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FABRICATION AND TESTING OF MAINTENANCE EQUIPMENT USED FOR PAVEMENT SURFACE REPAIRS

Automated Crack Sealing Machine Operation And Maintenance Manual

SHRP H-107A

Participating Organizations
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The success of this project has come from a concerted effort of individuals from Caltrans, Bechtel, and ERES in addition to a great team of students and staff from the University of California at Davis.

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Abstract

This document presents information essential to the proper operation and maintenance of the Automated Crack Sealing Machine (ACSM) which was developed under the SHRP H-107A project. The ACSM is relatively complex, and thus, this document is intended to provide potential users with adequate information for the operation and maintenance of the ACSM. The ACSM is comprised of two independent machine systems, one for longitudinal cracks and joints that exist at the edge of the lane (e.g., construction joints), and the other for general (random or transverse) cracks/joints that may extend across the roadway. This report discusses non operational considerations for the ACSM including transport to and from the work zone and storage of the machine, possible system configurations for both longitudinal and general crack sealing operations, instructions that are common to both systems, details related to the set-up, deployment, operation and shut down of each system, and finally, maintenance procedures for the various machine components.

Executive Summary

Worldwide, a tremendous amount of resources are expended annually maintaining highway pavement. Highway maintenance activities are generally labor-intensive and dangerous to both the workers and the traveling public. It is quite evident to most travelers that improved materials and procedures including the use of more advanced technologies are severely needed. This is even more pronounced in light of the significant current fiscal crises being experienced at all levels of government. Accordingly, the Strategic Highway Research Program (SHRP) has had the improvement of pavement maintenance as one of its primary goals. This area has been addressed in research projects in several key areas. These areas include a study of pavement maintenance effectiveness (SHRP H-101), maintenance measuring equipment (SHRP H-103 and H-104), improving work zone safety (SHRP H-108 and H-109), and the development of improved maintenance equipment (SHRP H-105 and H-107). Recognizing the need to additionally transfer these findings, SHRP has funded an implementation effort as well (SHRP H-110).

The research reported herein was performed under SHRP project H-107A, *Fabrication and Testing of Maintenance Equipment Used for Pavement Surface Repairs - Crack and Joint Sealing*. This study has been performed in parallel to SHRP H-107B which is aimed at the development of equipment for pothole repairs. The SHRP H-107 study was begun in December 1990 and was completed in March 1993. The ultimate goal of the SHRP H-107A project was to develop prototype automated machinery that will sense, prepare, and seal (or fill) cracks and joints on pavement. As such, the primary objectives of this project were to design machinery for the sealing and filling of joints and cracks in pavement in order to:

- Increase the cost-effectiveness of these operations,
- Increase the quality, consistency, and life of the resultant seals and fills,
- Increase the safety of workers and highway users, and
- Increase the use of remote operation and control of equipment to attain the above.

Machinery that satisfies these objectives will additionally reduce lane and highway closures and thus, will play a significant role in reducing traffic congestion, an area of considerable concern in the major urban regions around the world. The cost effectiveness of such machinery comes from a combination of

the increased speed and reduced manpower needs, in addition to the higher quality seal which will reduce the frequency of major highway rehabilitation's. Furthermore, considerable cost savings will be realized through improved worker safety, improved safety for the traveling public, and reduced congestion related costs.

This document is intended to provide potential users with adequate information for the operation and maintenance of the ACSM. The ACSM is comprised of two independent machine systems, one for longitudinal cracks and joints that exist at the edge of the lane (e.g., construction joints), and the other for general (random or transverse) cracks/joints that may extend across the roadway. This report discusses non operational considerations for the ACSM including transport to and from the work zone and storage of the machine, possible system configurations for both longitudinal and general crack sealing operations, instructions that are common to both systems, details related to the set-up, deployment, operation and shut down of each system, and finally, maintenance procedures for the various machine components.

This document constitutes Volume 2 of the Final Report for SHRP H-107A. The first volume of the report provides information on the development of the ACSM, including market and cost analyses, and provides details of the machine, its subsystems and its components including technical drawings.

1

BASIC INFORMATION

1.1 - Introduction

Worldwide, a tremendous amount of resources are expended annually maintaining highway pavement. In California alone, the state Department of Transportation (Caltrans) spends about $100 million per year maintaining approximately 33,000 lane-miles of flexible pavement (Asphalt Concrete - AC) and 13,000 lane-miles of rigid pavement (Portland Cement Concrete - PCC). A portion of these maintenance activities involves the sealing and filling of cracks (approximately $10 million per year) which, when properly performed, can help retain the structural integrity of the roadway and considerably extend the mean time between major rehabilitation.

The sealing and filling of cracks are tedious, labor-intensive operations. A typical operation to seal transverse cracks in AC pavement involves a crew of eight individuals which can seal between one and two lane miles per day. The associated costs are approximately $1800 per mile with 66% attributed to labor, 22% to equipment and 12% to materials. Furthermore, the procedure is not standardized and there is a large distribution in the quality of the resultant seal. In addition, the crack sealing work team is exposed to a great deal of danger from moving traffic in adjacent lanes.

The ultimate goal of the SHRP H-107A project was to develop prototype automated machinery that will sense, prepare, and seal (or fill) cracks and joints on pavement. As such, the primary objectives of this project were to design machinery for the sealing and filling of joints and cracks in pavement in order to:

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Machinery that satisfies these objectives will additionally reduce lane and highway closures and thus, will play a significant role in reducing traffic congestion, an area of considerable concern in the major urban regions around the world. The cost effectiveness of such machinery comes from a combination of the increased speed and reduced manpower needs, in addition to the higher quality seal which will reduce the frequency of major highway rehabilitation's.

During the course of this project, an Automated Crack Sealing Machine (ACSM) has been developed that meets the objectives listed above. The machine is relatively complex, and thus the purpose of this document is to provide operators with sufficient information to adequately run the machine. Details of the machine development, system architecture, component descriptions including detailed drawings, and commercialization issues are discussed in Volume 1 of the Final Report for SHRP H-107A.

1.2 - System Overview

The Automated Crack Sealing Machine (ACSM) is capable of tracking, preparing and sealing most common roadway cracks with a crew of three on board. It is a complete self contained unit able to drive at highway speeds during transport, and it can carry enough supplies for a full day's operation. Currently, the machine is set-up to seal flexible pavement cracks ranging from one eighth inch (3.2 mm) to one half inch wide (12.7 mm) and at least seven inches (178 mm) in length. The sealant generally applied by this machine is a hot applied polymer modified asphalt. Other sealants may be substituted, but the manufacturer should be contacted first for approval. The roadway cracks can be prepared prior to sealing in a variety of ways depending upon the preferences of the operator. The crack sealing machine can be configured to rout flexible pavement in either a low profile or one to one shape factor cut, heat the pavement or blow out the crack. This tooling can also be combined or configured with all three operating simultaneously prior to sealing. The Sealant Applicator, crack tooling and related support systems will be referred to in this document as the Applicator and Peripherals System or APS.

The crack sealing machine is fitted with two different mechanisms that present the APS to the road surface. Since both mechanisms share the same APS components, the machine can only support the operation of one of these mechanisms at a time. The Integrated Longitudinal Crack Sealing System is mounted on the side of the vehicle and it is designed to track and seal fairly straight longitudinal cracks along the edge of the lanes at relatively high speeds. The Integrated General Crack Sealing System is

mounted at the rear of the vehicle and it can track and seal cracks that run in any direction within the lane. The overall method of operation of each of these systems will now be discussed.

1.2.1 - Integrated Longitudinal Crack Sealing System

The longitudinal crack sealing machine consists of the Longitudinal Robotic Positioning System (LRPS), the Local Sensing System (LSS), the Applicator and Peripherals System (APS), and a control computer. The detailed descriptions of the LRPS, the LSS, and the APS are given in Chapter 4 of Volume 1 of the Final Report for SHRP H-107A, and the role of the control computer will be described below. Here, the interaction between these components during the operation of the longitudinal machine is described.

Unlike the general machine, there is no need for a global vision system to identify the location of the cracks when using the longitudinal machine, since the nature of the cracks addressed by the longitudinal machine is much more restricted. In addition, there is no need to pre-plan a path for the longitudinal machine. During operation of the longitudinal machine, the driver of the vehicle merely needs to maintain the center of the LRPS near the position of the longitudinal crack to be sealed. This can be done visually using a pointing device, or using a camera and a monitor.

The position of the LRPS is controlled by a hydraulic actuator, with the loop closed by a position transducer located on the hydraulic cylinder. This controller is capable of accurately positioning the center of the LRPS in the lateral direction, i.e. perpendicular to the centerline of the cart. The longitudinal motion of the system is dictated entirely by the motion of the vehicle.

The LSS is mounted as part of the crack sealing tooling for the LRPS. This sensor provides an error signal, which represents the offset of the center of the LRPS to the center of the longitudinal crack. This signal is used by the control computer to modify the desired position input for the closed-loop control system. This signal is then communicated to the actual closed-loop controller using an RS-232 serial communication line. With this updated position command, the LRPS can then track in to the actual crack position.

If, due to either large motion of the crack or the crack sealing vehicle, the longitudinal crack moves out of the 4 inch field of view of the LSS, the LSS will issue a saturated error signal, which will then drive the position command in the direction that the crack was last seen. In most cases, this will drive the LRPS back to the crack, and then the closed-loop control to follow the crack can proceed. If the LSS

does not detect a crack again within the range of motion of the LRPS, then an error signal can be generated to the ICU, which will then handle the situation by sending a signal to the operator.

The ICU will be used to maintain high-level control of the LRPS, and to receive status information from the control computer and the LSS. The ICU will function to initiate and terminate the sealant flow and the router. However, the LRPS, LSS and the control computer have been designed so that they can operate as a stand-alone unit, without the assistance of the ICU.

Finally, the LRPS can be manually controlled by an operator with a joystick. The operator moves the joystick in one DOF, and the LRPS cart extends or retracts based on the position of the joystick. The operator uses a video screen to monitor the position of the centerline of the LRPS cart and the crack, and jogs the stick to keep the cart centered over the crack. Using this method, the LRPS can follow and seal cracks at approximately 10 mph.

Chapter 4 of Volume 1 of the Final Report for SHRP H-107A includes detailed figures and description of the various configurations of the LRPS, and the interested reader is referred to that report for more information.

1.2.3 - Integrated General Crack Sealing System

The general crack sealing machine is composed of the Vision Sensing System (VSS), the Integration and Control Unit (ICU), the path planning module (which resides on the ICU), the Vehicle Orientation and Control (VOC) system, the general Robot Positioning System (RPS), the Applicator and Peripherals System (APS), and the Local Sensing System (LSS). The detailed descriptions for these components are given in Chapter 4 of Volume 1 of the Final Report for SHRP H-107A. In this section, the interaction between these components during operation of the general machine is described.

As the vehicle moves down the road, the VSS will buffer an image of the roadway for 20 feet, approximately half the length of the truck. The VSS identifies potential crack locations using the algorithm described in Section 4.2 of Volume 1 of the Final Report for SHRP H-107A. The output of the VSS consists of row and column numbers for the tiles in the current frame where the VSS located a potential crack, as well as the integer-valued direction number determined by the algorithm. This data is translated into real-world coordinates using information from the VOC; this will be described in more detail later. The VSS data is not in a form that is usable by the RPS, as there is no relationship between the identified crack points as output by the algorithm. The path planning algorithm will convert the data

into a format that is useful to the RPS. The VSS sends this information to the ICU over an Ethernet connection, and then begins to buffer up the next frame of data.

The ICU is the main coordinating process for the general crack sealing machine. All data for the various subsystems is routed through the ICU, and the ICU issues signals to the subsystems and handles signals received from the various subsystems. The ICU will take in the data from the vision system, initiate the path planning process, coordinate the transformation of the planned paths with the VOC data, and issue the paths to the RPS when the identified cracks are in the manipulator workspace. The ICU will also coordinate with the RPS by obtaining information regarding the current status of the crack sealing process. This status information is based mainly on the readings from the LSS, which is used to verify the planned path based on the VSS data, as well as to verify the presence and location of actual cracks. The ICU does not communicate directly with the LSS; instead, it receives LSS data indirectly by way of the RPS.

Once the VSS frame data has been received, the ICU notifies the path planning algorithm that data is ready. The path planning algorithm is part of the ICU, but is a separate process that runs in parallel with the main ICU routines. Path planning is used to clean up the VSS data, form connections between isolated but possibly connected crack segments, and form the data points into ordered sets that constitute reasonable paths for the RPS to follow to complete the crack sealing process. The path planning process begins by forming the VSS data into a matrix which represents an image of the road as identified by the VSS algorithm, and filters the data to clean it up. Then the planner identifies end points of individual segments and attempts to form connections between isolated points according to an empirically determined distance which represents the distance that actually connected crack segments may be separated by when processed by the vision system. The connections are made by placing a circular growth region, with a radius equal to half the above empirically determined distance, around each end point in the frame data. If segments are separated by less than the above distance, then they will be connected after this phase of the planning algorithm. The path planner next 'thins' this data to bring it back to images of cracks, using a thinning algorithm to strip out points in the data set while maintaining the general shape and connectivity of the image. After this, the path planner forms a data structure that represents all the connected crack paths for the entire frame of VSS data. When the ICU passes the coordinates of the current manipulator workspace to the path planning algorithm, it then extracts a data structure representing the connected crack paths for that workspace. This data is then transformed using information from the ICU, and passed to the RPS for sealing of the cracks. For a more detailed description of the path planning algorithm and its relation to the rest of the Integrated General Crack Sealing System, see "Path Planning for Robotic Applications in Roadway Crack Sealing" by T. A. Lasky and B. Ravani.

The VOC system tracks the position and orientation of the crack sealing vehicle relative to a world coordinate reference frame. As the VSS identifies potential crack locations, the VOC uses the position of the truck relative to the world frame, in conjunction with known and fixed transformations between the subsystem reference frames on the vehicle, to mark the position of the crack locations with respect to the world reference frame. At any subsequent time, the VOC can transform this point in the world reference frame into the RPS reference frame, using the known and fixed transformation from the vehicle frame to the RPS frame, along with the current transformation from the world frame to the vehicle frame. Thus, the paths that are established by the path planning algorithm, since they are essentially collections of points identified by the VSS, can be transformed into the RPS reference frame so that the RPS can guide its tooling along this path to seal the cracks.

The RPS takes the planned and transformed path from the ICU, and uses this path to position the tooling to prepare and seal the identified crack. The communication between the ICU and the RPS is over an RS-232 serial line. The RPS will initially use the pre-planned path to get to the start of the crack, and will subsequently use this path as a nominal position trajectory. Using the LSS sensor, which is mounted on the manipulator tooling, the RPS can verify the presence or absence of the identified crack. This is required for at least two reasons. First, the VSS cannot distinguish between cracks, oil on the roadway, and previously sealed cracks. As long as the image has the appropriate light/dark histogram to pass the VSS comparison algorithm, it will be identified as a crack. Only the LSS, with its ability to measure the height profile of the road, can actually verify the presence of the crack. Second, there will be accumulated error introduced by the VSS, the path planning algorithm, and the VOC. Without any local feedback of the position of the crack, the RPS would have no way to adjust for this accumulated error. The RPS will use the orientation information from the planned path without modifying it, as the LSS information is insufficient to determine a good measure of the crack orientation. The RPS can use this orientation information to align the tooling with the crack, the offset error of the tooling from the center of the crack can be identified with the LSS, and the RPS can modify its trajectory in a closed-loop fashion to eliminate this error. In the case that the accumulated error exceeds the range of the local sensor, the RPS can enter a search mode, in which it scans perpendicular to the assumed direction of the crack, until it locates a crack. The RPS will pass signals back to the ICU indicating the status of its operation. For example, the RPS can pass the LSS error signal back to the ICU periodically, and the ICU can monitor this information over time, and use it to identify the need for system or component recalibration. In addition, the RPS will send its location back to the ICU to facilitate control of the Sealant Applicator.

1.3 - Report Summary

This document is Volume 2 of the Final Report of SHRP H-107A: Fabrication and Testing of Maintenance Equipment Used for Pavement Surface Repairs. This document is intended to provide potential users with adequate information for the operation and maintenance of the ACSM. Chapter 2 discusses non operational considerations for the ACSM including transport to and from the work zone and storage of the machine. Chapter 3 presents the possible system configurations for both longitudinal and general crack sealing operations. Chapter 4 presents instructions that are common to both the Integrated General Crack Sealing System and the Integrated Longitudinal Crack Sealing System. Chapters 5 and 6 present details related to the set-up, deployment, operation and shut down of the Integrated Longitudinal Crack Sealing System and the Integrated General Crack Sealing System, respectively. Finally, Chapter 7 presents maintenance procedures for the various machine components of the ACSM.

2

NON OPERATIONAL CONSIDERATIONS

2.1 - Transport

The following guidelines describe the necessary steps that must be taken when the Automated Crack Sealing Machine is to be transported as shown in Fig. 2.1.1 or parked. It is recommended that the exposure of the machine to moisture be minimized, to extend the life of certain components that are not completely enclosed. For security reasons, it is also recommended that the vehicle be parked or stored inside a secured area whenever possible.

2.1.1- Within the Work Zone

In the process of sealing cracks, if the ACSM needs to moved to another location further down the roadway, the machine may be driven operational and deployed. The APS may not be engaged with the road, but all other systems may be left operational and the crew members may remain upon the truck bed. While driving deployed, the vehicle can travel at a maximum speed of 15 mph (24 km/hr). The driver may watch for obstructions that may be in the path of the LRPS cart, on the truck cab monitor. The vehicle speed must be reduced to the previous working speed to continue sealing cracks.

Figure 2.1.1 - The ACSM In Transport.(need)

2.1.2 - Highway Travel

To transport the ACSM to and from highway work zones, it must be completely shutdown, retracted and secured. All of the machine's power systems should be disconnected and the communication headsets stowed. The crew should leave the truck bed and stow the bed stairs. The generator access doors should be locked and the rear surveillance camera deployed. The complete start-up or shutdown procedures are detailed throughout this text. The ACSM should be covered when transported in the rain or driven long distances.

2.2 - Parking

To park the ACSM, all of the crack sealing systems must be shutdown, retracted and secured into their proper transport positions. If the ACSM is to be parked inside an enclosed space, the propane bottles must be removed from the truck bed and the cylinders stored outside or in a well ventilated area.

2.2.1- Quick Stop

When the truck engine has been brought up to normal operating temperature, it must be allowed to cool down prior to turning it off. The manufacturer of the White GMC truck recommends that the engine be cooled by idling it for five to ten minutes to prolong the life of the turbocharger system.

2.2.2 - Overnight

When the ACSM is parked overnight, or for several of hours, the following procedure should be followed. For outside parking in wet weather conditions, it is recommended that the truck be covered with its custom tarp. For hot weather above 120° F, or cold weather below 60° F, the Control Booth heater/air conditioner must be plugged into an external 120 VAC power source to protect the machine's computers (see Fig. 2.2.1).

Figure 2.2.1 - Control Booth Air Conditioner/Heater External Plug.

Overnight Shutdown Procedure:

1. Cool down the truck engine and turn it off.
2. Close the isolation valve on the auxiliary tank (see Fig. 2.2.2 Item A)
3. Open the 12 VDC knife switch in the truck's 12 VDC battery compartment (see Fig. 2.2.3 Item B)
4. Verify that the Uninterruptible Power Supply (UPS) is off (see Section 4.4.3)
5. Lock the access to both the truck cab and the control booth and remove all system control keys.

2.2.3 - Long-term

If the ACSM is to stored for longer than a week, the trucks air pressure should be monitored. The air pressure should not drop below 60 psi to protect the trucks air suspension system. If the air pressure should run low the truck's engine may be idled to allow its air compressor to repressurize the system. If the ACSM is stored outside, it should be covered with the custom tarp and power should be supplied to the control booth's AC/heater unit.

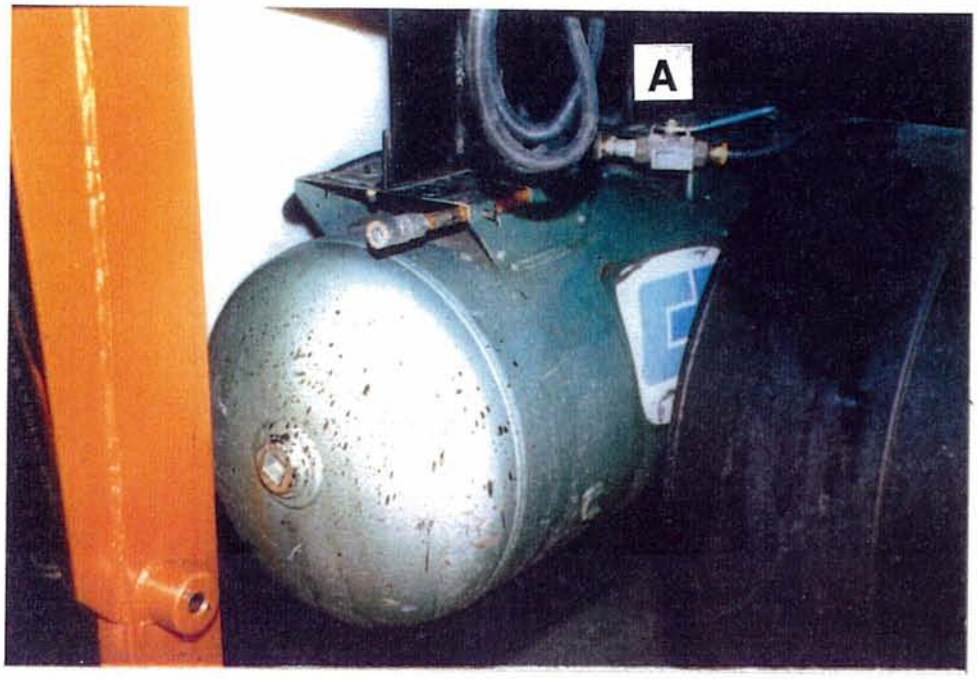


Figure 2.2.2 - Auxiliary Air Tank And Isolation Valve.

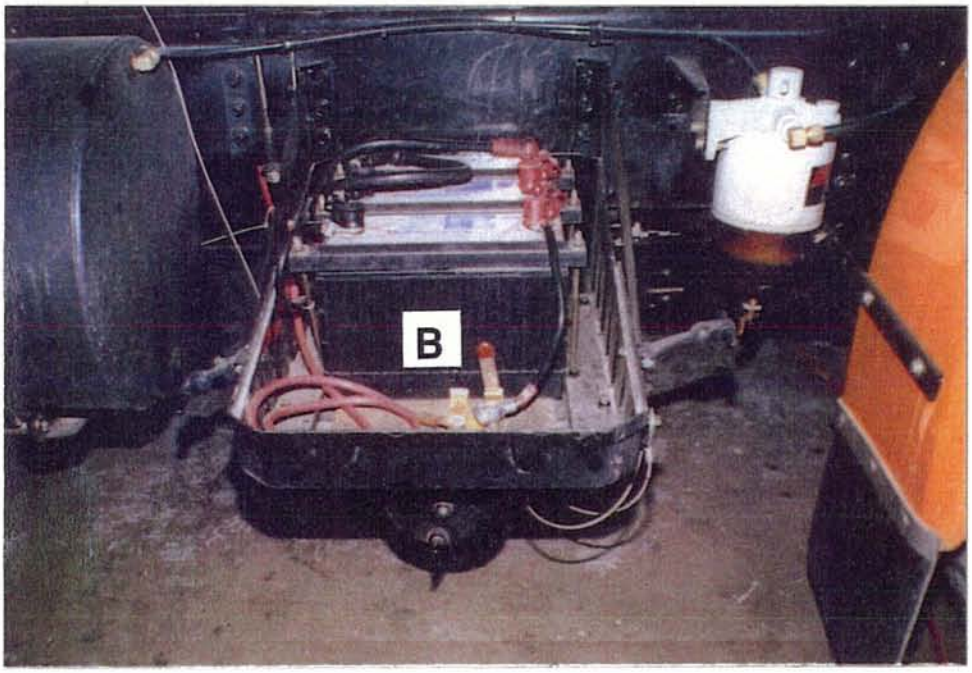


Figure 2.2.3 - Truck Battery Compartment And 12 VDC Knife Switch.

3

SYSTEM CONFIGURATIONS

3.1 - Basic Information

The Automated Crack Sealing Machine may be set-up in several different configurations to employ a large variety of crack sealing techniques representative of those currently employed. It is the responsibility of the user to determine the appropriateness of the equipment contained onboard the ACSM as it pertains to a particular road site and to choose the machine configuration that will produce the best results. It is recommended that the fairly straight cracks along the edges of the lane be sealed separately from all other cracks within the lane due to the ACSM's ability to seal the longitudinal cracks at a significantly higher production rate.

The ACSM should be configured, tested, and supplied, and the crew briefed on their responsibilities prior to deploying it on a working roadway. Furthermore, to minimize the crew's exposure to traffic, it is recommended that the machine never be reconfigured on a working roadway.

3.2 - Integrated Longitudinal Crack Sealing System Configuration

The Integrated Longitudinal Crack Sealing System's (ILCSS) Longitudinal Robot Positioning System (LRPS) mounted on the side of the ACSM, is designed to deploy a tooling cart to the road. The cart, shown in Fig. 3.2.1, rolls along the road surface on two caster wheel assemblies. The ACSM supplies the forward cart motion and guidance is provided by the lateral movement of the hydraulic cylinder on the mechanism. The cart has provisions to allow the attachment of each of the APS components in the correct proximity to the pavement surface. The exact location of the APS components may vary

depending upon the particular combination of components installed. The cart is large enough to mount all of the APS components together as necessary. In all cases, the installation or removal of the APS components from the LRPS tooling cart is best accessed with the LRPS deployed and all electric power disconnected. With any of the APS components mounted to the cart, the LRPS can be retracted for transport without disassembly.

Figure 3.2.1 - LRPS Tooling Cart With One Wheel Removed.

3.2.1- Sealant Applicator

As noted earlier, the sealant applicator is used in both the Integrated General and Longitudinal Crack Sealing Systems. The sealant applicator base remains mounted to the cart, and only the sealant applicator core will be moved between the positioning systems. The exact location of attachment in the cart is outlined in Section 3.2.6. The three connections to the sealant applicator are the sealant hose, electronic control cable, pneumatic hose and the flexishaft. The sealant hose remains connected to the sealant applicator core during reconfiguration. The control cable, flexishaft and the pneumatic hose are connected to the sealant applicator base plate with quick disconnections and these lines will need to be

disconnected during reconfiguration. The sealant, control and pneumatic lines are long enough to be routed to both positioning systems. The flexishaft is only an option for the LRPS configuration.

Sealant Applicator Installation:

Starting with the core and the base plate removed.

1. Deploy the LRPS frame (see Section 5.1).
2. Hold the base plate up to the bottom of the LRPS cart in the desired position.
3. Install the four bolts and wedge washers between the plate and cart.
4. Reroute the core and the attached supply hose under the skid as shown.
5. Insert the core into the base (see Fig. 3.2.2).
6. Hold retaining plate up to the heat fin and install the four cap screws through the core cap into it (see Fig. 3.2.3).
7. Connect the air line and the control cable.

Sealant Applicator Removal:

1. Disconnect the air line and the control cable.
2. With the sealant applicator hot, unscrew the core cap and remove the core from its base.
3. Wipe clean the end of the core with a kerosene soaked rag.
4. Set the core aside to cool.
5. Partially retract the LRPS frame so the cart is approximately 4 feet above the ground.
6. Wipe clean the inside of sealant applicator base where the core is in contact with it, with a kerosene soaked rag.

3.2.2 - Blower

The blower and its control system is permanently mounted to the ACSM truck chassis and it will remain intact even if the blower is not to be used. The blower's high volume air output is channeled to the burner and blower nozzle through a flexible hose, see Fig. 3.2.4. If the blower is not to be configured in the LRPS, the burner nozzle assembly is the only part of the blower system that can be removed from the vehicle. To configure the blower, the burner assembly has to be mounted to the LRPS cart in the locations indicated in Section 3.2.6. Once the burner is installed the LRPS may be retracted for vehicle transport without disassembly.

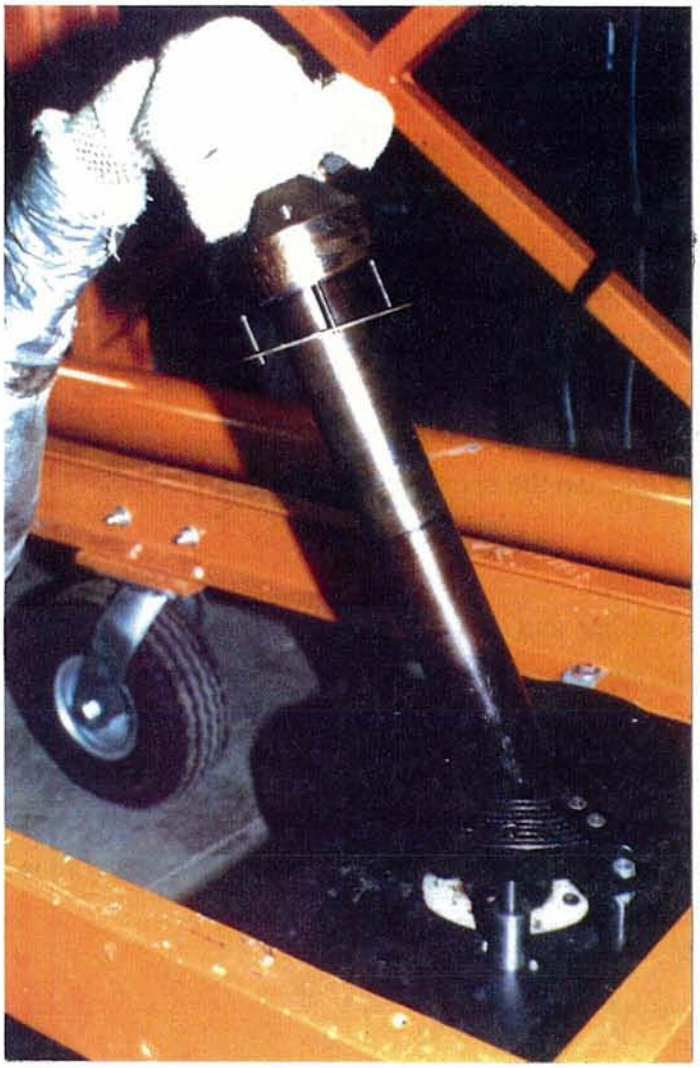


Figure 3.2.2 - Sealant Applicator Core Installation and Removal.

Figure 3.2.3 - Sealant Applicator Core Cap Installation and Removal.

Blower Installation:

These instructions assume that the entire blower assembly has been removed.

1. Deploy the LRPS frame (see Section 5.1).
2. Attach the burner arm to the LRPS arm cross bar.
3. Install the nozzle cradle in the cart.
4. Set the burner assembly nozzle in the cradle and attach the burner collar.
5. Attach the blower hose to the burner inlet and install a hose clamp.

Blower Removal:

To remove the blower assembly, follow the blower installation procedure in reverse.

3.2.3 - Heater

The heater configuration is the same as the blower configuration with the addition of the pyrometer assembly in the LRPS cart. The pyrometer is fitted with a mounting channel that bolts to the inside of

the cart directly following the burner nozzle assembly. The exact location of attachment is dependent upon the overall APS combination and is discussed in Section 3.2.6. The heater control system is an integral part of the ACSM truck chassis with a single quick disconnect control cable connecting it to the pyrometer in the cart. The LRPS may be retracted when configured with the heater with the only disassembly being the disconnection of the spark igniter cable.

Heater Installation:

1. Blower must be installed first. (see Section 3.2.2).
2. Set the pyrometer mounting channel inside the LRPS cart in the desired position (see Fig. 3.2.5 Item A).
3. Attach the channel to the cart with its two mounting bolts and wedge washers.
4. Connect the control cable and the air line to the pyrometer body (see Fig. 3.2.5 Item B).
5. Connect the spark igniter wire to the burner (see Fig. 3.2.5 Item C)

Heater Disassembly:

To dissemble the heating option, follow the heater installation procedure in reverse.

3.2.4 - Router

When the router component is installed on the LRPS, the caster wheels bolted to the cart, must be removed. The four caster wheels that support the router component are also used to carry the tooling cart along the road surface. The cart frame is attached to the router via two vibration mounts that allow the router to rotate and follow the road surface, while the cart remains parallel to the vehicle bed. The router's hydraulic system is supplied by two hydraulic hoses and it is controlled through a single quick disconnect cable. The controls for the router and the hydraulic power unit are an integral part of the ACSM truck chassis and therefore, are not removed during reconfiguration.

Figure 3.2.4 - Blower And Nozzle Assembly Deployed In The LRPS.

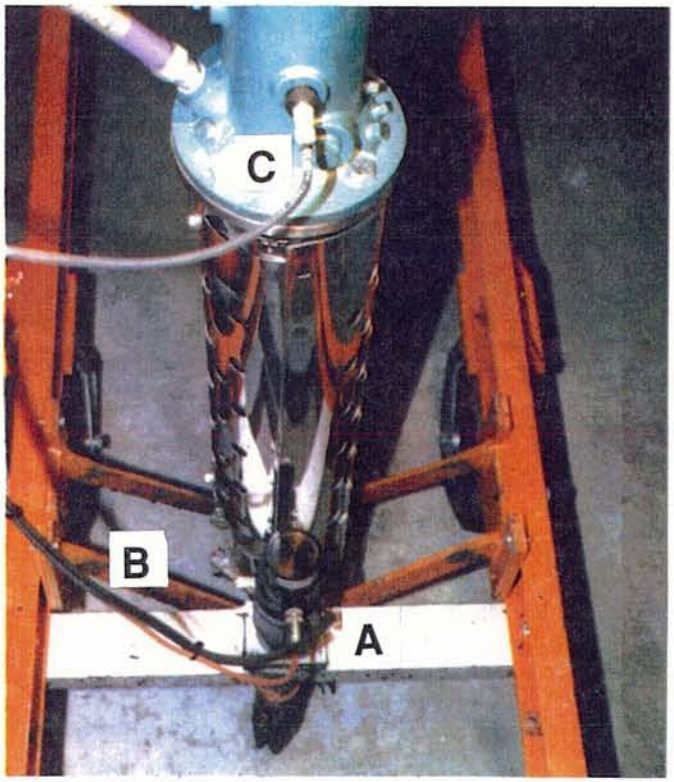


Figure 3.2.5 - Burner Assembly Including Pyrometer, Air Line & Cable.

Router Installation:

1. Raise or lower the LRPS frame so that the caster wheels are 3 inches above the ground.
2. Unbolt and remove the caster wheels (see Fig. 3.2.1).
3. Bolt the two vibration mounts to the inside of the cart (see Fig. 3.2.6).
4. Rotate the cart and roll in the router component (see Fig. 3.2.7).
5. Screw the mounting pins into the vibration mounts (see Fig. 3.2.8 Item A).
6. Retract and secure the LRPS frame.
7. Remove the storage caps from the router motor ports.
8. Remove the adapter joining the ends of the router hydraulic lines.
9. Attach the hydraulic lines to the motor port of the same color.
10. Install the cover (see Fig. 3.2.9).

