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HAZARDOUS SPILL SAMPLE RETRIEVER SYSTEM (HSSR)

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ABSTRACT

HAZARDOUS SPILL SAMPLE RETRIEVER SYSTEM (HSSR)

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A Hazardous Spill Sample Retriever System (HSSR), dispatched to a spill site, consists of the control van and the small Hazardous Spill Pickup Vehicles (Hazzy Vehicles). The lightweight Hazzy vehicles are carried to a safe point near a spill site and used, under remote control, to pick up samples of possible hazardous material, which are safely brought back to the HSSR van. The Hazzy vehicles are equipped with television cameras, to monitor activities at the site and transmit back to the control van, which contains two video receivers, a television set, a video cassette recorder and the remote control equipment for Hazzy control. This report states and describes the electrical and mechanical equipment which comprise the HSSR.

Chapter 1 provides a description of the electrical and electronic system and the mechanical system of the Hazardous Spill Sample Retriever System. The Electrical and Electronic System includes five major components, which are the drive system, actuators, camera control, camera video and power system. The mechanical system includes the body structure, supports and all mechanical operational functions, consisting of the wheels and drives, camera lens and camera, camera positioning mechanisms for tilt and pan, and pickup scoops or tubes and their associated drive mechanisms.

Chapter 2 provides information pertaining to the Robot Actuators. Data is given describing scoop design, syringe design, pan camera positioning and tilt camera positioning.

Chapter 3 details the vehicle electronics. The HSSR Detailed Block Diagram describes the relationship between the remote control I/O and transmitters in the control van and the signals through the vehicle receivers into the control processor on the Hazzy vehicle. Electronics System Operations is provided by a small printed circuit board, which is a standard 68000-based microcomputer system, and a larger board assembly containing the major functional groups of circuitry, which include the pulse width modulation amplifiers, power supply voltage monitor circuits, interface amplifiers for camera zoom, focus and iris, and circuits to interface this board to the 68000 board. The power system employs two 12 volt batteries and dc-to-dc current converters, which are connected to the main ON/OFF switch of the vehicle system.

Chapter 4 discusses the remote control system. Radio control is used for the control functions in the Hazzy vehicles. Transmitters are mounted in the control van and receivers are mounted in the Hazzy vehicles. Each radio control unit supplies five separate channels, so that there are 10 control channels on each Hazzy vehicles. These channels control drive wheels, sample pickup, auxiliary channel and camera operations to control pan, tilt, focus, iris and zoom.

Chapter 5 refers to the Implementation of Control Function. The wheel control and steering functions contain the joystick controls, transmitters, receivers and pulse-width modulators. The pickup mechanism control includes the scoop control for solid and powder pickup and syringe control for liquid pickup.

Chapter 6 deals with the Video Communication System. Each of the Hazzy vehicles carries a two-part camera consisting of a control unit and a remote head. The camera head is mounted on the camera tilt and pan servo. The control unit, connected to the camera head by an extension cable, is mounted in the body of the Hazzy vehicle. This section includes information on the video camera, video transmitter and video receiver.

Chapter 7 concludes with the Van Equipment and Operation. Information is provided on the electrical power supplies, video communication, video monitor, radio control equipment and operating procedures.

Abstract written by Robin J. Maskell.

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"The research reported herein was performed as part of the Advanced Highway Maintenance and Construction Technology Program (AHMCT), within the Department of Mechanical Engineering, Aeronautical and Materials at the University of California, Davis and 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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CHAPTER 1

1.0 SYSTEM DESCRIPTION

The Hazardous Spill Sample Retriever System (HSSR), dispatched to a spill site, consists of the control van and the small Hazardous Spill Pickup Vehicles. Control and monitoring equipment for the vehicles, with the associated tools, power supplies and safety equipment, are on board the control van.

A Hazardous Spill Pickup Vehicle is used to pick up samples of possibly hazardous material at a spill site, such as an overturned truck or other vehicle on a California highway, under the jurisdiction of the California Department of Transportation (abbreviated to Caltrans in this document).

Hazardous Spill Pickup Vehicles are approximately 15 inches wide, 24 inches long and 15 inches high. Individual vehicles are frequently referred to as "Hazzy" vehicles by Caltrans employees and others familiar with the system. Their function is to pick up samples, under remote control, from a possibly hazardous spill, and safely bring those samples back to the HSSR van used to carry personnel, vehicles and other equipment to the site of the spill. They are equipped with television cameras to monitor and record activities at the site.

In operation, the HSSR operators carry the Hazzy vehicles from the van to a safe point near the site of the spill. Hazzy vehicles are designed to be lightweight, rugged and intrinsically unable to emit sparks or heat sufficient to trigger possibly volatile or explosive materials at the spill site. Since they weigh less than 45 pounds, it is possible for an operator to carry the vehicles to and from the van with safety. The van has 110 volt AC generators to supply rechargers, utilized in recharging the batteries of the Hazzy vehicles. It also contains the remote control equipment for Hazzy control, two video receivers, a Television Set (TV) and a Video Cassette Recorder (VCR) to record activities observed through the remote TV camera.

Normally the van will be stationed within 300 feet of the spill site with its back end toward the spill site. This positioning allows the video antenna to be aimed directly at the spill site, to provide vehicle control without interference from the metal structure of the control van.

1.1 System Block Diagram - Electrical and Electronic

As shown in Figure 1.1, HSSR Overall System Block Diagram - Electrical and Electronic, there are five major components of the Electrical and Control System.

These components are:

1. Drive System
2. Actuators - Solid and Liquid Pickup Mechanisms
3. Camera Control
4. Camera Video
5. Power System - D.C. to D.C.

Radio Control Transmitters in the Control Van transmit high-frequency radio signals to the separate Hazzy vehicles. There are 10 radio channels to control each vehicle. Provision is made for controlling two separate vehicles at the same time by operators at two separate control stations on the control van.

Control signals are received by the 10 separate receiver channels on each vehicle and processed through the PW/D Converters and the Motorola 68000 computer system. Processed signals are directed to the drive system, the pickup mechanism actuators and the camera control system.

1.1.1 Drive System

Four separately driven wheels are controlled by the drive system. Each wheel has a separate brushless motor controlled by direct commands from the Hazzy vehicle's computer. The two left wheels are controlled together, as are the two right wheels. This control results in "skid steering". Instead of steering the angle of the wheels, the vehicle is turned by the differential speed of the two sets of wheels - much like a tank vehicle's treads are driven.

Commands from the computer are generated by a program in the Motorola 68000 microcomputer as directed by the assembly language program stored in EPROM. Control input to the computer is provided by phase-modulated signals from the radio receivers. These signals are modified by local circuits before being fed into the computer for processing. Within the computer software are correction programs and safety protection programs that prevent the wheels from running out of control, even if they are not touching the surface being traversed and would otherwise spin freely.

1.1.2 Actuators

Pickup tubes at the front of each vehicle contain actuators, which position the pickup mechanism, to pick up samples from the surface, and up to 2 inches below the surface of the ground. These pickup mechanisms are also driven by brushless motors controlled by the computer.

1.1.3 Camera Control.

Two additional brushless motors are controlled by the computer, in response to radio signals, to rotate the camera about a vertical axis (the Pan operation), and to tilt it up and down around a horizontal axis (the Tilt operation).

Three separate small motors are built into the camera itself to provide Zoom, Focus and Iris control of the camera. These are not proportional controls. They drive the Zoom, Focus and Iris functions at full speed in a selected direction, but have no feedback. Radio commands control only the direction of movement but not the speed. Pulse-modulated signals from the remote control radio transmitters are detected by the on-board receivers, processed by input circuitry and the computer, and used to control the Zoom, Focus and Iris functions.

1.1.4 Camera Video

Video signals, detected by the TV camera, are converted to the NTSC (RS-170) standard used in standard television, then fed to the Video Transmitter.

Camera video is separate from the control system but receives power from the power system. The video camera is positioned by the camera control to direct the camera lens and camera assembly in the appropriate direction. Joystick control, by the operator of each vehicle, controls this operation. Operator controls are available in the control van.

1.1.5 Power System

Two different power converters are used in the Hazzy vehicle to supply direct current power at different voltages to the electronics in the vehicle. Both of these units are supplied with 24 volts D.C. from the vehicle battery, which converts this voltage to +12 volts, -12 volts or +5 volts. One unit, the 2W24SCR15T, is 3 inches high x 2.5 inches wide x 0.75 inches thick, and supplies +5 volts, +12 volts and -12 volts to the system. The other unit, the 3W12SCR5S12-AM, is 2 inches x 2 inches x 0.5 inches thick, and supplies a separate +12 volts to the system. Each unit has pins approximately .25 inches long, extending down from the unit, making the actual units about 0.25 inches thicker than the thickness measure suggests. The former unit is made by UHF Power, ING., and the latter by Ericcson.

1.2 Mechanical System

The mechanical system includes the body structure, supports and all mechanical operational functions. The mechanical system consists of the Wheels and Drives, Camera Lens and Camera, Camera Positioning mechanisms for Tilt and Pan, and Pickup Scoops or Tubes and their associated drive mechanisms.

1.2.1 Body Structure and Supports

1.2.1.1 Body Material

The Hazzy vehicle body is constructed of three layers - a central layer of plastic honeycomb covered, on the inside and outside, by thin layers of carbon fiber. This combination of materials provides a stiff, strong, lightweight body, which is resistant to most chemicals encountered in the field operation. Wheel wells, battery compartments and drive motor clearance volumes are molded into the body of the vehicle. A removable cover allows access to the center of the vehicle, which is made of the same composite material as the rest of the body.

