GEORGIA DOT RESEARCH PROJECT 12-06 FINAL REPORT

RAISED PAVEMENT MARKER (RPM) PLACEMENT SYSTEM SUPPORT

**OFFICE OF MATERIALS AND RESEARCH
RESEARCH AND DEVELOPMENT BRANCH**

Contract Research

GDOT Research Project No. 12-06

Final Report

RAISED PAVEMENT MARKER (RPM) PLACEMENT SYSTEM SUPPORT

By

Jonathan Holmes
Research Engineer II

Georgia Tech Research Institute
of the
Georgia Institute of Technology

Contract with

Department of Transportation
State of Georgia

In cooperation with

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16. Abstract:
During the funding provided in FY2013, the GTRI developed RPM placement truck was reworked to prepare the truck for full-time service on Georgia roadways. During this effort, the RPM truck was configured for a certain type of lane striping – the single skip line. The single skip line configuration allows for laying down markers on multi-lane roads, which are the most challenging roadways from a safety standpoint.

After conducting a successful training and demonstration exercise with GDOT's District 3 personnel on May 28, 2013, the system is now in the hands of GDOT's maintenance crews to use on a regular basis. With the successful transition from research to full-time use, we look forward to future developments for automated RPM technologies.

17. Key Words: RPM, Raised Pavement Parker, Training, System Operation, Automation, Automated Systems	18. Distribution Statement:

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Acknowledgements

Executive Summary

The objective of the proposed effort is to provide continuing support, as required, to the Georgia Department of Transportation's (GDOT) Maintenance Activity Unit (MAU) to facilitate their use of the custom built automated RPM placement system by one of their marker-placement crews. This support included providing additional training, making repairs to equipment as needed, and recommending system enhancements. Some enhancements were implemented such as the imaging shroud enhancement, which improved operation of the imaging system. This work has been completed using the Georgia Tech Research Institute (GTRI) developed system delivered to GDOT under the Project FWHA-GA-09-0720.

A major barrier to successfully completing this effort has been the redirection of funding for GDOT's MAU. These issues were resolved and the truck was delivered to GDOT's District 3 on May 22, 2013. Afterwards, a training and demonstration session was completed on May 28, 2013. After uncovering some hardware issues, the RPM truck was successfully delivered to District 3 for full-time use.

Key Words

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Section 1: Summary of Work

Objective of work

The objective of the proposed effort is to provide continuing support, as required, to GDOT MAU to facilitate their use of the GTRI-built automated RPM placement system by one of their marker-placement crews. This support could include providing additional training, addressing issues that are discovered in operation, repairing failures, and developing system enhancements.

Schedule

Some delays were experienced early on due to the late delivery of the truck from GDOT to GTRI as well as delays in the skirt development on the system. These delays pushed out the system test to January of 2013. At that time, funding for GDOT's MAU was under question and the system was in GTRI's possession until a decision was made to transfer the system to GDOT's District 3 in May of 2013.
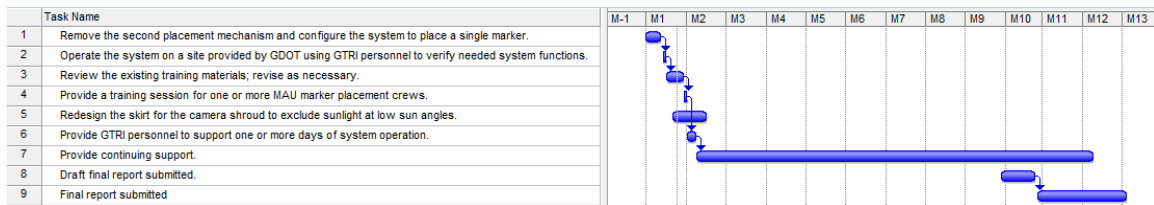
	Task Name	M-1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
1	Remove the second placement mechanism and configure the system to place a single marker.														
2	Operate the system on a site provided by GDOT using GTRI personnel to verify needed system functions.														
3	Review the existing training materials; revise as necessary.														
4	Provide a training session for one or more MAU marker placement crews.														
5	Redesign the skirt for the camera shroud to exclude sunlight at low sun angles.														
6	Provide GTRI personnel to support one or more days of system operation.														
7	Provide continuing support.														
8	Draft final report submitted.														
9	Final report submitted														

Figure 1: Schedule for RPM placement activities

Budget Status

Government Cost Report - D6769 - Jun - 2013

CONTRACTOR PROPRIETARY DATA
GEORGIA TECH RESEARCH INSTITUTE
PROGRAM COST STATUS
Jun   2013

Project Number:	D6769		Customer:	GA DOT
Project Title:	RPM REPLACEMENT SYS SUPP		Contract#:	02112 RES PROJ 12-06
Project Director:	Holmes, Jonathan F		Contract Type:	Cost Reimbursable
Effective Date:	06/11/2012		Contract Value:	$25,000.00
Expiration Date:	06/10/2013		Current Funding:	$25,000.00
			Months Remaining:	0

Cost Breakdown

Cost Item	Budget	Current Expenditure	Cumulative Expenditure	Cumulative Obligations	Free Balance
Direct Labor	$12,059.00	$0.00	$8,416.23	$0.00	$3,642.77
Labor Overhead	$8,909.00	$0.00	$6,265.05	$0.00	$2,643.95
Materials	$1,000.00	$0.00	$1,361.09	$527.51	($888.60)
Operating Expenses	$602.00	$0.00	$5,534.24	$0.00	($4,932.24)
Commit Burden	$0.00	$0.00	$0.00	$8.95	($8.95)
General Admin	$2,388.00	$0.00	$2,206.85	$0.00	$181.15
ODC Overhead	$42.00	$0.00	$105.49	$0.00	($63.49)
Total:	**$25,000.00**	**$0.00**	**$23,888.95**	**$536.46**	**$574.59**

Labor Breakdown

Labor Category	Current Month Hours	Current Month Cost	Cumulative Hours	Cumulative Cost
Prin Rsch Eng/Sci/Ass	0.00	$0.00	91.20	$5,457.42
Rsch Eng/Sci/Assoc II	0.00	$0.00	32.00	$1,317.31
Rsch Eng/Sci/Assoc	0.00	$0.00	6.00	$202.84
Technical Support	0.00	$0.00	10.00	$314.13
Student Asst	0.00	$0.00	5.50	$104.25
Compensated Absenc	0.00	$0.00	0.00	$342.10
Fringe Benefits	0.00	$0.00	0.00	$678.18
Total Labor:	**0.00**	**$0.00**	**144.70**	**$8,416.23**

The unofficial government cost report has a free balance of $574.59. It is expected the full amount will be expended once closeout is completed for this project.

Figure 2: Government cost report

Primary Tasks

A number of activities had to be completed to prepare the system for full function after being in storage for a couple of years. The following bulleted list contains a detailed description of these primary activities.

- Received marker placement truck from GDOT MAU on October 2. .

- Reconnected shore power supply.

- Powered up marker placement system.

- Verified UPS battery in working condition.

- Launched marker placement application. Observed that pavement imaging camera is not generating images.

- Temporarily replaced camera board of pavement imaging camera with GTRI-owned camera board. Verified operation of pavement imaging camera.

- Repaired compressed air leak in pressure regulator array in pneumatics panel.

- Used marker placement application to verify operation of inboard hopper and placement mechanism using manual-place function.

- Removed outboard placement mechanism to prepare system for single-skip operation.

- Reviewed current design of skirt on pavement imaging system. Reviewed problems observed in use of skirt during previous road trials. Discussed concepts for skirt redesign.

- Generated skirt design concept. Reviewed concept and agreed to proceed.

- Completed detailed design of skirt including cable lift mechanism to stow skirt for travel.

- Removed existing skirt from shroud.

- Released sheet metal drawings for quotation. Released purchase orders for all new hardware required. Released drawings for fabricated parts.

- Fabricated parts were completed and delivered. The sheet metal parts were painted.

- Completed installation of the new skirt assembly.

- Tested individual sub-systems.

- Performed a successful full-system test.

- Revisited and included training material for the system (See Appendix A).

- Transferred truck back to GDOT (District 3) on May 22, 2013

- Performed training and demonstration with GDOT staff on May 28, 2013

- Resolved hardware issues and completed truck delivery on May 30, 2013

Imaging System Skirt Design/Fabrication

Due to the complex nature of the skirt redesign, it was decided to feature this particular redesign as a section for this report. During our early evaluation of the system after being returned to GTRI, it was decided that the previous imaging system shroud (a.k.a. skirt) was inadequate for certain lighting conditions. This had been an issue in previous tests performed on local interstates in low sunlight angle conditions. The following figure shows the current design and how GTRI had to approach the clearance issues to fit within the battery tray and the left rear tire of the vehicle.
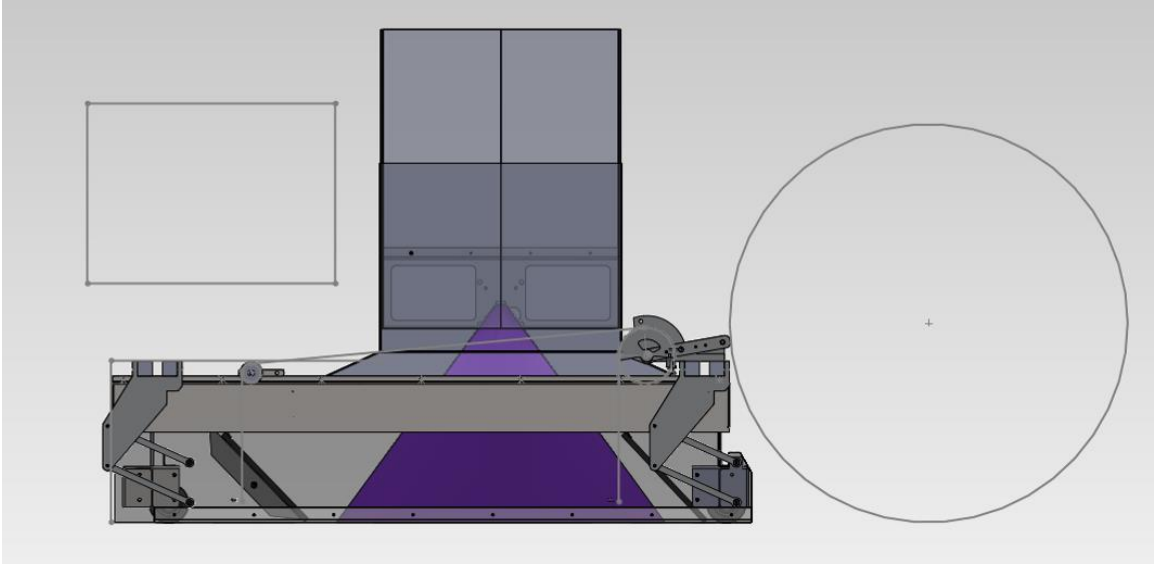
Figure 3: Solid model of new skirt design

The solid model of the new skirt design is shown in Figure 3. The existing camera shroud is in the center of the image along with the purple pyramid that represents the camera field of view. A line sketch represents various constraints including the rear axle and the battery box. The left side skirt, shown as translucent, is supported by two four-bar mechanisms and two caster wheels. The edge of the forward and aft skirts can be seen. Each is supported by a hinge at the top and drags on the pavement. Seals are provided between the edge of the hinged skirt and the face of the side skirt. A cover keeps light from entering at the top of the side skirt. A cable mechanism is provided to lift the skirts about 4 inches above the pavement for travel. The sheet metal structure is attached to the existing camera shroud. Aluminum T-slot extrusion attached to the sheet metal structure is used to support the four-bar mechanisms and the cable lift.

