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**A HUMAN ENGINEERING EVALUATION
OF THE
ML-1 & ML-1A MOBILE LOW POWER NUCLEAR POWER PLANT**

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October 1963

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OF THE
ML-1 & ML-1A MOBILE LOW POWER NUCLEAR POWER PLANT

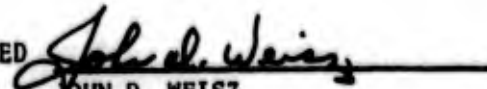
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ABSTRACT

This report is a continuation of the U. S. Army Human Engineering Laboratories' human engineering evaluation of the ML-1 Mobile Nuclear Power Plant and is being conducted at the request of the U. S. Army Corps of Engineers. It covers the period 1 April 1962 to 30 April 1963 and includes a simultaneous task analysis of the ML-1 start-up procedures, a review of the layout and operation of the Reactor, Power Conversion Skid, and Gas Storage Skid, the monitoring of the contractor's product improvement program, a proposed layout of the ML-1A Control Cab, a review of the training-simulator design. Recommendations are made for improving the operation and maintenance of this system. A brief description of the reactor plant is also included.

CONTENTS

ABSTRACT	iii
INTRODUCTION	1
DESCRIPTION OF MATERIEL	3
PROCEDURES	5
RESULTS AND RECOMMENDATIONS	7
Over-All System Evaluation	7
Simultaneous Task Analysis	8
Component Review	16
Project Improvement Program	16
ML-1A	20
ML-1A Specification Review	34
Design of Training Equipment	37
APPENDICES	
A. Component Review (PCS, Recator, and Gas Storage Skid)	41
B. Recommended Layout of the ML-1A Control Console and Cab	67
FIGURES	
1. ML-1 Mobile Low Power Nuclear Power Plant	vi
2. ML-1 Reactor Skid	2
3. ML-1 Power Conversion Skid	2
4. ML-1 Control Cab -- Exterior	4
5. ML-1 Control Cab -- Interior	4
6. ML-1 Power Cycle	6
7. Layout of Nomenclature on Clutch Coils Meter Selector Switch	24
8. Layout of Channels 1 and 2 Switch and Indicator	24

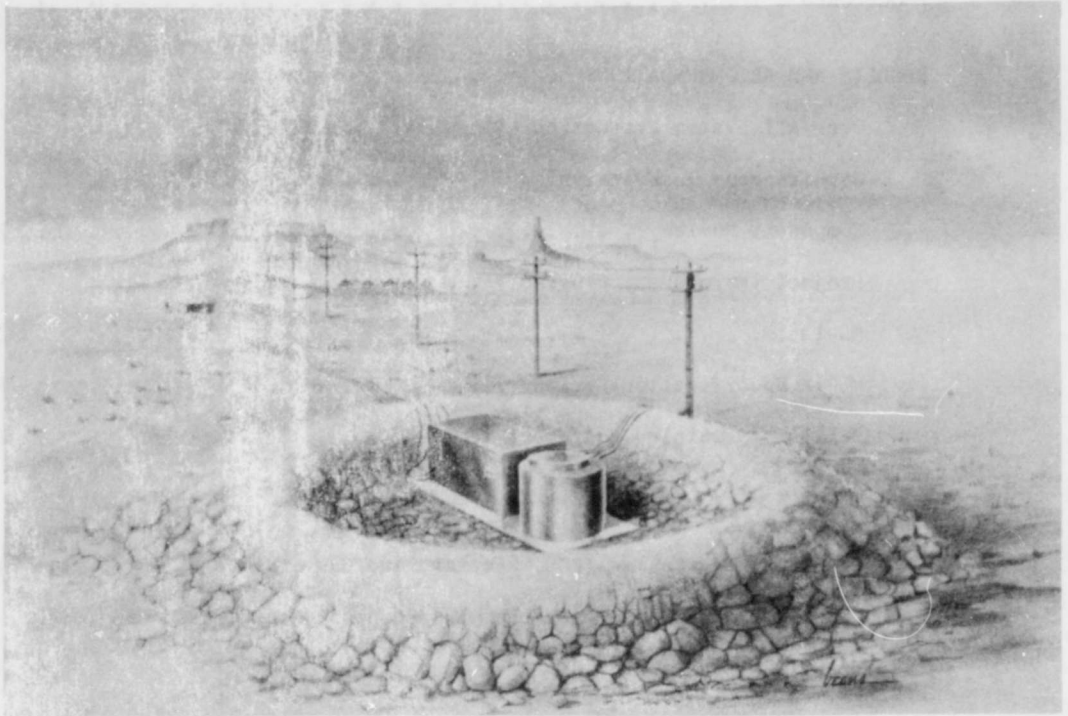


Fig. 1. ML-1 MOBILE LOW POWER NUCLEAR POWER PLANT -- TYPICAL FIELD INSTALLATION

**A HUMAN ENGINEERING EVALUATION
OF THE
ML-1 & ML-1A MOBILE LOW POWER NUCLEAR POWER PLANT**

INTRODUCTION

This report is a continuation of the human engineering evaluation of the ML-1 Mobile Nuclear Power Plant, conducted by the U. S. Army Human Engineering Laboratories (HEL), and performed at the request of the U. S. Army Corps of Engineers. An earlier report* covered the HEL effort to the report date. The present report covers the period 1 April 1962 through 30 April 1963.

The ML-1, Mobile, Low Power, Nuclear Power Plant (Fig. 1) is a merger of a high-temperature, gas-cooled, water-moderated reactor with compact power conversion equipment. This closed-cycle, gas-turbine power plant has as a goal an electrical power-generating capacity of 300 to 500 kw. The ML-1 is being used to develop an optimum mobile plant for use by the Army in the field to support such operations as tactical missile systems, field hospitals, depot maintenance complexes, and small remote military installations. The four major parts of the plant are the nuclear reactor skid, the power conversion skid, the control cab for instrumentation and control, and the auxiliary sub-systems used in start-up and shut-down. The system is designed to have a core life of 10,000 hours, weigh about 40 tons, and be transportable on the C-124, the C-130A, or the C-133 military transport aircraft, by ship or barge, by railroad flatcar, and on standard Army trailers.

The earlier report (HEL TM 8-62) was primarily a static evaluation of the control cab. Numerous human factors shortcomings were found and recommendations were given. Detailed ML-1 control cab operating procedures were included. Human engineering design criteria were also presented for use in the design of future systems.

The primary HEL effort during this reporting period was to conduct a simultaneous task analysis of the start-up procedures, review the major system components, i.e., Power Conversion Skid (PCS), Reactor, and Gas Storage Skid (GSS), monitor the product improvement program, propose an ML-1A control console, and monitor the training simulator design. Monthly progress reports submitted to the U. S. Atomic Energy Commission (AEC) contained comments, evaluations, and recommendations pertaining to the system. Several of these reports are included herein to provide a current summary of human engineering recommendations on the system. In addition, several new areas which have recently been finalized are discussed, e.g., the Simultaneous Task Analysis.

* A Human Engineering Evaluation of the ML-1 Mobile Low Power Nuclear Power Plant, HEL Technical Memorandum 8-62, April 1962, James E. McMurrer, Jr. & Marlin E. McCahan.

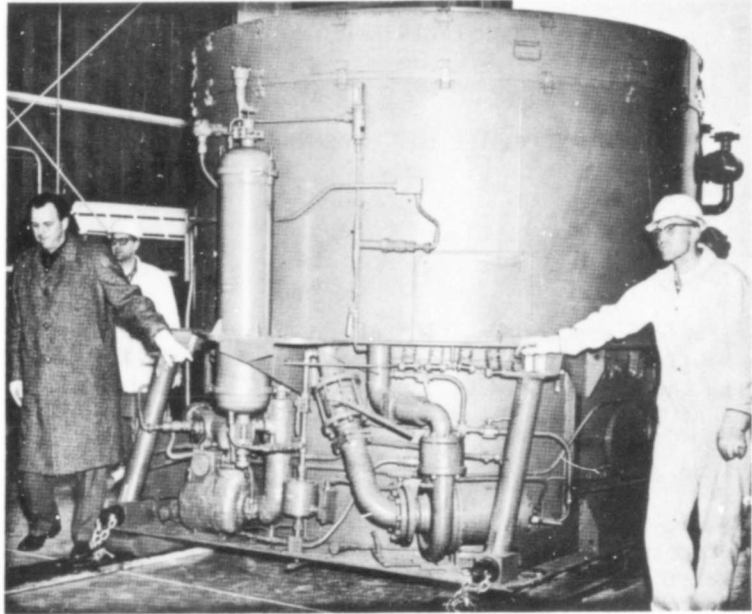


Fig. 2. ML-1 REACTOR SKID

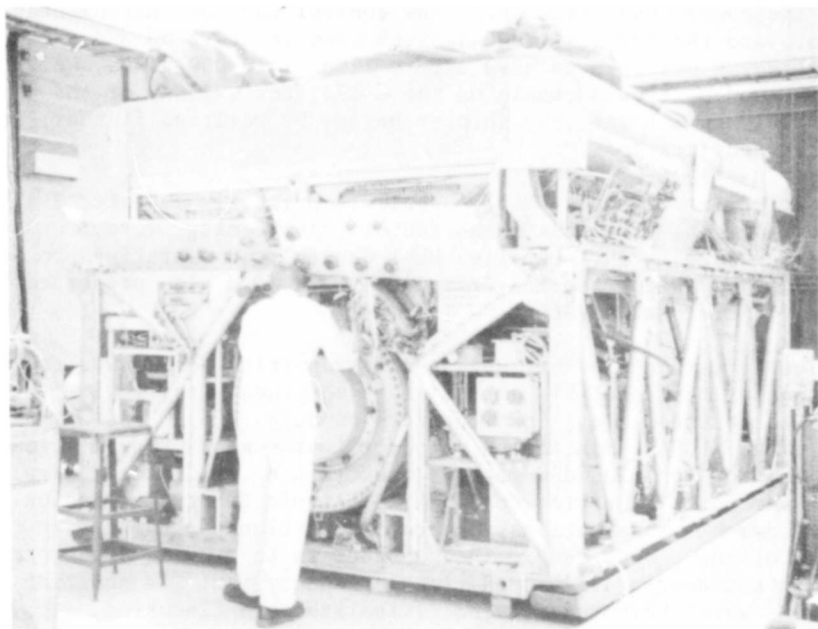


Fig. 3. ML-1 POWER CONVERSION SKID

DESCRIPTION OF MATERIEL

The ML-1 is a compact, transportable, nuclear power plant operating as a conventional Brayton closed-cycle gas turbine plant utilizing a nuclear reactor as the heat source and oxygenated nitrogen (0.5 vol % O_2 + 99.5 vol % N_2) as the power plant working fluid. The power plant is being developed to produce electrical power within the range of 300 to 500 kw., in ambient air temperatures ranging from -65 to $+100^\circ$ F. The power plant equipment is rated to produce a net 300 kw. at 100° F.

The power plant consists of two major skid-mounted power plant packages and a control cab skid as follows:

- a. The reactor skid: This includes the reactor core, shielding, and reactor auxiliaries (Fig. 2).
- b. The power conversion skid: This includes the turbine compressor set, recuperator, pre-cooler, alternator and starting motor, lubrication system, and electrical switch-gear (Fig. 3).
- c. The control cab skid: This includes the instrument and control console for remote plant start-up and operation (Fig. 4 and 5).

Auxiliary equipment (consisting of a cable reel, water treatment equipment, and gas storage equipment) is also skid-mounted.

The reactor and power conversion packages are both mounted on skids equipped with shock mounts. Both packages are rigidly coupled during operation to form a complete power plant, except for the instrumentation and control provisions located remotely in the control cab. Each of the packages may be transported separately on their individual skids, or the reactor and power conversion packages may be coupled into a single unit for transport. The capacity of the C-124 and C-130A does not allow simultaneous transport of reactor and power conversion skids.

The control cab can be located up to 500 feet from the power plant during operation, and is electrically connected to the power plant skids by four armored control cables. The control cab is an inclosed, compact central-control station on skid runners.

