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VEHICLE INTEGRATION AND TESTING OF THE OPERATOR CONTROLLED CRACK SEALING

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ABSTRACT

This project completed the development of an Operator Controlled Crack Sealing Machine (OCCSM). The OCCSM is a self-contained automated highway pavement crack sealing machine that combines an operator controlled computer control system with a long reach telescoping robotic arm and sealant kettle to seal highway pavement cracks with hot applied sealant. An earlier phase of this project supported the development of the machine's automated subsystems and the purchase of a support vehicle and additional support equipment. All of the subsystems were developed, integrated, and operated within a laboratory environment except the sealant application system. This project covered the integration of these systems onto the support vehicle where some of the sub-systems had been connected together for the first time. Other sub-systems had to be developed on the vehicle. With the integration completed, the OCCSM was tested with real sealant on real cracks at the AHMCT test road on campus. The machine is fully functional and is pending on-road testing with Caltrans. The OCCSM is intended to be a demonstration of automated crack sealing technologies.

EXECUTIVE SUMMARY

The Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center develops robotic equipment and machinery for highway maintenance and construction operations. The Operator Controlled Crack Sealing Machine is one of those projects, but is intended to be a demonstration of technology. The OCCSM is a self-contained automated highway pavement crack sealing machine that combines an operator controlled computer control system with a long reach telescoping robotic arm and sealant kettle to seal highway pavement cracks with hot applied sealant. An earlier phase of this project supported the development of the machine's automated subsystems and the purchase of a support vehicle. Initial sub-system development was initially conducted in a laboratory setting for improved accessibility and later because the truck chassis delivery was delayed. This report describes the integration phase of the OCCSM where the sub-systems are integrated onto the vehicle to create a fully functioning self-contained system. This work also covered the development of additional sub-systems, especially the sealant application system that did not lend itself to development in the laboratory. Integration included electrical power and signal wiring, hydraulic, pneumatic, fuel system, networking, sealant plumbing and assorted mechanical connections. Road testing was conducted to fine tune the operator interface and establish operational procedures. The OCCSM is fully functional, but a hose heating failure has prevented the final goal of conducting highway testing with Caltrans by the end of this project. The heated hose will be repaired and road testing will completed under the AHMCT deployment support project. Also an additional appendix is included to discuss in detail the automatic path planning component.

INTRODUCTION

Crack sealing and filling are valuable maintenance tasks to help prevent the deterioration of the highways. The purpose of crack sealing and filling is to prevent the intrusion of water and incompressibles into the crack, while crack filling is additionally used to hold broken pieces of pavement together. When properly performed, these operations can help retain the structural integrity of the roadway and considerably extend the time between major rehabilitation.

The sealing and filling of cracks are tedious, labor-intensive functions. In California, 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 procedure is not standardized and there is a large distribution in the quality of the resultant seal. In addition, while crack sealing/filling, the work team is exposed to the hazards of moving traffic from moving traffic in adjacent lanes.

The Advanced Highway Maintenance and Construction Technology (AHMCT) Center began investigating the potential to automate this process in 1989. Through funding from the Strategic Highway Research Program (SHRP) and Caltrans, under project SHRP H-107A, an Automated Crack Sealing Machine (ACSM) was developed in order to:

- Minimize the exposure of workers to the dangers associated with working on a major highway.
- Considerably increase the speed of the operation.
- Improve the quality and consistency of the resultant seal.

Increasing the speed of the operation has the accompanying effect of reducing traffic congestion since lane closure times will decrease. The combination of the increased speed and the higher quality seal lead to high cost effectiveness and reduces the frequency of major highway rehabilitations.

The ACSM has served as a demonstration of the potential for advanced technology to the highway maintenance area in general. As part of H-107A, a marketing and commercialization study was undertaken, and the ACSM's commercial cost was projected to be approximately $550,000. While the ACSM can be cost effective based on its increased productivity and reduced manpower requirements, nonetheless, its purchase would require a significant outlay of capital.

As part of the ACSM commercialization plan, AHMCT elected to develop a less complicated machine for addressing longitudinal cracks (e.g., construction joints that run with the highway) only. This less complex machine would utilize some of the ACSM technologies including sealant application unit, but would follow the cracks path by the driver controlling the support vehicle within the lane. This development has occurred in several stages, and the Longitudinal Crack Sealing Machine (LCSM) has been deployed and tested by Caltrans in the San Diego region (District Eleven). Based on the success of this testing, Caltrans Equipment Services has developed and integrated a double melter system onto the LCSM which will then be utilized as a pool vehicle throughout the state.