1.2.1.2 Supports

Inserted into the plastic material of the Hazzy vehicle are "hard points", which are used for mounting the electronics, motors, wheel supports and other constituents of the vehicle. These hard points are produced by drilling into the plastic body and epoxying the mounting hardware into the hole. Mounting hardware is usually made up of screws and nuts but other support items are also used.

1.2.2 Drive Wheels and Suspension

The Drive wheels are mounted on the suspension assemblies, supported by "hard points". The suspension assemblies allow the wheels, each mounted on a separate axle, to move up and down relative to the body, which allow for terrain variations and provide spring loading of the wheels to minimize shock and vibration.

The Drive wheels are purchased wheels containing an axle bearing and a rubber tire. The Wheels are seven inches in diameter, to provide ground clearance, and to provide the necessary drive ratio to achieve the specified 5 miles per hour maximum speed. The wheels are fastened to the gearbox shafts by means of machined aluminum hubs.

Each axle has a separate drive motor, which rides up and down with the suspension system and allows each drive wheel to be operating continuously, without regard to the position of the vehicle or the operation of the other wheels.

An external "boot" on each axle allows the wheel to move as required, but maintains a positive seal at all times to prevent external atmosphere and corrosion from entering the vehicle. This boot is formed of neoprene rubber, molded to fit over the axle housing and to cover the axle openings. The boot also acts to provide a resilient support to the axle and thus, dampen vibrations. The boot is clamped in place by four screws and an aluminum retaining ring.

1.2.3 Drive Motors

Drive motors are brushless Maxon motors, Type EC040-070-38EAA200A, driven separately by three-phase power drivers controlled by the signals from the main control computer. Phase-modulated signals from the radio control receivers are interpreted by the control computer through power amplifiers, to generate the required power drive currents to drive the motors at the desired speed.

1.2.4 Camera Mount

The camera is positioned by the pan and tilt actuator, which is mounted on the front of the Hazzy vehicle, and allows the camera to be moved as required around the pan and tilt axes. Surrounding the camera is a sealed housing of Lexan plastic to protect the camera from the environment, and prevent ignition of possible volatile gases in the environment from heat or sparks in the camera.

1.2.5 Antenna - Video

The video antenna is a cellular phone antenna approximately 10 inches long. It is mounted on the top-rear of the vehicle, near the center-line of the vehicle. It radiates in the 900-920 Megahertz range, at a power less than 0.075 watts. It is driven by a DAK "Pirate TV Transmitter", mounted in the rear electronic space of the vehicle.

1.2.6 Antenna - Remote Control

Two antennas are used to receive 75 MHz band signals, used to provide remote control of the vehicle from the control van. They are vertical whip antennas approximately three feet long. These antennas are thin wires which are routed through flexible hollow tubes. The tubes also contain removable steel stiffening rods. These rods should be removed during transport of the vehicles and re-inserted prior to use.

CHAPTER 2

2.0 ROBOT ACTUATORS

2.1 Scoop Design

Scooping up solids and powders is done by an external scoop mounted on a 1.5 inch diameter tube. The tube is extended and retracted by a geared motor, powered by the power-drive amplifiers under control of the central computer, as directed by the remote control signals.

2.2 Syringe Design

Liquid samples are picked up by a replaceable vacuum syringe, whose plunger is carried up and down inside a 1.5 inch diameter tube by a brushless motor. This motor is powered by the power-drive amplifiers, under control of the central computer, as directed by the remote control signals.

2.3 Camera Positioning - Pan

A pan and tilt mechanism is mounted on the front portion of the vehicle to position the zoom lens and camera in pan and tilt. Panning is a rotation about the vertical axis and in the horizontal plane, approximately parallel to the ground surface. Rotation range is 0 to 355 degrees. There is sufficient overlap in the lens view to allow viewing of objects over the entire 360 range.

The pan mechanism is driven by a brushless motor, powered by the power amplifier and controlled by the central computer. Control signals to the computer are supplied by the remote-control radio system.

2.4 Camera Positioning - Tilt

Tilt is a rotation about the horizontal axis of the camera. It allows the camera to see up to an angle of 150 degrees and look down at an angle of 20 degrees from the horizontal. The tilt mechanism is driven by a brushless motor, powered by the power amplifier and controlled by the central computer. Control signals to the computer are supplied by the remote-control radio system.

CHAPTER 3

3.0 VEHICLE ELECTRONICS

3.1 Electronic Block Diagram

Figures 3.1-1, entitled "HSSR Detailed Block Diagram", is a description of the relationships between the remote control I/O and transmitters in the control van, and the signals through the vehicle receivers into the control processor on the Hazzy vehicle. Controls provided are:

1. Drive - Left and Right - These control the actuation of the left and right wheels as described in Section 1.1.1 of the Operations Manual. Two proportional channels are assigned to these controls.

2. Actuator - Actuator 1 position and Actuator 2 position. Each of these actuators controls one of the two available pick-up mechanisms. These actuators run open-loop, therefore, operator control is needed to operate the actuators. The operator depends on visual information from the camera in controlling the movement of the actuators. The usual operation will be for the camera, on one vehicle, to monitor pickups by the other vehicle's actuators. Two proportional channels are assigned to the two actuators.

3. Control - One proportional channel has been converted to handle up to 16 on/off functions of which 12 are currently assigned. These functions are:

   a. System Reset - Resets system to its original conditions and sets all values to their initial state. This is used when it is desired to restart the system because of some malfunction or error condition.

   b. Drive Enable/Drive Disable - These two positions act as a toggle switch, to ensure that the operator has control of the drive functions. These functions are initially set to "Disable" by the vehicle startup software and must be specifically turned on by the vehicle operator.

   c. Actuator Enable/Actuator Disable - Provide specific operator control of the actuator movement so that a "fail-safe" condition exists. The operator must enable the actuators specifically in order to cause them to protrude from the vehicle.

d. Brake On/Brake Off - Initially, the brake is set to the ON position by startup software, and must be specifically turned OFF by the operator, before the vehicle can move.

3.2 Electronics System Operation

The smaller printed circuit board in each vehicle is a standard 68000-based microcomputer system. The control program is in EPROM chips on this board. Much of the "glue logic" is done in EPLDs.

The larger board assembly contains the following major functional groups of circuitry:

1. Eight Pulse-Width Modulation (PWM) Amplifiers
2. Power supply voltage monitor circuits
3. Interface Amplifiers for camera Zoom, Focus and Iris
4. Circuits to interface this board to the 68000 board

3.2.1 Pulse Width Modulation Amplifiers

There are eight pulse width modulation amplifiers. All eight amps are topologically identical, with four amps being located along one long edge of the circuit board, and the remaining four located along the other long edge.

Each PWM amp supplies power to one of the eight motors within the vehicle. Pulse Width Modulation is used, as it provides a convenient method of regulating the amount of power that is supplied to a motor, thus determining how fast its shaft will spin, how much torque will be produced, etc.

3.2.1.1 Pulse Width Modulation

A PWM amp is always, either completely ON, so that maximum power is delivered to the motor, or completely OFF, so that no power is delivered to the motor. Intermediate power levels are achieved by controlling the amount of time an amp is ON, versus the amount of time it is OFF. This time ratio is typically referred to as duty cycle, where

$$\text{Duty cycle} = t\text{on} / (t\text{on} + t\text{off}) .$$

The time lengths of $t$on and $t$off are measured relative to the period of a reference signal. All eight amps have their own 24 KHz reference signals, resulting in a reference period of

$$T = 42 \text{ microseconds} = (t\text{on} + t\text{off}) .$$

By changing, or modulating, the duty cycle of the reference signal, the average power delivered to a motor is also changed, thus providing control of how the motor functions. The PWM amps also provide a means of changing the polarity of the power signal delivered to the motors, which allows the motors to spin in both directions.

3.2.1.2 PWM Amp Outputs and Inputs

The output of each amp is supplied to its associated motor via a 12-pin connector. Connectors J1 through J4 are located along one long edge of the circuit board, and connectors J5 through J7 are located on the opposite edge. These connectors also interface some low-voltage, low-power control electronics located inside the motors of the amplifier on the circuit board.

The input to each amp is supplied by a Digital-to-Analog (D-to-A) converter, which is discussed below. The input is analog in nature, and the magnitude(voltage) of this signal determines the amount of power the amp will deliver to the motor - the greater the magnitude, the greater the duty cycle, the greater the power delivered. In addition, there are several logic (TTL-level) inputs to each amp. These are supplied by 8-bit registers located on the circuit-board assembly. They control functions such as motor direction (amplifier output polarity) and electronic braking.

3.2.1.3 LEDs

Each PWM amp has two LEDs. One GREEN LED indicates that the high-current power supply is connected to the associated amp. Normally this LED will be illuminated. If the LED is not illuminated there are two possible failures being indicated:

1. The fuse for the amp has blown, indicating a short circuit in the current circuit. The high-current fuses are designed to blow only in critical failure situations and should only be replaced by qualified service personnel.

2. The high-current supply and/or supply connection to the amp has failed.

Typically all four amps along one long edge will be affected simultaneously (four GREEN LEDs not illuminated), or all eight amps be affected simultaneously (all eight GREEN LEDs not illuminated). Refer to the field service manual for further information on troubleshooting these cases.

Each amp also has one RED LED. These are located underneath the top printed circuit board assembly. These indicate status and diagnostic information. During normal operation the state of the RED LED for each amp will change.

3.2.2 Power Supply Voltage Monitors

There are three integrated circuits devoted to monitoring the voltage of the main batteries and the power supply outputs derived from them. One ICL7665 monitors the battery itself. It gives indications when the battery voltage has dropped below 20.3 volts and when it drops below 18 volts. The first condition lights an LED indicator that shows on the monitor. It tells the operator that battery power is virtually gone and the vehicle should be returned immediately for recharging. The second condition actually shuts down the vehicle, to prevent draining the batteries to the point that they cannot ever be recharged again.