4

Figure 4: New shroud camera shroud including lift mechanism to stow while traveling
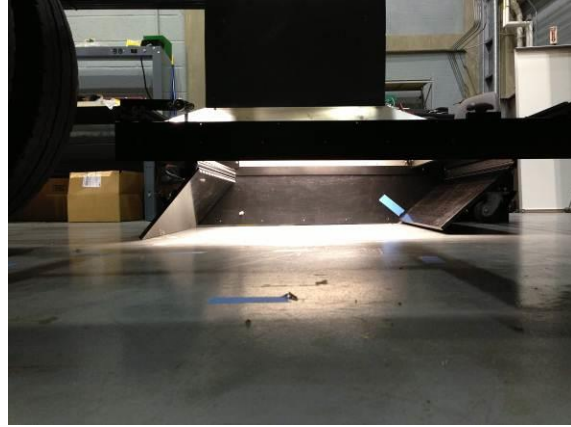

Figure 5: Side view of shroud to show fore and aft panels

Section 2: Testing

Detailed function tests were performed on the system prior to a planned delivery to the sponsor. These tests were important due to the fact the system had been in storage for approximately 2 years prior to returning to GTRI. The following actions or systems were tested:

- **Melter unit** – The melter unit was properly connected when the system was reconfigured for a single placement mechanism.
- **RPM dispensing mechanism** – during disassembly, the dispensing mechanism required some rework because previously attached impact plates fell off during disassembly.
- **Control software** – the software was configured as requested to handle solid and single skip lines.
- **Skirt efficiency** – the newly designed skirt was tested in different lighting conditions showing the improvements over the previous design.

Beyond these basic sub-system tests, an overall system test was performed on Lambert Street adjacent to GTRI's Food Processing Technology Building. A full system test was completed to demonstrate all components were working even though there was a new skirt design and the second placement mechanism had been removed.

After working out issues with reorganization of the GDOT's MAU, the RPM placement truck was delivered to District 3 on May 22, 2013. Shortly thereafter on May 28, 2013 training took place on site with GDOT staff. Several GDOT staff (including Michael Smith, Todd Ingram, and Jamie Fisher) were on site for the training exercise, which was conducted by Wiley Holcombe and Colin Usher from GTRI. After training was conducted, a road trial was executed that afternoon which resulted in approximately 200 RPMs being placed. Some issues were discovered during activities on May 28th, which are listed below:

- **Double Line Pattern** –The system is not intended to work on a double-line pattern with a single-line pattern selected. However, the system appeared to work, but to have a problem. The system was not experiencing any problems other than those caused by operating on a double-line pattern while selecting a single-line pattern.

- **Poor Stripe Condition** – The poor condition of the stripes on US19 proved to be challenging for the image analysis to reliably track the line and find the ends of the skips. The very wide, very dark band of crack sealant in line with the skip line was challenging. The broken skips with wide gaps was challenging. The symptoms included not tracking the skip line and not placing markers for many skips in a row. The system can be adjusted to place on stripes in that condition by making adjustments to threshold parameters. Detection was improved by turning "Automatic Thresholding" OFF and selecting an appropriate contrast threshold. We believe that the issue with the broken skips can be resolved by reducing the "Minimum Line Width" definition.

- **Failure of Adhesive Dispenser** – The adhesive dispenser quit working at the end of the day on May 28th. The signal to fire was being generated and a compressed air pulse was going to the pneumatic cylinder that operates the dispenser valve. After reviewing the symptoms it was determined that: 1)the piston became disconnected from the material valve or 2) the dispenser heaters quit working.

- **Miscellaneous Issues** – Motor overdrive error was resolved by GTRI staff on site due to line pattern recognition issue. Some markers failed to slide all the way down the chute and into the placement mechanism. The Lexan box on the placement mechanism may have been interfering with the marker at the end of the telescoping chute when the driver was following at one extreme side of the lane striping. The alarm on the diesel-engine generator set sounded many times, at least some of the time for a generator under-voltage warning. These miscellaneous issues created minor problems in specific conditions and do not prevent operation of the system.

After reviewing the issues found on May 28th, GTRI returned on May 30th to implement changes to the most critical item – the failure of the adhesive dispenser. After a quick troubleshooting exercise on the heater circuit, it was determined the likely cause of failure was on the connection to the pneumatic actuator. The dispensing carriage was changed out and the system was repaired. Despite some issues experienced under specific conditions, the general condition of the RPM placement truck was good.

Section 3: Conclusions and Recommendations

GTRI completed a number of tests to demonstrate the marker placement system was ready for deployment, placing single markers along the skip lines of multi-lane highways. Initially, testing was performed in controlled areas on Georgia Tech's property to test operation on a small scale. Finally, the system was tested on US HWY 19 with GDOT and GTRI staff present to verify proper functioning of the equipment. Some issues were discovered during testing, but the overall effectiveness of the system was good. The following issues are recommended to be addressed if operation of the system is to continue.

- Backup battery on PC motherboard needs to be replaced
- Edits to manual
    - Marker model number
    - Shutdown procedure
    - Deploy skirt
    - Warning labels for hot surfaces
    - Motor drive, axis one disable error and recovery
    - Motor drive terminal
    - Error message clarified for undefined errors
- At least one unhandled error from motor drive without means of recovery (this will require modification of both the motor drive software and the stripe tracker software)
- Markers bouncing out of chute (when boom is fully extended)
- Improve stripe detection thresholds for poorly striped pavement conditions
- Markers occasionally hanging up at placement entrance
- Dropping 2 or more markers
- Traveling long distances with markers in the hopper can be problematic
- Swapping skip line hopper
- Using 2 hoppers to feed skip lines/marker present at hopper
- Rotate the touch screen panel towards the left driver's seat (for improved operation)

It is recommended that GTRI be consulted for the previously recommended changes under a continued maintenance contract.

Appendix A: Training Materials

The following appendix includes training material to be used to train the unit that will be using the Automated RPM Placement Machine.

Automatic RPM Placement System User Manual
Revision 1.1

Automatic RPM Placement System
Developed by the Georgia Tech Research Institute
of the Georgia Institute of Technology
for the
Georgia Department of Transportation
Under Contracts GDOT TO 02-09 – GDOT PROJ RP 2046 and GDOT TO 02-45
Delivered October, 2008

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List of purchased equipment

| Equipment Description	Vendor
Two Each *Adhesive applicator with dual accumulators* Part Number 308274 Serial Numbers Order Number 203022 P.O. Number 0000014742 Ship Date 9/19/2006 and 10/16/2006	Spraymation, Inc. 5320 N.W. 35th Avenue Fort Lauderdale, Florida 33309-6314 Phone: 954/484-9700 Fax: 954/484-9778 www.spraymation.com
Thermopulse Hot-Melt Dispensing System as per quotation number 211858 Part Number 308429 Serial Number 82069834 Order Number 206481 P.O. Number 0000015832 Ship Date 4/4/2008	Spraymation, Inc. 5320 N.W. 35th Avenue Fort Lauderdale, Florida 33309-6314 Phone: 954/484-9700 Fax: 954/484-9778 www.spraymation.com
DC Pattern Controller 24V Actuation: Timer actuation open collector (simultaneous actuation independent operation) Part Number 3432 Serial Number Order Number 200969 P.O. Number 0000010332 Ship Date 1/9/2006	Spraymation, Inc. 5320 N.W. 35th Avenue Fort Lauderdale, Florida 33309-6314 Phone: 954/484-9700 Fax: 954/484-9778 www.spraymation.com
Externally heated hose, 20 ft., 240V Part Number 450920-20 Serial Number Order Number 200969 P.O. Number 0000010332 Ship Date 1/9/2006	Spraymation, Inc. 5320 N.W. 35th Avenue Fort Lauderdale, Florida 33309-6314 Phone: 954/484-9700 Fax: 954/484-9778 www.spraymation.com
25kW Generating Set Model Number D25-6S Serial Number CAT00C33JN3C00524 240/120VAC 1Phase P.O. Number 0000016491 Yancey Job Number 08-246 Project Manager: Christian Lammers	Yancey Power Systems 259 Lee Industrial Blvd. Austell, GA 30168 Phone: 770/941-2424 Toll Free: 877/278-6235 Fax: 770/941-2411 www.yanceypower.com
UPS	
Touch-screen monitor	
Low-speed cruise control	

List of vendor manuals

Equipment Description	Manual Details
25kW Generating Set	Caterpillar SEBU8134-02 May 2006 *Operation and Maintenance Manual* *C3.3 and C4.4 Generator Sets*
25kW Generating Set	Caterpillar SERP4335-01 August 2006 CDROM *C3.3 Generator Set Parts Manual*
Thermopulse Hot-Melt Dispensing System	System Data Sheet SL271 *User Bill of Materials Assembly 308429* Spraymation Gr308429, 4/4/08 Rev.~ *Thermopulse Hotmelt System* Spraymation Gr481118, 7/16/91 *Pumping System Maintenance &* *Troubleshooting* Spraymation Gr303416, 3/14/91, Rev. A *General Instructions For 303416 Run-Up* *Control Module* Spraymation Gr301939, 3/2/94, Rev. F *Instructions For 301939 Digital Display/Keypad* *Entry Unit* Spraymation Gr301937, 11/10/92, Rev. B *Troubleshooting The Temperature Control Module* *User Bill of Materials Assembly 308445* *User Bill of Materials Assembly 303743 Rev. C* *User Bill of Materials Assembly 308441* Drawings
Applicator/Dual-Accumulator	Spraymation GR-308274, 9/27/2006, Rev - *Model 308274 Applicator/Dual-Accumulator* *General Instructions* *User Bill of Materials Assembly 308247* *Rev. A 12/22/06*
DC Timer	
	Gemini manuals
	UPS
3M Touch-screen monitor	*ChassisTouch 450* *User's Installation Guide*

Automatic RPM Placement System Overview

The Automatic RPM Placement System places one or two markers per placement along with hot-melt adhesive while in motion at 5 mph. The system tracks the lane stripe and locates the ends of skip lines. For solid lines, the system places markers at a programmed distance interval, for example, every 80 feet. For skip lines, the system places markers at a programmed distance from the end of the next skip after a programmed distance interval. (For example, if skip lines are painted every 40 feet and markers are to be placed every other skip, the distance interval would be set at 80 feet to place on the next skip after 75 feet of travel.) Markers can be placed in any one of five patterns that correspond to stripe patterns. The labeled photograph identifies the system components.
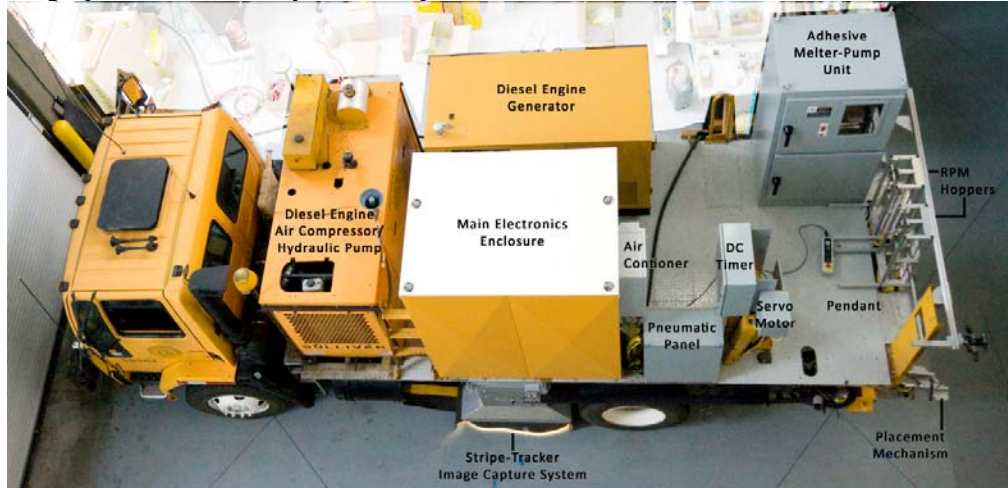
The Automatic RPM Placement System includes two placement mechanisms each capable of dispensing an RPM onto the pavement together with up to 57 g of hot-melt adhesive applied at 380°F while traveling at 5 mph. The placement mechanisms are supported on a pattern-change mechanism that can position the placement mechanisms to accommodate any of five specified RPM placement patterns. The pattern-change mechanism is mounted on the left paint carriage lift, which lifts the entire assembly into a stowed position for travel. The left paint carriage has three feet of travel and is used to keep the placement mechanisms aligned with the lane stripe. A pair of remote hoppers supplies RPMs to each placement mechanism as required for the five RPM placement patterns. The pair of remote hoppers are connected to the placement mechanism by a telescoping RPM slide that delivers one RPM to the placement ramp for each placement. A commercial hot-melt adhesive system with a fifty-gallon melt tank supplies the hot-melt adhesive at 1000 psi to the adhesive-dispensing applicators mounted on the placement mechanisms. A commercial timer unit opens and closes the valve on the adhesive-dispensing applicator based on a programmed time delay from the beginning of the RPM placement stroke. A hand-held, pushbutton pendant includes buttons to jog the left paint carriage in and out, to initiate RPM placements, and to generate an emergency stop.

