vehicle for highway travel, the operator must only depress the "Emergency Stop" button whereupon all hydraulic and air systems will shut down. Unless otherwise required, this should be done while the truck is in transit between markers so as to interrupt the apparatus when both the MC and DC mechanisms are in Position 2. After returning the appropriate switches on the Cab Control

Panel to "Manual Operation" and engaging the "Power to Pendant" switch, the operator will leave the cab and reconnect the umbilical pendant to the Rear Control Station. Using the pendant, the operator will raise both the MC and DC mechanisms to Position 1 and then raise the MC support frame to its tilted storage position. Next the operator will disconnect the pendant and shut down the auxiliary power unit. After folding in the Driver Guidance arm, the operator will return to the cab, disengage the "Power to Pendant" switch, and start the truck engine. The vehicle will then be ready for conventional highway travel.

SECTION V: STRUCTURAL DESIGN DETAILS

Construction details of the grooving mechanisms and their support structures are given in Drawing 703-2. (Drawing 703-3 provides an isometric view of the cutter carriages.) A box frame consisting of horizontal transverse channels and end plates [2]† forms the ways on which the gimbelled drain cutter column [6] rolls from side to side of the truck bed. The gimbel support consists of an outer box [3] on which wheels are mounted and from which is hung an inner box [4] on pivots. The column tube [5] is in turn mounted inside of [4] on a pivot trunnion. The inner box and column tube are made adjustable electrically by fastening electric linear actuators to the boxes and frames. Cylinder [7] locates the drain cutter column [6] vertically in Position 1, 2, or 3. Welded to and extending from the bottom of column [6] is an arm [9], the bottom surface of which is a flat plate set such that when [6] is vertical, the plate is horizontal. This plate forms the track along which the drain cutter carriage [14] - which supports the drain cutter bundles [13] and hydraulic motors - traverses, propelled by a hydraulic motor [8] which drives a rack and pinion set.

The angle of the drain cutter arm [9] as it relates to the fore and aft axis of the truck [15] is set by rotating the column [6] using a hydraulic motor [10] driving through gears [11], the larger of which is keyed to the column [6] with a sliding fit. This entire assembly is oil-filled and covered with a housing [12] from which the cylinder [7] is suspended.

The cutting of the main groove is accomplished by the assembly which overhangs and is suspended from the rear of the truck. As noted earlier, the two main cutter bundles are composed of 3/32 inch and 1/8 inch wide diamond sawblades ganged into 4-1/8 inch wide units [1]. Each bundle [1] is mounted on a mandril supported at both ends by bearing assemblies. These bearing assemblies are constructed to be split apart quickly so that the mandril and cutter bundle can be easily removed for replacement. Individual sawblades within the cutter bundle will not be changed at the job site; rather a complete replacement bundle will be kept on board the

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†Numbers in square brackets refer to component identification numbers on Drawing 703-2.

vehicle. The main cutter bundles, their associated mandrils, bearing assemblies, and hydraulic motors [22] are all mounted on the main cutter carriage [21] along with a hydraulically driven high pressure and high volume air blower [17] used to blow out water and debris from the groove after cutting. The main cutter carriage [21] is suspended on two shafts which have sliding blocks [23] at each end. The sliding blocks are constrained to move in slots cut into the sides of the main carriage support frame [24]. Extension and retraction of the main cutter carriage [21] is accomplished by the hydraulic motor [20] driving an endless chain. To eliminate chattering, the main carriage support frame [24] is constructed of thick (1-1/2 inch) steel plate. The slots in the sides of the frame [24] are cut so as to force the main cutter carriage to follow the inclined path required for cutting the longitudinally tapered profile and end recess. Affixed to the side of the main carriage support frame is the automatic reflector placer housing [18] which contains the placer arm and the reflective marker supply.

The main carriage support frame [24] is suspended from the frame hanger by four hydraulic cylinders [27]. The frame hanger [26] consists of two cross members and two stringers. The hydraulic cylinders [27] locate the main carriage [24] in Position 1, 2, or 3 and also provide the downward force required to hold the main cutters against the pavement during the groove cutting operation. Alignment between the main carriage support frame [24] and the frame hanger [26] is maintained by constraints on the cylinders [27] and the torsion bars [28].

Elevation of the main carriage support frame [24] and the frame hanger [26] both for servicing the main cutter bundles and for storage during highway transit is accomplished by the suspension system composed of the support arms [29], the hydraulic ram [30], the A-frame [31], and the A-frame braces [34]. Retraction of cylinder [30] tilts the entire main cutter assembly up to an angle of 60° with respect to the horizontal, an angle sufficient to meet the service requirements. Transverse movement of the entire main cutter apparatus is guided by wheel and track assemblies [32] and [33]. A hydraulic motor (not shown) driving an endless chain powers the transverse movement of the main cutter assembly.

SECTION VI: AUTOMATIC REFLECTOR PLACEMENT SYSTEM

An Automatic Reflector Placer (ARP) is designed into the machine. After the proper amount of adhesive has been deposited, the ARP automatically retrieves a reflector base/reflector unit from a storage container within the ARP housing and places it into the recess which has been cut at the end of the main groove. The ARP housing is shown as item [18] in Drawings 703-2 and 703-3. The arm maintains sufficient pressure on the reflector base/reflector unit to ensure bonding to the pavement and then retracts to reload and to repeat the cycle. A warning light on the Cab Control Panel signals the operator in advance of depletion of the marker supply, providing adequate lead time for the operator to refill the storage compartment. Refilling is done by using a magazine-type container in which the reflector base/reflector units are prepacked. The magazine is a cardboard container configured such that the units are slid into the storage compartment all at one time and in the proper orientation. Less than one minute is required for refilling the storage compartment.

The ARP storage and operating mechanisms housing is permanently mounted onto the side of the MC carriage support. The ARP unit is mounted on the MC carriage support in order to ensure alignment of the reflector base/reflector unit and the main groove. Minor relative alignment adjustments are easily accommodated by the self-alignment features of the vacuum pickup technique employed.

The ARP mechanism consists of an extensible placer arm which is motivated by an air-operated chain cylinder. A schematic of the ARP is given in Drawing 703-4. The arm is hung from and slides in a camming groove which is cut into a hinged pressure plate. Force is applied to the pressure plate by an air cylinder, the force being required to move the plate, and therefore the arm, up and down. The force also provides contact pressure between the reflector base, the adhesive and the roadway recess surface during marker installation. The storage compartment is directly above the hinged plate, and the reflector base/reflector units are delivered to the load position (See Drawing 703-4.), through an opening in the bottom of the storage compartment and a matching opening in the pressure plate.

At the end of the arm is a receptor with a flat surface which is brought into contact with the flat face of the reflector base/reflector when the arm is in the load position. At the proper time, a vacuum is applied to holes which have been drilled through the surface of the receptor, causing the reflector base/reflector to be picked up and held firmly until it is deposited and momentarily held in the recess. The vacuum is then shut off and the arm withdraws into the ARP housing, leaving the marker unit installed.

SECTION VII: AUTOMATIC ADHESIVE HANDLING SYSTEM

Automatic application of the adhesive into the reflective marker recess presents a number of technical problems. Typical performance requirements of adhesives for highway markers result in a two-component epoxy with a short cure time. In general, it is required of mixing and dispensing devices handling curing materials that all surfaces which contact the mixed components be flushed clean at intervals not exceeding 50% of the minimum gel time. Failure to conform to such a flushing frequency will result in a gradual buildup of hardened material on the interior surfaces and will eventually clog the apparatus. Adhesives which meet frequently quoted specifications (for example, California Specification 741-80-42) have a gel time of about 1 minute at 100°F; the effective maximum ambient operating temperature. This fact coupled with the 3 minute cycle time between adhesive "shots" effectively precludes the use of a conventional interior mixing applicator without flushing all mixing chambers and delivery lines after each injection.

The volume of solvent required to adequately flush a line of volume V_1 is approximately $3V_1$. Thus, a mixing and dispensing system requiring cyclic flushing would also require the vehicle to carry more than three times as much flushing solvent as adhesive. Further, health and safety considerations would require a solvent collection system for the post-flush mixture. Therefore, because of safety, health, cost and environmental concerns, a cyclic solvent flushing system is circumvented in this design.

The adhesive handling system consists of three 5-gallon storage containers and their associated pumps, one for each of the two adhesive components and one for the solvent; a three-way valve for each adhesive component; a double-acting metering piston for each of the adhesive components; and a dispensing head. To accomplish the adhesive injection, a two-component epoxy adhesive having a sufficiently long gel time to obviate a cyclic flushing requirement is used. A dispensing head dispenses the two components separately and mixes them externally, thus eliminating any requirement for line flushing. The adhesive dispensing head is mounted on the end of the ARP arm and engages just prior to the placement of the marker. For low ambient temperatures, the unit will heat the adhesive components prior to application. To ensure proper performance, both

delivery lines will be monitored for pressure and flow with corresponding warning lights provided on the Cab Control Panel.

SECTION VIII: HYDRAULIC AND PNEUMATIC SYSTEMS DESIGN DETAILS

Schematics of the complete machine hydraulic systems are shown in Drawings 703-5(A) and 703-5(B), and the pneumatic systems are shown in Drawing 703-5(C). The function and (or) the components associated with each of the subsystems are shown on the drawings. Definitions of the symbols used in these drawings are given in APPENDIX A. Because of their inherent simplicity, reliability and versatility, hydraulic components have been employed throughout the design for powering the various machine elements - the exceptions being the ARP which is pneumatically actuated and the plumbing of the DC column which is electrical.

The machine's design incorporates three separate hydraulic pump and motor systems. System 1, the high pressure (2500 psi) system, includes a variable displacement in-line piston pump driving the four axial piston motors which are attached to the MC and DC cutter bundles. System 2, the low volume/medium pressure (1500 psi) system, employs a variable displacement in-line piston pump driving the five gerotor motors which are used to power the transverse movement of the MC and DC assemblies, the traverse of the DC trolley, the extension of the MC carriage, and the rotation of the DC column. Also driven by the System 2 pump is the vane motor which drives the debris blower. System 3, the intermittant high volume/medium pressure (1500 psi) system, uses a variable displacement vane pump driving the fixed displacement vane motor used to power the truck transmission power takeoff unit.

The advantages of having three separate hydraulic systems are illustrated by FIGURE 5 which shows the combined flow requirements of all the hydraulic motors discussed above over one cycle of operation. As can be seen, demand for 2500 psi fluid to the cutter motors remains constant at 70 gpm throughout the cycle. The use of 2500 psi fluid to drive the cutter motors is necessitated by the small motor diameters required for common-shaft mounting with the cutter bundles. Lower pressure motors delivering the same power would be too large. In contrast to the constant high pressure flow demand on the 2500 psi system, variations in flow requirements for 1500 psi fluid are appreciable, the demand peaking at 60 gpm when the truck propulsion motor is in operation. To use a single pump to supply the 1500 psi fluid would involve unacceptable inefficiencies, since

such a pump would be dumping nearly 97% of its output over 77% of the cycle time. Thus, individual low volume and intermittant high volume 1500 psi systems are employed. When no demand exists in the high volume 1500 psi system, the pump idles while dumping its output at no head through a bypass valve to the reservoir.

For simplicity the "mark" numbers employed for identification of the various hydraulic and pneumatic system components are consistent with the "mark" numbers found on the electrical control schematics which are described in the next section. For example, a solenoid-operated hydraulic valve mark "30" may have associated with it two electrical solenoids, marks "30-1SOL" and "30-2SOL". (The "-1" identifies the element as an opening solenoid and the "-2" identifies the element as a closing solenoid. Refer to the electrical drawings which follow.) This correspondence should substantially assist in the comprehension of the schematics.

APPENDIX B gives a complete hydraulic components list for the machine, exclusive of pipe and hose requirements. Information presented includes quantity required, mark number, applicable system, manufacturer and model number. With regard to the use of hydraulic tubing and hoses, except in those instances where flexibility or shock absorption capability is required, metallic tubing will be employed to take advantage of its superior flow characteristics and ruggedness. In addition wherever possible, overall tubing and hose requirements have been reduced through the selection of multi-function stackable components.

SECTION IX: ELECTRICAL CONTROL SYSTEM DESIGN DETAILS

GENERAL NOTES

1. Sequential and Nonsequential Controls

   The electrical controls are divided into two general groups: sequential controls which are activated either by timer switches or by limit switches, and nonsequential controls which are operated manually. The nonsequential controls activate or deactivate lateral movement of the MC and DC support systems, final close adjustments of the vehicle prior to initiating the first cut of a series, vertical movement of the DC and MC support frames from Position 1 to Position 2 (and reverse), starting and stopping DC and MC motors, and starting and stopping the debris blower. All but the last of these functions are controlled by switches located on the umbilical pendant. The debris blower is controlled from the cab.

2. Numbering of Components

   Identification of the elements on the electrical and hydraulic drawings is consistent. The electrical and hydraulic drawings mesh where the solenoids of the electrical subsystem are mounted on hydraulic control valves. An electric solenoid which is so mounted is identified first by the electrical designation, for example, "28SOL", then by the identity of the valve on which it is mounted, for example, "28SOL (30-5A)". The letters "A" and "B" are used in this identification method to designate the direction of movement of the part controlled by the valve. In general, "A" indicates an extension of a cylinder or movement forward or to the right or clockwise of a part moved by a motor; the letter "B" indicates the opposite movements. Thus, the particular solenoid cited above is one which causes hydraulic valve No. 30-5 to open so that the support framework for the drain cutters will be moved to the right.

3. Standards Used

The format and symbols used in the electrical control system drawings conform to the standards established by the Joint Industrial Council in its publication "Electrical Standards for Mass Production Equipment" (EMP-1-1967). (See Appendix C.) However, because this investigation and report are designed to evaluate feasibility rather than to develop production drawings, a few liberties have been taken in the interest of simplifying the drawings and making them more readily understood. For instance, pilot lights and similar nonessential elements which would be included in final working drawings have been omitted. The drawings have been developed in sufficient detail to enable the estimation of an accurate cost analysis based on a bill of materials.

4. Component List

A list of the electrical control system components is given in Appendix D.

5. Standard Post Emergency Shutdown Procedure

In order to avoid having the operator make any decisions as to actions to take following an emergency shutdown, a Standard Post Emergency Shutdown Procedure has been developed. Following an automatic functioning of the emergency shutdown system, the operator will leave the cab and determine the cause of the emergency. The cause will be corrected. The operator will then return to the cab and push "19PB" (Post Emergency Shutdown Reset), which will automatically reset the appropriate circuits and return the necessary machine components to their proper places for automatic operation:

a. "1M" (Timer Motor) will recycle to "0".
b. [21] (MC Carriage) will retract to Position 1.
c. [24] (MC Carriage Support Frame) will retract to Position 2.
d. [14] (DC Carriage) will retract to Position 1.
e. [6] (DC Column) will retract to Position 2.
f. The ARP arm and pressure plate will retract to Position 1.