The Operator Controlled Crack Sealing Machine (OCCSM) incorporates features of the ACSM and the various versions of the AHMCT longitudinal crack sealing machines to create a machine that is significantly simpler than the ACSM yet allows for the sealing of both transverse and longitudinal cracks. An earlier phase of this project supported the development of the machine's subsystems within a laboratory environment. Detailed descriptions of these sub-systems is presented in the OCCSM Final Report and will not be repeated in this integration report, with the exception of the path planning algorithm that was not included in the previous OCCSM final report. In this project these subsystems have been integrated together on the truck platform where all the sub-system could be operated together for the first time. and operated, and the current project integrated these systems onto a support vehicle for on-road testing with Caltrans.

WORK COMPLETED

This project covered the integration of the many separate OCCSM sub-systems that were developed in the previous project, and the development of new sub-systems all put together into a fully functioning road testable machine. Descriptions of these components are discussed in detail in the OCCSM final report titled "Development of the Operator Controlled Crack Sealing Machine - the Long Reach Arm and Control Unit". With the exception of the automated crack planning component that was not included in this previous report, so it is added here as an appendix. This paper discusses in great detail the method and hardware utilized to enable the OCCSM controller to take minimal operator input and automatically plan complete and accurate crack sealing paths.

The mechanical phase of integration began with the fabrication and installation of a specially designed truck bed with canopy onto the previously purchased 26,000 lb GVW truck. A hydraulic PTO pump system was also installed to provide hydraulic power to the sealant melter. The long reach arm and curved rail support were installed below the frame rails on the rear of the truck. Three under body boxes were installed to house arm control and I/O hardware, AC generator and power distribution hardware. The camera boom and computer were installed on the bed canopy. The sealant melter was mounted directly to the truck body deck and hydraulic and fuel connections made. Finally, the complete sealant application system was developed and installed, including the sealing head, heated sealant hose, hose tray and hose retraction system.

With all of the systems attached to the truck platform the electrical integration phase began. Each component, or system was connected to power and the separate systems connected together. The OCCSM requires 220Vac, 110Vac, 13Vdc, 10Vdc and 5Vdc power. Most of the electrical power connections were located in the underbody Power Box, and to reduce EMI noise problems, all the AC lines and components are shielded. All DC power is derived from the trucks 13Vdc electrical system through a single cut-off switch. DC-DC converters provide the 10Vdc and 5Vdc power. A gasoline AC generator was mounted in the under body Power Box to provide the bulk of the 120Vac power. Transformers installed in the Power Underbody Box provide the 220Vac power. A pure sine wave inverter was also incorporated into the AC power system to provide uninterruptible AC power to the computers and controllers. Electrical connections to the sealant head, at the end of the arm, run the full length along the outside of the sealant hose to allow for the telescoping of the connection. The underbody Control Box, as the name suggests, contains most of the control hardware. This includes all of the I/O hardware, the servo drivers that drive the telescoping arm servo motors and the computer networking components. The camera computer was located up on the truck canopy close to the camera to improve image quality. The image is sent to the control computer over the onboard intranet network. The control computer is a laptop that can be connected directly by cable to the onboard network, or it can use the onboard wireless connection. A high luminosity XVGA LCD screen was installed in the truck cab to provide for direct sunlight readability of the user screen during road testing. With the mechanical and electrical development complete for the first time it could be operated as a single OCCSM system. This allowed for the final programming task to commence.

Prior programming development in the laboratory setting was limited to control of the arm together with the image. With integration completed, the user interface programming could be developed. The initial I/O program was rewritten to assist with this task. One by one, the user interface incorporated the many subsystems, I/O and network communications together into a single automated control. Initially all of the OCCSM subsystems were to be integrated onto one computer platform. Computer advancements lead to the development of a computer network approach; where the main components, the I/O, arm controller and vision computer are autonomous and are connected to the user control computer over an onboard intranet network. The user interface program was written in Windows Visual C++ and operates on a laptop computer running the Windows 2000 operating system. With the user interface and the networking programming completed, the truck was ready for road testing. Many assumptions had to be made on how the sealant head would operate to complete the user interface. Road testing with sealant was necessary to complete the user interface program. The OCCSM integration had progressed to a point were road testing could begin to primarily workout details of the sealant application control in the user interface.

To date about ten road tests have been conducted. The first two road test focused on imaging and path following. The truck was driven over several cracks, an image was taken and a path was planned. Planning can be done automatically, by freehand, or a combination of both. Freehand mode proved invaluable when there was old sealant present. The arm was then sent out to follow the path and the accuracy verified visually. These tests were very successful and helpful in developing operational procedures. All subsequent road tests would involve sealant. About half of I/O on the OCCSM is related to heating the sealant and all the passages that the sealant comes in contact with in its journey from the kettle to the road. The following couple of road tests focused bring the sealant and sealant application system up to pour temperature, develop an operator procedure and refine the user interface heater control program. The user interface automatically controls the six temperatures and four heaters required to complete this process. The remaining six road tests focused on sealing cracks and refining the sealing application hardware, the user program and operator procedures to produce a quality seal.

