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Technical Report

No. 13470

SAFETY ASSESSMENT

OF

TACOM'S RIDE MOTION SIMULATOR

JANUARY 1990

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NOTICES

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp. Date Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS None
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for Public Release: Distribution is Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) 13470	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Tank-Autmv Command RDE Center 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Warren, MI 48397-5000	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
SAFETY ASSESSMENT OF TACOM'S RIDE MOTION SIMULATOR

12. PERSONAL AUTHOR(S)
Alexander A. Reid

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 6/89 TO 10/89	90 Jan 24	53

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Ride Motion Simulator; CAMAC (Computer Automated Measurement and Control) System;

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This is a Safety Assessment of TACOM'S Ride Motion Simulator. The report details the system description and hazard controls in an effort to satisfy requirements for a Safety Release from the U.S. Army Test-Evaluation Command.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Alexander A. Reid	22b. TELEPHONE (Include Area Code) (313) 574-6676 22c. OFFICE SYMBOL AMSTA-RYA

DD FORM 1473, 84 MAR
83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

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1.0 INTRODUCTION

This report provides a general description of the Ride Motion Simulator (RMS) located at the United States Army Tank-Automotive Command (TACOM) in Warren, Michigan. It also provides the U.S. Army Test-Evaluation Command with the minimum protective measures, safety features of the Ride Motion Simulator, and the specific safety procedural controls and precautions to be followed during use of the system.

The Ride Motion Simulator was designed to include provisions for safeguarding personnel. Safety devices have been located on the equipment where necessary and are described in the user's manual.

The safety features included in the Ride Motion Simulator design are identified. These features include automatic pneumatic travel limiters; electronic travel limiters; occupant controlled hazard controls; operator controlled hazard controls; and detailed operating and safety instructions found in the user's manual.

2.0 OBJECTIVE

The primary goal is to obtain a Safety Release from the U.S. ARMY Test and Evaluation Command. This report is issued in conjunction with TACOM Technical Report No. 13469, "SYSTEM HAZARD ANALYSIS OF TACOM's RIDE MOTION SIMULATOR," and is an attempt to satisfy MIL-STD-882B.

3.0 CONCLUSION

All known safety hazards have been evaluated throughout the analysis of the Ride Motion Simulator. The system is considered safe to operate as long as the procedures stated in TACOM Technical Report No. 13464, "USER's MANUAL FOR THE RIDE MOTION SIMULATOR" are followed. The operating procedures are summed up in paragraph 5.4.

The safety devices and procedures for the Ride Motion Simulator will reduce the probability of injury to occupant or damage to equipment to the levels dictated in MIL-STD-882B.

4.0 RECOMMENDATIONS

Upon issuance of a safety release for the Ride Motion Simulator, it is suggested that the Safety Office at TACOM be given power to approve various test setups and issue safety releases for them.

5.0 DISCUSSION

5.1 Purpose and Intended Use

The Ride Motion Simulator is designed to provide a controlled environment simulation of the ride a person in a wheeled or tracked vehicle would experience traveling over a specific terrain.

The Ride Motion Simulator is designed to provide laboratory testing of new equipment or designs along with human interaction. Only military personnel will be test subjects in the simulator and will experience rides similar in severity to their normal duties.

5.2 <u>Background Information</u>

The idea of the Ride Motion Simulator took shape in the 1950's. A contract was let with Lehigh Engineering of New Jersey for development and construction. It was originally called the "Fire Control Simulator." The contract with Lehigh was terminated for lack of progress with the construction and testing performed in Building 40. It was then installed in Building 200A's computer room in a pit in the Northeast corner. The frame was made of welded steel tubing and the control circuits were vacuum tube circuits which required extended warm-up and balancing to achieve the required stability. It was used in this configuration for three to four years and then redesigned. In addition to developing the "absorbed power" concept as a measure of the severity of whole-human body vibration, simulation studies of visual acuity and many vehicle simulations were done. These included: Mauler Missile; Lunar Vehicle; M551 Recoil; Goer Seat Stability; SUSV; MBT-70; M113; M35A2; M39A1; XM104; and M60 fire control.

In 1972, when Building 215 was opened, the Ride Motion Simulator was moved to its present location.

The RMS has been used with human test subjects from the 1960's until 1982, without a single reported injury. Subject testing was halted in 1982 because of the Army's requirement of safety certification. At the present time, TACOM is in the process of satisfying AR 70-25, "Use of Volunteers as Subjects of Research." Upon completion of a safety release and AR 70-25 requirements, plans for the RMS include mounting various test systems onto the simulator (along with appropriate updates to the Safety Assessment Report) such as a flat-panel display and measuring soldiers response to various stimuli. When equipment is mounted onto the RMS, an update to this report will be provided detailing the safety of said equipment.

5.3 <u>System Description</u>

5.3.1 Structure. The Ride Motion Simulator is fundamentally a platform mounted in a framework so that four motions (four degrees of freedom) can be imparted to it simultaneously--linear motion along the vertical axis; rotational motion about the vertical axis (yaw); rotational motion about the transverse axis (pitch); and rotational motion about the longitudinal axis(roll). The motions are generally oscillatory in nature and comparable to the motions that might be experienced in the crew compartment of a wheeled or tracked vehicle under mild to severe operating conditions. The platform is large enough to allow cross-country simulation of a crew station or to simply evaluate a seating configuration. Investigations can be conducted on human tolerance to vibrations, in general, or on task performance in a vibrational environment.

In the current configuration, the input signals are generated from computer data files created on a CRAY-2 supercomputer using computer simulation of an army vehicle operating over specific bump courses (APG, Ft. Knox, etc.). These files are then modified and used to drive the Ride Motion Simulator using a micro-VAX II computer. With this configuration, a wide range of vehicles, bump courses, and seatings (gunners, commanders, drivers, etc.) can easily be simulated and recreated on the Ride Motion Simulator.

5.3.2 Subsystem and Assemblies. The RMS is described under the following equipment categories: (Figures 5-1 through 5-9 are photographs of the RMS and associated equipment).

° Computer Automated Measurement and Control (CAMAC) Computer System.

° Electronic conditioning modules.

° Pneumatic control panel.

° Motion system.

° Hydraulic control panel.

5.3.2.1 CAMAC Computer System. The CAMAC system acts as an interface between a micro-VAX II computer and the RMS. The micro-VAX II, which powers and controls the CAMAC, has 5M random access memory, a 71M hard-disk drive, and a 95M tape drive.

Data files, which are stored in the micro-VAX II, determine the terrain profile, vehicle, and speed the RMS will simulate. These data files are output to the RMS through the CAMAC via a Digital to Analog Converter (DAC). This DAC converts digital values in a computer to voltages which are sent to the electronic conditioning modules.

The CAMAC also has the ability to sample data (analog to digital converter), sense when a switch is thrown, and determine the presence of an applied voltage (this is used as part of the safety system, described later).

5.3.2.2 Electronic Conditioning Modules. These modules receive the voltages from the CAMAC system, and determine if the voltages exceed a preset limit (which corresponds to a position of the RMS), condition the voltages, and then send them on to the electrohydraulic servo-valves which, in turn, power the RMS.

If an input voltage exceeds a preset limit in any of the four degrees of travel, that degree of travel will shut down and the RMS will slowly ramp down to its neutral position. If any of the roll, pitch, or yaw limits are violated, all three degrees of travel will shut down.

There are essentially only two 10-turn potentiometers (pots.) which will need to be adjusted to operate the RMS. The SPAN pot. attenuates the input signal anywhere from 0% to 100% of its value. The STATIC pot. controls the static position of the RMS. The vertical STATIC pot. ranges in value from 0.0 to 10.0, with 4.57 being the center position. The roll, pitch, and yaw static pots. range in value from -10.0 to +10.0, with 0.0 being the neutral position. If, for some reason, the RMS shuts down to its neutral position, the vertical STATIC pot. would be turned to 1.13 (lowering the RMS to the bottom), so that the occupant could dismount. If the RMS is frozen, the "Bleed Valve" switch can be depressed, thus bleeding hydraulic fluid slowly out of the system and lowering the RMS at the same time.

To initiate a simulation, the "CYCLE-START" button must be depressed. This will increase the magnitude of the voltage to the servo-valves from 0% of the input signal to 100% of the input signal over a time span of approximately 5 seconds.

To discontinue a simulation, the "CYCLE-STOP" button must be depressed. This acts the opposite of the "CYCLE-START" button and decreases the magnitude of the voltage to the servo-valves from 100% of the input signal to 0% over 5 seconds.

5.3.2.3 Pneumatic control panel. The pneumatic control panel (Figures 5-4 and 5-6) provides the RMS operator access to the status and control of the pneumatic safety system.

° Master Stop - Depression of this push button will instantly stop the RMS from travel in all four degrees of freedom. This emergency stop is used only for dire emergencies because of the short shutdown time (approximately 1 second). Other shutdowns are provided which will ramp down the RMS's motion, thus providing a smoother shutdown.