EXPLANATION OF DRAWINGS

1. Drawing 703-6(A) (Nonsequential Umbilical Control Circuits)

a. DC Frame Lateral Adjustment

"15PB" (DC Lateral Adjust Right and DC Lateral Adjust Left) is a mechanically interlocked pair of pushbuttons. Pushing either element of the pair energizes the appropriate solenoid - "28SOL (30-5A)" for right movement and "28SOL(30-5B)" for left movement. In each instance, there is a simultaneous unlocking of the support mechanism through the energizing of either "33CR" (Unlock DC Frame - Right) or "34CR" (Unlock DC Frame-Left), which in turn energizes "40SOL" (Unlock DC Frame). "40SOL" is part of the electrical linear actuator which mechanically unlocks and locks the DC frame. "23LS" and "24LS" are limit switches which open at the extremes of lateral movement of the DC frame.

b. MC Frame Lateral Adjustment

"16PB" (MC Lateral Adjust Right and MC Lateral Adjust Left) is a mechanically interlocked pair of pushbuttons. Pushing either element of the pair energizes the appropriate solenoid - "30SOL (30-2A)" for right movement and "30SOL(30-2B)" for left movement. In each instance there is a simultaneous unlocking of the support mechanism through the energizing of either "35CR" (Unlock MC Frame Right) or "36CR" (Unlock MC Frame Left), which in turn energizes "41SOL" (Unlock MC Frame). "41SOL" is part of the electrical linear actuator which mechanically locks and unlocks the MC frame laterally. "25LS" and "26LS" are limit switches which open at the extremes of lateral movement of the MC frame.

c. Cylinder [30] Extend and Retract

"17PB" ([30] Extend and Retract) is a mechanically interlocked pair of pushbuttons. Pushing "17PB" ([30] Extend) energizes "42SOL" ([30] Unlock), "32SOL(30-8A)" ([30] Extend) and "37CR" ([30] Extension Alarm). "18LS" is a limit switch which opens at full extension of [30]. Pushing "17PB" ([30] Retract) energizes "33SOL(30-8B)" ([30] Retract).

d. Cylinder [30] Extension Alarm

Energizing "37CR" results in energizing "3AH" ([30] Extension Alarm).

e. DC and MC Movement Alarm

Lateral movement of the DC frame or the MC frame which closes "33CR", "34CR", "35CR" or "36CR" results in energizing "51CR" (DC and MC Frame Movement Alarm Relay), which closes and energizes "2AH" (DC and MC frame Movement Alarm).

f. MC Motor Control

Switch "7SS" (MC Motor Rotational Direction) is a manual selector switch located in the cab and is used to select the direction of revolution of the MC Motors. Pushing "6PB" (MC Cutter Motor Start) energizes either "8SOL(26-1A)" and "10SOL(26-2A)" (Front and Rear MC Motors CW Run) or "9SOL(26-1B)" and "11SOL(26-2B (Front and Rear MC Motors CCW Run, depending on direction of "7SS"; and simultaneously energizes "7CR" (MC Motors Run Holding Relay) which bypasses "6PB" after it is released, and "14LS", the limit switch which prevents the starting of the motors should the cutters be in contact with the pavement. "27CR" (MC Failure Mode) opens to deenergize the circuit and stop the MC motors if either cooling water rate or motor rpm drops below established limits. "CRM" is the general emergency shutdown relay. "18LS" closes to allow motors to run only when [30] is fully extended and stops the motors when it opens should [30] be retracted. "24PB" (Manual MC Motor Stop) can be pushed to stop the MC motors at any time without involving the emergency shutdown system as a whole, and is located at the rear of the vehicle. "26PB" (Manual MC Motor Stop) is another pushbutton for the same purpose, but is located inside the cab. "8CR" energizes to close a relay in the [27] Extend circuit to allow [27] to extend fully and bring the cutters into contact with the pavement. "2LS" closes when [27] is at Position 2 to permit the MC motors to start, and is bypassed for continuous running by "7CR".

g. DC Motor Control

Switch "8SS" (DC Motor Rotational Direction) is located in the cab and is a manual selector switch. Pushing "5PB" (DC Cutter Motor Start) energizes either "12SOL(30-9A)" and "14SOL(30-10A)" (Front and Rear DC Motors CW Run) or "13SOL(30-9B)" and "15SOL (30-10B)" (Front and Rear DC Motors CCW Run) and simultaneously energizes "9CR" (DC Motors Run Holding Relay) which bypasses "5PB" after it is released and "15LS" which opens when the cutters are in contact with the pavement to prevent starting the motors. "10CR" is energized at the same time as "9CR", and closes a contact in the [7] Extend circuit so that [7] can extend fully and bring the cutters into contact with the pavement after the motors start. "CRM" is the emergency stop relay. "28CR" opens to deenergize the circuit if either the DC motor rpm or the cooling water flow rate drops below preset limits. "3LS" closes to allow the motors to start when [7] is at Position 2. "3LS" is bypassed to permit continuous running of the cutter motors by "9CR". "23PB" is located at the rear of the vehicle and "25PB" is located in the cab; both pushbuttons are designed to allow manual stopping of the DC motors without shutting down the entire system through the CRM shutdown system.

h. Cylinder [7] Extend and Retract

"10PB" is a mechanically interlocked pair of pushbuttons. Pushing either element of the pair energizes the appropriate circuitry to extend or retract Cylinder [7], which raises or lowers the DC arm. Pushing the button marked "Lower DC Arm" energizes "4SOL(30-6A)" ([7] Extend) and simultaneously energizes "53CR" ([7] Unlock), causing the cylinder to extend until "3LS" opens when the cylinder reaches Position 2. In like manner, the DC arm is raised when the button "Raise DC Arm" is pushed, energizing "22SOL(30-6B)" ([7] Retract) which causes the cylinder to retract until "21LS" opens

when it has retracted to Position 1. "55CR" ([7] Unlock) is energized at the same time the solenoid is energized.

i. Cylinder [27] Extend and Retract

"9PB" is a mechanically interlocked pair of pushbuttons. Pushing either element of the pair energizes the appropriate circuitry to extend or retract [27] and to raise or lower the MC carriage support frame between Position 2 and Position 1. Pushing the button marked "Lower MC Frame" energizes "35CR" ([27] Unlock) and "2SOL(30-7A)" ([27] Extend) until "2LS" opens at Position 2. Pushing the button marked "Raised MC Frame" energizes "54CR" ([27] Unlock) and "23SOL(30-7B)" ([27] Retract) until "22LS" opens when Position 1 is reached.

2. Drawing 703-6(B) (Starting, Timer Motor, Reset and Sequential Control Circuits)

Automatic operation of the machine begins when "2PB" (Timer Start) is pushed. This energizes "1CR" (Timer Motor Relay) and "CRM" (Emergency Shutdown Relay). "1CR" maintains the automatic circuit, "1PB" is the manual emergency shutdown pushbutton, more than one of which will be installed at various locations on the machine, all in series. "1CRM", "2CRM" and "3CRM" are various emergency shutdown automatic relays.

a. Timer Motor

"1CR" closes, energizing "1M" (Timer Motor). "4PB" is a push-button used to test the timer motor. "28CR", "29CR", "30CR", and "31CR" are shutdown relays associated with carriage feed failure modes. "2CR" is the automatic reset relay.

b. Post Emergency Shutdown Reset (PESR)

This circuit provides a single means of bringing all controlled activities back to their starting positions after an emergency shutdown. After such a shutdown, "19PB" (PESR) is pushed, energizing "40CR" (PESR Relay), which in turn energizes "2CR" (Timer Reset Relay) which closes and energizes the timer motor reset circuit. It also energizes "19SOL(30-1B)" (MC Retract),

"21SOL(30-3B)" (DC Retract), "22SOL(30-6B) ([7] Retract), "46CR" (ARP PESR Circuit) and "23SOL(30-7B)" ([27] Retract).

c. Timer Reset to "0"

"3PB" (Timer Reset) is pushed to energize "2CR" (Timer Reset Relay) and "56CR" (Timer Reset Holding Relay) which causes the timer motor to run until "1LS" (Timer Motor at "0") opens to deenergize the circuit. "40CR" is the PESR relay.

General Note:

The following circuits, which appear both on the remaining portion of this Drawing (Drawing 703-6(B)) and all remaining electrical control system drawings, are activated in regular sequence either by the closing of individual switches located on the timer switch (1M) or by the closing of various limit switches which are closed by contact with moving parts of the machine.

d. MC Water Valve Opens

"1TR-1" closes to energize "17SOL" (MC Water Valve Open). "13CR" opens on retraction of the DC carriage to stop water flow.

e. [27] Extend

"1TR-2" closes to energize "55CR" ([27] Unlock Control Relay) and "2SOL(30-7A)" ([27] Extend) which are deenergized when "3LS" opens at full extension (Position 3) of [27].

f. Vertical Alignment Control

"1TR-3" closes to energize "5SS" (Automatic Vertical Alignment Switch), which determines whether or not vertical alignment of the DC column is required, and selects the proper relay for such alignment as is required. Energizing "3CR" or "4CR" will correct alignment in one vertical plane and "5CR" and "6CR" will correct alignment in the orthogonal vertical plane, each by causing the motor in the proper linear actuator to rotate either clockwise or counterclockwise. Movement is continued until "5SS" determines that the column is vertical, at which time the relays involved will open and deenergize the motor. "3SS" permits movement of

the column through manual control of the relays. "41LS" closes when the cutters are in contact with the pavement. If adjustment of the column is attempted when there is such contact, there is an emergency shutdown as "CRM" is energized through "41LS".

g. Vertical Alignment Motor

With [7] at full extension and the cutters in contact with the pavement, "15LS" opens, preventing any movement of the DC column. The appropriate motor is energized so as to rotate in the appropriate direction when either "37LS", "38LS", "39LS" or "40LS" is energized in the control circuit described in (f) above. If the physical limits of movement are reached, the corresponding limit switch ("37LS", "38LS", "39LS" or "40LS") will be opened, deenergizing the circuit and stopping the motors. At the same time the involved limit switch will also close the vertical alignment alarm circuit, energizing "1ABU" (Verical Alignment Limit Alarm Buzzer) and "25CR" (Vertical Alignment Control Limit Relay) which will deenergize all control relays, stopping all motors.

h. Automatic DC Arm Rotator Control

"1TR-4" closes to energize "18SS" (DC Arm Angle Selector Switch). This switch senses the grade of the pavement and determines to which angle the DC arm must be rotated for optimizing the effect of grade on drainage of the groove which is to be cut. The switch then selects the appropriate solenoid to energize (if any). For clockwise rotation of the arm, "5SOL(30-4A)" is energized, and it will remain energized until the appropriate angle has been reached. At the proper angle, the selected limit switch will be opened and the movement stopped as the solenoid is deenergized. Simultaneously, with the energizing of the solenoid controlling movement, "57CR" ([7] Unlock Relay) will be energized, unlocking the column so that it can be rotated, and also "16CR" (DC Column Rotator Locked) will be energized. This will prevent the movement of the DC cutters into the pavement. Similar comments relate to counterclockwise rotation of the DC arm.

3. Drawing 703-6(C)(MC,DC and ARP Sequential Control Circuits)

a. MC Carriage Feed and Retraction

"1TR-9" (MC Carriage Feed and Retraction) closes and energizes "18SOL(30-1A)" (Automatic MC Carriage Feed Control Relay) which causes the MC carriage to begin the cut, continuing until "16LS" (MC Carriage Full Extend) is tripped open, simultaneously causing "19SOL(30-1B)" (Automatic MC Carriage Retract Control Relay) to be energized and thus, the carriage to be retracted. In this circuitry, the following other elements are contained:

"11SS" (Automatic/Manual Selector Switch)
"2PRS" (MC Carriage Feed Surface Obstruction Sensor)
"3PRS" (MC Carriage Feed Rebar Sensor)
"2FLS" (MC Cooling Water Flow Detector)
"3FLS" (MC Low RPM Detector)
"3PS" (MC Carriage Feed Excessive Force Detector)
"4PS" ([27] Fully Pressurized Detector)
"29CR" (MC Carriage Feed Failure Relay)
"19CR" (Brake Release Relay and Dump Valve Close)
"57CR" (MC Feed TR Bypass Relay)
"17LS" (MC Fully Retracted Limit Switch)
"30CR" (MC Carriage Retract Failure Relay)
"13CR" (MC Water Cutoff and Retract Circuit Bypass Relay)

For normal operation, "11SS" is set at "AUTOMATIC". "MANUAL FEED" and "MANUAL RETRACT" are used for test purposes. "57CR" maintains the feed circuit after the circuit has been energized by closing "1TR-9". For the retraction phase, the circuit is maintained by "13CR". "2PRS", "3PRS", "2FLS", "3FLS", "3PS" "4PS", "14CR" and "16LS" must all be closed before the feed circuit is complete and before "18SOL(30-1A)" can be energized. If any of these (except "14CR" and "16LS") is not closed, then "29CR" will be energized which will cut off the cooling water by energizing "13CR" and the alarm "3ABU" will sound. If the feed action has begun, and any of these (except "19CR" and "16LS") is opened, then "29DR" will be energized, energizing in turn "13CR" and "19SOL(30-1B)" which

will cause immediate retraction. If "19CR" is not closed, a warning light (not shown) will be energized. If "1PRS" is not closed for retraction, "30CR" will be energized, maintaining the cooling water cutoff and energizing a warning light (not shown). The post emergency shutdown reset circuitry causes the MC carriage to retract fully. When "40CR" closes, "41CR" (Reset Holding Relay) is energized which allows "19SOL(30-1B)" to be energized, retracting the carriage until "17LS" opens and deenergizes the circuit.

b. DC Water Valve Open

"1TR-17" closes to energize "16SOL"(DC Water Value Open) and this solenoid remains energized until "15CR" (DC Water Value Cutoff) opens. "15CR" is deenergized either upon retraction of the DC carriage or because of DC carriage feed failure. "7PB" is for testing the circuit.

c. [7] Unlock and Extend

"2SS" (Automatic/Manual Selector Switch) is used primarily for test purposes. In normal operation, it will remain in the "AUTOMATIC" mode. "10PB" is the test pushbutton. Closing "1TR-8" energizes "53CR" ([7] Unlock) and "4SOL(30-6A)" ([7] Extend), causing [7] to extend (and the DC arm to descend) until stopped by the opening of "15LS" when [7] is at full extension. It is necessary for "1FLS" (DC Cooling Water Detector), "4F1S" (DC Low RPM Detector), "10CR" (DC Motors Running) and "19CR" (APM Valve Close and Brakes Set) all to be closed for the circuit to be complete. Should any of these (except "10CR") not be closed, the emergency shutdown "CRM" circuit will be energized.

d. Automatic Reflector Placer (ARP) Extend Arm

"1TR-14" (ARP Extend Arm Position 1 to Position 2) closes and energizes "21CR" (Circuit Holding Relay) and "34SOL" (ARP Extend Arm) until the circuit is deenergized when "28LS" opens at Position 2. "5S" (ARP Extend Arm) allows this circuit to be cut off. "14PB" is the test button.

e. DC Carriage Feed and Retract

"12SS enables the selection of manual or automatic operation. "1TR-10" (DC Carriage Feed and Retract) closes to energize "20SOL (30-3A)" (Automatic DC Carriage Feed Control Relay) which causes the DC carriage to feed and make its cut, continuing normally until "19LS" (DC Carriage Full Extend) is tripped open, simultaneously closing the other element of "19LS" (DC Carriage Retract) which energizes "20SOL(30-3B)" (Automatic DC Carriage Retract Control Relay) which causes the carriage to be retracted. At full retraction, "20LS" (DC Carriage At Full Retraction) opens, deenergizing the circuit. In this circuitry, the following other elements are contained:

"4PRS" (DC Carriage Feed Surface Obstruction Sensor)
"6PRS" (DC Carriage Feed Rebar Sensor)
"1FLS" (DC Cooling Water Detector)
"4FLS" (DC Low RPM Detector)
"4PS" ([7] Fully Pressurized Detector)
"3PS" (DC Carriage Feed Excessive Force Detector)
"16CR" ([7] Locked Relay)
"59CR" (DC Carriage Feed Holding Relay)
"28CR" (DC Carriage Feed Failure Relay)
"4ABU" (DC Carriage Feed Failure Alarm Buzzer)
"5PRS" (DC Carriage Retract Surface Obstruction Detector)
"23CR" (DC Carriage Retract Holding Relay)
"22CR" (DC Carriage Retraction Preventer Until ARP Arm Clears)
"17CR" (DC Retraction Started Relay - Allows [7] to start retraction)
"15CR" (DC Cooling Water Cutoff)
"31CR" (DC Carriage Retract Failure Relay)
"42CR" (DC Carriage Feed/Retract Post Emergency Shutdown Reset Relay)
"60CR" (DC Cooling Water Cutoff - DC Carriage Feed Failure)

For normal operation, with "12SS" set at "AUTOMATIC", "59CR" will maintain the feed circuit after the circuit has first been energized by the closing of "1TR-10". For the retraction phase, the circuit is maintained by "23CR". "4PRS", "6PRS", "1FLS", "4FLS", "4PS",

"3PS", "16CR" and "19LS" must all be closed before the feed circuit can be completed. Should any of "4PRS", "6PRS", "1FLS", "4FLS" or "3PS" not be closed, then "28CR", "4ABU" and "60CR" will be energized, cutting off the cooling water, sounding a buzzer and starting immediate retraction if the ARP arm is clear. If the ARP arm is not clear, there will be no forward feed and as soon as the arm is clear, there will be retraction. If "5PRS" is not closed for retraction, or if it opens during retraction, "31CR" will keep the cooling water cut off and energize a warning light (not shown). The PESR circuitry causes the DC carriage to retract fully. When "40CR" closes, "42CR" (PESR Holding Relay) is energized, which allows "21SOL(30-3B)" to be energized, retracting the carriage until "19LS" opens to deenergize the circuit.

f. [7] Unlock and Retract

"13SS" allows either manual or automatic operation. Normally the circuit will function in the "AUTOMATIC" mode. "1TR-11" closes to energize "22SOL(30-6B)" ([7] Retract),"39CR" (Circuit Holding Relay) and "52CR" ([7] Unlock). "17CR" prevents retraction of [7] until the DC carriage retraction begins. "21LS" opens and stops retraction at Position 2. "44CR" will be energized when "40CR" (PESR Relay) is closed, causing retraction of [7] to Position 2, regardless of the position of the DC carriage.