Software running on a personal computer (PC) tracks the stripe, initiates marker placements, and provides a touch-screen display for system operation. The stripe tracker software analyzes images of the pavement to identify the stripes. The camera that captures the pavement images is housed in a shroud that is linked to and travels with the left paint carriage. The stripe tracker makes measurements of travel along the lane using a wheel odometer.

A touch-screen monitor is provided in the truck cab as the operator interface. The operator interface allows the operator to start and stop the system, select the stripe pattern, trigger manual placements, and introduce a lateral offset in the RPM placements. The operator interface shows the processed image from the stripe tracker and the calculated speed from the system odometer.

The delivered Automated RPM Placement System is mounted on a GDOT-owned paint striping truck that has had the majority of the painting equipment removed.

Automatic RPM Placement System Description

The delivered Automated RPM Placement System is mounted on a GDOT-owned paint striping truck that has had the majority of the painting equipment removed. Components of the painting equipment that are utilized in the delivered system include the engine-driven air compressor and hydraulic pump; the left paint carriage, four-bar-linkage lift, hydraulic cylinder, and steering valve; and the guide boom. The delivered system includes one or two placement mechanisms capable of dispensing an RPM onto the pavement together with up to 57 g of hot-melt adhesive applied at 380°F while traveling at 5 mph.

Placement Mechanisms The placement mechanisms are supported on a pattern-change mechanism that can move the outboard placement mechanism to one of two positions and can move the inboard placement mechanism to one of three positions, thereby accommodating any of the five RPM placement patterns specified in the Phase 1 requirements document (see Appendix F, Final Report, Revision 1, *Development Of An Automated Raised Pavement Marker Placement Machine (A-7348)*). The pattern-change mechanism is supported by the four-bar-linkage lift on the left paint carriage, which lifts the entire assembly into a stowed position for travel. The hydraulically driven left paint carriage travels laterally three feet and is used to keep the placement mechanisms laterally aligned with the lane stripe.

Remote Hoppers A pair of remote hoppers supplies RPMs to each placement mechanism as required for the five RPM placement patterns specified in the Phase 1 requirements document. The pair of remote hoppers are connected to the placement mechanism by a telescoping RPM slide that delivers one RPM to the placement ramp for each placement.

Adhesive Dispensing A commercial hot-melt adhesive system that includes a fifty-gallon melt tank, a high pressure pump, six heater controls, and a pump control supplies the hot-melt adhesive to the individual, custom, adhesive-dispensing accumulator/applicators mounted on the placement mechanisms. A commercial timer unit opens and closes the valve on the adhesive-dispensing accumulator/applicators based on a programmed time delay from the beginning of the RPM placement stroke.

Servo Controller A commercial servo controller is used to control the lateral movement of the left paint carriage and to control the operation of 12 pneumatic valves that operate the placement mechanisms, the RPM dispensers and loaders, and the pattern-change mechanism. The servo controller controls a brushless DC gearmotor that turns the hydraulic steering valve, originally controlled by the operator on the paint striping truck, to control the lateral position of the left paint carriage. The servo controller software also provides the associated error handling for these operations. The servo controller software also provides functionality for a hand-held, pushbutton pendant that includes buttons to jog the left paint carriage in and out, to initiate RPM placements, and to generate an emergency stop.

Stripe Tracker Software running on a personal computer (PC) provides a number of functions. The PC software includes the stripe tracker function. The stripe tracker analyzes images of the pavement to identify the stripes and to find the offset between the center of the image and the center of the stripe pattern. This offset is used to generate a move command that the PC issues to the servo controller to control the lateral position of the left paint carriage. The stripe tracker also has an algorithm for identifying existing RPMs in the pavement image. The stripe tracker makes measurements of travel along the lane based on a wheel odometer encoder. The distance

measurements are used to trigger pavement image capture and to trigger RPM placements. The hardware that provides the images analyzed by the stripe tracker includes a shroud that is supported by a lateral carriage that is linked to and travels with the left paint carriage. The shroud houses a compact fluorescent lamp illumination system along with a camera housed in an NEMA 4 enclosure. The PC software includes communication functions to support communication between the PC and the servo controller. The PC software includes the operator interface function.

Operator Interface A touch-screen monitor is provided in the truck cab as the operator interface. The operator interface allows the operator to start and stop the system, select the stripe pattern, trigger manual placements, and introduce a lateral offset in the RPM placements. The operator interface shows the processed image from the stripe tracker and the calculated speed from the system odometer.

Supporting Systems Electrical power is provided to the system either from a 100-amp power cable from the building system or from a diesel-engine-driven generator. An automatic switch selects between the two input circuits. The power circuits include the necessary disconnect with lockout, protective fuses and circuit breakers, and contactors that control individual circuits. One 24 VDC and one 5 VDC power supply are provided to power the input and output devices that are connected to the servo controller and PC. An uninterruptible power supply (UPS) is provided to power the PC and the touch-screen monitor. An emergency-stop relay is provided to allow the operators to stop all motion of the system and remove energy to all system actuators by activating any one of three emergency-stop switches. (The four-bar-linkage lift is NOT protected by the emergency stop circuit.)

System Enclosures Five enclosures are provided on the truck bed to house the various components. The main electronics enclosure houses the PC, UPS, servo controller, input and output interfaces, encoder interface, and AC and DC power circuits. The valve enclosure houses the pneumatic control valves along with the regulators, filters, main electric valve, and main manual valve with lockout. The timer enclosure houses the DC pattern controller that provides the programmable time delay for both adhesive dispensing accumulator/applicators. The motor enclosure provides protection for the servo motor. The hot-melt adhesive enclosure houses the hot-melt adhesive melter-pump system. A sixth enclosure, mounted in the cab, houses the touch-screen monitor and the system operating switches.

Start-up Procedure

Start air compressor. *Operating instructions are on inside of instrument door.*	 End of compressor on right side of truck
Start generator. *Power up controls by inserting highlighted fuse inside control enclosure.* *Press RUN.*	 Inside rear door of diesel-engine-generator set
Turn ON main disconnect switch.	 On left door of main electronics enclosure
Lower odometer wheel onto tire.	 Above rear axle on right side of truck

Deploy placement mechanism.	
Release tie down straps on placement mechanisms and telescoping slides. Stow straps on lifting eyes.	View of left rear of truck
Raise the placement mechanism using the manual air valve beside the placement mechanism.	View of left side of truck at rear of truck bed
Remove the clevis pin at the bottom of the turn buckle that supports the placement mechanism.	View of left rear of truck
Lower the placement mechanism using the manual air valve beside the placement mechanism.	View of left side of truck at rear of truck bed
Jog out the placement mechanism using the pendant. *Press JOG OUT*	Pendant is at the end of a 20-foot cable that is attached to the main electronics cabinet.
Deploy guide boom.	View of front of truck

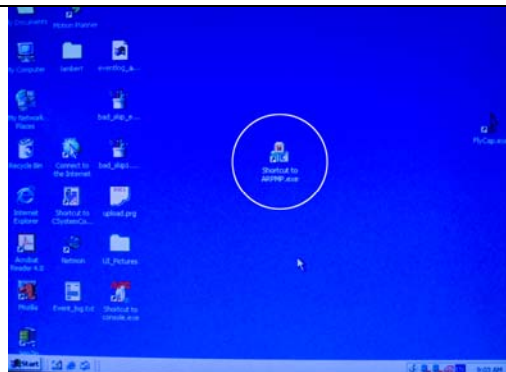|	
Monitor melter-pump unit display until temperatures reach setpoints.	 Inside hot-melt adhesive system cabinet
Turn ON UPS (uninterruptible power supply)**.** *Press* $\dfrac{1}{Test}$ *button highlighted in lower right.* **Turn ON PC** (Stripe Tracker personal computer)**.** *Press button highlighted in upper right labeled with a switch icon.*	 Inside right door of main electronics cabinet
Turn ON adhesive pump. *Press highlighted PUMP START button*	 Upper door of hot-melt adhesive system cabinet
START ARPMP Software (Automated RPM Placement). *Double click icon on Touch-Screen Display.*	 touch-screen display inside truck cab

Move the truth to position the image-capture system over a lane stripe.	 left side of truck in front of rear axle

Move the truck to position the image-capture system over a lane stripe.
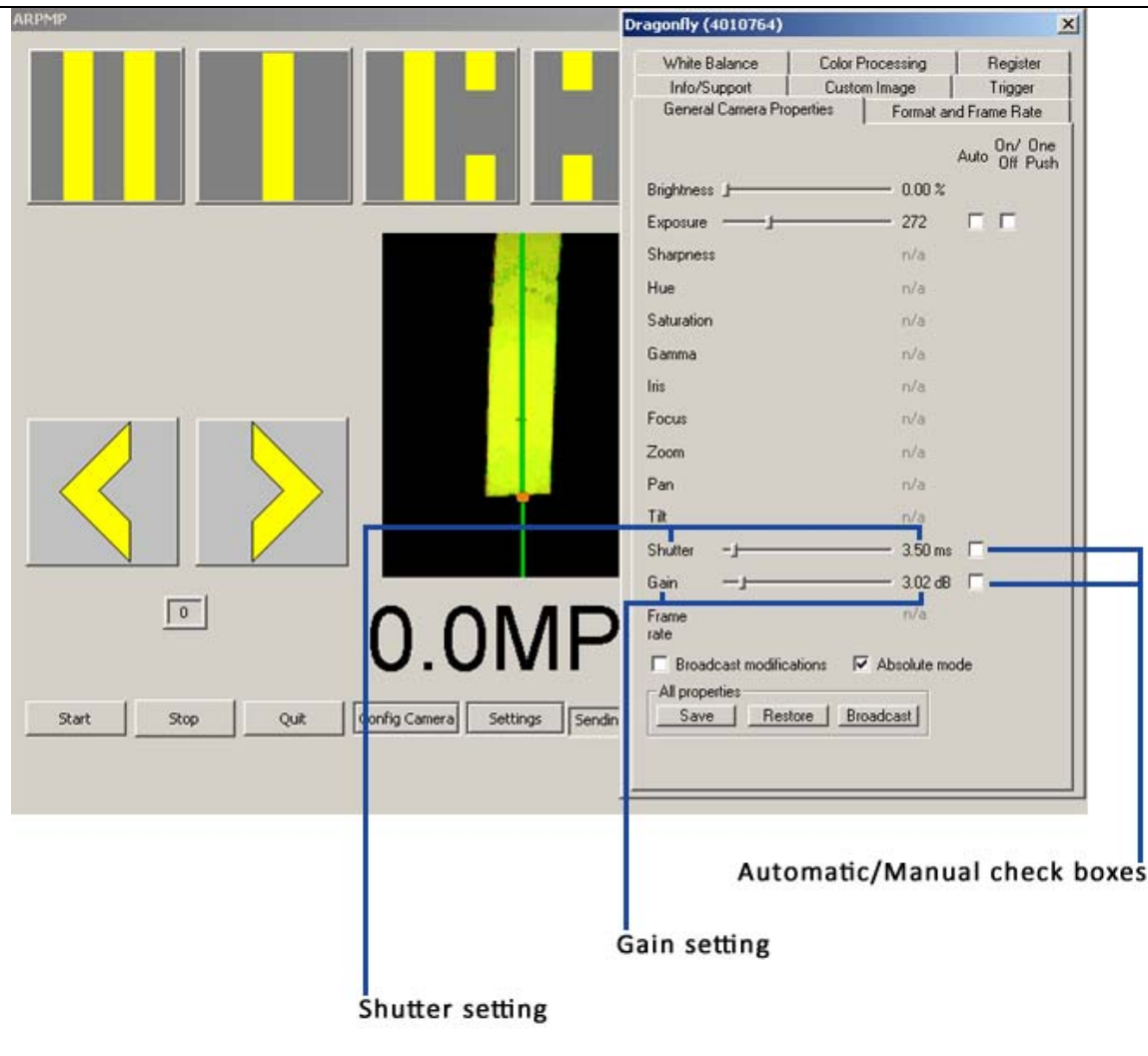
left side of truck in front of rear axle

Open camera configuration window

Press Config Camera button

A processed image of the stripe is then displayed.

Verify that camera settings are acceptable.