° Stop Roll, Pitch, Yaw - Depression of this push button will instantly stop the RMS from travel in the roll, pitch, and yaw degrees of motion.

° Stop Yaw - Toggling this switch to the "UP/DOWN" position

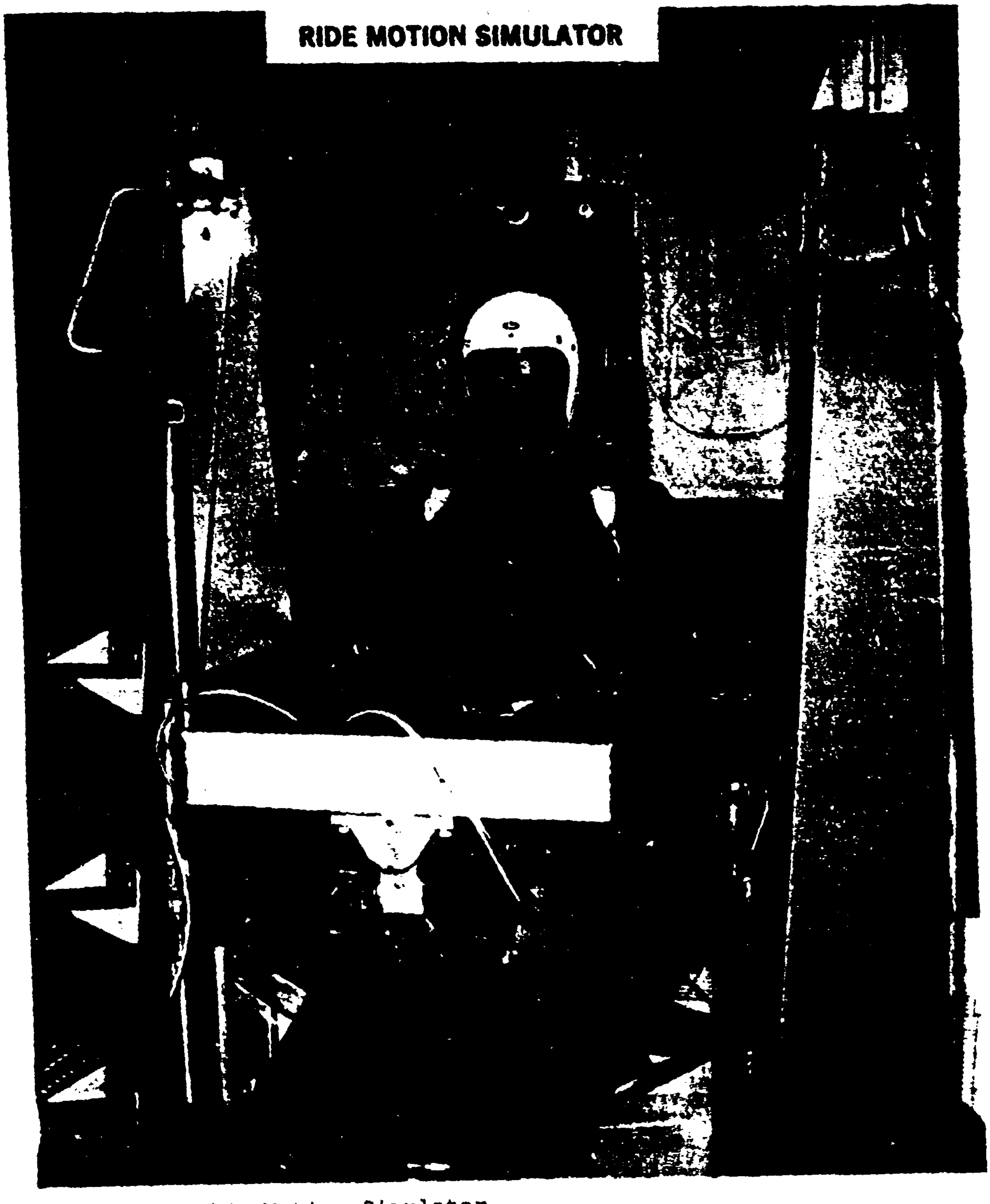

Figure 5-1. Ride Motion Simulator