After the operator plans a crack path clicks a seal command the crack sealing application process is fully automated and requires no user input. Therefore, it is critical to refine the application program control variables. The first sealant test went quite well and produced a fairly good crack seal, but variables were taken to their limits to determine their effects. Even though this experimentation was in progress, a good video of this test was recorded and is being used for promotional purposes. The OCCSM was then displayed successfully at the AHMCT equipment show without sealant. The next road test ended when the electrical sealant hose failed during sealant heat-up. The heaters make possible sealant flow and the OCCSM cannot operate without them. This electrical element had shown some signs of problems in the past. The heater evaluation testing had just begun on the LCSM, when that machine was pulled from service by Caltrans Equipment before any data on the element could be established. Testing of the electrical hose element on the OCCSM was far more difficult, but the only remaining viable option. More difficult because of how complicated the OCCSM hose assembly is and how difficult it is to access it. The hose resides inside the telescoping arm and the retraction mechanism, it has several electrical, one pneumatic and tension cables running down its length.

When the heating element fails inside an OCCSM hose full of sealant the entire hose assembly has to be effectively replaced. Fabricating an identical hose assembly with the same electrical element would have certainly been the quickest route to get the OCCSM back out on the road for continued testing, but the element would have certainly failed again and most likely before testing could be completed.

The OCCSM heated hose utilizing this electrical heating element was chosen because it has many benefits over other methods. It is very efficient, inexpensive, simple and easy to control. The electrical element utilized up to this point had a manufacturing defect that caused the insulation between the bus wires to flow away slowly when hot and eventually cause a short. The element cannot be repaired and the entire 80ft is scrap. The manufacturer was contacted and they felt a custom element could be manufactured without the defect, but a full 1000ft spool would have to be ordered. Currently the manufacturer derates the specification low enough that the defect is not any longer an issue. The problem with going with the custom ordered element is that to get the required output in the OCCSM, the element is driven by a higher than specified voltage, so if the custom element did not perform as requested there would not be any recourse. With additional work, the development of a robust electrical heating element should be possible, but a test platform, simpler and less expensive than the OCCSM, must be found for evaluating new designs.

There are several commercially available electrically heated sealant hoses available and Caltrans currently is using some of these products. None of these heated hoses can handle the constant bending and the long length that the OCCSM application requires. Therefore, a new sealant hose heating system had to be developed that is robust and preferably could also provide more heat energy to the sealant in the hose. Oil heat was chosen, because its source of heat, hot heat transfer oil, already exists in the sealant melter. Oil heated hoses have been around for many years, but sealant melter manufactures are moving away from this technology in favor of electrical heat for many reasons. Utilizing an oil heated hose in the short term is the best option to a timely completion of OCCSM road testing. Any subsequent OCCSM projects should include an effort to development a robust electrical sealant hose heater.

A sealant hose with hot oil heat was developed and installed on the OCCSM truck for testing. The road testing of this new hose had a bad sealant leaking problem from the beginning. Heating hose stretch at operating temperature caused the leak and attempts to quickly repair the leak and resume testing failed. The fabrication of a new hose assembly is currently in progress, but will not be completed by the end of this project.

Unfinished Tasks

The full integration of the OCCSM has been completed and the machine is in the process of field testing, but before final road testing could be completed, the heated hose failed, putting a halt to the road testing. Progress is under way to develop a new heating system for the sealant hose, but as of the close of this project a successful system has yet to be installed on the OCCSM so road testing can resume. Work will continue on the heated hose replacement under the

AHMCT deployment project until road testing can be completed. The final goal of this project is to operate the OCCSM on the highway with Caltrans to demonstrate the advancements made in automated pavement crack sealing by this project. These demonstrations will be recorded to assist in continued future demonstrations of the OCCSM.

Deliverables

This project developed a fully functioning self-contained automated crack sealing machine. The OCCSM is intended as a demonstration platform and could be demonstrated widely to develop interest in developing a commercial machine. This machine was never intended to be deployed in the field by maintenance personal and only carries a minimum sealant supply for demonstration purposes. Due to the complexity of this system, AHMCT personal will be required to assist in the operation of this machine. Documentation of this part of the OCCSM development is intended to be viewed in conjunction with the final report of the first phase of development that addresses more of the technical aspects of this machine. In addition to this project’s final report, documentation provided includes, an operator's manual, technical drawings and programs on CD. The operator’s manual describes the OCCSM and its many sub-systems and includes component and operator display images. Technical drawings are included on CD in both AutoCad and Pro E formats of the detailed component designs. A complete copy of the control program is also included on the CD that is written in Visual C++.

DISCLAIMER / DISCLOSURE

The research reported herein was performed as part of the Advanced Highway Maintenance and Construction Technology (AHMCT) Program, within the Department of Mechanical and Aeronautical Engineering at the University of California, Davis and the New Technology and Research Program of the California Department of Transportation. It is evolutionary and voluntary. It is a cooperative venture of local, state and federal governments and universities.