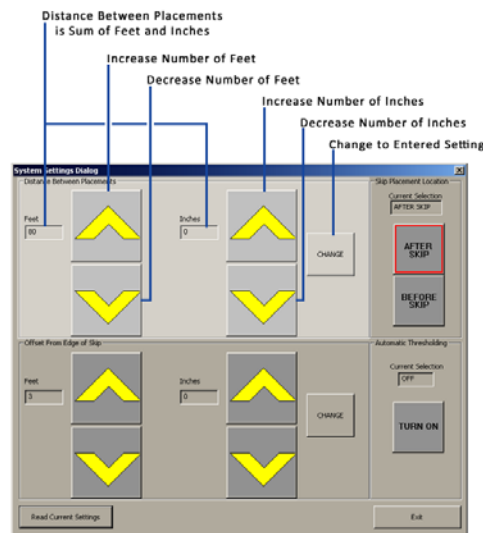**Open settings window.** *Press Settings button.*

Set desired placement distance.

Increase or decrease using arrow buttons or enter value with keyboard. Setting is sum of feet and inches.
Press CHANGE button to change to new value.
Press Read Current Settings button to verify setting
For example, enter 80 feet and 12 inches, Press CHANGE, Press Read Current Settings. 81 feet and 0 inches is displayed as the current setting.
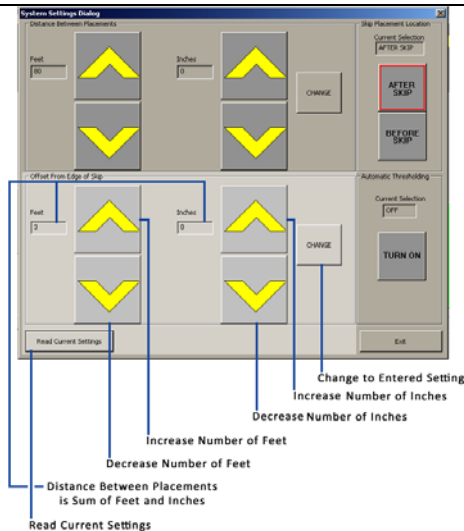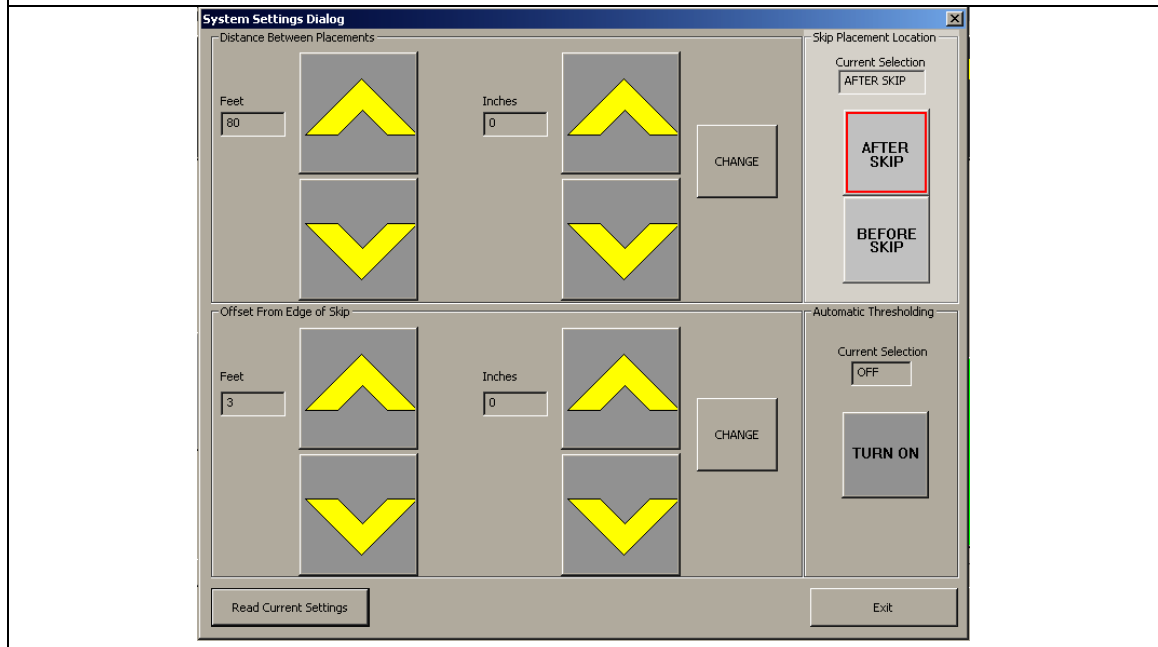
Set desired offset distance from end of skip

Increment using arrow buttons or enter value with keyboard. Setting is sum of feet and inches.
Press CHANGE button to change to new value.
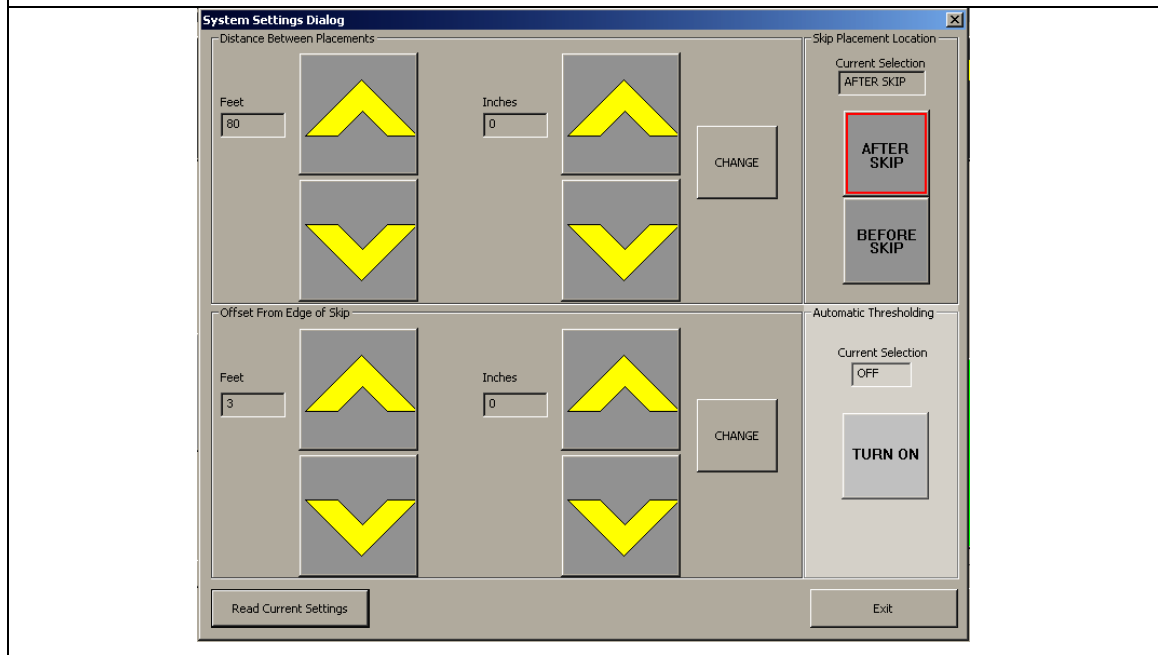*Press Read Current Settings button to verify setting*

Select placement before the skip or placement after the skip.

Turn Automatic Thresholding ON or OFF

This setting affects the operation of the stripe tracking software. The setting determines how the software classifies areas of the image as stripe or as not-stripe.
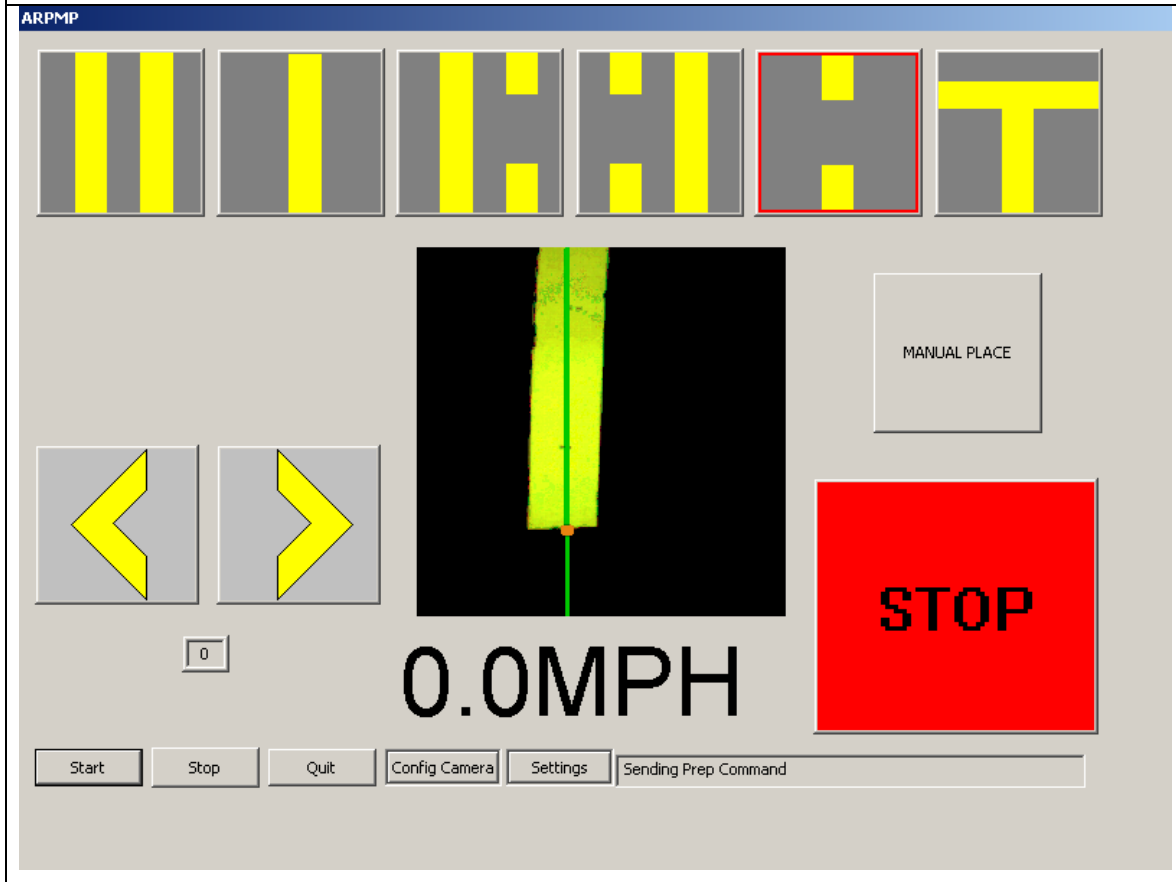
Start Automatic RPM Placement
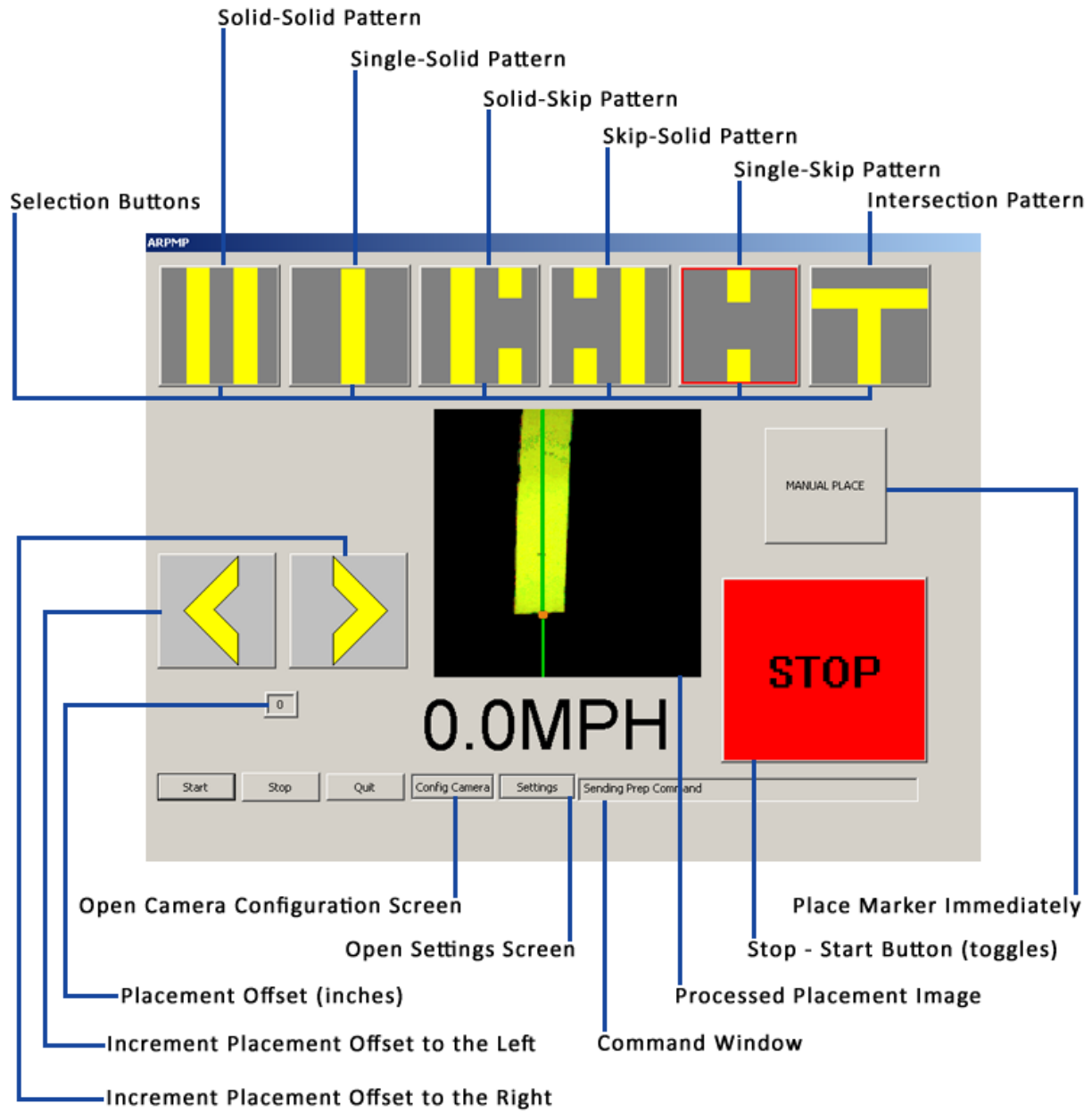
Press appropriate pattern-selection button.