4. Drawing 703-6(D) (AAS, ARP and APM Sequential Control Circuits)

a. DC Arm Return to "0"

"15LS" prevents rotation of the DC arm when the cutters are in contact with the pavement. "1TR-7" closes to energize either "7SOL(30-4B)" (DC Arm Rotate CCW) if "44LS" (DC Arm Displaced CW) is closed or "5SOL(30-4A)" (DC Arm Rotate CW) if "45LS" (DC Arm Displaced CCW) is closed. In either case, a holding relay (either "48CR" or "49CR") is energized to maintain the circuit bypassing both the displacement limit switch and the timer switch until the arm has reached "0", at which time either "9LS" or "4LS" will open to deenergize the circuit. In either case, the arm will be unlocked by either "61CR" or "63CR" to allow rotation. "21PB" is for testing.

b. Adhesive Applicator System (AAS)

This circuit is designed only to activate the Adhesive Applicator System (AAS) which will contain its own control circuitry (not shown). "1TR-6" closes to energize "47CR" (Activate AAS) and "50CR" (AAS Holding Relay). "17LS" closes when the MC carriage is fully retracted and "19LS" closes at full extension of the DC carriage, completing the circuit.

c. Automatic Reflector Places (ARP) Mechanism

"1TR-15" closes to energize "34SOL(104A)" (ARP Extend Arm) which extends arm from Position 2 to Position 3. "29LS" closes when the MC carriage clears as required for placement. "3LS" closes when [7] is at Position 2 and therefore clear. "32CR" opens to deenergize the circuit and to allow ARP arm retraction after marker placement has occurred. At full extension of the arm, "31LS" closes, energizing "35SOL(105)", forcing the ARP pressure plate downward and applying pressure to the reflector, pressing it into the adhesive. "46CR" opens to deenergize the circuit to allow for PESR activation. At full downward movement of the pressure plate, "32LS" open to deenergize "35SOL(105)" and closes to energize "36SOL (112)" (ARP Vacuum Cutoff) and "22CR" (ARP Holding Relay). The momentary delay which is part of "35SOL(105)" causes pressure to be maintained on the reflector until all evidence of the vacuum has dissipated, to be sure that the reflector is not lifted as the ARP pressure plate is retracted. "22CR" keeps the vacuum cut off until "35LS" opens when the pressure plate is lifted clear of the reflector. Simultaneously with its opening, "35LS" also closes to energize "37SOL(104-B)" (ARP Arm Retract) and "32CR" (ARP Arm Extend Release Relay), which retracts the arm until full retraction when "36LS" opens to deenergize the circuit. "46CR" is energized when "40CR" (PESR System) is energized; this shuts off the vacuum, lifts the pressure plate and retracts the ARP arm back to Position 1. "11PB" is for testing the circuit and "4S" allows it to be deactivated.

d. [27] Retract

"14SS" allows for manual or automatic operation. Under normal operation, this switch will be set to "AUTOMATIC". "1TR-12" closes to energize "54CR" ([27] Unlock) and "23SOL(30-7B)" ([27] Retract). This will occur only if "17LS" (MC Fully Retracted) and "36LS" (ARP Arm Fully Retracted) are closed. "22LS" opens at Position 2 to deenergize the circuit. PESR is energized when "40CR" is closed, energizing "43CR" (Holding Relay) and "23SOL (30-7B)" which will retract [27] until it reaches Position 2.

e. Auxiliary Propelling Motor (APM) Control

"15SS" allows the selection of either UMBILICAL, MANUAL (located in the cab), or AUTOMATIC operation of the auxiliary propelling motor (APM). "16SS" determines AHEAD or REVERSE movement when operating with MANUAL controls from the cab. "18PB" is a mechanically interlocked switch on the umbilical. Pushing one element energizes "24SOL(7B)" (APM Reverse) and "18CR" (Brake Release Relay and APM Circuit Dump Valve Close) which releases the brakes and then closes the hydraulic dump valve so that the APM hydraulic system is pressurized. Pushing the button the other element energizes "19CR" (Brake Release Relay and APM Circuit Dump Valve Close) which releases the vehicle's brakes and closes the hydraulic dump valve to pressurize the APM hydraulic system and "25SOL(7A)" (APM Ahead). In this circuit, all control is manual. In the AUTOMATIC MODE, "1TR-13" closes to energize "19CR" and "25SOL(7A)" if "3LS" ([7] at Position 2) and "2LS"([27] at Position 2) are closed. "43LS" is the odometer spacing switch, which is manually set to determine the spacing between markers and which will open to stop the vehicle at the preset distance of travel. "45CR" will open if the reflector has not been placed, and a warning light (not shown) will notify the operator as to the reason the vehicle is not moving.

f. Reflector Not Placed Warning

When [7] has been withdrawn to Position 2, "3LS" closes. If the reflector has not been left in place on the pavement, "5PS" will

close when the vacuum is reimposed on the ARP arm, before it has retracted to pick up the next reflector. This will close the warning circuit, energizing "45CR" (Holding Relay) and "2ABU" (Reflector Not Placed Warning Buzzer). The circuit is deactivated by pushing "20PB" after the warning has been recognized.

g. Vehicle Brake Release and APM Dump Valve Close

Closing either "18CR" (Brake Release Relay and APM Circuit Dump Valve Close) or "19CR" (Brake Release Relay and APM Circuit Dump Valve Close) energizes "43SOL(6)" (APM Dump Valve Close), "26SOL (106)" (Vehicle Brake Release) and "1AH" (Brake Release Warning Horn).

General Note:

The following circuits are nonsequential and are controlled by manual switches.

h. Concrete/Asphalt Feed Speed Selector Control

In order to obtain the optimal cutting feed rates for either concrete or asphalt pavements, a manual cutting feed selector switch may be set at either CONCRETE or ASPHALT. Proper cutting rates for concrete or asphalt pavements are determined by setting (manually) "17SS" (Concrete/Asphalt Feed Speed Selector) at the desired position. For the CONCRETE setting, "18SOL(53-1A)" (MC Carriage Feed Speed - Concrete) and "20SOL(53-2A)" (DC Carriage Feed Speed - Concrete) will be energized, opening the hydraulic circuitry to the desired fluid flow rate. For the ASPHALT setting, "38SOL(53-1B)" (MC Carriage Feed Speed - Asphalt) and "39SOL(53-2B)" (DC Carriage Feed Speed - Asphalt) will be energized.

i. Debris Blower

The Debris Blower is turned on by switch "3S" (Debris Blower) which energizes "27SOL(35)" (Debris Blower), opening hydraulic valve No. 35.

SECTION X: SUMMARY AND RECOMMENDATIONS

Previous researchers have shown the grooved stripe recessed reflective marker system to be an effective plow-resistant wet-night lane delineation system. A similar system having a linear tapered profile which accomplishes the same delineation and plow resistance but whose installation requires less energy consumption and less machine wear has been presented. A reflector base/reflector unit with an easily replaceable reflector has been proposed for use with the linear tapered profile. The widespread adoption of any RRM delineation system depends in part upon the development of cost-effective installation techniques.

A mechanized vehicle to install the RRM delineation system in both Portland cement and bituminous pavements has been described. The basic equipment which requires a single operator has been designed to mount onto the bed of a standard Ford F-700 (or similar) truck. This apparatus automatically cuts the longitudinal main groove and the transverse drainage groove, cuts the reflective marker recess, removes cutting debris from the groove, dispenses the adhesive for securing the reflector base/reflector unit to the pavement, installs the reflective marker, and propels the vehicle between adjacent markers. Details of the mechanical, hydraulic, pneumatic and electrical subsystems have been designed and presented. All of the design criteria given in Section III have been substantially satisfied.

Because of the lack of quantitative data relating to requirements for cutting power, cutter wear and cutter coolant, the proposed apparatus has been conservatively designed. Also, the apparatus contains greater versatility and monitoring capability of operating parameters than those which would be required for a machine whose design was based on more specific parameters. Thus, this apparatus is capable of providing quantitative test data which can be used to provide specific guidelines for a production model. Therefore, it is recommended that

1. the vehicle which has been designed be built in order to demonstrate the feasibility of the mechanized installation of the RRM delineation system; and that
2. the vehicle be used to obtain quantitative data related to pavement cutting operations.

While the large-scale production model costs can not be accurately fixed at this time, it is nevertheless possible to compute an approximate per-marker installation cost. Based upon the following assumptions:

1. A fifteen (15) year equipment life cost of $300,000.00, excluding cutter replacements,
2. $70,000.00 per year for operating labor, maintenance and consumables, including replacement of cutters,
3. Six (6) hours of equipment operation per day,
4. Five (5) days of equipment operation per week, and
5. Fifty (50) weeks of equipment operation per year;

the per-marker cost, excluding the cost of the marker, is approximately $3.00.

REFERENCES

1. Allison, J.R., and Gurney, G.F. Grooved Stripes for Plow-Resistant Wet-Night Lane Delineation. Phase I. Evaluation of Systems. Research Report FHWA-RD-75-93, Federal Highway Administration, U.S. Department of Transportation, October 1975.

2. Bryden, J.E., Allison, J.R., and Gurney, G.F. Grooved Stripes for Plow-Resistant Wet-Night Lane Delineation. Phase II. Recessed Reflector Delineation. Research Report FHWA-RD-76-131, Federal Highway Administration, U.S. Department of Transportation, August 1976.

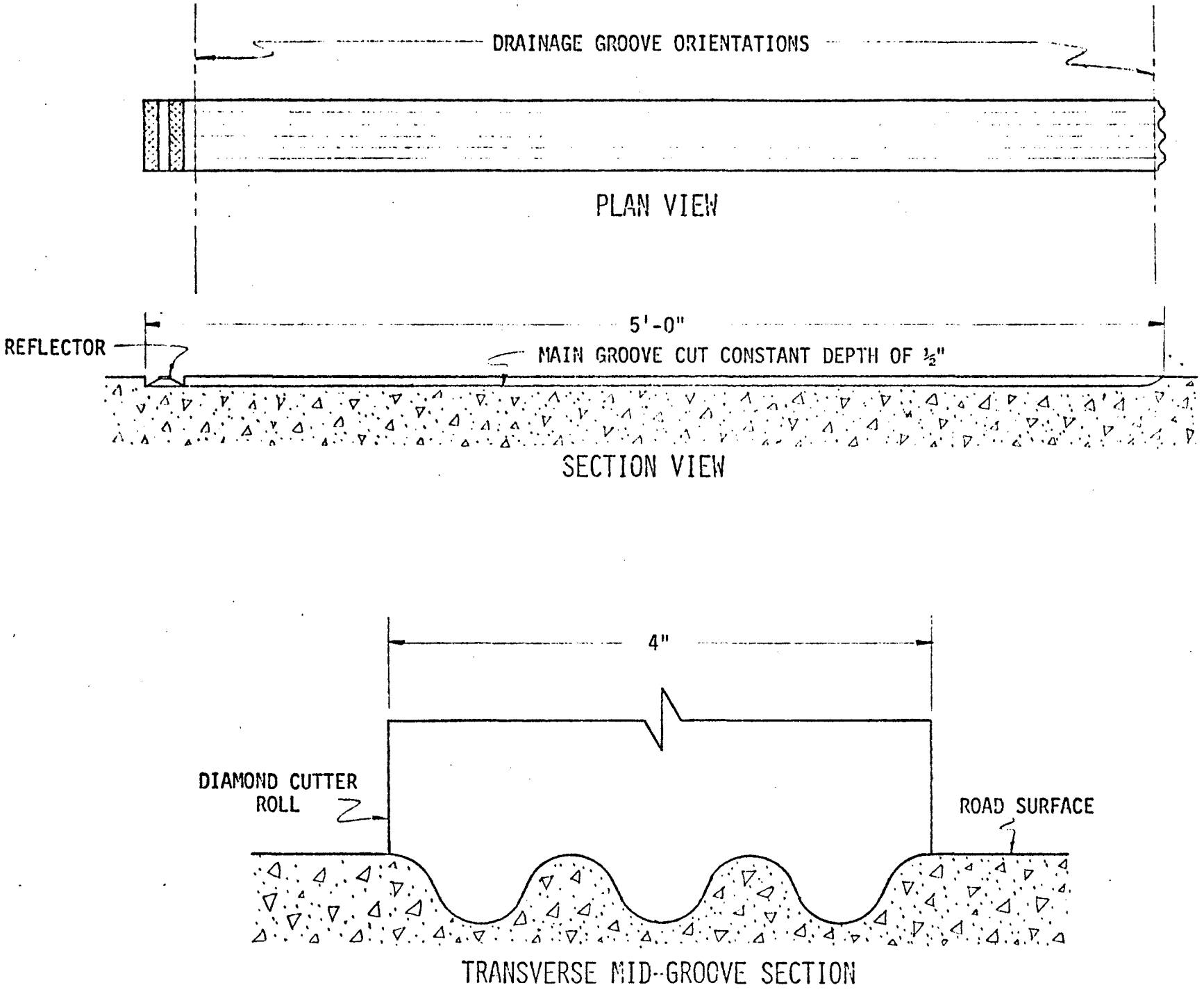


FIGURE 1. PRESENT RECESSED REFLECTIVE MARKER SYSTEM.