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Operator Control Crack Sealing Machine

Operators Guide

Advanced Highway Maintenance and Construction Technology Center
University of California Davis

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OVERVIEW

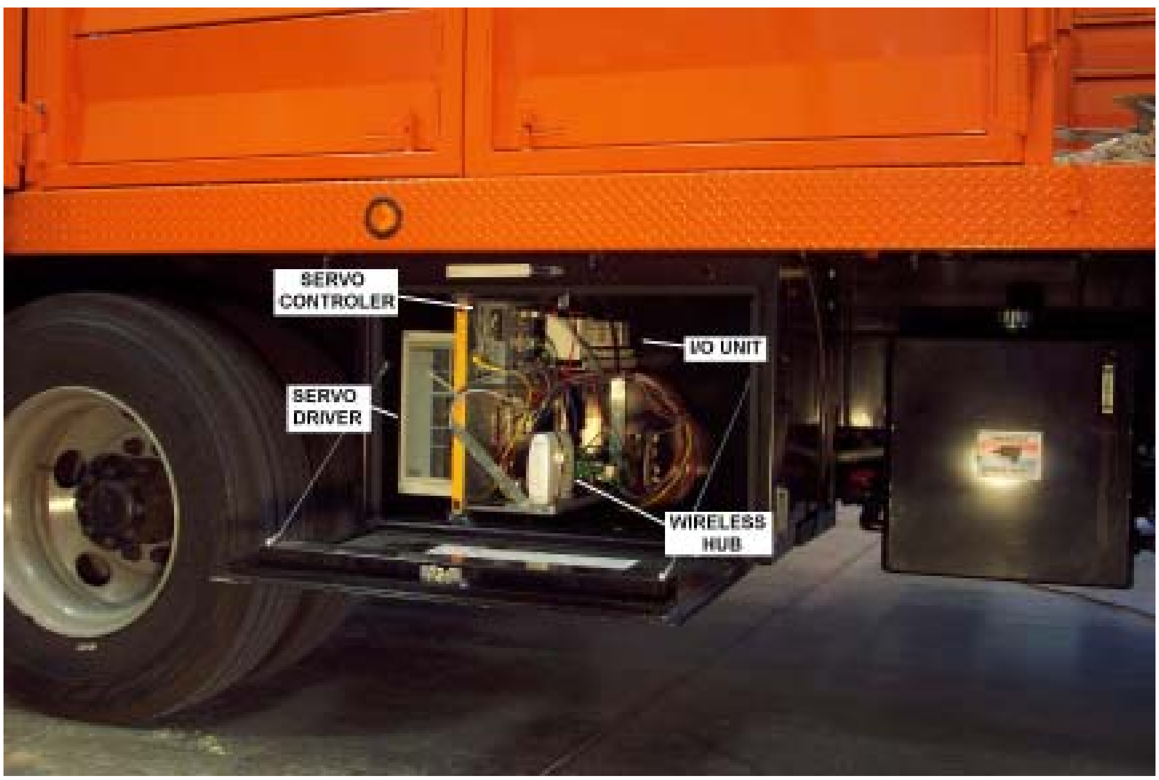
The Operator Control Crack Sealing Machine (OCCSM) is an automated highway crack sealing machine. It was developed as a demonstration of the application of new technology to improve safety for workers conducting hazardous tasks on the highway. In this case, the hazardous task of highway pavement crack sealing which requires a minimum of two workers handling the application of hot sealant while being directly exposed to highway traffic. The OCCSM removes the workers from direct exposure and enables them to seal highway pavement cracks from within a vehicle. The OCCSM accomplishes this with the use of a computer controlled telescopic robotic arm attached to the lower rear of the truck bed. The operator in the truck cab is able to identify the cracks to be sealed with the machine's help, and when selected by the operator, the machine seals the cracks automatically. The operation of this process is very simple, but the system to accomplish this level of automation is quite complex. At this stage of development of the OCCSM, the complexity of the system limits the field deployable nature of this machine. At this point, the OCCSM is intended as a fully functioning technology demonstration platform with its operation supervised by qualified AHMCT personnel. Future generations of this equipment could be developed with more advanced user interface and simplified operation procedures to construct a field deployable OCCSM.

PURPOSE

The purpose of this document is to describe the OCCSM and its operation. This guide breaks the machine down into its major sub-systems and describes the function of each. It also describes how each sub-system works independently and together with other sub-systems to do its part in the overall automated sealing process. The information in this guide is meant to explain the OCCSM project and its future potential. This manual does not contain the level of information required to operate the OCCSM without considerable training by qualified AHMCT staff. Maintenance and operation of the OCCSM should remain the responsibility of AHMCT.

OCCSM NETWORK

The OCCSM is comprised of many systems connected together over an on-board intranet computer network. The center of the network is a wireless dual speed hub (fig 1) that connects to the sub-systems through CAT 5 cable using the TCP/IP protocol. The hub also creates a wireless network carried around the truck to enable the connection of the control computer and additional computers to the OCCSM system. The wireless connection is very convenient for development and demonstration, but for highway operation the Ethernet connection is the preferred connection of the control computer to avoid possible EMI interference.