Press START button on user interface.

Once START is pressed, system is running and green START button changes to red STOP button.

Processed camera image is displayed in center of screen. Green line shows the center of the pattern. Orange dot shows end of skip.

User Interface Description:

Starting the User Interface Software

The user interface software is designed to automatically start when the RPM system is powered up. The User Interface covered in this manual is the interface that will appear on the touch screen monitor located inside the cab of the truck.

If the User Interface does not automatically start, it can be manually started by double clicking the executable (.EXE) file 'ARPMP.exe' located on the system desktop.

Operating the User Interface

The User Interface is operated via a touch screen monitor. Touching the desired button on the screen with your fingertips can activate each button. When a button is activated, it will highlight to acknowledge a change. Some buttons, such as the pattern buttons, will remain highlighted with a red outline when selected.
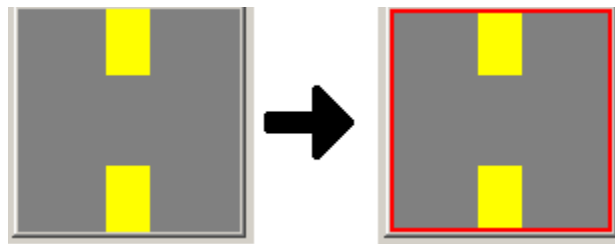
Figure 1

Button Descriptions:

Start/Stop Button

Once the user interface program has started, the system will be in a STOP state. No processing will happen until the Start ("GO") button is pressed. When pressed, the button will change from a green "GO" to a red "STOP."

- To start the system, press the "**GO**" button.

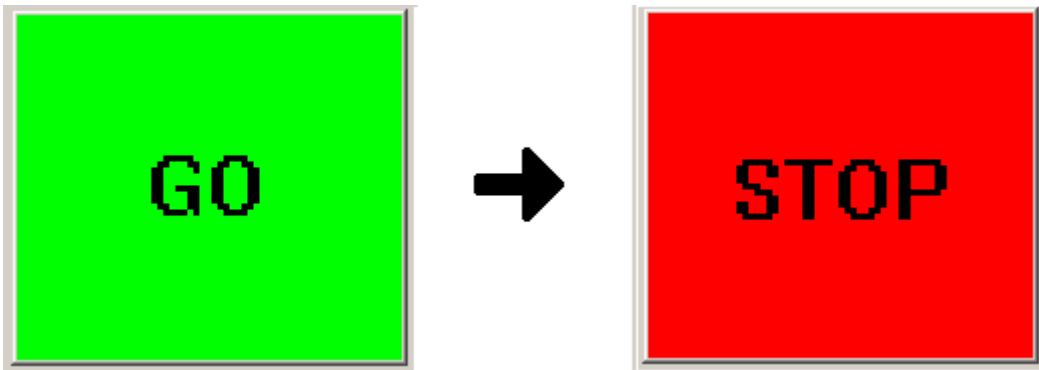- To stop the system after it has started, press the "**STOP**" button.

Figure 2

Pattern Change Buttons

To change a selected RPM placement pattern due to changes in the painted pattern on the road, the user must select the proper pattern from those available on the User Interface. Selecting one pattern will de-select all other patterns and set the RPM placement system mode to the current selected pattern. The selected pattern will be outlined with a red border as shown in Figure 3.
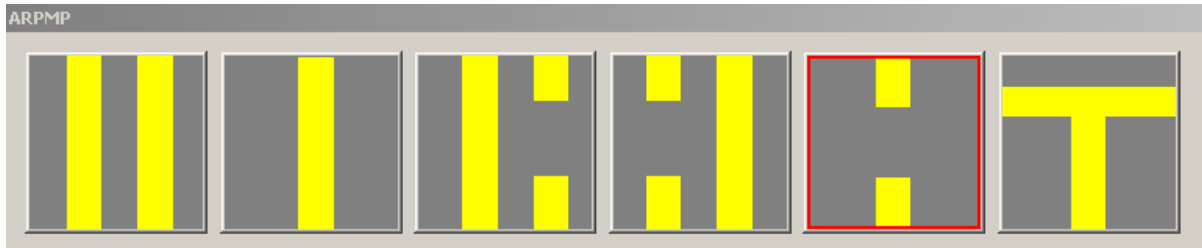

Figure 3

1. **Solid-Solid**: When selected, this will de-select all other patterns and set the RPM system into Solid-Solid Mode.
2. **Single-Solid**: When selected, this will de-select all other patterns and set the RPM system into Single-Solid Mode.
3. **Solid-Skip**: When selected, this will de-select all other patterns and set the RPM system into Solid-Skip Mode.
4. **Skip-Solid**: When selected, this will de-select all other patterns and set the RPM system into Skip-Solid Mode.
5. **Single-Skip**: When selected, this will de-select all other patterns and set the RPM system into Single-Skip Mode.
6. **Intersection**: When selected, this will de-select all other patterns and set the RPM system into Intersection Mode.

Changing patterns is important because the RPM system needs to know which pattern is currently being analyzed in order for it to make proper decisions on RPM placement location.

IMPORTANT NOTE: When the system is not automatically identifying pattern changes, the correct pattern button needs to be pressed at the time that the boom on the front of the truck passes over a pattern change.

Placement Offset Buttons

Occasionally, RPM placement needs to be shifted laterally from the expected placement location due to issues such as the pavement seam location or other problems with the road surface. The system allows a user to specify how much to shift a placement location (in inches) from the automatically located position.

- To shift the placement location to the left, press the **left arrow** button (Figure 8) on the User Interface.
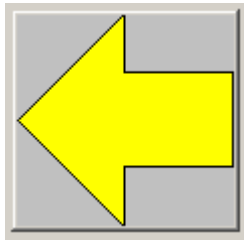
Figure 4

- To shift the placement location to the right, press the **right arrow** button (Figure 9) on the User Interface.
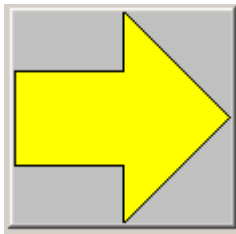
Figure 5

Each time the button is depressed, the placement location will be offset by one inch in the corresponding direction. The resulting offset will be displayed under the offset buttons (see User Interface Legend Item #12). **Negative numbers mean the offset is to the left; positive numbers mean the offset is to the right.**
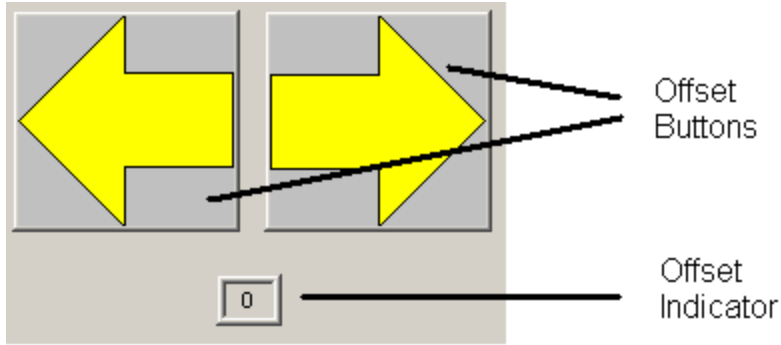
Figure 6

Manual Place Button

Sometimes it is required to place RPMs manually during operation of the system. In order to perform an immediate placement of an RPM, simply press the **Manual Place** button located above the start/stop button.

Once depressed, the system will automatically prepare and place one RPM. Once an RPM is manually placed, the RPM placement system will reset all values and begin looking for the next automatic placement location.

Figure 7

IMPORTANT NOTE: All marker placements are based on distance traveled. For Solid-Solid and Single-Solid patterns, the system places markers at a programmed distance interval. For Skip patterns, the system places markers at the next skip after a programmed distance interval. A manual placement sets the distance measurement to zero. After a manual placement, the system begins a new marker placement distance interval.

Display Descriptions:

Placement Offset Display

This display is used to show the offset of an automatic placement location. The units displayed are in inches. For more information, see the Placement Offset Buttons description in the Button Descriptions section. **Negative numbers mean the offset is to the left; positive numbers mean the offset is to the right. A zero means there is no offset for the current placement location.**
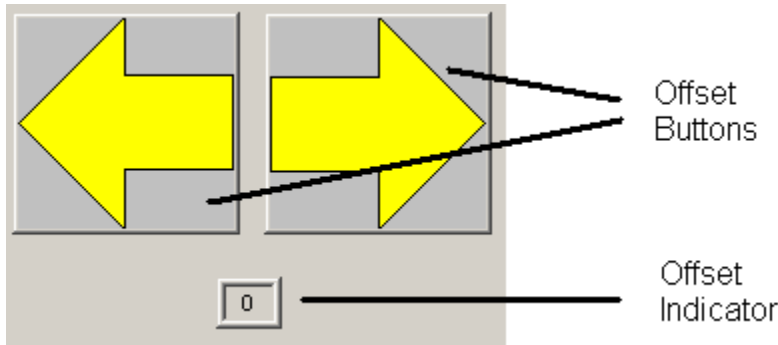

Figure 8

Current Speed Display

This display shows the speed that the truck is currently traveling. The ideal speed for automatic RPM placement is 5 mph. This display allows the user to better keep within the ideal speed range.

Figure 9

Processed Image Display

This display shows the user the last image processed by the system. <mark>This allows the user to see how centered up he/she is on the paint stripe and also allows the user to identify proper operation of the RPM placement system.</mark>
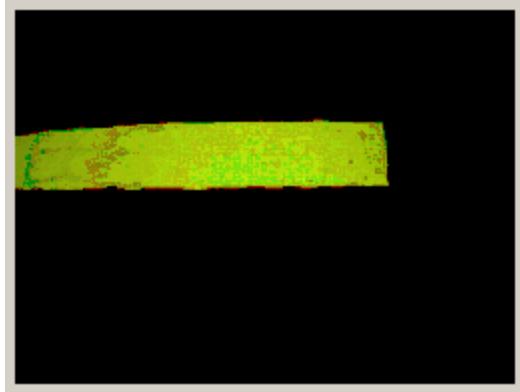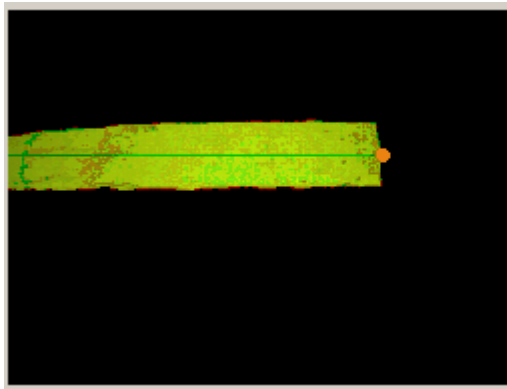

Figure 10

The output display will show both the identified center (middle of the stripe pattern) and also any valid placement location found along the end of a stripe.