The reactor is a heterogeneous, water-moderated type, fueled by enriched uranium dioxide (UO_2). The core consists of 61 pressure tubes connecting the inlet (upper) and outlet (lower) plenum chambers. The reactor heat is transferred to the reference working fluid as it flows through pin-type fuel elements inserted in the pressure tubes. At the ambient design condition of 100° F., the coolant enters the reactor at a nominal 800° F., and leaves at 1200° F. The de-mineralized water moderator surrounds the pressure tubes and flows under forced convection counter-current to the gas flow. The core, reflector, and shielding are inclosed in a tank of borated water during operation to provide additional neutron shielding.

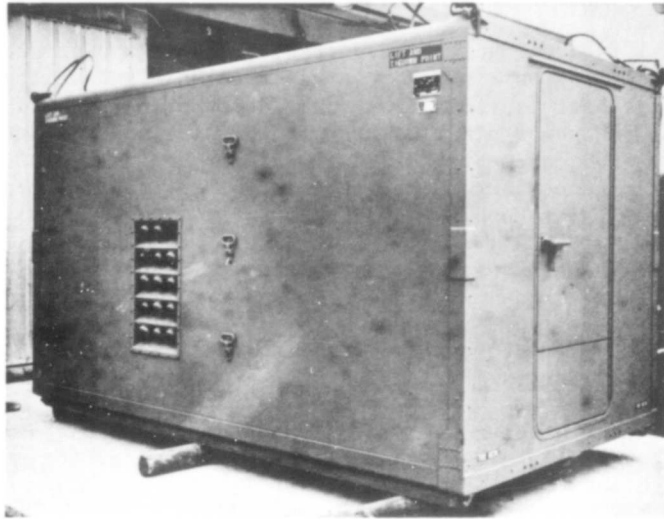


Fig. 4. ML-1 CONTROL CAB -- EXTERIOR



Fig. 5. ML-1 CONTROL CAB -- INTERIOR

Reactor control is effected by six pairs of semaphore-type control blades which sandwich between the pressure tubes. The control blades are actuated by electro-mechanical devices in accessible cavities in the periphery of the shield water tank. Five pairs of blades provide shim-scrum service, and one pair allows fine control of reactivity of the reactor. All blades are fully inserted to scram (emergency shutdown) the reactor.

Major components of the power conversion system are a turbine-compressor set and reduction gear; alternator and starting motor; pre-cooler with fans; recuperator; lubrication system; switch gear and connecting piping and valving. The hot gas leaves the reactor at 1200° F. (Fig. 6); expands in the turbine; passes through the low pressure side of a regenerative heat exchanger (recuperator) and through an air-cooled pre-cooler where the waste heat is rejected to the atmosphere. After being compressed in the compressor, the gas is pre-heated to about 800° F., as it passes through the high pressure side of the recuperator, thence through the reactor to the turbine inlet, completing the cycle. The turbine drives the direct-coupled compressor and the alternator through a gear box. The net useful output from the turbine shaft drives the rotor of a brushless alternator operating at 3600 rpm. The equipment is mounted on a light-weight, shock-isolated skid. The sides of the structure are opened during operations to permit flow of air through the pre-cooler.

For a reactor outlet temperature of 1200° F., the lifetime of the first ML-1 core loading was initially estimated to be about 3000 hours, limited by corrosion. The current estimate is up to 6000-7000 hours with intermediate reshimming. The goal of the second core will be to produce 10,000 full power hours of operation without a requirement for reshimming. At ambient temperatures less than 100° F., it is possible to achieve rated power output with lower reactor temperatures. At an ambient temperature of 50° F., it is possible to reduce the fuel temperature and corrosion, thus about doubling fuel lifetime.

PROCEDURE

Three methods of collecting data were employed: (1) review of equipment design from manuals and blueprints, (2) discussions with designers, and (3) observations of engineering tests.

Methods 1 and 2 were used in combination as a continual process throughout this phase of the evaluation, both in familiarizing personnel with up-to-date design changes and in resolving HEL recommendations.

Method 3 was used at appropriate times where the engineering tests illustrated the various phases of system operation.

In conducting the evaluation, personnel were contacted at the Aerojet-General Plant, Azusa, California; Aerojet-General Nucleonics Plant, San Ramon, California; Vitro Laboratories, Silver Springs, Maryland; and ML-1 Site at the National Reactor Test Station, Idaho.

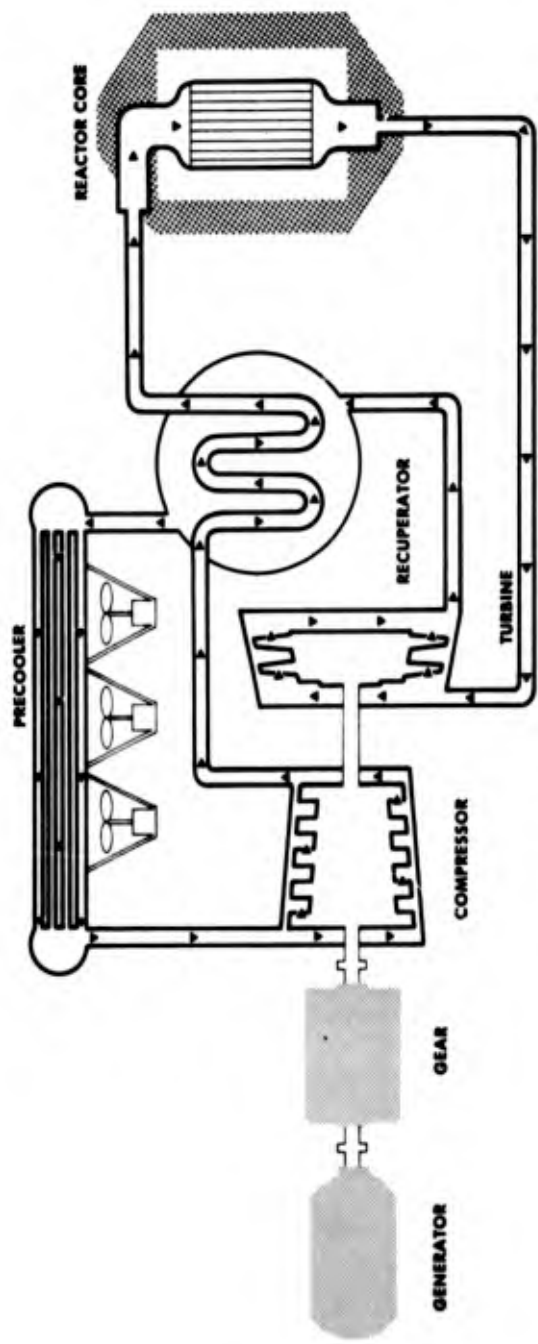


Fig. 6. ML-1 POWER CYCLE

RESULTS AND RECOMMENDATIONS

Over-All System Evaluation

In conducting the human factors evaluation of the ML-1, it was found that stated and defined military field requirements did not exist. It was evident that the absence of such requirements placed a severe handicap on any understanding of the military operations, procedures, and policies involved in the ML-1 system. To answer any questions, one had to rely on the Military Characteristics (MCs) which are very general and do not detail current practices.*

It is recommended that prior to initiating work on the ML-1A, the appropriate military agency formulate stated and defined military field requirements for a field-type ML-1.

These field requirements should include but not be limited to:

a. Type of maintenance policy to be followed, e.g., refueling shall or shall not be conducted by field crews; what items of equipment shall fall into what echelons of maintenance, etc.

b. Extent of support personnel available for setup, operation, and transport.

c. TDs, TO&Es, and missions.

In evaluating the ML-1 for use in a military field environment, three factors are of prime consideration: people, time, and supplies. Following are several comments on critical areas in the ML-1 relating to these factors:

a. Support -- It should be noted that the ML-1 will require considerable support in terms of both personnel and equipment. Some examples are:

(1) Some site preparation may be necessary, particularly in rough terrain.

(2) An earth berm, sand bags, or some other form of expedient shielding may be required to reduce the radiation level for operating personnel.

(3) Power-transmission lines must be rigged to connect the ML-1 with the supported organization.

* The ML-1/ML-1A development program is now being conducted in accordance with the policies and procedures of AR 705-5, Research and Development of Materiel, dated 14 January 1963. These procedures provide a means to define military field requirements.

(4) An Army Water Purification Plant must be ready to provide pure water to the system.

(5) A 500-foot exclusion radius around the reactor must be secured in some manner.

These activities will require the utilization of personnel and equipment from several different military agencies, thereby demanding close liaison and coordination to efficiently complete a mission.

b. Set-up Time -- The MCs for the ML-1 system require that "the plant shall be capable of being installed and delivering rated power within 12 hours after arrival at an operating site." It appears that this requirement will be met; however, only if the equipment is employed on an "emergency" basis. (See the two exceptions to task chart listed on page 15)

In the mobile and fluid battle concepts of the Army, set-up time of a piece of equipment is a major factor. Several missions where the ML-1 may be applicable would probably demand electrical power in a short time span. In many instances conventional sources can be employed that have considerably less set-up time than the ML-1. The ML-1 has many advantages over conventional sources but a faster set-up time is highly desirable.

In any system redesign, methods for reducing set-up time should be given high design priority.

c. Logistics and Supply -- A rather extensive amount of spare parts and supplies may be required to maintain and operate the ML-1 in the field. Certainly, the ML-1 will be unable to rely on the supply system of the unit they are supporting, i.e., the missile system or field hospital, etc., due to the individuality of the ML-1 components, namely filters, pumps, nitrogen, fuel elements, valves, etc. These components will not be standard stocked items and will require a separate logistics and supply system. The logistic and supply system for the ML-1 should be thoroughly investigated at this time to determine its complexity and cost. This investigation might point to several areas in the system design where redesign efforts should be concentrated.

Simultaneous Task Analysis

General Comments on Analysis

A portion of the human engineering evaluation of the ML-1 has been the development of a preliminary simultaneous task analysis. An attempt has been made to predict characteristics of the ML-1A in view of its expected use as a field plant. Since certain characteristics of the ML-1A operation have not been formalized as of this writing, the following ground rules have been made to insure completion of this task analysis:

a. Preparation and deactivation of the ML-1A site are not included in the task analysis; the procedures begin with the arrival of the equipment, to include a fueled reactor, and seven-man operating crew at a prepared site.

b. Although the vehicles are not included as integral equipment to the power plant, the drivers will be expected to assist with such tasks as off-loading the control cab and PCS/Reactor, cable laying, etc.

c. The PCS and Reactor are expected to be transported in a coupled configuration.

d. Since preparation of shield water must begin shortly after arrival at the site, a source of purified water will have to be immediately available.

e. It has been assumed that the moderator system can be filled without use of the moderator pump.

f. It is anticipated that the shield water will be a 10% boron solution. This area is currently under investigation by the contractor, and solutions that may considerably alter the task chart are being considered.

The Simultaneous Task Analysis Chart appears on pages 12 and 13. Comments on critical areas in the preparation of the system begin on page 14.

To aid the crewman during pre-start operations, several checklists have been prepared by examining the available standard operating procedures and separating the non-prototype equipment from the prototype and analysis equipment. These checklists are referenced in the task analysis and begin on this page.

CHECKLIST 1

Gas Storage Skid Valve Positions

V-320-1	CLOSED
V-319-1	CLOSED
V-319-2	CLOSED
V-319-3	CLOSED
V-301-1	OPENED
V-302-1	CLOSED
V-315-2	OPENED

All valves on Gas Handling Panel in Control Cab - CLOSED

CHECKLIST 2

PCS Operations

V-646-5	CLOSED	
V-646-6	OPEN	
V-646-1	OPEN	
V-601-1	Main Lube Pump Suction Valve	OPEN
V-603-1 & -2	Lube Oil Supply Filters	CLOSED
V-603-3	Lube Oil Cooler Vent	CLOSED
V-603-4	Lube Oil Cooler Drain	CLOSED
V-618	Main Lube Sump Drain	CLOSED
V-619	Compressor Seal Gas Supply	OPEN
V-625	Lube Oil Separator Gas Outlet	OPEN
V-634	Lube Oil Separator Gas Outlet Vent	CLOSED

Inlet and Outlet valves on sump equalizing
compressor OPEN

Check the following oil levels:

- Main Lube Oil Sump
- Startup Compressor
- Sump Equalizing Compressor
- Refrigeration Compressor

Check moisture content in refrigeration system working fluid.