[Fig 1]

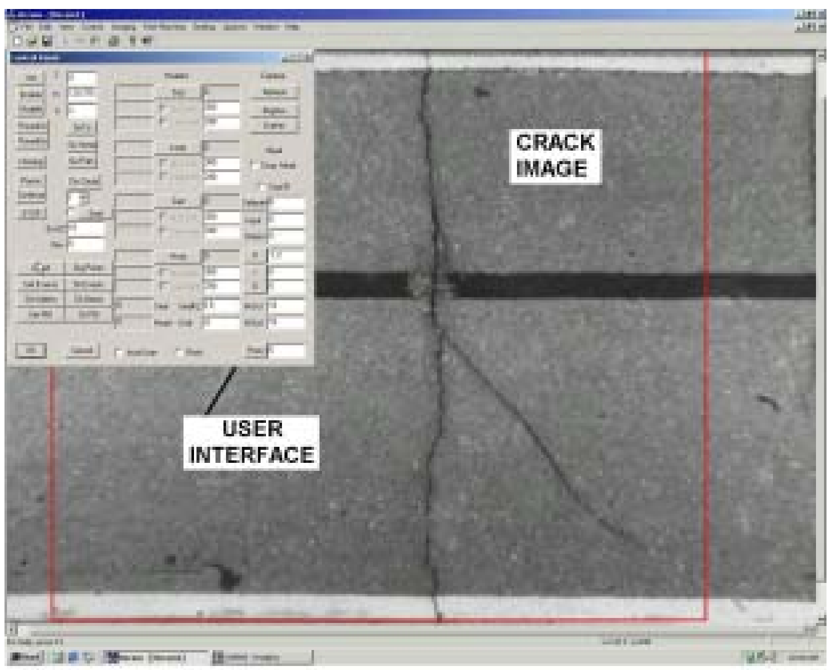
CONTROL COMPUTER

The network structure of the OCCSM eliminates any hardware connections between the truck and control computer. This dispenses with the conventional dedicated on-board computer scheme allowing for the establishment of multiple, generic control computers. Should a control computer (fig 2) fail in operation, a back-up computer can be substituted quickly to keep the OCCSM operational. AHMCT currently can operate the OCCSM on either one of two laptop computers. Any current Windows computer can be utilized to operate the OCCSM after the installation of OCCSM control software, applications and component drivers. For demonstration purposes, the OCCSM has even been controlled over the internet from a different city. Operation of the OCCSM outside in the sunlight can cause glare problems on the computer screen making the viewing difficult. A high luminosity 12Vdc LCD display has been incorporated to allow for good screen readability even in direct sunlight. The display has been mounted in the center of the cab (fig 2) so both the driver and the passenger can view it. Also, a good computer pointing device is important. Various pointing devices have been tested for field use. The track ball and finger mouse have worked the best.

[Fig 2]

USER INTERFACE

Commanding the OCCSM to seal cracks is quite a simple task requiring only a basic introduction. The user interface is a program that resides on the control computer. A click of the mouse is all that is required to plan a crack path and command the robot to seal it. The status of operation is displayed to the user along with status of many important temperatures. System startup can be completely controlled from the user interface window (fig 3). The User Interface developed for this project is a hybrid of system diagnostics and basic user information. It looks complicated, but under normal operation the operator only is concerned with a few of these items.



[Fig 3]

CONTROL PROGRAM

The user interface is a simplified entry to the control program; a way for the control program to obtain instructions from the operator. Unseen by the operator, it is the control program that automatically manages all of the many complex OCCSM systems to work together. Multitasking is the key to the success of the control program. Even with the OCCSM system sitting at idle, several independent programs are running at any one time. It is in constant communication with independent sub-systems and the user interface. The control program stores the step by step process of events that must happen to plan and seal a pavement crack. A simple user input command is interpreted by the control program into a whole process of commands and replies that need to be distributed to sub-systems and monitored. This program is written in Visual C++ and resides on the control computer.