A second ICL7665 monitors the +5v supply for over voltage and the balance between the +/-12 volt supplies from the UHF Power module.

A TL7770-12 monitors both of the +12 volt supplies . Separate indications are given when either supply is too high or too low.

The outputs of most of these voltage monitors are read by the software and used to perform software branches, including shutdown, as indicated.

3.2.3 Camera Zoom, Focus, and Iris (ZFI) Interface Amplifiers

The ZFI amplifiers are identical. They are designed to provide a voltage of +12 volts or -12 volts to small DC motors in the lens that perform these three functions. Each amplifier consists of a single LH4104 used in comparator mode. This amplifier is capable of supplying the 50 ma needed by the lens motors.

3.2.4 68000 Interface Electronics

There are three functional types of interface circuits and components:

1. Digital-to-Analog converter ICs
2. 8-bit data registers
3. Address decoding logic

All of the above circuits/components serve as interfaces between the 68000 system and the electronic systems described above. The 68000 system signals are supplied to the second printed circuit board assembly, via the 96-pin board-to-board connector.

3.2.4.1 Digital-to-Analog Converters

The digital-to-analog converters convert data values, supplied by 68000 system, to the analog control input signals for the PWM amps. There are two, four-channel D-to-A converter ICs used. One serves four amps along one long edge of the circuit board, while the other serves the other four amps.

3.2.4.2 One 8-bit Register

There is one 8-bit register for every two PWM amps. The 68000 system writes data to these registers. The outputs of the registers supply the logic (TTL-level) required by each amp.

3.2.4.3 D-to-A Converters and Registers

All D-to-A converters and registers are memory mapped within the 68000's address space. A single IC (IC27) is used to implement all decoding logic required to generate the needed chip select signals.

3.2.5 In-Line Fuses

Fuses have been installed in the battery supply circuit. These fuses are in-line with the battery supply, located as close to the battery as possible.

3.2.6 Camera-visible LEDs

Four LEDs are built into the camera housing and show on the monitor as out-of-focus color centers. The significance of these four LEDs is as follows:

A flashing green LED indicates that the microprocessor is executing instructions normally.

A yellow LED indicates that a sample retriever has been activated and is not in the fully withdrawn position.

A red LED indicates that battery power is almost gone and the vehicle should be returned for charging immediately, or the user risks having it stranded at the spill site.

The following information concerns the question of the other green LED.

There are two jumpers, located on the M68000 controller PC board, that determine how these LEDs respond to a hardware reset.

1) If JMP9 is installed and JMP10 is not installed, all camera-visible LEDs will illuminate when the M68000 controller is in a hardware reset state. That is, the hardware reset signal state itself causes this condition and the M68000 has no control over the illumination while the signal is

asserted. With this, the unused GREEN LED should illuminate during a hardware reset state, and may be used as a deterministic indicator of this state.

2) If JMP9 is not installed and JMP10 is installed, a hardware reset condition will not change the last state of the LEDs, as directed by M68000.

3.3 Power System

3.3.1 Battery Supplies

Two 12 volt batteries are used in series to provide the 24 volt power used to operate the Hazzy vehicle and all functions in the vehicle.

3.3.2 Power Converters

Direct Current to Direct Current converters are used to generate + 12 volts, - 12 volts and + 5 volts to operate the electronic equipment on the Hazzy vehicle and provide power to drive the brushless motor drivers.

3.3.3 Power Controllers and Regulation

Batteries are connected to the main ON/OFF switch to control power to the vehicle system. This circuit is fused to protect the components against short circuits in the motors and other power loads.

CHAPTER 4

4.0 REMOTE CONTROL SYSTEM

Radio Control is used for the control functions in the Hazzy vehicles. Two separate ACE Nautical Commander radio control units are used in the HSSR system. Transmitters are mounted in the control van and receivers for them are mounted in the Hazzy vehicles. Each radio control unit supplies five separate channels operating in the 75 MHz band, so that there are 10 control channels, on each Hazzy vehicle, that control the functions listed below:

4.1 Control Functions

4.1.1 Drive wheels control - Total of two channels required.

4.1.1.1 Left wheels drive velocity and direction

One proportional control channel required.

4.1.1.2 Right wheels drive velocity and direction

One proportional control channel required.

4.1.2 Sample Pickup - Total of two channels required

4.1.2.1 Scoop control

Mechanism to pick up either a solid or powder sample under remote control - One channel required.

4.1.2.2 Syringe control - Liquid pickup

One channel required. Works in the same way as the scoop control does.

4.1.3 Auxiliary Channel

This channel is divided into three separate functional channels, which are used to turn on vehicle power, provide an emergency STOP function and actuate remote reporting signals on the remote monitoring display, which is observed by the camera.

4.2 Camera Control Operations - Total of five channels required.

4.2.1 Pan control

Rotates the camera viewpoint through 355 degrees - One proportional channel required. Driven by a brushless motor.

4.2.2 Tilt control

Provides for tilting camera viewpoint up, through 150 degrees, and down 20 degrees - One proportional channel required. Driven by a brushless motor.

4.2.3 Focus control

Adjusts camera lens to obtain best definition - One proportional channel required. The Rainbow lens has the capability to focus, in response to a remote control signal, and does not depend on ultrasonics or RF reflection for control.

4.2.4 Iris control

Opens and closes camera iris to control amount of light received and imaged on CCD sensors. Controlled by proportional control channel. The Rainbow lens has separate iris control, operated electronically.

4.2.5 Zoom control

Zoom allows changing image size, observed by the camera, to allow details to be enlarged, as necessary. One proportional channel necessary for this function. The Rainbow lens has electronically operated zoom.

CHAPTER 5

5.0 IMPLEMENTATION OF CONTROL FUNCTIONS

5.1 Wheel Control and Steering Functions

5.1.1 Joystick Controls

Joysticks used for control are mounted on an ACE Nautical Commander control box, at the operator's position, in the Caltran control van. Two joysticks are used for wheel control; one for the left wheels and one for the right wheels.

5.1.2 Transmitters

There are two ACE Nautical Commander control units for each vehicle. They are located in the van at the operator's position. Five radio control channels are provided on each ACE Nautical Commander control box. These channels share the same carrier frequency. The carrier for each ACE transmitter is in the 75 MHz band .

5.1.3 Receivers

Receivers for the radio control signals are mounted in the Hazzy vehicle body. These ACE receivers operate in the 75 MHz band and are supplied with power from the Hazzy power supply. There are 2 receivers in each vehicle, each processing 5 channels. Output from the channel receivers is further processed by Hazzy vehicle electronics and sent to the Pulse-Width Modulators in the Hazzy vehicle.

5.1.4 Pulse-Width Modulators

The information coming out of the receivers is encoded as pulse-position-modulated (PPM) information. To interface this to the motor drive chips, it is necessary to convert the PPM to PWM. This function is performed at this point in the control sequence.

5.2 Pickup Mechanism Control

5.2.1 Scoop control - Solid and powder pickup

5.2.1.1 Scoop extension

The scoop has a flat section with guides on each side. A hinged cover protects the contents of the scoop. The scoop is made of brass to prevent sparking, and extends out, from the forward part of the Hazzy vehicle, at an angle of about 45 degrees from horizontal. Since the bottom of the Hazzy vehicle will be about 4 inches above the ground level, the scoop will need to be about 8.5 inches long, to provide a total vertical component of movement of 4 inches plus 2 inches, which allows for picking up material at least two inches below ground level.

When the scoop is fully extended, the scoop cover is opened by a spring, to allow the scoop to pick up sample material at least two inches below the ground level.

5.2.1.2 Sample pickup

The scoop mechanism, as a unit, is removable from the Hazzy vehicle for cleaning and easy replacement. Protection of operators must be considered in this operation. In most cases, the operators will be adequately protected by wearing gloves during the removal and cleanup operations.

Scoop operating mode - The scoop is manually operated under control of radio signals from the control van. No other transmission should be needed since all power and actuation information is already on board the Hazzy vehicle.

5.2.2 Syringe control - Liquid pickup

Operation of the syringe control is similar to that of the scoop control.

5.2.2.1 Syringe extension

The syringe is tubular in form, about 1.5 inches in diameter, and extends out from the forward part of the Hazzy vehicle at an angle of about 45 degrees from horizontal. Since the bottom of the Hazzy vehicle will be about 4 inches above the ground level, the syringe will need to be about 8.5 inches long, to provide a total vertical component of movement of 4 inches plus 2 inches, which allows for picking up material at least two inches below ground level. When fully retracted the syringe is enclosed within the body of the Hazzy vehicle.

5.2.2.2 Liquid pickup operation - Syringe operating mode

The syringe is manually operated, under control of radio signals from the control van. No other transmission should be needed since all power and actuation information is already on board the Hazzy vehicle.

CHAPTER 6

6.0 VIDEO COMMUNICATION SYSTEM

Each of the Hazzy vehicles carries a two-part camera consisting of a control unit and a remote head. The camera head is mounted on the camera tilt and pan servo. The control unit, connected to the camera head by an extension cable, is mounted in the body of the Hazzy vehicle. The JVC camera was selected, as described in section 6.1 below, using a Rainbow lens, as described in section 6.2 below. The lens and camera both use a C mount.

6.1 Video Camera Information

The Specifications for the Hazzy vehicles specify a range minimum of 300 feet, yet it is desirable to have 1000 feet. For a standard TV picture a bandwidth of 2.5 MHz is required. However, if possible, a bandwidth of 4.0 MHz or more is desirable to give better resolution. The camera chosen was:

JVC TK-900U CCD Color Video Camera
Dimensions - Head 64x 67x 42 mm (2-9/16 x 2-11/16 x 1-11/16 inches)
CCU (Control unit) 64 x 62 x 162 mm (2-9/16 x 2-7/8 x 6-7/16 inches)
Weight of head - 370 gram (13 oz.)
Weight of control unit - 530 gram (18.7 oz.)