Check the following filters:

- Main Oil Sump Filter F-601
- Lube Oil Supply Filters F-604-1, & -2
- Compressor Seal Gas Filter F-621
- Desiccant Gas Filter F-626
- Lube Oil Separator Filter F-643

Insure that all connections are secure.

CHECKLIST 3

Moderator Fill Valve Positions

V-202	OPEN	(Between PCS & Reactor)
V-211	OPEN	(On PCS Cooler)
V-217	OPEN	(On PCS Cooler)
V-206	OPEN	
V-207	OPEN	
V-208-2	OPEN	
V-225	OPEN	
V-231-1	OPEN	
V-231-2	OPEN	
V-232	OPEN	
V-244	OPEN	
V-291	OPEN	
V-221	CLOSED	
V-223	CLOSED	
V-224	CLOSED	
V-226	CLOSED	
V-228	CLOSED	
V-229	CLOSED	
V-242	CLOSED	
V-246	CLOSED	
V-249	CLOSED	
V-222	CLOSED	

O P E R A T O R

Time in hours	A	B	C	D	E	F	Time in hours
1		Offload PCS/Reactor (Assisted by 2 drivers). For detailed operation see AGN TM-389, P. III-21		Assist Operators A & B		Offload Auxiliary Skid (Assisted by 2 drivers). For detailed operation see AGN TM-389, P. III-27	1
2	Connect and secure cables M-1303, -1304, -1305, -1306, -1701, -1901 and -1902 to PCS. Insure that all circuit breakers (C.B.) on PCS are open. Close C.B.'s K and L. Inform cab.	Offload Gas Storage Skid (Assisted by 2 Drivers). For detailed operation see AGN TM-389, P. III-27	Connect and secure cables AGC 60081/8, /10, /11, /12, and /13 to PCS and to reactor. Connect and secure Mod Vent Valve Jumper cable to Reactor. Mount Mod Vent Valve. Check Reactor Demineralizer.		Offload Control Cab (Assisted by 2 drivers). For detailed operation see AGN TM-389, P. III-27	Offload Control Cab (Assisted by 2 drivers). For detailed operation see AGN TM-389, P. III-27	2
2	Prepare Gas Storage Skid (GSS) 1. Remove protective screens. 2. Inspect equipment. 3. Connect and secure cables M-1901 & -1902 to GSS. 4. Check lube level of transfer compressor and vacuum pump; check pressure of N ₂ & O ₂ . 5. Position valves as per Checklist 1. 6. Reinstall protective screens. 7. Connect and secure lines 316 and 317 to GSS. Inform cab.		Fill Moderator System: 1. Set up demineralizer. 2. Attach M-1701 to demineralizer. 3. Connect line 501 between arny purification plant (APP) and demineralizer. 4. Connect line 511 between pipe 509 on demineralizer and pipe 221 on reactor. 5. Position valves as per Checklist 3. 6. Open V-502-1 and V-509-1 when demineralizer meter has power. 7. Open outlet valve on APP. Inform cab.		Prepare Control Cab 1. Supply inv per: turn Start Auxiliary Gen. lights and SAM per OM. 2. Start generator. 3. Prepare cab for AUX per 3. When all ays cables are secured, turn power ON. 4. Unstrap chair, meter cabinet, and servans transmitter. 5. Remove mast sections from stored position. 6. Mount servans and ambient temperature probe to mast and to cab. 7. Mount meter cabinet.	1. Driver will position vehicle containing cables skid within 10 ft of PCS. 2. Attach all cable grip eyes to PCS. 3. Drive truck in direction of Control Cab. Monitor unwinding cables. 4. Stop truck close to Control Cab and rotate reel manually until cables can be detached. 5. One operator will attach cables M-1303, -1304, -1305, and 1306 to control cab. 6. Prepare Control Cab 1. Connect cable. 2. Start generator. 3. When all ays cables are secured, turn power ON. 7. Mount meter cabinet.	2
3	Close C.B.'s C, D, and E. Inform cab. Check out Precooler and Mod/Lube Oil Cooler for AGN Rpt. AN-AGCR-267, June 1963, P. 10-11 and HEL TM 8-62, P. 201, stan K.	1. Close C.B.- J. Inform cab 2. Remove pre-cooler covers. 3. Remove side panels. 4. Perform visual inspection. 5. Inform cab operator when oil sump temp. is and 130°F.	Prepare Shield Water Mixing tank 1. Set up tank T-501. 2. Insert tank supports. 3. Drive in tent pegs, raise tank, and tie ropes. 4. Assemble mixer and stand over tank. 5. Attach electrical cable between demineralizer and mixer. 6. Connect line 504 between demineralizer and tank T-501. 7. Connect line 510 between tank T-501 and reactor shield water input. 8. Complete Filling Mod System 1. Close valves V-211 and V-217 when water appears from these vent lines. 2. Close valve V-225 and outlet valve on APP when water appears from vent on line 225. 3. Close V-502-1 and V-509-1.		1. Close remaining circuit breakers and check rack status. 2. Turn air conditioner ON. 3. Check console status. 4. Check run-safe key switch in SAFE. 5. Test emergency power system. 6. Test SAM system 7. Turn console power key switch ON.	1. Pressurize System - refer to AMSOP 14292 and HEL TM 8-62, P. 194, step I.4. 2. Turn Main Oil Sump Heaters ON.	3

SIMULTANEOUS TASK AN


SIMULTANEOUS TASK ANALYSIS CHART

<p>Offload Gas Storage Skid (Assisted by 2 Drivers). For detailed operation see AGN TM-389, p. III-27</p>	<p>Connect and secure cables W-1303, -1304, -1305, -1701, -1901 and -1902 to PCS. (C.B.) on PCS are open. Close C.B.'s K and L. Inform cab.</p>	<p>Fill Moderator System: 1. Set up demineralizer. 2. Attach W-1701 to demineralizer. 3. Connect line 501 between army purification plant (APP) and demineralizer. 4. Connect line 511 between pipe 509 on demineralizer and pipe 221 on reactor. 5. Position valves as per Checklist 3. 6. Open V-502-1 and V-509-1 when demineralizer meter has power. 7. Open outlet valve on APP. Inform cab.</p>	<p>Prepare Shield Water Mixing Tank 1. Set up tank T-501. 2. Insert tank supports. 3. Drive in tent legs, raise tank, and tie ropes. 4. Assemble mixer and stand over tank. 5. Attach electrical cable between demineralizer and mixer. 6. Connect line 504 between demineralizer and tank T-501. 7. Connect line 510 between tank T-501 and reactor shield water inlets. Complete Filling Mod System 1. Close valves V-211 and V-217 when water appears from these vent lines. 2. Close valve V-225 and outlet valve on APP when water appears from vent on line 225. 3. Close V-502-1 and V-509-1.</p>	<p>Fill Shield Water 1. Open V-503-1 and V-502-1. 2. Open outlet valve on APP to fill tank T-501 (Requires approximately 50 min). 3. Disconnect line 511 between pipe 509 on demineralizer and pipe 221 and reactor, cap line 221. 4. When tank T-501 is full, close outlet valve on APP, V-502-1, and V-503-1. 5. Turn on immersion heaters. 6. When water temp reaches 130°F, add B₂O₃ and turn on mixer. 7. Test solution for proper concentration. 8. Open V-251 and V-253 9. Open V-505-1 to flood shield water pump. 10. Instruct cab operator to start pump. Turn immersion heaters off when level is below them. Instruct cab operator to turn off pump when T-501 is drained and to turn on shield water heaters. 11. Close V-505-1.</p>	<p>Repeat the previous task, Fill Shield Water, until the reactor is within 4 inches of being full and shield water has proper concentration. Since tank T-501 contains 500 gals and 2500 gals are required to fill the reactor, this task will be completed at approximately 10 hrs and 45 mins.</p>
<p>Connect and secure cables AGC 60081/8, /10, /11, /12, and /13 to PCS and to reactor. Connect and secure Mod Vent Valve jumper cable to Reactor. Mount Mod Vent Valve. Check Reactor Demineralizer.</p>	<p>Connect and secure cables W-1303, -1304, -1305, -1701, -1901 and -1902 to GSS. 4. Check lube level of transfer compressor and vacuum pump; check pressure of N₂ & O₂. 5. Position valves as per Checklist 1. 6. Reinstall protective screens. 7. Connect and secure lines 316 and 317 to GSS and PCS. Inform cab.</p>	<p>Prepare Control Cab Start Auxiliary Gen. 1. Supply lvr per: turn 1. Connect cable. Lights and SAM per ON: 2. Start generator. 2. Turn commo system ON: 3. When all sys cables are secured, turn power transmitter. 3. Unstrap chair, meter ON cabinet, and servovane 4. Remove mast sections from stored position. 5. Mount servovane and ambient temperature probe to mast and to cab. 6. Mount meter cabinet. 7. Close remaining circuit breakers and check rack status. 8. Turn air conditioner ON. 9. Check console status. 4. Check run-safe key switch in SAFE. 5. Test emergency power system. 6. Test SAM system 7. Turn console power key switch ON.</p>	<p>1. Pressurize System - refer to ANSOP 14292 and HEL TM 8-62, p. 194, step I.4. 2. Turn Main Oil Sump Heaters ON.</p>	<p>1. Moderator System - Refer to ANSOP 14251. 2. Complete System pressurization procedures. Refer to ANSOP 14292 and HEL TM 8-62, p. 194, Step I.4. Shield System - Refer to ANSOP's 14270 and 14271.</p>	<p>1. Check out Pre-cooler and Mod/Lube Oil Cooler Refer to AGN Rpt. AN-AGCR-267, June 1963, p. 10-11 and HEL TM 8-62, p. 201, step K. 2. Check out Pre-cooler and Mod/Lube Oil Cooler Refer to AGN Rpt. AN-AGCR-267, June 1963, p. 10-11 and HEL TM 8-62, p. 201, step K.</p>
<p>Offload Cable Reel Skid (Assisted by 2 drivers). For detailed operation, see AGN TM-389, p. III-27.</p>	<p>Adjust T-C and re-supervisor pre-stress rods. 1. Note Checklist 2.</p>	<p>1. Close C.B.'s C, D, and E. Inform cab. 2. Check out Pre-cooler and Mod/Lube Oil Cooler Refer to AGN Rpt. AN-AGCR-267, June 1963, p. 10-11 and HEL TM 8-62, p. 201, step K. 3. Close C.B.'s G&H - Inform cab. 4. Remove pre-cooler spring lock rods. 5. Remove pre-cooler spring cell shims. 6. Adjust pre-cooler spring cells. 7. Check bellows assembly tie rods. 8. Close C.B.'s I, J, K - Inform cab.</p>	<p>1. Close C.B.'s J. Inform cab 2. Remove pre-cooler covers. 3. Remove side panels. 4. Perform visual inspection. 5. Inform cab operator when oil sump temp. is 60°F and 130°F.</p>	<p>1. Close C.B.'s C, D, and E. Inform cab. 2. Check out Pre-cooler and Mod/Lube Oil Cooler Refer to AGN Rpt. AN-AGCR-267, June 1963, p. 10-11 and HEL TM 8-62, p. 201, step K. 3. Close C.B.'s G&H - Inform cab. 4. Remove pre-cooler spring lock rods. 5. Remove pre-cooler spring cell shims. 6. Adjust pre-cooler spring cells. 7. Check bellows assembly tie rods. 8. Close C.B.'s I, J, K - Inform cab.</p>	<p>1. Note Checklist 2.</p>