Faint Green line shows located center of pattern.

Small orange circle shows possible placement location identified.

Figure 11

The output display will update with every image taken by the RPM placement system.

Changing System Settings

Accessing the Dialog

By touching the button along the bottom of the user interface labeled "Settings" as seen in Figure 12, a dialog for changing RPM placement criteria can be accessed. This dialog allows the user to change the distance between placements (typically 80ft), the distance from a skip that the RPM should be placed (typically 2 ft), the image background removal routine (auto recommended), and whether to place before or after a skip (after-skip recommended). This allows the user to configure all aspects of the automatic placement to accommodate special placement requirements.
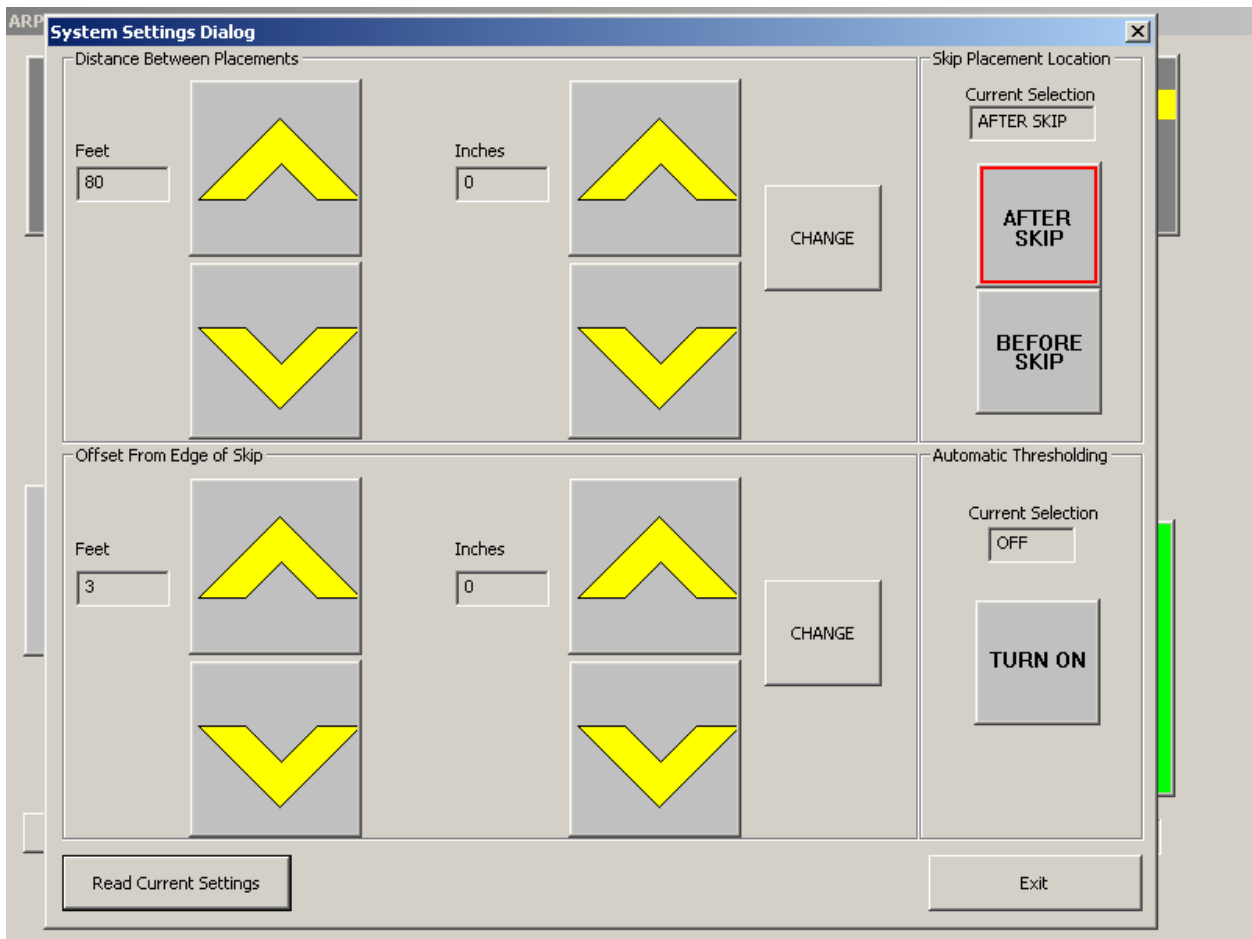

Figure 12 – Settings Dialog

Hopper Loading

The hoppers are labeled inner and outer and numbered starting at the left. This assumes you are standing on the truck looking rearward. The hopper on your left is the inner hopper since it supplies markers to the inboard placement mechanism. The hopper on your right is the outer hopper since it supplies the outboard placement mechanism.

RPM - Hopper Designation for two lane roads

Inner Hopper 1	Inner Hopper 2	Outer Hopper 1	Outer Hopper 2
Yellow	Yellow	Blank	Yellow
Blank	Yellow	Yellow	Yellow

For Inner Hopper 1, the marker's blank side should face forward.
For Outer Hopper 1, the marker's blank side should face rearward.

RPM - Hopper Designation for multi-lane roads

Inner Hopper 1	Inner Hopper 2	Outer Hopper 1	Outer Hopper 2
	White		
	Red		

For multi-lane roads, only inner hopper 2 is used and the marker's red side should face forward.

Error Messages:

When the RPM system encounters any type of error during operation, a message box will be displayed on the User Interface to notify the user of the error condition. When an error condition occurs, the system will not restart until the error is resolved and the message box is cleared by touching the OK button.
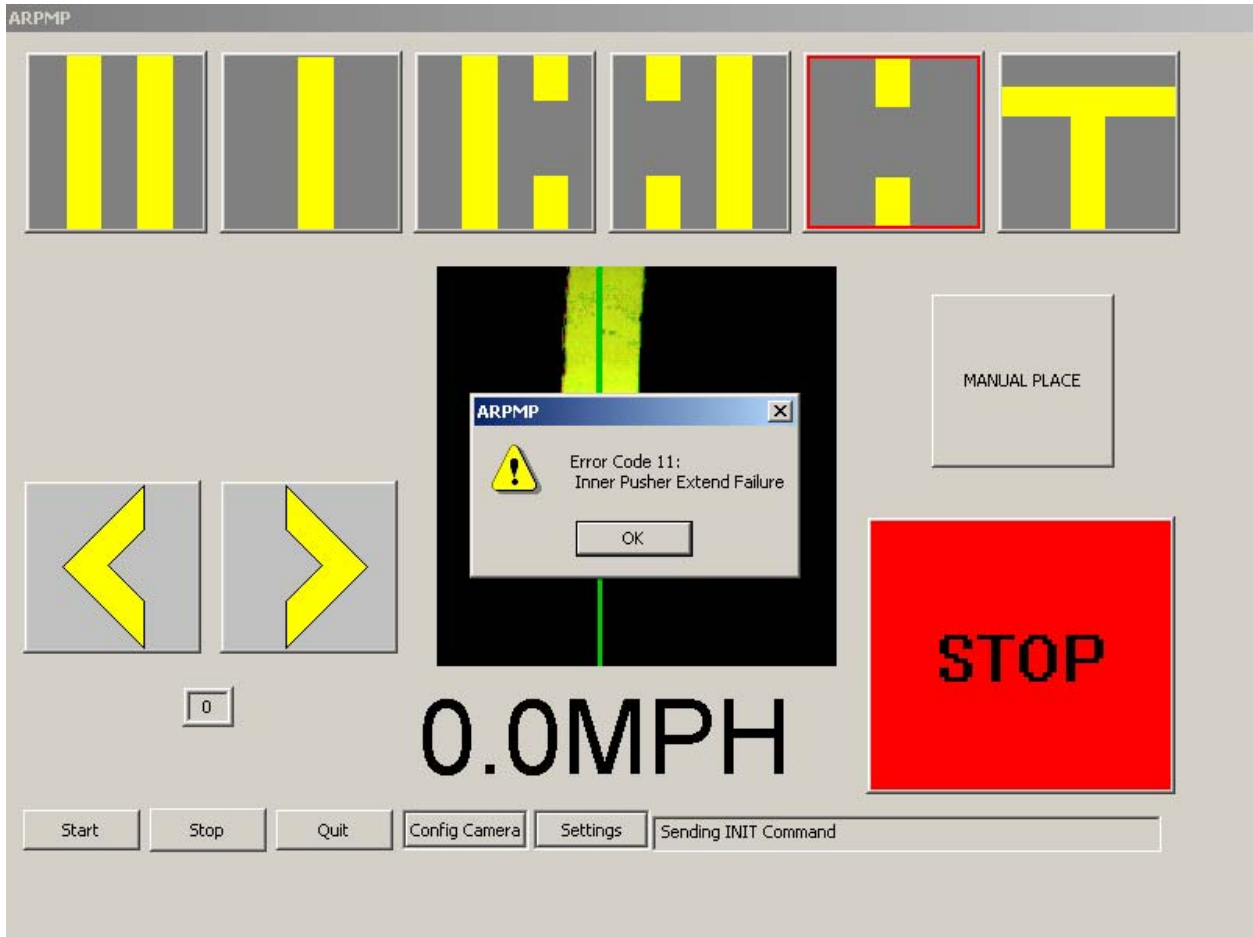
Figure 13 - User Interface with Error Message

System E-Stop Function

When the E-stop is pressed, a message box will notify the user that the system has been halted by an E-stop.
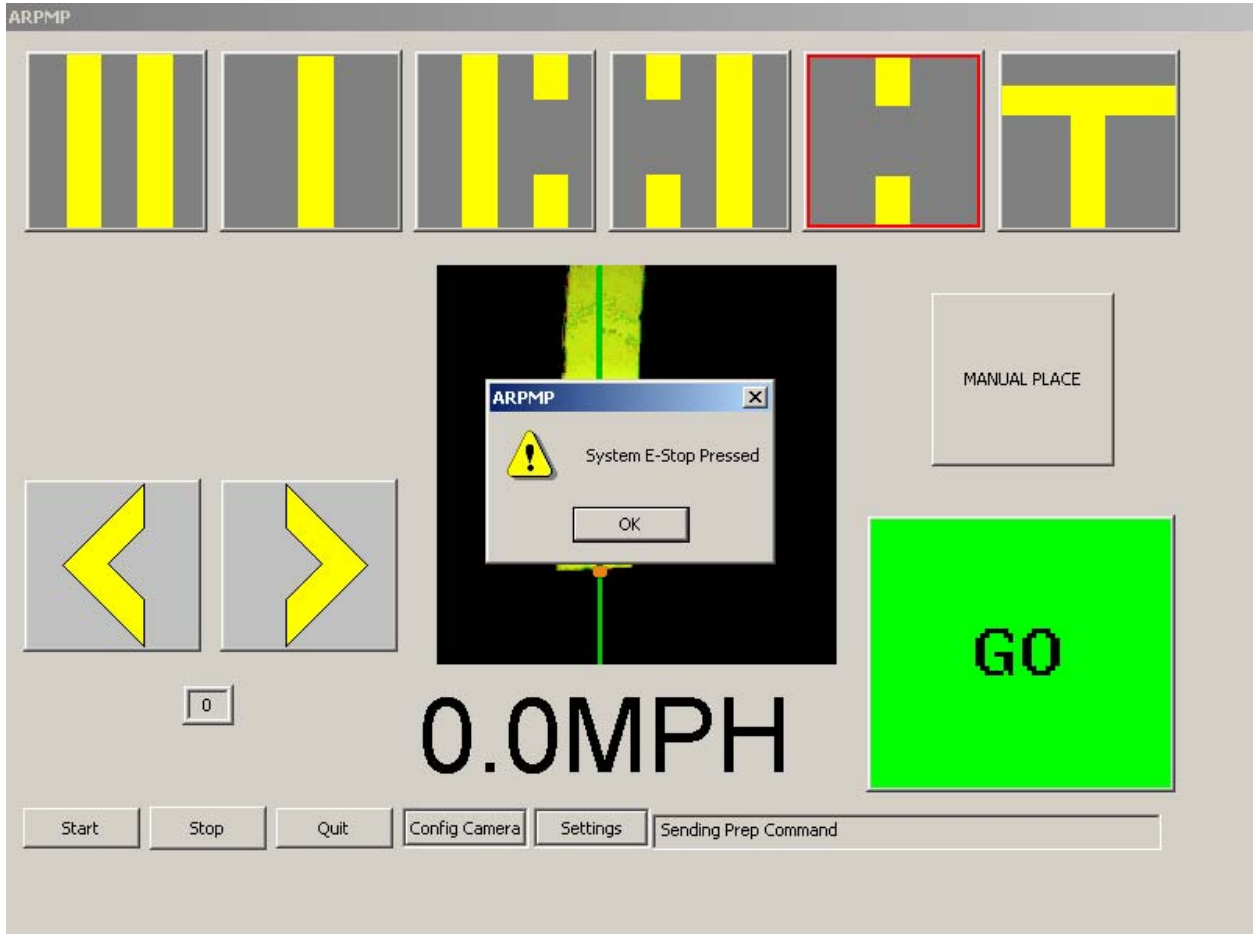
Figure 14

To recover from an E-stop, the user must touch the OK button and then restart the software by hitting the "GO" button. If the system is still in an E-Stop state when the "GO" button is pressed, the system will immediately report to the user that the system is still in an E-Stop state.