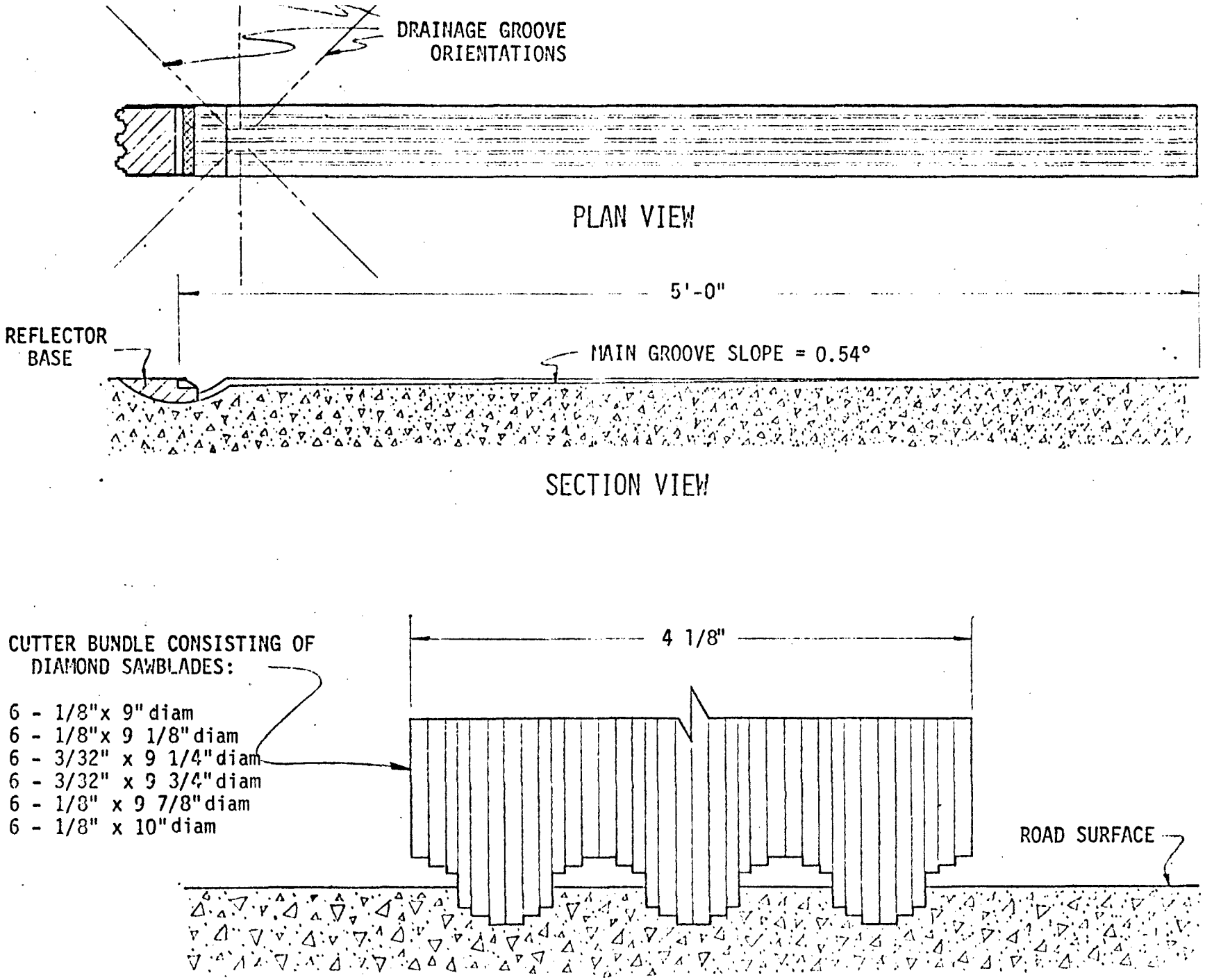
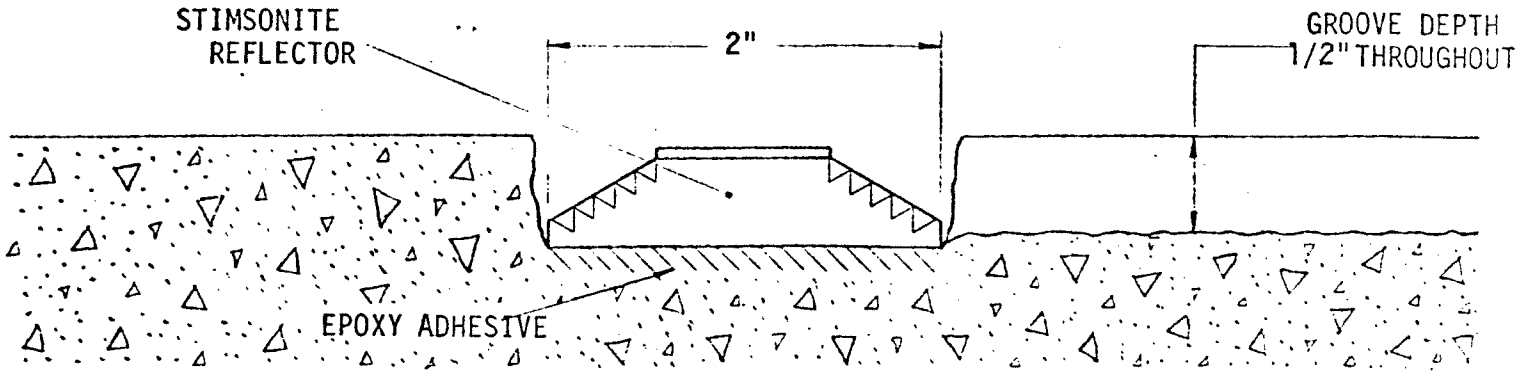
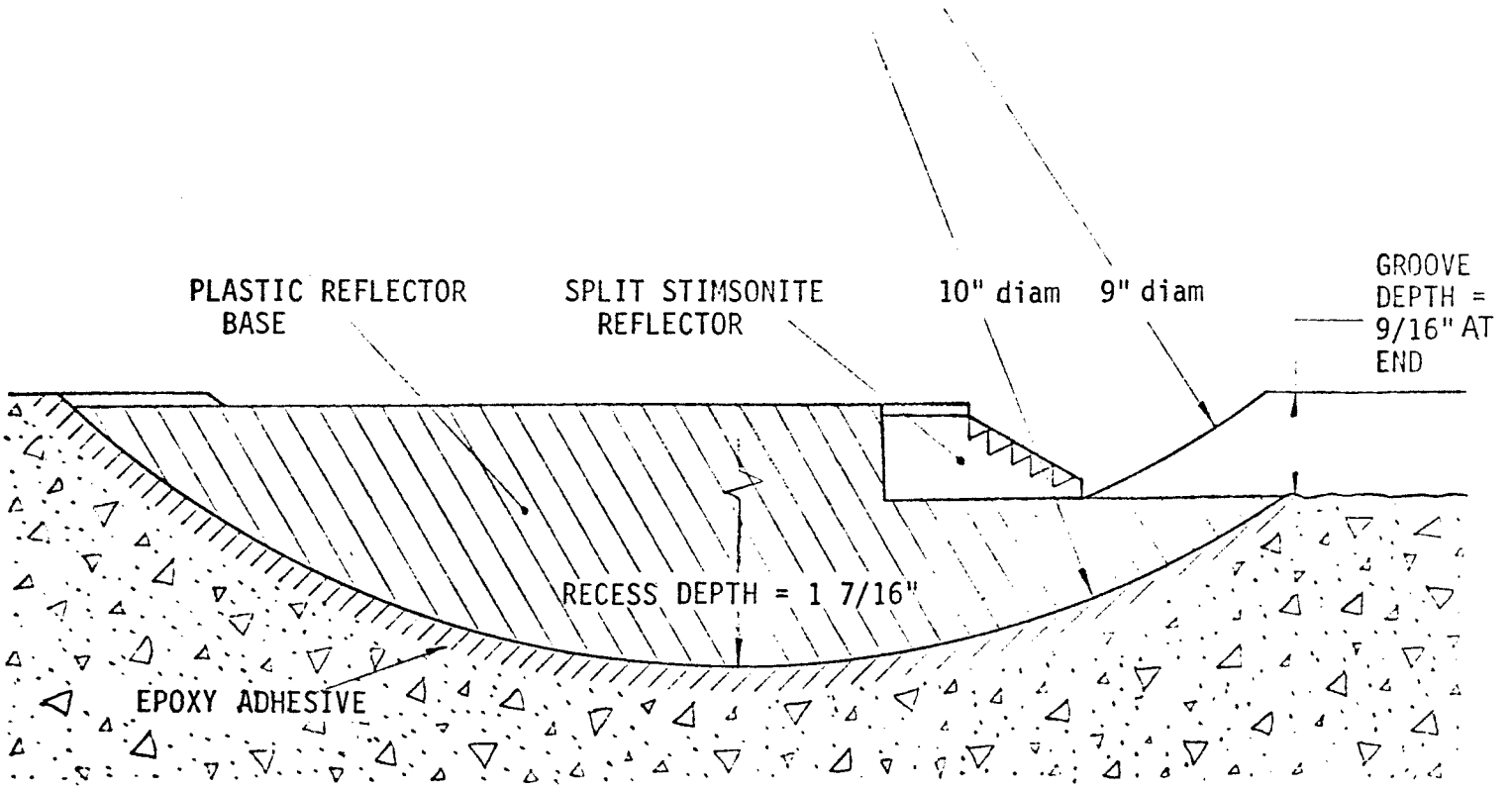


FIGURE 2. PROPOSED RECESSED REFLECTIVE MARKER SYSTEM SHOWING GANGED-SAW CUTTER BUNDLE.



NEW YORK DOT RECESSED MARKER



PROPOSED RECESSED MARKER

FIGURE 3. PRESENT AND PROPOSED RECESSED REFLECTIVE MARKERS.

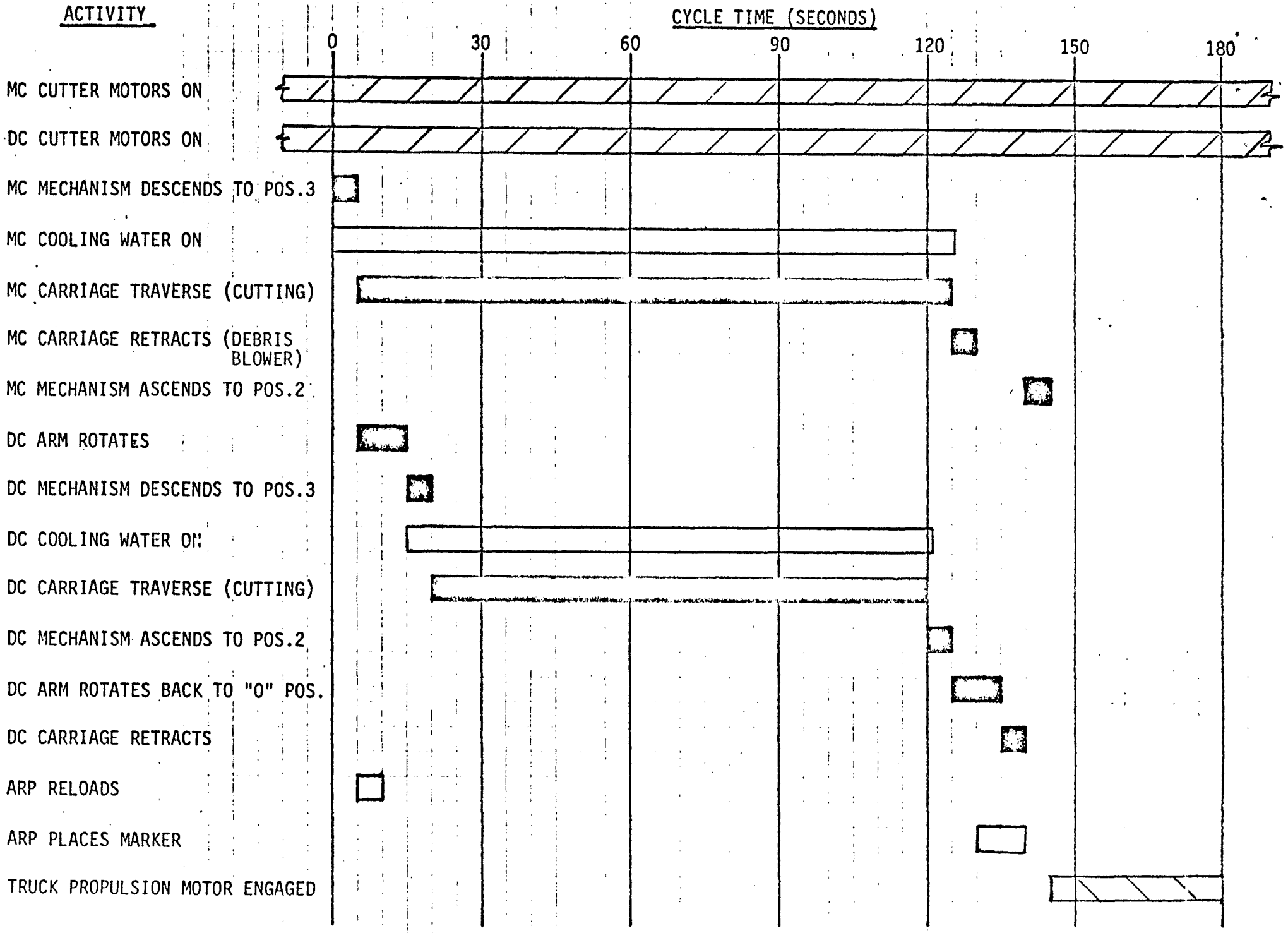


FIGURE 4. SCHEDULE OF SIGNIFICANT MACHINE OPERATIONS AND MANEUVERS.

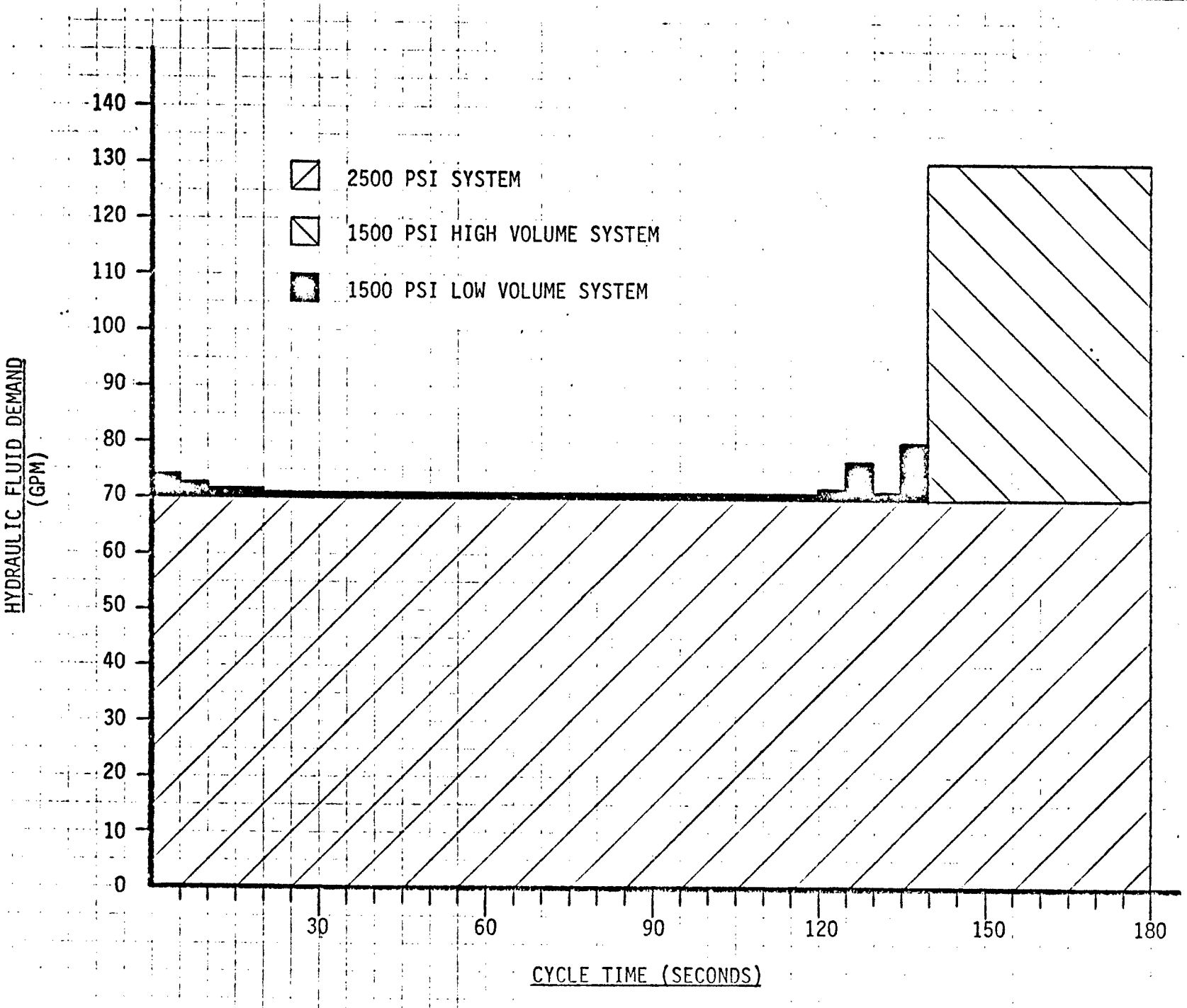
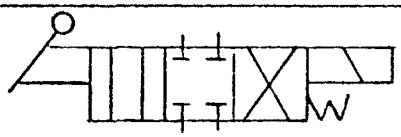
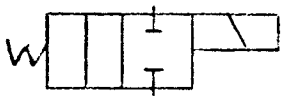
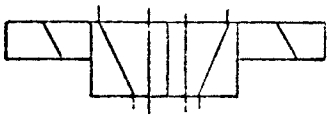
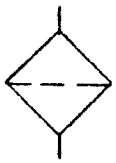
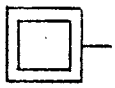
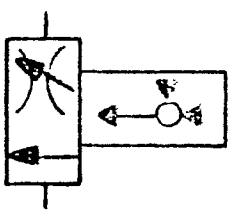