Router Removal:

1. Retract and secure the LRPS frame.
2. Remove the hydraulic hoses from the router motor.
3. Connect the two ends of two hoses with a male to male JIC adapter.
4. Place JIC caps on the motor ports.
5. Lower the LRPS frame until all four of the routers wheels touch the ground.
6. Remove the cover bolts and the cover on the router.
7. Unscrew the mounting pins.
8. Rotate the cart so the router may be rolled away.
9. Attach the cart caster wheels.

Figure 3.2.6 - Isolation Mounts in LRPS Cart.

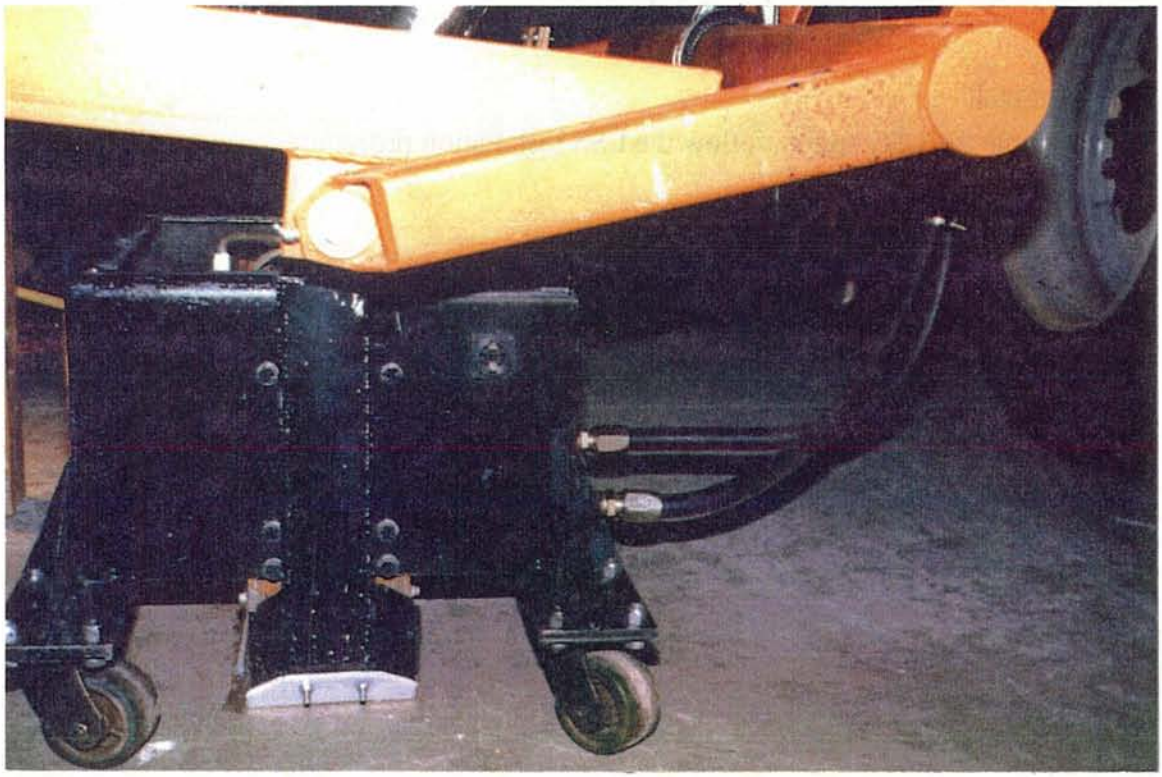


Figure 3.2.7 - LRPS Cart During Router Installation And Removal.

3.2.5 - Local Sensing System Laser Range Finder Sensor

The Local Sensing System's laser range finder sensor remains mounted to the inside of a protective enclosure that simply bolts to a mounting angle that, in turn, bolts to the top surface of the cart. The location of the laser range finder sensor in the cart depends on the APS combination as detailed in section 3.2.6. The controls for the Local Sensing System are permanently mounted inside the control booth with two control cables routed to the laser range finder sensor body.

LSS Installation:

1. Deploy the LRPS frame
2. Set the laser range finder sensor's enclosure mounting angle across the top surface of the cart in the correct position (see Fig. 3.2.10).
3. Attach the angle to the cart with two bolts and wedge washers.
4. Bolt the laser range finder sensor enclosure, with the laser always mounted inside, to the mounting angle.
5. Thread the LSS control cables through the hole in the enclosure's LRPS cover.
6. Screw the cover to the top of the enclosure.
7. Connect the laser control cables.

LSS Removal:

To dissemble the LSS option, follow the LSS installation procedure in reverse.

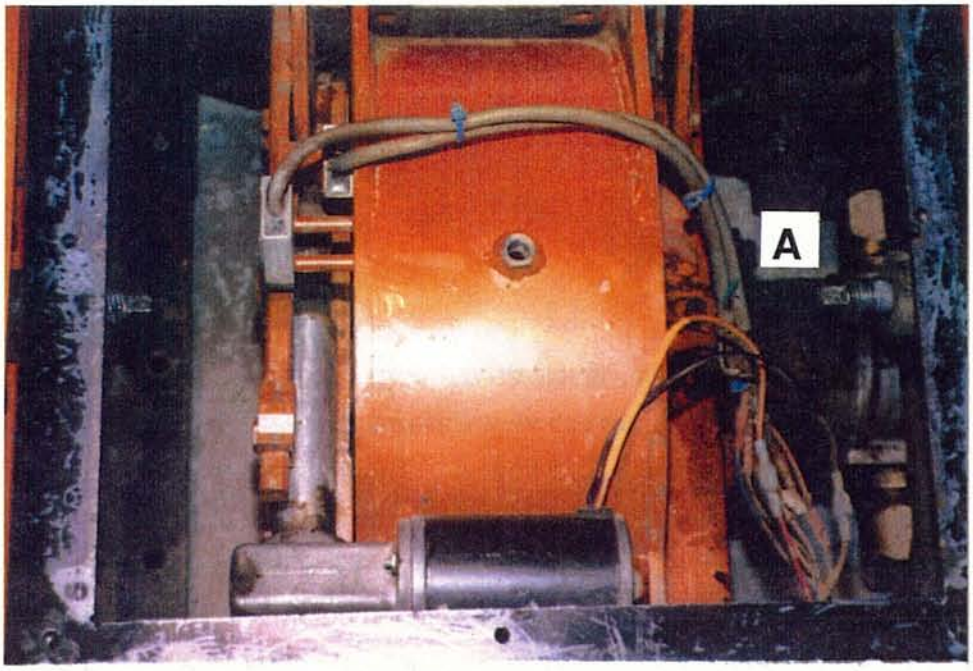


Figure 3.2.8 - Inside The Router Component.

Figure 3.2.9 - The Router Component Installed.

3.2.6 - Combinations

The installation of the APS components to the LRPS tooling cart is the same as described above for any combination. The only difference may be the location of attachment for optimum performance. The following drawings illustrate the various possible configurations and the locations of the relevant APS components in the cart (Fig. 3.2.11, Fig. 3.2.12, Fig. 3.2.13, and Fig. 3.2.14).

3.2.7 - Surveillance System

The operation of the LRPS requires the vehicle driver to be able see the front of the tooling cart and the road several feet in front of it. The driver can view this image on a 13 inch monitor, that is suspended from the roof of the truck cab (see Fig. 3.2.15 Item A). The image may also be viewed inside the control booth on the surveillance monitor in the control console (see Fig. 3.2.16 Item A),. The image from the LRPS camera is available on the trucks video network by selecting video input channel "B" (see Fig.s 3.2.15 Item B and 3.2.16 Item B)The LRPS camera is mounted on a detachable arm with its 12 VDC electrical connections and video network, permanently attached to the vehicle (see Fig. 3.2.17). The surveillance system remains intact for any configuration.

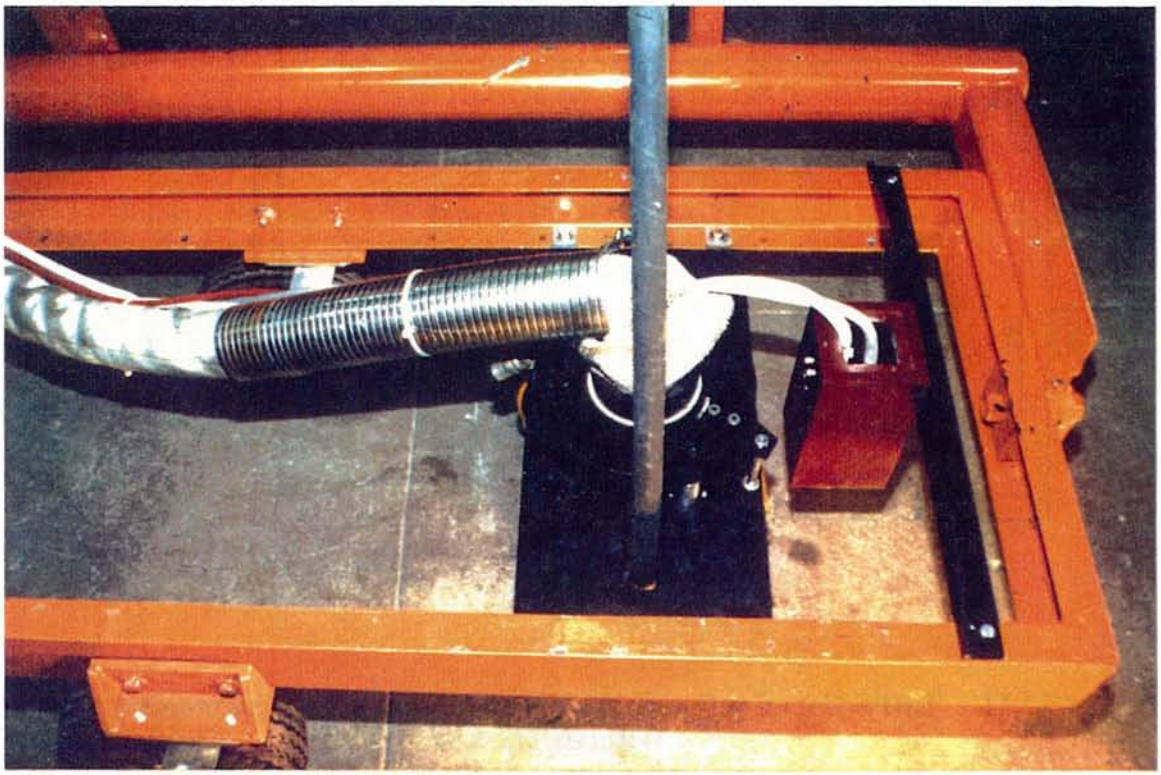


Figure 3.2.10 - LSS Enclosure And Cables.

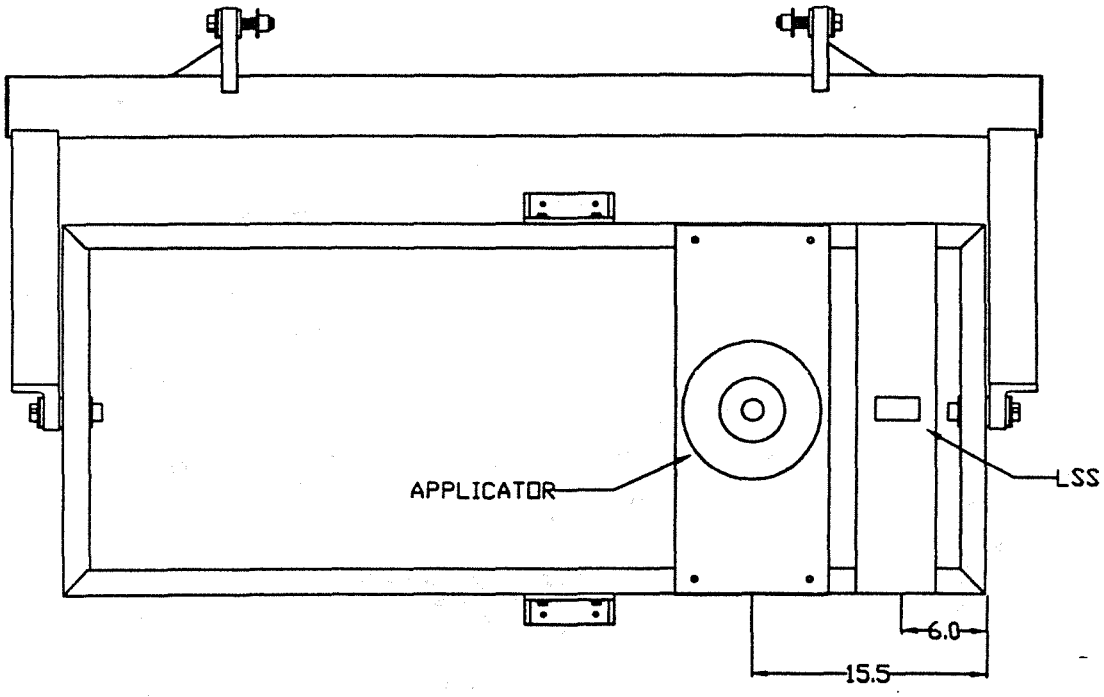


Figure 3.2.11 - LRPS Cart Configuration With The Applicator Component And With Or Without The LSS.

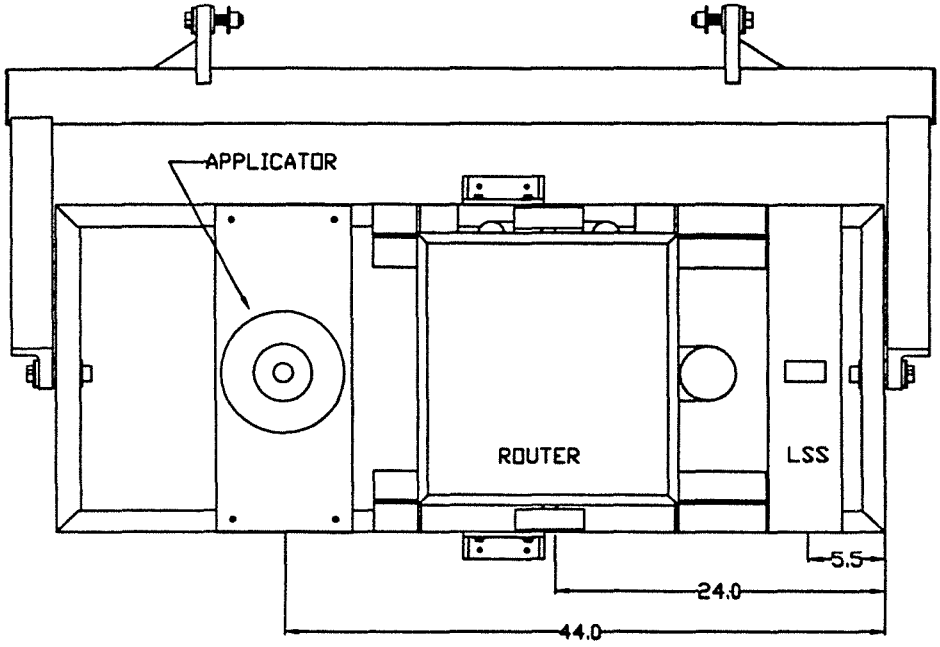


Figure 3.2.12 - LRPS Cart Configuration With The Applicator Component, The Router Component And With Or Without The LSS.

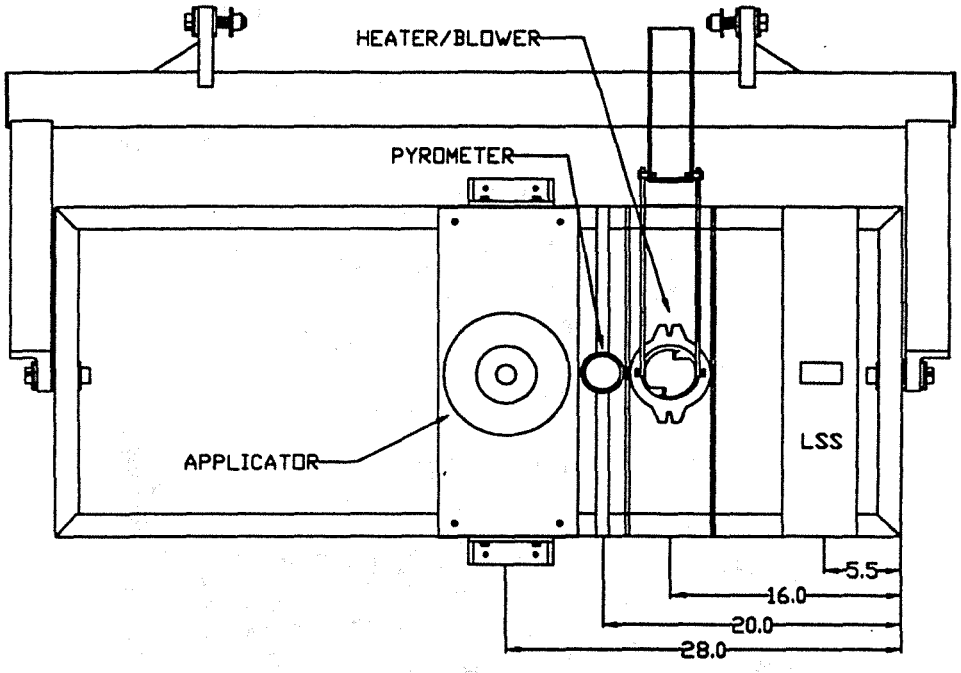


Figure 3.2.13 - LRPS Cart Configuration With The Applicator Component, The Blower, With Or Without Heat And With Or Without The LSS.

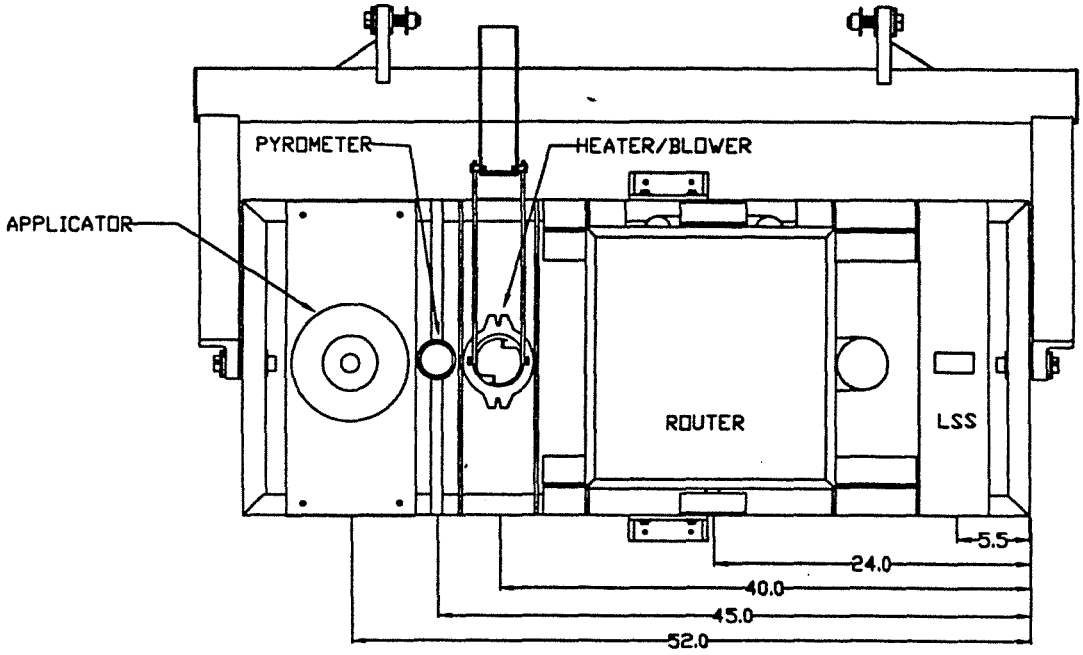


Figure 3.2.14 - LRPS Cart Configuration With The Applicator Component, The Router Component, The Blower, With Or Without Heat And With Or Without The LSS.

Figure 3.2.15 - Surveillance Monitor In The Truck Cab.

Figure 3.2.16 - Control Console In The Control Booth.

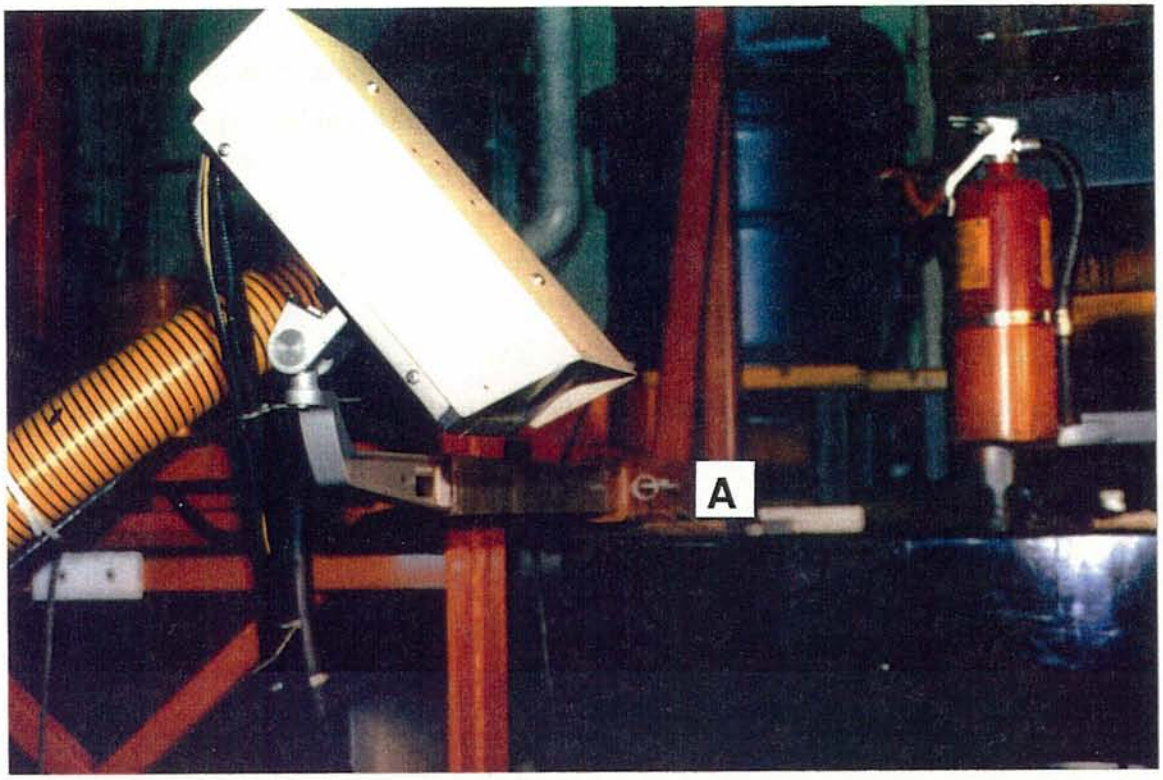


Figure 3.2.17 - Surveillance Camera Deployed on the LRPS

3.3 - General Crack Sealing System Configuration

The Integrated General Crack Sealing System has the ability to seal cracks within the lane in any pattern or direction. This system's Robot Positioning System (RPS) consists of the GMF robot that tracks the crack and a secondary arm to support the LSS and the sealant applicator. The RPS and its control systems remain integrated on the truck for any configuration. The RPS may be retracted for transport by simply decoupling the secondary arm from the robot and lashing both mechanisms to the bottom of the truck bed. Also when the ACSM has been configured for general crack sealing operation, the LRPS need not be disassembled any further than removing the applicator core and LSS, for use on the Integrated General Crack Sealing System.

3.3.1 - Sealant Applicator

The Integrated General Crack Sealing System's sealant applicator base remains connected to the secondary arm assembly. Only the sealant applicator core, control cables and supply hose are repositioned in this configuration.

Assembly:

Starting with the Applicator core removed.

1. Deploy the secondary arm (see Section 6.1.4)
2. Reroute the core and the attached supply hose under the skid and along the secondary arm as shown in Fig. 3.3.1.
3. Insert the core into the base (see Fig. 3.2.2).
4. Hold retaining plate up to the heat fin and install the four cap screws through the core cap into it (see Fig. 3.2.3).
5. Connect the air line and the control cable.

Disassembly:

1. Disconnect the air line and the control cable.
2. With the sealant applicator hot, unscrew the core cap and remove the core from its base (see Figs. 3.2.2 and 3.2.3).
3. Wipe clean the end of the core with a kerosene soaked rag.
4. Set the core aside to cool.
5. Partially retract the secondary arm (see Section 6.1.4).
6. Wipe clean the inside of sealant applicator base where the core is in contact with it, with a kerosene soaked rag.

3.3.2 - Local Sensing System

The LSS laser range finder sensor remains mounted to the inside of a protective enclosure that simply bolts to the end of the tooling shaft. The controls for the LSS are permanently mounted inside the control booth with two control cables routed to the laser body along the Secondary Arm.

LSS Installation:

1. Retract the secondary arm (see Section 6.1.4).
2. Bolt the laser range finder sensor's enclosure cover to the end of the tooling shaft.

3. Thread the LSS control cables through the access hole in the enclosure.
4. Place the laser range finder sensor's enclosure, with the laser always mounted to it, up into the cover.
5. Screw the enclosure to the cover.
6. Connect the laser control cables (see Fig. 3.3.1).

LSS Removal:

To dissemble the LSS option, follow the LSS installation procedure in reverse.

3.3.3 - Surveillance System

The operation of the Integrated General Crack Sealing System requires the vehicle driver and the system operator inside the control booth, to be able see the work space of the RPS robot. The image can be displayed on the monitor in the truck cab (see Fig. 3.2.15 Item A) and on the control console's upper monitor in the Control Booth (see Fig. 3.2.16 Item A). The RPS camera can be mounted on a retractable arm attached to the ACSM's rear bumper, with its 12 VDC electrical connections and video network permanently attached to the vehicle (see Fig. 3.3.2). The surveillance system remains intact for any configuration, but during transport the camera is to be mounted on the bracket attached to the top of the robot slide table (see Fig. 3.3.3). The RPS camera transport position allows the ACSM driver to view the blind spot directly behind the vehicle on the driver monitor in the cab. The images from the RPS camera are available on the ACSM's video network by selecting video input channel "B" (see Fig. 3.2.16 Item B).

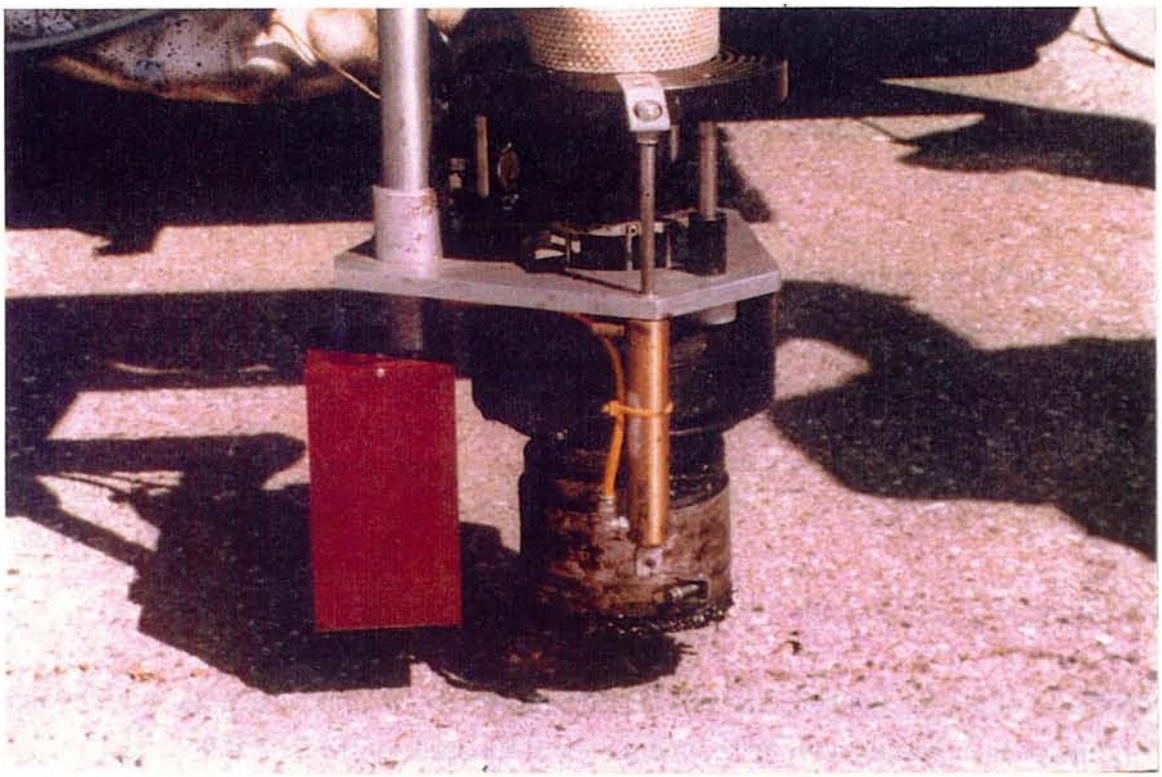


Figure 3.3.1 - LSS Enclosure Mounted To The RPS.

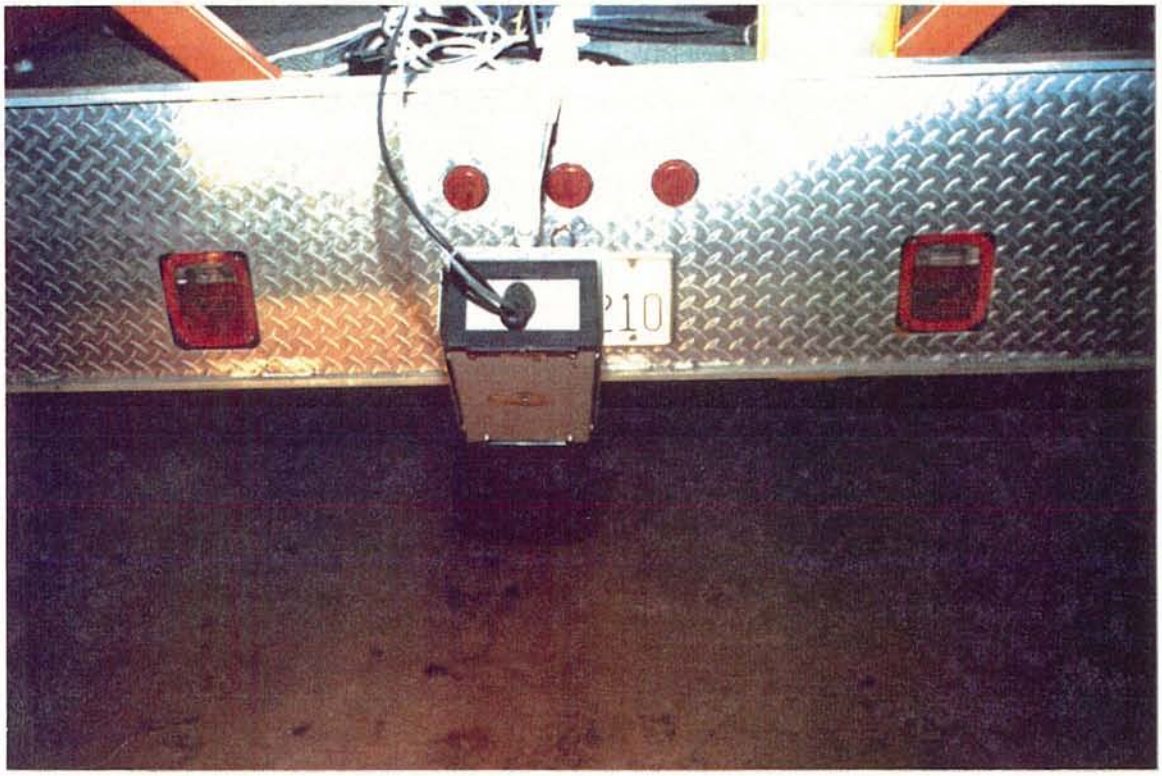


Figure 3.3.2 - RPS Surveillance Camera Viewing The Robot Work Space.

Figure 3.3.3 - RPS Surveillance Camera Transport Position. (need)

4

COMMON OPERATION INSTRUCTIONS

4.1 - Preoperation Instructions

1. All users must carefully read and completely understand all relevant sections of this manual prior to any attempt to operate any part of the ACSM.
2. To safely operate the ACSM, the recommended minimum crew size for any configuration is three persons. The minimum crew requires a vehicle driver, a person outside on the equipment deck, and an operator inside the control booth.
3. Each crew member must be clear of which duties they are responsible for during operation and they must always wear communication head sets.
4. The ACSM should never be transported with riders on the truck bed or inside the control booth.
5. If the ACSM has been stored prior to operation, the machine will need to be prepared for operation before transport. Systems to check include the 12 VDC system, propane tanks and the pneumatic isolation valve.
6. The road site should be properly secured with the necessary safety precautions that are dictated by the governmental agency that is responsible for the road.
7. While the ACSM is in operation, the entire crew should remain on board the truck and any other personnel should remain a safe distance away.

4.2 - White GMC Truck

Federal and State laws require the driver to conduct a pre-trip inspection of the vehicle. The driver should familiarize themselves with 49 CFR 396.11 and 396.13 concerning Federal requirements for vehicle inspection. Certain state laws may also apply. In all states a special class license is necessary to legally operate this vehicle on public roads. A driver qualified to drive this vehicle should have completed several hours of training and have many hours of experience operating similar vehicles, but if specific questions should arise, a copy of the manufacturer's recommended operating procedures is located in the truck cab.

4.3 - Fuel Systems

The ACSM has two fuel systems on board. The propane system supplies the heater and melter burners and the diesel system supplies the engines in the truck, AC generator and Hydraulic Power Unit. All diesel fuel is stored in the standard twenty seven gallon truck fuel tank. The Propane fuel is stored in three refillable twenty five gallon cylinders mounted in a rack against the vehicle headboard (see Fig. 4.3.1 Item A). A flexible hose with three regulators is used to connect the propane bottles to the gas system (see Fig. 4.3.1 Item B). The gas is carried to the melter and heater through a rigid piping system that is routed beneath the walkway on the truck bed and is fitted with a shutoff valve near the bottle rack (see Fig. 4.3.1 Item C). It is strongly recommended that the valves on the propane bottles be shut-off during transport. A diagram of the propane fuel system is included as Fig. 4.3.2.