This camera has a separate camera head which is small and connected to the control unit by a coaxial cable about 25 feet long. In tilt and rotational application, the cable length allows the camera head to be tilted as required, without disturbing the camera control unit.

The lens used is the Rainbow H6X8M described below:

Lens- Rainbow H6X8M 4-8 mm. Zoom, Size 70 x 60 x 96.6 mm, (Size - 2.75 x 2.36 x 3.80 inches) Weight approx. 500 grams. (Weight 17.5 ounces)

Total length - Camera and lens assembly = 10.3 inches long
Total weight - Camera and lens assembly = 2 lbs. 8.5 oz.

Electronic control of Iris, Focus, Zoom provided.

Total length to be moved, camera plus lens = 4-13/16 inches.
Total weight including lens = 49.2 ounces = 3 lbs, 1.2 oz.

6.2 Video Transmitter

A DAK "Pirate video transmitter" is mounted inside the Hazzy vehicle, near the rear of the vehicle, and receives 12 volts at 100 ma. from the Hazzy power converter. It transmits in the 900-920 MHz range and can be tuned by a control knob on the transmitter case. When two video transmitters are used, in separate Hazzy vehicles, each is tuned to a separate frequency between 900 and 930 MHx with a separation of at least 8 MHz from the other frequency being used.

6.3 Video Receiver

A DAK Pirate video receiver is mounted in the control van. It operates on signals in the 900-920 MHz range, which are picked up on a Yagi Antenna, mounted on an antenna rotator on top of the control van. This receiver is supplied with power from the van D.C. power supply. It is tuned to one of the two transmission frequencies being used in the HSSR system, so that it receives from the selected Hazzy vehicle.

Tests of the "Pirate" TV transmitter and receiver, upon delivery, indicated that the quoted range of the system of 100 feet was realizable. When a Yagi antenna, with 12 db gain, is mounted on top of the control van and connected to the receiver, a power gain ratio of 15.84, or a range gain of $(15.84)^{1/2,}$, or 3.98, should be realized. This gives a theoretical range of about 400 feet for the video system. Longer, higher-gain antennas can be obtained, or built, up to 16 db gain, if necessary; potentially a power gain of 39.8, or a range gain of 6.31, or total range of 631 feet, is possible. The narrow beam is still 20 degrees wide. An antenna rotator on the van is used to point the receiving antenna, for optimum signal, and can be rotated as necessary to improve the TV picture.

In actual implementation of this Yagi antenna, it was found desirable to stack two identical antennas, one above the other, and separated by about 20 to 24 inches. When the antennas were stacked in this way and fed by a suitable split coaxial feed, the system produced a good color signal at a distance of 300 feet or more. Usable black and white signals were observed at 350 to 400 feet. Color signals, using an existing camera, allowed a newspaper page to be read, with normal type faces, at a range of 300 feet when the camera was correctly focussed on the newspaper at a range from 8 to 12 inches.

CHAPTER 7

7.0 VAN EQUIPMENT AND OPERATION

7.1 Electrical Power Supplies

Caltrans will supply 110 volt AC on the control van. This power will be used to supply the battery chargers, VCR, TV and other equipment on the van. AC power will be generated on the van by generators driven from the van motor.

7.2 Video Communication

Video communication is in the range of 900-920 MHz, and is accomplished by using InnerView V-9900 transmitters and receivers, available from the DAK Company as "Pirate" TV transmitters, on the Hazzy vehicles, and corresponding receivers in the van, as described in sections 4.2 and 4.3 above. Address and technical information on this equipment is given in Appendix 1.

Reception of signals at the van is accomplished by a stacked Yagi type antenna. Specifications of this antenna are provided in Appendix 1. The antenna is mounted on the rear of the van so that the antenna may swing out over the van for operation or storage, or can be extended out from the rear of the van for maximum range and directional operation. Rotation of the antenna to a desired direction is done by an electrically-driven rotator, controlled by a rotator dial at the communication station inside the van.

When the antenna is rotated to a position over the van roof it can be manually hinged down, sideways, and secured by clamps, so that the van can move down the highway safely at full speed.

7.3 Video Monitor

The video monitor for the Caltrans remote control van is a Magnavox CRM132AT combination 13" TV/VCR. This equipment can be used, on-line, to record the information transmitted and received on the video communication system for the Hazzy vehicles. Range of the system is 300 feet.

The video information can be used for testing of the communication system and to record the scenes observed while operating the Hazzy vehicles. This information can also be used for training of operators and to maintain legal records of the Hazzy vehicle operation.

7.4 Radio Control Equipment

The radio-control equipment in the van consists only of the ACE R-C Transmitters, as discussed previously.

7.5 Operating Procedures - see Operations Manual

APPENDIX 1

STACKED YAGI ANTENNA

Two identical antennas are assembled into a stacked array of antennas, to increase the gain and decrease the beamwidth of the antenna used on the control van that receives signals from the Hazzy vehicles. This antenna is mounted, as described, in Section 5.1 of the Operations Manual.

The two antennas are connected together by a coaxial cable (RG-58U). Two separate cables, one from the drive of each antenna, are connected by a T-shaped junction. Cables from the two antennas are cut to an exact number of quarter wave lengths and connected together by a T- connector. The two antennas are stacked, about 20 to 25 inches apart, one above the other. Vertical separation of the antennas is not critical in this range. Phase length in the connecting cables is set to 5 quarter wave lengths so that the impedance presented to the antennas is 100 ohms and the impedance at the T junction matches the 50 ohm impedance of the RG-58U cable used. For maximum gain and directivity the cables are cut to within 0.1 inches of the same length so that the electrical phasing of the two antennas is closely the same and will cause the signals to add together to give maximum gain. (See Reference 1 for more detail). It is important, in calculating the length of the cables, to take into account the velocity of radio waves in the cable, which is 0.66 the velocity of light or radio waves in free space. This calculation is:

L = length of cable required for one wavelength
c = velocity of light in free space = $3 * 10^{10}$ cm./sec.
Vcable = 0.66 * c ; velocity of signal in cable
n = number of quarter wavelengths at desired frequency in the cable.
f = operating frequency of the video transmitter = 910 MHz.
lamda = c/f = wavelength of the radio signal.
lamda_cable = lamda * Vcable

Antennas used were manufactured by the Down East Microwave company at RR 1 Box 2310, Troy, ME 04987, Telephone number (207) 948-3741. Two antennas, part number 3318LYARM were used. Nominal wavelength is 33 cm.

Antenna specifications are:

18 element, rear-mount loop Yagi, 910- 930 MHz. Gain 16.5 dBi; 3-dB beamwidth (E plane), 28 degrees; F/B, 20 DB. Boom length, 6 feet; boom diameter, 1". Max. power 550 watts; Weight 3 lb. Price $79

Reference:

1. ARRL handbook, page 33ff, Chapter 3.

APPENDIX 2

POSITIONING AND SPACE ALLOCATION - ELECTRONIC EQUIPMENT

1. Camera Control Body - Located in the front part of the bottom center compartment of the Hazzy vehicle. Dimensions are: 7.125 in. long x 2.51 in. wide x 2.44 in. high or 181 mm. x 64 mm. x 62 mm. Weight - 530 gm. or 20 oz.

2. Camera Head - Mounted on the pan and tilt mechanism, which is on the top of the front portion of the vehicle. Dimensions are: 64 mm. wide x 68 mm. high x 43 mm. long or 2.52 inches x 2.68 inches x 59 inches. Weight - 370 gm. or 13 oz. It is connected to the Camera Control Body by a 2 meter long electrical cable. The connecting cable comes from the bottom, center, rear of the head and is recessed, under the head, so it does not interfere with normal mounting of the head. The cable is coiled in the bottom center of the Hazzy vehicle body, just in front of the rear wheel wells.

3. Camera Lens- Rainbow H6X8M 4-8 mm. Zoom. The Rainbow lens is mounted on the camera head, on the pan and tilt mechanism. Dimensions: Size 70 mm x 60 mm x 96.6 mm or 2.75 inches x 2.36 inches x 3.80 inches. Weight approx. 500 grams. or 17.5 ounces.

4. Video Transmitter - Mounted in the bottom center of the Hazzy vehicle, on the level of the top of the wheel wells and above the Camera Control Body. For wiring and space convenience, it is mounted upside down, with the antenna connection downward, to connect with the video antenna cable.

5. Electronics Assembly Boards. There are two printed circuit boards mounted together. No. 1 - Four-layer fiberglass board with etched circuits, in which are mounted, the electronic components (about 800 items). Circuits, on this board, control the eight drive motors and their associated electronics, for control and connection to the microprocessor board, No. 2.

Dimensions of Board No. 1 are: 13.50 inches long x 12.25 inches wide x 3.63 inches high, including a 44 pin PLCC connector socket.

Dimensions of Board No.2 are: 13.50 inches long x approximately ** 6 inches wide x 0.761 high, including PLCC connector socket.

Total electronic boards assembly is 1.300 inches high x 13.50 inches long. Circuit boards are connected together by 96 pin connecters mounted on both boards at the rear of the vehicle.

Circuit boards are mounted at the top of the Hazzy vehicle, just below the rear lid assembly. They extend down 1.30 inches from their mount and come down to within about 1.6 inches of the wheel wells. They are mounted in the rear section of the vehicle, and do not interfere with the camera pan and tilt mechanism and the pickup tubes mechanisms, mounted in the forward section of the vehicle. The rear section starts above the rear-end of the forward wheel wells and extends to the rear-end of the vehicle. The forward section starts above the rear-end of the forward wheel wells, and extends forward to the nose of the vehicle.