Figure 5-2. CAMAC System and Control Console

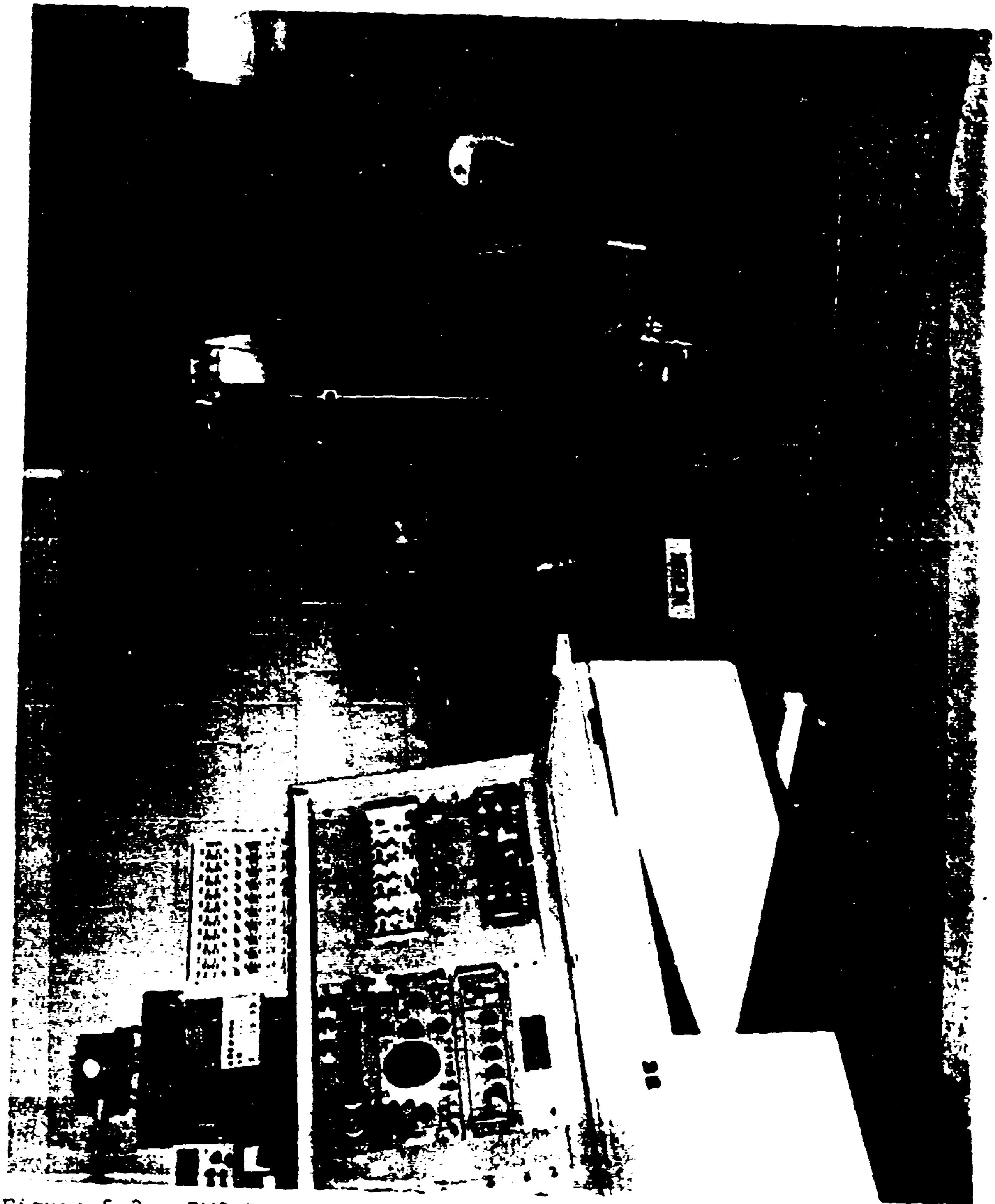

Figure 5-3. RMS Bay Room

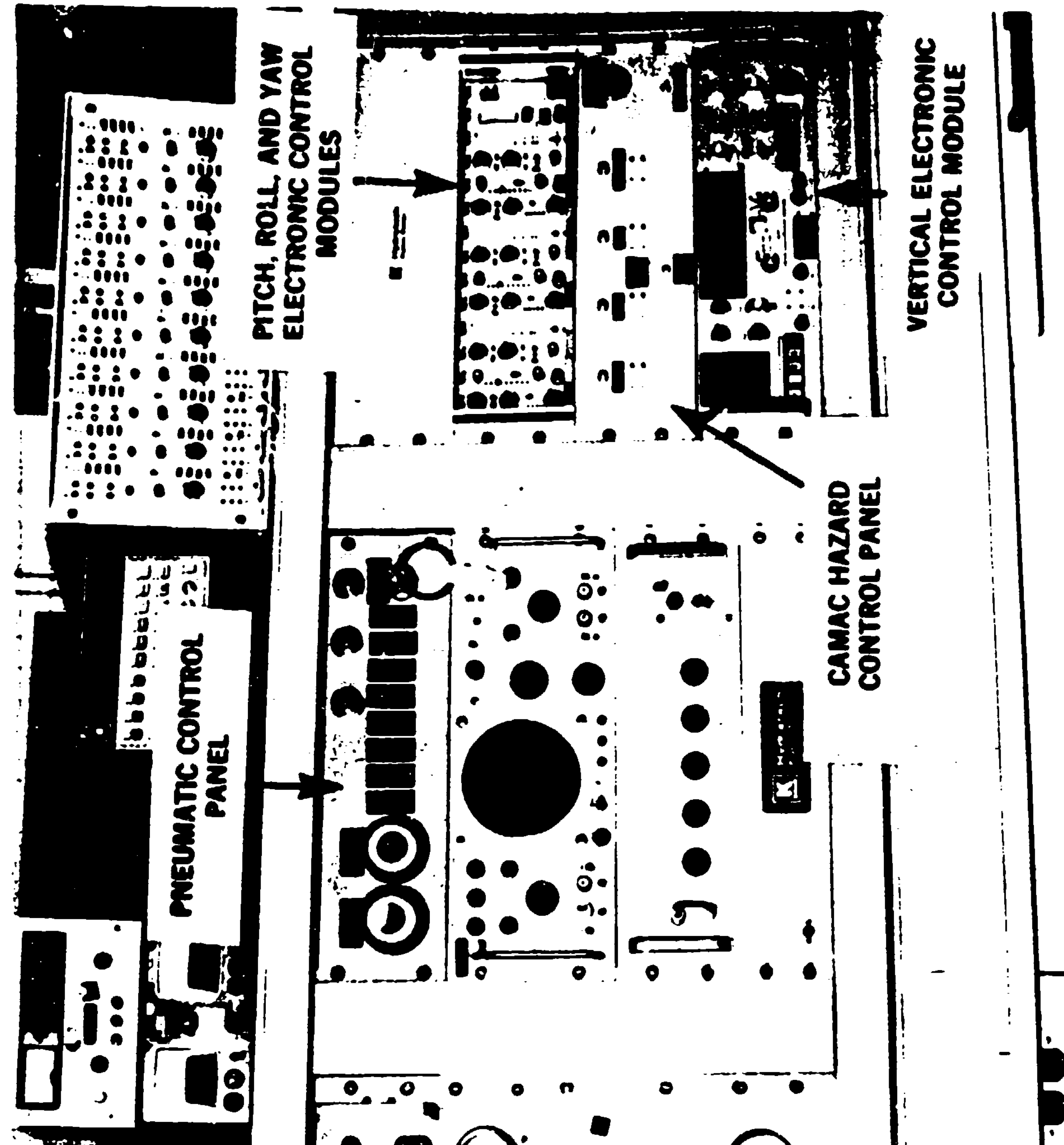

Figure 5-4. Control Console

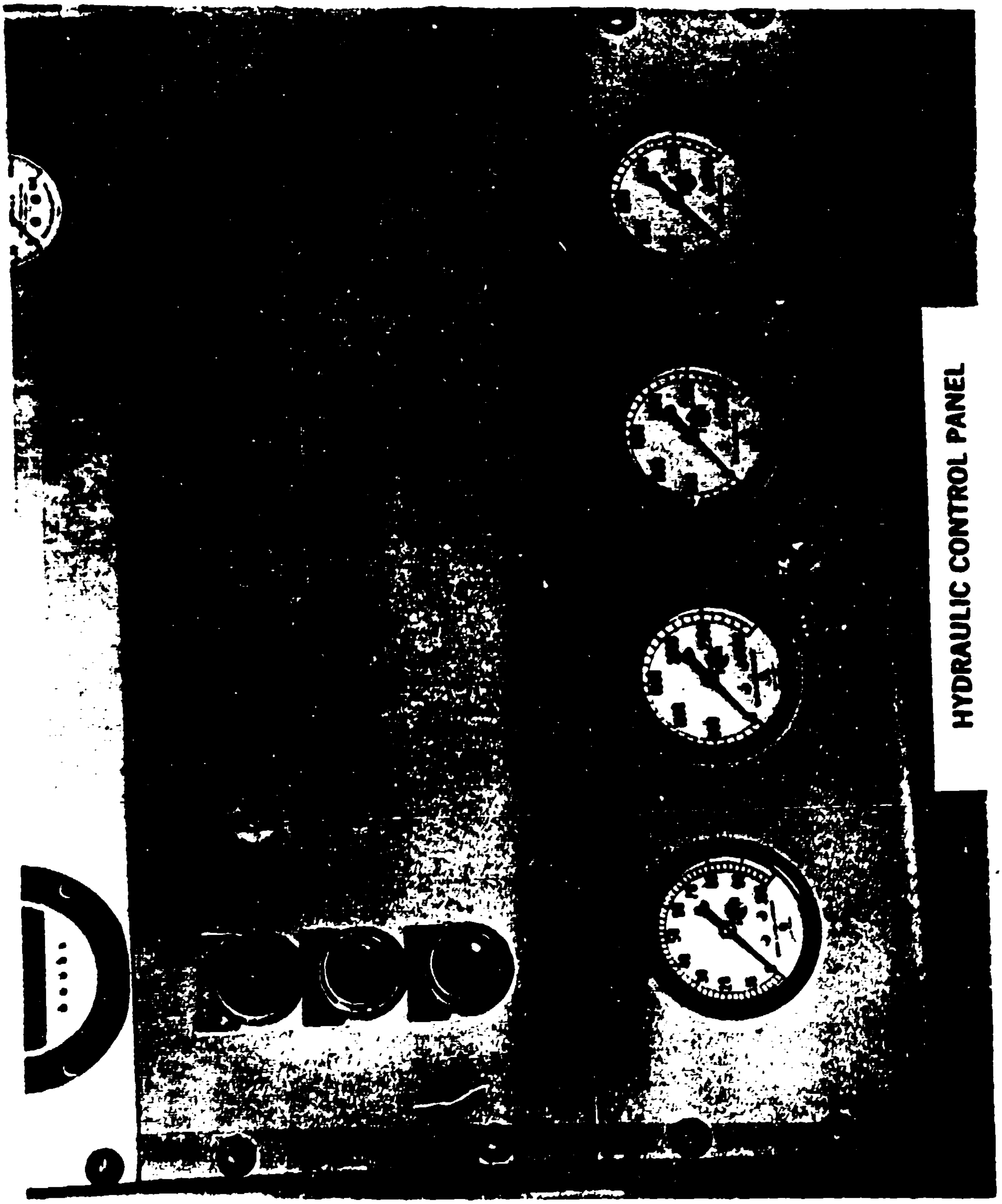

Figure 5-5. Hydraulic Control Panel

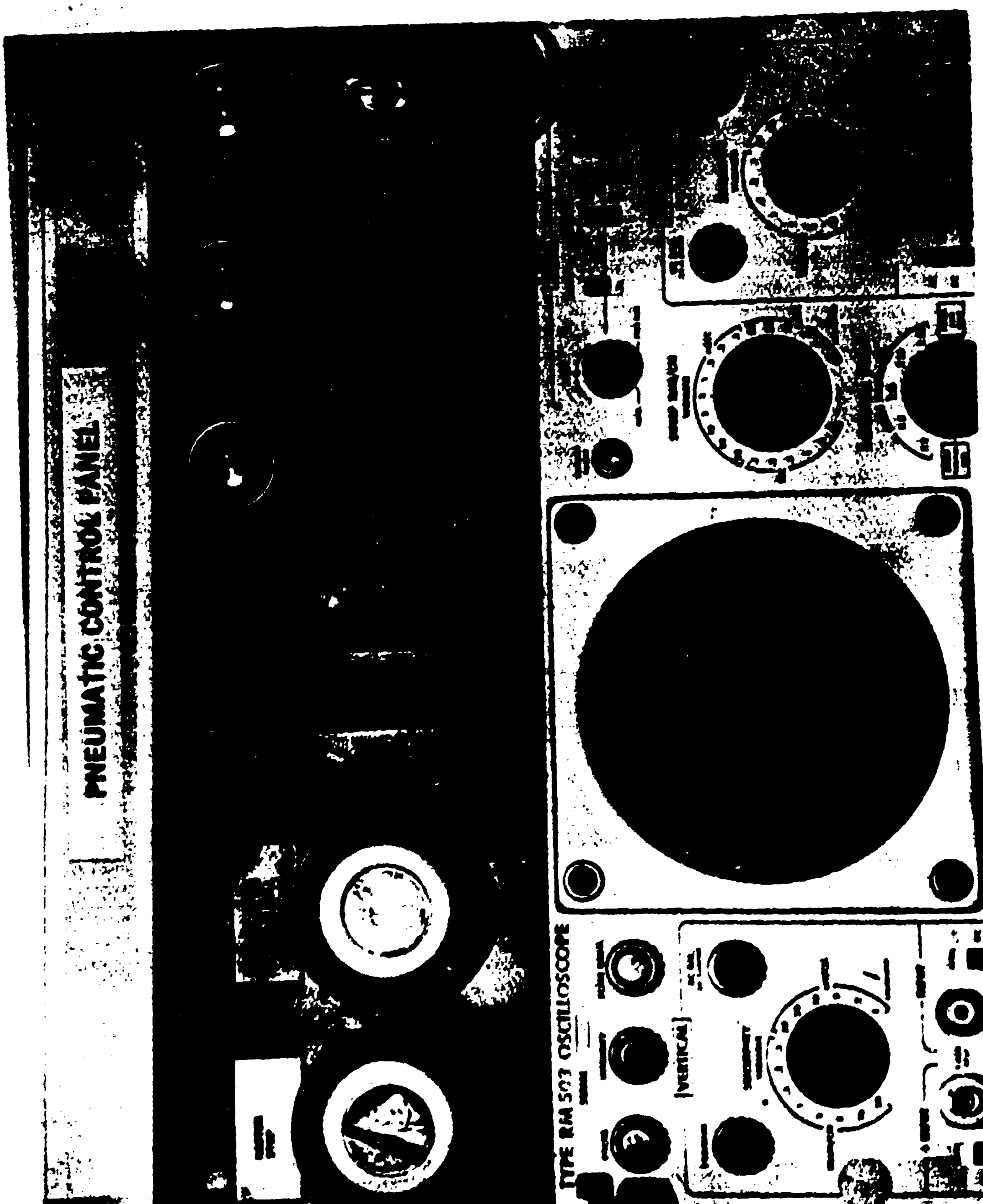