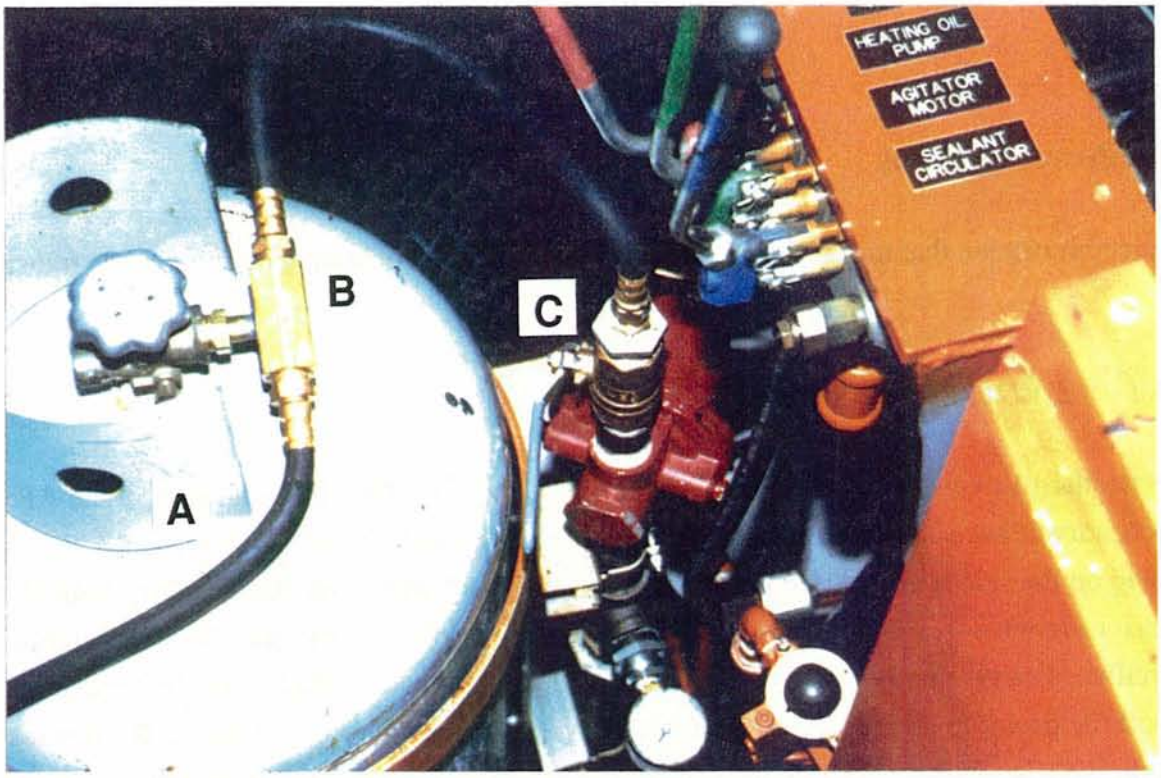


Figure 4.3.1 - Propane Fuel Connection.

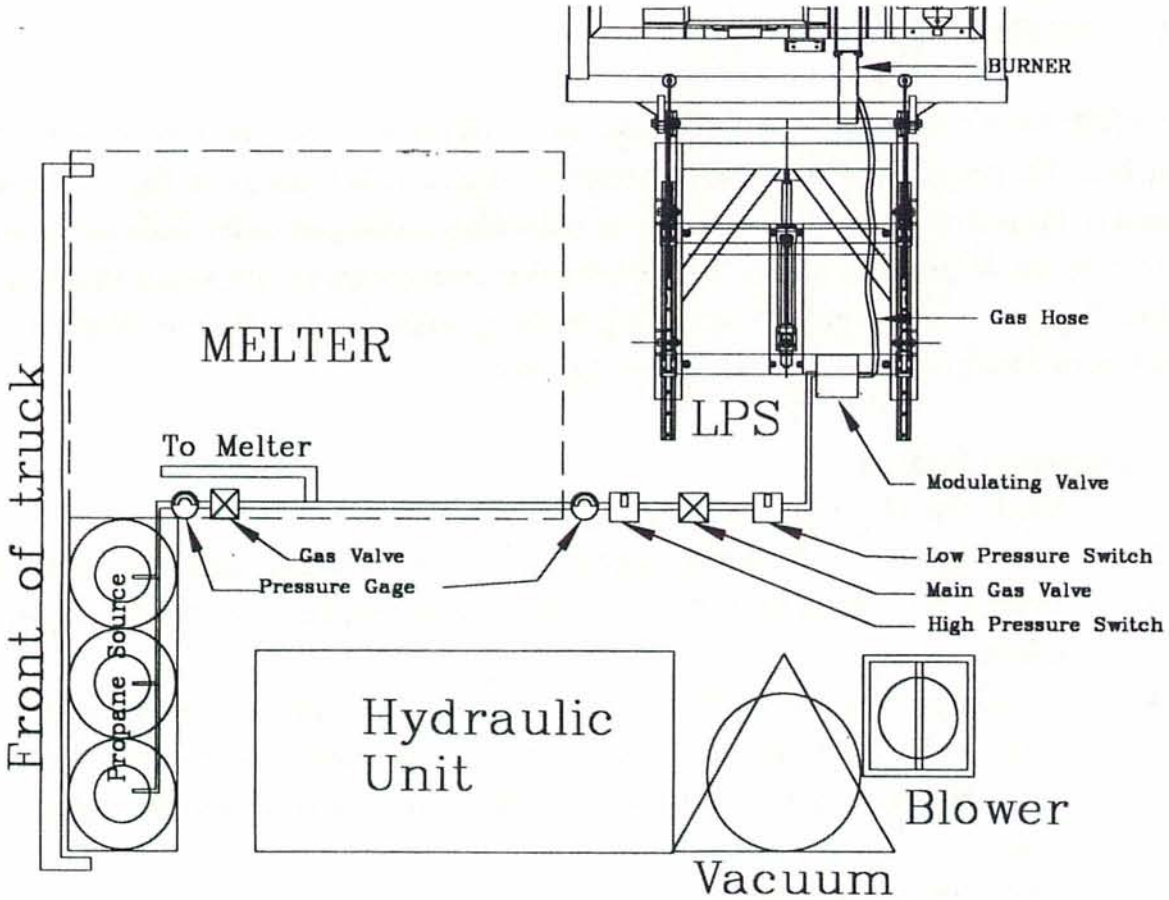


Figure 4.3.2 - Propane Fuel System Diagram.

4.4 - Power Systems

It is recommended that the AC and Hydraulic systems not be operating during vehicle transport.

4.4.1 - 12 VDC Power System

The standard 12 volt DC system on the truck is used to power the basic operation of the APS, LPS winch, surveillance cameras and auxiliary lighting. The auxiliary light switch panel (see Fig. 4.4.1) is located on the side of the main control box out on the truck bed. The nine auxiliary light switches consist of five halogen lights, for night illumination, two amber traffic warning lights and the two surveillance camera power switches. The DC system has a knife switch in the battery compartment to cut-off the power to all the 12 VDC crack sealing equipment (see Fig. 2.2.3 Item B). It is recommended that the 12 VDC system be disconnected when the truck is not operated overnight or longer.

4.4.2 - AC Generator

The ACSM has a three phase, twenty five kilowatt, diesel engine driven generator, mounted below the truck bed. The generated AC power is then routed through a main breaker (see Fig. 4.4.2 Item A), located on the generator coil, to the load center in the main control box on the truck bed (see Fig. 4.4.3). From there, the AC power is broken down into thirteen independent circuits with breakers to supply the various AC systems on the truck. The controls for the generator reside in the box directly above the blower across from the main control box (see Fig. 4.4.4).

AC Generator Start-up:

1. Verify that all the breakers in the load center are off.
2. On the generator control panel, set the `AUTO/OFF/MANUAL SWITCH` to `MANUAL`.
3. Depress the `PREHEAT BUTTON` on the generator control panel for 10 to 20 seconds and release.
4. Immediately hold the `START/STOP SWITCH` to `START` to crank the engine. Hold the switch until it starts, then release the switch to its centered `RUN` position. CAUTION! Do not crank engine continuously for longer than 30 seconds or the heat may damage the starter motor.
5. Let engine stabilize and warm up.

6. Check all applicable instrument and gauge readings. When certain that all readings are correct, switch on all required breakers in the load center.

AC Generator Shutdown:

1. Turn off all AC circuits and flip off the breakers in the load center.
2. Set the POWER SWITCH on the generator control panel to the OFF position.
3. Turn off the POWER SWITCH on the UPS.

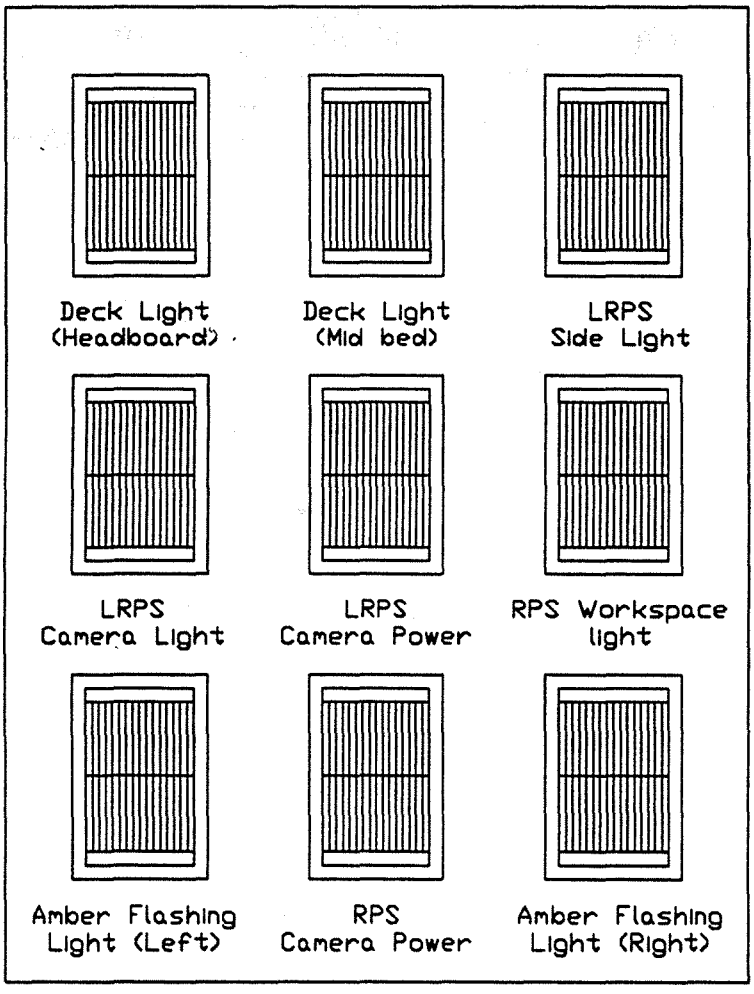


Figure 4.4.1 - The auxiliary light switch panel Diagram.

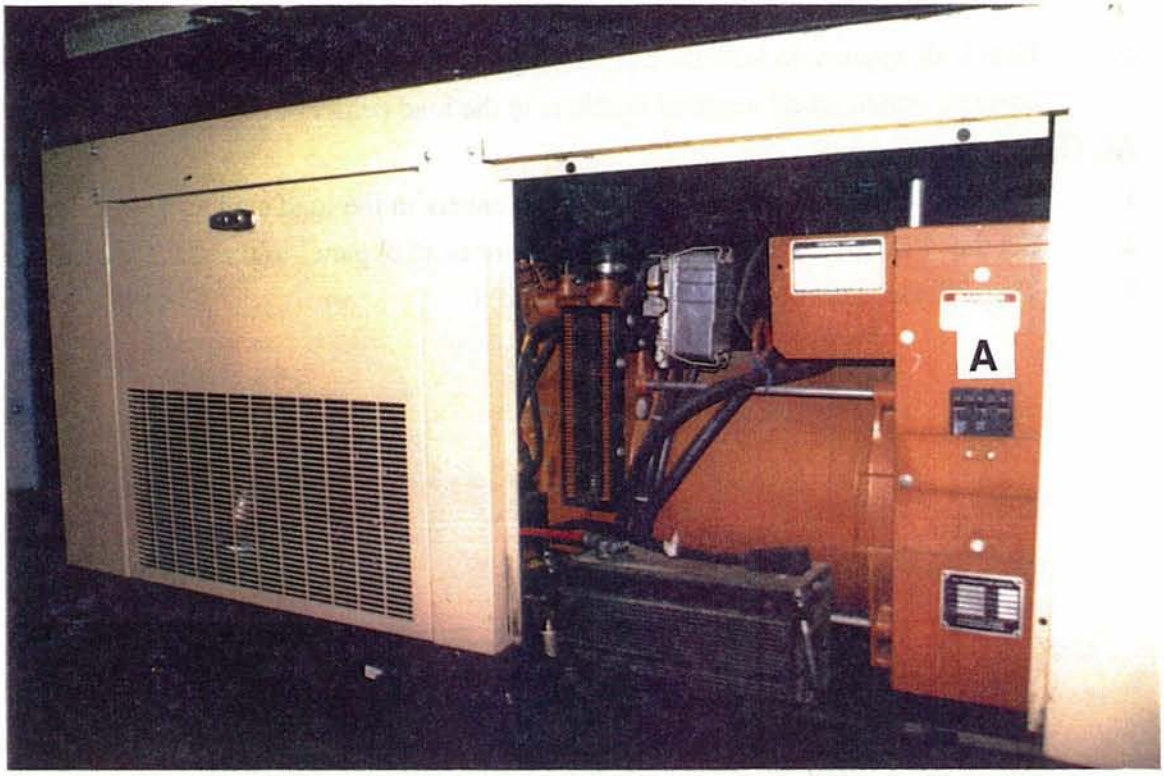


Figure 4.4.2 - AC Generator.

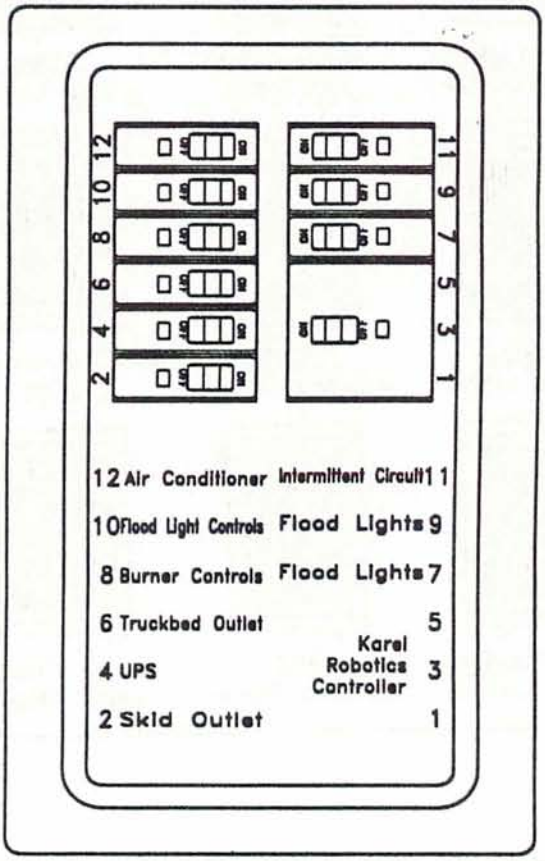


Figure 4.4.3 - AC Load Center Diagram.

4.4.3 - UPS System

The ACSM has an Uniteruptable Power Supply (UPS) connected to the AC network inside the Control Booth. In the event of an AC power loss, the UPS is designed to supply several minutes of power to all of the system computers, allowing the computers to be shutdown in an orderly fashion. The UPS is located inside a metal cabinet, mounted to the skid floor next to the robot controller. If during the operation of the ACSM, the AC power should fail, the UPS will sound an alarm and all the systems running on AC power will fail, except the ACSM computers. All programs at this point should be exited and the computers powered down, until the AC power can be restored on the truck. Whenever the AC system is turned off, the UPS must also be turned off to prevent the battery in the UPS from completely draining.

Start-Up Instructions:

1. Start the AC generator (see Section 4.4.2).
2. Turn on the `BREAKER #4` in the load center (see Fig. 4.4.3).
3. Depress the `ON, TEST, ALARM DISABLE` switch (see Fig. 4.4.5) on the UPS.
4. Verify a sufficient battery charge (see Fig. 4.4.5).

Shutdown Instructions:

To turn-off the UPS simply depress the `OFF` switch on the UPS (see Fig. 4.4.5).

Figure 4.4.4 - AC Generator Control Panel.

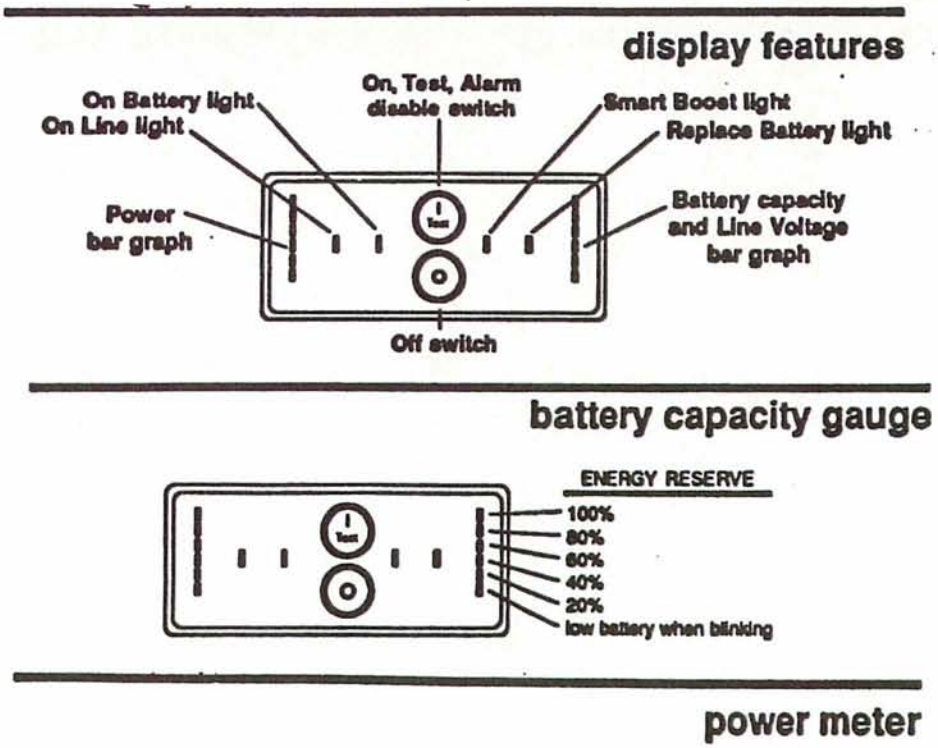


Figure 4.4.5 - UPS Display Diagram.

4.4.4 - Hydraulic System

The Hydraulic Power Unit mounted on the truck bed, supplies all the hydraulic power required to operate the ACSM. Four systems require hydraulic power: the Router, the LRPS positioning cylinder, the Melter, and the Blower. All four hydraulic circuits are controlled via 12 VDC switches on the main control panel (see Fig. 4.4.6) and burner control panel (see Fig. 4.4.7). The four switches are titled: Router power, Melter Hyd., Positioner Hyd. and Blower. These switches have the ability to be locked out if access to any of these components is necessary, while the power unit in running. The complete Hydraulic System is diagrammed in Fig. 4.4.8 and the Hydraulic Power Unit Control Panel is shown in Fig. 4.4.9

Hydraulic Power Unit Start-up:

1. Verify that all four hydraulic circuits are off on the main control panel.
2. Verify that the throttle, located on the side of the power unit, is in the one half position (see Fig. 4.4.9 Item A).
3. On the power unit's Control Panel, press the Reset button and move the `STOP/RUN` key switch to the `RUN` position and push the `START` button until the engine starts (30 seconds maximum).
4. Release the `START` button to stop cranking the starter.
5. Once the engine starts, continue to hold the `RESET` button until the oil pressure stabilizes.
6. Move the throttle to the idle position (1200 rpm). Observe the gauges (pressure, temperature and volts) for proper indications.
7. Perform a visual inspection of the power unit while it is idling. Look for oil and coolant leaks and loose or broken components.
8. Allow the power unit to stabilize at low idle before switching on the hydraulic circuits.

Hydraulic Power Unit Shutdown:

1. Turn off all four hydraulic circuits.
2. Throttle down engine to 750 rpm for 5 minutes to cool down.
3. Turn the `STOP/RUN` switch to Stop.

Figure 4.4.6 - Main Control

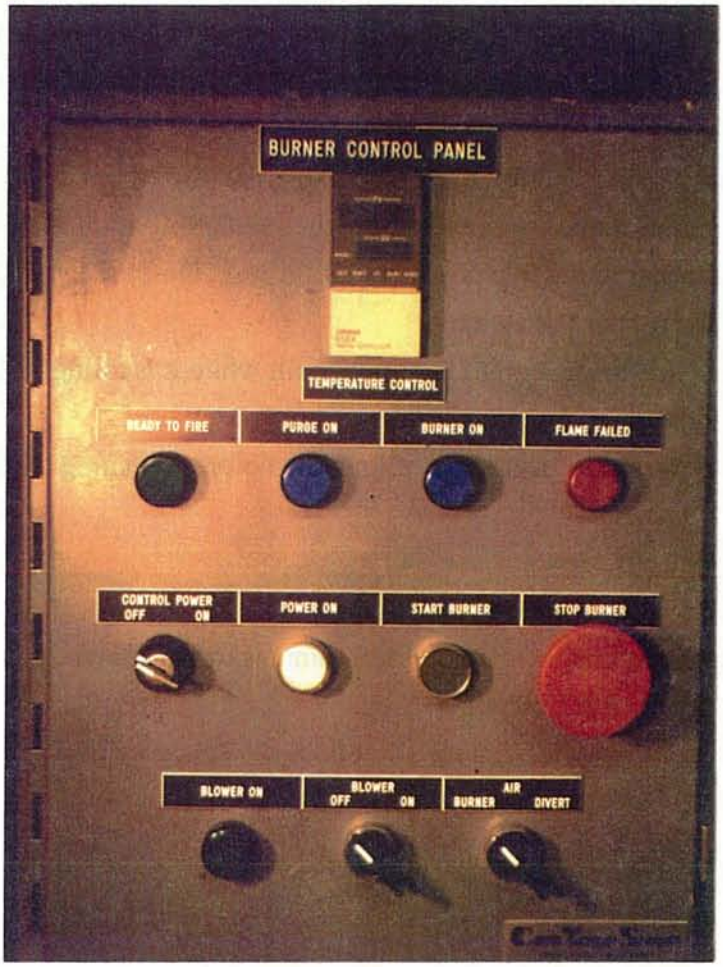


Figure 4.4.7 - Burner Control Panel.

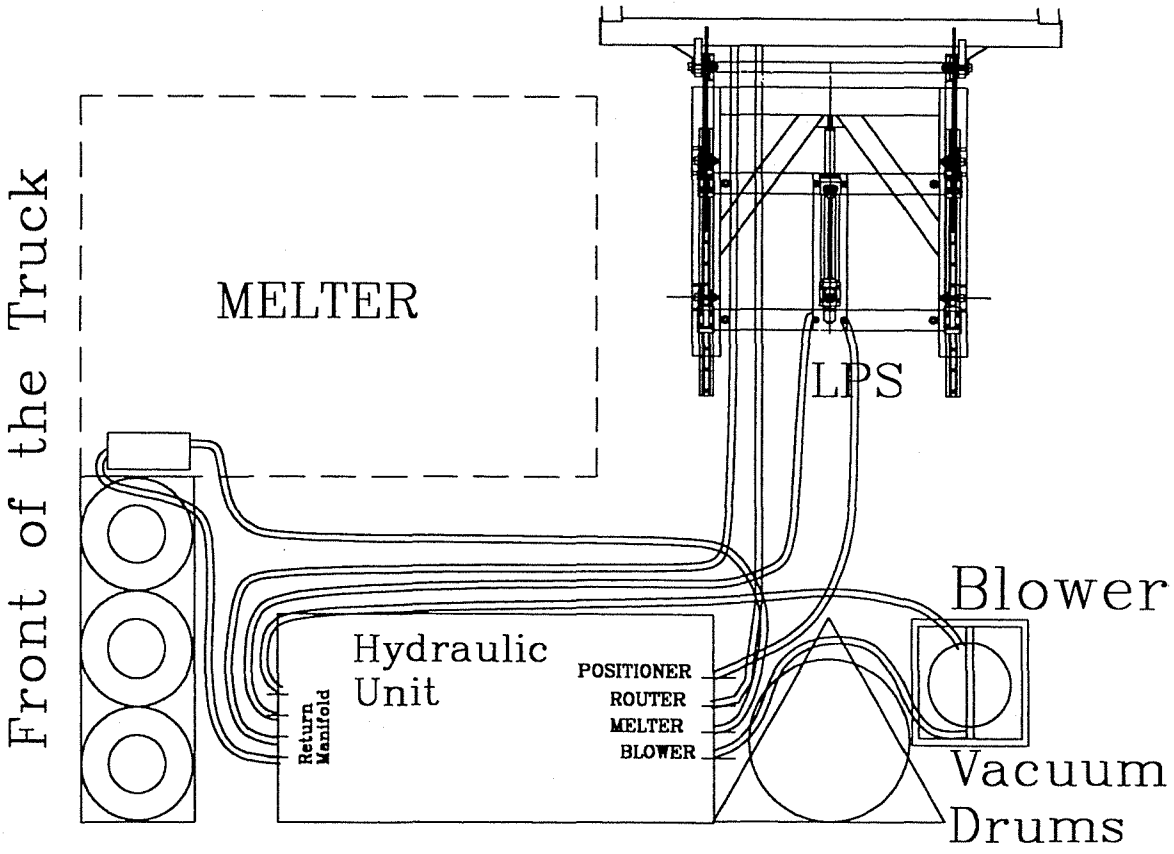


Figure 4.4.8 - Hydraulic System Diagram.

Figure 4.4.9 - Hydraulic Power Unit Control Panel.

4.4.5 - Pneumatic System

The air for pneumatic system on the ACSM is stored in a twenty five gallon supplementary tank mounted below the truck bed beneath the LRPS frame. Compressed air is supplied to this supplementary tank via a line tapped into the accessory air tank on the truck. The compressed air system on the truck, has a compressor that runs off the truck engine to supply compressed air to the air brake system. As the air brake pressure exceeds 90 psi a pressure relief valve opens and fills the accessory tank to a maximum pressure of 120 psi. The relief valve will also prevent the accessory tank from bleeding the air brake pressure below its 90 psi operating pressure. An isolation valve has been inserted in the line between the accessory tank and the supplementary tank, which must be open when the ACSM is operating (see Fig. 2.2.2 Item A). The truck engine should always be kept running when out on the road to maintain proper air pressure.

4.5 - Communication System

The operation of the ACSM requires the continuous communication of at least three of the crew members. Therefore, the ACSM is equipped with a voice powered communication system with three access jacks that are hardwired together through the vehicle chassis. The crew members wear headsets and battery powered amplifiers that plug into the jacks. The three crew members that need a communication link are the vehicle driver in the truck cab (see Fig. 4.5.1), the system operator in the control booth (see Fig. 4.5.2), and the systems tender on the truck bed deck. The systems tender must wear the noise attenuating headset to filter out the noise on the truck bed (see Fig. 4.5.3). It is recommended, for safety reasons, that the crew members in the three critical stations, always be connected to the communication system while the truck is operating. Also if any of the crew members fails to respond, the crack sealing operation should be halted immediately and the station repaired.

System Pre operation:

1. The crew should have discussed and agreed upon a common communication protocol and a defined set of system definitions.
2. Verify that all stations are properly operating and have a fresh 9 Volt battery in the amplifier.

To Talk:

1. Wait for a break in the conversation. (Two messages may not be sent at the same time)
2. Depress the `PUSH TO AMPLIFY` button on the amplifier and hold while talking (see Fig. 4.5.3 Item A).
3. Release the button after message is complete.

Figure 4.5.1 - Vehicle Driver Wearing Communication Headset.

4.6 - APS

The ACSM utilizes a common Applicator and Peripheral Systems for any configuration of both integrated sealing systems. The APS control systems, mounting hardware and related APS support equipment, are all an integral part of the truck chassis, with only the tooling component itself requiring repositioning. The theory of operation for all APS components are identical for either positioning system. Any APS information that might be uniquely related to a specific configuration would be discussed in the relevant systems' APS section of this document.

4.6.1 - Sealant Melter

Since a hot applied sealant is the material of choice for the ACSM, a skid mounted Sealant Melter has been incorporated on the truck to heat and pump the sealant to the application component. The propane fired Melter is supplied with propane and hydraulic power from the truck and it, in turn, supplies hot sealant to the sealant applicator head through an oil jacketed supply line. This melter is capable of supplying up to 100 gallons of hot sealant per hour with a 200 gallon storage capacity.

Start-up Procedure:

1. Turn on the supply of propane to the melter (see Section 4.3).
2. Fill Oil Jacket to proper level with heat transfer oil, as shown on dip stick attached to fill cap. Note: Level should be between end of stick and first notch when cold.
3. Replace the fill cap on oil jacket and verify that the vent pipe is open. CAUTION! It is important that the oil jacket be vented to the atmosphere at all times. A clogged vent pipe can cause extreme and dangerous pressure on the oil jacket, with resulting damage.
4. Set the melter oil temperature to the necessary temperature to provide the desired material temperature. Note: In no case should it exceed 550 degrees F.
5. Make certain there is no gas in the firebox. Note: Following an unsuccessful attempt at lighting the pilot, allow 2 to 3 minutes for the gas to dissipate from the fire box before relighting.
6. Depress both the GAS RELEASE and the SPARK IGNITER buttons, until the gas ignites. Note: Do not hold the GAS RELEASE button for longer than 5 seconds.
7. If the gas ignites, immediately release the SPARK IGNITER button and continue to hold the GAS RELEASE button until the FLAME OUT light turns off.
8. Start the hydraulic unit (see Section 4.4.4) and turn on the MELTER HYDRAULIC POWER switch (see Fig. 4.4.6).
9. Verify that material bypass valve is open (see Fig. 4.6.1 Item A).
10. When the oil temperature reaches 250° F, engage the OIL CIRCULATION valve in the FORWARD position (see Fig. 4.6.2).
11. After the oil temperature has been sustained at between 450 to 500° F for about a half an hour, the MATERIAL AGITATOR may be started (see Fig. 4.6.2).
12. After determining that the pump is sufficiently hot, engage the MATERIAL PUMP hydraulic valve to the FORWARD position (see Fig. 4.6.2).
13. Routinely verify the maximum material and oil temperatures.

Melter Operation Procedure

After the Melter has been started, the melter material pump and agitator should always be running to prevent the material from coking in the kettle chamber. While operating the sealant applicator, the Melter bypass valve, which controls the pressure and flow of the sealant in the supply line, should be closed. The melter should be operated at near full capacity; therefore, additional blocks of sealant should be placed in the melter as the material is dispensed. The Melter heating system has a thermostat that automatically maintains the temperature of the sealant at its ideal application temperature (between 350 and 400° F). It is recommended though, that the temperature be regularly verified during operation on the material temperature gauge mounted to the Melter. If during operation, the pump pressure drops below its normal operating pressure, it is almost certain that the pump system is vapor locked. To relieve a vapor lock and restore pressure, it is necessary only to open the by-pass valve (see Fig. 4.6.1). Normally, within a few seconds, the pump will expel the vapor, and when the valve is closed, pressure will recover to normal on the gauge.

Figure 4.5.2 - Control Booth Crew Wearing Communication Headset.

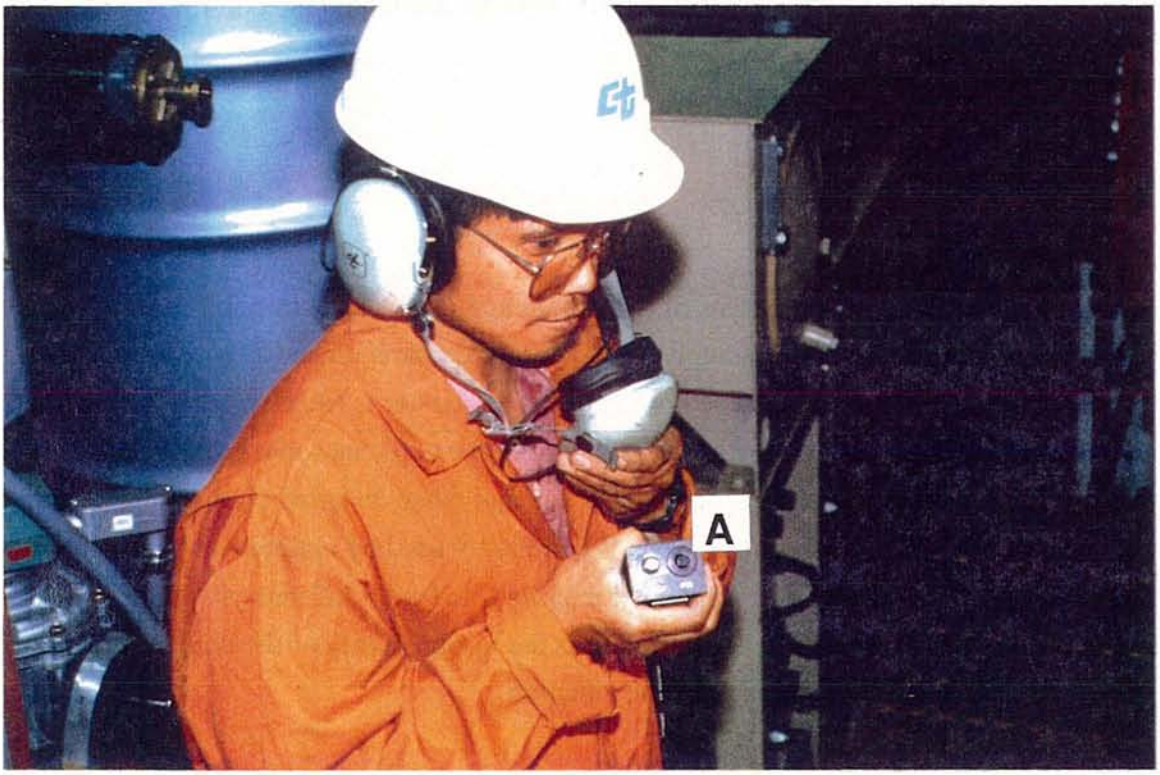


Figure 4.5.3 - System Tender Wearing Communication Headset.

Melter Shutdown Procedure

Begin this procedure with the truck engine running, the sealant applicator deployed, the sealant applicator control power on, and the sealing cycle off.

1. Switch the MATERIAL PUMP HYDRAULIC valve to REVERSE (see Fig. 4.6.2).
2. Thread the sealant applicator blowout hose into the blowout valve on top of the sealant applicator (Fig 4.6.3 Item A).
3. With the blowout valve closed, connect the other end of the blowout hose to the quick connect port on the auxiliary air tank (see Fig. 4.6.3 Item B).
4. Verify the auxiliary air tank pressure is at its maximum of 120 psi.
5. Place a containment box under the sealant applicator.
6. Depress the sealant applicator VALVE OPEN button (see Fig. 4.4.6)
7. Verify that the sealant applicator is down and inside the containment box.
8. Open the blowout valve and watch for billowing white smoke to appear from the kettle cover. (If the smoke does not appear before the air pressure drops below 60 psi, close the valve and repeat this step when the air pressure returns to 120 psi.).
9. Close the blowout valve and turn off the MATERIAL PUMP HYDRAULIC valve.
10. Turn off the MELTER HYDRAULIC POWER switch on the control panel of the Control Box.
11. Open the material bypass valve.