6. There are two 12 volt batteries in the Hazzy vehicle, type Powersonic PS-1230. Each battery is 5.23 inches long x 2.60 inches high (plus connection tabs) x 2.64 inches wide. Weight of the batteries is 2.6 pounds each. They are located nearly at the longitudinal center of the vehicle and on each side of the vehicle compartment at the bottom.

7. Power Converters - Two different power converters are used in the Hazzy vehicle, to supply direct current power, at different voltages, to the electronics in the vehicle. Both of these units are supplied with 24 volts D.C. from the vehicle battery and convert this voltage to +12 volts, -12 volts and +5 volts. One unit, the 2W24SCR15T, is 3 inches high x 2.5 inches wide x 0.75 inches thick, and supplies +5 volts and +/-12 volts to the system. The other unit, the 3W12SCR5S12-AM, is 2 inches x 2 inches x 0.5 inches thick, and supplies +12 volts to the system. Each unit has pins approximately .25 inches long, extending down from the unit, so the actual units are about 0.25 inches thicker than the thickness measure suggests.

1. Camera Control body - 530 gms. or 18.7 oz. = 1.16 lbs
2. Camera Head - 370 gm. or 13 oz. = 0.81 lbs.
3. Camera Lens - 500 grams. or 17.6 ounces. = 1.1 lbs.
4. Video Transmitter - 17 oz. = 1.06 lbs.
5. Circuit Board Assembly - Estimated at 5 lbs. now
6. Batteries - 6 pounds each. They are located nearly at the longitudinal center of the vehicle and on each side of the vehicle compartment at the bottom.

This location provides an optimum center of gravity for the vehicle and minimizes the length of wires carrying relatively high currents. Shorter wires have less energy loss and cause less electrical noise.

Field Service

I. No Picture

A. Tune the UHF receiver for a picture

B. If no picture comes in, tune for a uniform snowy screen. Adjust Iris control for a picture.

C. If Iris control has no effect, operate it in both directions while standing near the robot. You should hear a faint whining/grinding sound as a small motor in the lens varies the Iris opening. If this is not observed, change the circuit boards using the procedures in Part V. If this does not help, return the unit to CSU-Chico for service.

D. If you can hear the Iris motor and still get no picture, set the Iris control to the maximum Open position and continue to tune the UHF receiver SLOWLY while watching the screen. When the tuning setting is right, the screen will be very bright. The Iris control will have to be turned down to get a usable picture.

II. Snowy Picture and/or no Color (weak video signal)

A. Point the Yagi antenna at the vehicle

B. Check all connections between the antenna and TV/VCR combination (including AC power!)

C. Check all settings of the TV/VCR combination.

D. Check spacing of the Yagi elements on the mast

E. Make sure that the feed cables from the Yagi elements to the BNC "T" connector have equal lengths. If all of these things are in order, the most probable cause of the problem is a failed UHF transmitter in the robot. Return robot for service.

III. Malfunctioning vehicle motion controls, sample retrievers or camera pan and tilt

A. The first step is to ascertain whether the problem lies in the R/C circuitry or the motor-driver circuitry. To make this determination, remove the cover from the robot to expose the PC boards. On the left front of the larger board there are three small toggle switches with their positions labeled "A" and "B". You will find them in the AAA position, because this is used for normal robot functioning. Five of the other seven possible combinations define test modes for the various robot functions. To test one of the robot functions, the switches are set for the appropriate code and the subminiature pushbutton switch near the opposite corner of the large board is pressed to reset the robot into the appropriate test routine. Whichever function is selected will then cause oscillating mechanical motion of the corresponding item on the robot. The codes are;

AAA Normal functioning
ABA Test solid sample retriever
ABB Test liquid sample retriever
BAA Test camera tilt
BAB Test camera pan
BBA Test vehicle drive motors

For example, if the BAA code is set with the toggle switches and the reset switch is pressed, the camera should tilt up and down around its starting position continuously until the vehicle is turned off or another code is set with the toggle switches and reset is again pressed.

B. If the oscillatory test response is not obtained, the problem is in the motor drivers on the PC boards, and the spare board set should be installed, observing the procedures in Part V of this section. If the test mode shows satisfactory results, the problem is in the RC circuitry. The R/C circuitry is in three parts:

1. The circuitry in the robot that interfaces the R/C receiver outputs to the motor drivers.
2. The Ace R/C transmitters at the control van
3. The Ace R/C receivers inside the robot

If all the robot functions (or possibly all but one) are impaired, the fault is in the first part of the circuitry. The board set should be replaced using the procedures of Part V of this section.

C. If vehicle motion and sample retrievers are OK, but camera functions are not, snap the back off the camera R/C transmitter. In the upper left hand corner is a small PC board with the crystal in a socket. Put the crystal into one of the spare R/C transmitters, making sure that all of the slide controls are centered. Using the new transmitter with the old crystal, see if correct operation of camera pan and tilt controls are restored. If so, the old transmitter is defective. Replace the old crystal into it and return it to Ace R/C for service (address in the Appendix). If the crystal swap does not restore correct operation, either the crystal itself is defective or the Ace R/C receiver in the robot is defective. Replace the old crystal in it and return the transmitters and robot to CSU-Chico for service.

D. If camera functions are OK but vehicle motion and sample retrievers are not, repeat the procedures of the previous paragraph, but on the R/C transmitter for the vehicle.

IV. Jamming of the sample retrievers

If this occurs, the behavior will differ from a failure of the type addressed in Part III in that you will hear a high-pitched screeching sound as the motors strain against an object they can't move and the current limit circuitry holds them back. Center the sample retriever control on the R/C transmitter and turn off both the robot and the transmitter.

A. Solid retriever. Pull the cap off the top of the solid retriever mechanism, taking care not to crush the yellow heat-shrink tubing. Spray silicone lubricant into the inside of the mechanism and manually work it up and down several times, then test the mechanism again. If it works satisfactorily, carefully replace the cap. If it still does not work, return it to CSU-Chico for repairs.

B. Liquid retriever. Remove the two screws near the top of the sample retriever mechanism and pull; the top off. Position the robot so the lower end of the actuator points out over the edge of a table or bench. Grab the lower end and pull it out. Any dirt should be cleaned off and the gears should be sprayed with

silicone lubricant. Then it should be re-installed from below. Having the top off facilitates getting the gears properly lined up with the rack inside the tube. After the sample retriever is thus re-installed, move the robot back away from the edge of the table or bench and test the mechanism. If operation is satisfactory, put the top back on and fasten it with the two screws previously removed. If it still does not work, return it to CSU-Chico for repairs.

V. Replacement of the circuit boards on the robots.

A. Remove the board cover, by removing the 10 Philips screws (8-32 x 5/8") that hold down the rim. and carefully lifting up. DO NOT FORCE ANYTHING. If anything restrains the cover, it will be the coils at the base of the video antenna in back of the robot, or the LED connector at the front of the PC board set on the inside. It is permissible to gently bend the antenna back to allow the lid to come clear.

B. There are 13 connectors around the perimeter of the board that must be removed next. Again, gentleness is called for. Under no circumstances should these be removed by grasping the wires coming out of the connectors and pulling. A small screwdriver can be used to pry these connectors away from their board-mounted plugs. Once a given connector is loose on one side, the screwdriver may be used to loosen the other side. If necessary, the connector is then rocked gently back and forth while maintaining a pull on the connector by grasping the sides of it. The ten connectors along the sides of the board have retaining wires to hold them in such a position that they cannot get lost in the innards of the robot or get accidentally connected to the wrong place. Under no circumstances should these wire retainers be removed. If they break, they should be replaced immediately.

There are three other connectors as well. The LED connector is at the front of the board set. When it is removed, it should be taped somewhere so that it can be retrieved easily. The power connector connects at the right rear of the smaller board. Since the wires to this connector are fairly heavy, they have less tendency to get lost. They can be bent out of the way to allow exchange of the board sets. The final connector is the hardest to see, and is the most fragile. It connects the Zoom, Focus and Iris (ZFI) motors in the lens to the lower circuit board. This plugs in at the rear of the robot and is both hard to see and access because it is between the boards. If possible, this connector should be both removed and re-installed later without even touching the wires that terminate in the connector. It is particularly important that this cable be positioned for easy retrieval after the new board set is installed.

C. Ten black nylon screws around the perimeter of the lower board must be removed. In doing so, an H-shaped brace for the middle of the board set will be released and drop into the robot's central cavity. Make note of which screws retained this brace. There are four in all that do so. Insure that the ZFI cable remains UNDER this brace.

D. Remove the old board and immediately replace it with the new one TAKING CARE THAT THE NEW BOARD IS ORIENTED IDENTICALLY TO THE OLD ONE.

E. Reconnect the cables to the new board, paying particular attention to the ZFI cable. This is necessary not only because of its fragility, but because it is easy to get it improperly lined up with the board-mounted plug that mates with it. If the connector is offset by one space, no harm will be done, but ZFI functions will be non-operative.

F. Test the robot before fastening down the board. If operation is satisfactory, the nylon screws can be re-installed. None should be tightened down until all are started. When you get to the screws that mount the brace, it is necessary to reach your fingers through the same holes in the board-mounting brackets through which the connectors are fed to pull the brace up against the underside of the board-mounting bracket so that the screws can reach it. All other screws have a captive nut on the board-mounting brackets to fasten them, but the four holes that accommodate the screws which mount the brace do not. Instead, the brace has the captive nuts for these screws.

G. When all screws are started, tighten them down gently. Do not overtighten to the point where there is a risk of shearing them off in their nuts.

H. Re-install the cover, again taking care not to force anything. It must be oriented properly. The part with some grinding out shown is the front.