Figure 5-6. Pneumatic Control Panel

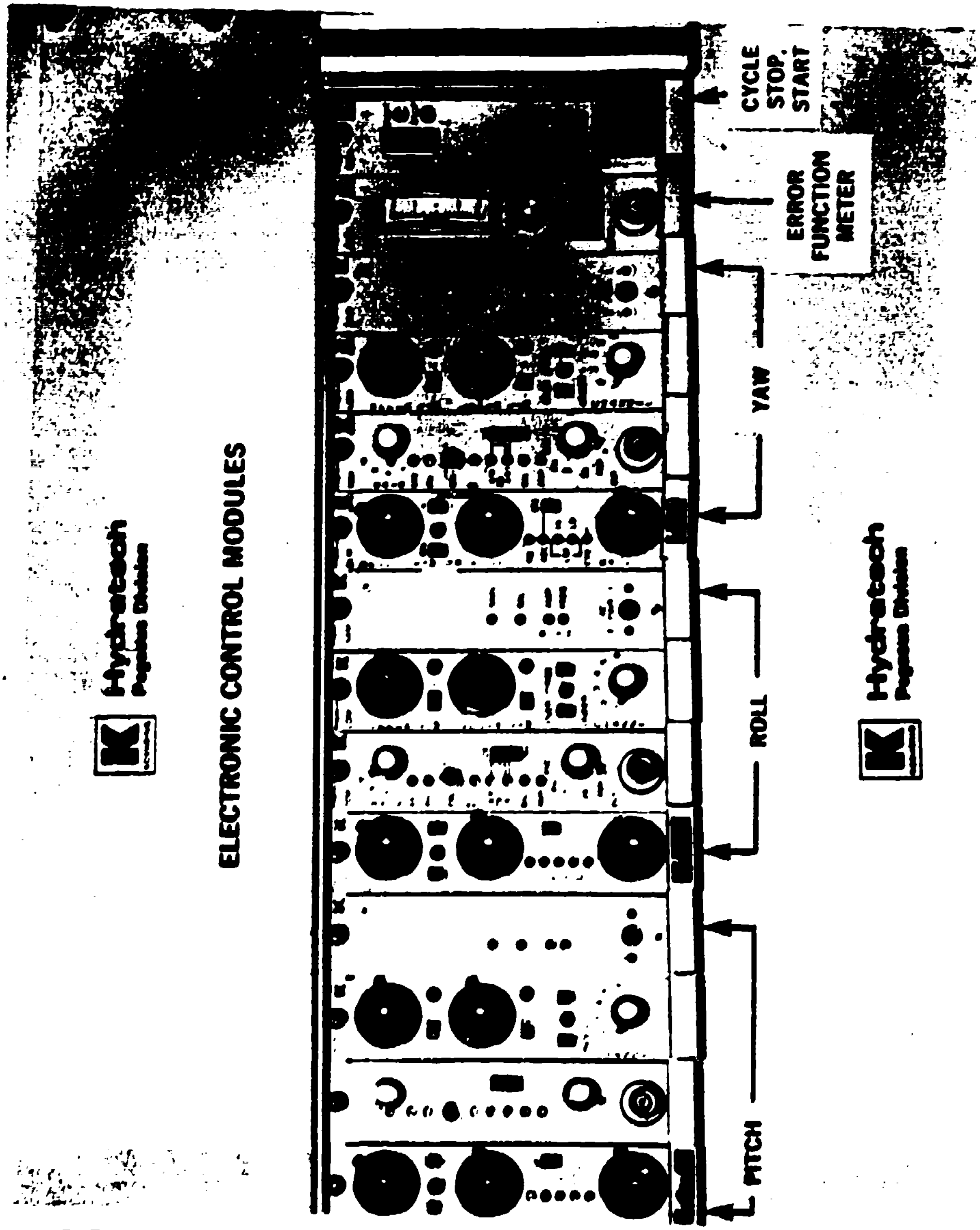

Figure 5-7. Electronic Control Modules (Roll, Pitch, Yaw)

Figure 5-8. Vertical Electronic Control Panel

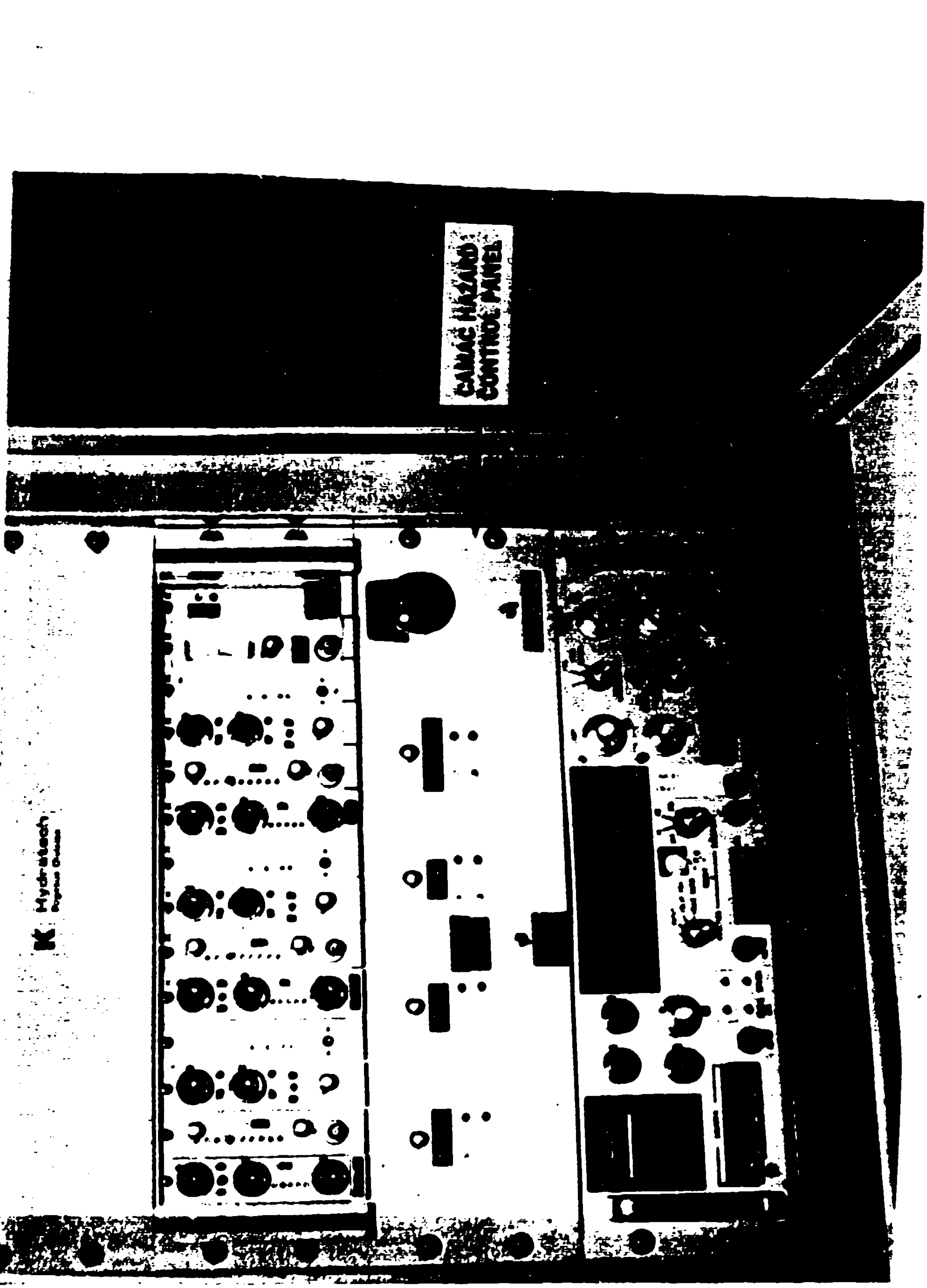

Figure 5-9. CAMAC Hazard Control Panel

will stop travel in the yaw degree of motion.