Error Code Descriptions
Placement Device Errors 5, 10 – 18

These errors will be reported to the User Interface when a hardware malfunction occurs with the placement device. When one of these errors occurs, the hardware placement device must be inspected manually for any problems.

| Error Message	Cause	Resolution
Error Code 05 No Signal From PC	The RPM device never received a placement signal it was expecting from the PC.	Check between the OPTO-22 card and the Servo I/O board to ensure all cables are connected. Press the OK button to clear the error and resume operation.
Error Code 10 Inner Pusher Retract Failure	The RPM pusher failed to retract during a placement or a prep command.	Check placement device for any errors such as disconnected cables or debris blocking the hardware operation. Press the OK button to clear the error and resume operation.
Error Code 11 Inner Pusher Extend Failure	The RPM pusher failed to extend during a placement or a prep command.	Check placement device for any errors such as marker jam, disconnected cables, or debris blocking the hardware operation. Press the OK button to clear the error and resume operation.
Error Code 12 Outer Pusher Retract Failure	The RPM pusher failed to retract during a placement or a prep command.	Check placement device for any errors such as disconnected cables or debris blocking the hardware operation. Press the OK button to clear the error and resume operation.
Error Code 13 Outer Pusher Extend Failure	The RPM pusher failed to extend during a placement or a prep command.	Check placement device for any errors such as marker jam, disconnected cables, or debris blocking the hardware operation. Press the OK button to clear the error and resume operation.
Error Code 14 No Pattern Set	The system is started, but no pattern is selected.	Press the OK button to clear the error and select the appropriate stripe pattern.
Error Code 15 No RPM Present on Inner Placement Ramp	A placement trigger was received with no RPM present.	Inspect inner hopper, dispenser, and telescoping slide to resolve marker feeding problem. Press OK to clear the error.
Error Code 17 No RPM Present on Outer Placement Ramp	A placement trigger was received with no RPM present.	Inspect outer hopper, dispenser, and telescoping slide to resolve marker feeding problem. Press OK to clear the error.
Error Code 18 Error in Check Error Command	This error is displayed when an unknown error code is returned.	Inspect placement device. Press OK to clear the error and resume operation.

Other Errors 20 – 29, 38, 39

A failed hardware device causes all of the errors below. Lack of power, loose cabling, or device failure are causes of these errors. If any of the errors below occur, once the hardware problem is resolved, the system will require a reboot.

Error Message	Cause	Resolution
Error Code 20 Config File Not Found	System configuration file is missing or not loaded properly.	Verify location of CSystemCFG.cfg file and restart RPM software. This file should be located in the same directory as the executable file (arpmp.exe).
Error Code 21 Unable to Connect to Ethernet	Servo controller lacks power. Cable between PC and controller not connected. Random communication error.	Verify network cable connection between PC system and servo controller. Verify Servo controller is powered up. Restart RPM software.
Error Code 22 No Camera Detected	Camera not detected by PC.	Check cable and connection to camera from PC. Restart RPM software.
Error Code 23 Unable to Initialize Camera	Camera not detected by PC. Camera detected by PC, but unable to be initialized.	Check cable and connection to camera from PC. Restart RPM software.
Error Code 24 Camera was not Initialized Correctly	Camera not detected by PC. Camera detected by PC, but unable to be initialized.	Check cable and connection to camera from PC. Restart RPM software.
Error Code 25 Camera/PC System Error, Press OK to Stop Processing	PC encountered unrecoverable error and needs to stop the placement system.	Check all CPU connections/cables. Restart RPM software.
Error Code 26 Opto Card was not Initialized	PC was unable to initialize the I/O card.	Check Opto-22 card and cables. Restart RPM software.
Error Code 38 Servo Thread did not Start	System encountered error while trying to start the servo controller communication.	Restart RPM software. Reboot computer if problem persists.
Error Code 38 Opto Thread did not Start (could not stop opto thread)	System encountered error while trying to start the I/O card module.	Restart RPM software. Reboot computer if problem persists.
Error Code 27 Could not Stop Servo Thread	System encountered error while trying to stop servo controller communication.	No resolution. System should successfully recover when next started.
Error Code 28 Could not Stop Opto Thread	System encountered error while trying to stop the I/O card module.	No resolution. System should successfully recover when next started.
Error Code 29 System Emergency Stop Pressed	The system is in an emergency-stop condition.	Reset emergency-stop button and reset emergency stop relay. Press OK on message box to clear E-Stop and press "GO" on user interface to continue system operation.

System Communication Errors 30 – 37

Occasionally, the system communication may get out of synchronization due to external factors. The software is designed to automatically recover from errors in communication. If the system is unable to recover from a communication error, a reboot of the system will usually clear the problem. These types of errors are very rare.

Error Message	Cause	Resolution
Error Code 30 Error in Move CMD	PC system was unable to successfully send a MOVE command to the controller.	Press the OK button on the message box.*
Error Code 31 Error in Stop Program CMD	PC system was unable to successfully send a STOP PROGRAM command to the controller. This means that when a user attempted to shut down the RPM system by hitting the STOP button, the RPM system did not successfully shut down.	Press the OK button on the message box.*
Error Code 32 Error in Place CMD	PC system was unable to successfully send a PLACE RPM command to the controller. This means that an RPM placement location was identified, but the RPM was not placed.	Press the OK button on the message box.*
Error Code 33 Error in Manual Place CMD	PC system was unable to successfully send a MANUAL PLACE RPM command to the controller. This means that the RPM was not placed because of a communication problem.	Press the OK button on the message box.*
Error Code 34 Error in Prep CMD	PC system was unable to successfully send a PREP command to the controller. An RPM was not prepped for the next placement.	Press the OK button on the message box.*
Error Code 35 Error in Check Error CMD	PC system was unable to communicate with the controller to receive an error message from the controller.	Press the OK button on the message box.*
Error Code 36 Error Sending Clear Error CMD	PC system was unable to successfully send a CLEAR ERROR command to the controller.	Press the OK button on the message box.*
Error Code 37 Error in Pattern Change CMD		Press the OK button on the message box.*

*The software has been designed to automatically recover from any communication errors. If a communication error persists, check all cabling and power to the hardware and restart the entire system. If a restart does not solve the problem, it is possible that a cable or piece of hardware is malfunctioning.

| Error Code 38
Servo Thread did not Start | See Page 28 | |
| Error Code 38
Opto Thread did not Start
(could not stop opto thread) | See Page 28 | |

Configuration Variable Explanations

This document lists the Configuration File (CSystemConfig.xml) variables and a short description of their purpose.

- **m_logFileBase** – Name of the log file for the system to use.
- **m_logFileDir** – Location of Log File.
- **m_logFileMaxSize** – Maximum allowable log file size.
- **m_logLevel** – Specifies how much information to log, such as run-time, or debug level logging.
- **SnapCount** – Number of encoder counts necessary before capturing an image of the road surface. Default is 1,200 counts.
- **PlacementOffset** – Distance in encoder counts from the camera leading edge FOV to the exit of the RPM placement device.
- **BGThreshold** – The manual offset from the peak red histogram value used in background removal routine
- **ActuatorTimeDelay** - The time for the PC software to "Sleep" and wait for actuation of the RPM placement hardware.
- **CountsPerPixel –** Number of encoder counts per pixel used to make conversion from pixel values to encoder coordinates.
- **EdgeOffset** - Offset in encoder counts of the desired distance from a stripe edge to place an RPM.
- **PlacementCount** – Distance in encoder counts of desired placement distance from one RPM to the next (typically 80 ft).
- **ServoCoordsOut** – Number of encoder counts to move servo device 1 foot to the outside.
- **ServoCoordsIn** - Number of encoder counts to move servo device 1 foot to the inside.
- **PixelsPerInch** – The number of pixels per inch.
- **Boom_Distance** – Distance from the front of the truck boom to the location of the placement device.
- **m_feetPerEncoderCount** – The number of feet per encoder count.
- **m_camera_red** – The camera's red value for color processing.
- **m_camera_green** – The camera's green value for color processing.
- **m_camera_blue** – The camera's blue value for color processing.
- **m_camera_gain** – The camera's gain value in decibels.
- **m_camera_integrationTime** – The camera's integration time in milliseconds.
- **m_farLimitSwitchChannel** – The opto22 far limit switch channel.
- **m_nearLimitSwitchChannel** – The opto22 near limit switch channel.

```
<CSystemConfig>
        <m_logFileBase>logfile</m_logFileBase>
        <m_logFileDir>.\</m_logFileDir>
        <m_logFileMaxSize>100000000</m_logFileMaxSize>
        <m_logLevel>3</m_logLevel>
        <SnapCount>1500</SnapCount>
        <PlacementOffset>19000</PlacementOffset>
        <BGThreshold>40</BGThreshold>
        <ActuatorTimeDelay>200</ActuatorTimeDelay>
        <CountsPerPixel>6.45</CountsPerPixel>
        <EdgeOffset>6000.000000</EdgeOffset>
        <PlacementCount>50000</PlacementCount>
        <ServoCoordsOut>14126</ServoCoordsOut>
        <ServoCoordsIn>10900</ServoCoordsIn>
        <PixelsPerInch>20.00000</PixelsPerInch>
        <Boom_Distance>92879.000000</Boom_Distance>
        <m_feetPerEncoderCount>.000666667</m_feetPerEncoderCount>
        <m_camera_red>42</m_camera_red>
        <m_camera_green>62</m_camera_green>
        <m_camera_blue>61</m_camera_blue>
        <m_camera_gain>4.15</m_camera_gain>
        <m_camera_integrationTime>3.5</m_camera_integrationTime>
        <m_farLimitSwitchChannel>2</m_farLimitSwitchChannel>
        <m_nearLimitSwitchChannel>3</m_nearLimitSwitchChannel>
        <m_findRpms>0</m_findRpms>
        <m_determinePattern>0</m_determinePattern>
        <m_automaticThresholding>1</m_automaticThresholding>
        <m_histogramSmoothAmount>0</m_histogramSmoothAmount>
        <fx>491.84404805284811</fx>
        <fy>491.939753564028</fy>
        <cx>337.55881078588271</cx>
        <cy>234.36227186940596</cy>
        <k1>-0.36072540018896587</k1>
        <k2>0.15667255074456543</k2>
        <p1>0.00019523632630189756</p1>
        <p2>-0.0010369948417614215</p2>
        <PlaceAfterSkip>1</PlaceAfterSkip>
        <DeadZone>5</DeadZone>
</CSystemConfig>
```

Automated RPM Placement System Reference Guide – Revision 1.1

Start-up Procedure
1. Start air compressor.
2. Start generator.
3. Turn ON main disconnect switch.
4. Lower odometer wheel onto tire.
5. Deploy placement mechanism.
    a. Release tie down straps on placement mechanisms and telescoping slides.
    b. Raise the placement mechanism using the manual air valve beside the placement mechanism.
    c. Remove the clevis pin at the bottom of the turn buckle that supports the placement mechanism.
    d. Lower the placement mechanism using the manual air valve beside the placement mechanism.
    e. Jog out the placement mechanism using the pendant.
6. Deploy guide boom.
7. Monitor melter-pump unit display until temperatures reach setpoints.
8. Turn ON UPS (uninterruptible power supply).
9. Turn ON PC (Stripe Tracker personal computer).
10. Turn ON adhesive pump.
11. Double click to launch ARPMP Application.
12. Position the image-capture system over a lane stripe.
13. Open camera configuration window to display a processed image of the stripe and verify that camera settings are acceptable.
14. Open settings window and set desired configuration
    (placement distance, offset distance from end of skip,
    placement before or after the skip).
15. Press appropriate pattern-selection button.
16. Press START button on user interface.