I. Re-install the cover screws. It is again advisable not to tighten any of them until all are started.

J. If switching the PC board set does not restore the unit to service, return it to CSU-Chico for service.

VI. Battery Replacement

On occasion it may be necessary to replace the batteries if there is no time to recharge them before the vehicle is needed again. Battery removal and replacement should be done in an area free from debris and waste with a table to support parts removed during the battery replacement operation. Batteries are removed by:

1. Removing 10 screws in the main cover of the vehicle.
2. Carefully removing the vehicle cover and placing it carefully aside.
3. Removing the connectors to the two layers of electronic boards made up as one assembly.
4. Removing the nylon screws which hold the electronic board assembly in place.
5. Removing the electronic board assembly and setting it aside carefully on a protective surface. Great care should be used to prevent dirt and other foreign substances from getting into the electronic assembly.
6. Sliding off the power connection clips on the batteries.
7. Carefully observing which wire goes to which polarity terminal of the battery. This is necessary because the Powersonic batteries (orange) have their terminals reversed relative to the Panasonic batteries (black).
8. Removing the batteries by partially unscrewing the screws which mount the battery retainers to the sides of the vehicle.

Batteries are replaced by:

1. Placing new batteries correctly in the battery holders.
2. Re-tightening the battery hold-down clips.
3. Replacing the power connection clips on the batteries. Match the positive battery contacts with the positive wire (red). Match the negative battery contacts with the negative wire (black).
4. Replacing the electronic board assembly on its support brackets and aligning it carefully.
5. Replacing the hold-down screws of the electronic board assembly Insert all screws and tighten partially before tightening any screw completely. Then tighten all screws completely. Be careful not to bend the electronic boards during this operation.
6. Replacing the cover and aligning it with its mounting holes. Check carefully to ensure that the gasket seal is in place and properly seated.
7. Replacing the 10 screws holding the cover.

VII Wheel Replacement

Wheels are mounted on the axle suspension system and may be removed and replaced by removing the boot assembly screws and the boot assembly.

VIII Motor Replacement

Drive motors are brushless Maxon motors, Type EC040-070-38EAA200A, and are driven separately by three phase power drivers. They are replaced by removing the mounting screws securing them to the suspension frame and replacing with new motors as needed.

VENDORS and SUPPLIERS
Phone numbers, addresses and specifications required.

PURCHASED ITEMS

PART NUMBER	ITEM DESCRIPTION	VENDOR IDENT.	ITEM USE
	Color Video Camera JVC TK 900U CCD ($970)	NV 1	Camera Assembly
	Rainbow Lens ($409)	NV 1	Camera Assembly H6X8M
	CRM 132AT Magnavox 13" TV/VCR ($469)	NV 1	Video Monitor, van
	Nautical Commander 5 channels ($214.95) 20G550810 FMCD	ACE	Remote Control Units
	ACE/DEANS Connectors 19K20F 3 pin Female 19K20M 3 pin Male ($1.00 each)	ACE	Remote Control Units
	Crystals 75 Mhz.band (included)	ACE	Remote Control Units
	Pirate TV RCVR/TR V9900 $49.90	DAK	Video transmitter and Receiver 910 MHz.
	Neoprene Sheet HRH 10 3/16 3 lbs Cell size 3/16 ($86 minimum)	E J	Material for Wheel Boots
	Plastic Syringes 69 7780 30cc. 10 per package $18.28/package	CBS	Disposable syringes for liquid pickup. Modified for use in Hazzy vehicle.

Maxon Motors
EC040.070 38EAA200A MAX Hazzy Drive Motors
$206.65 for all drives
2932.701 009.0 00 MAX Planetary Gearheads
$151.00
2932.702 0019.0 000 MAX Planetary Gearheads
$160.05
2932.703 0100.0 00 MAX Planetary Gearheads
$175.25

VENDOR LIST _

Vendor Ident	Vendor Name	Vendor Address and Telephone
ACE	Ace R/C	116 W. 19th Street, P.O. Box 511 Higginsville, MO 64037
CBS	Carolina Biological Supply Company	2700 York Road Burlington, NC 27215 (919) 584 0381
DAK	DAK Industries Inc.	8200 Remmet Ave. Canoga Park, CA 91304 4182 1 800 888 7808 Cust. Serv. 1 800 888 9818 Tech. Info.
E J	Erskine Johns	3621 Seaport Blvd., West Sacramento, CA 95691 Attn: Larry Ting (916) 371 2000
MAX	Maxon Precision Motors, Inc.	838 Mitten Road Burlingame, CA 94010
NV 1	Northern Video	4234 North Freeway Blvd. Suite 500 Sacramento, CA 95834 (916) 646 0033 FAX (916) 646 1221 Contact: Rick Takunaga

OPERATION MANUAL FOR AUTOMATED HAZARDOUS SAMPLE RETRIEVER (AHSR) SYSTEM

Section 1.0 INTRODUCTION

The purpose of this document is to provide connection and operation instructions for the AHSR system as a whole, and the AHSR vehicles in particular.

1.1 Major Purpose of the AHSR system. The purpose of the system is to provide a way in which samples of hazardous spills along the highways can be retrieved more quickly, inexpensively, and more safely than by sending humans into the spill area.

1.2 Related Documents. Owner's manual for the Magnavox TV/VCR

1.3 Proficiency/License Requirements. The subcontractor does not require special training of potential operators of the system. However, CALTRANS may wish to institute a required training program to insure proper handling of the equipment.

1.4 Special Data. None.

Section 2.0 GENERAL DEFINITION AND DESCRIPTION OF THE AHSR SYSTEM

The purpose of this section is to give an overview of the AHSR system.

2.1 General Description. The AHSR system is an ensemble of equipment whose purpose is not only to obtain samples of hazardous spills by remote control, but to provide support to the sample-retrieval vehicle and to produce hardcopy of the vehicle mission. A photograph of the vehicle is shown in Fig. 2.1

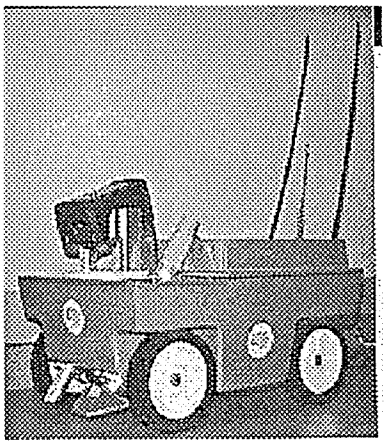

Fig. 2.1 A sample-retrieval vehicle (aka robot)

2.2 Major Parts. The major parts of the AHSR system are the R/C Controllers, the stacked Yagi antenna system, the antenna rotator system, the UHF receiver, the TV/VCR combination, and two AHSR vehicles.

Section 3.0 DETAILED DESCRIPTION OF MAJOR PARTS

3.1 R/C Controllers. These are radio-control transmitters that are used to send motion and camera-control commands to the AHSR vehicle. These transmitters are commercially purchased from ACE R/C. The model used is called the Nautical Commander, because it was designed for radio control of model boats. They operate in the FM R/C band in the vicinity of 75 MHz. Two Nautical Commanders are required to control all functions of each AHSR vehicle. One controls forward and backward motion, turning and actuating the solid and liquid sample-retriever mechanisms. The other controls functions of the on-board video camera. A pair of these controllers are shown in Fig. 3.1.

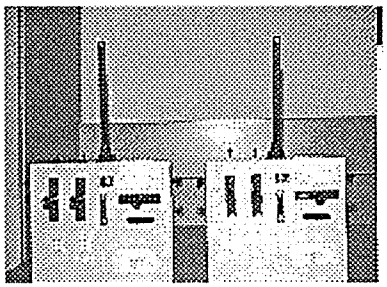

Fig.3.1 The Ace Nautical Commanders

3.2 The stacked Yagi antenna system. This is the antenna used to receive the video signal transmitted by the camera on the AHSR vehicle. The antenna is optimized for frequencies in the vicinity of 1 GigaHertz. Two identical antennas are stacked on the same mast to increase the signal strength received from the antenna system. These antennas were manufactured by Down East Microwave Company. This antenna is shown in Fig. 3.2.

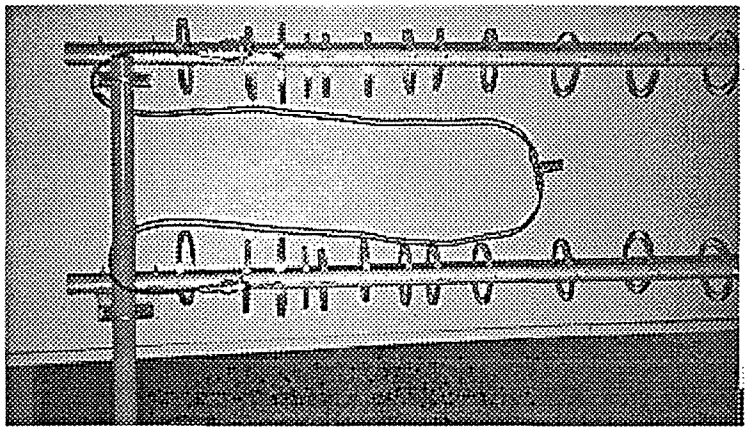

Fig.3.2 Stacked Yagi antenna

NOTE

In order to maintain the highest possible signal level from the antennas, the spacing between them on the mast should not be changed.

This antenna is to be mounted on a mast which will in turn be mounted on a control van that CALTRANS will provide.

3.3 The antenna rotator system. This system is composed of a rotator motor and a rotator controller. These two pieces were bought as a unit from Radio Shack. They serve to point the antenna at the AHSR vehicle.