4.6.2 - Sealant Applicator

The sealant application system consists of the sealant applicator, its control circuits, oil heated supply lines, and the proportional valve assembly. Together, these parts reduce the complicated sealing process into a simple On or Off operation. The bottom of the applicator is fitted with either a rubber ring, or a stainless steel wire brush ring, which is the only part of the applicator that actually contacts the road. These rings have been fabricated in 5 inch diameters and when installed on the Applicator produce a 5 inch wide flush seal. This seal configuration is commonly used by maintenance crews, but the Applicator is not limited to it. The Applicator may be fitted with different ring diameters or it can be cocked to produce an overband configuration. It is the responsibility of the user to determine which configuration or ring is best for their specific situation.

Sealant Applicator Startup Procedure

After the sealant applicator has been deployed, only two tasks have to be completed, before sealant can be applied. The first is to turn on the Sealing Cycle Power switch on the Control Box panel, enabling the entire sealing system. The second task is to establish sealant flow through the sealant applicator. The hot oil from the Melter's oil circulation system, is pumped through lines wrapped around the sealant supply line to the sealant applicator core and back. This passage is heated by the melter oil to the pouring temperature of the sealant automatically whenever the Melter is at operating temperature. Therefore, to establish sealant flow through the sealant applicator, simply complete the melter's startup procedure (see Section 4.6.1). A problem may occur whenever the sealant applicator supply line is charged with sealant for the first time; i.e., the sealant flow might pause for several seconds, before sealant appears from under the sealant applicator. This is caused by air in the supply line and line temperatures slightly lower than ideal. The best scenario is to start the sealant for the first time on the shoulder of the road for a few feet of seal in order to completely charge the supply line. If the sealant fails to flow from the sealant applicator after several feet, cease the sealing cycle and wait a few minutes for the supply line temperature to increase.

Sealant Applicator Operation

To begin applying sealant, simply press the Cycle Start button on the Control Box panel (see Fig. 4.4.6). To stop the application of sealant, press the Cycle Stop button (see Fig. 4.4.6). When the Cycle stop button is pressed, the sealant flow is immediately terminated. During operation the air pressure control panel (see Fig. 4.6.4) should read a maxium inlet pressure of 120 psig, a sealant head down pressure of 10 psig and a sealant head up pressure of 50 psig.

Sealant Applicator Shutdown Procedure

To shutdown the sealant applicator after sealing operations are complete, complete the Melter shutdown procedure (see Section 4.6.1) and turn off the Sealer Power switch.

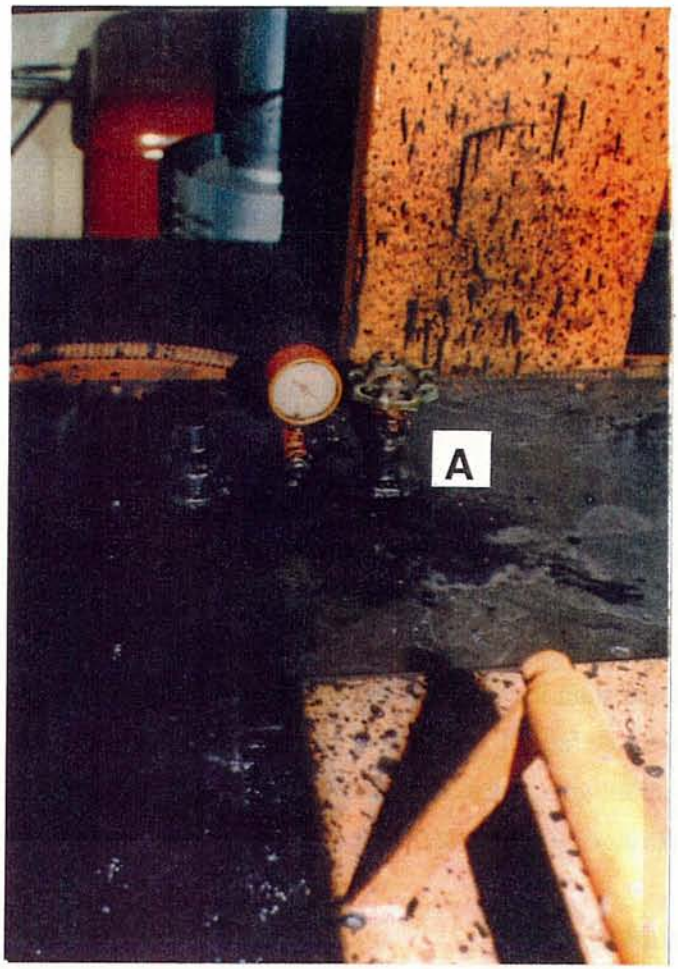


Figure 4.6.1 - Melter bypass Valve.

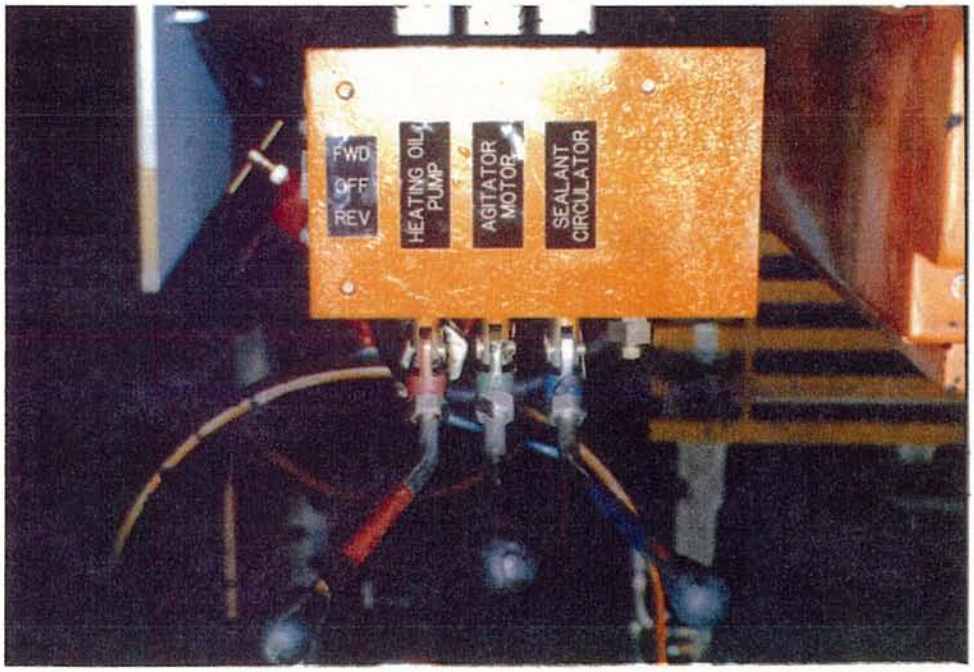


Figure 4.6.2 - Hydraulic Control Valves.

Figure 4.6.3 - Melter Blowout Hose.

Figure 4.6.4 - Applicator Air Pressure Controls.

5

INTEGRATED LONGITUDINAL CRACK SEALING SYSTEM

5.1 - ILCSS Set-Up and Deployment

Upon arrival at the road site, the ACSM should be stopped, and the parking brake set, 50 feet (15 m) short of the beginning of the first crack to be sealed. Each crew person should understand which start-up procedures that they are responsible to complete. Perform the Common Operation Instructions (see Section 4) first, then complete the following procedure which is specific to the ILCSS. The truck should not be moved until the machine is completely deployed and operational, and all the crew members are on the truck bed.

ILCSS Deployment Procedure:

1. Turn on the AMBER FLASHER lights (see Section 4.4.1).
2. Start the AC generator (see Section 4.4.2).
3. Start the Hydraulic Unit (see Section 4.4.4).
4. Unscrew the LRPS transport pins and, if conFig.d with the router, remove the router transport chain.
5. Lower the LRPS cart to the road, by holding the winch control switch in the cable out position. A crew member will need to pull the cart away from the truck when the cart touches the road. Continue to unwind the winch cable until the LRPS mechanism is fully deployed.
6. Remove the winch cable from the cart link and insert the pair of table pins.
7. Rewind the winch cable.
8. Install the flex-shaft between the Head Rotation motor and the Applicator.
9. If the Heater is to be operated, connect the spark plug wire (see Fig. 3.2.5, Item C)

5.1.1 - Surveillance System Set-up

The ILCSS operation requires the driver and the control booth operator to be able see both the front of the cart and the road several feet ahead of the tooling cart. The camera may have to be adjusted periodically to maintain the image pictured in Fig. 5.1.1. The video monitors are connected to the surveillance network with a two-channel selector that needs to be set to channel "A" to view the LRPS image. The upper monitor in the control console has a dual purpose, it can be used to view the robot workspace by selecting input Line A or it can be used as the display for the PC by selecting input RGB A (see Fig. 5.1.2).

Surveillance System Set-up Procedure:

1. Do not deploy the camera until after the LRPS is fully deployed.
2. Slide the camera boom into its receptacle in the LRPS loop, and insert the two locking pins.
3. Send 12 VDC power to the camera by switching on the `LRPS CAMERA` switch (see Fig. 4.4.1).
4. Place the Driver Monitor into its mount attached to the truck cab ceiling, and plug in its 12 VDC power cord to the cigarette lighter receptacle (see Fig. 3.2.15).
5. Press the `LINE A` Input Selection Button on the upper control console monitor (see Fig. 5.1.2).
6. Select video input channel `"A"` on both monitors.

Surveillance System Shutdown Procedure:

1. Turn off the 12 VDC power to the side camera by switching the `LRPS CAMERA` rocker switch off (see Fig. 4.4.1).
2. Remove the camera boom locking pins, and remove the camera boom from its receptacle in the LRPS loop.

Figure 5.1.1 - Surveillance Camera Image.

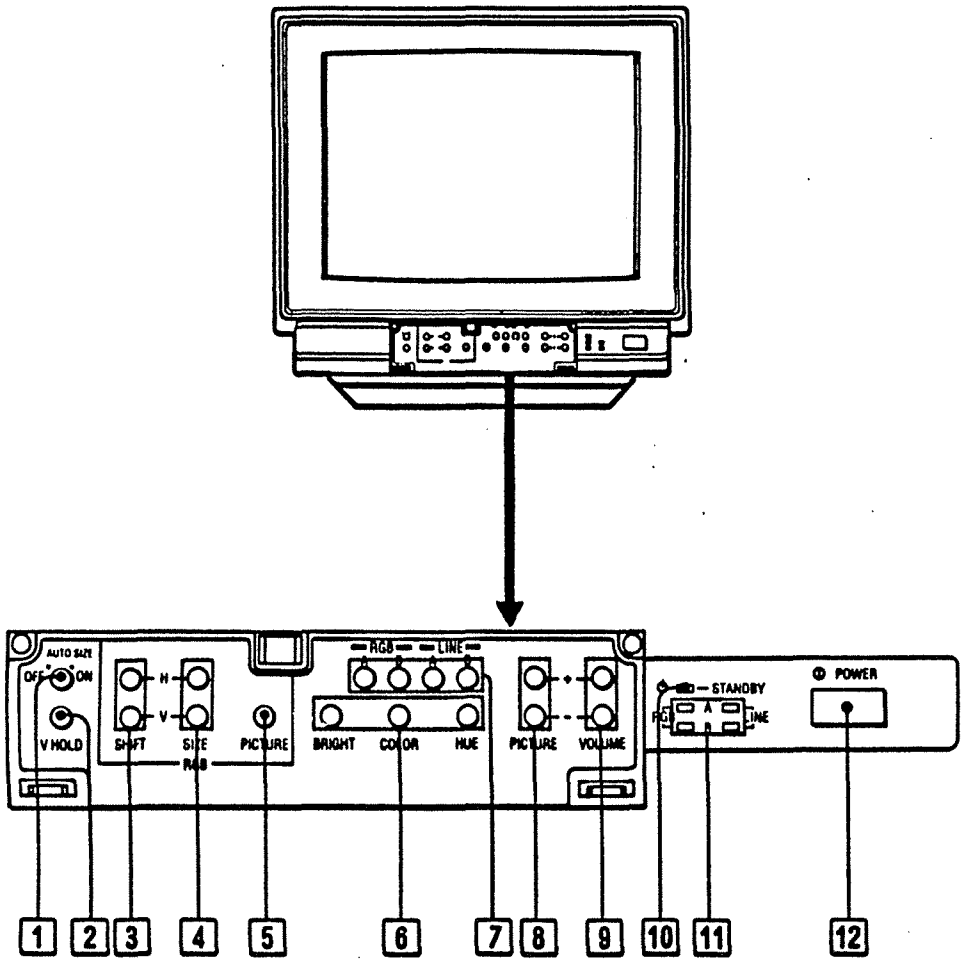


Figure 5.1.2 - Control Booth Surveillance (upper) Monitor.

5.1.2 - Hydraulic Positioner Start-up

For safety reasons, the Parker control unit must always be running when the Positioner hydraulics are on. The LRPS slide table is equipped with a flashing amber light that will automatically flash when the Positioner Hyd switch (see Fig. 4.4.6) is turned on, to warn the crew to keep clear. It is recommended that the crew always stay on the vehicle when the Positioner is powered up. Should access to the cart be required during operation, the Positioner Hydraulic switch should be turned off and the lockout key removed. Returning to positioner operation will not require a reboot of the positioner controllers.

Hydraulic Positioner Startup Procedure:

1. Turn on the power to the Parker controller.
2. Verify that the Hydraulic Power Unit is operating.
3. Verify that the positioner workspace is clear
4. Turn the `POSITIONER HYD` switch on.
5. Initiate either the following Manual Mode or the LSS Guided control procedure

Hydraulic Positioner Shutdown Procedure:

1. Complete the relevant guidance shutdown procedure (see Section 5.1.3 or 5.1.4).
2. Turn off the power to the Parker controller.
3. Turn off the `POSITIONER HYD` switch.

5.1.3 - Manual Guidance

The hydraulic positioner can be operated manually using a joystick to move the LRPS cart. The joystick is connected to the rack mount PC computer, which reads in the joystick position, and sends the appropriate motion commands to the Parker control unit.

Start-up Procedure:

1. Make sure that the LRPS workspace is clear of all personnel and obstacles. The LRPS frame will move to the center of its travel during the startup procedure.
2. Verify that power is available to the Parker control unit.
3. Turn on the rack mount PC computer.
4. Set the upper control console monitor input to the computer display.
5. When the computer has completed its boot procedure, type

   ```
   manlrps
   ```

   to initiate the manual LRPS program on the PC.
6. Follow the instructions on the screen to calibrate the joystick and enter the manual control mode.
7. Once the program has completed its initialization, switch the input of the upper control console monitor to the LRPS surveillance camera by changing the input switch on the monitor itself, and making sure that the A/B switch for the monitor is set to the correct position for the LRPS surveillance camera.

Shutdown Procedure:

1. Move the LRPS cart to its fully retracted position using the joystick. When the cart is fully retracted, press the joystick trigger button to end the manual control program. NOTE: if the LRPS operation requires an abort at any time due to unexpected problems, it is generally possible to jog the LRPS cart manually using the keypad on the Parker controller. See the Parker controller manual for more details.
2. Switch the upper control console monitor input back to the computer display. Verify that the PC program has exited correctly.
3. Turn off the rack mount PC computer.
4. Stow the LRPS if operation is complete for the day. See section 5.3 for the detailed stowage procedure.

5.1.4 - LSS Guidance

The hydraulic positioner can also be operated automatically using the Local Sensing System (LSS) to locate the crack position relative to the center of the LRPS cart. Based on the LSS signal, the LRPS cart will move towards the crack. The LSS is connected to the rack mount PC computer, which reads in the LSS scan, extracts the crack position, and outputs the appropriate motion commands to the Parker control unit.

Start-up Procedure:

1. Make sure that the LRPS workspace is clear of all personnel and obstacles. The LRPS frame will move during the startup procedure. Make sure that the LSS is positioned over a segment of pavement that does not have a crack in it, as it will perform an initialization based on measurement of the road surface roughness, which requires uncracked pavement.
2. Turn on the `POWER` switch on the LSS laser unit, and enable the `LASER KEY` switch. Observe all precautions in the MVS documentation when operating the laser. In particular, do not look at the invisible laser scan line, as it can cause eye damage.
3. Verify that power is available to the Parker control unit.
4. Turn on the rack mount PC computer.
5. Set the upper control console monitor input to the computer display.
6. When the computer has completed its boot procedure, type
   `autolrps`
   to initiate the automatic LRPS program on the PC.

7. Follow the instructions on the screen to calibrate the local sensor and enter the automatic control mode.
8. Once the program has completed its initialization, switch the input of the upper control console monitor to the LRPS surveillance camera by changing the input switch on the monitor to Line A (see Fig. 5.1.2), and make sure that the video channel switch is set to A for the LRPS surveillance camera.

Shutdown Procedure:

1. Switch the upper control console monitor input back to RGB A (see Fig. 5.1.2).
2. Press the 'ESC' key to end the `autolrps` program. This will cause the LRPS to move to its fully retracted position. NOTE: if the LRPS operation requires an abort at any time due to unexpected problems, it is generally possible to jog the LRPS cart manually using the keypad on the Parker controller. See the Parker controller manual for more details.
2. Verify that the PC program has exited correctly.
3. Turn off the rack mount PC computer.
4. Turn off the laser `POWER` switch.
4. Stow the LRPS if operation is complete for the day. See section 5.3 for the detailed stowage procedure.

5.2 - ILCSS Operation

The operation of the individual APS components configured in the LRPS cart is identical for both modes of cart positioning, and is discussed in detail in the APS Operation Sections. The operator in the control booth has the controls to start and stop the sealing process, while the crew member on the truck bed tends the equipment. When the start-up and deployment procedures are complete, the crew can verify their communication links and begin to seal cracks. The driver may then release the parking brake and approach the first crack. The truck driver is responsible, in either guidance mode, to position the center of the LRPS cart motion range within 12 inches of the targeted crack as the vehicle is driven. Since the cart is moving laterally, the best targeting method is to mark the center of the cart's movement on the driver's monitor. The driver will then steer the truck to keep the mark on the crack.

5.2.1 - Hydraulic Positioner

Manual Mode

The hydraulic positioner can be operated manually using a joystick to move the LRPS cart. The joystick is connected to the rack mount PC computer, which reads in the joystick position, and sends the appropriate motion commands to the Parker control unit. Essentially, the program watches for displacement of the joystick from the center position, and sends an offset signal to the Parker controller. The offset signal is not proportional to the displacement of the joystick, i.e. the cart will move the same amount for small joystick displacements as for large.

1. The driver attempts to maintain the position of the center of travel of the LRPS cart near the location of the crack while proceeding forward at the desired operating rate.
2. The operator in the booth will observe the position of the crack and the position of the centerline of the cart (indicated by the connection bolt) as seen on the upper control console monitor, which is connected to the LRPS surveillance camera.
3. The operator jogs the joystick in the appropriate direction to move the cart centerline over the crack position.
4. At any time, in an emergency situation in which the cart motion should be stopped, the operator can push the trigger button on the joystick. This will cause the cart to stop in its current position, and end the `manlrps` program on the PC.

LSS Guided

The hydraulic positioner can also be operated automatically using the local sensor to locate the crack position relative to the center of the LRPS cart and jog the LRPS cart. Once the system has been conFig.d and initialized for automatic operation, there is little need for operator input. The operator will be mainly responsible for monitoring the status of the procedure, and ending or aborting the operation if necessary.

1. Observe the sealing operation on the upper control console monitor. Watch for any error conditions or impending collisions.
2. In the case of an error or an emergency situation, hit `'R'` on the keyboard to fully retract the LRPS and abort the operation.
3. To terminate the operation under normal conditions, hit the `'ESC'` key.

5.2.2 - APS In The LRPS

The applicator operation in the LRPS is the same in either positioning system, except for the reaction of the sealing Cycle Stop button. In the ILCSS configuration, the applicator head may not lift up immediately. The applicator controller has a sealant level relay that holds the head down on the pavement if there is extra sealant in the reservoir. This feature prevents the extra sealant, in the Applicator, from puddling at the end of the crack. Instead this sealant is run out on the road until the relay is tripped and the head pops up. An Emergency Head UP button is included on the controller to lift the Applicator head from the pavement immediately, regardless of the sealant level. This may be used to avoid obstructions in the Road.

5.2.3 - Blower

The Blower system is designed to supply low pressure air at extremely high flow rates, to clean the road surface directly in front of the applicator. The Blower system consists of a hydraulically driven 300 cfm blower, two diverter valves, a burner and nozzle assembly and the connecting PVC piping. The Air Diverter switch toggles the position of the diverter valves, directing the path of the blower output. If the Air Diverter switch is off, the high velocity air is vented through a vertical pipe. If the Diverter Valve switch is On, the high velocity air is directed through the burner nozzle assembly to the ground.

Blower Startup Procedure:

1. With the AC generator running, flip on `BREAKER #8` on the AC load center (see Fig. 4.4.3).
2. Verify that the `AIR DIVERTER` switch is in the `OFF` position.
3. With the hydraulic power unit running, turn on the `BLOWER HYDRAULIC` switch, on the main control panel (see Fig. 4.4.6). Note: A yellow indicator light on the Main Panel will illuminate indicating that the blower is rotating.
4. To direct the air flow to the road surface, turn on the `AIR DIVERTER` switch (see Fig. 4.4.7).

Blower Shutdown Procedure:

To shutdown the Blower, follow the startup procedure in reverse.

5.2.4 - Heater/ Pyrometer

The heater operates with the blower to apply a high volume of heated air onto the pavement ahead of the sealant applicator. Pavement temperature is measured by the pyrometer and it is used in the feedback loop to the gas modulating valve. The system is controlled by the temperature control module in the burner control panel, and during operation, the road surface is heated automatically to the set temperature value. At start up, the system is purged for approximately 20 seconds before the flame ignites, and the start sequence must be coordinated with respect to the other operations. To prevent overheating of the pavement, the vehicle must be moved forward within 5 seconds of burner ignition.

A check that the LRPS and heater are properly deployed and that no air or gas lines are damaged or kinked must be performed prior to use. The cable between the ignitor and burner must be connected, and it must be slack enough to allow movement of the LRPS. The gas supply will be on if the sealant system is being used. The 'Ready to Fire' light will not come on unless both gas and air pressures are within range. Every time the gas pressure is turned off the low gas pressure switch between the regulator and the burner gas solenoid valve must be reset.

Heater Start-up:

1. Check that the low GAS PRESSURE switch has been reset
2. Turn on the burner control panel POWER SWITCH (see Section 4.4.7)
3. Set the BURNER/DIVERT switch to BURNER.
4. Turn the BLOWER HYD. power on at the Main Control Panel.
5. Wait for READY TO FIRE light.
6. Notify crew of the intent to start operation
7. Press the START BURNER button.
8. Wait untill the burner fires (about 20 seconds).
9. Notify crew that the burner is operating.

Heater Shutdown:

1. Press the STOP BURNER button.
2. Turn off the gas supply unless it is being used for other operations.
3. Wait 3 minutes minimum to cool the burner before turning off or diverting the blower.
4. Turn off the BLOWER switch.
5. Turn off the burner control panel POWER switch.

5.2.5 - Router

The Router is a self contained unit with a hydraulically driven motor that spins an internal tooling plate, which is outfitted with carbide cutters. When the cutters impact the pavement, they chip away the pavement in a grove with preset dimensions. The Router's control circuit is designed to simplify the starting and deployment of the cutter into a simple On and Off operation. The forward motion of the Router is furnished by the movement of the vehicle or the Positioner attached to it (see Figure 5.2.1). The debris and dust produced by the cutting of the pavement is drawn up from inside the router through a flexible hose into the dust removal canister mounted on the truck bed. The vacuum for the dust removal canister is created by the inlet to the Blower; therefore, the Blower must be operating wile the router is cutting.

Figure 5.2.1 - The Router Component.

Router Startup Procedure:

1. Verify the operation of the Hydraulic Power Unit.
2. Follow the Blower startup procedure (see Section 5.2.3)

3. Turn on the ROUTER POWER switch (see Fig. 4.4.6).

Note: The Router OFF button should be pressed if an error occurs, in the following procedure, to reset the controller.

4. Verify that the red HEAD UP indicator is lit
5. Press the Router START button (see Fig. 4.4.6). Note: The yellow indicator should light to verify the rotation of the cutting plate.
6. When the cutting plate has been fully extended and locked into the pavement the green CUTTER DOWN indicator should light-up.

Router Operation Procedure

As the Router is moved, a groove will be cut in the pavement to the preset dimensions. The router can be started and stopped for each crack encountered on the fly. The groove should be ideally centered over the crack to be sealed. Never move the Router faster than 2 mi/hr or the cutters may be damaged. Watch for cutter wear by routinely verifying the dimensions of the groove. Should the groove dimensions become unacceptable, the cutters should be adjusted or replaced.

Router Depth Adjustment Procedure:

1. Follow the LRPS Hydraulic Positioner shutdown procedure (see Section 5.1.2).
2. Lockout the LRPS POSITIONER HYD. switch (see Fig. 4.4.6)
3. Complete the following Router shutdown procedure.
4. Lockout the ROUTER POWER switch (see Fig. 4.4.6).
5. Remove the Router cover.
6. Loosen the bolts in the sliding pivot blocks, through the access holes in the Routers outside case (see Fig. 5.2.2 Item 1) and the internal retaining bolts (see Fig. 5.2.3 Item 6).
7. Turn the adjusting screws an equal amount to the desired height (see Fig. 5.2.3 Item 4).
8. Retighten the Sliding pivot block bolts to 100 lb-ft.
9. Replace the cover.
10. Replace the lockout keys into the ROUTER POWER and the POSITIONER HYD. switches.
11. Follow the Hydraulic Positioner startup procedure (see Section 5.1.2).

Figure 5.2.2 - External Router Sliding Block Retaining Bolts.

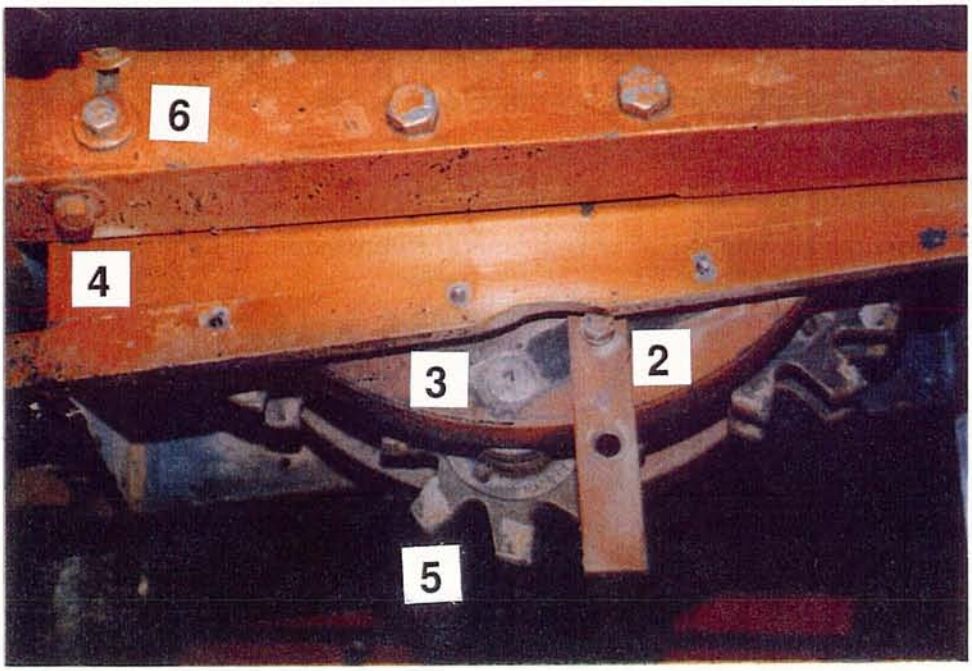


Figure 5.2.3 - Underside Of The Router Component.

Router Cutter Replacement And Width Of Cut Adjustment Procedure:

1. Follow the LRPS Hydraulic Positioner shutdown procedure (see Section 5.1.2).
2. Lockout the POSITIONER HYD. switch.
3. Complete the following Router shutdown procedure.
4. Lockout the ROUTER POWER switch (see Fig. 4.4.6).
5. Carry out the LRPS frame retraction procedure (see Section 5.1). Note: Be sure to install the router safety chain.
6. Remove the control Box cover and flip the CUTTER CHANGE switch On.
7. Remove the side brushes (see Fig. 5.2.3).

Note: For each cutter to be replaced, repeat steps 8 through 12.

8. Line up the cutter axle with the cut-out in the router base (see Fig. 5.2.3).
9. Remove the pin retaining straps (see Fig. 5.2.3 Item 2).
10. Slide out the pin out of the tooling plate, wile catching the spacer washers (see Fig. 5.2.3 Item 3).
11. Place the new cutter and the old spacer washers back on the cutter axle as it is slid back into the tooling plate (see Fig. 5.2.3 Item 5). Note: The placement of the washers on the cutter axles dictates the width of the router's cut.
12. Repeat steps 8 through 11 for each cutter axle.
13. Reassemble and enable the router by following steps 1 through 7 in reverse.

Router Shutdown Procedure:

1. To cease routing operation, simply press the Router Stop button.
2. The red Cutter Up indicator light should illuminate.
3. Turn off the Router Power switch.
4. Turn off the Blower Hydraulics switch.
5. Follow the Hydraulic Power Unit shutdown procedure, if applicable (see Section 4.4.4).

5.2.6 - Vehicle Speed

The maximum speed that the vehicle can be driven while the APS is engaged with the road is dependent upon the specific APS configuration installed in the LRPS cart. The maximum speed is limited to whichever is lower: the slowest component speed or the fastest speed at which the guidance system can track the crack. The approximate maximum speeds of the APS components are as follows: the applicator can operate up to 10 mph, the blower and heater up to 7 mph, and the router can cut the road at speeds up to 2 mph. The operator should continuously inspect the quality of the sealing process and

convey any recommended speed changes to the driver. The tracking capability of the guidance system is dependent upon the specific APS components and the straightness of the crack. Maximum speed guidelines are difficult to recommend, but since the driver can directly see the response of the guidance system on the cab monitor, speed adjustments can be made easily .

5.3 - ILCSS Shutdown and Stowage

When the crack sealing operation is complete, the machine must be completely shutdown and secured before transport. The vehicle must be stopped and the parking brake set, before the crew members leave the vehicle to begin the Shutdown procedure.

ILCSS Shutdown And Stowage Procedure:

1. Turn off the ROUTER POWER switch (see Fig. 4.4.6).
2. Turn off the Blower (see Section 5.2.3) and the BURNER POWER switch (see Fig. 4.4.7).
3. Follow the Positioner Shutdown procedure (see Section 5.1.2).
4. Execute the Sealant Melter Shutdown procedure (see Section 4.6.1).
5. Carry out the Hydraulic Power Unit Shutdown procedure (see Section 4.4.4).
6. Turn off the APPLICATOR POWER switch.
7. Close all propane valves.
8. Exit all computer programs (Section 5.1.3) or (Section 5.1.4).
9. Power down the rack mount PC computer.
10. Execute the AC Generator Shutdown procedure (see Section 4.4.2).
11. Turn off the UPS.
12. Remove the surveillance camera from the LRPS loop and turn off the LRPS CAMERA power switch (see Fig. 4.4.1).
13. Remove both table pins.
14. Retract the LRPS frame.
15. Connect the Router safety chain and screw in the LRPS transport pins.
16. Turn off the AMBER FLASHER lights (see Fig. 4.4.1) and clear the crew from the truck bed before transport.

6

INTEGRATED GENERAL CRACK SEALING SYSTEM

6.1 - IGCSS Deployment And Start-up

Upon arrival at the road site, the ACSM should be stopped, and the parking brake set, in an area near where cracks are present to begin the startup procedure. The truck may need to be moved during the LSS startup procedure (see Section 6.1.5) to locate the laser over a crack. If the truck is to be moved, the crew member off the vehicle should use the communication system to give instructions verbally to the driver. The setup crew should understand which start-up tasks they are responsible to perform, and the appropriate timing of these tasks, in relation to the other crew members tasks. The crew should keep the others informed, step by step, when their tasks are complete.

Perform the Common Operation Instructions (Section 4) first, then complete the following instructions, which are specific for the IGCSS. It is very important that the IGCSS startup procedures be carried out in the order that they are presented. Never deviate from this order, or the machine will not startup properly. Should a system failure occur during startup, carryout the IGCSS shutdown procedure (see Section 6.2) and then the startup procedure may be attempted again.

6.1.1 - Light And Camera Bar Deployment

With the common operating procedures complete, begin the RPS deployment with the unfolding of the light bar. The light bar is folded up to the front of the truck for transport and is locked in place with two pins, and a chain is employed as a fail-safe measure. The physical deployment of this frame requires two crew members and a minimum of assembly at the road site. Two additional 12 inch outboard light

fixtures need to be attached to the light bar during deployment to extend the operational area. A shroud will also need to be assembled to prevent external light from creating unwanted shadows on the scanned pavement. The operation of the light bar is controlled by the VSS and this is discussed in further detail in Section 6.1.6.

Light and Camera Bar Deployment Procedure:

1. Remove the chain and release the pins to unfold the light bar. Support the light bar manually, with two crew members, so that it does not drop rapidly (see Fig. 6.1.1).
2. Swing the light bar away from the vehicle. The light bar will stop at about truck bumper level.
3. Pull the front of the light bar out away from vehicle until it is fully extended.
4. Add the left and right light outboard fixtures by sliding them into the square tubing openings located on either end of the front light bar. Secure these fixtures with pins (see Fig. 6.1.2).
5. Connect electric cords for the outboard fixtures to the light bar outlets.
6. Install the metal rings around the camera enclosures (see Fig. 6.1.3).
7. Slide the canvas sleeves around the camera rings.
8. Spread the shroud around the light bar (see Fig. 6.1.4).
9. Snap on the canvas skirt sections.
10. Turn on each of the four `VSS LIGHTS` one at a time to avoid electrical surges (see Fig. 6.1.5).

Light And Camera Bar Retraction Procedure:

1. Turn off each of the `VSS LIGHTS`.
2. Remove the canvas skirt sections.
3. Remove the shroud from the light bar.
4. Remove the canvas sleeves from the camera rings.
5. Remove the metal rings from the camera enclosures.
6. Disconnect the electric cords for the outboard fixtures from the light bar outlets.
7. Remove the left and right light outboard fixtures by sliding them out of the square tubing openings located on either end of the front light bar.
8. Push the front of the light bar toward the vehicle until it is fully retracted.
9. Swing the light bar up toward the vehicle until it is against the front of the cab.
10. Insert the pins and attach the chain to secure the light bar.

Figure 6.1.1 - Light And Camera Bar Deployment.

Figure 6.1.2 - Light And Camera Bar Outboard Fixtures.

6.1.2 - Surveillance System Set-up

The operation of the IGCSS requires that the vehicle driver and the control booth operator can see the workspace of the robot. The camera may have to be adjusted periodically to view the entire workspace. The video monitors are connected to the surveillance network with a two channel selector that needs to be set to channel "B" to view the RPS image. The upper monitor in the control console has a dual purpose, it can be used to view the robot workspace by selecting input Line A or used as the display for the PC by selecting input RGB A (see Fig. 5.1.2).