° Stop Roll & Pitch - Toggling this switch to the "UP/DOWN" position will stop travel in the roll and pitch degrees of motion.

° Mode Select - Putting this switch in the "UP" position activates two pneumatic safety switches which are mounted near the RMS occupant. To stop motion in the RMS, the occupant needs only to press one of these switches. Putting the mode select switch in the "DOWN" position activates a dead man's switch which is held by the occupant and depressed at all times. Release of this switch will stop all motion in the RMS.

° Test Vertical Valve - Depressing this switch overrides the vertical pneumatic shutoffs.

° High-Limit Override - Depression of this switch will override the "HIGH-LIMIT" pneumatic switch on the vertical degree of motion, thereby restoring control of motion to the RMS, in the event that the RMS has exceeded the "HIGH-LIMIT" stop for any reason. This should only be used when bringing the RMS to a neutral position using the static pot. on the electronic control module. The span pot. should be dialed to 0.0 during this procedure.

° Start Roll & Pitch - Depressing this switch will reset the pneumatic switch to "ON" for roll and pitch and enable motion in these degrees of freedom.

° Start Yaw - Depressing this switch will reset the pneumatic switch to "ON" for yaw and enable motion in this degree of freedom.

° Start Yaw - Depressing this switch will reset the pneumatic switch to "ON" for yaw and enable motion in this degree of freedom.

° Low-Limit Override - Depression of this switch will override the vertical "LOW-LIMIT" pneumatic switch, thereby restoring control of motion to the RMS, in the event that the RMS has exceeded the "LOW-LIMIT" stop for any reason. This should only be used when bringing the RMS to a neutral position using the static pot. on the electronic control module for lowering the RMS. The span pot. should be dialed to 0.0 during this time.

° Vertical Start Key - Turning this key in a clockwise direction will reset the pneumatic switch to "ON" for vertical and enable motion in this degree of freedom.

There are three red/green indicators above the start switches. From left to right they are roll and pitch, yaw, and vertical. The indicator will be "RED" if a pneumatic shutoff is in effect for that degree of motion and "GREEN" if motion is enabled.

5.3.2.4 Motion system. The motion system of the RMS is electrically controlled and hydraulically powered. The power system is a self-contained, fully integrated system including controls, reservoir, pump, accumulators, manifolds, filters, and a water-cooled heat exchanger.

While system pressure can be set as high as 3000 psi, the RMS will only be operated at 1500 psi to provide an extra safety margin. For the following calculations, we will use the following assumptions:

weight of occupant	-	180 lbs.
weight of simulator	-	500 lbs.
total weight	-	680 lbs. (21.1 slugs)

Vertical motion is accomplished by two actuators. To calculate the maximum possible force in a given direction use the equation:

$$\text{Force} = \quad * \; [(\text{piston diameter}/2)^2 - (\text{rod diameter}/2)^2] * (\text{system pressure})$$

$$\text{Max. Acceleration (g's)} = (\text{force} / \text{weight}) +/- \text{gravity}$$

The up acting actuator has a 2-inch-diameter piston and the pressure acts on the piston head side, so that at 1500 psi:

maximum force = 4,712 lbs
max. acceleration = 5.93 g's

The down actuator has a $^{7}/_{8}$-inch shaft diameter and a 1.5-inch piston. The net surface area is then 1.166 square inches so that at 1500 psi:

maximum force = 1,749 lbs
max. acceleration = 3.57 g's

The pitch actuator has a $1^{1}/_{8}$-inch shaft diameter and a 2-inch piston giving a surface area of 2.15 square inches. The lever arm is 13.5 inches long, so that at 1500 psi:

maximum extension force = 4,712 lbs
maximum retraction force = 3,221 lbs
max. acceleration = 6.93 g's

The roll actuator has $^{1}/_{2}$-inch shaft diameter and a 1-inch piston giving a surface area of 0.59 square inches. The lever arm is 9.5 inches long, so that at 1500 psi:

maximum extension force = 1,178 lbs

maximum retraction force = 884 lbs
max. acceleration = 1.73 g's

The yaw actuator has $1^{3}/_{8}$-inch shaft diameter and a $1^{7}/_{8}$-inch piston giving a surface area of 1.28 square inches. The lever arm is 9.5 inches long, so that at 1500 psi:

maximum extension force = 4,142 lbs
maximum retraction force = 1,914 lbs
max. acceleration = 6.09 g's

All of the actuators are position driven.

5.3.2.5 Hydraulic Control Panel. The hydraulic control panel (Fig 5-5) provides the operator control of the hydraulic system.

The description of the buttons and toggle switches are described as follows:

° Power On - The "RED" indicator will light up when the pump's circuit breaker is closed. The "BLACK" start push button turns on the pump, and the "RED" stop button turns off the pump.

° Pressure Compensator - This switch will adjust the pressure generated by the pump. Pushing the switch up will increase the pressure, and pushing it down will decrease the pressure.

° Main Pressure - This switch activates a blocking valve which will block hydraulic flow from the pump to the hydraulic system. In the "OFF" position, flow is blocked and in the "ON" position, the valve is open, and power is applied to the system.

° Pressure Dump - This switch will direct hydraulic flow into the reservoir when in the "ON" position and into the hydraulic system in the "OFF" position.

° Bleed Valve - By pressing this switch "UP", pressure will be bled out of the accumulators and into the reservoir. If for some reason, the RMS is stuck and cannot be electronically lowered, it can be lowered by slowly bleeding the hydraulic oil out of the accumulators.

° Pressure Relief - This switch controls the position of the relief valve which limits pressure buildup in the system. This should be set by lowering its pressure setting until a high pitched whine is heard (oil flowing through the relief valve), then raising the setting until the whine disappears. This control is used in conjunction with the pressure-compensator control, when it is desired to raise or lower the working pressure of this system. The system pressure is not changed as a routine matter.

The description of the pressure gauges are as follows:

Filter - Indicates the pressure across the low-pressure filter. A pressure of 25 PSI or higher indicates a requirement for replacement.

Pump - Indicates the operating pressure of the hydraulic pump.

UP Ram - Indicates the hydraulic pressure applied to the "UP" vertical actuator.

DOWN Ram - Indicates the hydraulic pressure applied to the "DOWN" actuator.

5.4 System Operations

5.4.1 Operating Procedures.

5.4.1.1 Standard Operation of Ride Motion Simulator.

Step 1. Execute the computer program which will drive the RMS. This program is located on the Micro-VAX II in the RMS room and is stored in the account $disk1:[USER] under the name SEAT.FOR. This program will guide the operator step by step through the SOP. Execute the program by typing "SEAT" upon login.

Step 2. Notify the ambulance (x47117) of the upcoming test.

Step 3. Turn on the electronics. Allow 20 minutes warm-up time per manufacturer's instructions.

Step 4. Pressurize the pneumatic system. A manually operated valve is located on the wall behind the control console. The air pressure must not be less than 75 psi. The gauge is located on the left third of the control console, one rack panel down from the top (Fig 5-5).

Step 5. Turn on the coolant pump by means of the switch box on the wall behind the control console. Close the circuit breaker first, then push the start button.

Step 6. Close the circuit breaker for the main pump motor. The breaker is located on the wall above the work bench. The red indicator light on the left side of the hydraulic control panel will light up.

Step 7. Ensure that the span pots. are set to 0.0 for all four degrees of motion on the electronic control modules. The electronic control modules are located on the right third of the control console (Fig. 5-7 and 5-8).

Step 8. Check the inputs to the electronic control modules from the CAMAC via the electronic filters. These filters are preset to 10 Hz. Connections should be made as follows:

Channel	Degree of Motion
1	Vertical
2	Roll
3	Pitch
4	Yaw

Verify the CAMAC hazard control connections from the box to the strip on the back of the CAMAC.

Step 9. Set the pitch, roll, and yaw meter function switch to "E" for detecting the position error signals. The switch is located on the right-hand side of the roll, pitch, and yaw control module (Fig. 5-7).

Step 10. Ensure that the static pots. for the roll, pitch, and yaw motions are set to 0.0. The static pots. are located on the electronic control modules (Fig. 5-7).

Step 11. The following switch settings on the vertical electronic control module must be set as follows:

1) Meter function switch to "POS ERROR."

2) Meter sensitivity switch to "X1" setting.

3) Static position pot. to "1.13."

4) Mode switch to "POS."

5) Limit mode switch to "POS."