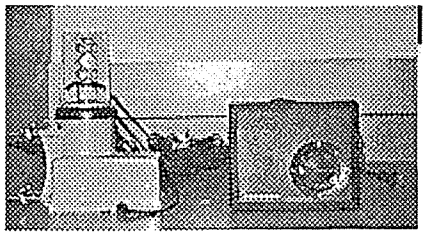

Fig. 3.3 Antenna Rotator System

Since the stacked Yagi antenna is quite direction sensitive, it must be kept pointing at the AHSR vehicle to assure the cleanest possible video signal.

3.4 UHF receiver. This is a receiver that receives the signal from the stacked Yagi antenna and translates it down to the frequency of TV channel 3 or 4 (in the range of 60-72 MHz). It is also a purchased unit manufactured by Universal Security Inc. This receiver is shown in Fig. 3.4

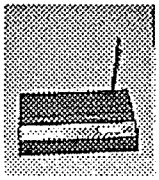

Fig. 3.4 UHF Receiver

3.5 The TV/VCR combination. This is an integrated unit that is capable of both recording and playing back a VHS videotape. It receives the signal out of the UHF receiver and can both display it on the TV screen and record in on the VCR. It is intended

to be installed in the control van. The TV/VCR combination is manufactured by Magnavox. The TV/VCR combination is shown in Fig. 3.5.

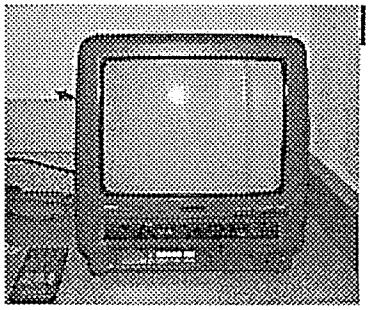

Fig. 3.5 TV/VCR Combination

3.6 The AHSR vehicles. These are robotic vehicles capable of being remotely operated by the R/C controllers. Each carries a video camera which can transmit back to the stacked Yagi antenna and provide a closeup view of the spill site and the sample retrieval operation. Each vehicle also carries a pair of sample retrievers. One is for liquid samples, and the other is for solid ones. These are actuated by signals from the R/C controllers once the vehicle is properly positioned.

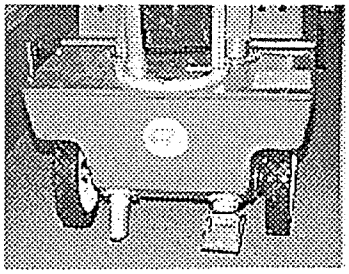

Fig. 3.6 Front view of robot showing liquid retriever on left and solid retriever on right

In general, a sample-retrieval mission will involve both vehicles. One will serve as the "eyes", and the other will obtain the samples. This arrangement was necessitated by the placement of the camera on the top of the vehicle (which was done to minimize the possibilities of the camera becoming obscured by any organic spills that might be able to attack its protective plastic case). A dual vehicle approach not only allows the operator to "see" in the blind spot of the sample retrieval vehicle, but it provides extra protection against aborted missions if some function of one vehicle malfunctions.

Section 4.0 THEORY OF OPERATION

The purpose of this section is to set forth some of the principles of operation of the AHSR system.

4.1 Skid Steering. This is a form of steering in which a turn is executed by allowing the wheels on one side of the vehicle to turn more rapidly than those on the other side. For the sharpest possible turn, the wheels on the inside of the turn do not rotate at all. Since the R/C controllers allow independent motion of the right and left sets of wheels, skid steering is easily achieved.

4.2 Radio transmission and reception. It is important to remember that the AHSR vehicle contains two separate radio systems.

The low frequency system (about 75 MHz) has only receivers (two) in the vehicle. These receive the transmissions from the R/C controllers. There are two symmetrical antennas (about one yard long) on the vehicle to feed these two receivers.

The high frequency system (about .94 GHz) has only a transmitter on board the vehicle. This transmitter sends out the signal from the video camera via the cellular phone antenna in the center rear of the vehicle. This signal goes back to the stacked Yagi antenna at the control van.

Section 5.0 OPERATING PROCEDURES

The purpose of this section is to provide instruction on the setup and operation of the system.

5.1 Setup

5.1.1. The antenna mast and rotator motor must first be mounted on the control van in a manner to be determined by CALTRANS personnel.

5.1.2. The antenna rotator control box should be mounted inside the van - preferably near the rear of the van - in close enough proximity to the rotator motor that the flat three-wire cable can reach between them.

5.1.3. Connect the flat three-wire cable between the rotator motor and the rotator control box. Of the three wires in the cable, one of them is tinned, and the other two are plain copper. Position the rotator
controller upside down in front of you with the three screw terminals closest to you. Fasten the tinned wire to the rightmost screw terminal on the rotator controller using a medium flat-blade screwdriver. This terminal is labeled "1". Connect the center wire of the cable to terminal "2", and the remaining wire to terminal "3".

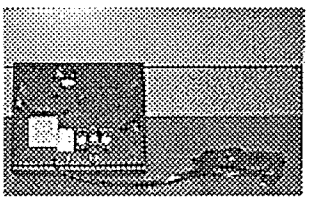

Fig. 5.1 Rear view of antenna rotator control unit showing three screw terminals

5.1.4. Each array of the stacked Yagi antenna has a female BNC connector mounted on it near the end closest to the mast. This connector is the takeoff point for the signal from

that array. Connect equal lengths of coaxial cable (with male BNC connectors on both ends) from each array to the ends of a BNC "T" connector as shown in Fig. 3.2. A closeup of the BNC "T" connector is shown in Fig. 5.2.

Fig. 5.2 BNC "T" connector with two female inputs and one male output

NOTE

IT IS IMPORTANT THAT THE TWO PIECES OF CABLE HAVE THE SAME LENGTH. Failure to observe this precaution may result in significant reduction of the video signal sent to the UHF receiver.

The male connection at the output of the "T" goes to another length of coaxial cable that takes the summed signals from the two arrays of the stacked Yagi antenna and carries this sum to the UHF receiver. This cable has a male BNC connector at the receiver end, and a female BNC connector at the other end to mate with the center of the "T" and is shown in Fig. 5.3.

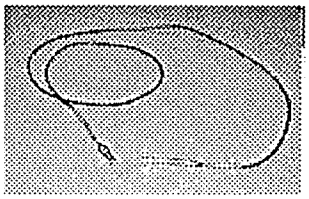

Fig.5.3 RF cable which carries antenna signal to UHF receiver in the van

Route the coaxial cable from the "T" connector to where the TV/VCR combination is to be situated inside the van. The nearer this is to the back of the van, the better for operating flexibility.

5.1.5. The ideal arrangement is to have the TV/VCR combination and UHF receiver mounted on a swing-out arm. If this is not possible, both units may set on whatever counter space is available. Connect both units to 110 VAC power. The power for the UHF receiver is derived from a small wall transformer. The output connector from this transformer plugs into the rear

of the UHF receiver as shown. The TV/VCR plugs directly into the AC power line.

5.1.6. Connect the coaxial cable from the stacked Yagi antenna to the UHF receiver by plugging it into the jack on the right side of the UHF receiver. The location of this jack is shown in Fig. 5.4.

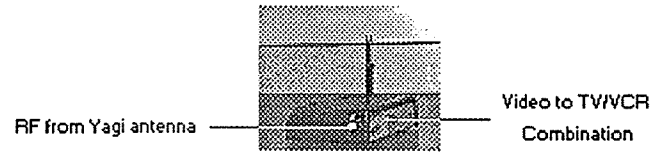

Fig. 5.4 RF and Video connections to UHF receiver

5.1.7 Connect the output of the UHF receiver to the input of the TV/VCR combination. As shown in Fig. 5.4, the output of the UHF receiver is taken from a female "F" connector at the center of its back panel. Fig. 5.5 shows a closeup view of the "F" connectors.

Fig. 5.5 "F" connectors: Male on the left and Female on the right

The cable which connects to the "F" connector on the back of the UHF receiver has male "F" connectors at both ends. The other end connects to the female "F" connector on the back of the TV/VCR combination. This cable is shown in Fig. 5.6.

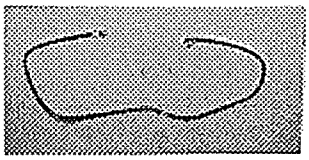

Fig. 5.6 Video cable

This cable connects to the TV/VCR combination at the location shown in Fig. 5.7.

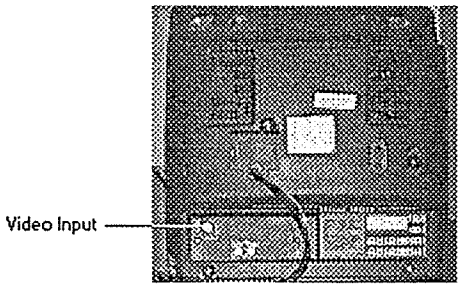

Fig. 5.7 Rear of the TV/VCR combination

5.1.8. Turn on the power to both the UHF receiver and the TV/VCR combination. The UHF receiver is turned on by pressing the POWER SWITCH in the right front corner of the top of the unit. The location of this switch may be seen in Fig. 5.8.

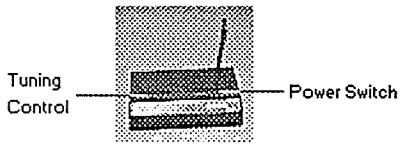

Fig. 5.8 UHF Receiver

The TV/VCR combination is turned on by pressing the "POWER" switch just below the lower right-hand corner of the screen. This location is shown in Fig. 5.9.