Assist Operators C & D

SIMULTANEOUS TASK ANALYSIS CHART

<p>K and L. Inform cab.</p> <p>Prepare Gas Storage Skid (GSS)</p> <ol style="list-style-type: none"> 1. Remove protective screens. 2. Inspect equipment. 3. Connect and secure cables W-1901 & -1902 to GSS. 4. Check lube level of transfer compressor and vacuum pump; check pressure of N₂ & O₂. 5. Position valves as per Checklist 1. 6. Reinstall protective screens. 7. Connect and secure lines 316 and 317 to GSS and PUS. Inform cab. 	<ol style="list-style-type: none"> 1. Close C.B.'s J. Inform cab. 2. Remove pre-cooler covers. 3. Remove side panels. 4. Perform visual inspection. 5. Inform cab operator when oil sump temp. is 60°F and 130°F. 	<ol style="list-style-type: none"> 1. Close C.B.'s C, D, and E. Inform cab. 2. Check out Pre-cooler and Mod/Lube Oil Cooler Refer to AGN Rpt. AN-AGCR-267, June 1963, p. 10-11 and HEL TM 8-62, p. 201, step K. 3. Close C.B.'s G and H - Inform cab. 4. Remove pre-cooler spring lock rods. 5. Remove pre-cooler spring cell shims. 6. Adjust pre-cooler spring cells. 7. Check bellows assembly tie rods. 8. Close C.B.'s F. Inform cab. 	<ol style="list-style-type: none"> 1. Adjust T-C and re-supervisor pre-stress rods. 	<p>Offload Cable Reel Skid (Assisted by 2 drivers). For detailed operation, see AGN TM-389, p. III-27.</p>	<p>Assist Operators C & D</p>	
<ol style="list-style-type: none"> 4. Connect line 511 between pipe 509 on demineralizer and pipe 221 on reactor. 5. Position valves as per Checklist 3. 6. Open V-502-1 and V-509-1 when demineralizer meter has power. 7. Open outlet valve on APP. Inform cab. 	<p>Prepare Shield Water Mixing Tank</p> <ol style="list-style-type: none"> 1. Set up tank T-501. 2. Insert tank supports. 3. Drive in tent pegs, raise tank, and tie ropes. 4. Assemble mixer and stand over tank. 5. Attach electrical cable between demineralizer and mixer. 6. Connect line 504 between demineralizer and tank T-501. 7. Connect line 510 between tank T-501 and reactor shield water sump. 8. Complete Filling Mod System 9. Close valves V-211 and V-217 when water appears from these vent lines. 10. Close valve V-225 and outlet valve on APP when water appears from vent on line 225. 11. Close V-502-1 and V-509-1. 	<p>Fill Shield Water</p> <ol style="list-style-type: none"> 1. Open V-503-1 and V-502-1. 2. Open outlet valve on APP to fill tank T-501 (Requires approximately 50 min). 3. Disconnect line 511 between pipe 509 on demineralizer and pipe 221 and reactor, cap line 221. 4. When tank T-501 is full, close outlet valve on APP, V-502-1, and V-503-1. 5. Turn on immersion heaters. 6. When water temp reaches 130°F, add B₂ O₃ and turn on mixer. 7. Test solution for proper concentration. 8. Open V-251 and V-253 9. Open V-505-1 to flood shield water pump. 10. Instruct cab operator to start pump. Turn immersion heaters off when level is below them. Instruct cab operator to turn off pump when T-501 is drained and to turn on shield water heaters. 11. Close V-505-1. 	<p>Repeat the previous task, Fill Shield Water, until the reactor is within 4 inches of being full and shield water has proper concentration. Since tank T-501 contains 500 gals and 2500 gals are required to fill the reactor, this task will be completed at approximately 10 hrs and 45 mins.</p>	<p>Shield System - Refer to ANSOP's 14270 and 14271.</p>	<p>Shield System - Refer to ANSOP's 14270 and 14271.</p>	
<ol style="list-style-type: none"> 1. Mount main cable. 2. Mount main cable. 3. Close remaining circuit breakers and check rack status. 4. Turn air conditioner ON. 5. Check console status. 6. Check run-safe key switch in SAFE. 7. Test emergency power system. 8. Test SAM system 9. Turn console power key switch ON. 	<ol style="list-style-type: none"> 1. Pressurize System - refer to ANSOP 14292 and HEL TM 8-62, p. 194, step I.4. 2. Turn Main Oil Sump Heaters ON. 	<ol style="list-style-type: none"> 1. Check out Pre-cooler and Mod/Lube Oil Cooler Refer to AGN Rpt. AN-AGCR-267, June 1963, p. 10-11 and HEL TM 8-62, p. 201, step K. 1. Moderator System - Refer to ANSOP 14251. 2. Complete System pressurization procedures. Refer to ANSOP 14292 and HEL TM 8-62, p. 194, Step I.4. 				

OPERATOR

A	B	C	D	E	F	Time in hours
	<ol style="list-style-type: none"> 1. Check that the pressure meter on N₂ static seal bottle reads _____. 2. Call control cab and check that static seals switch/indicator is in "PRESS" position. 3. When cab operator calls, open V-603-1, V-603-2, and bleed air from oil cooler thru V-603-3. 4. Close C.B. - B. Inform cab. 5. Reinstall side panels. 6. Clear area. 			<p>Lube System - Refer to AMSOP 1A131.</p>		10
	<ol style="list-style-type: none"> 1. Disconnect hoses and cap lines. 2. Disassemble mixer and stand. 3. Disassemble tank T-501. 4. Remove all equipment from PCS area. 5. Clear area. 			<p>Speed control system checks - Refer to AMSOP 1A210 and HEL TM 8-62, p. 196-201, step J.</p>		10
	<p>Return to control cab area and assist with clean up operations.</p>	<ol style="list-style-type: none"> 1. Flush out hoses. 2. Rinse out tank T-501. 3. Store all equipment. 		<p>Non-nuclear SCRAM checks - Refer to AMSOP 1A070 and HEL TM 8-62, p. 203-206, step N.</p>		11
				<p>Nuclear Instrumentation Checks - Refer to HEL TM 8-62, p. 206-210, step O</p>		11
				<p>Control Blade System Checks - Refer to HEL TM 8-62, p. 210-213, step P.</p>		12

TANEIOUS TASK ANALYSIS CHART (Continued)

11	12	13	
<p>Nuclear Instrumentation Checks - Refer to HEL TM 8-62, p. 206-210, step 0</p>	<p>Control Blade System Checks - Refer to HEL TM 8-62, p. 210-213, step P.</p>	<ol style="list-style-type: none">1. Perform Reactor Startup Operations - Refer to ACR Rpt. AN-ACCR-266, June 1963, p. 5-8, and HEL TM 8-62, p. 213-2182. Supply customer load.	

11	12	13	
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Comments on Critical Areas

The information received from the contractor indicates that the time required to prepare the shield water solution and fill the shield water tank is approximately ten hours. The process of filling the shield tank cannot commence until power is available to the shield water pump. Referring to the task chart, this is not available until approximately two hours after the ML-1 arrives at the set-up site. The actual start-up of the plant cannot commence until all personnel have left the PCS area. This means start-up cannot begin until 12 hours have elapsed. This does not meet the MCs.

It is recommended that the entire area of shield tank filling be investigated, i.e., new method of fill, different composition of shield solution, different methods of preparation, etc.

There are several methods of easing the burden of shield water preparation. The discussions below will not dwell with the detailed economics of the problems but merely with the apparent advantages and disadvantages of each method.

Additional Preparation Equipment

Additional preparation equipment could be utilized for the field ML-1. This equipment could be in the form of additional tanks, additional mixers and heaters, additional makeup demineralizers, or any combination of the above.

The additional equipment will place an increased burden of maintenance on the personnel. The supply of the unit will have to be increased to keep all the equipment serviceable. Additional personnel may or may not be required to operate the equipment. The amount of time required to prepare the water will be decreased.

Larger-Capacity Equipment

By the use of larger-capacity equipment, the preparation time could be cut. A demineralizer with a greater output, larger heaters with more heating power, a larger mixer, a larger tank used in connection with any of the above, or any combination of the above could result in less preparation time. Training of personnel for maintenance and handling of this larger-capacity equipment would probably be increased. This larger-capacity equipment would probably require more power to operate.

The ML-1A specification package, paragraph 3.1.2.4.3.1, references a standard military water-purification equipment capable of delivering 600 gallons per hour. With the use of larger-capacity equipment this output would have to increase.

New Solution

A new solution could be used for the shield water. The contractor is presently considering a solution of B₁₀. This B₁₀ will stay in solution easier, will go into solution at a lower temperature, and less quantity required than the present solution.

The B₁₀, however, does cost considerable more than the present solution.

Use of Military Tanker

The military system presently uses a semitrailer, alcohol, 3000 gallons, 2-W, XM388, to supply fuel to the REDSTONE missile. This tanker has an aluminum tank, recirculating system, metering device, immersion heaters, and a 250 gpm. pump.

HEL feels that AEC should investigate the use of this tanker for transport and preparation of the shield water. If the philosophy of support teams for several ML-1 field units is accepted, this tanker could be assigned to the support group and service all the designated units. The preparation of shield water could be performed at a central location and merely pumped straight into the reactor from the tanker in the field. This would decrease both start-up time and equipment from the field plant.

The task chart represents one possible mode of operation. Two important exceptions to this chart should be noted:

(1) One of the ground rules stated on page 9 was that the reactor would be transported with the fuel elements in the core. Transportation in this configuration may not be in accordance with accepted procedures during peace-time missions. If the reactor is to be fueled at the site, the chart must be altered to include the corresponding tasks.

(2) Another assumption stated on page 9 was that the PCS and Reactor will be transported as a coupled unit. In this configuration, the "trailer tandem axle loads exceed the axle loading and gross weight allowances of any state of the United States" (Reference page III-1, AGN Rept TM 389). Thus the normal transport configuration would be as separate units. If the set-up time for the normal condition is desired, the task chart would have to be altered to reflect the additional unloading and coupling tasks.

One of the tasks performed by crewmen 3 and 4 is to "Fill Shield Water". This task includes testing of the shield solution by one of the crewmen using a Boron Field Test Kit. This kit was designed and developed by the contractor. The kit is not one which is readily usable for field units. The test must be conducted in a controlled environment and borders on a lab-type experiment. This in itself is time consuming. It would be better if the test could be conducted simply and easily.

When the final decision is made as to the nature of shield solution, a thorough investigation should be conducted to determine if a simple and direct method of testing the solution could be developed.

One method of attack could be to request an investigation for an acceptable field test by the U. S. Army Chemical Corps.

One of the control cab operator's tasks is to remove the meter cabinet from its shipping case and mount it in the cab. This task is both cumbersome and time consuming. HEL has commented on this meter cabinet previously; however, no effort has been exerted toward improvement of this situation. When the ML-1 reaches the field unit stage, the meter cabinet, which is supposed to be a delicate piece of instrumentation, should be shock mounted in the control cab as a permanent chassis.

Component Review

The Power Conversion Skid (PCS), Reactor, and Gas Storage Skid (GSS) were investigated in detail to determine the possible human engineering problem areas. The evaluation was performed during the period 17-23 June 1962 at the National Reactor Test Station. Reports containing comments, evaluations, and recommendations on the individual components are included as part of the monthly progress reports to AEC covering the periods 13-30 June 1962 for the PCS and 1-31 July 1962 for the Reactor and GSS (See Appendix A).

Project Improvement Program

The ML-1 Change Status Reports issued monthly by AGN that describe the ML-1 Power Plant Changes have been continually reviewed, and appropriate changes have been discussed with AGN personnel in detail. Following are HEL comments and recommendations on several of the changes. All comments are referenced to ANSOL #0803.

a. 0803-58A Control Cab: Lockout Automatic Control During Startup.

An interlock has been added to the circuitry to prevent the system from entering the automatic mode when the reactor power is not high enough, even though the operator activates the switch. To aid the operator, a white panel light has been added to the annunciator with the label, "REACTOR POWER LOW FOR AUTO". This annunciator panel will be lighted until the predetermined level has been reached.

This method of informing the operator degrades the purpose of the annunciator. The annunciator should only display those parameters which can be detrimental to the system. The "REACTOR POWER LOW FOR AUTO" indication is one of status of the system during start-up and should be mounted on the console.