Step 12. Ensure that the main hydraulic pressure control switch is in the "OFF" position (up). This will block any hydraulic flow from the pump to the system. The switch is on the left third of the console, midway up from the bottom (Fig. 5-5).

Step 13. Ensure that the pressure-dump switch is in the "ON" position (up). This will divert any flow from the pump back to the reservoir. This switch is on the same panel as the main hydraulic pressure-control switch (Step 12).

Step 14. Start the motor for the main hydraulic power supply. Press the large black pushbutton on the left side of the hydraulic control panel.

Step 15. Move the pressure dump switch to "OFF." Wait for pressure to build up to operation level (1300 to 1800 psi).

Step 16. Pressurize the system by moving the main pressure switch to "ON." Wait for the roll, pitch, and yaw error signals to go to "Zero." This is monitored on the meter by flipping the switch located below the meter from "1" pitch, to "2" roll, and "3" yaw.

Step 17. To adjust hydraulic pressure, use the compensator and pressure-relief switches on the hydraulic control panel. The compensator is a system inside the pump which controls the pressure the pump can produce up to the design limit of the pump. The relief valve is an independent device in the system, which limits the pressure buildup in the system. The correct adjustment for the two devices is to have the compensator pressure set just below the cracking pressure of the relief valve. To check the setting of the relief valve, lower its pressure setting until a high-pitched whine is heard (oil flowing through the relief valve), then raise the setting until the whine disappears.

Step 18. Check and ensure that the roll, pitch, and yaw error signals are still "Zero." Verify this on the meter on the right-hand side of the electronic controllers. If the "Limit" light is lit up on the vertical controller, press the "Limit Reset" button. On the roll, pitch, and yaw controllers, if any of the red "Limit" LED's are on, flip the limit-on switch "UP" and "DOWN" to clear these limits.

Step 19. Toggle the "START PITCH AND ROLL" switch (located on the pneumatic control panel) to energize the pitch-and-roll blocking valve. There is now hydraulic pressure in these channels. Yaw is energized by toggling the "START YAW" switch. The red indicators will flip to green when the respective channels are energized.

Step 20. Press the "Low-Limit Override" toggle switch (located on the pneumatic control panel) and hold. This will energize the vertical blocking valve and consequently flip the red indicator to green.

Step 21. Raise the simulator by increasing the static position pot. on the vertical controller to (4.57) mid-position. Look at the two strips of tape on the left side of the RMS, to confirm that they are even. This confirms that the RMS is in mid-position.

Step 22. Release the "Low-Limit Override" switch and reset the lower pneumatic safety switch on the left side bottom of the RMS. This will de-energize the vertical-blocking valve, and the vertical indicator will flip back to red.

Step 23. Turn the vertical start key on the pneumatic control panel clockwise and back. This activates the vertical blocking valve and resets the vertical indicator to green. The vertical channel is now engaged.

Step 24. Test the CAMAC switches and limits in the order dictated by the computer program. Use the static pots. to move the RMS to extreme positions and toggling of the CAMAC shutdown switches. Clear the limits when appropriate (Fig. 5-9).

Step 25. Place the RMS back into its neutral position by dialing the roll, pitch, and yaw static pots. to 0.0 and the vertical static pot. to 4.57. If the limit light is lit up on the vertical controller, press the "Limit Reset" button to clear it. If any of the red "Limit" LED's on the roll, pitch, or yaw controllers are on, flip the "Limit On" switch up and down to clear these limits. Clear the CAMAC limits, if necessary.

Step 26. Turn on the strip-chart recorder to monitor the input signal. Press carriage return to perform one simulation of each profile.

Step 27. Press the "CYCLE START" button on the far right side of the roll, pitch, and yaw electronic control modules. The red LED will turn off, and the green LED will come on. Then press the "CYCLE-START" button on the bottom right side of the vertical electronic control modules, which will illuminate green, and the "CYCLE-STOP" button will darken. Dial all spans to 10.0 (refer to Fig. 5-8 for these steps). The system is now ready for use.

Step 28. Start the trial run on the computer. Monitor this on the strip-chart recorder. Look for any unacceptable movements or limit violations.

Step 29. When the trial run is complete, dial all span pots. to 0.0 and press "CYCLE-STOP" on both controllers (Figs. 5-7 and 5-8).

Step 30. Press the vertical "Low-Limit Override" pneumatic toggle switch and hold. Dial the vertical static pot. to 1.13, thus lowering the RMS. Release the toggle switch, and the green vertical indicator will flip to red.

Step 31. Ensuring that the rider wears the proper headgear, board him/her into the RMS. Help the rider fasten the appropriate seat/shoulder/safety belts and harnesses.

Step 32. Press the vertical "Low-Limit Override" pneumatic switch and hold, causing the vertical indicator to flip from red to green. Dial the vertical static pot. to 4.57, thus moving the RMS to its neutral position.

Step 33. Release the "Low-Limit Override" switch (causing the vertical indicator to flip to red) and reset the lower pneumatic safety switch on the left-side bottom of the RMS.

Turn the vertical start key clockwise and back, thus changing the vertical indicator to green. The vertical channel is now engaged.

Step 34. Press the "Limit-Reset" button on the vertical controller, to clear the extension and retention limits.

Step 35. Press the "CYCLE-START" buttons on both controllers and dial all spans to 10.0. Clear the CAMAC limits.

Step 36. Start the simulation on the computer. Be alert for any problems.

Step 37. When the simulation is complete, dial all span pots. to 0.0 and press "CYCLE-STOP" on both controllers.

Step 38. Press the vertical "Low-Limit Override" pneumatic switch and hold. Dial the vertical static pot. to 1.13, thus lowering the RMS.

Step 39. Release the "Low-Limit Override" switch, thereby disengaging the vertical channel. Press the "Black" Stop Roll, Pitch, and Yaw button on the pneumatic control panel, thus disengaging these channels.

Step 40. Help the rider unfasten the appropriate seat/shoulder/safety belts and harnesses. Carefully, help the test subject dismount.

Step 41. Flip the main pressure switch on the hydraulic control panel to "OFF." This will block hydraulic flow to the RMS.

Step 42. Flip the pressure-dump switch to the "ON" position. This will reroute the hydraulic flow to the reservoir.

Step 43. Turn "OFF" the hydraulic pump by depressing the black button on the left-hand side of the hydraulic control panel.

Step 44. Hold the "Bleed-Valve" switch down until pressure is bled out of the actuators. Check the pressure gauge (Fig. 5-5) to verify this.

Step 45. Turn "OFF" the main pump breaker and the electronics.

Step 46. Turn "OFF" the recirculating pump.

Step 47. Turn "OFF" the air.

5.4.1.2 Hazard Controls

The RMS has a total of eight pneumatic fail-safe devices, plus two sets of electronic travel limiters, to protect humans from injury and valuable components from damage. These devices can be activated automatically by the test subjects, or by the RMS operator.

The following is a description of each safety device, how it works and how it protects subjects and components.

5.4.1.2.1 Pneumatic Hazard Controls.

° "Red" master stop button (operator controlled). Located on the pneumatic console (Fig 5-6) is a "Red" master stop button, which is controlled by the operator. If the operator should see any uncommon happenings, he will press the button, which will deactivate blocking valves on all four degrees of freedom. This will stop hydraulic flow to the actuators, thereby stopping all motion of the RMS.

° "Black" stop roll, pitch, and yaw button (operator controlled). This button is located adjacent to the "Red" master stop button on the pneumatic control panel (Fig. 5-6). This button operates identically to the "Red" master stop button, except it does not stop vertical motion.

° Mode selection (subject controlled). There are three stop buttons located on the RMS. One is hand-held by the subject, and the other two are located within arm's length. All three of these stop buttons cannot be used at the same time. The type of test determines the mode selected.

Dead Man's Switch - With the mode select switch in the "down" position, the dead man's switch (hand-held by the subject) is operational, while the other two switches are inoperative.

The dead man's switch is normally open; it is activated by the subject releasing the stop button, if he feels that he is in an unsafe condition. When the button is released, air pressure is released through a "quick exhaust valve," which in turn stops all RMS motion.

"Stop" Button Switches - These two switches are in operation when the mode select switch is in the "UP" position. This leaves the dead man's switch inoperative. These switches are normally closed and are activated by pressing the "STOP" button (one or the other), to stop all simulator motion. Motion is stopped by deactivating the hydraulic blocking valves, thereby stopping hydraulic flow to all actuators.

° "Upper-" and "Lower-Limit Override" switches (automatically activated). The "upper-" and "lower-limit override" pneumatic switches are safety devices that are automatically activated when the simulator travel exceeds a preset amount of movement in the vertical degree-of-motion. When the simulator activates the override switches (whether it be upper or lower), air pressure is released through the "Quick Exhaust Valve," which in turn deactivates the vertical-blocking valve, stopping motion vertically.

° Air pressure system (automatically activated). If air pressure is lost due to a break in an air line, the air pressure system fail-safe mode activates the quick-exhaust valve, thereby deactivating all blocking valves and stopping all motion. The RMS would be lowered by bleeding the hydraulic oil out of the actuators by depressing the "Bleed Valve" switch.