IMAGE COMPUTER

The workspace of the sealing robot is to the rear of the truck and since the operator is in the cab, a high quality workspace image is essential to the operation of the OCCSM system. The operator can toggle between a live workspace image, useful for truck positioning, and a higher quality still workspace image. The still crack image (fig 3) is taken with the arm retracted and the operator plans paths from the still image so that the arm doesn't block the view of the cracks as the arm is working. A high resolution monochrome CCD digital camera (fig 4) is the heart of the image system. To achieve a sufficient resolution to detect a 3mm [1/8 in] crack over a 4.6m [15ft] by 4m [13ft] area scan a 2/3in CCD or greater was found to be mandatory. To take the image a camera boom was designed to deploy the camera 3.35m [11ft] above the road and 3.65m [12ft] out off the back of the truck directly over the center of the robot workspace. The CCD camera chosen has a separate camera body and imaging hardware, so the camera at great risk at the end of the boom is far less expensive to replace. The image computer located at the base of the extendable boom (fig 4), creates the image and dumps it onto the onboard network where for easy accessibility by the control computer. Since the camera operates in a wide range of lighting conditions, an auto iris lens is essential, but unfortunately, the combination of low focal length and resolution made the search for an off-the-shelf auto iris lens unsuccessful. As a quick fix a motor driven lens shade was attached to the protective window of the camera enclosure. It consists of two polarizing lenses that control camera lighting remotely on the user program. The center of the image is the point of reference that the arm is initialized to.

[Fig 4]

ROBOT CONTROLLER

The telescoping robotic sealing arm mounted on the rear of the truck is driven by two electronic servo motors (fig 5). One drives the extension of the arm and the other drives rotation. Combined, the two motors can position the sealing head mounted to the end of the arm anywhere in the 3.65m [12 ft] by 4m [13 ft] workspace to within 0.4mm [1/64 in] of an inch. The two axis servo controller accepts paths and velocities off of the on-board network sent by the control computer. It determines from the path what positional signals to send to the amplifiers that drive each motor independently. The controller also dumps information onto the onboard network for the I/O to retrieve when certain events occur or end. A homing program is used to locate the arm with respect to its mechanical limits every time the arm is powered up. An initialization process has been conducted in the lab to determine the physical relationship between the robot workspace and the center of the camera image. This constant is hardcoded in the control program and is always present.

[Fig 5]

I/O CONTROL

All remaining system monitoring and switching is handled by the I/O Control unit. It also is connected to the onboard network, where it both sends and receives information to and from other OCCSM components. The I/O unit (fig 1) converts between digital information and the various electrical signals that the physical devices operate with. Some of these devices include valves, thermocouples, potentiometers, lights, relays and sensors. The operator does not normally access this unit directly. The I/O unit works primarily with the user program where I/O points are directly accessed or controlled automatically within an automated process. The I/O control program also has PID capability to control three heaters and the sealant level on the sealant head.