Another problem with this design is that the operator must note the point at which the light goes out to determine when to switch to automatic. A more direct indication of a "go" status would be an indicator which would light when the proper power level is reached.

Recommendation

Alter change -58A to eliminate the portion of the change dealing with the annunciator. Instead, mount a green indicator labeled "REACTOR READY FOR AUTO" adjacent to the automatic switch. The indicator should extinguish upon switching to the automatic mode, in order that the operator not be faced with useless information during normal power operations.

- b. 0803-112 and 113 Control Cab: Speed Control for Precooler and Moderator Fans.

Placards have been placed adjacent to the precooler and moderator fan controls warning the operator to turn off the fans for 20 seconds before switching from fast to slow speed. If this precaution is not followed, the fan motors may burn out. AGN has investigated the use of a time-delay switch and found that, with the existing wiring and controls, a time-delay switch would introduce a signal to the scram logic chassis which would be interpreted as a loss of power signal. This would generate a scram.

Placards do not prevent the operator from operating the fans incorrectly. A distracted operator could inadvertently ignore the caution with serious consequences to both the system and the mission.

Recommendation

On field plants, time-delay switches be used to turn off the moderator and precooler fans for 20 seconds when switching from fast to slow speeds, and the wiring be such that scram signals are not generated. If this recommendation is incorporated, the warning placards should be removed.

- c. 0803-120 Control Cab: Lube Oil Separator Control System.

Floats, valves, and switches have been added to the separator tank. One switch/indicator and two indicators have been added to the console to inform the operator of the conditions in the separator. The first indicator shows the operator that the oil is low. The second indicator shows the operator that the oil is high. The switch/indicator shows the operator that the oil is extra high and that an overflow valve has opened

and is removing the extra oil. The switch portion of the switch/indicator serves as a manual backup to the automatic system. The high and low indicators are misnomers. The oil is supposed to fluctuate between these levels. As a result these two indicators are constantly going on and off, the normal cycle being approximately 30 seconds. Certainly the operator will not be required to monitor this cycle to insure that the separator is functioning properly. In fact, the operator will probably tend to ignore the flashing lights.

However, the operator should be warned if the separator is not functioning properly. Therefore, there should be two amber alarms (OIL SEP TANK LEVEL HIGH and OIL SEP TANK LEVEL LOW) on the annunciator panel, which will activate when the oil level goes beyond the normal high or low levels.

No one is quite sure what the operator will do if the overflow valve indicator comes on but does not clear up the overflow condition.

Recommendation

This entire area should be carefully examined, and the high and low indicators and the switch portion of the overflow switch/indicator be eliminated from the console. Two amber alarms (OIL SEP TANK LEVEL HIGH and OIL SEP TANK LEVEL LOW) should appear on the annunciator indicating when the oil level goes beyond the normal high or low levels. It is further recommended that AGN find out what to do if the overflow valve cannot clear up the extra-high situation.

d. ANSOL 0803-188 Control Cab: Scram Logic Coincidence Switch Relocation.

The scram logic coincidence switch has been relocated from inside the chassis to the chassis panel face to permit better access for the operator. The switch has two positions: "ONE OUT OF THREE" and "TWO OUT OF THREE". The position of this switch determines how many of the three high-power nuclear channels must be inoperable to effect a scram.

It is understandable that a switch of this nature would appear in an accessible position on an experimental or test reactor; however, it would seem difficult to justify accessibility on a field plant where the operator might decide to temporarily avoid a scram. In order to perform maintenance, a coincidence switch would be desirable; such a switch should not be easily accessible to an operator.

Recommendation

On field plants, the coincidence switch should be eliminated from the front panel but should appear on the chassis behind the panel.

e. 0803-206 Control Cab: Reactor Outlet Temperature Meter Replacement.

The Reactor Outlet Temperature meter on the console has been replaced with a new meter which has a range of 0° F. to 1500° F. with major markings at every 100° and numerals at every 300°. The meter, because of the existing wiring in the chassis, zeros at 600° F. These characteristics are contrary to good human engineering design.

Recommendation

The Reactor Outlet Temperature meters have a range of 0° F. to 1400° F. (this is maximum required) and be numbered at every 200°. The meter should zero at 0° F.

f. 0803-208 Control Cab: Scram Bypass Annunciator.

The new annunciator panel "SCRAM BYPASSED" now incorporates only the process scrams. The operator should have an indication when any scram is bypassed.

Recommendation

This annunciator should include the nuclear scram bypasses.

g. 0803-216A Human Engineering Improvements

In concurrence with an HEL recommendation, a headset is being provided to the operator in the control cab. Due to difficulties experienced in communicating over the intercom system at Idaho, a headset is also being provided for the PCS operator. The model numbers for the sets are:

(1) REMLER-A-359C1 (one earmuff for the cab operator)

(2) REMLER-A-359D1 (two earmuffs for PCS operator)

These headsets should be checked to verify that they meet military specifications. Further investigation should be made into available headsets that are GFE.

Recommendation

The entire commo package should be GFE.

h. 0803-221: Shield Water Conductivity System

When AGN switched from a 2% boric acid solution for the shield system to a 10% boric acid solution, they discovered that the meter on the chassis was not able to register the conductivity. By adding a resistor to the circuitry they were able to use the present meter, but, in order to read the conductivity correctly, the operator now has to multiply the chassis meter reading by two and the control console meter reading by 20.

On the field plant the meters should read correctly without interpolation by the operator.

Recommendation

Redesign the circuitry to the shield water conductivity meters such that the meters can be read directly without multiplication factors.

ML-1A

Recommended ML-1A Control Console Layout

The recommended layout of the ML-1A control console and cab was completed and submitted to the Gas-Cooled Reactors Branch (Army Reactors), Division of Reactor Development, U. S. Atomic Energy Commission, in the HEL monthly progress report for the period 1-31 October 1962. The recommended layout is inclosed in this report as Appendix B.

As a result of (1) a review of this layout by AEC personnel and contractor (AGN) personnel at NRTS, and (2) expected changes or actual prototype hardware modifications at NRTS, several changes have been recommended by NRTS for the HEL proposed layout.

These changes are included in a letter from Mr. R. L. Morgan, Idaho Operations Office, to Mr. C. E. Miller, AEC Headquarters, dated 7 Feb 1963, Subject: HEL Proposed ML-1A Control Cab Layout.

HEL has reviewed this letter and concurs in several of the recommended changes. The HEL proposed layout will not be altered at this time, but the changes indicated below and any subsequent ones will be considered during the ML-1A design phase.

The following paragraphs have been extracted from the referenced letter. HEL comments are given immediately following the statement to which they pertain:

1. Speed Control System

- a. *The by-pass valve control may require considerable manipulation. It would appear that its present location on the panel (which seems to require the operator to stand up) is not convenient for an average right handed operator.*

HEL Comment

It has been the understanding of these laboratories that there would be little or no necessity of manually positioning the by-pass valve after initiating the automatic mode of operation. Future testing of the power plant at NRTS should verify the reliability of the automatic speed control, and until this time the by-pass valve position control knob will remain as recommended.

- b. *Because of technical considerations, in switching from automatic to manual control it is highly desirable to have an indication of where the manual control knob is set in relation to the actual by-pass valve position. This can be done by either combining the knob with the turbine speed meter, or by putting a scale around the knob in its present position.*

HEL Comment

A scale and pointer arrangement could be added to the by-pass valve position control knob to permit prepositioning of the knob prior to shifting from automatic to manual control, thereby reducing the chance of introducing violent changes in the valve positioning. The scale would be engraved on the panel and marked off so as to be consistent with required accuracy.

- c. *It is felt the "overspeed valve open" light should be of such a color as to indicate a scram condition.*

HEL Comment

Even though the overspeed valve opens as a result of a SCRAM condition, i.e., turbine overspeed, it is not the cause of the SCRAM condition and by itself does not indicate a "NO-GO". It is, in fact, a condition that the operator wants to see in conjunction with the TURBINE SPEED HIGH annunciator. For this reason, the OVERSPEED VALVE OPEN indicator should remain amber.

2. Gas System

- a. *In order to accurately determine reactor power and to calibrate nuclear channels, reactor inlet temperature should be indicated. This could be done by using the reactor outlet temperature meter with a selector switch.*

HEL Comment

The reactor outlet temperature meter could be used as suggested; a two-position selector switch would normally be set at OUTLET and spring-loaded to the INLET position. The meter title could be changed to REACTOR TEMPERATURE.

- b. *Consideration should be given to having an indication of gas flow. With the described instrumentation, the only method of determining flow is by use of a compressor map.*

HEL Comment

The information is not necessary for operation of the power plant. If desired for calibration, a meter could be placed on the racks.

3. Electrical System

- a. *The "PCS-GEN" indicator under the frequency meter may be more clear if it were labeled "ALT" or "PCS-OUT".*

HEL Comment

PCS-GEN should be changed to PCS-ALT.

- b. *It may be desirable to have the electrical system and the power transfer system grouped together.*

HEL Comment

A rearrangement may be considered at a later date.

4. Lubrication System

- a. Bearing outlet temperatures should definitely be monitored. Although there is one annunciator for high bearing temperatures, it is highly recommended that all critical bearing outlet temperatures be monitored. There should be an indication as to which bearing outlet is being monitored. A possible solution is one temperature meter with a selector switch.

HEL Comment

This information could be made available on the racks.

- b. Although there is one annunciator indicator for bearing flow, it would be desirable to monitor the Δp across all critical bearings. This might be accomplished with one meter and a selector switch.

HEL Comment

This information could be made available on the racks.

5. Shield/Moderator Systems

- a. There should be an indication of moderator water purity and shield water poison concentration (e.g., conductivity, or resistivity). While these limits are annunciated, it is felt that it is particularly important to monitor moderator water purity in order to foresee the need to change demineralizer resin.

HEL Comment

A meter to measure moderator water purity and shield water conductivity could be placed on the racks.

6. Clutch Power

- a. The function (volts or amps) being read when the selector switch is at SAFE 1, SAFE 2, etc., should be specified.

HEL Comment

Figure 7 is a method whereby the function can be designated at the subject conditions.

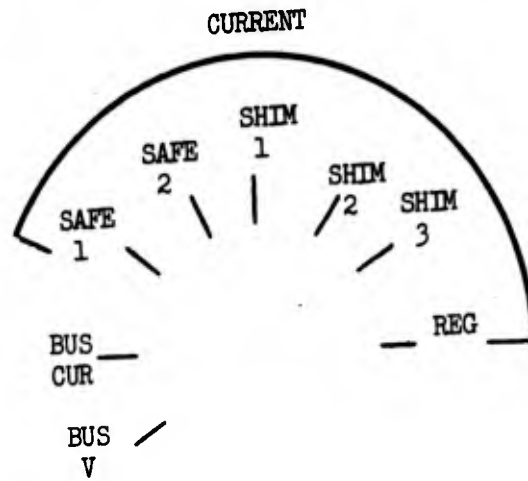


Fig. 7. LAYOUT OF NOMENCLATURE ON CLUTCH COILS METER SELECTOR SWITCH

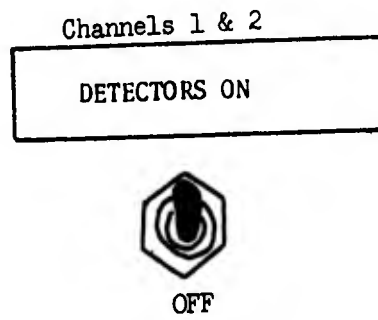


Fig. 8. LAYOUT OF CHANNELS 1 & 2 SWITCH AND INDICATOR

b. *The function of the power reset is not clear.*

HEL Comment

The POWER RESET switch performs the same function as the switch portion of the TRANSFER SWITCH SCRAM BYPASS (HEL TM 8-62, para 3.2.35.1) in the ML-1.

c. *The meaning and function of "Scrams By-passed" indicator is not clear.*

HEL Comment

The SCRAMS BYPASSED indicator is the same as the indicator portion of the TRANSFER SWITCH SCRAM BYPASS (see above reference).