The rider would dismount and repairs would be made to the air line.

5.4.1.2.2 Electrical Hazard Controls.

° Solenoid valve (automatically activated). In the event that the main electrical supply is cut off to the console, the electrically operated solenoid valve will automatically divert the air supply flow through the quick-exhaust valve which, in turn, activates the master valve, stopping all motion.

To restore movement, perform the following:

- ° Locate the cause of electrical power loss and repair it
- ° Perform the standard start-up procedure

° Electronic control panel limits (automatically activated). During operation, the seat travel in all four degrees of movement is continuously monitored by the control modules. If roll, pitch, or yaw travel exceeds a value preset by the operator, the limiter is activated, resulting in an automatic shutdown ("CYCLE-STOP") of roll, pitch and yaw. Vertical travel is monitored separately but operates the same as the roll, pitch and yaw limiter.

° Uninterruptible power supply (UPS) (automatically activated). In the event of a loss of electrical power, UPS will provide battery backup power to the entire RMS system for up to 30 minutes.

In the case of a loss of power, the operator will use normal shutdown procedures for the RMS. After locating the cause of the problem and restoring the electrical power, the standard start-up procedure will be used to restore the RMS operation.

5.4.1.2.3 CAMAC Hazard Controls.

° Emergency shutdown "RED" pushbutton switch (operator activated). Located on the CAMAC control panel (Fig. 5-9), is a "RED" pushbutton switch which is controlled by the RMS operator. If he should see any uncommon happenings, he will press the pushbutton, which will lock the output signal from the CAMAC at its current value, thereby freezing the RMS at its present position. The operator then presses "CYCLE-STOP" and sets all the span pots to 0.0.

° Ramp-down toggle switch (operator controlled). Located on the CAMAC control panel is a "ramp-down" toggle switch which is controlled by the RMS operator. If, for any reason, he wishes to stop the test but does not need to have a very sudden shutdown, he may operate this switch. This will cause the CAMAC to ramp the RMS to its neutral position from its current position. The operator then presses "CYCLE-STOP" and sets all the spans to 0.0.

° Electronic travel limiters (automatically activated). The remainder of the CAMAC control panel consists of electronic travel limiters. Each degree of motion has two sets of green and red LED's, an input BNC connector which measures the position of the RMS, and an output BNC connector which lets the CAMAC know if a travel limit has been exceeded.

When RMS travel is between preset position limits, the "GREEN" LED's for that degree of motion will be turned on. When travel exceeds either the lower limit or the upper limit, the corresponding "RED" LED will turn on, and a signal will be sent to CAMAC, which will cause the RMS to halt motion immediately. The operator then will press "CYCLE-STOP" and dial all spans to 0.0.

5.4.1.3 Restart Procedures.

5.4.1.3.1 Pneumatic Shutdowns.

Step 1. Press the "CYCLE-STOP" button on both controllers.

Step 2. Dial all span pots. to 0.0.

Step 3. Adjust the vertical static pot. to set the position error voltage to -1.84 volts. This will correlate the actual position of the seat where the vertical controller thinks it should be. When we energize the vertical channel, the RMS will not "jump" into the position where the controller is pointing.

Step 4. To abort the test -

- Press the "RED" pneumatic master stop button located on the pneumatic control panel. This will disengage all channels of motion.

- Press and hold the corresponding "vertical-limit override" switch.

- Dial the vertical static pot. to 1.13, thus lowering the RMS to its reset position.

To continue the test -

- Press and hold the corresponding "vertical-limit override" switch.

- Dial the vertical static pot. to 4.57, thus moving the RMS to its neutral position.

- Release the "limit-override switch", and reset the tripped limit.

- Reactivate vertical motion by turning the vertical start key clockwise and back.

- Press "CYCLE-START" on both electronic controllers.

- Dial the span pots. to 10.0 and continue the test.

5.4.1.3.2 Electronic Controller Limits Exceeded.

Step 1. Press "CYCLE-STOP" on both controllers.

Step 2. Reset the limits.

Step 3. Dial all the span pots. to 0.0.

Step 4. If the error has been corrected, then -

1) Press "CYCLE-START" on both controllers.

2) Dial all the span pots. to 10.0.

If the error has not been corrected, follow standard shutdown procedures.

5.4.1.3.3 CAMAC "POSITION LIMITS" and "SHUTDOWN" Switches Activated

Step 1. Press "CYCLE-STOP" on both controllers.

Step 2. Dial all the span pots. to 0.0.

Step 3. If the error has been corrected, then -

1) Clear the CAMAC limits by using the toggle switch on the CAMAC panel.

2) Restart the CAMAC program. Skip down to Step 24, (Step 23 in the computer guide).

3) Follow the computer's instructions to finish the test.

If the error has not been corrected, follow standard shutdown procedures.

5.4.1.4 Boarding Personnel Into Simulator.

Step 1. Perform a subject briefing. Instruction will include use of the pneumatic safety switches ("deadman's" or "press-to-activate"), use of safety/shoulder/seat belts and harnesses and the goals of the test.

Step 2. After Step 28 of the starting procedure has been completed (ensuring all safeties work), have the rider (with assistance) climb into the simulator.

Step 3. The operator must keep a close watch on the simulation and in the event something does not seem correct, he must be prepared to press the "RED" Master Stop pneumatic button.

5.4.1.5 Shut-down Procedures, Normal Operation.

Step 1. Press "CYCLE-STOP" on both controllers.

Step 2. Dial all span pots. to 0.0.

Step 3. Press the "BLACK" Stop Roll, Pitch, and Yaw pneumatic button to deactivate these degrees of motion.

Step 4. While pressing the "Low-Limit Override" switch, dial the vertical static pot. to 1.13, thus lowering the seat. Release the "Low Limit Override" switch.

Step 5. Dismount the test subject.

Step 6. Move the main pressure switch to the "OFF" position. This will block any hydraulic flow to the system.

Step 7. Move the dump pressure switch to the "ON" position. This will redirect all hydraulic flow to the reservoir.

Step 8. Turn off the pump by pressing the "RED" button on the hydraulic control panel.

Step 9. Depress the "BLEED-VALVE" switch until pressure is bled out of the system.

Step 10. Turn "OFF" the main pump breaker and the electronics.

Step 11. Turn "OFF" the recirculating pump.

Step 12. Turn "OFF" the air.

5.4.2 Special Procedures Needed To Assure Safe Operations

a. Assure the test subject is apprised of all safety switches that he/she will operate, if necessary. Also provide a thorough explanation of all safety/shoulder/seat belts and harnesses and a description of the test and how the simulator works.

b. Assure the simulator operator meets qualifications, as stated in the user's manual.

c. Assure that personnel stay away from the simulator during the test.

d. Assure that the fire extinguishers located in the room are charged.

e. Assure that the fire department/paramedics are aware of the ongoing test.

5.5 System Safety Engineering

The methodology of MIL-STD-882B and AR-385-10 was used to identify and rank potential hazards associated with the Ride Motion Simulator.

During the 30-year existence of the Ride Motion Simulator (17 years in its current configuration with safety devices), there has not been a single documented injury incurred by a test subject. To ensure continued safety, a System Hazard Analysis has been conducted. Hazardous conditions and their respective hazard severity levels, probability levels and control measures are described in the following report: "System Hazard Analysis of TACOM's Rice Motion Simulator", Report No. 13469.

5.6 Health Hazard Assessment

A study of the RMS room illumination levels and noise during a test run was made. The report is enclosed as Appendix C. Both illumination and noise were found to be at acceptable levels with no modifications or hearing protection required.

LIST OF REFERENCES

1) AR 385-10.

2) MIL-STD-882B.

3) TACOM RDE CENTER Technical Report #13464, "USER's MANUAL FOR THE RIDE MOTION SIMULATOR", Alexander A. Reid, August 1989.

4) TACOM RDE CENTER Technical Report #13469, "SYSTEM HAZARD ANALYSIS OF TACOM's RIDE MOTION SIMULATOR", Alexander A. Reid, January 1990.

APPENDIX A

AMSTA-CZ (385-16) 19 September 1989

MEMORANDUM FOR Dir of Design & Mfg Tech (AMSTA-T), ATTN: Robert Culling

SUBJECT: Safety Release of the Ride Motion Simulator.

1. Reference AMSTA-T Memorandum, 25 Aug 89, SAB.

2. The above referenced SAR and Hazard Analysis have been reviewed and concurrence is given, provided the following comment is incorporated in the Safety Assessment Report. On page 29 of the SAR, step 39, second sentence should be placed at the end of step 37.

3. POC for this office is Mr. W. Jay Grebner, X-45636, or Mr. Patrick Kelley, X-46310.

Richard M. Grnya

RICHARD M. GRNYA
Safety Director

CF:
AMSTA-RYA, Mr. Reid

APPENDIX B

SLCHE-TA 30 Aug 89

MEMORANDUM FOR Dir of Des & Mfg Tech (AMSTA-T), ATTN: Al Reid

SUBJECT: Safety Release for the Ride Motion Simulator

1. Reference Memorandum, TACOM, AMSTA-T, 25 Aug 89, Suspense: 15 Sep 89, SAB.

2. Per your referenced request, the subject documents have been reviewed by this office; this office concurs with the documents.