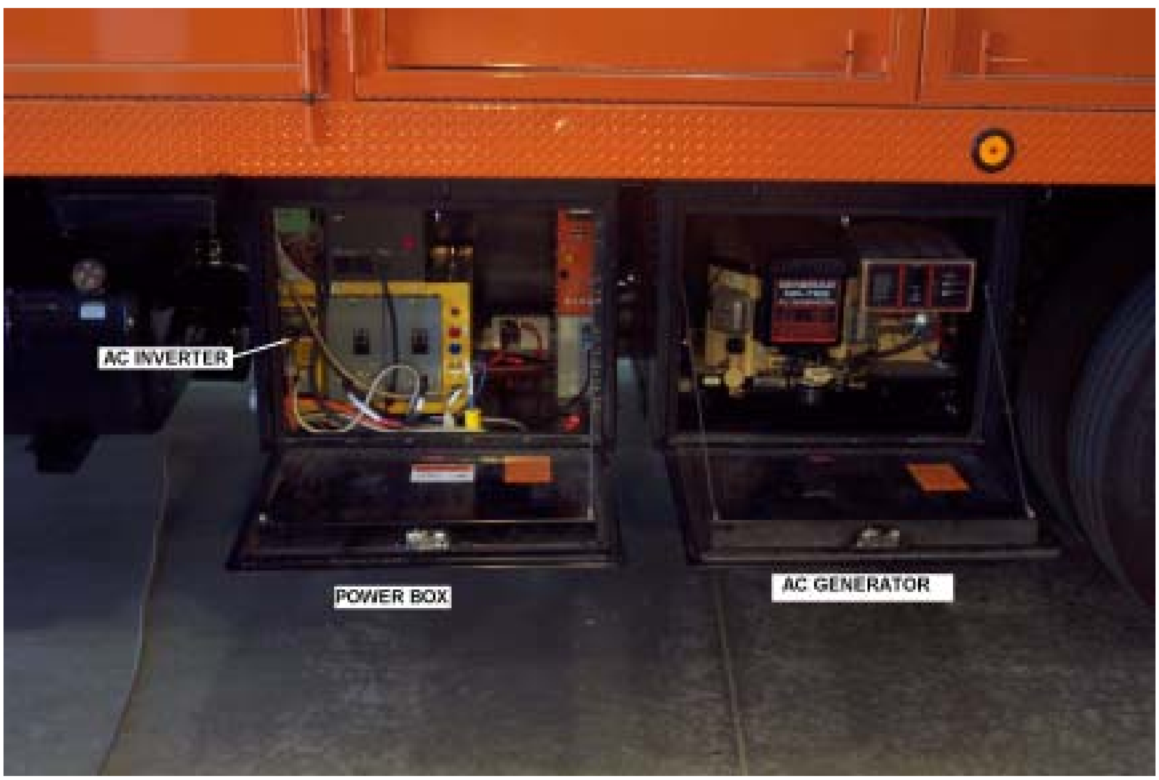
SEALANT SYSTEM

The application of sealant is a completely automated process. The operator need only to click a box on the user interface and the OCCSM system seals the crack. To accomplish this, a majority of the I/O points deployed on the OCCSM are related to control of the sealant application system. Since sealant must be heated to 400 deg F for application, any surface that contacts sealant must be heated. A 125 gallon diesel fired sealant kettle (fig 4) initially melts the sealant into a liquid. The kettle pumps the hot sealant through a flexible heated hose (fig 4) out to the sealant head mounted on the tip of the robotic arm (fig 6). All the passages through the sealant head are heated with electric heaters till the sealant leaves the sealing head. Several PID control loops in the control program automatically maintain the various head temperatures. The sealing head creates a pressurized sealant reservoir where it contacts the pavement to provide an adequate supply to fill the crack. Sensors on the reservoir provide level feedback to control the melter pump and sealant flow. The telescoping nature of the arm necessitates that the sealant hose is delivered to and from the arm from the hose tray between the truck frame rails below the bed deck. The 40ft long sealant hose is under constant tension by twin tool balancers to withdraw the hose from the arm as it retracts. The hose consists of an internal sealant passage that operates at 400 deg F, covered with insulation and wrapped with high temperature wires that carry the I/O signals to and from the tip of the arm.

[Fig 6]

POWER BOX

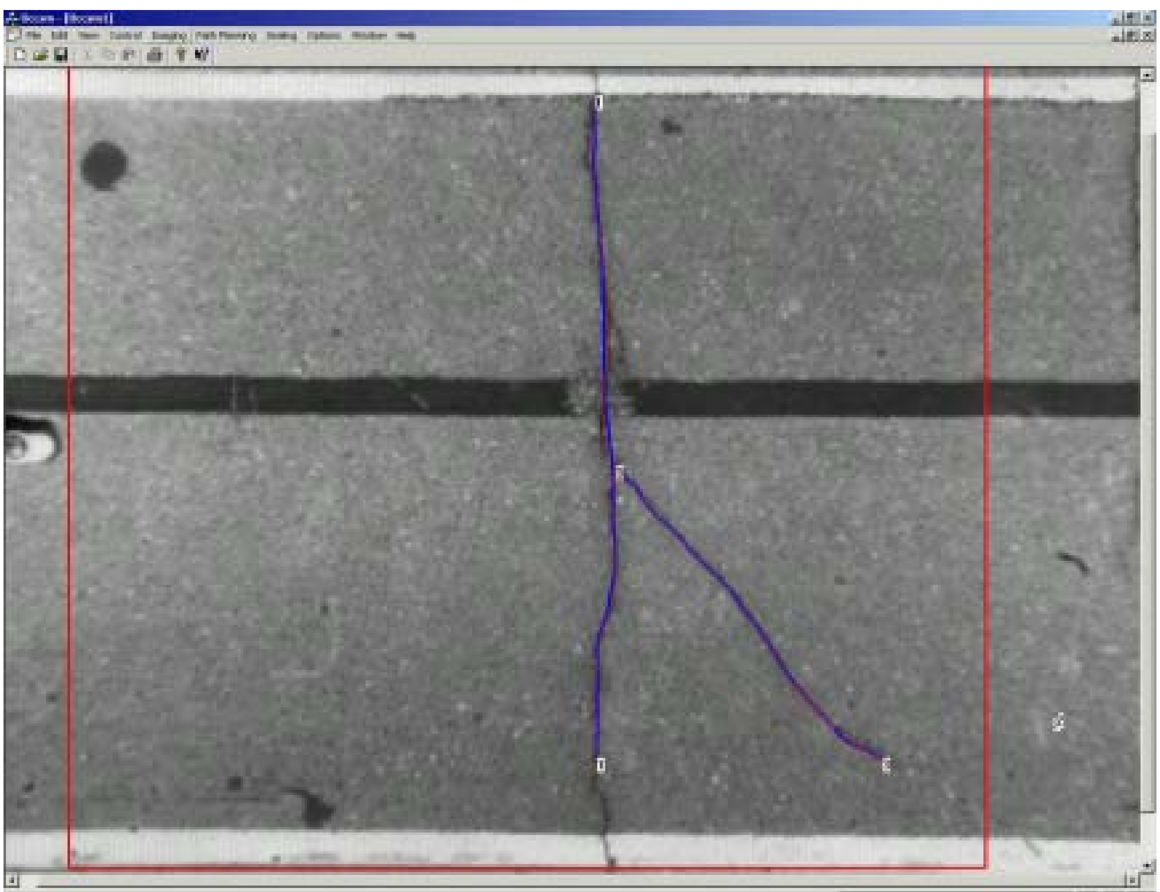
The OCCSM is primarily an electrically powered system. Various electrical voltages are required to operate this machine, but all are derived from either the trucks 13Vdc electrical system or a 120Vac gasoline generator (fig 7). From these two sources additional voltages are derived including 220Vac, 10Vdc and 5Vdc. All of the major electrical power connections and circuit protection is contained inside the underbody power box (fig 7). Plug connections inside the power box allow for easy conversion from mobile to house power for operation indoors. Careful attention was taken to shield the DC circuits from AC circuits to reduce EMI problems. To provide for uninterruptible power to the computer systems, an AC inverter was installed in the power box to convert the trucks 13Vdc battery power into a small supply of clean 110Vac power.