7. *Nuclear Instrumentation*

a. *Channel 1 and 2 switch may be more properly labeled "High Voltage ON" and "High Voltage OFF".*

HEL Comment

The indicator above the CHANNEL 1 and 2 switch could be labeled HIGH VOLTAGE ON or DETECTORS ON. The OFF condition would be represented by the switch position. The layout would then be as shown in Figure 8.

b. *According to HEL criteria, green does not seem to be the proper color for channel 1 and 2 ON indicator since at normal power the high voltage should not be on.*

HEL Comment

The indicator should be white. The text description is in error; the photograph is the intended layout.

8. Power Transfer

- a. *The middle position of the selector switch under the synchroscope may be more clear if it were labeled "ALT".*

HEL Comment

The title should be changed from PCS-GEN to PCS-ALT to be consistent with 3a above. The indicator under the PLANT POWER selector switch should also be labeled PCS-ALT.

9. Control Blade System

- a. *It should be noted that the present ML-1 blade control system contains both mechanical and electrical interlocks to prevent simultaneous rod withdrawal whereas this system appears to contain only electrical interlocks. The relative merits of a possible reduction in safety should be weighed against the value of the standardization to be gained by using the described system.*

HEL Comment

Toggle switches for blade operation will be pull-to-unlock to prevent accidental actuation. The interlock, which prevents actuation of more than one switch, can be provided electrically.

- b. *The use of various color lights in this system seems to lack complete consistency.*

HEL Comment

No change is anticipated in the color coding of the indicators. In determining the color coding for the control blade system, HEL assumed a specific operating rod pattern; namely that the rod position for each shim will be roughly identical during operation. Therefore, none of the shim blades should ever be in their full out position; thus the amber OUT indicator. The regulating blades should not be full out or in; thus the amber color for its OUT and IN indicators. If this assumption is not valid it is conceivable that a full out position of one of the shims could be a normal condition warranting a green light. The final design for color coding of the indicators will be determined when the operating rod pattern is fixed.

10. Auxiliary Electrical Equipment

a. Moderator

- (1) *The description of the switch labeling for the standby moderator pump is not consistent with the photograph.*

HEL Comment

The photograph is in error; the text description is the intended layout.

- (2) *There appears to be duplication of indication of the standby moderator pump on here and on the annunciator.*

HEL Comment

Complete and accurate information on the Standby Mod Pump System is not available to HEL at this time. A redesign of these controls is presently being considered.

- (3) *The description of the switch labeling for the "Scram By-pass" control is not consistent with the photograph.*

HEL Comment

The photograph is in error; the text description is the intended layout.

b. Static Seals

- (1) *Unless the static seals are interlocked with the start motor, there should be a red indicator light labeled ON.*

HEL Comment

It is anticipated that the static seals will be interlocked with the start motor.

c. *Startup Compressor*

- (1) *The description of the manual control switch labeling is not consistent with the photograph.*

HEL Comment

The photograph is in error; the text description is the intended layout.

- (2) *The description of Tach Relay Override switch labeling is not consistent with the photograph.*

HEL Comment

The photograph is in error; the text description is the intended layout.

d. *Standby Oil Pump*

- (1) *The description of the manual control switch labeling is not consistent with the photograph.*

HEL Comment

The photograph is in error; the text description is the intended layout.

- (2) *The description of the Tach Relay Override control switch labeling is not consistent with the photograph.*

HEL Comment

The photograph is in error; the text description is the intended layout.

11. *Annunciator System*

- a. *In the sixth row, "Mod Water Precooler Outlet Temp Low" indicator should be labeled "Mod Water Cooler Outlet Temp Low", and "Mod Water Precooler Outlet Temp High" indicator should be labeled "Mod Water Cooler Outlet Temp High".*

HEL Comment

As suggested, the two annunciators in question should read MOD WATER COOLER TEMP LOW and MOD WATER COOLER OUTLET TEMP HIGH.

- b. *In the eighth row standby oil pump activation is indicated; this is a duplication of an indication on the auxiliary electrical equipment panel.*

HEL Comment

The annunciator STANDBY OIL PUMP ACTIVATION could be eliminated.

- c. *In the tenth row the reason for white lights (as opposed to amber) is not clear.*

HEL Comment

The color coding of the annunciator indicators will be examined by HEL.

- d. *Standby Moderator Pump Indicator - (See comment 10.a.2 above).*

HEL Comment

Complete and accurate information on the Standby Mod Pump System is not available to HEL at this time. A redesign of these controls is presently being considered.

- e. *It is to be noted that the ML-1 presently incorporates a scram for compressor inlet pressure low. This is a backup for the fast pressure loss scram. If this backup scram is to be incorporated in ML-1A, an additional annunciator should be added.*

HEL Comment

If this scram is included in the ML-1A, the appropriate annunciator will be added.

- f. *It is felt that the scram control and the Alarm Silence should be in a more accessible position which does not require the operator to stand up to reach them.*

HEL Comment

These laboratories maintain their previous position with regard to these controls (Ref: HEL Technical Memorandum 8-62, pp: 43 and 44), and recommend adoption as is described in the text and photograph.

12. *General Comments*

- a. *Since details of the racks are not presented, it can only be assumed certain instruments and controls are located there such as instrument calibration and test controls, coincidence switches, emergency power controls, etc.*

HEL Comment

In general, recommended rack design is included in HEL TM 8-62. It is suggested that detailed layout of chassis be postponed until such time as their content is more fully finalized.

- b. *It is recommended that all automatic scrams have provisions for manual reset.*

HEL Comment

This suggestion appears to have merit and will be considered during the design of the ML-1A.

- c. *It is recommended that ambient temperature, and wind velocity and direction indicators be included.*

HEL Comment

An accurate, reliable, inexpensive thermometer might be an aid to an experienced operator. The anemometer is of questionable value as it would not have power at such time as its readings would be of value.

- d. *It is recommended that provisions be made for "load dump".*

HEL Comment

The "load dump" would only duplicate the function of the OUTGOING CIRCUIT BREAKER.

- e. *It is recommended that provision be made for incorporating a multichannel variable speed power recorder in the cab.*

HEL Comment

A recorder of this type might be of value in an ML-1A. This recommendation will be reconsidered during the design phase of the ML-1A.

- f. *It is recommended that provisions be made for bypassing the safe 1 and 2 interlocks.*

HEL Comment

Only two reasons are obvious for providing by-passes on the SAFE 1 and 2 interlocks: (1) to save time during start-up procedures, and (2) to save wear and tear on the drive motors when testing or performing start-up procedures. Neither of these reasons seem applicable in a tactical system since only about 20 minutes are saved. It is anticipated that neither testing nor start-up will be performed that often that motor life will be seriously shortened. A serious safety problem would be present with the by-pass switches since they permit the operator to go critical on the SAFE BLADES. Provisions for by-passing SAFE 1 and 2 interlocks should not be provided.

- g. *It is recommended that necessary controls for an emergency seal gas system be included.*

HEL Comment

If an emergency seal gas system is included in the ML-1A, controls for this system should be incorporated.

- h. *It is recommended there be provisions made for an oscilloscope to be installed in the cab for maintenance and calibration purposes.*

HEL Comment

The presence of maintenance and calibration equipment in the cab is fully dependent on the design of the ML-1A system. If it is expected that the equipment is relatively unstable and will require maintenance and calibration at a high frequency, then there is no alternative but to provide oscilloscopes, etc., in the cab. The further consequences of this action are that each operator must be trained to perform these functions, thereby requiring higher caliber personnel and extensive training periods.

If, however, maintenance and calibration are to be performed at a low frequency, it could be done at a higher echelon and there would be no need for oscilloscopes, etc., in the cab.

A fully tactical field system should be designed along the latter lines and the HEL proposal reflects this design.

- i. *It is to be noted that no provisions are made for an emergency cooling system or an ultimate shutdown system.*

HEL Comment

If an emergency cooling system or an ultimate shutdown device is included in the ML-1A, controls will be incorporated.

- j. *It is recommended that an evaluation of the system for defining the proper color of indicator lights be made. While the system used in this design is generally consistent with previous HEL criteria for nuclear power plants, it is in many cases contrary to standard practice.*

HEL Comment

Reference: Military Specification, General Specification for Nuclear Power Plant Control and Instrumentation Equipment, MIL-N-___, (CE) (Tenative), 15 June 1960.

Paragraph 3.7.8.1 defines a color coding scheme which is identical to the HEL criteria (TM 8-62, para 6.1.2) except for the blue indicator. It would seem that this code has been accepted as standard practice.

- k. *If a compressor low scram is to be included in the ML-1A, it is recommended that a bypass for it be included.*

HEL Comment

The need for a by-pass for a compressor pressure low scram seems questionable for a tactical field system. If a low compressor pressure is a serious enough condition to warrant a scram, an operator shouldn't have the alternative of a by-pass. No change is contemplated in this subsystem.

- l. *It is recommended that an annunciation of seal Δp be included.*

HEL Comment

The seal Δp could be annunciated as suggested.

- m. *This review has been made without consideration of ML-1 improvements and changes which may be accomplished in the future such as use of air as a coolant and use of a DC start motor.*

HEL Comment

The proposed ML-1A console layout will be modified to reflect the proper coolant and a DC start motor at such time as these changes are included in the system.

ML-1A Specification Review

AEC sent HEL a final draft of the ML-1A Performance Specification, AGC-60222, dated 2 November 1962. This specification established the requirements for the design and fabrication of a mobile nuclear gas-cooled power plant. AEC requested HEL to review the subject Specification and submit any comments to them.

The specification was reviewed by HEL. The following formal comments were transmitted to AEC by letter report on 23 Nov 1962.

1. General Comments:

a. Although the subject specification describes the environmental and transportability expectations of the ML-1A, it does not describe those tests, in sufficient detail, which will qualify this equipment in these categories.

b. Reference paragraph 4.2 Test Program. The last sentence states, "Integral test operation of the power plant utilizing the reactor as an energy source is not considered a part of this specification". The advisability of omitting the requirement for an integral test operation (i.e., "system" test) is questioned by these laboratories. If such a program is anticipated, it should be mentioned and, if possible, outlined briefly in the subject specification. This is not to suggest that additional specifications concerning such testing are to be eliminated.

c. It is suggested that this specification place the requirement on the contractor for preparation of complete procedures to include simultaneous task charts. These charts would be subject to Government review and approval and would be verified during the "system" test mentioned in paragraph 1b above.

2. The following are recommended additions or corrections to particular paragraphs in the subject specification:

a. Page 3, paragraph 2.1 Applicable Documents - The ML-1A Military Characteristics should be referenced under Publications, Military.

b. Page 6, Table II.

(1) The C-130 aircraft is no longer used. The aircraft now in use is the C-130A.