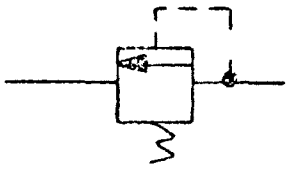
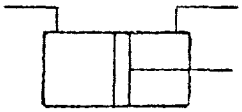
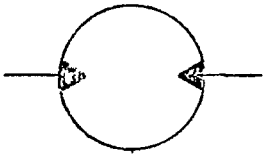
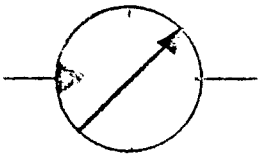
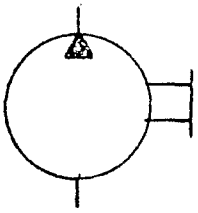
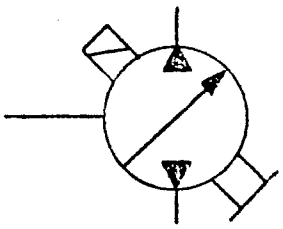
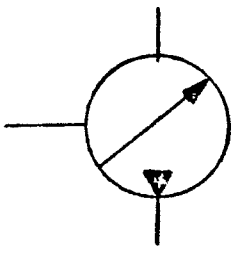
FIGURE 5. HYDRAULIC FLUID DEMAND DURING OPERATING CYCLE.

APPENDIX A: HYDRAULIC GRAPHIC SYMBOLS

(PER AMERICAN NATIONAL STANDARD / ANS Y 32.10)

SYMBOL	DESCRIPTION
	DIRECTIONAL CONTROL VALVE - Solenoid operated one way, manually(handle) operated other way with spring return - reverses direction of flow
	TWO WAY VALVE - Solenoid operated, spring return on/off valve
	THREE WAY VALVE - Solenoid operated - used as system selector
	FILTER
	SUMP
	POWER SOURCE (INPUT POWER)
	CHECK VALVE
	FLOW CONTROL VALVE - Temperature and pressure compensated
	ACCUMULATOR
	FLOW CONTROL VALVE - Servo operated, adjustable, temperature and pressure compensated

(HYDRAULIC GRAPHIC SYMBOLS continued on next page.)

SYMBOL	DESCRIPTION
	RELIEF VALVE
	HYDRAULIC CYLINDER (DOUBLE ACTION)
	HYDRAULIC MOTOR (BIDIRECTIONAL)
	HYDRAULIC MOTOR (UNIDIRECTIONAL) Variable displacement
	HYDRAULIC PUMP (UNIDIRECTIONAL) Hand operated
	HYDRAULIC PUMP (BIDIRECTIONAL) Solenoid and handwheel controlled variable displacement
	HYDRAULIC PUMP (UNIDIRECTIONAL) Variable displacement

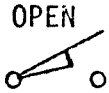
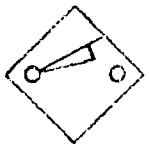
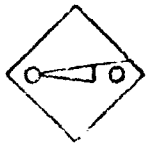
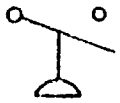
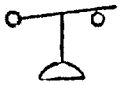
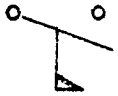
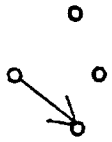
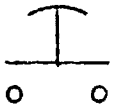
APPENDIX B: HYDRAULIC COMPONENTS

QUAN	MARK NO.	COMPONENT	SYSTEM*	MANUFACTURER & & MODEL*
1	1	Reservoir	ALL	SMC
1	2	Filter	APS	VKR
1	3	Pump	APS	VKR 50V85A-IC10-130
1	4	Accumulator	APS	VKR
1	5	Check Valve	APS	
3	6	Solenoid/Pressure Relier & Dump V	ALL	FLD 7AR17-R20T-30-2-12-SV
1	7	Direction Valve (Solenoid)	APS	VKR DG554-L-10-2DB-2-12V
1	8	Flow Control Valve (Reverse)	APS	VKR DGFN-06-50
1	9	Elec Mod. Flow Control Valve-FWD	APS	VKR FGE-06-60-002-(E)-10
1	10	Check Valve	APS	
1	11	Overcenter Valve	APS	FLD 1E21-F-20T-30-SV
	12	Not Used		
1	13	Motor	APS	VKR 45M130A-1-C-20
1	14	Diesel Engine	ALL	
	15-20	Not Used		
1	21	Filter	HPS	VKR
1	22	Pump	HPS	VKR PVB90-FRDF-20-H10
	23	Not Used		
	24	Not Used		
2	25	Flow Control Valve	HPS	VKR
2	26	Directional Valve (Solenoid)	HPS	VKR F3DG5S4042-C-WL-G-40
2	27	Flow Control Module	HPS	VKR F3DGFN-06-50
2	28	Motor	HPS	DEN MICI-052-21
4	29	Relief Valve	HPS	VKR CG-06-C-4
10	30	Directional Valve (Solenoid)	HPS/LPS	VKR F3DG4V-3-2-S-WL-G-10
5	31	Flow Control Module	HPS/LPS	VKR F3DGFN-01-20
2	32	Motor	HPS	DEN MICI-024-21
4	33	Motor	LPS	CHL MS03-6
1	34	Motor	LPS	CHL MSo3-12
1	35	Valve	LPS	VKR
1	36	Filter	LPS	VKR
1	37	Pump	LPS	VKR PVB10-R-D-W-30-C-C-E-10
1	38	Accumulator	LPS	VKR
1	39	Check Valve	LPS	VKR
	40	Not Used		
1	41	Filter	LPS	VKR
1	42	Flow Control Valve	LPS	VKR
3	43	Counterbalance Valve	LPS	VKR RC-G-03-F-1-20
3	43	Flow Control Module	LPS	VKR DGFN-01-20
1	44	Cylinder	LPS	MIL J84B-3.25x24(CLEVIS)
4	46	Cylinder	LPS	MIL H84B-1.50x10(CLEVIS)
1	47	Cylinder	LPS	MIL H84B-1.50x 9(CLEVIS)
13	48	Relief Valve	LPS	VKR CG-03-C-10
4	49	Relief Valve	HPS	VKR F3CT-03-F-40
1	50	Filter	APS	VKR
2	51	Pump (Hand)	LPS	
14	52	Check Valve	LPS	VKR
2	53	Valve	LPS	VKR
8	54	Flow Control Valve	LPS	VKR

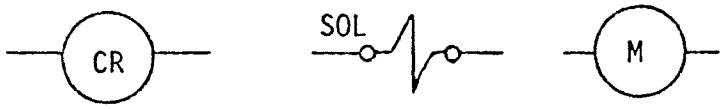
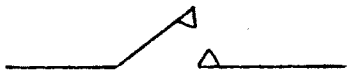
*See next page.

APPENDIX C: ELECTRICAL GRAPHIC SYMBOLS

(AS PER JIC EMP-1-1967)

PART	SYMBOL	DESIGNATION
LIMIT SWITCH	NORMALLY OPEN  CLOSED  HELD OPEN  CLOSED 	LS
PROXIMITY SWITCH	NORMALLY OPEN  CLOSED 	PRS
PRESSURE OR VACUUM SWITCH	NORMALLY OPEN  CLOSED 	PS
FLOW SWITCH (WATER or HYDRAULIC)	NORMALLY OPEN  CLOSED 	FLS
ROTARY SELECTOR SWITCH		SS
PUSH BUTTON SWITCH	NORMALLY OPEN  CLOSED  DOUBLE CIRCUIT 	PB

(ELECTRICAL GRAPHIC SYMBOLS continued on next page.)

PART	SYMBOL	DESIGNATION
CONNECTIONS	CONNECTED NOT CONNECTED PLUG AND RECEPTICLE 	NONE
RELAY CONTACTS	NORMALLY OPEN CLOSED 	CR (Number matches activating coil)
COILS	RELAY SOLENOID MOTOR 	AS INDICATED
ALARMS	HORN BUZZER 	HORN = AH BUZZER = ABU
TIMER SWITCH		TR

Numbering practice:

1. Numbers before the designation identify the part number.
2. Numbers following a switch refer to an element of a multiple switch.
3. Numbers (and letters) following a solenoid identify the component to which the solenoid is attached.

APPENDIX D: ELECTRICAL CONTROL COMPONENTS

Solenoids (SOL)

1SOL - Not Used
2SOL - #27 Extend
3SOL - Not Used
4SOL - #7 Extend
5SOL - DC Arm Rotate CW
6SOL - Not Used
7SOL - DC Arm Rotate CCE
8SOL - DC Motor #1 - Run CW
9SOL - DC Motor #1 - Run CCW
10SOL - DC Motor #2 - Run CW
11SOL - DC Motor #2 - Run CCW
12SOL - MC Motor #1 - Run CW
13SOL - MC Motor #1 - Run CCW
14SOL - MC Motor #2 - Run CW
15SOL - MC Motor #2 - Run CCW
16SOL - DC Water Valve - Open
17SOL - MC Water Valve - Open
18SOL - MC Carriage Feed
19SOL - MC Carriage Retract
20SOL - DC Carriage Feed
21SOL - DC Carriage Retract
22SOL - [7] Retract
23SOL - [27] Retract
24SOL - APM Reverse
25SOL - APM Forward
26SOL - Vehicle Brake Release
27SOL - Debris Blower
28SOL - DC Lateral Movement - Right
29SOL - DC Lateral Movement - Left
30SOL - MC Lateral Movement - Right
31SOL - MC Lateral Movement - Left
32SOL - [30] Extend
33SOL - [30] Retract
34SOL - ARP Arm Extend
35SOL - ARP Pressure Plate Down
36SOL - Vacuum Shutoff
37SOL - ARP Arm Retract
38SOL - MC Carriage Feed Selector (Asphalt)
39SOL - DC Carriage Feed Selector (Asphalt)
40SOL - DC Lateral Movement Unlock
41SOL - MC Lateral Movement Unlock
42SOL - [30] Unlock
43SOL - Dump Valve Close
44SOL - MC Carriage Feed Selector (Concrete)
45SOL - DC Carriage Feed Selector (Concrete)

Relays (CR)

1CR - Timer Motor Run Holding
2CR - Timer Motor Reset
3CR - DC Column Vertical Alignment Linear Actuator - CW - YZ Plane - Control
4CR - DC Column Vertical Alignment Linear Actuator - CCW - YZ Plane - Control
5CR - DC Column Vertical Alignment Linear Actuator - CW - XZ Plane - Control
6CR - DC Column Vertical Alignment Linear Actuator - CCW - XZ Plane - Control
7CR - MC Motors Valves Open Holding
8CR - MC Motors Valves Open (Allows #27 to Extend to Position 3)
9CR - DC Motors Valves Open Holding
10CR - DC Motors Valves Open (Allows #7 to Extend to Position 3)
11CR - Not Used
12CR - Not Used
13CR - MC Water Valve Closed for Retraction
14CR - Not Used
15CR - DC Water Valve Closed for Retraction
16CR - DC Rotator Locked (Allows [7] to Extend to Position 3)
17CR - DC Carriage Retraction Started
18CR - Vehicle Brakes Released and Dump Valve Close - Reverse
19CR - Vehicle Brakes Released and Dump Valve Close - Forward
20CR - Bypasses 2LS and 3LS after [27] and [7] pass Position 2
21CR - ARP Arm Extending Holding
22CR - ARP Arm Retracting Holding
23CR - Allows DC Retraction to Position 1 after ARP Retraction to Position 1
24CR - Allows [27] Retraction to Position after ARP Retraction to Position 1
25CR - DC Column Vertical Alignment Movement Limit
26CR - Not Used
27CR - Not Used
28CR - DC Failure: Low Water or RPM's, Surface or Rebar Obstruction, Low #7 Pressure
29CR - MC Failure: Low Water or RPM's, Surface or Rebar Obstruction, Low #27 Pressure
30CR - MC Failure: Surface Obstruction (Retraction)
31CR - DC Failure: Surface Obstruction (Retraction)
32CR - ARP Arm Extend Deenergize to Allow Retraction
33CR - DC Lateral Movement Unlock and Alarm - Right
34CR - DC Lateral Movement Unlock and Alarm - Left
35CR - MC Lateral Movement Unlock and Alarm - Right
36CR - MC Lateral Movement Unlock and Alarm - Left
37CR - [30] Extend Alarm
38CR - Not Used
39CR - [7] Extend Holding
40CR - Post Emergency Shut Down Reset, General (PESR)
41CR - PESR, MC Carriage Feed
42CR - PESR, DC Carriage Feed
43CR - PESR, [27]
44CR - PESR, [7]
45CR - Reflector Not Dropped

(Relays continued on next page.)