[Fig 7]

SEALING PROCESS

With all of the OCCSM sub-systems initialized and operational, the operator can begin the sealing process. The operator drives the truck watching for pavements cracks to appear in the robot workspace using the live camera image screen on the operator display. The driver stops the truck when a crack to be sealed is inside the workspace and clicks refresh on the user interface program. A high resolution still image of the workspace is then on display for path planning. The operator clicks the beginning and end of the first crack to seal and the path planning program displays a seal path. The operator can either approve, or modify the path. If approved the program automatically conditions smoothes the path (fig 8). The operator clicks the seal button and the robot automatically seals the crack with hot applied sealant (fig 9). The operator is free to plan another crack path as the robot is in the process of sealing cracks. When all the cracks are sealed in the workspace, the operator clicks the home button and the arm retracts so not to block the camera image. The live image window is clicked to allow the operator to drive the truck forward watching for more cracks.



[Fig 8]

SUMMARY

The OCCSM is a fully field operational machine capable, of automatically identifying and sealing pavement cracks with hot applied sealant, with minimal operator input. This machine was developed under the auspice of a demonstrational display of technology and does not carry the normal quantities of supplies required to conduct a full day's production of sealing. Crack cleaning has also not been incorporated onto this machine, but several approaches could be added. The OCCSM is intended to be a hands-on display, but only under the supervision of trained AHMCT staff. Detailed technical drawings and schematics of this machine have been provided in this project, but are purposely not included in this guide. Any maintenance of the complicated machine will remain the responsibility of AHMCT. The machine is currently in the final road testing phase and will then remain as a demonstration machine.

OCCSM SPECIFICATIONS

Robot

Workspace	Software limited to 12ft Wide x 13ft Deep
Max Tip Speed	3ft/sec
Accuracy	+/- 0.2” Over the entire workspace
Overall Length	25ft Extended 12ft Retracted
Arm Cross Section	14” High x 10” Wide Max at Base Section
Weight	350Lbs
Drive System	Electronic Servo Motors
Power	240Vac 8amps (max)

Truck

Chassis	1998 GMC T-Series
Load Rating	26,000 GVW
Chassis Length	188” WB 156” CA 249” CE
Suspension	Rear- 23,000 lb Air Front- 12,000 lb Tapered Leaf
Engine	6.6L Cat Electronic Diesel 250 hp
Transmission	6 Speed Automatic MD3560P Allison
Bed Size	8’ Wide 23’ Long 12’ High (@ canopy)

Hydraulics

Pump	Pressure Compensated 2,500psi
Power	PTO Driven 10gpm @ any RPM

Electrical

General AC Power	7.5KW Gas Generator 110V
AC Computer Power	2.5KW Pure Sine Wave Inverter 12Vdc to 110Vac
12Vdc Truck Power	(3) Onboard 12Vdc Batteries
220Vac Power	(2) 2KW Step-up Transformers Converts 110Vac to 220Vac

Sealant Kettle

Sealant Capacity	125 gallons Double Boiler Type
Burner	250,000 BTU Diesel
Pump	Submersed Gear Drive Proportional Flow Control
Hose Heater	Direct Hot Transfer Oil Internal Heat

Sealant Applicator

Seal Profile	4” Tooled Overband
Heating	Electrical Elements 110Vac
Speed	1.5ft/sec (max)
Material	Hot Applied Polymer Modified Sealant

Crack Camera

Image Size	13’ – 6” Wide x 15’ Long
Crack Resolution	3/16” Min
Image Resolution	1134 x 972 Pixels (interlaced) 2/3”CCD
Image Rate	Live 1-1/2 Sec / Frame (non-interlaced)
Lens	6.5mm Focal Length Manual Iris

Computer Control

Image Computer	486Mhz Compact Enclosure Windows 98
Control Computer	1.6Ghz Notebook Windows XP
Image Display	1124 x 768 Pixels High Luminosity 2000 NITS 13Vdc
Image Size	13’ – 6” Wide x 15’ Long
Crack Resolution	3/16” Min
Network	10/100BASE-TX Ethernet Wireless IEEE 802.11b

APPENDIX

Automated Crack Path Planning