3. The POC for this action is Bob Fox, ext. 45785.

Ralph Ahrens for:

MOHSIN SINGAPORE
C, HEL Detachment
TACOM

APPENDIX C

DISPOSITION FORM

For use of this form, see AR 340-15, the proponent agency is TAGO.

REFERENCE OR OFFICE SYMBOL	SUBJECT
HSXP-WAR (385-101)	Noise and Illumination Survey - Building 215

TO/ THRU C, Safety Ofc (AMSTA-CZ)

FROM Industrial Hygienist (HSXP-WAR)

DATE 4 Nov 87 Mr. Bonkowski/gpl/4-6256

CMT 1

TO C, Sys Sim & Tech Div ✓ (AMSTA-RY)

1. At the request of Mr. Paul Spanski, an Illumination and Noise Survey was conducted in Bldg 215, RMS Bay (Ride Motion Simulator) on 2 Nov 87 by the writer.

2. Test results are on the attached Data Sheet.

3. Findings:

a. The illumination level at the computer table and control console is below the GSA Illumination Standard of 50 Foot-candles.

b. Excessive noise levels were not found at this time.

4. Recommendation:

a. Replacement of the fluorescent lights, and cleaning of the fluorescent light lens.

b. Request a reevaluation of the illumination levels by the Occupational Health Clinic upon completion of cleaning and repair of lighting fixtures.

K. Bonkowski

KENNETH BONKOWSKI
Industrial Hygienist

Atch

CF:
CPT D. Ellis
(HSXP-SEL)

Bruno Burgess, M.D.
(HSXP-WAR)

ILLUMINATION AND
NOISE DATA SHEET

Building 215, RMS Bay
3 NOV 87

TEST #	LOCATION	ILLUMINATION LEVEL - FOOT-CANDLES
	GSA ILLUMINATION STANDARD	50
1	Computer Table	42
2	Control Console	32 - 39
3	Center of Room	48

TEST #	LOCATION	NOISE LEVEL, dbA
	O.S.H.A. PERMISSIBLE EXPOSURE LIMIT	85
1	At Computer Table	76
2	AT Control Console	80
3	Next to RMS at floor level	83
4	Door way	75

DISPOSITION FORM

For use of this form, see AR 340-15, the proponent agency is TAGO.

REFERENCE OR OFFICE SYMBOL	SUBJECT
.SXP-WAR (385-10i)	Illumination Re-Survey, Bldg 215

79 THRU C, Safety OFc (AMSTA-CZ)

FROM Industrial Hygienist (HSXP-WAR)

DATE 1 Apr 88 Mr. Bonkowski/gp1/4-6256

CMT 1

TO C, Sys Sim & Tech Div (AMSTA-RYA)

1. At Mr. A. Reed's request, the illumination levels in Bldg 215, Ride Motion Simulator (RMS) room, were re-measured by the writer on 01 Apr 88.

2. The test results are on the enclosed Data Sheet.

3. Findings:
The present illumination levels in the RMS room exceed the value recommended by the Illumination Engineering Society for ordinary seeing tasks (see enclosed Table I, General Recommended Values of Illumination).

4. No further corrective action is recommended.

K. Bonkowski

Encls

KENNETH J. BONKOWSKI
Industrial Hygienist

CF:
CPT D. Ellis
(HSXP-SEL)

Dr. B. Burgess
(HSXP-WAR)

Ms. D. Jones, R.N.
(HSXP-WAR)

Ms. S. Wessel, R.N.
(HSXP-SEL)

ILLUMINATION DATA SHEET
BUILDING 215, RMS ROOM
01 APR 88

TEST #	LOCATION	ILLUMINATION FOOT-CANDLES
	ILLUMINATING ENGINEERING SOCIETY STANDARD FOR ORDINARY SEEING TASKS	30
1	Computer Table	41
2	Control Console	37-39
3	Work Bench	38

TABLE I.—General Recommended Values of Illumination.

	Current Recommended Practice Footcandles in Service (On Task or 30" above floor)
MOST DIFFICULT SEEING TASKS	
Finest Precision Work	200-1000*
Involving: Finest Detail; Poor Contrasts; Long Periods of Time	
Such as: Extra-fine Assembly; Precision Grading; Extra-fine Finishing	
VERY DIFFICULT SEEING TASKS	
Precision Work	100
Involving: Fine Detail; Fair Contrasts; Long Periods of Time	
Such as: Fine Assembly; High Speed Work; Fine Finishing	
DIFFICULT AND CRITICAL SEEING TASKS	
Prolonged Work	50
Involving: Fine Detail; Moderate Contrasts; Long Periods of Time	
Such as: Ordinary Bench Work and Assembly; Machine Shop Work; Finishing of Medium-to-Fine Parts; Office Work	
ORDINARY SEEING TASKS	
Involving: Moderately Fine Detail; Normal Contrasts; Intermittent Periods of Time	30
Such as: Automatic Machine Operation; Rough Grinding; Garage Work Areas; Switchboards; Continuous Processes; Conference and File Rooms; Packing and shipping	
CASUAL SEEING TASKS	
Such as: Stairways; Reception Rooms, Washrooms and other Service Areas; Active Storage	10
ROUGH SEEING TASKS	
Such as: Hallways; Corridors; Passageways; Inactive Storage	5

*Obtained with a combination of general lighting plus specialized supplementary lighting. Care should be taken to keep within the general brightness ratios (indicated in Table III) and to avoid glare conditions when light colored materials are involved.

tion will be maintained even where maintenance conditions are favorable, it is necessary to design the system to give initially more light than the recommended in-service level. The system should be designed initially at least 50% above the in-service level. Where safety goggles are worn, the light reaching the eye is likely to be materially reduced, and the level of lighting should, therefore, be increased in accordance with the absorption of the goggle in use. It is important that the quantity of light be measured at the point and in the plane at which the seeing task is performed, be it horizontal, vertical, or some intermediate angle.

(d) The Illuminating Engineering Society has in recent years been studying the illumination needs of specific industries. The results of those studies which have been completed are included in Table II.

2.2.3—*Quality of Lighting*

2.2.3.1—*General*—(a) The factors involved in quality of lighting are many and complex. Glare, diffusion, direction and uniformity of distribution, color, brightness and brightness ratios have a significant effect upon visibility and ability to see easily, accurately, and quickly. Certain seeing tasks require much more careful analysis and higher quality lighting than others. Areas where the seeing tasks are casual or relatively infrequent need high quality lighting much less than areas where the seeing tasks are severe and are performed over long periods of time. Good appearance of certain areas also often dictates the use of high quality lighting even though the seeing tasks in the area are not difficult. Lobbies, auditoriums, etc. usually fall into this class.

(b) Installations extremely deficient in lighting quality are easily recognized as very uncomfortable and even harmful. Unfortunately, more moderate deficiencies are not readily detected, although the cumulative effect of even slightly glaring conditions can result in material loss of seeing efficiency and in undue fatigue.

2.2.3.2—*Direct Glare*—(a) Glare may be defined as any brightness within the field of vision of such character to cause discomfort, annoyance, interference with vision or eye fatigue, or both. When the condition is caused directly by the source of the lighting, whether natural or artificial, it is described as direct glare.

(b) To reduce direct glare, the following steps may be taken:

(1) Decrease the *brightness* of light sources or lighting equipment, or both.

(2) Reduce the *area* of high brightness causing the glare condition.

(3) Increase the *angle* between the glare source and the line of vision.

(4) Increase the *brightness* of the area surrounding the glare source and against which it is seen.

(c) Unshaded windows are frequent cause of direct glare. They may permit direct view of the sun, bright portions of the sky, and of bright adjacent buildings. These often constitute large areas of very high brightness in the normal field of view. The condition may be controlled by shading the windows with shades, blinds, louvers, or baffles.

(d) Artificial lighting luminaires which are too bright for the environment in which they are located produce direct glare. To reduce this glare, direct general-lighting luminaires should be mounted at sufficient height to keep them well above the normal line of vision. They should be properly designed to limit both the brightness and the quantity of light emitted in directions directly below the horizontal since such light is likely to be well within the field of view and interfere with vision. There is such a wide divergence of conditions in industry that it is often necessary to modify the ideal luminaire characteristics to meet practical limitations of efficiency and maintenance. In offices and in industrial areas where similar environmental conditions can be established, a shielded zone from horizontal to approximately 45° below is recommended in accordance with the "Recommended Practice of Office Lighting"* (See Fig. 1). It is always desirable to provide as large a shielded zone as practicable. Ideally, from Sec. 2.3.1, the brightnesses of the room should be relatively uniform including the luminaire. This condition is usually difficult to achieve particularly with the direct lighting equipment most frequently used in industry. Usually the *surfaces* above the lighting equipment and the upper surfaces of

*Published by the Illuminating Engineering Society.

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