46CR - Refector Not Dropped
47CR - PESR, ARP System
48CR - Adhesive Applicator System Control
49CR - DC Arm Return to "0"
50CR - Adhesive Applicator System Holding Control
51CR - DC and MC Lateral Movement Alarm
52CR - [7] Unlock (Retract)
53CR - [7] Unlock (Extend)
54CR - [27] Unlock (Retract)
55CR - [27] Unlock (Extend)
56CR - Timer Reset Holding
57CR - MC Carriage Feed Holding
58CR - Not Used
59CR - DC Carriage Feed Holding
60CR - DC Water Cutoff
61CR - [7] Unlock - Rotate DC CCW
62CR - [7] Unlock - Rotate DC by 18SS
63CR - [7] Unlock - Rotate DC CW

Relays (CRM)

CRM - Emergency Stop (General)
1CRM - DC Vertical Alignment Failure
2CRM - DC Rotator Failure
3CRM - [7] Extend Failure

Selector Switches (SS)

1SS - [27] Extend - Manual/Auto Mode Selector
2SS - [7] Extend - Manual/Auto Mode Selector
3SS - DC Column Vertical Alignment - Manual
4SS - DC Column Vertical Alignment - Manual/Auto Mode Selector
5SS - DC Colume Vertical Alignment Control (Special Automatic Device)
6SS - DC Arm Rotator Mode Selector - CW, CCW, Auto
7SS - MC Motors Rotation Direction Selector - CW/CCW
8SS - DC Motors Rotation Direction Selector - CW/CCW
9SS - Not Used
10SS - Not Used
11SS - MC Carriage Movement Selector - Manual/Auto Feed and Retract
12SS - DC Carriage Movement Selector - Manual/Auto Feed and Retract
13SS - [7] Retract - Manual/Auto Mode Selector
14SS - [27] Retract - Manual/Auto Mode Selector
15SS - APM Mode Selector - Manual/Auto/Umbilical
16SS - APM Direction Control Selector - In Cab Manual Ahead/Reverse
17SS - DC and MC Speed Selector - Concrete/Asphalt
18SS - DC Arm Position Selector (Special)

Limit Switches (LS)

1LS - Timer at "0"
2LS - [27] at Position 2
3LS - [7] at Position 2
4LS - DC Arm Rotator - CW - at 0°
5LS - DC Arm Rotator - CW - at (+)135°
6LS - Not Used
7LS - DC Arm Rotator - CW - at (+)45°
8LS - DC Arm Rotator - CW - at (-)45°
9LS - DC Arm Rotator - CCW - at 0°
10LS - Not Used
11LS - DC Arm Rotator - CCW - at (-)135°
12LS - DC Arm Rotator - CCW - at (+)45°
13LS - DC Arm Rotator - CCW - at (-)45°
14LS - [27] Fully Extended - at Position 3
15LS - [7] Fully Extended - at Position 3
16LS - MC Carriage Feed at Limit
17LS - MC Carriage Retract at Limit
18LS - [30] Fully Extended - at Position 3
19LS - DC Carriage Feed at Limit
20LS - DC Carriage Retract at Limit
21LS - [7] Fully Retracted - at Position 1
22LS - [27] Fully Retracted - at Position 1
23LS - DC Lateral Movement - Right Limit
24LS - DC Lateral Movement - Left Limit
25LS - MC Lateral Movement - Right Limit
26LS - MC Lateral Movement - Left Limit
27LS - [30] Fully Retracted - at Position 1
28LS - ARP Arm at Position 2
29LS - MC Carriage Clears [9] on Retraction
30LS - ARP Arm at Position 1 - Retracting
31LS - ARP Arm at Full extension - Position 3
32LS - ARP Pressure Plate Fully Down
33LS - Not Used
34LS - Not Used
35LS - ARP Pressure Plate Fully Retracted
36LS - ARP Arm at Retract Limit
37LS - DC Column Vertical Alignment Limit - CW - YZ Plane
38LS - DC Column Vertical Alignment Limit - CCW - YZ Plane
39LS - DC Column Vertical Alignment Limit -CW - XZ Plane
40LS - DC Column Vertical Alignment Limit - CCW - XZ Plane
41LS - [7] Fully Extended - at Position 3
42LS - ARP Arm Retracting - Any Point Between Position 2 and Position 1
43LS - Odometer Spacer
44LS - DC Arm Displaced CW from "0"
45LS - DC Arm Displaced CCW from "0"

Timer Motor Switches (TR)

1TR- 1 - MC Water Valve Open
1TR- 2 - [27] Unlock and Extend Position 2 to Position 3
1TR- 3 - DC Column Vertically Align
1TR- 4 - DC Column Rotate
1TR- 5 - Not Used
1TR- 6 - Adhesive Applicator System On
1TR- 7 - DC Arm Return to "0"
1TR- 8 - [7] Unlock and Extend Position 2 to Position 3
1TR- 9 - MC Carriage Feed and Retract
1TR-10 - DC Carriage Feed and Retract
1TR-11 - [7] Unlock and Retract Position 3 to Position 2
1TR-12 - [27] Unlock and Retract Position 3 to Position 2
1TR-13 - APM Forward
1TR-14 - ARP Arm Extend Position 1 to Position 2
1TR-15 - ARP Arm Extend Position 2 to Position 3
1TR-16 - Not Used
1TR-17 - DC Water Valve Open

Toggle Switches (S)

1S - Not Used
2S - Not Used
3S - Debris Blower
4S - Umbilical (In Cab)
5S - ARP Cutout

Flow Switches (FLS)

1FLS - DC Water Flow Detector
2FLS - MC Water Flow Detector
3FLS - MC Hydraulic Oil Flow Sensor
4FLS - DC Hydraulic Oil Flow Sensor

Pressure Switches (PS)

1PS - MC Carriage Feed Force Regulator
2PS - [27] Full Pressure Detector
3PS - DC Carriage Feed Force Regulator
4PS - [7] Full Pressure Detector
5PS - ARP Arm Vacuum Detector

Proximity Switches (PRS)

1PRS - MC Carriage Retract Surface Obstruction Detector
2PRS - MC Carriage Feed Surface Obstraction Detector
3PRS - MC Rebar Sensor
4PRS - DC Carriage Feed Surface Obstruction Detector
5PRS - DC Carriage Retraction Surface Obstruction Detector
6PRS - DC Rebar Sensor

Push Buttons (PB)

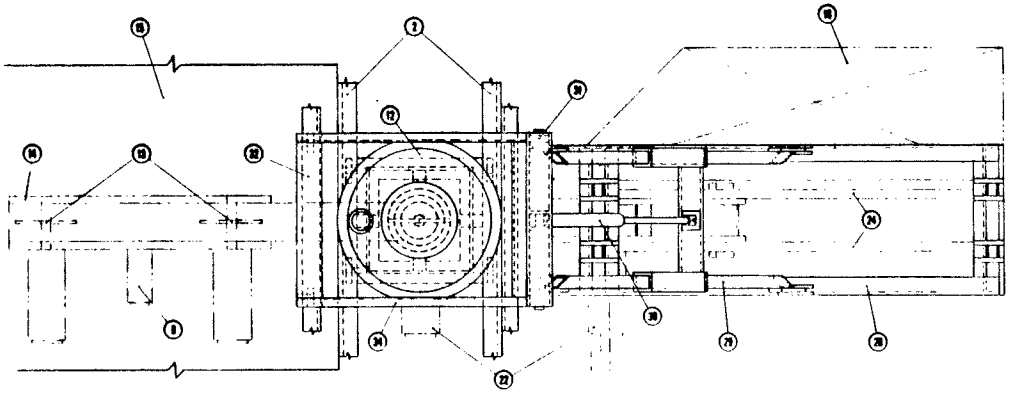
1PB - Emergency Stop
2PB - Timer Start
3PB - Timer Reset
4PB - Timer Adjust
5PB - DC Motors Run (On Umbilical)
6PB - MC Motors Run (On Umbilical)
7PB - DC Water Valve Open
8PB - MC Water Valve Open
9PB - [27] Unlock and Extend (On Umbilical)
10PB - [7] Unlock and Extend (On Umbilical)
11PB - ARP Arm Extend (2-3)
12PB - Vacuum Cutoff
13PB - ARP Arm Retract
14PB - ARP Arm Extend (1-2)
15PB - DC Lateral Movement (On Umbilical)
16PB - MC Lateral Movement (On Umbilical)
17PB - [30] Extend/Retract (On Umbilical)
18PB - APM Forward/Reverse (On Umbilical)
19PB - Post Emergency Shutdown Reset (PESR)
20PB - Reflector Not Dropped Reset
21PB - DC Arm Return to "0" - Test
22PB - Not Used
23PB - DC Motors Stop - Located at Rear of Vehicle
24PB - MC Motors Stop - Located at Rear of Vehicle
25PB - DC Motors Stop - Located in Cab
26PB - MC Motors Stop - Located in Cab

Motors (M)

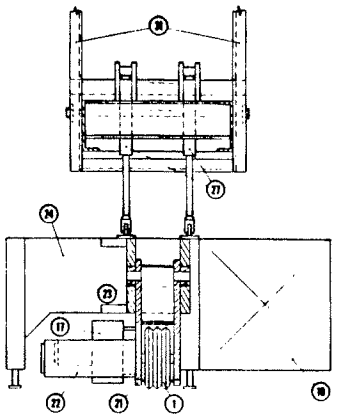
1M - Timer Motor
2M - DC Column Linear Actuator (Vertical Alignment - YZ Plane)
3M - DC Column Linear Actuator (Vertical Alignment - XZ Plane)

Alarms (ABU and AH)

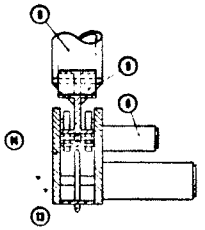
1ABU - DC Column Vertical Alignment Limit Alarm Buzzer
2ABU - Reflector Not Placed Buzzer
3ABU - MC Carriage Feed Failure Buzzer
4ABU - DC Carriage Feed Failure Buzzer
1AH - APM Power On Alarm Horn
2AH - DC or MC Lateral Movement Alarm Horn
3AH - [30] Extend or Retract Alarm Horn



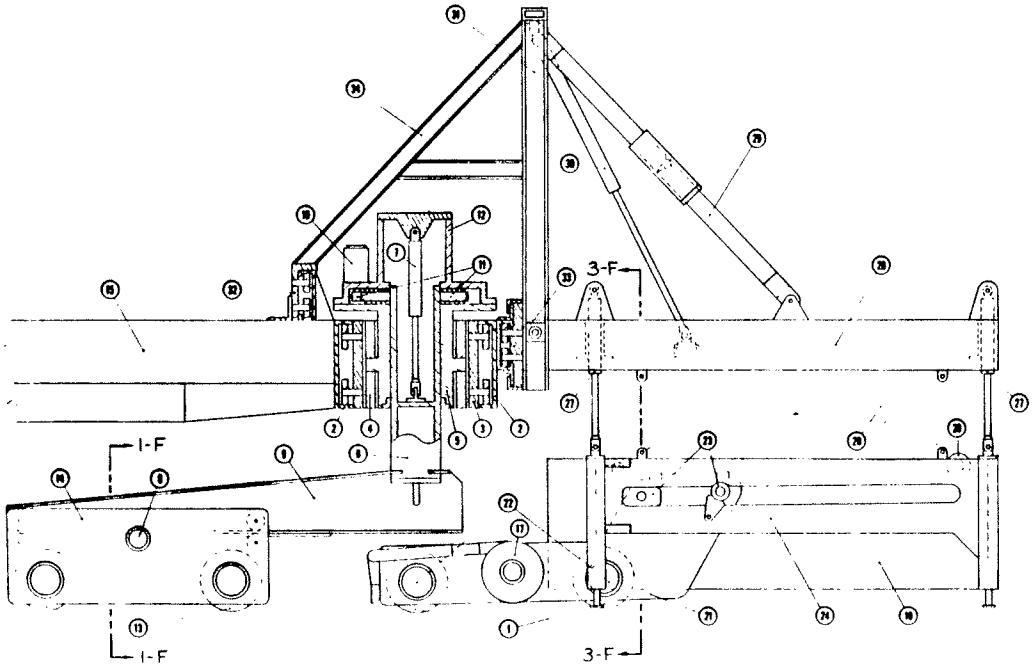
PLAN VIEW



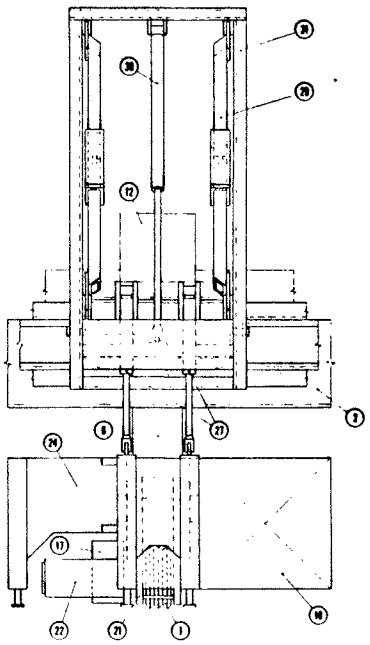
SECTION 3-F



SECTION 1-F



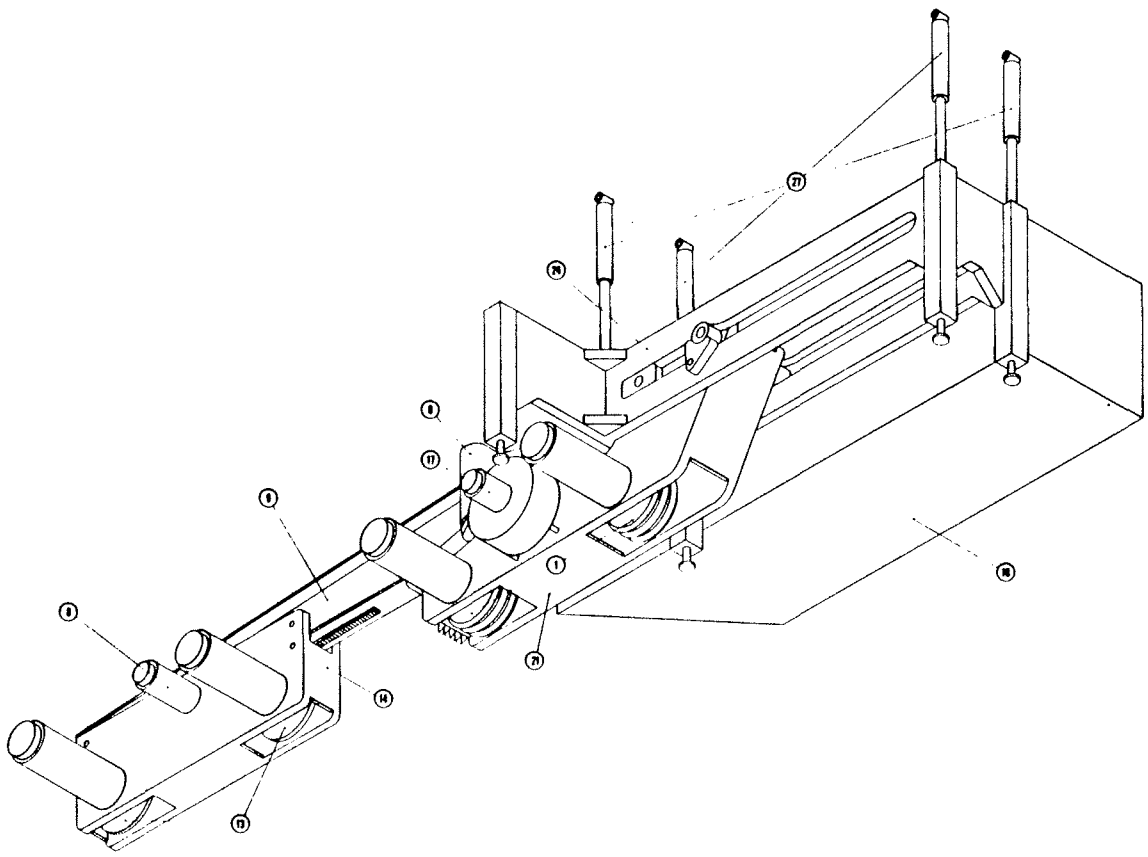
PROFILE VIEW



REAR VIEW

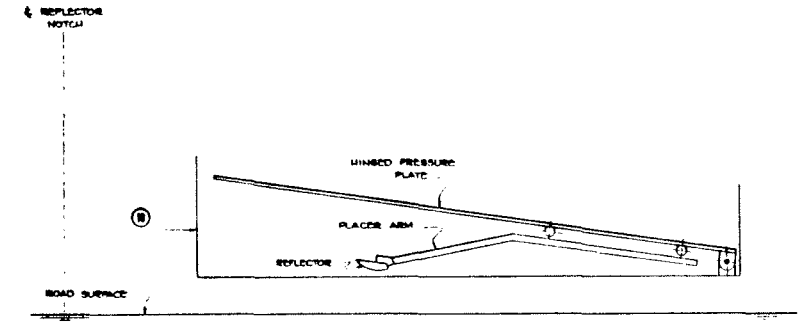
NOTE: FOR ELEMENT DESCRIPTIONS SEE SECTION II, "STRUCTURAL DESIGN DETAILS", UHAD TASK A FINAL REPORT