(2) This table requires that the control shelter, gas storage assembly, cable reel assembly, and ancillary equipment be either truck- or skid-mounted when being transported by the C-130. In considering paragraph 2.b.(1) above, the height of the loading door of a C-130A is 108 inches (Reference: TM 57-210). The maximum heights (page 5, Table I) of the control shelter, gas storage assembly, cable reel assembly, and ancillary equipment is 83 inches. The various heights from the ground to the floor of the bed of fully loaded 2-1/2-ton trucks are:

M34 - 41-1/2" M35 - 49-7/8" M35 - 51-3/8" M36C - 51-3/8"

(Reference: Military Vehicle Characteristics Data Sheets)

The heights of the loaded vehicles range from 124-1/2 inches to 134-3/8 inches, which require that the items listed above be skid-mounted, not truck-mounted, when being transported by C-130A aircraft.

c. Page 7, paragraph 3.1.2.1.3.3.1 Loading and Unloading - "Design provisions shall be made to permit rapid loading and unloading of each unit by standard weight-handling techniques". This should be changed to read: "...unit by standard military-handling techniques".

d. Page 10, paragraph 3.1.2.4.4 Radioactive Waste states, "Disposal of radioactive waste shall be performed in accordance with procedures approved by the Chief Chemical Officer". The last sentence should be changed to read: "...approved by the appropriate U. S. Army Agency".

e. Page 11, paragraph 3.1.3.4 Lubricants. The last sentence states, "The plant design shall be such that the plant can run for extended periods without requiring addition or replacement of lubricants". This should be changed to read: "...can run for a minimum of 720 hours (Reference: 3.1.2.4.1) without requiring..."

f. Page 23, paragraph 3.3.2.1.7.2 Side and end Structure. The statement "As many side members as necessary shall be removable to permit access to the power conversion equipment". This should be changed to read: "...power conversion equipment during routine maintenance. Required access for emplacement or march order operations will not require removal of side or end members".

g. Page 24, paragraph 3.3.3.2.1.(e) "An intercommunication system to provide a communication link between the power plant and the control shelter during periods of plant maintenance". This should be changed to read: "...between the control shelter and all other appropriate stations".

h. Page 25, paragraphs 3.3.3.2.3 Operating Console and 3.3.3.2.4 Instrumentation Racks should reference the layout of the control cab and console as recommended by these laboratories.

i. Page 27, paragraph 3.3.3.4.3 Fuses and Circuit Breakers. The last sentence states, "Front panel mounted fuses (with mounted spares) are acceptable if the fast response of fuses is required. This should be changed to read: "...mounted blown fuse indicators (with mounted spares) are..."

j. Page 40, paragraph 3.3.3.9 Annunciator System should have an additional sentence added: "The audible alarm should also be activated by energizing the test circuit".

k. Page 42, paragraph 3.3.4.2.1 Plant gas charging and make-up - "The Gas Storage Assembly shall be capable of charging the power plant gas system with gas to the start-up system operating pressure within a period of 20 minutes, and of maintaining pressure in the plant system at \pm 2 psi during normal plant operation".

1. Page 42, paragraph 3.3.4.3.2 Protective shroud - "A metal screen shroud shall be provided to cover the entire Gas Storage Assembly. The screen shall prevent access by unauthorized personnel during operation and shall prevent entry of small animals or foreign objects. The screen shall include easily removable panels for adjustment and maintenance of the equipment in the assembly". The following sentence should be added: "The pipes and cables should be capable of being easily connected with the protective screens in place".

Design of Training Equipment

The AEC forwarded HEL the report, "Preliminary Design of ML-1A Nuclear Power Plant Training Simulator", TR 01748.01-1, and requested a review. HEL comments on this report follow:

a. Reference page 5-3 -- The report states "The (power conversion) skid also contains as auxiliary equipment a lubrication system for the turbine compressor set and alternator, a vacuum pump for purging all coolant piping and electrical switchgear".

This statement is in error. The vacuum pump is located on the Gas Storage Skid.

b. Reference page 5-5 -- The upper right diagram on page 5-5 shows the vacuum pump mounted on the Power Conversion Skid.

This diagram is in error. The vacuum pump is located on the Gas Storage Skid. Note comment a.

c. Reference page 7-8 -- Tables 7-1, Blade Control Panel, and 7-2, Nuclear Instrumentation, are in error. Included in Table 7-1 is the Scrams Bypassed indicator. Included in Table 7-2 are the Clutch Coils Indicator (Clutch Coils Meter) and the Clutch Coils Indicator Selector Switch. None of these items are located on the panels indicated by the corresponding tables. Since they are located on the Clutch Power Panel, they should be located in a separate table titled Clutch Power Panel.

In addition, Table 7-1 states that the Clutches Energized indicator is labeled "CLUTCHES ENERGIZED". There is no such indicator on the panel and it should be deleted from this table. However, there is a Clutch Power Available indicator, and this indicator should also be included in the Clutch Power Panel table.

d. Reference page 7-7 through 7-23 -- Table 7-9, Annunciator Light Matrix, is the only table which should list the annunciator lights. Lights referenced in other tables should not be referred to as annunciators. These lights are indicators and not annunciators.

e. Reference page 7-10 -- Table 7-3, Shield-Moderator System, is in error. The table states that the labeling for the Mod Cooler Louver Control Switch is (UNLABELED) NEUTRAL and CLOSE (UNLABELED). The position labeling for this switch should be "OPEN", "NEUTRAL", and "CLOSE".

f. Reference page 7-12 -- Table 7-6, Lubrication System, is in error. The table states that the Lube Oil Temperature Indicator Selector Switch is labeled "SUMP" and "BEARING" and that the light is labeled "LUB". The labeling for the switch should be "SUMP" and "BEARING INLET". There is no light associated with this switch.

The table also states that the labeling for the Lube Cooler Lower Control switch is "OPEN" and "CLOSE". This switch should be labeled "OPEN", "NEUTRAL", and "CLOSE".

g. Reference page 7-14 through 7-17 -- Table 7-9, Annunciator Light Matrix, references only eight annunciators as being tied into the alarm. All of the annunciators are tied into the alarm.

h. Reference page 7-21 -- Table 7-12, Power Transfer Panel, is in error. Included in this table is the Power Reset Button. This control is also located on the Clutch Power Panel and should be identified in a separate table. See comment c. above.

i. Reference page 7-22 -- Table 7-13, Gas Handling Monitor Panel, is in error. Omitted from this table are the Nitrogen Addition, Gas Return, and Empty Tank switches.

j. Reference page 7-22 -- Since the console does not contain a panel titled "GAS HANDLING CONTROL PANEL", Table 7-14, Gas Handling Control Panel, should be deleted, and the items described therein should be included in Table 7-13, Gas Handling Monitor Panel.

k. Reference page 7-22 -- Table 7-15, Miscellaneous Indicators, is in error. Included in this table are the Oxygen Addition and the Evacuate System switches. These switches should be included in Table 7-13, Gas Handling Monitor Panel, since they are located on this panel.

l. Reference pages 7-22 and 7-23 -- Table 7-15 references only a few components. There are many more switches, meters, and indicators which will require operator action and observation. These components should be included on the final design of the simulator.

m. Reference page 7-26 -- The report states "There are two automatic systems in the ML-1A system. One is the temperature regulator which controls the reactor control rods".

The temperature regulator does not control all of the reactor control rods -- only the one regulating rod.

n. Reference page 7-29 -- The second paragraph references annunciators for Moderator/Lube Cooler, Fan 2, Slow and Fast. These are not annunciators in the system and have no apparent meaning as referenced here.

APPENDICES

- A. Component Review (PCS, Reactor, and Gas Storage Skid)
- B. Recommended Layout of the ML-1A Control Console and Cab

APPENDIX A

COMPONENT REVIEW

- I. Power Conversion Skid
- II. Reactor
- III. Gas Storage Skid

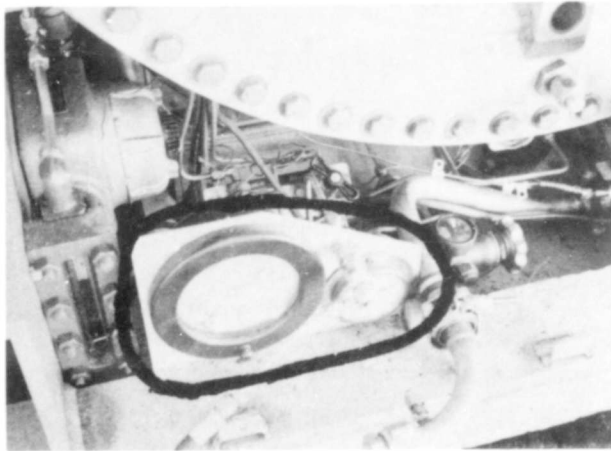


Fig. 1A. LUBE OIL SUMP METERS

I. POWER CONVERSION SKID

1. Component Identification

Many components are not identified. Components should be labeled to aid the operators and to minimize errors.

Recommendation

All components have numerical labels. Components which are utilized by operating personnel have descriptive labels in addition to the numerical labels.

2. Access to Components

Access to many components is extremely poor. In many instances, operation and maintenance will be performed with great difficulty. It is realized that severe restrictions are placed on the design of the PCS by the large number and size of subassemblies and the small volume available. However, to minimize the time required to prepare the PCS for operation or the "down time" for maintenance, a direct effort to make many components more accessible should be initiated.

Recommendation

"User" items be relocated to improve access.

3. Lube Oil Sump Meters

The lube oil sump meters (Fig. 1A) cannot be seen with end panels in place.

Recommendation

Provision be made in the panels, such as a sliding door, hinged subpanel, etc., which will permit the operator to view the meters with panels emplaced.

4. Lube Oil Sump Temperature Meter

The scale of the lube oil sump temperature meter is poor. The present meter face is shown in Figure 2A. The scale markings on this meter do not follow good human factors principles.

Recommendation

The scale be redesigned as shown in Figure 3A.

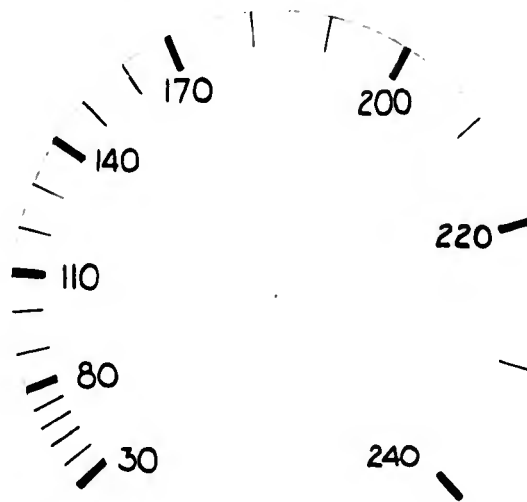


Fig. 2A. PRESENT LUBE OIL SUMP TEMPERATURE METER



Fig. 3A. PROPOSED LUBE OIL SUMP TEMPERATURE METER

5. Lube Oil Sump Pressure Meter

The lube oil sump pressure meter is poorly designed. The present meter face is shown in Figure 4A. The scale markings on this meter do not follow good human factors principles and the pointer is also poorly designed.

Recommendation

The meter be redesigned as shown in Figure 5A.



Fig. 4A. PRESENT LUBE OIL SUMP PRESSURE METER



Fig. 5A. PROPOSED LUBE OIL SUMP PRESSURE METER

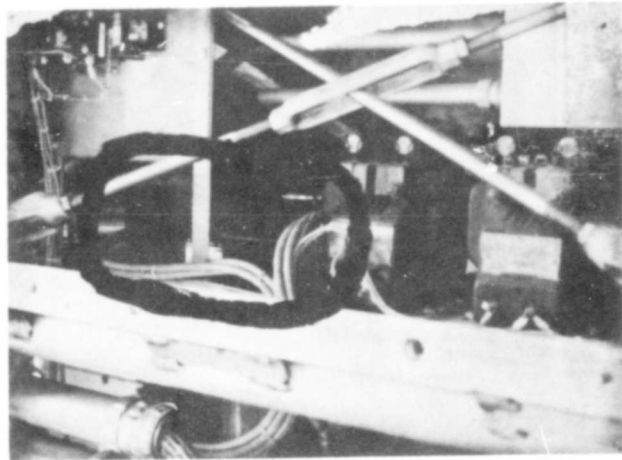


Fig. 6A. CIRCUIT BREAKER "B"

6. Circuit Breakers

The circuit breakers are improperly labeled and arranged. The circuit breakers in the control cab are labeled C, D, E, F, G, H, J. The circuit breakers on the PCS are numbered CB 1201 through CB 1209. The labeling on the PCS should agree with control cab terminology. The breakers should be arranged alphabetically.

Recommendation

a. The circuit breakers be arranged alphabetically, and the cover panel be labeled C, D, E, F, G, H, J, K, L above the respective breakers.

b. In future designs the circuit breakers should be mounted such that direction of throw is vertical. Breakers should be arranged with sufficient space between them so that schematic numbering on the mounting panel may be visible to maintenance personnel. The titles, both numerical and alphabetical, should agree with order of throw.

7. Circuit Breaker "B"

Both location and orientation of circuit breaker "B" are poor. In its present orientation (Fig. 6A), switch position labels, i.e., "ON" and "OFF", cannot be seen by the operators, which increases the error potential. Secondly, circuit breaker "B" is the only manually operated circuit breaker that is not located on the circuit-breaker panel. In order to provide for rapid identification of all system conditions and for access to circuit breakers, all manual circuit breakers should be located in one area.