Surveillance System Set-up Procedure:

1. The RPS camera must be deployed and the image shown on both monitors, before the robot can be powered-up.
2. Relocate the camera from on top of the robot mount to the bumper boom (see Fig.s 3.3.2 and 3.3.3).
3. Send 12 VDC power to the camera by switching the `RPS CAMERA` rocker switch on (see Fig. 4.4.1).
4. Place the Driver Monitor into its mount on the truck cab ceiling and plug in its 12 VDC power cord to the cigarette lighter receptacle and select line `B` on the dash selector (see Fig. 3.2.15).
5. Select the `LINE A` Input Selection Button on the upper control console monitor, in the booth, and select channel `B` on the console selector.

Surveillance System Shutdown Procedure:

1. Turn off the 12 VDC power to the rear camera by switching the `RPS CAMERA` rocker switch off. (Fig. 4.4.1).
2. Relocate the camera from the bumper boom to the top of the robot mount.
3. Fold the boom up (see Fig.s 3.3.2 and 3.3.3).

6.1.3 - GMF Robot Start-up And Secondary Arm Deployment

The GMF robot and the secondary arm link-up must be executed in a coordinated fashion for a safe and successful link-up. Due to the way that the coupling is designed, the robot end-effector must be lowered onto the coupling on the secondary arm. This procedure requires two crew members: one to operate the robot, and the other to guide the secondary arm coupling under the robot end-effector. The crew member guiding the secondary arm must remain outside the robot workspace and in communication with the robot operator throughout this procedure. To safely move the robot, the robot operator must

observe the link-up operation through the RPS surveillance camera, and be prepared to hit the Emergency Off button for the robot arm power in the case of incorrect operation or emergency.

GMF Robot / Secondary Arm Start-up Procedure:

1. Pull out the robot safety pin prior to doing any work with the robot.
2. Unstrap the robot arm.
3. Release the arm from its transport position by removing the transportation straps and lowering the arm down to its operating position.
4. Move the secondary arm to the link-up position.
5. Turn on robot `BREAKER #3` (see Fig. 4.4.3).
6. Turn on the robot `POWER` switch. The robot will automatically initialize itself and run the correct program for the ACSM. Wait until the initialization process is complete. This can be monitored using the LCD screen on the robot teach pendant.
7. Press the button marked `PRE-LINK-UP POSITION` to move the robot from its home position to a point above the link-up position. NOTE: The arm will move at this time. Make sure that all personnel are out of the robot workspace.
8. Move the secondary arm so that its coupling lines up with the robot end-effector (see Fig. 6.1.6).
9. When the alignment is correct, press the `LINK-UP` button to lower the robot end-effector to link with the secondary arm. This procedure should be closely monitored to assure correct alignment, and if anything appears incorrect, the Emergency Stop button should be hit.
10. At this time, the end-effector pins should be halfway engaged in the coupling slots (see Fig. 6.1.7). If this is so, press the Robot Ready button. This will inform the robot that the hardware is configured and ready for the sealing operation.

Figure 6.1.3 - Light And Camera Bar Shroud.

Figure 6.1.4 - Light And Camera Bar Canvas Skirt.

Figure 6.1.5 - Light Switch Cluster.

Figure 6.1.6.- Robot And Secondary Arm Connected.

GMF Robot /Secondary Arm Shutdown Procedure:

1. When the ICU receives a quit signal, it will send a shutdown signal to the robot. On receiving this signal, the robot will perform all necessary operations to prepare its controller for shutdown. It will then return the arm to the link-up position. Verify that the ICU has completed its shutdown before proceeding with this operation.
2. One operator should hold the secondary arm in place. This operator must stay outside of the robot workspace at all times, as the robot will move during the shutdown procedure.
3. Press the `HOME ROBOT` button. The robot will move away from the link-up position and return to its home position.
4. Replace the robot safety pin.
5. Turn off the robot `POWER` switch.
6. Turn off the electrical supply to the robot by switching off `BREAKER #3` (see Fig. 4.4.3).
7. Manually move the secondary arm to line up with its storage position under the truck bed (see Fig. 6.1.8).
8. Strap the secondary arm to the truck bed frame.
9. Install the transport safety chain.
10. Strap the robot to the frame.

6.1.4 - VOC Deployment

The VOC encoder fifth-wheel assembly is mounted between the vehicle's rear wheels. The VOC encoders send information to a control board that resides inside the ICU computer. During operation the VOC system is transparent to the operator. Wile transporting the vehicle, the VOC mechanism is suspended by a chain several inches above the road (see Fig. 6.1.9 Item A). To deploy the VOC simply remove the chain which will allow the wheel to contact the road during operation (see Fig. 6.1.10).

Figure 6.1.7 - Robot Coupling.

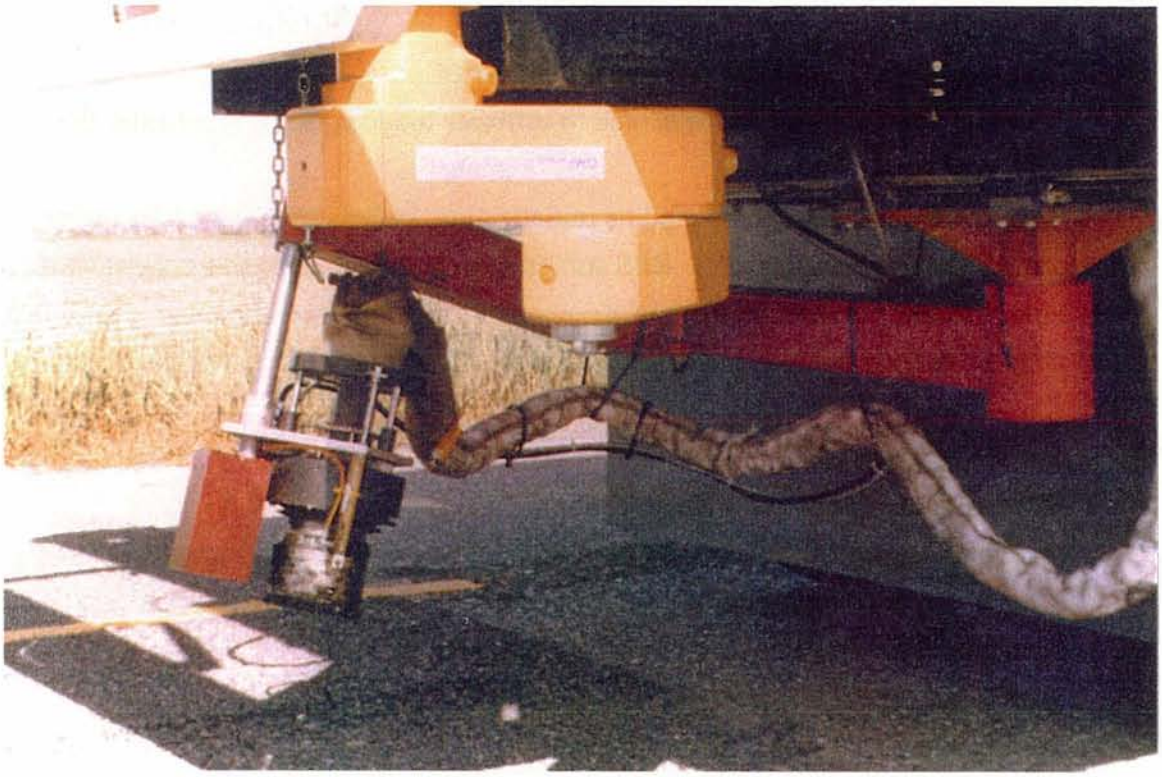


Figure 6.1.8 - Robot And Secondary Arm Transport Position.

6.1.5 - LSS Startup

The local sensor must be calibrated to the current pavement characteristics. In particular, the LSS will need a measure of the roughness of the pavement so that the program can distinguish surface roughness from actual cracks.

LSS Startup:

1. Make sure that the RPS workspace is clear of all personnel and obstacles. Position the LSS over a segment of pavement that does not have a crack in it, as the system performs an initialization based on measurement of the road surface roughness. This measurement requires uncracked pavement.
2. Turn on the laser unit `POWER` switch, and enable the `LASER KEY` switch. Observe all precautions in the MVS documentation when operating the laser. In particular, do not look at the invisible laser scan line, as it can cause eye damage.
3. Turn on the rack mount PC computer.
4. Set the upper control console monitor input to the computer display by selecting the `RGB A` input selection button on the upper control console monitor (see Fig. 5.1.2).
5. When the computer has completed its boot procedure, type

   ```
   rpslss
   ```

   to initiate the LSS program for the RPS on the PC.
6. Follow the instructions on the screen to calibrate the local sensor and enter the automatic control mode.
7. Once the program has completed its initialization, switch the input of the upper control console monitor to the RPS surveillance camera by changing the `LINE A` Input Selection Button on the upper control console monitor, and making sure that the `A/B` switch for the monitor is set to channel `B` for the RPS surveillance camera.

LSS Shutdown Procedure:

1. Make sure that the robot is already shutdown.
2. Switch the upper control console monitor back to the computer input by changing to `RGB A` input selection button on the upper control console monitor (see Fig. 5.1.2).
3. Press the `ESC` key to end the `rpslss` program.
4. Verify that the PC program has exited correctly.
5. Turn off the rack mount PC computer.
6. Turn off the laser `POWER` switch.

6. The VSS is ready to recieve instructions from the ICU.

Figure 6.1.11 - ICU Connector Box.

VSS Shutdown Procedure:

1. The VSS will receive a shutdown signal from the ICU when the ICU program is shutdown.
2. Upon receipt of this shutdown signal, the VSS program will perform all the necessary operations to terminate the VSS program and prepare the VSS computer system for shutdown.
3. When the VSS program has terminated, turn off the VSS computer.

6.1.7 - ICU Startup

In the RPS configuration, the ICU is the main system that controls the other subsystems that are transparent to the operator; therefore, the ICU computer has to be the last system started in the IGCSS startup procedure. When the ICU is started, it will automatically establish communications with the VSS and RPS and launch the initial operational programs in the VOC and the Path Planning sub-systems. The ICU computer resides in the rack in the rear of the operator's booth (directly behind the

door). During operation of the ACSM, the user screen is the only peripheral required by the ICU. However, during startup procedures, the portable vt100 terminal must be connected to the ICU to input the startup sequence. To connect the terminal, plug the serial connector from the terminal into the port marked "ICU Terminal" on the connector box in the computer rack (see Fig. 6.1.11). With the following input sequence keyed into the ICU, the operator can remove the vt100 and command the RPS with the user screen in the control console.

ICU Startup Procedure:

1. Use the power switch on the front panel of the ICU to turn the power on and verify that the power to the User Interface screen is on.
2. Input the following on the vt100 terminal at the appropriate prompt. (The <> symbol indicates a return key).

PROMPT	USER INPUT REQUIRED
>	`br <>`
Rombug:	`g <>`
scsi_id:	`2`
lun:	`0 <>`
make -f=make540	<>
load -d /h0/cmds/bootobjs/t3	<>
2 devices on line	<>
User name:	`super <>`
Password:	`user <>` (note: this will not echo on screen)
OS9>>	`chd demo/icu <>`
OS9>>	`acsm <>`

3. Verify the ICU's ACSM program is running by observing if the color User Interface screen appears on the screen.
4. Using the mouse at the operator station, click the `POWER ON` button on the User Interface screen.
5. Click the General Machine button on the User Interface screen.
6. The mouse at the operator station is now set to interact with the ACSM program (see Fig. 6.1.12).

ICU Shutdown:

1. To quit the ACSM program, click the `STOP` button on the User Interface and enter `CONTROL-C` (both keys simultaneously) on the vt100 keyboard .
2. The ICU will send signals to the subsystems with which it is in communication (VSS and robot) to commence their shutdown procedures. At the same time, the ICU will clean up its internal state and prepare for shutdown of the ICU computer.
3. When the ICU program has successfully terminated (indicated by a blank User Interface Screen), turn off the power switch on the ICU computer.

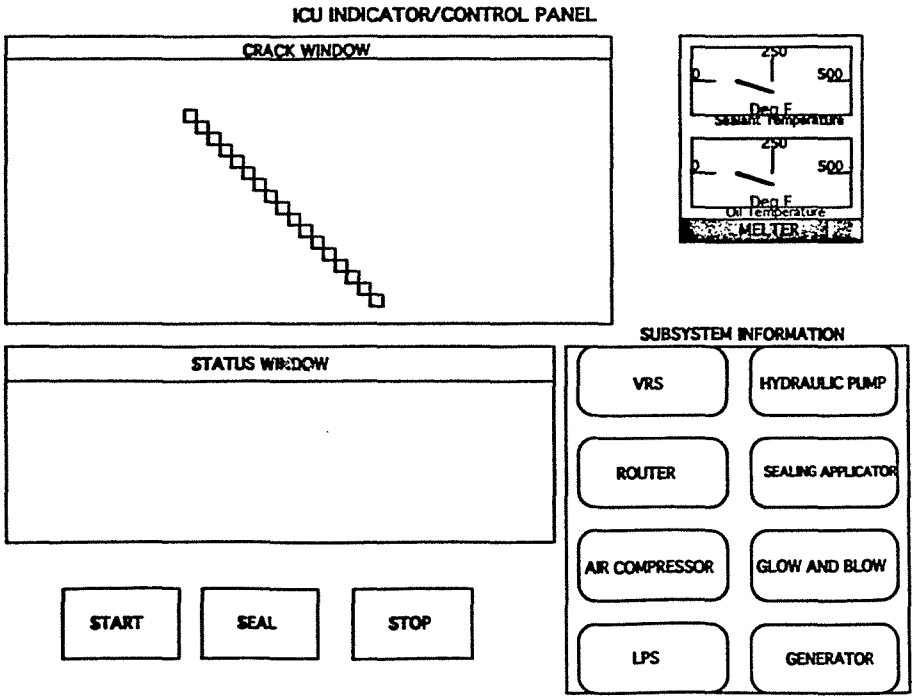


Figure 6.1.12 - The ICU User Screen.

6.2 - IGCSS Operation

6.2.1 - Overview of ACSM Operation

The following will give an overview of the operation of the Truck during a Sealing Operation. For details of the sealing operation please refer to "Sealing Operation" in the next section.

The operation of the Truck prior to and during sealing is closely linked to the User Interface. The buttons on this User Interface, Start, Seal and Stop, are used for this purpose.

1. Click the `START` button on the User Interface.
2. Position the Truck before the crack(set of cracks) to be sealed.
3. Wait for a Ready To Seal message on the User Interface
4. Drive the Truck forward over the crack at 2mph and stop with the crack under the Robot workspace.
5. Click the `SEAL` button on the User Interface
6. Wait for a Sealing Completed message on the User Interface.
7. Move the Truck over the next crack and click `SEAL` button.
8. Continue steps 5 through 7 if there are more cracks to be sealed.
9. Click `STOP` button if all cracks have been sealed.
10. Drive forward at normal speed till the next set of cracks is reached and repeat the above steps.

6.2.2 - ICU Operation

General Guidelines

A sealing operation is defined to be after the operator presses the Start button and before the Stop button is pressed. Note: Please see Sealing Operation for details on Start and Stop buttons.

During a sealing operation, the following guidelines should be followed:

The truck must never be backed up. This will confuse the vehicle orientation program. In the event that the truck is backed up during an operation, all cracks within the workspace of the robot and forward must be re-sensed. The operator should then stop the operation by pressing the Stop button (please see 'Sealing Operation' for details) and the driver should then completely backup to a position to re-sense the cracks. After the truck is repositioned, the operator should restart the operation by pressing the Start button.

The truck should be driven forward at no more than 2 mph.

The driver should use the alignment marks on the screen in the cab to stop the truck such that the robot is over the correct workspace.

After the Stop button is pressed (a sealing operation is over), the driver may travel at normal speeds to the next site.

Sealing Operation

Please refer to the diagram "ACSM Screen" (Fig. 6.1.12). When the operator is ready to commence the sealing operation:

1. Click on the START button of the ACSM screen using the mouse.
2. The Status Window will display messages from the Diagnostics which will be performed at this time. A Diagnostics Complete message will appear when this has been completed.
3. Wait for a Ready To Seal message in the Status Window.
4. When the Truck is stopped over the crack to be sealed; click the SEAL button of the ACSM screen using the mouse. The Crack window will display the configuration of the crack being sealed. When the sealing of the current workspace has been completed the Status Window will display a message. The vehicle can now be moved to the next workspace to be sealed.
5. Continue to click the SEAL button each time it is required to seal cracks after the vehicle has been positioned.
6. After completion of sealing for a set of cracks click STOP to reset the ICU. After theThe placement of the washers dictates the width of cut button is pressed the ICU program will continue running and the START button may be pressed when a new operation is to begin.

Subsystem Information

To obtain information about the status of a particular subsystem:

1. Click on the particular subsystem in the Sub-System Information area. This pops up a window on the sub-system.
2. Click on the CLOSE button of the sub-system screen to close the sub-system window.

6.3 - IGCSS Shutdown and Stowage

To begin the Shutdown and stowage procedure, all sealing operations must be ceased, and the vehicle stopped with the parking brake set.

IGCSS Shutdown And Stowage:

1. Conduct the Melter Shutdown procedure (see Section 4.6.1).
2. Shutdown the ICU computer (see Section 6.1.7).
3. Turn off the LSS (see Section 6.1.5).
4. Disengage the GMF robot from the Secondary Arm (see Section 6.1.3).
5. Shutdown the GMF robot (see Section 6.1.3).
6. Shutdown the VSS computer (see Section 6.1.6).
7. Shutoff and retract the Light And Camera Bar (see Section 6.1.1).
8. Strap the GMF robot and the Secondary Arm under the truck bed.
9. Reconfigure the surveillance system (see Section 6.1.2).
10. Retract the VOC assemblies (see Section 6.1.4).
11. Follow the Hydraulic power shutdown procedure (see Section 4.4.4).
12. Turn off the applicator power switch (see Fig. 4.4.6).
13. Execute the AC generator Shutdown procedure (see Section. 4.4.2).
14. Turn-off the UPS (see Section. 4.4.3).
15. Turn off the amber flasher lights (see Fig. 4.4.1) and clear the crew from the truck bed before transport.

7

Maintenance Information

7.1 - Maintenance Introduction

This manual contains the necessary information required to ensure that the Automated Crack Sealing Machine is properly maintained and serviced. The information contained in this document is not intended to be all inclusive. It is intended to discuss, in sufficient detail, the normal maintenance required to keep the machine in optimum operating condition. Should an unscheduled failure occur, the machine should be shutdown and the manufacturer of that component contacted immediately for repair information. It is strongly recommended that only trained and skilled maintenance personnel be permitted to work on any of the ACSM systems.

7.2 - Daily Maintenance

Each of the following procedures should be completed every time the ACSM is to be operated, without exception. These procedures are a mixture of pre trip, operation concurrent and post trip tasks. The crew is responsible to decide when and where to execute these procedures to protect the machine and personnel.

7.2.1 - White GMC Truck

A standard pre trip inspection of the truck is required by State and Federal law. The exact procedure may vary slightly from state to state, but each state mandates a complete safety inspection of the truck

chassis and addresses an inspection of the load. In this case the load is the ACSM itself. The machine should be inspected prior to transport to verify that all parts are locked and secured. Further detail on these procedures is available in the service section.

7.2.2 - AC Generator

The AC generator must be opened and inspected prior to the initial startup procedure. Remove the doors from the generator and complete a visual inspection for loose parts or leaking fluids. On the AC generator engine complete the following tasks:

- Check the motor oil level in the engine.
- Check the coolant level.
- Check the belts and hoses.
- Check the battery fluid level.

Further detail of these procedures is available in the service section.

7.2.3 - Hydraulic System

Prior to the initial startup procedure, all of the circuit hoses and connections should be inspected for cuts and leaks. The Hydraulic Power Unit (HPU) fluid reservoir level should be checked and filled if low. The filter impasse indicator must be checked and the filter replaced if clogged (see Fig. 7.2.1). Remove both doors from the HPU and completely inspect the engine. Look for loose parts or leaking fluids inside the engine compartment and complete the following tasks.

- Check the motor oil level in the HPU.
- Check the coolant level.
- Check the belts and hoses.
- Check the battery fluid level.

Further detail of these procedures is available in the service section.

7.2.4 - Communication System

The voice powered communication headsets are equipped with amplifiers that are battery powered. The 9 volt battery should be replaced each day (see Fig. 7.2.2). The batteries should last an entire day, but it is recommended that replacement batteries be brought along when the machine is in operation.

7.2.5 - Surveillance System

Dirt and dust tends to buildup on the camera enclosure lens during operation. It is recommended that the lens be cleaned with a damp cloth at least once a day.

7.2.6 - GMF Robot

Maintenance information for the GMF Robot is included with the materials in Appendix B.

7.2.7 - Melter

The Melter should be inspected externally for loose parts and leaking fluids prior to the initial startup procedure. The heating oil level should also be checked. The oil should register as high as the mark on the dipstick when the melter is at ambient temperature (see Fig. 7.2.3). If the oil level is low, fill the reservoir with standard petroleum based heat transfer oil #1. Never attempt to operate the melter when the oil level is low, the melter may sustain damage

Figure 7.2.1 - Hydraulic power Unit Filter.

Figure 7.2.2 - Amplifier Battery Replacement.

Figure 7.2.3 - Melter Oil Dipstick.

Figure 7.2.4 - Blower Fluid Sight Glass.

7.2.8 - Heater/Blower

Check the fluid level in the sight glass on the blower unit and refill if low with automatic transmission fluid (see Fig. 7.2.4).

7.2.9 - Router/Debris Removal

The cutters on the Router should be inspected for excessive wear or breakage The cutters are easily inspected when the LRPS is retracted. The procedure to change the cutters is detailed in the preceding operation manual. The filter in the debris removal system tends to get clogged with dust from the routing process (see Fig. 7.2.5). The filter should be blown clean at least once a day.

7.2.10 - Applicator

The Applicator brush needs to be inspected each time the machine is operated (see Fig. 7.2.6). If the brush is damaged of worn, replace it with a new one. Replacement may be easier when the applicator is heated up to operating temperature and protective gloves are worn to protect hands from burns.

Brush Replacement Procedure:

1. Retract the applicator approximately six inches above the road.
2. Remove the brush retaining clamps.
3. Remove the brush.
4. Slide on the new brush so that it protrudes approximately 1/4 inch from the bottom of the Applicator.
5. Reinstall the brush retaining clamps.

Figure 7.2.5 - Vacuum Canister Filter.

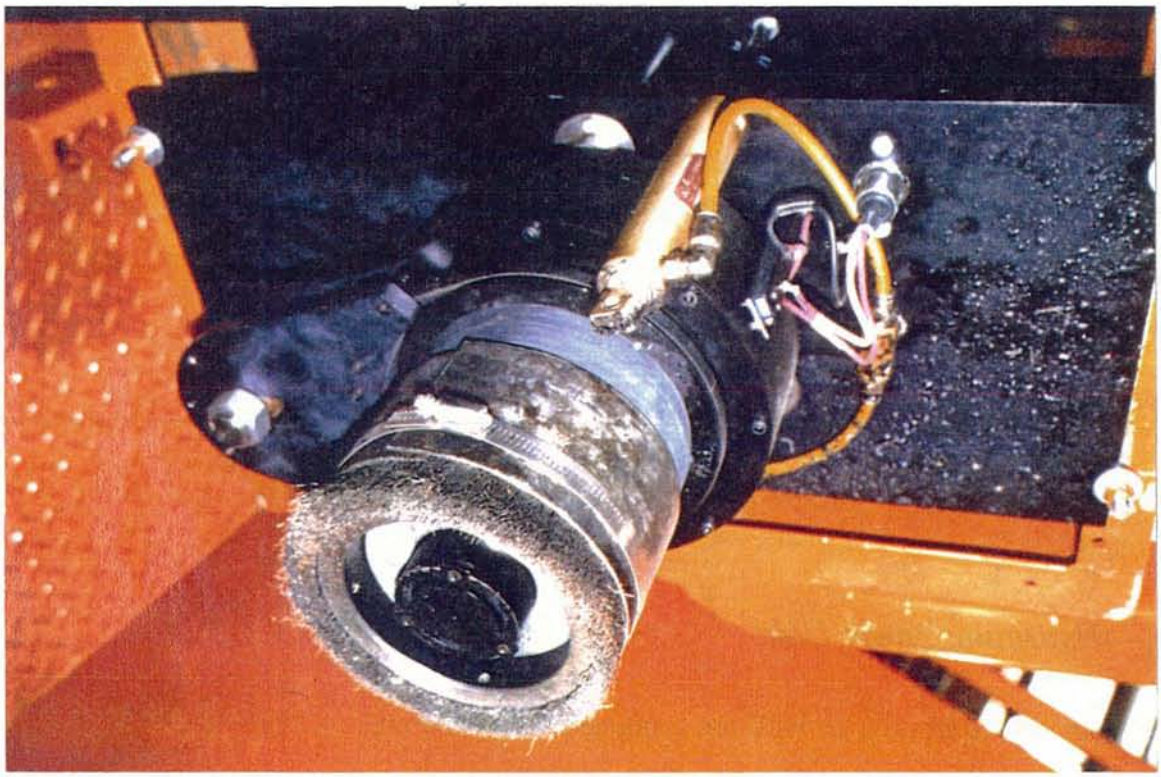


Figure 7.2.6 - Applicator brush.

7.2.11 - LSS

The LSS enclosure is fitted with a lens that tends to gather dirt during operation. It is recommended that the lens should be changed each day.

7.3 - Periodic Maintenance

This section chronicles the maintenance procedures which must be performed on various components following prolonged use of the ACSM.

7.3.1 - White GMC Truck

Maintenance procedures for the White GMC truck are contained in Appendix C.

7.3.2 - 12 Volt DC

The indicator lights on the main control box may burn out and need to be replaced. To replace the bulbs, unscrew the indicator lens, grasp the bulb and pull it out of its socket. Replace with any G3-1/2 or T3-1/4 lamp.

7.3.3 - AC Generator

Maintenance procedures for the AC generator are contained in Appendix D.

7.3.4 - Hydraulic Power Unit

Maintenance procedures for the HPU are contained in Appendix E.

7.3.5 - Pneumatic System

The moisture that condenses inside the auxiliary air tank, mounted under the truck bed, should be drained following several days use of the ACSM. Also, pneumatic oil should be added to the air line oiler at this time.

7.3.6 - Hydraulic Positioner (LRPS)

Once a week apply multi-purpose lithium grease to the lubrication fittings on the four bearing gliders beneath the LRPS slide table.

7.3.7 - LRPS Frame

Once a week apply multi-purpose lithium grease to the four lubrication fittings on the lower links of the frame.

7.3.8 - VOC

Once a week apply multi-purpose lithium grease to the lubrication fittings on the upper and lower pivot arms of the VOC encoder assembly.

7.3.9 - Light And Camera Bar

Should one of the Tungsten-Halogen lamps burnout on the light bar, it may be replaced with a GE Q500T3/CL 500W filament.

7.3.10 - GMF Robot

Maintenance procedures for the GMF Robot are contained in Appendix B.

7.3.11 - Secondary Arm

Once a week, apply multi-purpose lithium grease to the lubrication fittings on the bearing gliders and to the bearings in the arm joints.

7.3.12 - Melter

Maintenance procedures for the Melter are contained in Appendix F

7.3.13 - Applicator

If the floater plate inside the sealant reservoir should begin to stick during operation, sealant buildup in the applicator will have to be removed. This procedure may be performed with the applicator base mounted to the truck. Remove the applicator core as outlined in Section 3.2.1. Place the applicator base down into a bucket of kerosene which is deep enough to submerse the entire sealant reservoir. Allow the base to soak until all the sealant buildup can wiped off with a cloth. It is also recommended that the linear potentiometer shaft be wiped clean when it becomes dirty.

7.3.14 - Heater

Should the Pyrometer lens become dirty, blow or brush off the lens. Clean the remaining dirt using a "Q-Tip" dampened in denatured alcohol, wiping gently as to avoid scratching the lens.

7.3.15 - Router

Once a month apply multi-purpose lithium grease to the lubrication fittings on all the four bearings inside the router component. The best access to the fittings is through the top cover.

7.3.16 - Debris Removal

Maintenance procedures for Debris Removal are contained in Appendix G.

7.4 - Service Information

The ACSM is a complex mixture of prototype and after market equipment. Repair of this machine requires far more knowledge than what is contained within this manual. Should the machine require service for an unscheduled system failure, the University of California, Davis should be contacted for further instructions. Should the problem be with one of the after market components, contact the manufacturer for detailed information on its repair. A complete list of manufacturers and model numbers is included as Appendix AA. The following appendices contain detailed information on select ACSM components.

Appendix H: GMF Robot
Appendix I: AC Generator
Appendix J: Hydraulic System
Appendix K: Pneumatic System
Appendix L: Surveillance System
Appendix M: Winch(LRPS)
Appendix N: Melter
Appendix O: Heater/Blower

Appendix A: Manufacturer Component List

Manufacturer	Component	Model
APS Components:		
Aeroquip	Hydraulic System Connections	Misc.
Allenair	Pneumatic Cylinders	
American Power Conversion	Uninteruptible Power Supply	Smart-UPS 2000
Bellofram	Pneumatic Transducer	I/P Type 1000
Berry	Melter	BMA-200
Control Technology Specialists	Burner Control System	
Dayton	3/4 HP DC Motor	2M169
Eclipse	Thermal Blast Burner	
EG & G Rotron	Debris Separator	IVM2000PF
Generac	25 KW Generator	SD025G
Hoffman	NEMA 12 Box with Window	20x16x8
Hydraulic Controls, Inc.	Hydraulic Pumping Unit	Custom
Kaydon	Angular Contact Ball Bearings	KA series
Maurey Instrument Corp.	Linerar Motion Potentiometer	P1613-3-202
McMaster-Carr	Flex Shaft	442A36
Paxton	Centrifugal Blower	CB-87
Raytek	Infrared Pyrometer	ET3LT
Thompson	Linear Bearings	Super-8
UC Davis	72" Crimped Steel Wire Brush	Custom
Worcester	Positioner	Pm15 S
Worcester	Positioner Mounting Kit	MK 191
ICU Components:		
Computer Machinery Corp.	Ethernet Comm. Software Driver	CMC ENP-10 Driver
Computer Machinery Corp.	Ethernet Communications Card	CMC ENP-10
Heurikon Corporation	Backplane	HSE/17R-12V-W60-F3-S150
Heurikon Corporation	CPU Card	HK68H/V3E-16MB
Microware Corporation	OS-9 Professional	Ver. 2.4
Microware Corporation	Real-Time Audio Visual Environment (RAVE)	MM1250
Vigra Inc.	Multimedia Graphics Card	MM1250
Xycom	Analog I/O Card	XVME540
Xycom	Digital I/O Card	XVME201
Xycom	Software Driver	XVME982

LRPS Components:		
Bastech	LRPS Frame	Custom
Columbia Winch and Hoist	Hoist	H2000A1-01
Industrial Computer Solutions	Rackmount 486 PC System	
McMaster-Carr	Wheel Size Swivel Casters for LRPS	2443T32
Parker Hannifin	Digital Process Servo Valve Controller and Actuator	PMC 10
Parker Hannifin	F-Style Actuator, Proportional Valve, and Controller.	PLA2X12LF7M10NB10
Sony	13" Video/Data Monitor	GVM 1310
TDK	Bearing Rails	SR 35W
LSS Components:		
Modular Vision Systems, Inc.	Digital Signal Processing Board	SKY321-PC
Modular Vision Systems, Inc.	LaserVision Profile Board	LPB
Modular Vision Systems, Inc.	LaserVision Sensor	MVS-30
RPS Components:		
Fanuc Robotics	Robot Manipulator	A-510
Fanuc Robotics	Karel Controller	RH, "C" Size
Fanuc Robotics	KAREL software	Version 2.21
Fanuc Robotics	Servo Driven Robot Transport, linear slide	Custom, 50 " Travel
Fanuc Robotics	3.5" Serial Floppy Disk Drive	
Fanuc Robotics	AD Module	
Fanuc Robotics	8-Bit I/O Module	
Fanuc Robotics	Serial Communications Option for KAREL Controller.	
Vehicle Components:		
Amerigas	Propane Gas System	Custom
Bastech	Robot Mount	Custom
David Clark	Communication System	3800 Series
Harrington Plastics	Elevated Walkway	I-4015 Series
KT Design	Operator Booth Skid	Custom
T & N Manufacturing	Operator Booth	Custom
T & N Manufacturing	Truck Bed	Custom
White GMC	Truck	XPEDITOR Series

VOC Components:		
BEI Motion Systems	Shock Proof Optical Encoder	
Fafnir	Pillow Block Link Mount Bearing , 1" Dia.	YAS-1
R & K Industrial Wheels	Encoder Wheel	Custom
Timken	Tapered Roller Cone	LM67048
Timken	Tapered Roller Cup	LM67010
Xycom	Computer Counter Card	XVME230
VSS Components:		
DataCube	FeatureMax MKll	260-0369 Rev. 02
DataCube	Image Flow Software ver. 2.1.2	940-1001-HH-MM
DataCube	Max-Scan 10MHZ	260-0250 Rev. 05
DataCube	MaxGraph	260-0225 Rev. 04
DataCube	ROI Store 512	260-0243 Rev. 08
DataCube	ROI Store 2048	260-0243 Rev. 08
Datron Technology	Optical Encoder	Correvit WPT-4500
Hubble	Floodlight Fixture	QL505
JML	TV Lenses (12.5mm, F1.3)	P/N 71846
Loral Fairchild	Line Scan Camera	CAM1301R
PELCO	Pressurized Camera Enclosures	#EH8004/SPL
Phillips	500 Watt Tungsten Halogen Lamps	500T3Q/CL FCL
Radstone	3.5" Floppy Drive	
Radstone	4MByte, Dual Port Memory Module	8SB/201
Radstone	20 Slot Chassis with 1200W PSU, 6 Slot VSB Backplane	cs-20 2/001
Radstone	68-33/100 CPU Module with 4M RAM, 50 MHz	68-33/100
Radstone	170 MB Hard Drive	WK-3/300
Radstone	Ethernet Card	ENET-1/100 112
Radstone	OS-9 Professional	Rel. 5
Radstone	Tape backup, 60 MB	TK-1/100
Z-World	Little Giant Controller	SBC200-E

Appendix B: GMF Robot Maintenance

I. OVERVIEW AND CONTROLLER MAINTENANCE

APPENDIX 3 PREVENTIVE MAINTENANCE SCHEDULES

3.1 Preventive Maintenance Schedules

Refer to the maintenance replacement/adjustment sections for exact information pertaining to these procedures.							
Check items	Daily	350 hours	500 hours	1000 hours	2000 hours	Special purpose	As required
Overall system	*						
Greasing bearings					*		
Greasing cyclo drive						* Replace bi-ennually (100000 hrs)	
Greasing Z and R axes				*			
Repeatability	* Visual check						* After repair
Mist oil							*
Cables	* Visual check						* Replace
Ventilation system	* Access doors						* Clean or repair
Backlash					* Check		* After replacement
Belts (timing)				* Check			* Replace
Brakes					* Observe dropping		

Check items	Daily	350 hours	500 hours	1000 hours	2000 hours	Special purpose	As required
Voltage (DC)					* Check		
Batteries (RAM memory)						* Replace once a year	* Replace

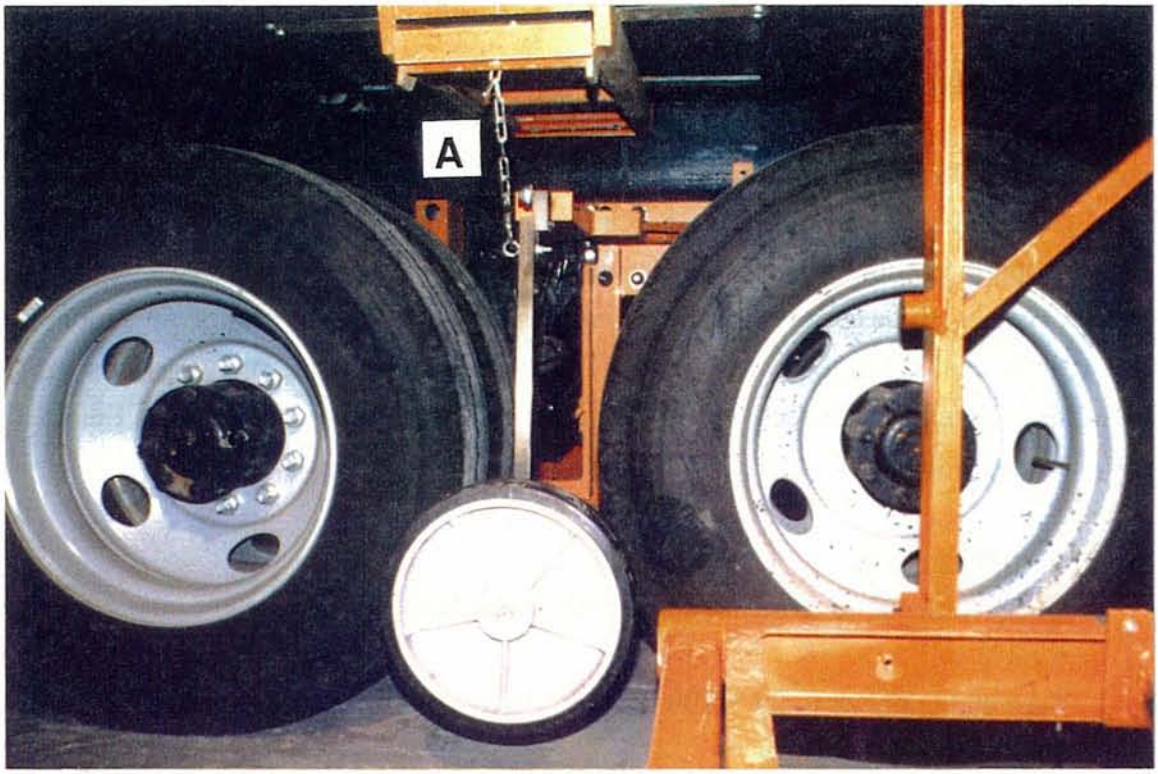


Figure 6.1.9 - VOC Retracted.