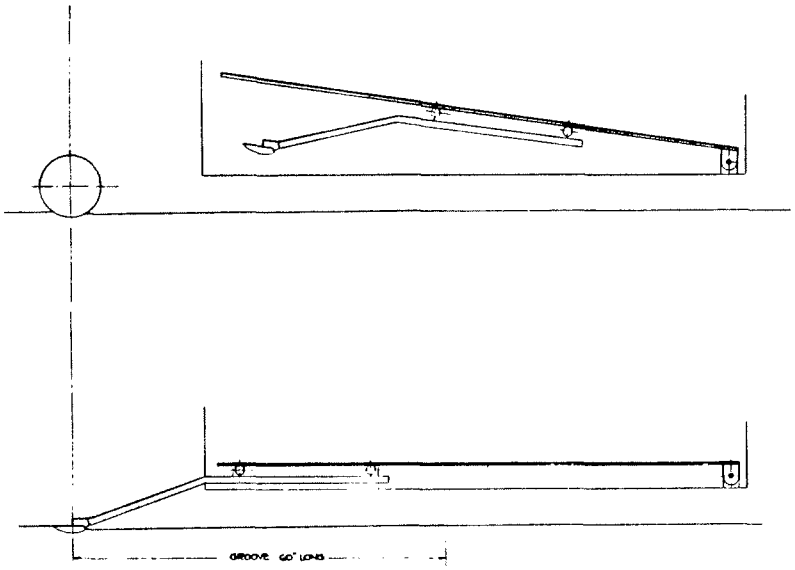
THE SUPERIOR MACHINERY CO.	
703	GSRM STRUCTURAL DETAILS
F N/A	703-2



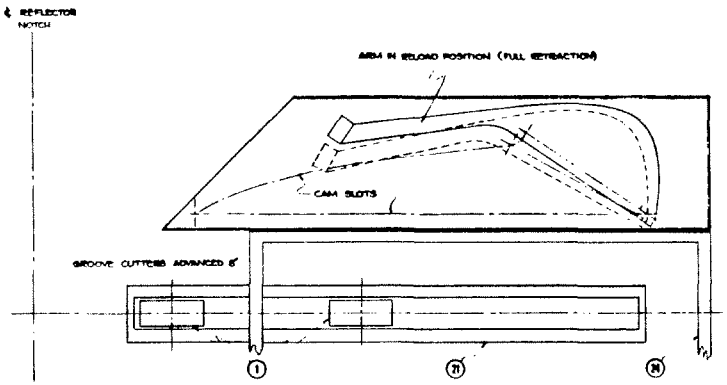
NOTE: FOR ELEMENT DESCRIPTION SEE SECTION 17, "STRUCTURAL DESIGN DETAILS", HHAD TASK A FINAL RPT

		GSPM ISOMETRIC
703		
	F N/A	703-3

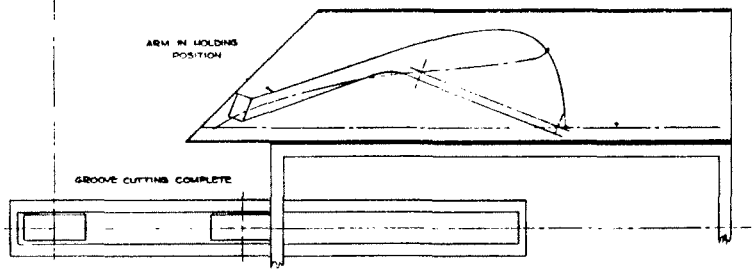




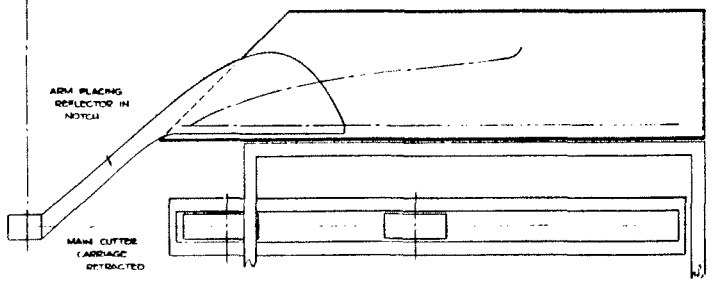
PROFILE VIEWS



LOAD POSITION



HOLD POSITION



PLACING MARKER

PLAN VIEWS

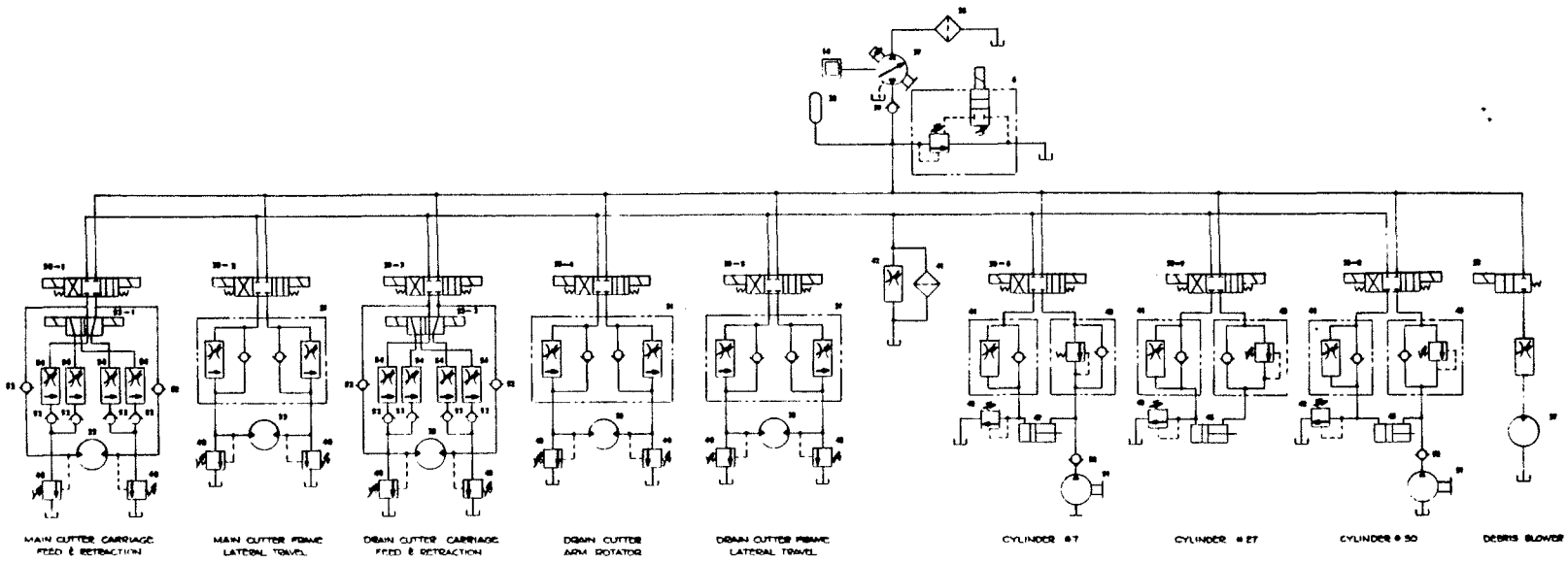
THE GUNNOD MACHINERY CO

703

ARP SCHEMATIC

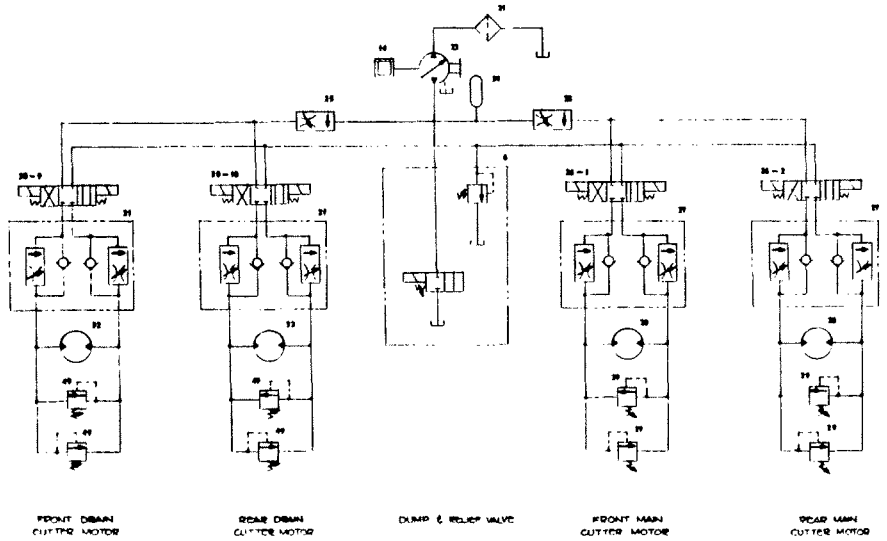
F N/A

703-4

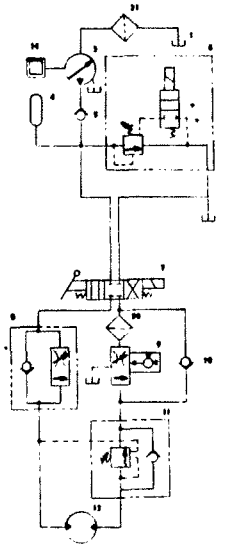


1500 PSI HYDRAULIC SYSTEM

THE BUNTING MACHINERY CO			
703		LOW PRESSURE (1500 PSI) HYDRAULIC SYSTEM	
		F	N/A	703-5(A)



2500 PSI HYDRAULIC SYSTEM



1500 PSI AUXILIARY PROPULSION SYSTEM

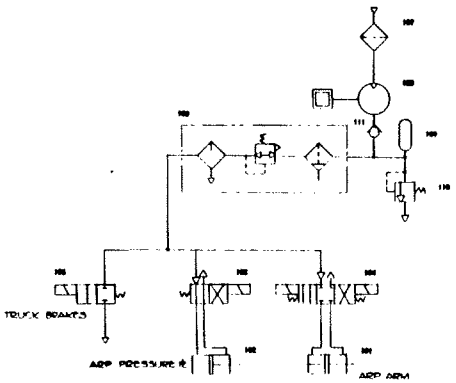
THE ROBBINS MACHINERY CO.

703

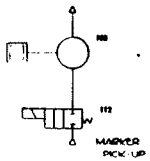
HIGH PRESSURE (2500 PSI) & APS (1500 PSI) HYD SYSTEMS

N/A

703 - F(B)