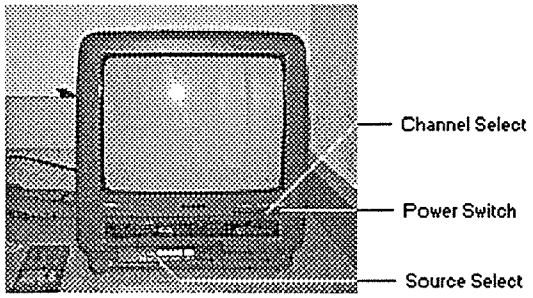

Fig. 5.9 Power Switch Location on TV/VCR Combination

After a brief warmup, the screen should show a solid bright-blue color everywhere except in the upper right hand corner, where the channel number will be shown. This should read "03". If it does not, use the Channel Up/Down buttons just to the left of the POWER switch on the front of the TV/VCR combination or on the remote control unit to change the channel to "03".

5.1.9. Locate the switch on the front of the TV/VCR combination labeled "SOURCE". Press this until the word "TUNER" appears on the screen.

5.1.10. With both AHSR vehicles setting on the ground, turn on the power switch at the rear of whichever of the AHSR vehicles will provide the video transmission. Adjust the TUNE knob on the top of the UHF receiver until an image appears on the screen.

5.1.11. Set the knobs on both sides of both of the R/C controllers for the video vehicle to the center of their range.

5.1.12. Turn on both of the R/C controllers for that vehicle simultaneously.

CAUTION

Failure to turn on both controllers within a second or so of each other may cause the AHSR vehicle to move unexpectedly, and damage either itself or some other nearby object.

NOTE

If no picture was obtained in part 5.1.10, the most probable cause is that the Iris of the camera is closed. Use the right-hand adjustment on the R/C controller for the camera to open the Iris, and again adjust TUNE on the UHF receiver to get the image from the camera on the TV/VCR combination.

Once the image is obtained, some out-of-focus lights will be seen in the picture. These can also be seen looking at the front of the camera. The significance of each of these lights will be discussed later in the text. For now, note only that a flashing green light means that the software is executing, and therefore operation is normal.

5.1.13. Turn on the AHSR vehicle that will be used to retrieve the sample.

5.1.14. Turn on both controllers for this AHSR vehicle.

CAUTION

Failure to turn on both controllers within a second or so of each other may cause the AHSR vehicle to move unexpectedly, and damage either itself or some other nearby object.

5.2 Operation.

Operation of the system should be performed by two people standing outside the control van with the R/C controllers. Each person should operate the controls for one vehicle. In general, the person controlling the sample vehicle will not need to operate their camera controls at all. The person operating the video vehicle will have to operate their vehicle controls to get into position, and then their camera controls to get a good picture of the site to be sampled.

5.2.1. The video vehicle should be moved into the site of the spill with its camera pointing straight forward and down to the ground as much as possible without obstructing the view with the front of the vehicle.

5.2.2. The operator should be looking for a container that the spilled material may have come from. If such a container is found, the camera controls should be adjusted to give the best image possible. If the image appears either dark or washed out, adjust Iris first. The Zoom and Focus controls are quite slow, and may have to be activated for several seconds before significant change in the image can be seen.

5.2.3. After the Iris setting is satisfactory, adjust the Focus. This is the control on the left side of the camera R/C controller. Then adjust Zoom to bring in the image as much as possible.

5.2.4. There is a certain amount of interaction between the Zoom, Focus and Iris controls. In particular, after Focus and Zoom are adjusted, it is advisable to go back and adjust the Iris once more. The Iris adjustment strongly influences the signal to noise ratio of the picture. The greater the distance of the video vehicle from the control van, the more critical the Iris adjustment is. When all controls are properly adjusted, it is possible to read newsprint at a range of 300 feet.

5.2.5. If a container cannot be found, but spilled material is seen, a sample should be collected. Position the video vehicle on the far side of the sample pickup site, and facing the control van. It should preferably be about 6 feet beyond the site. Point its camera straight at the site.

5.2.6. The sample vehicle should approach the sample site along a line perpendicular to the axis of the video vehicle. This will give the camera on the video vehicle the best possible view of the site. The video vehicle is oriented facing the control van so that, for example, a rightward movement of the camera's pan joystick will cause the camera to pan to the operator's left, but this will make the image appear to move to the right.

5.2.7. Bring the front of the sample vehicle right up to the selected sample site and stop.

5.2.8. To retrieve a sample, select the proper sample retriever control on one side or the other of the Ace R/C controller, and slide that control toward the bottom and front of the Ace R/C controller. After one to two seconds, return the control to its center position. For a solid sample, the scoop will open as the actuator is lowered. It is then necessary to move the vehicle forward slowly to push some of the spilled material into the scoop. Such motion is neither necessary nor desirable in collecting a liquid sample.

5.2.9. After the sample is retrieved, slide the control on the side of the R/C controller for the sample vehicle toward the top and rear of the R/C controller to withdraw the actuator back into the body of the vehicle. After a delay of one to two seconds, return the slide control to its center position.

5.2.10. The yellow light will come on in the camera housing and will show on the TV/VCR combination when either sample retriever is activated.
5.2.11. Bring both vehicles back to the control van. Using protective gloves, turn off the power switches on both vehicles.
5.2.12. Before removing samples from the vehicle, standard operating procedures must be observed as to the protective clothing to be worn. To remove a solid sample, pull the pin that retains the scoop on the
bottom of the controller. This allows the removal of the scoop in its entirety. To remove a liquid sample, put a container underneath the opening, and press the plunger sticking up out of the top of the liquid sample retriever.
5.2.13. Test the sample and clean the vehicles. They are capable of being hosed down safely with water. The nature of the sample will suggest the proper cleaning method for the solid scoop if one was used. If a liquid sample was not hazardous, the syringe in the sample retriever can be removed, cleaned, and replaced. If the sample was hazardous, discard the syringe and replace it.

5.3 Battery charging.

5.3.1. The AHSR vehicles are each powered by two 12 volt dc sealed lead-acid batteries connected in series. As the batteries discharge and their voltage drops, three things happen. The first is that a red lamp lights in the camera housing and on the screen. If this is observed, the vehicle should be returned immediately. The second is that a short time after the appearance of the red light, another green light may show briefly. This indicates that the computer has been reset. This will always happen when the power is first turned on, but in this case, it means that the power supply voltage has dropped too low for the computer to function properly, so it resets itself and tries again. The third thing that happens is that a power-cut-off circuit in the vehicle is activated. This slows current drain from the battery to a trickle, and prevents destruction of the battery from its being deeply discharged.

5.3.2. To charge the battery, make sure that the AHSR vehicle's power switch is turned off on the back panel. Plug the battery charger cable into the receptacle on the back of the AHSR vehicle. The power switch and charger jack are shown in Fig. 5.10.

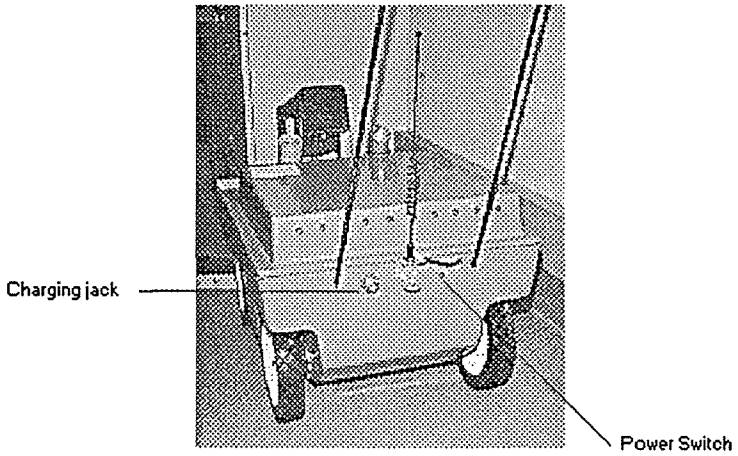

Fig. 5.10 Rear view of robot

Plug in the battery charger and turn it on with the toggle switch on its rear panel. The left hand light on the front panel of the charger will light. It is labeled "POWER". After about eight hours, the "POWER" light will go off, and the right hand one (marked "OVERCHARGE") will come on. This allows the charging current to taper down to a trickle and holds the battery in a fully charged state indefinitely. Charger is shown in Fig. 5.11.

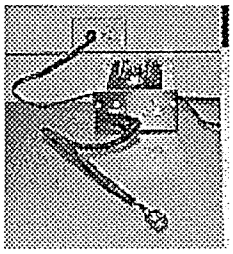

Fig. 5.11 Robot Battery Charger

5.3.3. The R/C controllers are each powered by a pack of eight rechargeable nickel-cadmium batteries. These controllers have a front-panel meter to indicate the charge state of their batteries. As long as the meters indicate in the green, or on the line between green and red, the batteries are OK. When the meter gets down into the red, operation is impaired. Once these units get too low, they should be left on until the batteries completely discharge, and then recharged.

CAUTION

Failure to completely discharge the Nickel-Cadmium cells before recharging will cause permanent loss of capacity of the batteries.

The chargers look like small wall transformers. They have two charging cables coming out of them. The one marked TX+ is for the R/C controllers, and should be plugged into the small jack on the bottom edge of the R/C controllers. There are red lights on the chargers that will come on while the batteries are being charged. If the R/C controllers are turned on while being charged, the red lights will go off, indicating that charging is no longer taking place, since the normal current drain of the R/C controllers is greater than the current capability of the charger. Turn the units off to complete the charge cycle. These chargers are shown in Fig. 5.12.

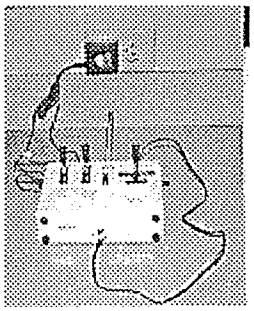

Fig. 5.12 Ace R/C Charger and Controller