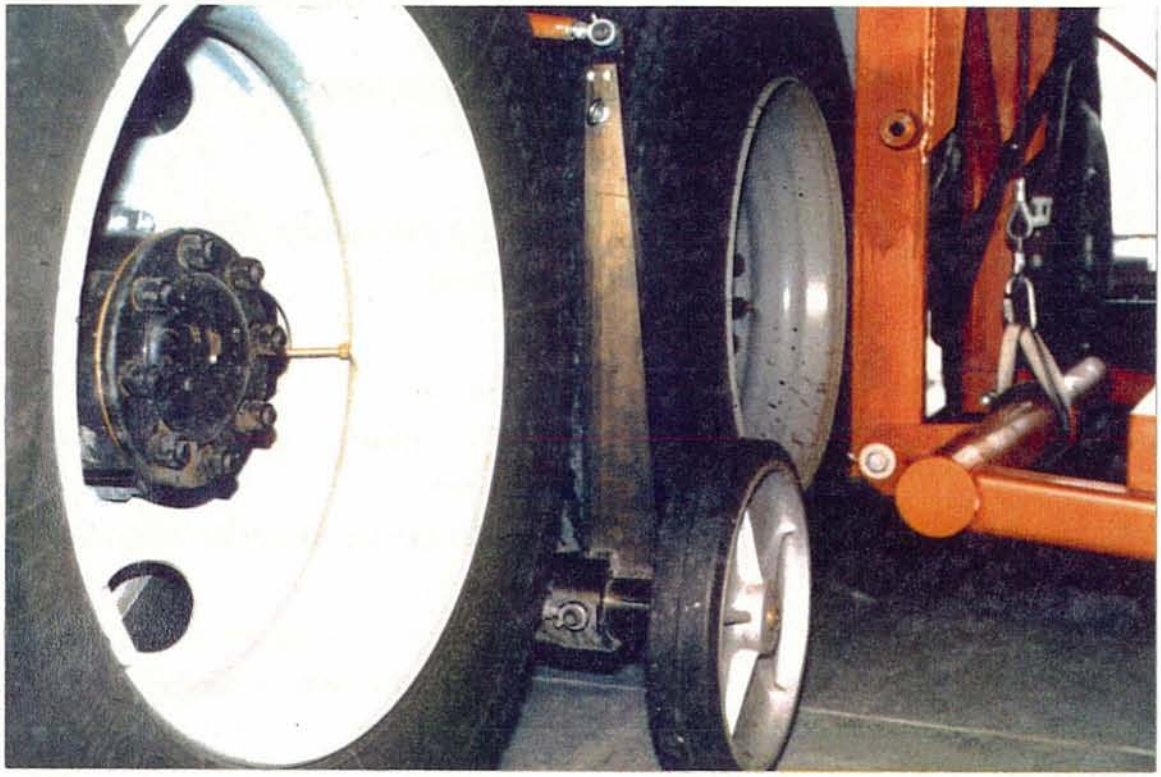


Figure 6.1.10 - VOC Deployed.

6.1.6 - VSS Startup

Execution of the VSS startup procedure only initiates the crack detection process within the VSS computer. The ICU computer ultimately has the control over the VSS and issues directions as to when to start and stop processing the line scan images of the road. At startup of the VSS, the operator chooses the type of pavement to be scanned. If the pavement type should change during operation, the new pavement choice could be entered through the ICU user screen while the vehicle is stopped. During operation, the VSS processed crack information is automatically sent to the ICU via Ethernet link and this is transparent to the user.

VSS Startup Procedure:

1. Connect the vt100 terminals serial cable to the VSS Terminal on the connector box (see Fig. 6.1.11).
2. Turn on the power to the vt100 terminal, located in the control console, and wait for the vt100 window to appear.
3. Turn on the power to the VSS computer system.
4. When the VSS is ready, a prompt will apear in the vt100 window.
5. Input the following sequence into the vt100. (The <> symbol indicates a return key).

PROMPT	USER INPUT REQUIRED
>	<>
romBug: setime ;* start system clock yy/mm/dd hh:mm:ss [am/pm]	g <> (Enter the date and time followed by the return key)
Time:	
1 devices on line	<>
User name?:	super <>
Password:	user <> (Note: This will not echo on screen)
super:	vision<>
VSS Menu	(Press the appropriate key for the type of pavement.)
0 - Maintenance Control	(Note: '0' is for maintenance used only and should not be selected for normal operations.)
1 - Light Colored Asphalt Concrete	
2 - Medium Colored Asphalt Concrete	
3 - Dark Colored Asphalt Concrete	
4 - Concrete	

3.2 Preventive Maintenance Check List

Item	Schedule	Data checked (other than daily)											
Air control set: Air pressure Oiler oil mist Oiler oil level Hose leakage	Daily												
Cables (visual check)	Daily												
Vibration	Daily												
Repeatability	Daily												
Peripheral devices	Daily												
Each part (clean and check)	Daily												
Ventilation	Daily												
Lubrication	Monthly (500 hrs)												
Each part (for play and looseness)	Monthly (500 hrs)												
Connectors (for looseness)	Monthly (500 hrs)												
Belt tension	Quarterly (1000 hrs)												
Z-axis brake	Quarterly (1000 hrs)												
Greasing bearings	Semi-anually (2000 hrs)												
DC power voltage	Semi-anually (2000 hrs)												
Control PCB offset voltage	Semi-anually (2000 hrs)												

Item	Schedule	Data checked (other than daily)											
Lubrication oil	Semi-anually (2000 hrs)												
Backlash	Semi-anually (2000 hrs)												
RAM backup batteries (replacement)	Anually (4000 hrs)												
Cyclo drive (greasing)	Bi-ennually (100000 hrs)												
Cable (replacement)	Bi-ennually (8000 hrs)												
Timing belt (replacement)	Bi-ennually (8000 hrs)												

4. PREVENTIVE MAINTENANCE

Preventive maintenance is based upon the amount of hours of operation of the robot. Some applications require a robot to be operational for 24 hours a day, while others require less on-time. If the robot is to operate continually, all check items should be maintained accordingly. The following chart should be used as a quick reference guide for preventive maintenance. This chart is based upon hours of operation and not calendar time. Some items should be checked as a daily routine by the operator. Quality of the work accomplished by the robot should be checked to determine the need for maintenance. Use the chart to indicate minimum preventive maintenance requirements. Hot, dusty, dirty or other poor environment will accelerate the frequency of maintenance.

Note) Appendix 3 contains a reference matrix of preventive maintenance schedules and a maintenance check list.

4.1 Daily Checks

Clean each part, and visually check the overall system and component parts for damage before daily system operation. Check the following items as the occasion demands.

1) Before automatic operation check items one through eight, listed in Table 4.1
2) After automatic operation, return the robot to the zero position and turn off the power. Continue the maintenance checks by checking items nine through 11 in Table 4.1.

Table 4.1 Daily preventive maintenance checks

Item	Check items		Check points
1	When air control set is combined	Air pressure	Check air pressure using the pressure gauge on the air regulator. If it does not meet the specified pressure of 5-7 kg/cm^2 (standard 5 kg/cm^2), adjust it using the regulator pressure setting handle. See Fig. 4.1.
2		Oiler oil mist quantity	Check the drop quantity during wrist or hand motion. If it does not meet the specified value (1 drop/10-20 sec), adjust it using the oiler control knob. Under normal usage the oiler becomes empty in about 10 to 20 days under normal operation.
3		Oiler oil level	Check to see that the oiler level is within the specified level shown in Fig. 4.1.
4		Leakage from hose	Check the joints, hoses, etc. for leaks. Repair leaks, or replace parts, as required.
5	Visual check of cables		Refer to II-6.3 (A-200) and III-6.4 (A-510).

Item	Check items	Check points
6	Vibration, abnormal noises, and motor heating	Check to see that each axis moves smoothly.
7	Changing repeatability	Check to see that the stop position of the robot has not deviated from previous stop positions.
8	Peripheral devices for proper operation	Check whether the peripheral devices operate properly according to commands from robot.
9	Operating condition of Z-axis brake	Check for excessive drop (visual inspection only).
10	Cleaning and checking of each part	Clean each part (remove chips, etc.) and check component parts for cracks and flaws.
11	Ventilation portion of control unit	If the ventilation portion of the control unit is dusty, turn off power and clean the unit.

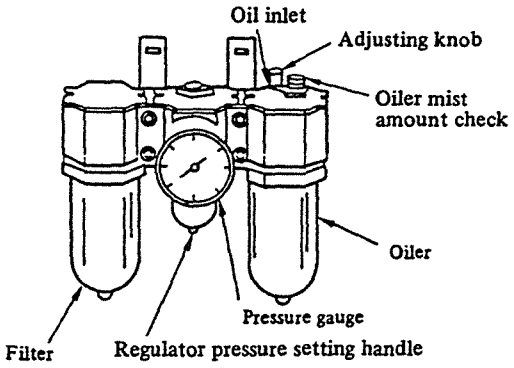


Fig. 4.1 Air control set

4.2 Monthly Checks (Determined by hours of operation)

Check the following items monthly. Additional inspection areas and times should be added to the table according to the robot's working conditions, environment, etc.

Table 4.2 Monthly preventive maintenance checks (or 500 hours)

Item	Check items	Check points
1	Check lubrication	Refer to II-2 (A-200) and III-2 (A-510).
2	Check each part for play and looseness	
3	Check connectors for looseness	Push-in connector assembly and retighten lock ring.

4.3 Quarterly Checks

Check the following items once every three months (or 1000 hours).

Table 4.3 Quarterly preventive maintenance checks

Item	Check items	Check points
1	Greasing	Refer to II-2 (A-200) and III-2 (A-510).
2	Check belt tension	Refer to II-4.3 (A-200) and III-4.1 (A-510).

4.4 Semiannual Checks

Check the following items once every 6 months (or 2000 hours).

Table 4.4 Semiannual periodic maintenance checks

Item	Check items	Check points
1	DC power voltage check	Check the +5 V, +15 V, +24 V, and -15 V power supplies of the power unit and the +24 V, +15 V, and -15 V power supplies of the servo unit for the specified values.
2	Check of Z-axis brake	The Z-axis drops.
3	Check backlash	Refer to II-4.5 (A-200) and III-4.5 (A-510).

4.5 Periodic Replacement

Replace the following parts in specified periods.

Item	Replaced parts	Replace
1	Timing belts	Refer to II, Table 3.3 (A-200) and III, Table 3.3 (A-510).
2	Moved cables	Refer to II, Table 3.3 (A-200) and III, Table 3.3 (A-510).
3	Filter cover on control unit	Replace once every two years if needed.

4.6 Maintenance Tools

The following instruments and tools are required for the maintenance procedures contained in this manual.

1) Measuring instruments

Instruments	Accuracy/Tolerance	Applications
AC voltmeter	AC power voltage measurement. Tolerance: Less than ±2%	AC power voltage measurement
DC voltmeter	Maximum scale 10 V, 30 V Tolerance: Less than ±2% (A digital voltmeter is required 20,000 ohm/volt)	DC power voltage measurement
Oscilloscope	Frequency bandwidth: DC to greater than 5 MHz, 2 channels	

Item	Check items	Check points
Dial gauge	1/100 mm	Measurement of positioning and backlash.
Slide calipers	150 mm	
Push/pull tension gauge	10 kg	Bolt tension

2) Tools

Tool	Size
Cross-point (+) screwdrivers	Large, medium, and small sizes
Conventional (-) screwdrivers	Large, medium, and small sizes
Hexagonal wrench key sets (metric)	M3 - M16
Adjustable wrenches	Medium and small sizes
Pliers	Adjustable, long nose
Cutting pliers	Diagonal
Grease gun	With output pipe and fitting
Pliers for C-retaining ring	Internal and external
Dial indicator and stand	0-10 mm range
Socket wrench set	
Torque wrench	

II. A-200 MECHANICAL UNIT MAINTENANCE

2. LUBRICATING CONDITION CHECK

2.1 Monthly Checks

Check the following item on a monthly basis.

Table 2.1 Monthly preventive maintenance checks (A-200)

Item	Check item	Check points
1	Lubricating condition of the R/Z-axis ball screw	After removing the cover and bellows, check the surface of ball screw for proper lubrication, drift and foreign substance.

2.2 Quarterly Checks

WARNING) Never perform greasing procedures with the power on.
Lubricate the air route with oil and other points with grease.

For parts that require greasing, grease once every three months.
For location of greasing points and the procedure to be used, refer to Fig. 2.2 (a) and Table 2.2 (a).
All parts other than those covered in Table 2.2 (a) employ a grease-sealed bearing or an oilless bearing so that no greasing is required.
For greasing the harmonic drives refer to Table 2.2 (c) and Fig. 2.2 (f).

Table 2.2 (a) Lubrication and greasing (A-200)

	Oil/greasing point	Amount	Recommended oil/grease	Oil/greasing method
1	Oiler of air control set	200 cc	Table 2.2 (b)	Apply oil after removing the cap from the top of the oiler.
2	θ-axis gear	20 cc	OMEGA 73	Remove the casing cover. Apply grease on the tooth surface with brush.
3	θ-axis harmonic drive	800 cc	Harmonic grease SK1	Remove the casing cover. Apply to the grease nipple.
4	R-axis ball screw shaft	20 cc	ALVANIA No. 2	Remove the casing cover. Apply grease to the shaft with brush.
5	R-axis ball screw nut	20 cc	ALVANIA No. 2	Remove the casing cover. Apply to the grease nipple.
6	R-axis ball spline shaft	20 cc	ALVANIA No. 2	Remove the casing cover. Apply grease to the shaft with brush.
7	R-axis slider bearings	100 cc	ALVANIA No. 2	Apply grease to the grease nipple.

	Oil/greasing point	Amount	Recommended oil/grease	Oil/greasing method
8	Z-axis ball screw shaft	20 cc	ALVANIA No. 2	Remove the casing cover. Apply grease to the shaft with brush.
9	Z-axis ball spline shaft	20 cc	ALVANIA No. 2	Apply grease to the shaft with brush.
10	Z-axis ball spline bearings	50 cc 100 cc	ALVANIA No. 2	Apply a 50 cc grease at the left side and 100 cc at the right side when viewed from the front.
11	α-axis gear	10 cc	OMEGA 64	Remove the casing cover. Apply grease on the tooth surface with brush.
12	α-axis harmonic drive	40 cc	Harmonic grease SK1	Remove the motor and grease the harmonic drive.
13	β-axis gear	10 cc	OMEGA 64	Remove the casing cover. Apply grease on the tooth surface with brush.
14	β-axis harmonic drive	20 cc	Harmonic grease SK1	Remove the motor and grease the harmonic drive.

Table 2.2 (b) Recommended lubrication oil (A-200)

Source	Grease	Oil (for the air control set)
Mobil oil	MOBILUX GREASE No. 2	DTE OIL LIGHT
ESSO Standard Oil	VICON No. 2	TELESSO 32
Shell Oil	SHELL ALVANIA No. 2	SHELL TURBO OIL T32
Mitsubishi Oil	DIAMOND MULTIPURPOSE GREASE No. 2	DIAMOND TURBINE OIL 32
Nihon Oil	No. 2 EPNOC	FBK TURBINE 32
Idemitsu Oil	DAPHENE COLONEX GREASE No. 2	DAPHENE TURBINE OIL 32
Maruzen Oil	LIMAX No. 2	Special A TURBINE OIL 32

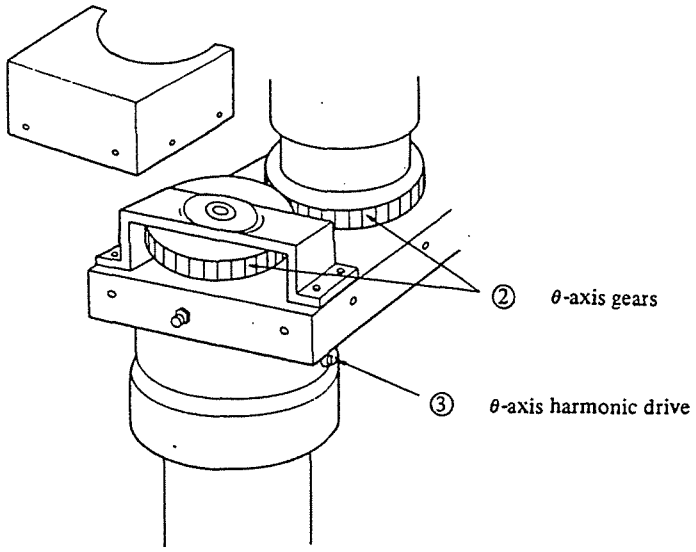


Fig. 2.2 (a) θ-axis greasing points (A-200)

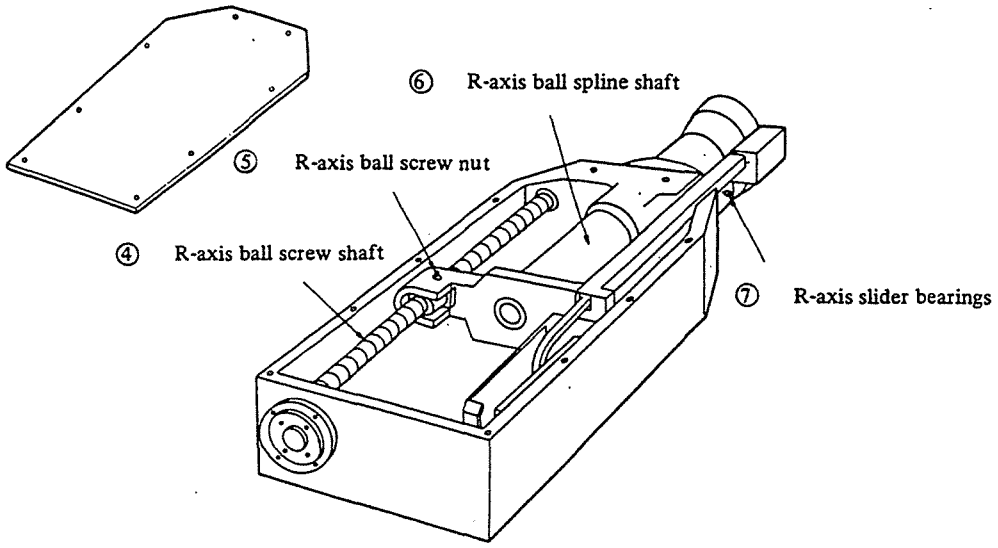


Fig. 2.2 (b) R-axis greasing points (A-200)

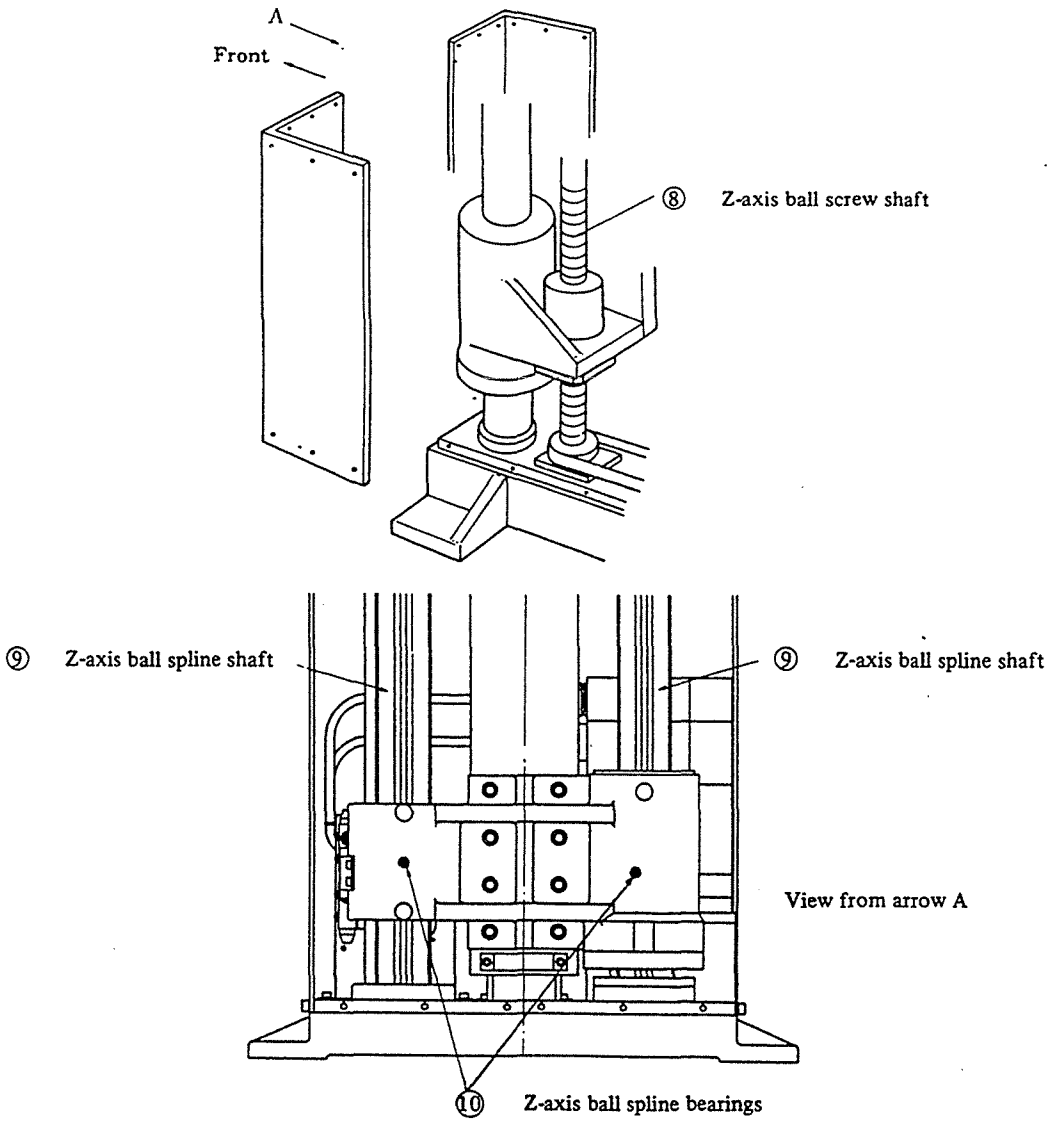


Fig. 2.2 (c) Z-axis greasing points (A-200)

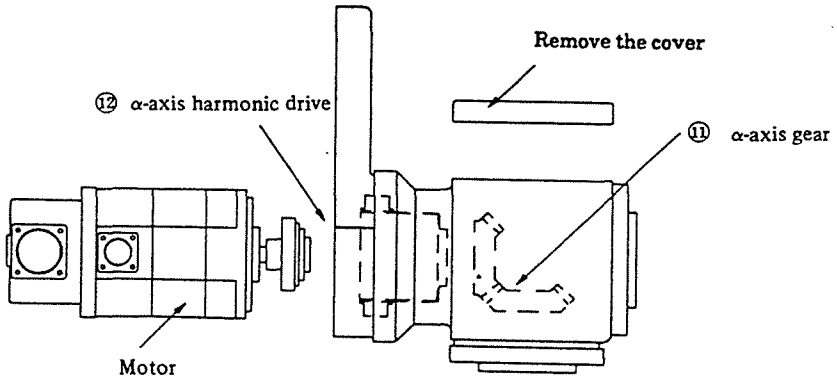


Fig. 2.2 (d) Wrist E greasing points (A-200)

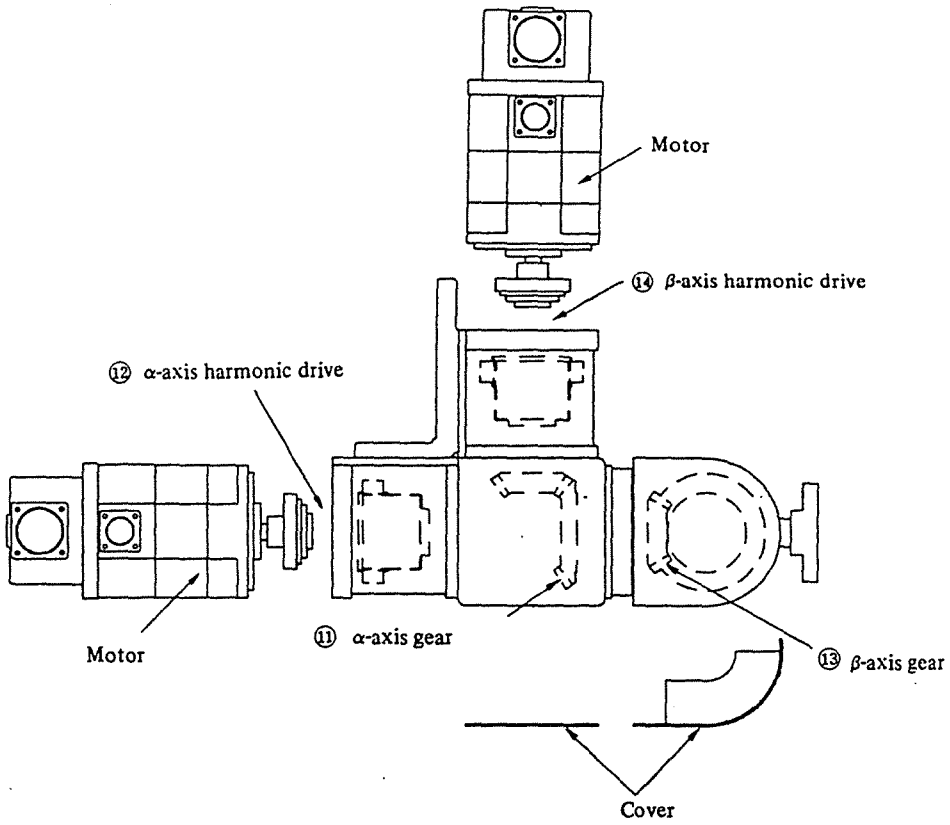


Fig. 2.2 (e) Wrist F greasing points (A-200)

Table 2.2 (c) Greasing harmonic drives (A-200)

	Greasing point	Greasing procedure
1	Circular spline	Fill tooth groove with grease.
2	Flex spline	Apply thin coat to outer circumference. Fill tooth groave with grease. Apply grease according to ball diameter.
3	Wave generator	Fill space between balls with sufficient grease. Apply grease to all surfaces of Oldham's coupling.

① Circular spline ② Flex spline ③ Wave generator

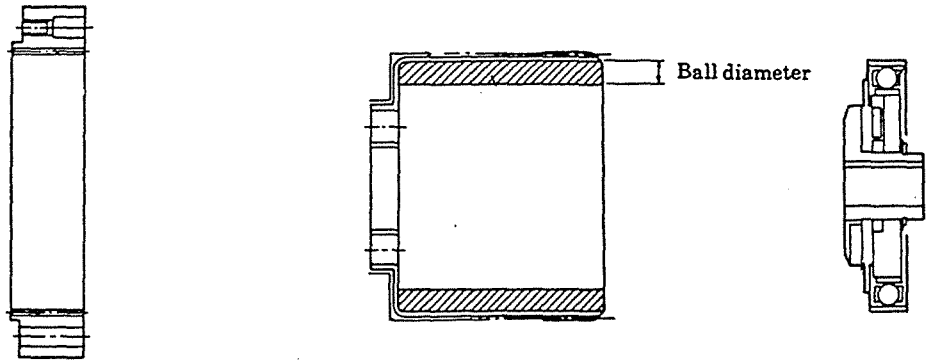


Fig. 2.2 (f) Greasing procedure (A-200)

III. A-510 MECHANICAL UNIT MAINTENANCE

2. LUBRICATING CONDITION CHECK

2.1 Monthly Checks

Check the following item monthly.

Table 2.1 Monthly preventive maintenance checks (A-510)

Check item	Check points
Lubricating condition of Z-axis ball screw and guides.	After removing the rear lid on the Z-axis column, check the surface of ball screw and the guides for proper lubrication, drift, and foreign substance.

2.2 Quarterly Checks

WARNING) Never perform greasing procedures before turning off power.

Supply grease once every three months.
For greasing points and method, refer to Fig. 2.2 and Table 2.2 (a).
All parts other than those covered in Table 2.2 (a) employ a grease-sealed bearing or an oilless bearing, so that no greasing is required.

Table 2.2 (a) Greasing points (A-510)

	Item	Grease	Qty	Procedure
1	Z-axis ball screw	See Table 2.2 (b)	10 cc	Apply to grease nipple on ball screw nut.
2	Z-axis guide		10 cc	Apply to grease nipples on guides.
3	Angular-contact bearing of Z-axis ball screw		10 cc	Apply to grease nipple.

Table 2.2 (b) Recommended lubricating grease (A-510) (Z-axis)

Manufacturer	Grease
Mobil Oil	MOBILAC GREASE No. 2
ESSO Standard Oil	VICON No. 2
Shell Oil	SHELL ALVANIA No. 2
Mitsubishi Oil	DIAMOND MULTIPURPOSE GREASE No. 2
Nihon Oil	No. 2 EPIKNOCK
Idemitsu Oil	DAPHNE COLONEX GREASE No. 2
Maruzen Oil	LIMAX No. 2

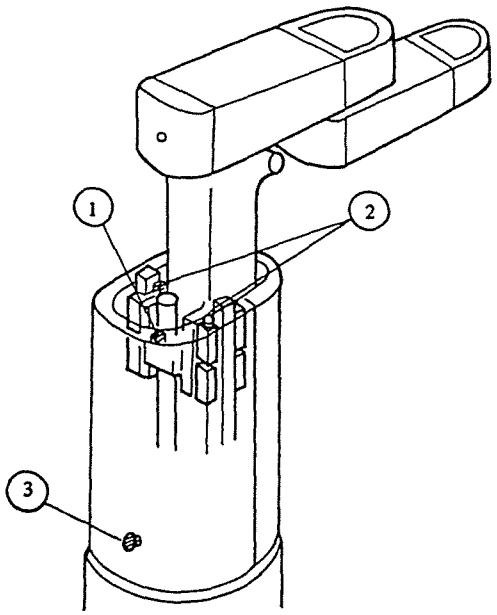


Fig. 2.2 (a) Greasing points for Z-axis (A-510)

2.3 Two-year Check

Change the grease of the θ-axis gear unit and the U/α unit once every two years or every 10,000 running hours. Refer to Table 2.3 and Fig. 2.3 (a) and (b).

a) θ axis
   ① Remove the grease nipple from the grease inlet and the silencer from the air outlet that is inside the cover of the θ axis.
   ② Remove all grease by blowing air into the outlet.
   ③ Reattach the grease nipple to the inlet, and reattach the silencer to the outlet.
   ④ Apply the grease that is specified below to the grease nipple.

b) U/α axis
   ① Remove the guide from the gear box. (Note that grease has flowed out during normal operation)
   ② Clean out the old grease.
   ③ Reassemble the guide on the gear box.
   ④ Apply the grease that is specified below to the grease nipple.