Placement Operation

Driver responsibilities
Steer vehicle to keep guide caster on lane stripe.
Maintain speed at 5 mph.
Select new pattern button when guide caster crosses a change in stripe pattern.

Operator responsibilities
Load hot-melt adhesive into melter-pump unit.
Load markers into hoppers in proper orientation.
Observe marker placement for straightness and position of marker on adhesive puddle. Request vehicle stop if adjustments are necessary to improve marker placement quality.
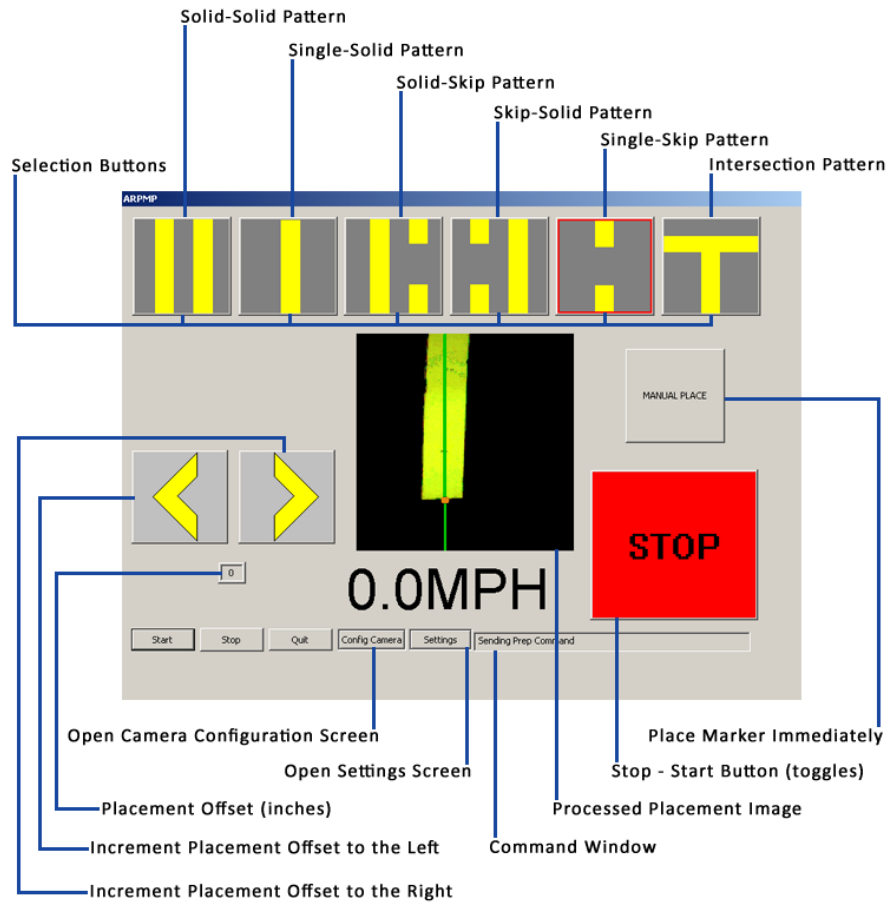
Figure 1 *above*: Main Operator Screen
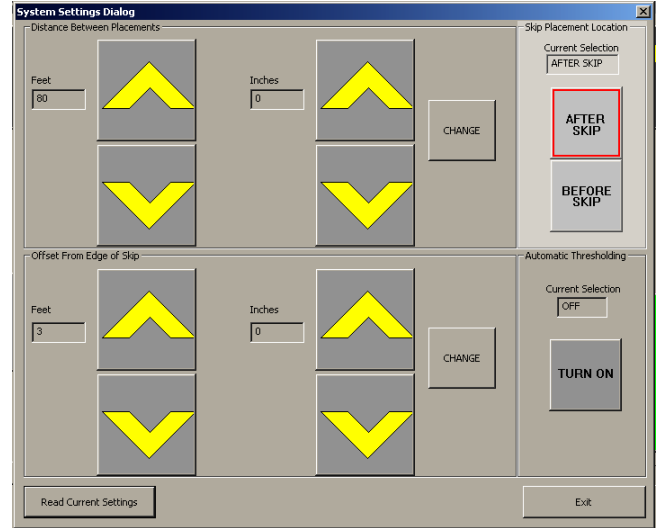**Figure 2** *below*: Camera Configuration Screen
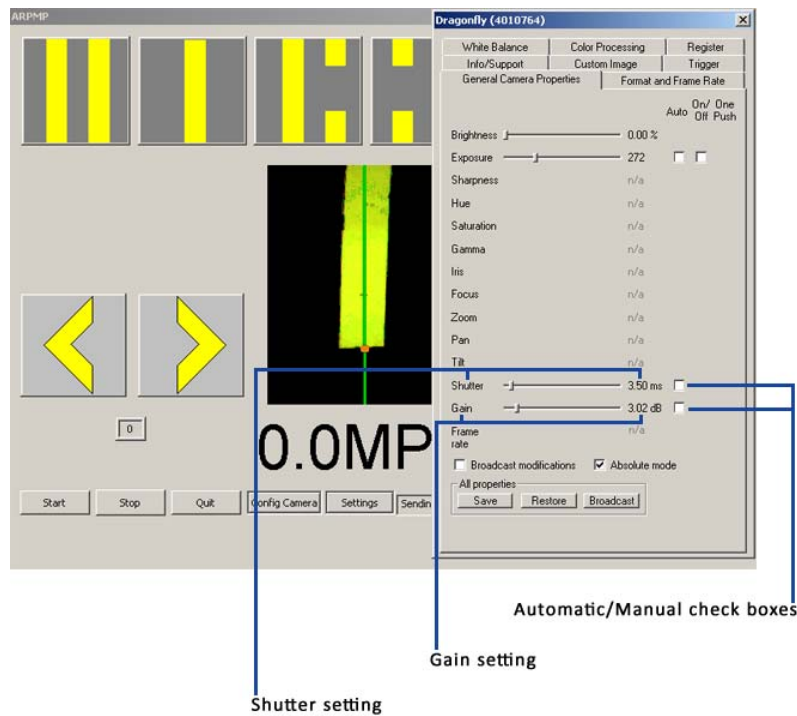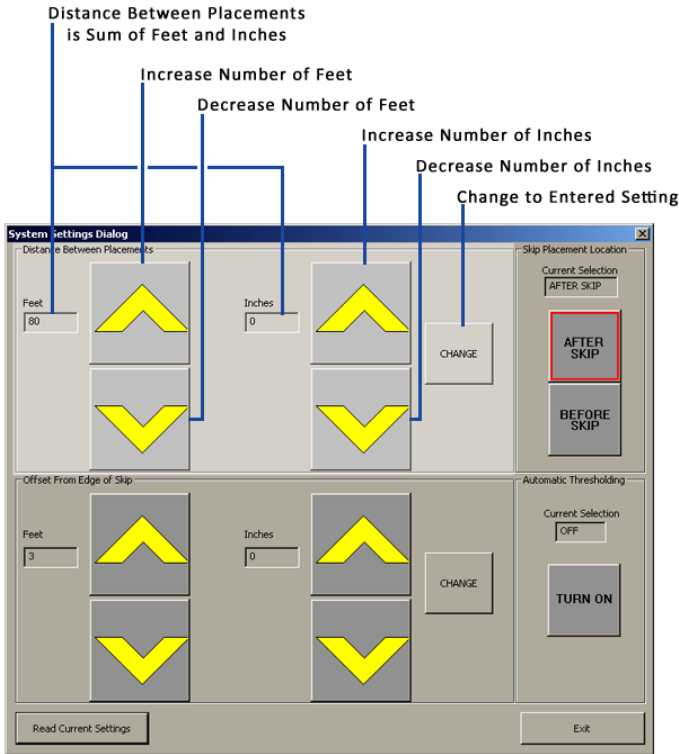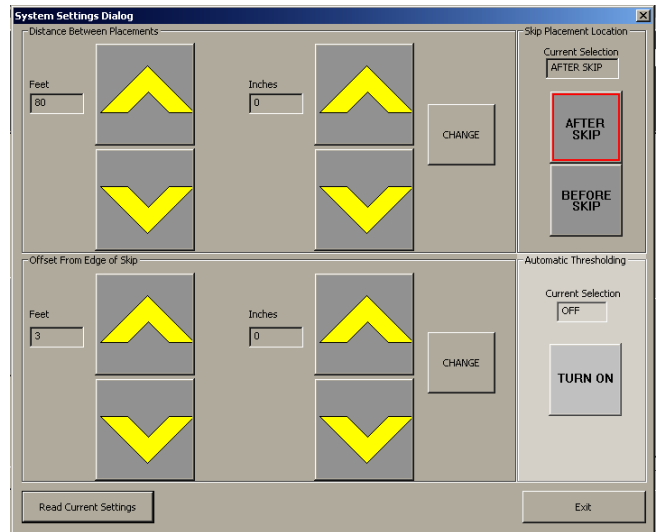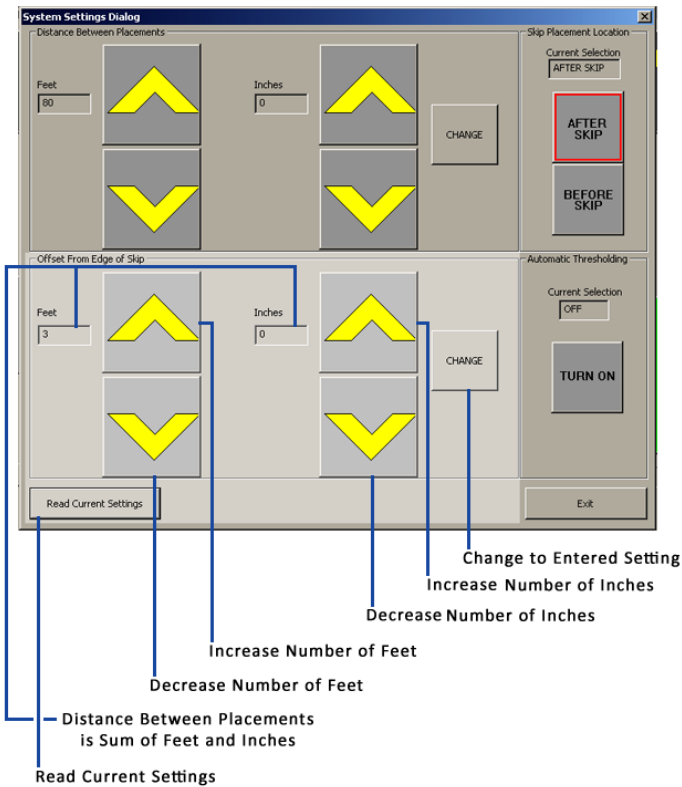
Figure 3 *above*: Configuration Screen
distance-between-placements setting
Figure 4 *below*: Configuration Screen
offset-from-edge-of-skip setting

Figure 5 *above*: Configuration Screen
place-before-or-after-the-skip selection
Figure 6 *below*: Configuration Screen
automatic-thresholding selection

Save Date 9/9/2008

Shut-down Procedure

1. Press STOP button on user interface.
2. Shut Down PC (Stripe Tracker personal computer).
3. Switch air compressor from RUN to START to begin 5-minute, cool-down period for air compressor engine.
4. Turn OFF main disconnect switch to begin 5-minute, cool-down period for generator engine.
5. Stow guide boom.
6. Stow placement mechanism.
   a. Jog in the placement mechanism using the pendant.
   b. Raise the placement mechanism using the manual air valve beside the placement mechanism.
   c. Install the clevis pin at the bottom of the turn buckle that supports the placement mechanism.
   d. Install the tie down straps on placement mechanisms and telescoping slides.
7. Stow the odometer.
8. Turn OFF UPS (uninterruptible power supply).
9. Shut down air compressor.
10. Shut down generator.