100 PSI COMPRESSED AIR SYSTEM



10 INCH (Hg) VACUUM AIR SYSTEM

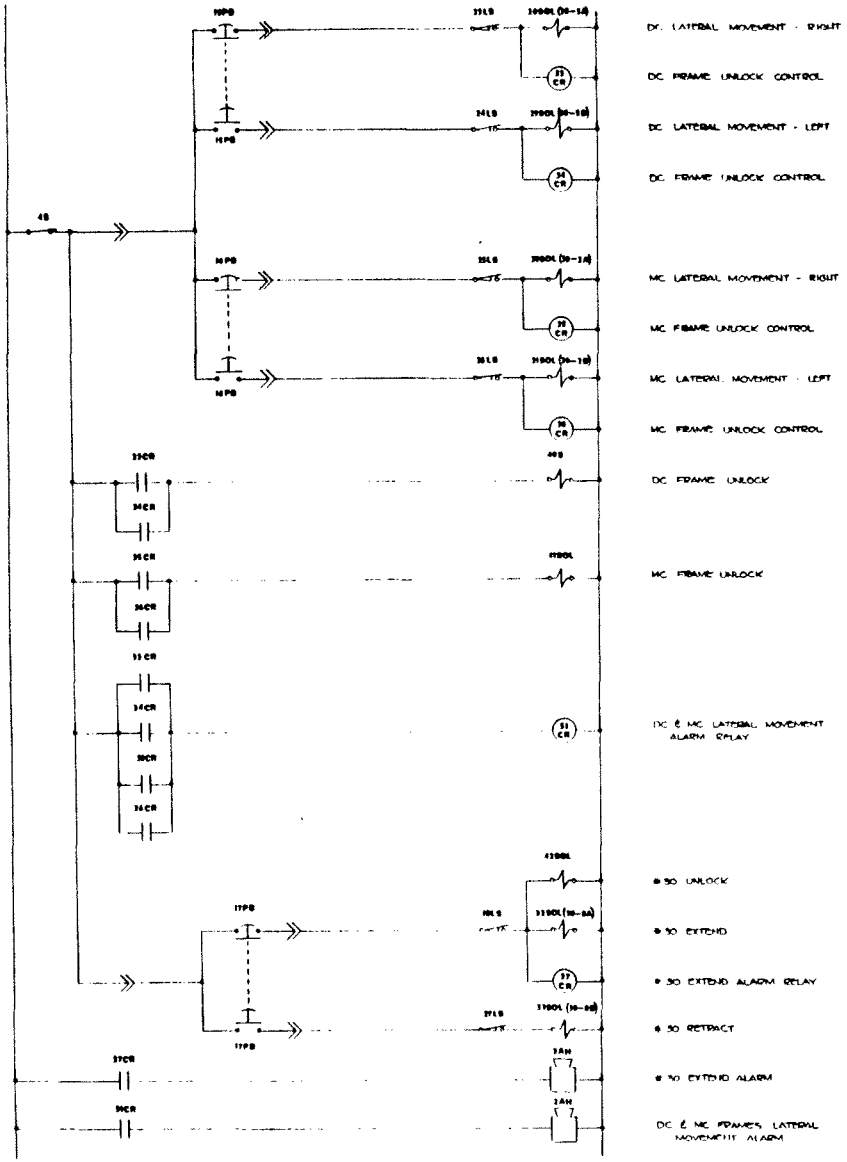
THE BURROUGHS MACHINERY CO

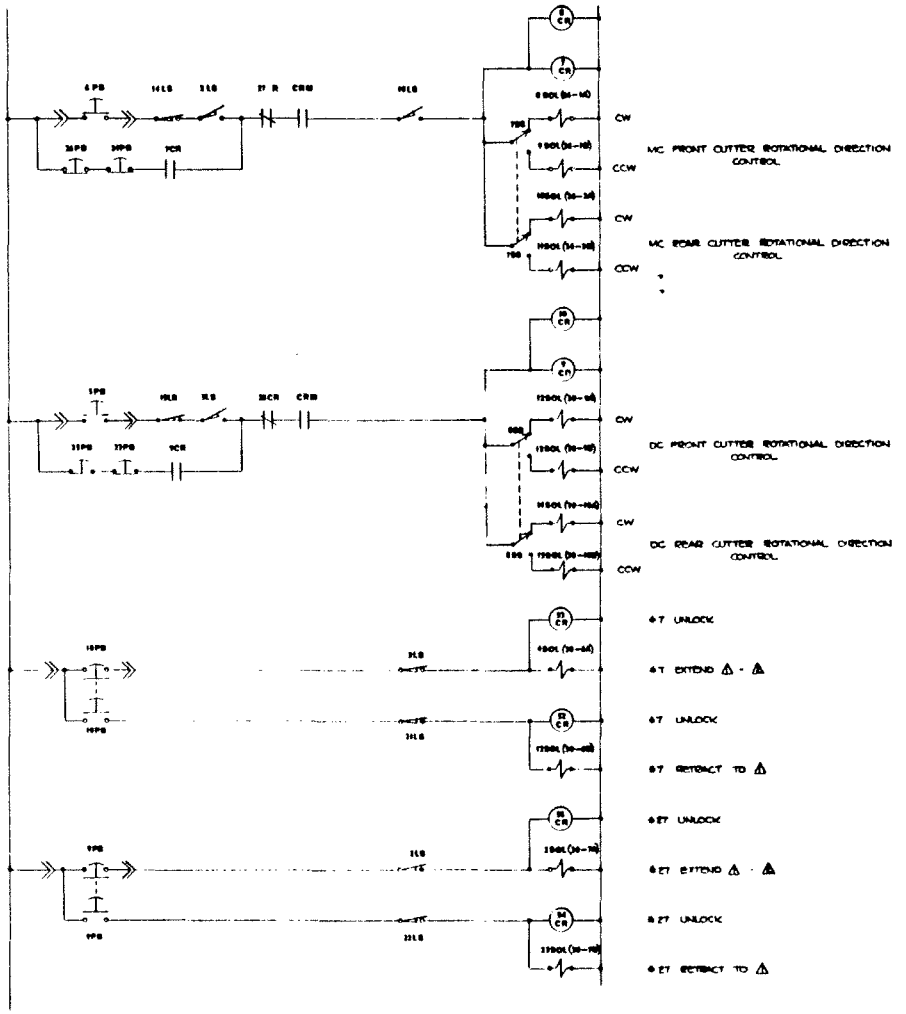
PNEUMATIC SYSTEMS

703

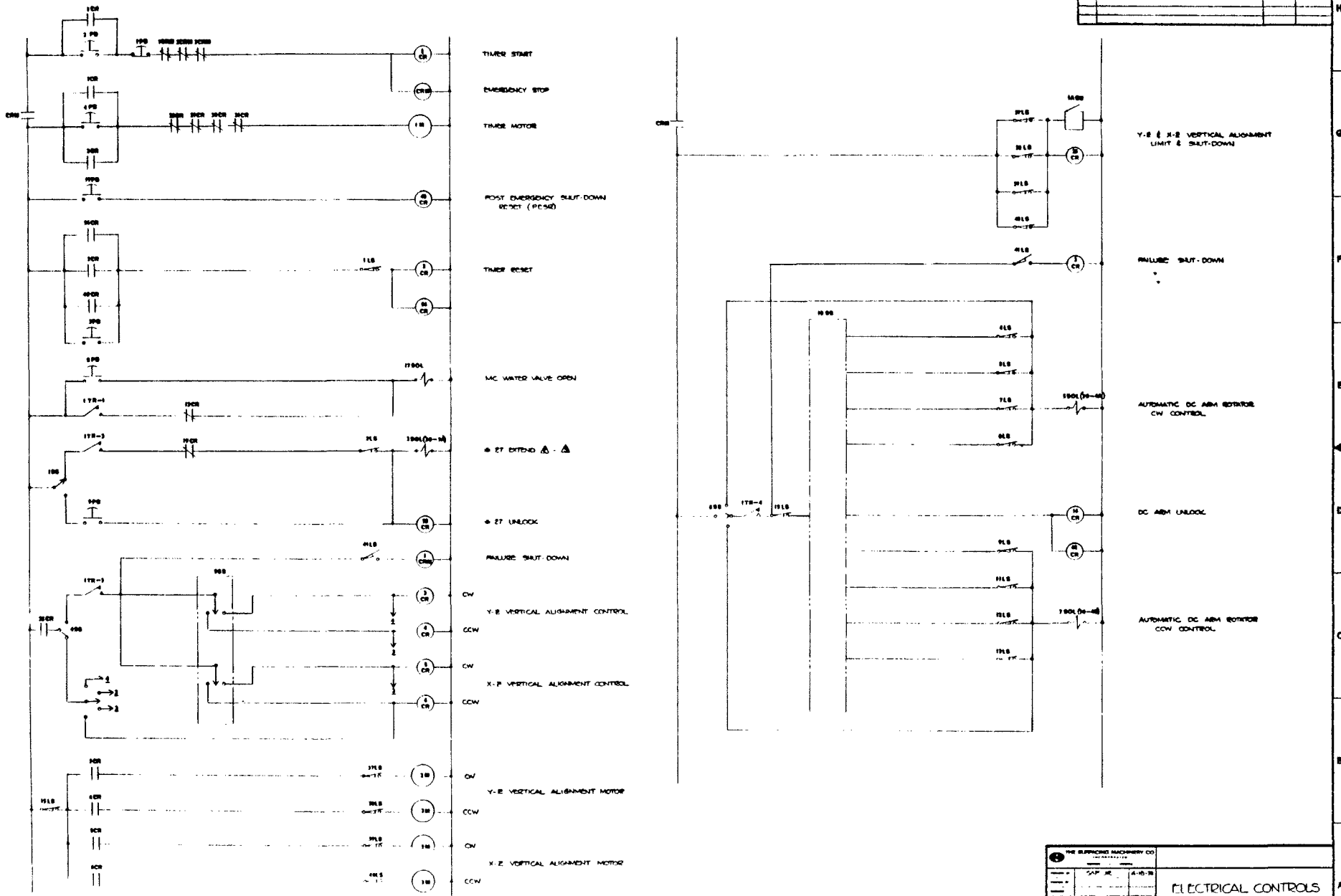
P N/A

703-5(C)





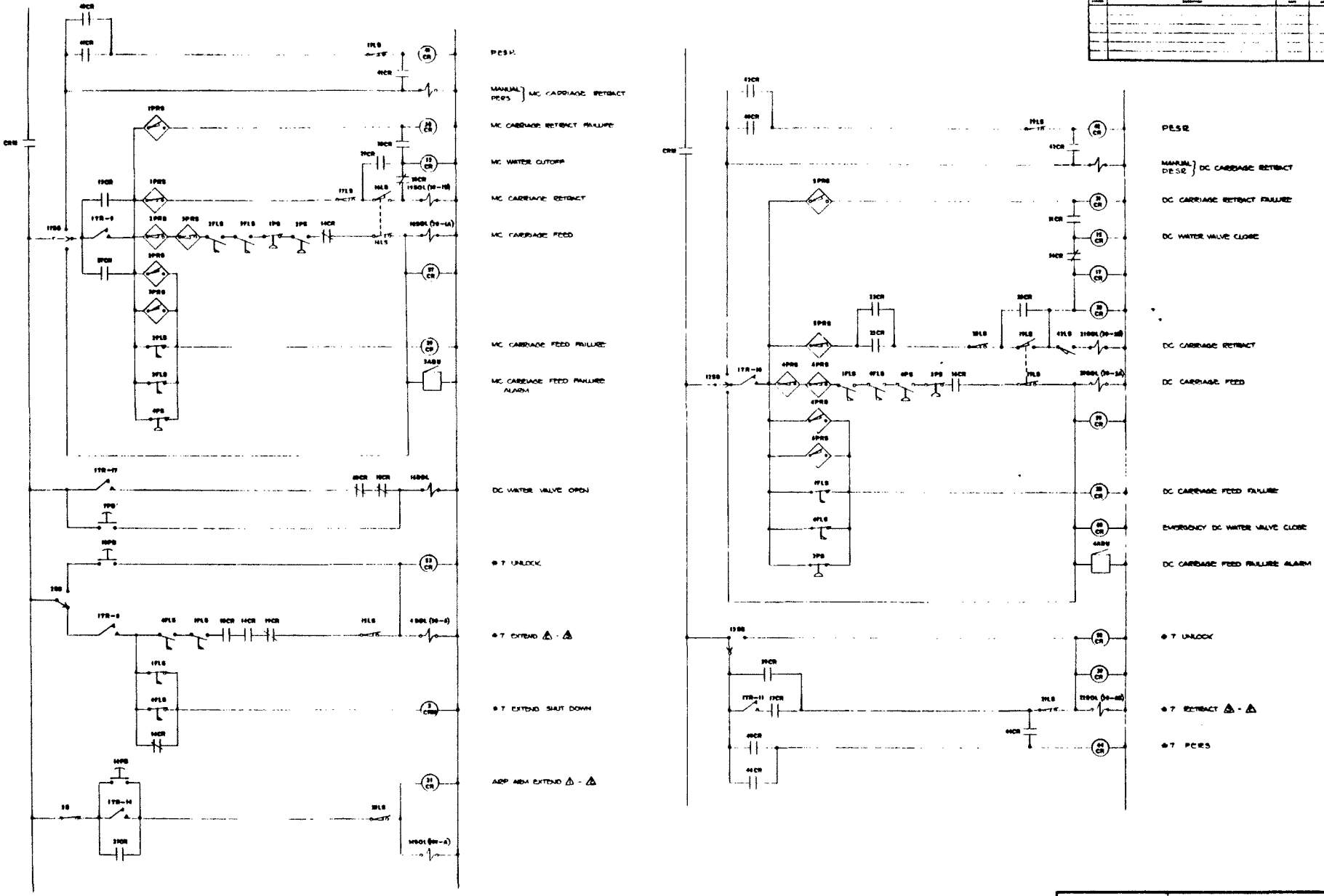
	703		ELECTRICAL CONTROLS
		F N/A	703-6(A)



REVISIONS			

THE SUPERIOR MACHINERY CO.

SAP JR.	4-16-76	ELECTRICAL CONTROLS
703	10-17-77	
F		703-6(B)



REVISIONS			

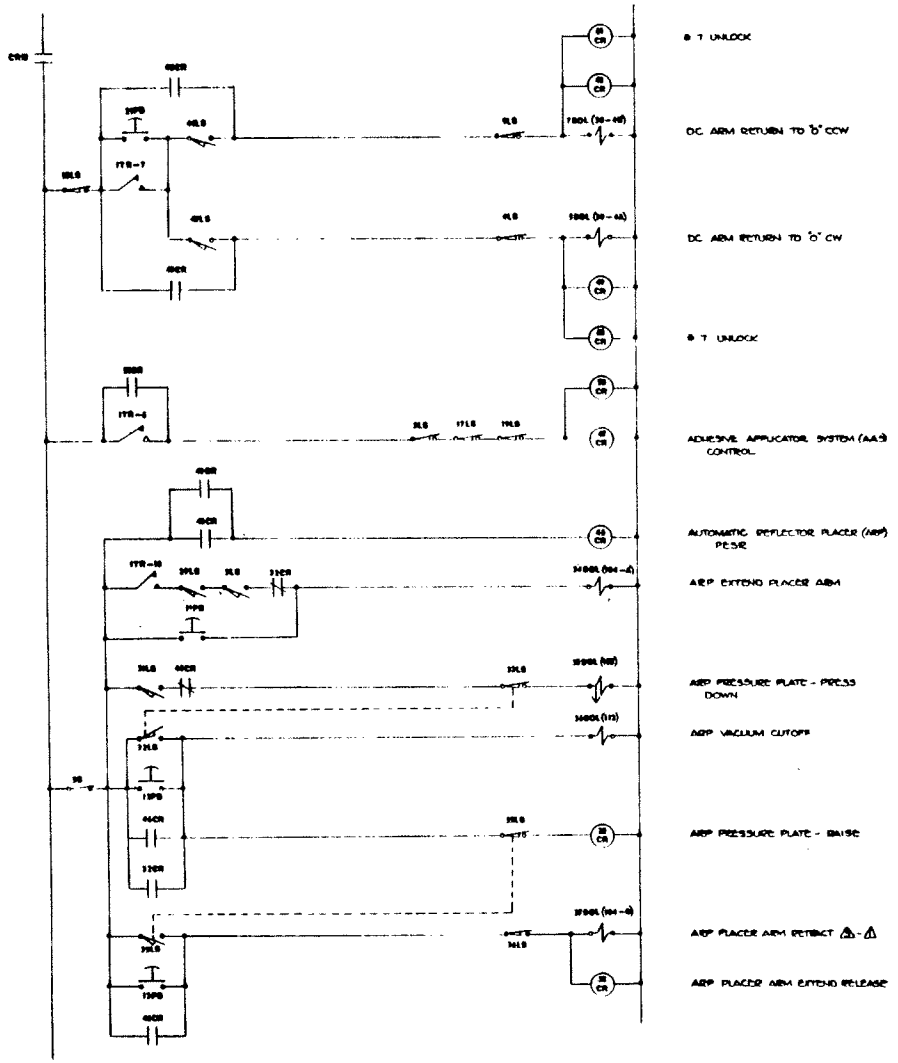
THE BLANCHARD MACHINERY CO.

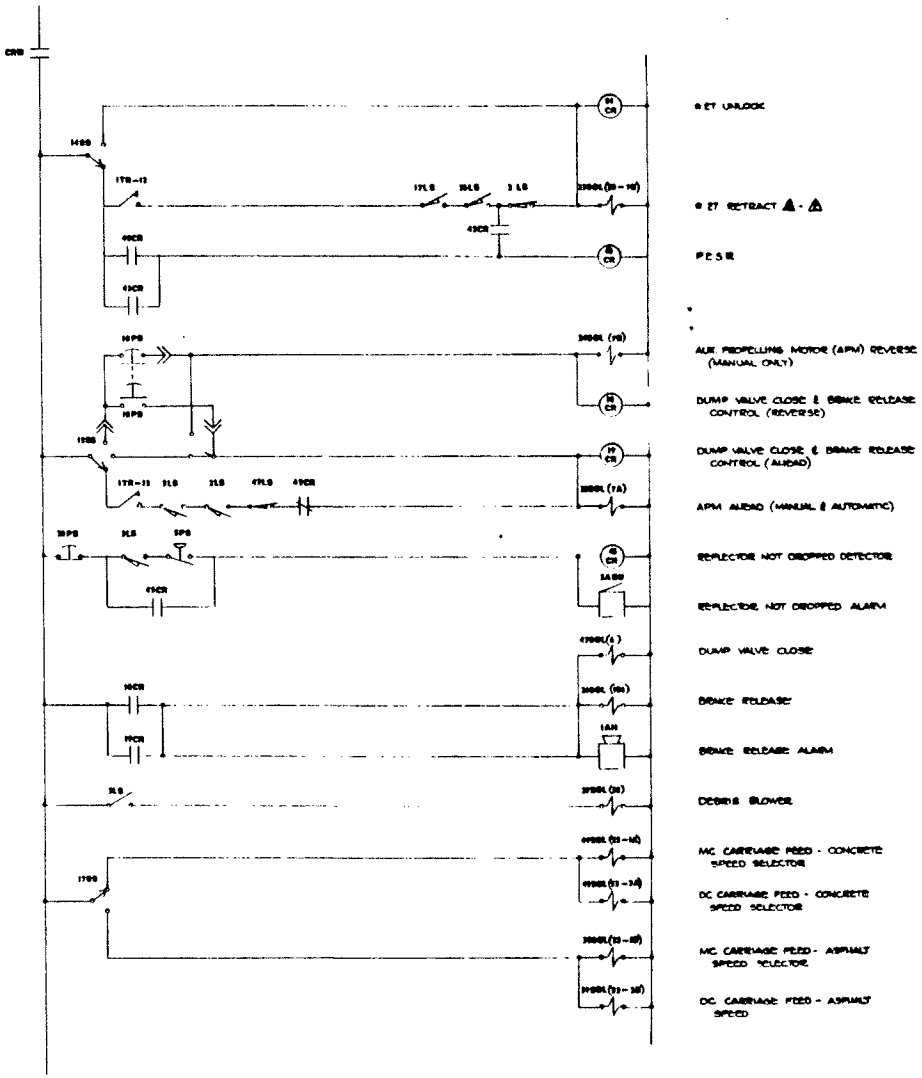
703

ELECTRICAL CONTROLS

F

703-6(C)





REVISIONS			

THE BLAW-KNOX EQUIPMENT CO.

ELECTRICAL CONTROLS

703

703-6(D)