Table 2.3 Recommended lubricating grease (θ-, U-, α-axis) (A-510)

Manufacturer	Grease
Shell	DRIUM R
Nihon Oil	PYLONOC #0

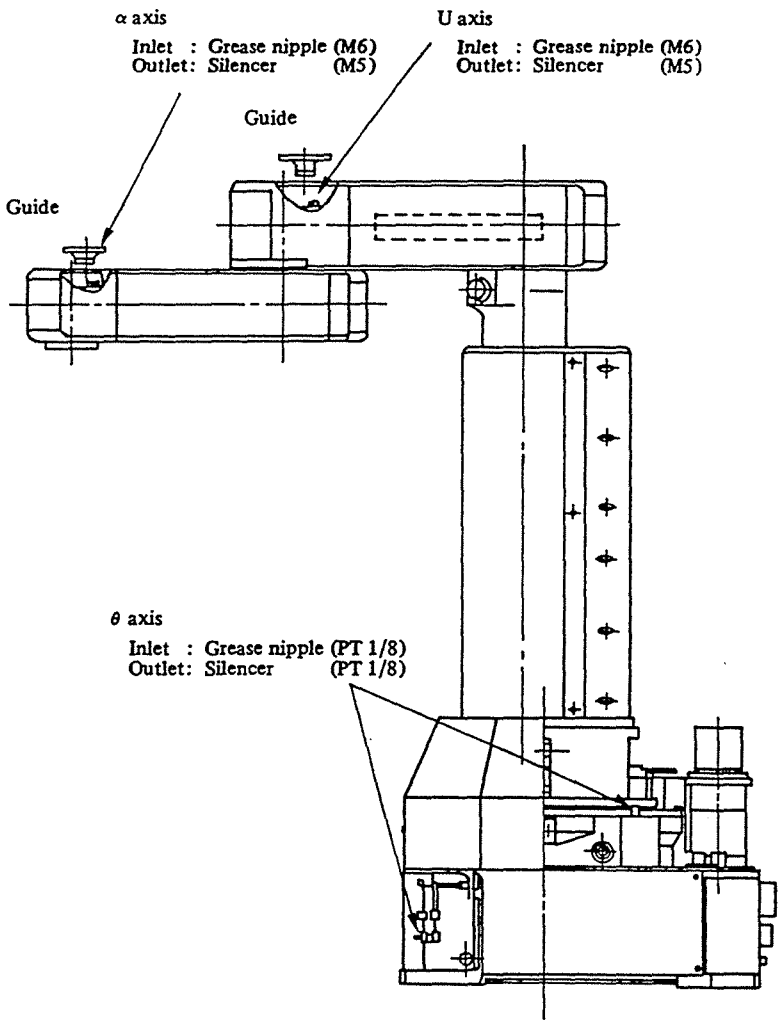


Fig. 2.3 (a) Greasing points for the θ, U and α axes (upright mount) (A-510)

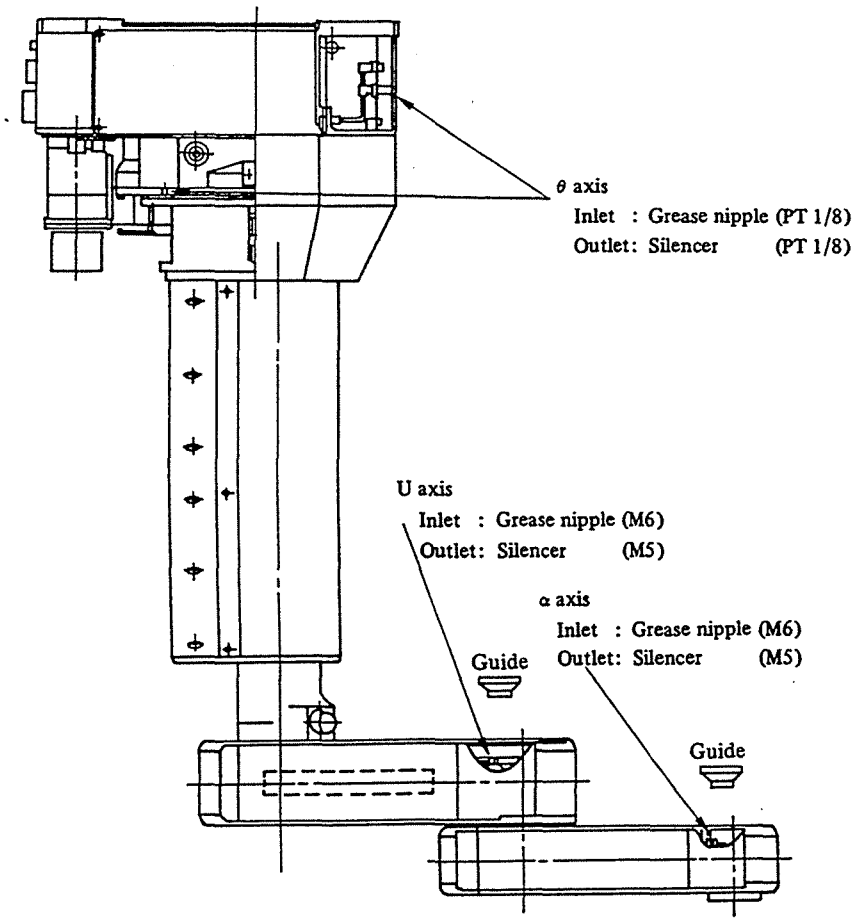


Fig. 2.3 (b) Greasing points for the θ, U and α-axes (upside-down mount) (A-510)

Appendix C: Truck Maintenance

1310-9

Fig. 99: Power Steering Dipstick

Checking Power Steering Oil Fluid

Check the oil level with the dipstick fixed to the reservoir cap. The engine must be switched off. The level should be at the MAX mark. If the level is below the max mark, then top-up with Dexron II.

CAUTION: Do not fill the oil above the *max/full* mark. Overfilling could cause excessive pressure in the system and possibly blow out the seals.

Replace the filter once a year or when the steering gear has been repaired.

Maintenance

Service Manuals

If you need literature on the maintenance and repair of your vehicle, a service manual may be purchased from your local dealer.

It is strongly recommended that you do not attempt to service, repair or maintain your vehicle yourself unless you are fully trained, have the proper tools, equipment and parts.

When your truck is serviced, insist on genuine original equipment (OEM) parts. These parts have been engineered and manufactured to provide long life, good service and safety of your vehicle.

Preventive Maintenance

The information in this section is not intended to be all inclusive. It is intended to serve as a guide to ensure that the vehicle is properly maintained, serviced and repaired.

Regular checks and maintenance are necessary to get the best economical return from your truck. Your local dealer can establish a maintenance program that suits your operation.

Your local dealer is best prepared to maintain your truck because he has:

- Product know-how
- Special tools
- Literature produced specially for your truck
- Stock of genuine parts.

Preventive maintenance is a maintenance program geared to time and mileage and is suitable for all types of operations.

The program consists of Basic Service (BS) and Additional Service (AS). Your truck should have basic service checks every three months and one annual service each year. These intervals may need to be modified based upon application.

Lubrication services L3 and L4 are normally performed every three months, but for vehicles used in special operations the interval should be shortened.

L3 and L4 intervals and times are already logged in the Operator's Manual.

The maintenance schedule, information starting on page 94, in the Service Information section of this manual, contains a list of the checks and maintenance your truck requires.

Mismatched or incorrect fasteners may result in damage to the vehicle or possibly personal injury.

Chassis General Lubrication

General lubrication includes lubricating all the grease fittings in the drivetrain, front and rear suspensions, power steering and front wheel bearings using a grease gun.

The cooling system must be also checked at the same time.

All lubricating points will be found in the lubrication chart in this manual on page 101.

Body Lubrication

Primarily door hinges, strike plates and lock plungers should be oiled or greased. We recommend that this be performed every second lubrication to avoid squeaking noises and unnecessary wear. See Door Lubrication table on page 104.

Lubricating Grease (MPG)

Multipurpose-type Grease (MPG), which contains 3 percent to 5 percent molybdenum disulfide (MPGM), is preferred. NLGI No. 2 Grade is recommended for normal temperatures and No. 0 Grade for extremely low temperatures.

Lubrication During Breaking in Period

During the first 3,000 to 6,000 miles (4800 to 9600 km) of operation, the moving parts of the truck should be allowed to "break-in" to obtain smooth and wear-resistant surfaces. Oil changes should be performed more often during the breaking-in period than later on.

Engine (VOLVO)

The first oil and filter change should be between 3,000 and 6,000 miles (4800 and 9600 km) maximum. Subsequent oil change intervals should be according to the manufacturer's maintenance recommendations. For more information on subsequent oil changes for the VOLVO engine, see the VOLVO Diesel Engines table on page 113.

Transmission

The first oil and oil filter change should be at 3,000 miles (4800 km) maximum. Flush the transmission with same type of oil. Subsequent VOLVO transmission oil changes should be every year or 60,000 miles (96500 km). For specific recommendations, refer to the manufacturer's recommendations.

Rear Axle (VOLVO)

The first oil and oil filter change should be at 3,000 miles (4800 km) maximum. Flush the rear axle with the same type of

(96500 km) or at least once a year. Refer to manufacturer's recommendations.

Power Steering

The oil and filter change should be between 3,000 and 6,000 miles (4800 and 9600 km) maximum. Subsequent changes should be according to the manufacturer's maintenance recommendations.

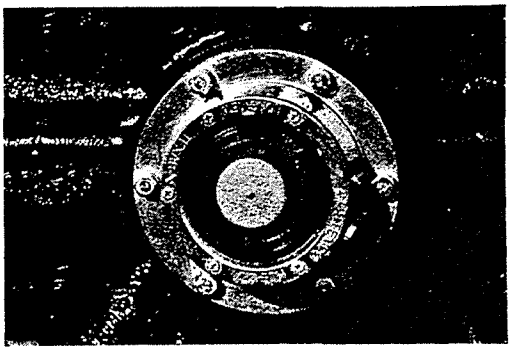
Crankcase Ventilation

For VOLVO Engines, use a downdraft breather tube mounted to the valve lifter cover plate on the right side of the engine. This tube should be kept clean and clear of any obstructions internally.

Viscous Fluid Fan Clutch - VOLVO

A viscous fan clutch is used on the VOLVO engines. The sealed nut on the backside is used to lock down the fan clutch to a fixed drive. To engage the fixed fan, turn the hex nut either direction and rotate the fan blade slowly until the pin locks into the drive plate. Using the fixed drive for any length of time could damage the fan hub bearings and cause the fan to come apart. Should this happen, the fan clutch should be replaced within 200mls. (320 km).

Oil-Lubricating Wheel Bearings



1262-10

Fig. 100: Wheel Bearing

The wheel bearings of both the front and rear axles are oil-lubricated. Rear axle wheel bearings are lubricated by the same lubricant used in the differential carrier and housing. Front axle wheel bearings should be lubricated with SAE 30 engine oil.

An optional front axle hub cap end face is provided with a transparent insert (sight glass) or plug and an oil level mark for convenience in checking and filling.

Rear hubs are lubed by the lubricant in the differential carrier and housing. If the axle shafts are removed, the hub cavity should be refilled before reinstallation of the shafts. Always check differential oil level(s).

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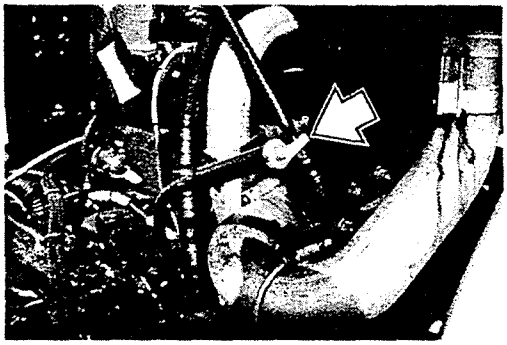
Transmissions



1310-26

Fig. 101: Transmission Dipstick

Lubrication

Proper lubrication procedures are the key to a good all around maintenance program. For the types of lubricants to be used, refer to the chart on 104, Transmission Oil Capacities. If the oil is not doing its job, or if the oil level is ignored, all the maintenance procedures are not going to keep the transmission running or assure it's long life.

To keep the transmission in good working order, follow these procedures:

1. Maintain proper oil level. Inspect regularly.
2. Change oil regularly.
3. Use the correct oil grade and type.

VOLVO Transmission lubricants

See the VOLVO Transmission table on page 104.

Use a straight mineral oil. Oxidation inhibitors, anti-rust additives, anti-foaming agents and other additives to sink the lower point should be included to improve the characteristics for these oils. Lubricants currently recommended for use in the VOLVO transmissions are listed by the API designation and are detailed below the transmission oil capacity chart on page 104. As a general rule, most oils of another manufacturer should not be mixed. Oils of different makes consist mostly of basic oils and composition. Therefore, most oils are not to be intermixed and precautions must be taken when topping-up. Do not use additional additives.

Automatic transmission

To check the oil, use the following procedure:

1. Make sure that the vehicle is on a level surface.
2. Start the engine and make several shifts through the shift range.

NOTE: Shift the engine for at least one minute at 1000-1200 rpm to clear the system of air.

3. Place the vehicle in neutral and apply the parking brake.
4. Remove the dipstick and wipe off.
5. Replace the dipstick making sure that it goes all the way in.
6. Remove the dipstick again, then check the oil level by the markings on the dipstick.

NOTE: The style and type of dipstick will depend on the model of transmission. Do not mix the dipsticks.

Changing oil

Change oil when it is warm. To drain off the oil, place a pan under the drain plug. Remove the drain plug and allow the oil to drain out into the pan. Dispose of the oil properly.

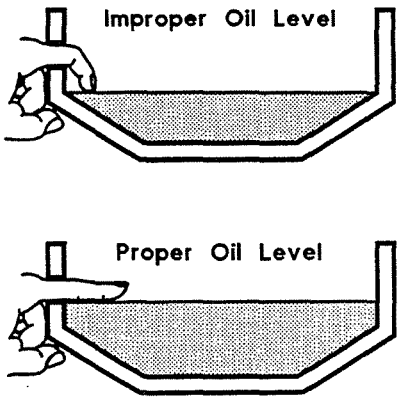


Fig. 102: Proper Oil Level

On Fuller transmissions, fill the transmission to the level of the filler opening. If the transmission has two filler openings, fill to the level of both openings on twin countershaft models. See Figure 102 above.

Clean the drain plug before reinstalling. When refilling the transmission with new oil, use the fill/level plug. The amount of oil used will depend on the transmission installation angle. Do not overfill the transmission. For proper fill levels depending on the type and installation angle, contact the transmission manufacturer.

Lubrication change intervals

- Before the first 3,000 miles (5000 km), change the oil in a new or rebuilt transmission.
- Every L3 service or three months, check the oil level and for any oil leaks. Have oil leaks repaired and top-up as required.
- Every L4 service or 12 months, change the transmission oil. If the transmission is equipped with an oil filter, replace the filter. Also, if an oil cooler is used, drain out the lines and cooler core.
- Do not forget to add additional oil for the filter and the oil cooler.

NOTE: On any internal repairs on the transmission, clean out the housing and use new oil when refilling.

Rear Axles

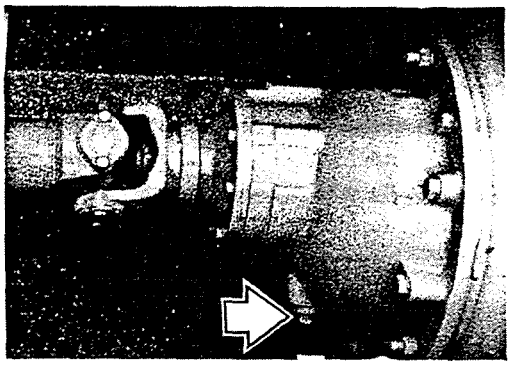


Fig. 103: Differential Housing

CAUTION: On Rockwell rear axles, in the differential housing there is a stud and nut protruding out. Do not loosen these nuts, as these are the retainers for

the ring gear thrusts shoes. See Figure 103.

See Rear Axle table on page 105.

VOLVO Rear axle lubricant

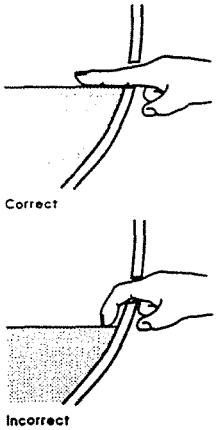
The design of hypnoid gears makes a greater demand on the film of oil between the teeth. Lubricating oil for gears of this type have chemical additives to ensure suitable lubrication. These additives usually consist of sulphur and phosphor.

The oil also has additives that give it a good resistance to oxidation, a low solidification point and less tendency to foam.

Oil of this type is known as hypnoid oil or EP (extreme pressure) oil.

The lubricant currently recommended for use in the VOLVO rear axles are listed by the API designation given below the rear axle capacity chart on page 107. The oil is also given a military specification of MIL-2105B and C.

Eaton rear axle



NOTE: The lube fill capacities will vary somewhat on the basis of the angle the axle is installed in a particular chassis. Always use the filler hole as the final reference. If the lube is level with the bottom of the hole, the axle is properly filled. Axles installed at angle exceeding ten degrees or operated in areas of continuous and lengthy grades may require standpipes to allow for the proper fill level.

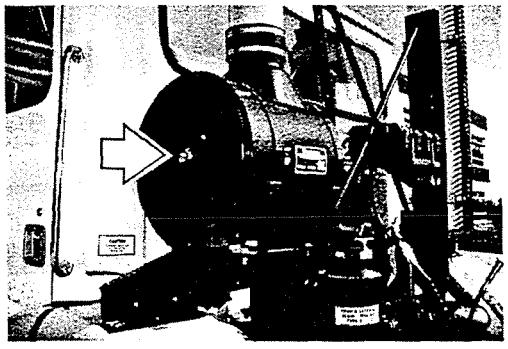
Lubrication change intervals

Before the first 3,000 miles (4800 km) change the oil in a new or rebuilt rear axle.

Every L3 or 3 months, check the oil level and check for any oil leaks. Have oil leaks repaired and top up as required.

Every L4 or 12 months, change the rear axle oil.

NOTE: If any internal repairs are done on the differential, the housing bowl should be cleaned out and new oil used when refilling.



1310-10

Fig. 105: Air Cleaner

Air Cleaner

Element change or cleaning intervals are influenced by the dust conditions under which the vehicle is operated. A maintenance interval is provided in the lubrication charts. However, a more precise interval may be established by frequent inspection of the element and by using a water manometer or vacuum gauge to check restriction. The element should be replaced when restriction reaches 25" of water (6.2kPa) under a maximum air flow condition. Maximum air flow occurs when a turbo-charger Diesel is at full throttle, load and speed.

Air Induction Restriction Chart		
Engine Make & Type	**Maximum Restriction**	**Checking Conditions**
Volvo diesel (Turbocharged)	25" (H2O) (6.2 kPa)	Rated Speed Full Load

NOTE: Rated speed is governed speed under a full load.

NOTE: The chart shows the maximum air cleaner restriction allowed by engine manufacturer's.

Air Cleaner Intake System

The air cleaner intake system starts with the air being drawn in through two screens. These screens are located on top of the hood with a built-in passageway on the underside of the hood. The intake air is directed through this passageway into the air cleaner assembly where the filter element removes any foreign particles.

A seal is provided to prevent engine heated air from entering the cleaner where the ducting separates for tilting the hood.

Installed in the air cleaner housing is a evocator valve; which, expels the large particles of dirt. The lip of this valve must be closed, otherwise unfiltered air enters the engine.

WARNING: Always cover the hood air intake grille openings before going through a washing facility or wetting down a load of gravel, sand, etc. Failure to do so can result in serious engine damage.

Changing Filter Element

1. Remove the cover and lift out the cover and filter element.
2. Clean the inside of the air cleaner.
3. Install a new filter element. Ensure that the element is positioned correctly against the inner wall of the housing.
4. Tighten the nuts or wing nut.
5. Check the air cleaner hoses for damage and ensure that the hose clamps are tight.
6. Clean the vacuator valve; make sure the lips are closed. Normally it is not necessary to remove the air cleaner housing. If it has to be removed, however, ensure that it is reinstalled correctly.

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NOTE: Before reinstalling the element, always check for pin holes, punctures or tears.

Checking Drive Belts

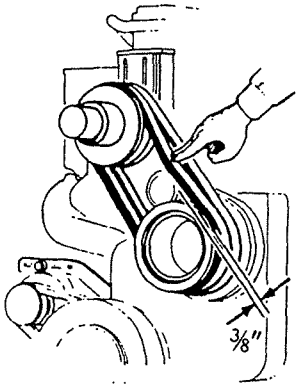

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Fig. 106: Belt Adjustment

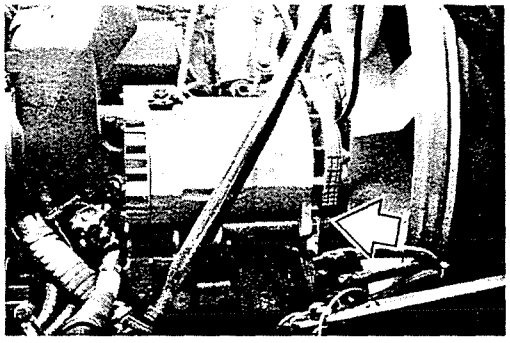
All engine drive belts should be checked at each lubrication period. Check the belt tension by depressing the belt midway between the pulleys.The belt may be depressed a maximum of 3/8" (10mm). Dual belts must be changed in pairs. A slipping drive belt may impair engine cooling and alternator charging.

A "V" belt has the correct amount of tension if the deflection is as indicated in the following table, when a force of 13 pounds (6 kg) is applied to the belt at the midway point of the belt span.

Belt Width		Deflection per Ft. (Cm) of Beltspan	
Inch	Cm	Inch	Cm
1/2	12.7	13/32	10.3
7/8	22.2	1/2	12.7

CAUTION: Do not tighten the belts beyond the figures given. Over tightening a belt may damage bearings as well as belts.

Alternator Belt Adjustment



1355-18

Fig. 107: Belt Adjustment

The alternator belts must be kept properly adjusted. Slipping belts may cause the alternator to operate incorrectly which could cause the batteries to become discharged.

Ft. (Cm) ›an	Cm
10.3	
12.7	

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1355-18

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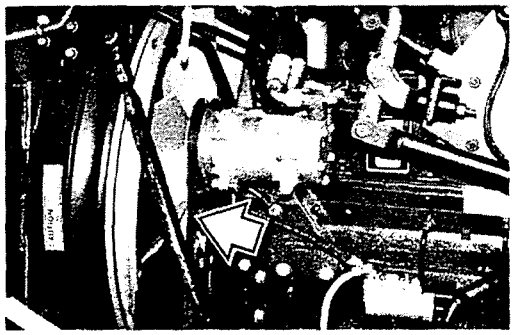


1302-30

Fig. 108: Air Conditioner Belt

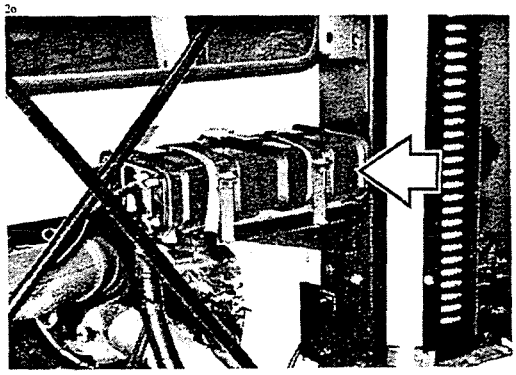
Air Conditioner Compressor Belts

The air conditioner compressor belts must be kept properly adjusted. Loose belts may cause the air conditioner to operate incorrectly and may damage the compressor clutch.

NOTE: Dual belts must always be changed in pairs, even if only one is damaged.

Cooling System

The cooling system is pressurized to raise the boiling point of the coolant, and permit higher, more efficient operating temperatures.



1304-30

Fig. 109: Coolant Level

Check the following items on a regular basis:

1. *Coolant level* - keep the system filled to the correct level. Use only clean coolant. Never pour cold coolant into the system when the engine is cold. Do not remove the radiator fill cap when engine is at operating temperature.
2. *Antifreeze* - the freeze point should be checked periodically with an accurate hydrometer. If additional antifreeze is required, be sure to use the same type that is already in the system.

> **WARNING:** Exercise care when working around hot engine coolant. Severe scalding and burns can occur.

CAUTION: On vehicles equipped with a water filter, a minimum concentration of 33 percent antifreeze is required. Lower concentrations reduce the solution stability, adversely affecting performance of the corrosion resistor. DO NOT USE antifreeze with anti-leak additives; these additives collect in the water filter and restrict coolant flow.

3. *Fan drive belts* - the tension of the belts should be checked at regular intervals; belt slippage will cause overheating.
4. *Temperature* - keep a close watch on the temperature gauge. Any unusual rise in temperature should be investigated, the cause deter-

mined, reported and corrected by your local dealer.

5. *Shutdown* - always let a hot engine operate at idle for at least five minutes before shutting it down to allow the cooling system to dissipate the engine heat.
6. Inspection of the entire system for leaks is important. Check for swollen or deteriorated heater and radiator hoses, loose hose clamps and water line connections and radiator leaks.

WARNING: Inspect the fan blade assembly for cracks or loose mounting before starting the engine. *Never* stand along side a rotating fan assembly, particularly at high fan speeds. Failure to observe these precaution can result in serious personal injury.

NOTE: When the vehicle is equipped with a VOLVO cooling system, the radiator used is of the automotive type. Any repairs to this vehicle are to be made by a local authorized dealer.

Antifreeze

Before antifreeze is installed, the cooling system should be thoroughly flushed and the hoses tightened. Remove and test the condition of thermostats.

Do not use anti-leak solution. Since practically all antifreeze solutions contain a rust inhibitor as part of their make-up, it is not normally necessary to add soluble oil (or other inhibitors) when antifreeze is in the system. When a water conditioner is incorporated in the system, be sure to replace the cartridge when the yellow color of the water pales. Refer to engine manufacturer's recommendations for proper levels of antifreeze and rust inhibitor concentrations.

WARNING: Under some conditions, the ethylene glycol in engine coolant can be combustible. To help avoid being burned when adding coolant, do not spill the coolant on the exhaust system or engine parts that may be hot.

Unsuitable rustproofing and antifreeze fluids cause foaming. With foaming there is a risk of parts seizing, or causing damages which may be expensive to repair.

The genuine VOLVO antifreeze is specified in the VOLVO Group Standard 98505. Note the requirement of the copper-inhibitor additive.

Antifreeze consists of pure ethylene glycol with anti-corrosive and foam restricting additives. It has two functions: to protect against frost and to protect against rust.

If, however, it is used to provide adequate protection against corrosion and the vehicle is equipped with a water filter, there must be at least 30 percent in the cooling system; otherwise, the effect may be exactly the opposite. Protection

Checking the Cooling System

The coolant level should be checked everyday before starting and when refueling. The cooling system expansion tank is located at the rear center of the radiator. Top-up the tank with the same mixture of coolant already in the system. Top-up with water + glycol (50 percent water and 50 percent glycol.

> **WARNING:** To help avoid being burned:
>
> - Do not raise the engine hood if you see or hear steam or coolant escaping from the engine compartment. Wait until no steam or coolant can be seen or heard before raising the hood.
> - Do not remove the coolant surge tank cap if the coolant in the surge tank is boiling. Also, do not remove the cap while the engine and radiator are still hot. Scalding fluid and steam may be blown out under pressure if the cap is taken off too soon.

Cooling System (VOLVO diesel)

The type of cooling system used in the VOLVO diesel engine is sealed and pressurized. The pressure valve opens at 6.4 to 7.8 psi or 44 to 54 kPa. The thermostat is the wax type and the marking temperature is 82^{0}C. The thermostat starts to open at 176^{0}F to 183^{0}F or 80^{0}C to 84^{0}C. The thermostat is fully

199^{0}F to 207^{0}F or 93^{0}C to 97^{0}C. It has a capacity of 11 gallons or 42 liters. Use antifreeze that meets the GM 6038M formulation, which limits the amount of silicate to .15 percent maximum, or VOLVO 1129700-9.

NOTE: Never operate the engine without the thermostat.

Water Pump/Idler Pulley Lubricant

Chevron SRI Grease 2, a new grease for water pumps and belt idler pulleys, has been introduced into production. It has a higher resistance to temperature and gives a longer life to the water pump.

The new grease should be used when overhauling water pumps and idler pulleys. It is supplied in 8 oz. (225 gr) tubes, P/N 11611121.

Cooling System Maintenance

Intercooler systems

The cooling system should be inspected at least once a year. Cleaning and replacing the coolant in the system should also be done once every year.

The cores should be kept clear to enable the air flow to pass through the system without any restrictions.

CAUTION: Never cover the radiator. All VOLVO diesel engines are equipped with intercoolers and are sensitive to overheating caused by a covered radiator.

See Antifreeze Ratios table on page 104.

Ethylene glycol will protect against freezing down to -56°F (-49°C). It would be pointless to increase the glycol proportion beyond this amount as protection decreases above this point.

CAUTION: Glycol or antifreeze of any other type must not be mixed with anti-corrosion additives.

NOTE: The coolant must be changed once a year. After a year, the anti-corrosion agent in the coolant loses some of its efficiency. This applies both to glycol and to anti-corrosion additives.

Anti-Corrosion Additive for Coolant

In some geological locations it may not be necessary to use antifreeze. An anti-corrosion additive should be mixed in with water. Use VOLVO part no. 1129709-0.

CAUTION: Do not mix corrosion additive with antifreeze, only mix with water or the maximum efficiency to protect against frost and rust will not occur.

Changing the Coolant

When changing the coolant, once a year, the cooling system must be thoroughly flushed clean. Fill the system with water and add anti-corrosion additives. Run the engine warm immediately after topping-up so the additive may give the best possible effect. To retain the anti-corrosion efficiency, add 1/2 quart (1/2 liter) anticorrosion additive (do not use if in conjunction with filter/conditioner or an overcharge may result) to (19,200 km) (or 400 hours of operation).

Draining Cooling System

> **WARNING:** Do not drain the system while it is hot.

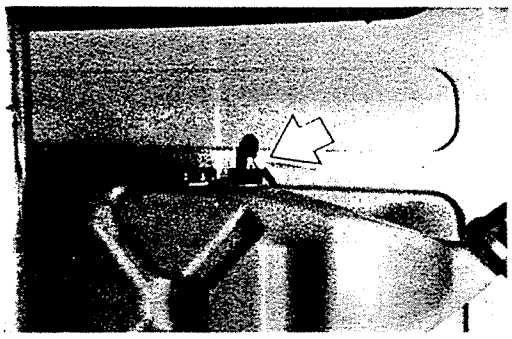
To drain the cooling system, proceed as follows:

1. Remove the radiator fill cap.
2. Open the drain cock located in the radiator outlet tank.
3. Open the cylinder block drain cocks.
4. Open the drain valve on the air compressor.
5. After the cooling system has been drained, operate the engine at idling speed for a minute or two. Shut the engine off.

Filling the Cooling System

1. Fill the system with clean coolant through the fill neck in the expansion tank. The fill rate is not to exceed 2 gpm (8 l/m). The engine should not be running and the heating control should be at warm.
2. Fill up the system to the bottom of the fill neck. The cooling system vents automatically.
3. Check the level after running the engine at high idle for five minutes. Add the coolant, as required.

VOLVO Engine Protection



1358-4

Fig. 110: Low Water Sending Unit

All vehicles equipped with a VOLVO engine have a low coolant level sender in the radiator surge tank, an indicator light on the instrument panel and a warning alarm.

Visual Inspection

Inspect all air lines, hoses and gasket connections at each oil change. Make sure the constant torque hose clamps are tightened to the correct torque. Check all welded joints for cracks and make sure all brackets are tightened in position and are in good condition. Use compressed air to clean a cooler core blockage caused by debris or dust. Inspect the cooler core fins for damage, debris or slat corrosion. Use a stainless brush with soap and water to remove corrosion.

NOTE: When air to air aftercooler system parts are repaired and/or replaced, a leak test is recommended.

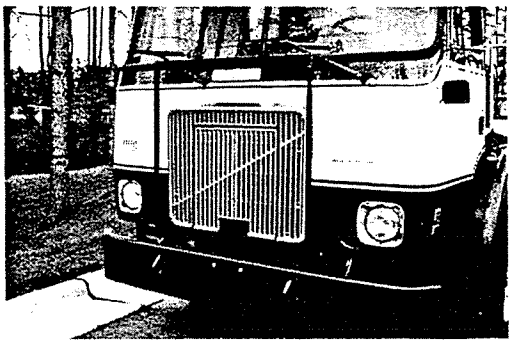
Water Conditioner

VOLVO does not recommend the use of a water conditioner in the VOLVO engines. It is recommended that VOLVO antifreeze be used and the system flushed clean every year and new coolant be put into the system.

As an option VOLVO can provide water conditioners to customers who prefer to use them. Use either Fleetguard W2051 or Perry S273 UN.

NOTE: Always test the coolant before adding the conditioner or replacing a canister-type water filter. Over servicing is just as bad as under servicing the system. Refer to the manufacturer's recommendations for the type of water conditioner to be used.

Winterfront



1355-8

Fig. 111: Winterfront

The use of a winterfront is not recommended on VOLVO engines because it may cause the engine to overheat.

Appendix D: Generator Maintenance

OWNER'S Manual

STANDBY GENERATOR

GENERAC
CORPORATION

Printed in U.S.A.

Periodic Maintenance Schedule

* Preventive Maintenance to be performed by an authorized mechanic.

** Preventive Maintenance to be performed by authorized operator.

A. After First 30 Hours of Operation

*1. Check/adjust valve clearance.
*2. Retorque engine cylinder head bolts.
*3. Retorque intake/exhaust manifolds.
*4. Retorque oil pan bolts.
*5. Retorque engine fan bolts.
*6. Test fuel injection nozzles.
*7. Check injection timing.
*8. Inspect wiring.
*9. Change engine crankcase oil.
*10. Inspect engine fan belts.
*11. Inspect battery and cables.

B. Every Month

** 1. Test standby generator system.
** 2. Inspect battery and cables.
** 3. Check engine oil level.
** 4. Check gearbox oil level (if so equipped).
** 5. Check coolant level.
** 6. Check generator ground connections.
** 7. Test/inspect optional starting aids.

C. Every Two Years

* 1. Replace all rubber hoses.
* 2. Replace engine fan belts.
* 3. Evaluate the Standby Generator System.
* 4. Drain, flush, refill cooling system.

D. Every 120 Hours or Every Three Months (whichever comes first)

** 1. Inspect and test fuel system and connections.
** 2. Inspect exhaust system.
** 3. Inspect/test fuel supply system.

E. Once Every Six Months

* 1. Change engine oil and filter.
* 2. Lubricate engine controls.
* 3. Service engine air cleaner.
* 4. Service engine fuel filter.
* 5. Inspect a-c generator.
* 6. Test engine safety controls.
* 7. Inspect fan belts.
* 8. Check engine coolant level.
* 9. Inspect engine cooling system hoses.
*10. Check optional starting aids.
*11. Check battery.
*12. Check engine compression.
*13. Check electrical connections.
*14. Check/test annunciator panel.
*15. Perform operational test.

F. Once Annually

* 1. Check engine valve clearance.
* 2. Test fuel injection nozzles.
* 3. Test injection timing.
* 4. Inspect all wiring.
* 5. Test engine starter operation.
* 6. Drain water from fuel tank.
* 7. Retorque fan bolts.

G. Every 1000 Operating Hours

* 1. Disassemble and inspect engine d-c alternator.
* 2. Disassemble and inspect engine starter.
* 3. Retorque engine mounting brackets.
* 4. Retorque intake and exhaust manifold.
* 5. Retorque oil pan bolts.
* 6. Remove/test fuel injection pump.
* 7. Remove/test cooling system thermostat.

H. As Required

* 1. Bleed engine fuel system.

PERIODIC MAINTENANCE

INTRODUCTION

A rigorous program of scheduled periodic maintenance should be established and maintained. Such a program, if adhered to diligently, will provide added assurance that your standby electric system functions properly when it is needed.

Keeping a MAINTENANCE LOG is highly recommended. Such a log should be a continuous record of repairs, parts replacements, gauge and instrument readings during operational tests, etc.

GENERAC recommends that you establish a CUSTOMER MAINTENANCE INSPECTION AGREEMENT between the user of this equipment and the installing dealer/distributor. This agreement (Part No. 53263) provides for prestart and engine running tests and checks for a qualified service technician to perform at six-month and one-year intervals. Ask your dealer (or consult the factory) about this agreement.

The tasks listed in the PERIODIC MAINTENANCE SCHEDULE cover the minimum recommended maintenance requirements for this equipment.

Note that many of the tests and checks listed in the SCHEDULE are to be performed only by an authorized mechanic. Recommended torque values may be found in Table A. Fluid capacities and recommendations, as well as other applicable specifications, are listed in the SPECIFICATIONS section.

TEST STANDBY GENERATOR SYSTEM

At least once each month, you should have an authorized operator test the operation of the standby generator system. During this operational test, record all instrument and gauge readings in a MAINTENANCE LOG. Also have the transfer system tested at this time. Run the engine at least 30 minutes and immediately correct any discrepancies you find during the test.

Every six months, have an authorized mechanic or service technician perform a system operational test.

INSPECT BATTERY

Once each month an authorized operator should inspect the engine battery system. At this time battery fluid level should be checked and distilled water added if needed. Battery cables and connections should also be inspected for cleanliness and corrosion.

Once every six months, an authorized mechanic or service technician should inspect the battery system. At this time the battery CONDITION and STATE OF CHARGE should be checked using a battery hydrometer. Recharge battery or replace any defective battery as required.

INSPECT STANDBY GENERATOR SYSTEM

Qualified operators should perform a close inspection of the entire standby generator system monthly. Inspect the transfer switch for evidence of arcing, pitted or burned contacts. Inspect wiring and wiring connections. Check for engine oil and coolant leaks. Look for fuel leaks at engine and in fuel supply system. Check all fuel lines and fittings for tightness. If any discrepancies are found, contact an authorized service technician.

CHECK FLUIDS

Check Engine Oil Level: Engine oil level should be checked by a qualified operator at least once each month. Maintain oil level between the FULL and ADD marks on engine dipstick. See SPECIFICATIONS for recommended oil.

Check Gearbox Oil Level (if so equipped): If the generator is equipped with a gearbox (Figure 31), check gearbox oil level once each month. Replenish as needed with SAE 90 GEARLUBE oil.

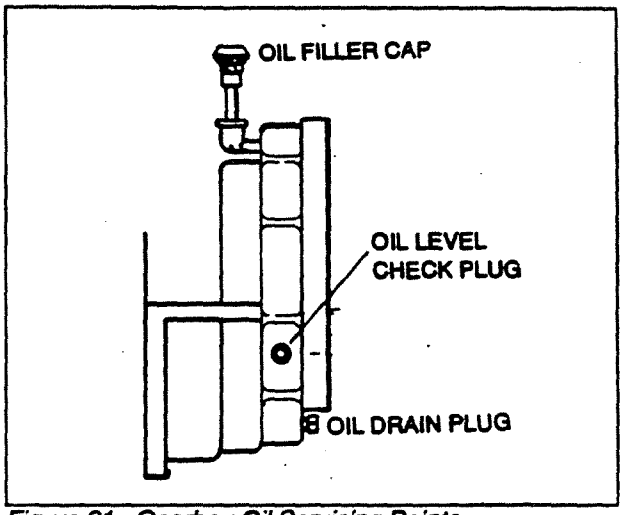


Figure 31. Gearbox Oil Servicing Points

Once annually, the gearbox should be completely drained and refilled with SAE 90 GEARLUBE oil.

To add oil to gearbox, remove OIL FILLER CAP and OIL LEVEL CHECK PLUG. Add the recommended oil until it just starts to flow from OIL LEVEL CHECK PLUG opening. Finally, install and tighten OIL FILLER CAP and OIL LEVEL CHECK PLUG.

Check Coolant Level: Check engine coolant level once each month. See SPECIFICATIONS for recommended coolant mixture.

CHECK CONNECTIONS

Check Generator Ground Connection: Inspect generator grounding system. Repair as necessary. Refer to GROUNDING THE GENERATOR on Page 16.

Test/Inspect Optional Starting Aids: Inspect optional starting aids (Battery Charger, Block Heater, Battery Heater, etc.) once each month. Make sure these devices are operational.

Check Fuel System Connections: Check all fuel system connections at least once every 120 hours of operation, or quarterly, whichever occurs first. All connections must be TIGHT and in good condition. A loose fuel system line may show no signs of leakage, but may draw air into the system, causing rough operation and starting difficulties.

INSPECT EXHAUST SYSTEM

Inspect the entire exhaust system every 120 operating hours, or quarterly, whichever comes first. Repair or replace any defective or leaking component immediately. During each operational test, listen for abnormal noise levels which may indicate a defective exhaust pipe or muffler.

INSPECT/TEST FUEL SUPPLY SYSTEM

Inspect and test the fuel supply system at least once every 120 hours of operation, or quarterly, whichever comes first.

RECOMMENDED ENGINE COOLANT MIXTURE

Use a mixture of half ethylene glycol base anti-freeze and SOFT water in the engine cooling system. Also add a high quality rust inhibitor to the recommended mixture. See SPECIFICATIONS for cooling system capacity.

DANGER! *DO NOT* REMOVE THE RADIATOR PRESSURE CAP WHILE THE ENGINE IS HOT OR SERIOUS BURNS FROM BOILING LIQUID OR STEAM COULD RESULT.

DANGER! ETHYLENE GLYCOL BASE ANTI-FREEZE IS *POISONOUS. DO NOT* USE MOUTH TO SIPHON COOLANT FROM RADIATOR, RECOVERY BOTTLE OR ANY CONTAINER.

CAUTION: Some commonly used rust inhibitors are CHROMATES, BORATES, NITRATES, NITRITES and SOLUABLE OIL. DO NOT use any CHROMATE base inhibitor with ethylene glycol base anti-freeze or chromium hydroxide (green slime) will form, causing a low heat transfer rate and possible overheating. Engines that have been operated with a chromate base inhibitor must be chemically cleaned before adding ethylene glycol base anti-freeze. Also, some SOLUABLE OILS are NOT recommended to use with this equipment.

Engine Component Tightening Torques
Table A

Injection Pump Adapter to Block Bolts	23 foot-pounds (3.0 m-kg)
Main Bearing Caps	89 foot-pounds (11.7 m-kg)
Connecting Rod Caps	42 foot-pounds (5.5 m-kg)
Camshaft Bearing Retainer Bolts	48 foot-pounds (6.3 m-kg)
Camshaft Sprocket to Camshaft Bolt	70 foot-pounds (9.2 m-kg)
Oil Pan Bolts	14 foot-pounds (1.8 m-kg)
Flywheel to Crankshaft	76 foot-pounds (10 m-kg)
Flywheel to Torque Converter Bolt	46 foot-pounds (6.1 m-kg)
Intake Manifold	41 foot-pounds (5.3 m-kg)
Exhaust Manifold	28 foot-pounds (3.7 m-kg)
Rocker Pivot to Cylinder Head Bolt	28 foot-pounds (3.7 m-kg)
Oil Cooler Hoses (both ends)	26 foot-pounds (3.4 m-kg)
Engine Mounting to Frame Bracket Bolt (Series A)	35 foot-pounds (4.6 m-kg)
Engine Mounting to Frame Bracket Bolt (Series C)	23 foot-pounds (3.0 m-kg)
Glow Plug	15 foot-pounds (2.0 m-kg)
Starter Motor to Cylinder Block Bolt	32 foot-pounds (4.2 m-kg)
Oil Pump to Bearing Cap Bolt	18 foot-pounds (2.3 m-kg)

Appendix E: Hydraulic Power Unit Maintenance

Section 2 - Maintenance Guidelines

Table of Contents

Maintenance Schedules - General Information

Maintenance periods are given in the following engine maintenance schedule. If the engine is operating in ambient temperatures consistently below -18° C [0° F] or above 38° C [100° F], perform maintenance at shorter intervals. Shorter maintenance intervals are also required if the engine is operated in a dusty environment or if the average operating time is less than 15 minutes. Consult your Cummins Authorized Repair Location regarding special interval recommendations.

The recommended maintenance schedule for overhauled engines is the same as for new engines **except** the initial lubricating oil and filter changes **must** be made after 20 hours of operation.

B Series Power Unit Engine Maintenance Schedule

Daily or Every 20 Hours	Every 3 Months or 250 Hours	Every 6 Months or 500 Hours	Every 12 Months or 1000 Hours	Every 2 Years or 2000 Hours
Check	———	Change/Replace	———	
Oil Level	Lubricating Oil	Lubricating Oil	Lubricating Oil	Lubricating Oil
Coolant Level	Lubricating Filter	Lubricating Filter	Lubricating Filter	Lubricating Filter
Fuel Water Trap		Coolant Filter		Coolant Filter
Drive Belt		Fuel Filter	Fuel Filter	Fuel Filter
Fuel Tank Level				Antifreeze*
				Fuel Strainer
	———	Adjust	———	
			Valve Lash Clearance	Valve Lash Clearance
	———	Check/Inspect	———	
	Air Cleaner	Air Cleaner	Air Cleaner	Air Cleaner
	Intake System	Intake System	Intake System	Intake System
		Antifreeze	Antifreeze	Air Compressor
			Fan Hub	Fan Hub
			Belt Tensioner	Belt Tensioner
			Bearing	Bearing
			Belt Tension	Belt Tension
				Damper

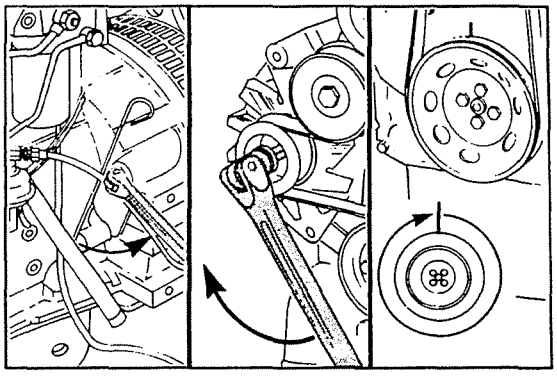
*Change coolant mixtures containing water pump lubricants and corrosion inhibitors according to the manufacturer's recommendations.

Maintenance Record

Engine Serial No. _____ Engine Model _____

Owner's Name _____ Equipment Name/Number _____

Date	Km [Miles], Hours or Time Interval	Actual Km [Miles] or Hours	Maintenance Check Performed	Check Performed By	Comments



Maintenance Following an Extended Period of Non-Use

Always bar the crankshaft to make sure it rotates freely.

After periods of non-use of 6 to 9 months, perform the 6 months maintenance recommendations.

Thoroughly inspect all units that have **not** been used for more than 9 months.

Perform the 6 months maintenance recommendations.

Drain and flush the coolant system if there is any question about the condition or age of the coolant.

Maintenance Tools Required

In the text, a symbol followed by the wrench size or tool description is used to identify the tooling required to perform each step. A list of wrench sizes and descriptions indicates more than one tool is needed.

Sockets	Wrenches	Other Tools
19 mm	17 mm	Filter Wrenches (75 to 80, 90 to 95, and 118 to 131mm)
17 mm	15 mm	Ratchet (1/2 inch drive)
15 mm	14 mm	Torque Wrench
	13 mm	Flat Screwdriver
	10 mm	5/16 Allen Wrench
	7/16 in	Feeler Gauges (0.25 and 0.51mm)
		Barring Gear, Part No. 3904682

Daily Maintenance or Every 20 Hours

Preventive maintenance begins with a day-to-day awareness of the condition of the engine and its systems.

Before starting the engine, check the oil and coolant levels. Look for:

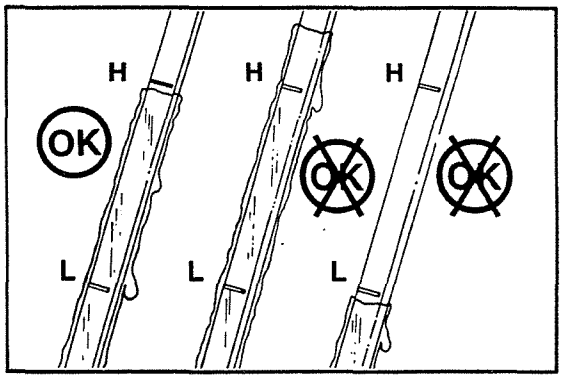
- Leaks
- Loose or damaged parts
- Worn or damaged belts
- Any change in engine appearance

Oil Level - Checking

Caution: Never operate the engine with the oil level below the "L" (Low) mark or above the "H" (High) mark. Low or high oil levels can cause damage to the engine components. Wait at least 5 minutes after shutting off the engine to check the oil. This allows time for the oil to drain to the oil pan.

4 B Series,
Low to High = 0.95 Litres [1 U.S. Quart]

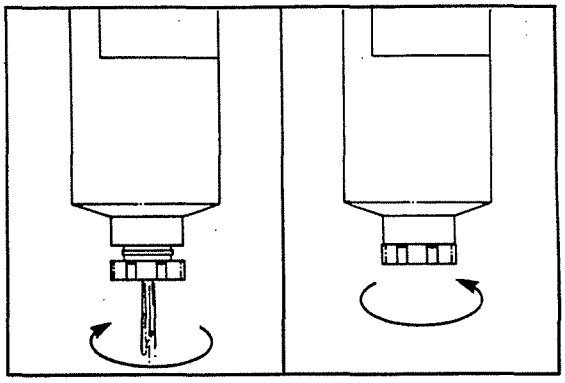
6 B Series,
Low to High = 1.9 Litres [2 U.S. Quarts]



Fuel-Water Separator - Draining Water and Sediment

Open the valve on the bottom of the fuel filter to allow water to drain. Close the drain when clean fuel is visible.

Caution: Do not over-tighten the plastic valve, this can damage the threads or break the valve.

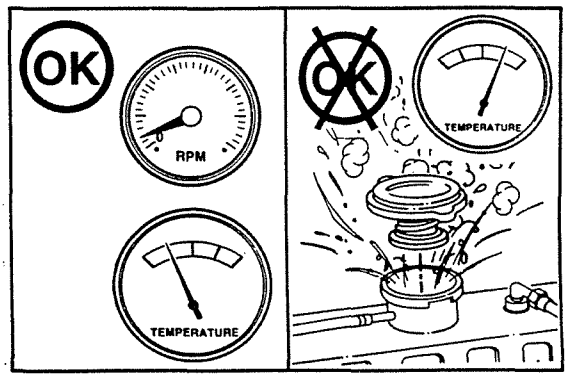


Coolant Level - Checking

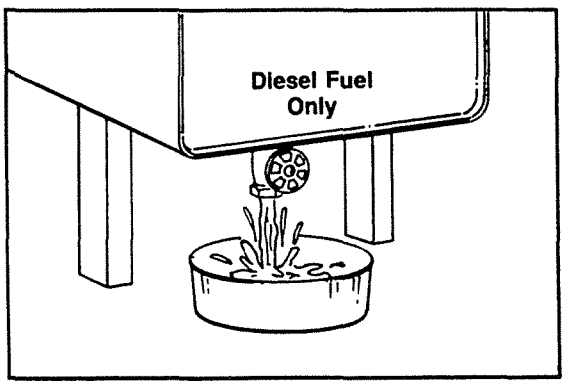
Warning: Check the coolant level only when the engine is stopped. Wait until the temperature is below 70° C [160° F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.

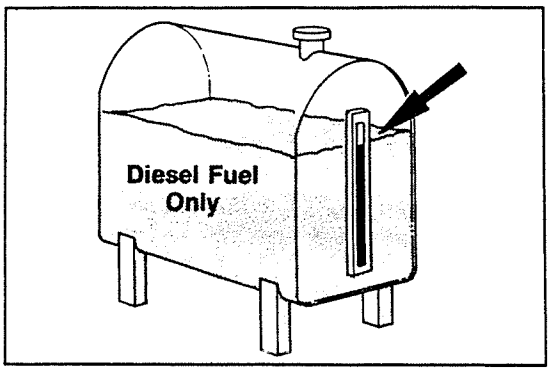
Remove the filler cap slowly to relieve coolant system pressure.

NOTE: Never use a sealing additive to stop leaks in the coolant system. This can result in coolant system plugging and inadequate coolant flow.



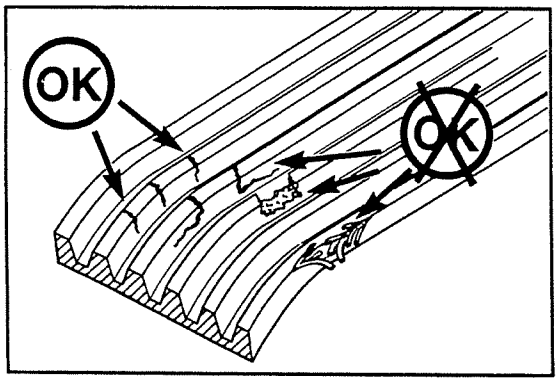
Drain the sediment from the fuel tank.





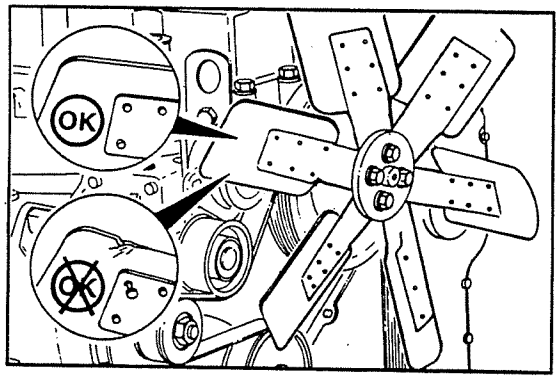
Checking the Fuel Tank Level

Use only good quality ASTM Grade No. 2-D climatized diesel fuel.



Drive Belt - Inspection

Visually inspect the belt. Check the belt for intersecting cracks. Transverse (across the belt width) cracks are acceptable. Longitudinal (direction of belt length) cracks that intersect with transverse cracks are **not** acceptable. Replace the belt if it is frayed or has pieces of material missing. Refer to **Adjustment and Replacement**, Section 4.



Fan - Inspection

Warning: Never use the fan to rotate the crankshaft. The blade(s) can be damaged causing a fan failure which can result in personal injury or property damage. Use the engine barring tool or threaded dowels temporarily installed in the front of the crankshaft.

Check the fan for cracks, loose rivets, and bent or loose blades. Make sure it is securely mounted. Tighten the capscrews if loose. Replace damaged fans.

Maintenance Required at 250 Hours or 3-Month Intervals

Perform the daily maintenance checks and the following:

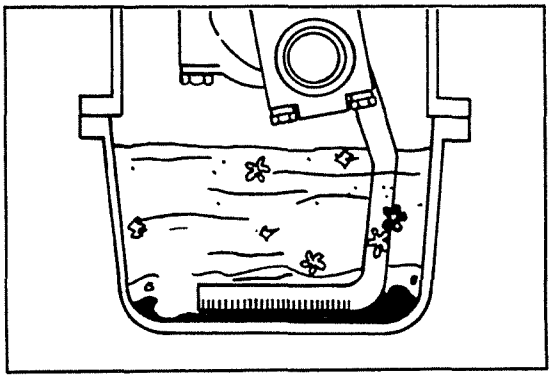
- Change the lubricating oil
- Change the lubricating oil filter
- Inspect the air intake system
- Inspect the air cleaner

PROTECT THE ENVIRONMENT: Handling and disposal of used engine oil can be subject to federal, state and local law and regulation. Use authorized waste disposal facilities, including civic amenity sites and garages providing authorized facilities for receipt of used oil. If in doubt, contact your state and local environmental authorities or the Environmental Protection Agency (EPA) for guidance as to proper handling and disposal of used engine oil.

Caution: If the engine is being operated, under no circumstances can the oil drain interval extend beyond 250 hours or 3 months. Extended oil change increases the contaminants in the oil and **decreases** the life of the engine components.

Change the oil and filters to remove the contaminants suspended in the oil.

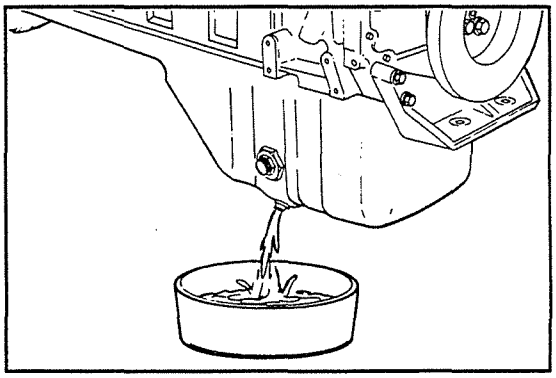
NOTE: Drain the oil only when it is hot and the contaminants are in suspension.



17 mm

Warning: Hot oil can cause personal injury.

Operate the engine until the water temperature reaches 60° C [140° F]. Shut off the engine. Remove the oil drain plug.

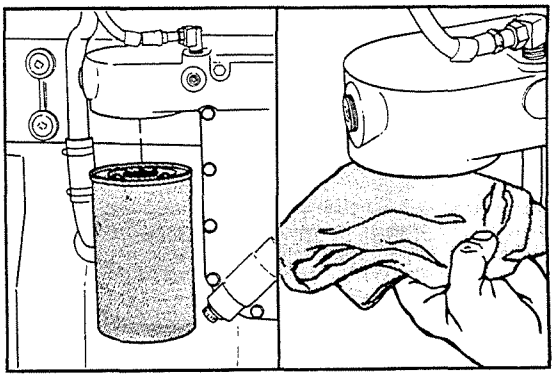


Oil Filter - Changing

90 to 100 mm Filter Wrench

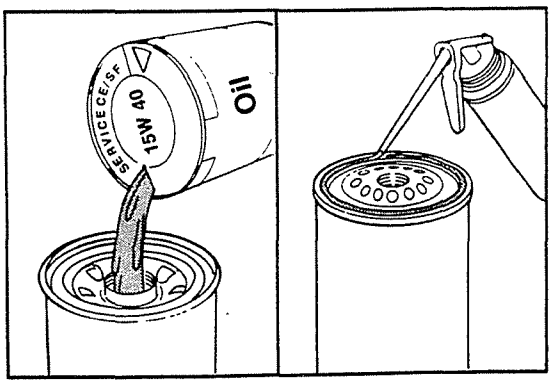
Clean the area around the lubricating oil filter head. Remove the filter. Clean the gasket surface of the filter head.

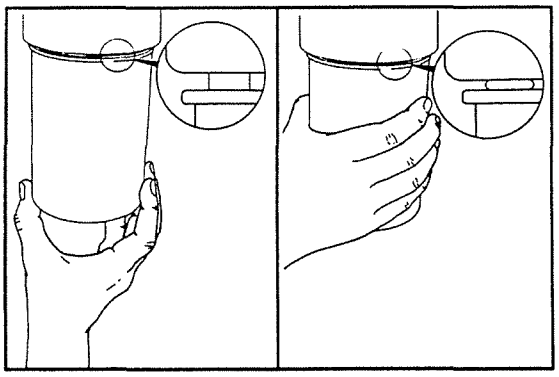
NOTE: The o-ring can stick on the filter head. Make sure it is removed.



Caution: Fill the filters with clean lubricating oil before installation. The lack of lubrication during the delay until the filters are pumped full of oil is harmful to the engine.

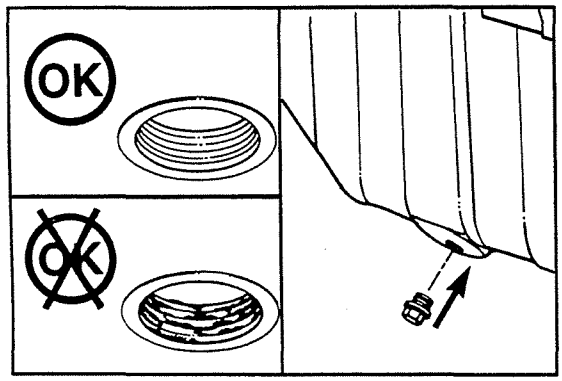
Apply a light film of lubricating oil to the gasket sealing surface before installing the filters.





Caution: Mechanical over-tightening can distort the threads or damage the filter element seal.

Install the filter as specified by the filter manufacturer.

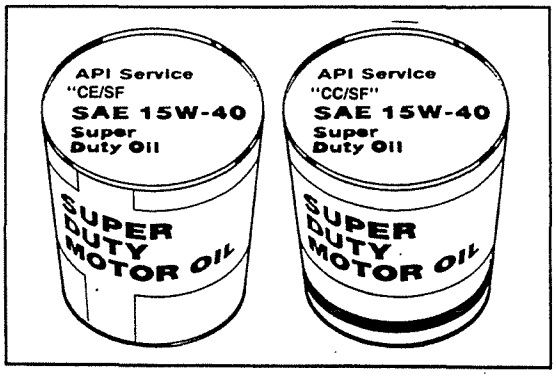


17 mm

Clean and check the oil drain plug threads and sealing surface.

Install and tighten the oil pan drain plug.

Torque Value: 80 N•m [60 ft-lb] torque.

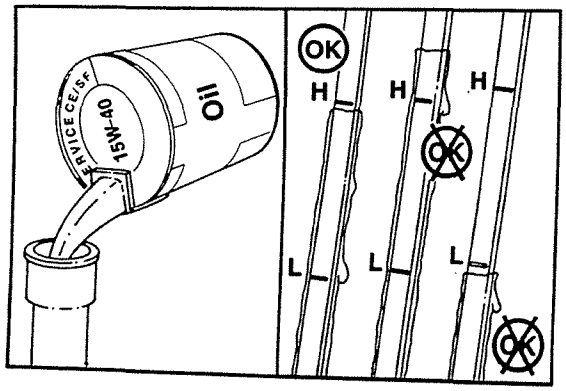


NOTE: Use a high quality 15W-40 multi-viscosity oil, such as Cummins Premium Blue, or its equivalent in Cummins engines. Choose the correct oil for your operating climate as outlined in **Specifications,** Section 5.

- Turbocharged engines CE/SF

  NOTE: CD/SF oil can be used in areas where CE/SF oil is not yet available.

- Naturally aspirated engines CC/SF.



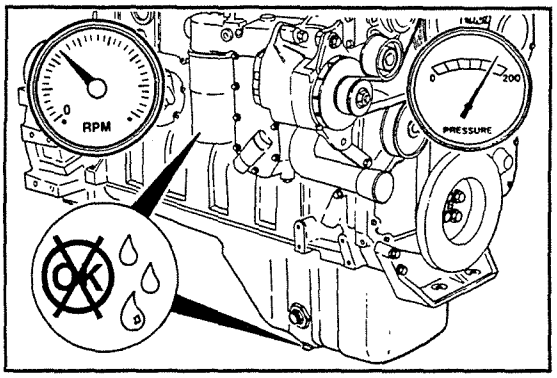
Fill the engine with the required amount of oil.

Oil Pan Capacities:

4 B Series - 9.5 Litres [10 U.S. Quarts]

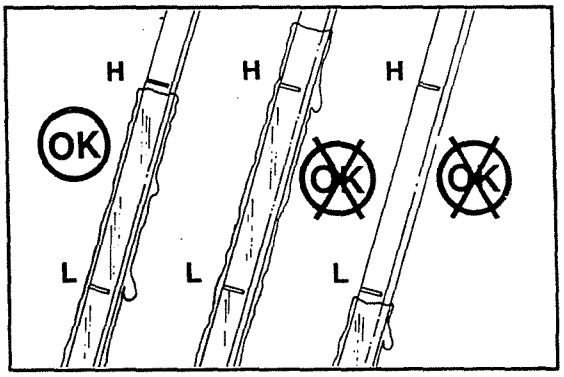
6 B Series - 14.2 Litres [15 U.S. Quarts]

Idle the engine to inspect for leaks at the filters and the drain plug.



Shut off the engine. Wait approximately 5 minutes to let the oil drain from the upper parts of the engine. Check the level again.

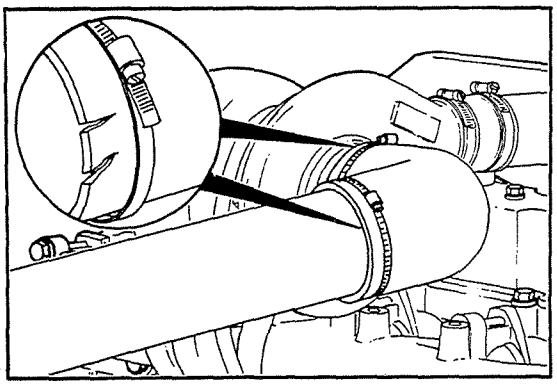
Add oil as necessary to bring the oil level to the "H" (High) mark on the dipstick.



Air Intake System - Inspection

Inspect the intake piping for cracked hoses, loose clamps, or punctures which can damage the engine.

Tighten or replace parts as necessary to make sure the air intake system does **not** leak.



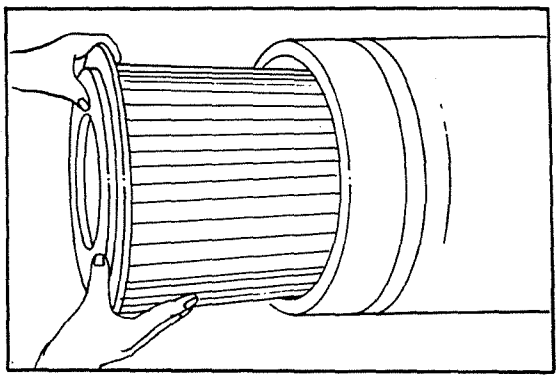
Air Cleaner Element - Inspection

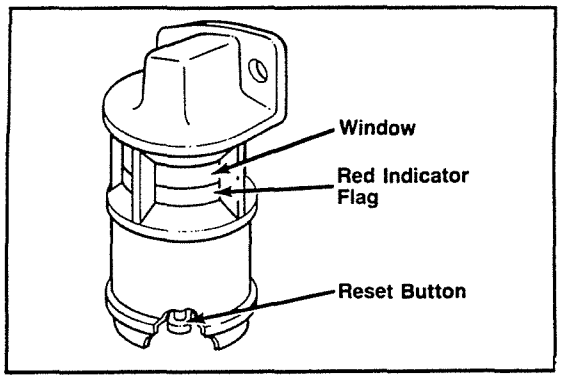
Maximum intake air restriction is 635 mm [25.0 inch] of water for turbocharged engines. Naturally aspirated engines have a maximum restriction of 510 mm [20.0 inch] of water.

Turbocharged engines **must** be operated at rated RPM and full load to check maximum intake air restriction.

Naturally aspirated engines can be operated at rated RPM at no load to check intake air restriction.

Replace the air cleaner element when the restriction reaches the maximum allowable limit or clean according to the manufacturer's recommendations.





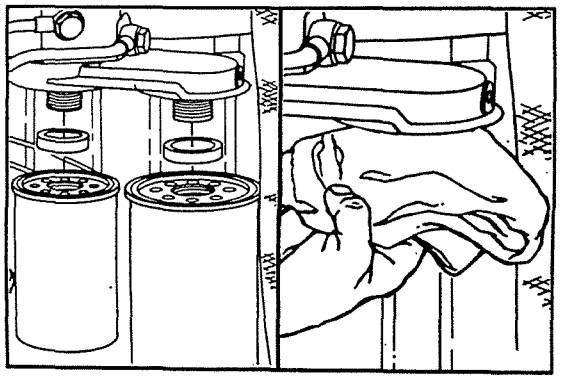
NOTE: Follow the manufacturer's instructions when cleaning or replacing the air cleaner element.

Check the air cleaner service indicator, if equipped. Change the filter element when the red indicator flag is at the raised position.

Caution: Never operate the engine without an air cleaner. Intake air must be filtered to prevent dirt and debris from entering the engine and causing premature wear.

Maintenance Required at Each 500 Hours or 6-Month Intervals

Perform the 3 months or 250 hours maintenance and the following:

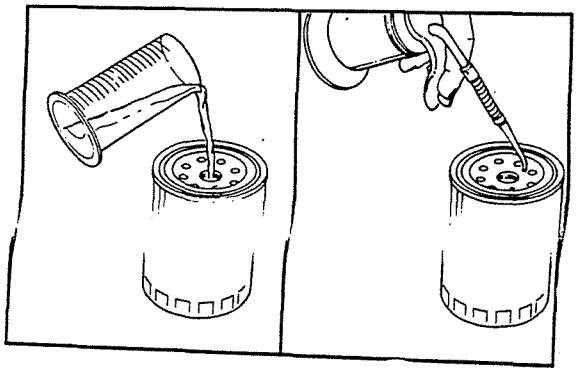


Fuel Filter - Replacement

75 to 80 and 90 to 95 mm Filter Wrenches

Clean the area around the fuel filter head. Remove the filters. Clean the gasket surface of the filter head.

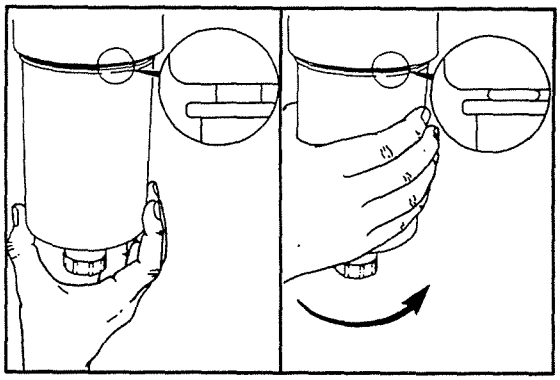
Replace the o-ring.



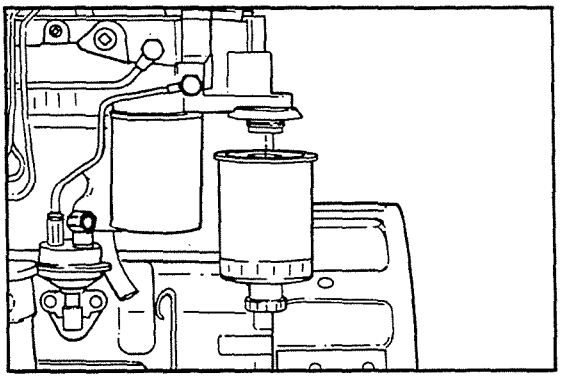
Fill the new filter(s) with clean fuel, and lubricate the o-ring seal with clean lubricating oil.

Caution: Mechanical over-tightening can distort the threads or damage the filter element seal.

Install the filter as specified by the filter manufacturer.



Install the second filter on the dual filter adapter.

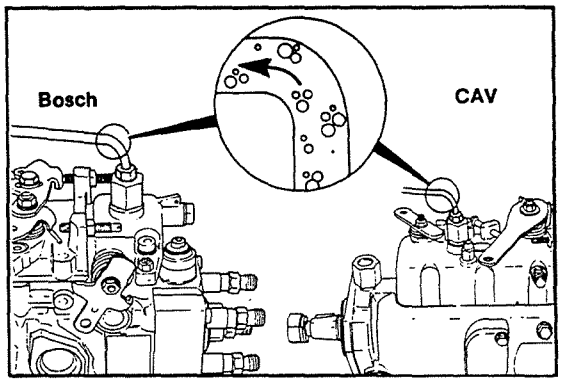


Bleeding the Fuel System

Controlled venting is provided at the injection pump through the fuel drain manifold. Small amounts of air introduced by changing the filters or injection pump will be vented automatically if the fuel filter is changed in accordance with the instructions.

Manual bleeding will be required if:

- The fuel filter is not filled prior to installation.
- The injection pump is replaced.
- High pressure fuel lines are replaced.



Venting the low pressure lines and fuel filter

10 mm

Open the bleed screw.