Recommendation

a. Rotate circuit breaker "B" 90° such that labels are visible.

b. In future designs relocate circuit breaker "B" to the circuit breaker panel.

8. Allen Bolts on Tapered Plug Connector

There is insufficient room for a crewman to tighten or loosen the four Allen bolts on each tapered plug connector. These bolts are located inside the flanged tapered plug supports (Fig. 7A and 8A). Access to these bolts with a wrench is hindered by the skid support and the turbine inlet line on one side of the PCS and the skid support on the other.

Due to the access problem, Idaho personnel have improvised a device consisting of part of an Allen wrench welded to a standard hex nut which is inserted into the Allen head bolt. An open-end wrench is then used to tighten the bolts. Although the task of tapered plug adjustment will normally be performed at a higher echelon of maintenance, it should be performed quickly and easily and without the use of special tools.

Recommendation

Better access be provided for adjusting Allen bolts.

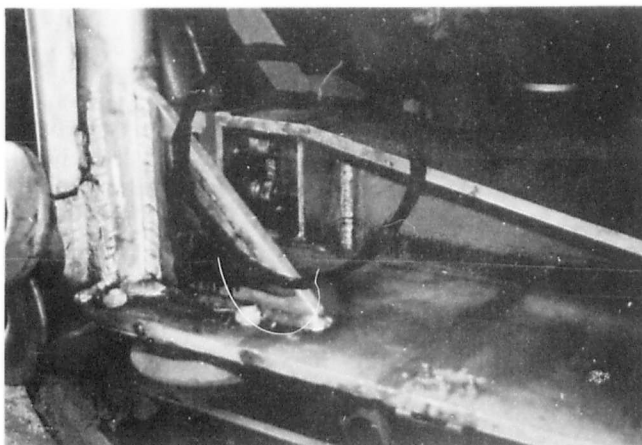


Fig. 7A. ALLEN BOLT ACCESS

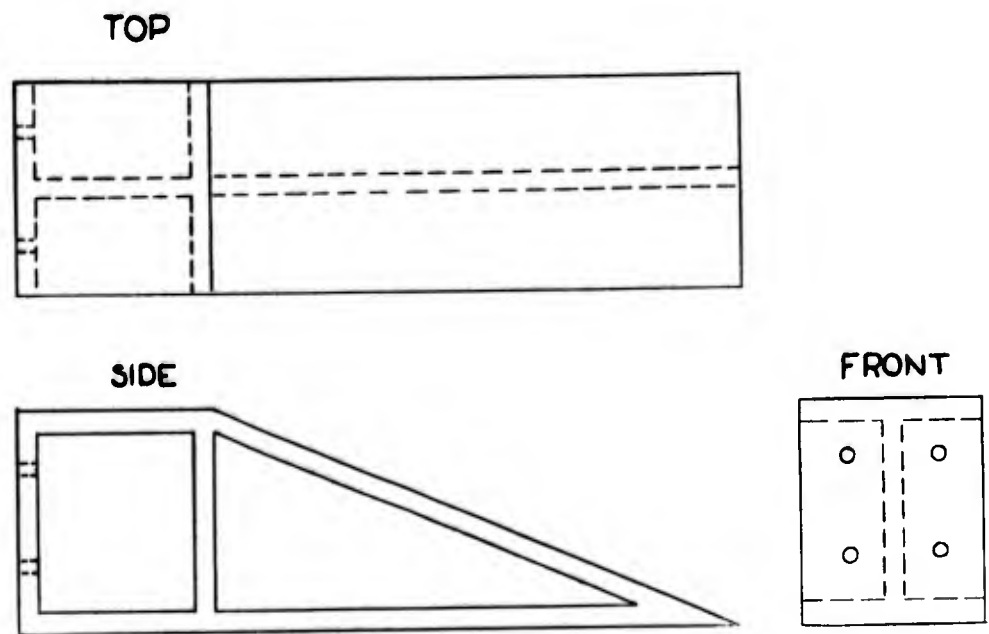


Fig. 8A. THREE-VIEW SKETCH OF TAPERED PLUG SUPPORT

9. Tie-Down-Reactor Interference

The tie downs below the tapered plugs on the PCS may possibly interfere with the base of the Reactor in the coupling operation (Fig. 9A). To prevent this, the tie downs must be unscrewed and removed prior to coupling. However, since stowage space is not provided, the tie-down units will be loose. Loose items should be avoided due to the potentiality of loss.

Recommendation

Tie-down units be relocated so that removal for coupling is not necessary. If this is not feasible, stowage locations should be provided in proximity to their normal position.

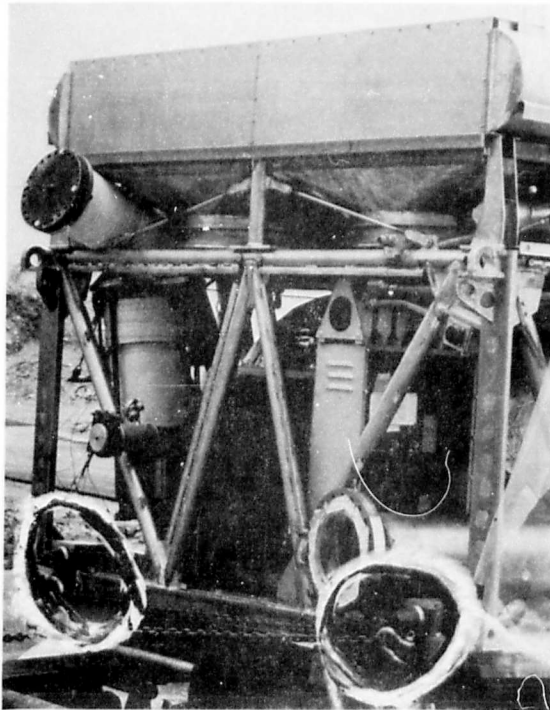


Fig. 9A. TIE DOWNS ON PCS

10. N₂ Recuperator Outlet Line Support

Installation and removal of the N₂ recuperator outlet line support is extremely difficult. The support must be installed prior to transport. Wrench access to the bolts for the support is hindered by the N₂ line and the skid supports (Fig. 10A and 11A). A minimum of two crewman will be required for this operation -- one to insert and hold the support, another to adjust the bolts. A third crewman may be required to lift the line.

Recommendation

Improve access and task of installation and removal.

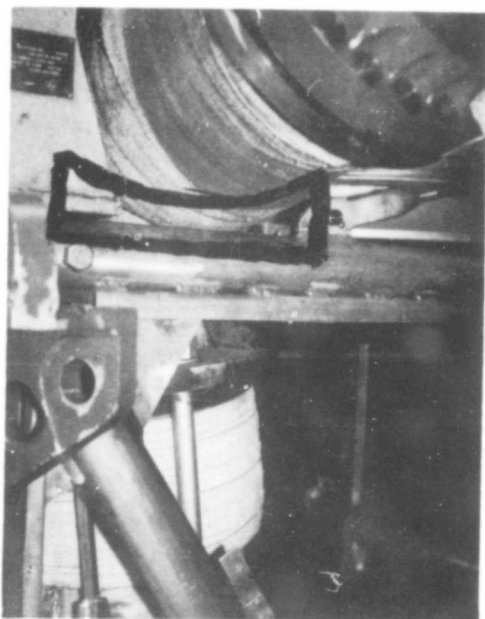


Fig. 10A. LOCATION FOR N₂ RECUPERATOR OUTLET LINE SUPPORT

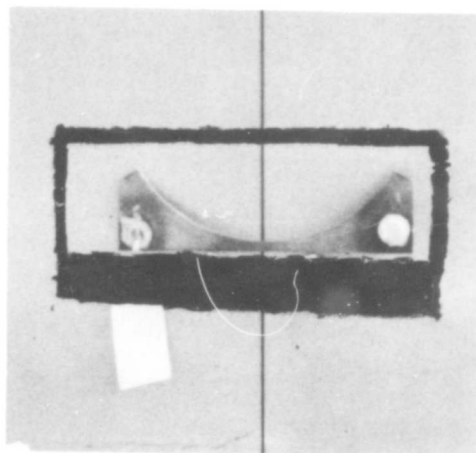


Fig. 11A. N₂ RECUPERATOR OUTLET LINE SUPPORT



Fig. 12A. CRANE REMOVAL OF PRECOOLER COVERS

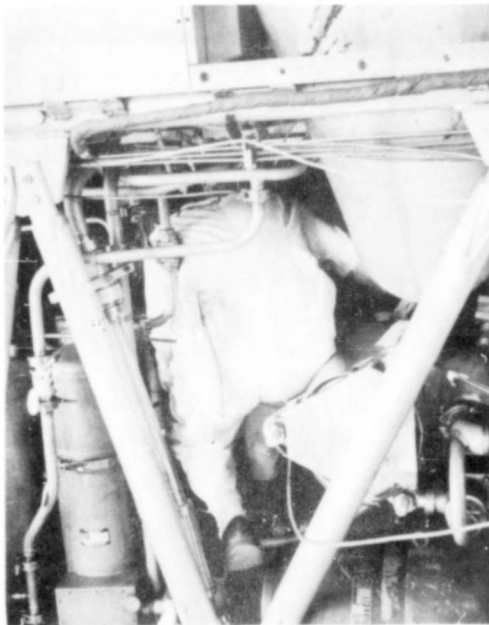


Fig. 14A. CREWMAN "IN" SKID

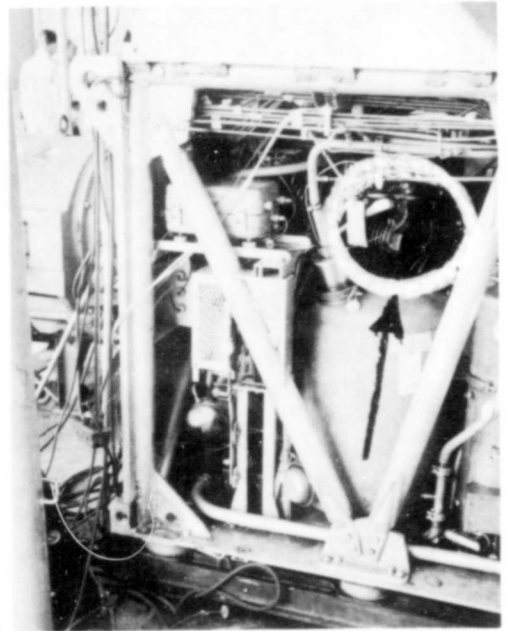


Fig. 13A. SUMP EQUALIZING COMPRESSOR

11. Precooler Covers

The task of removing the precooler covers could cause serious injury to personnel or serious damage to equipment. The design of the covers requires that personnel be on top of the PCS to perform the task of cover removal or replacement. Sufficient space for footing is not provided and, in addition, the covers are heavy and awkward to handle. These circumstances could cause a person to drop the covers, lose his balance or even fall, resulting in damage to equipment and/or injury to the person. Use of this equipment in an arctic environment would increase the hazard.

Personnel could alleviate some of the problems by sliding the covers over the header, but this action may cause damage to either the tubes or the header.

To avoid the problems associated with cover removal, personnel at NRTS, Idaho, utilized the overhead crane as can be seen in Figure 12A.

Recommendation

a. The precooler covers be manufactured from lightweight material and be hinged at the center spacer bar. Support rods should then be used to secure the covers upright during operation. The support rods should be designed so that they may be attached by personnel standing on the skid, thereby reducing the potential for injury to personnel and/or damage to equipment.

b. A study be conducted to determine the possibility of using grating or expanded metal instead of the covers, thus eliminating the need for cover removal and still providing tube protection.

12. Startup Compressor

Insufficient space for an oil drain pan between the skid floor and the startup compressor causes a "housekeeping" problem when performing an oil change.

Recommendation

Either mount the startup compressor so as to facilitate the task of changing oil or add a line with a petcock to drain to the side of the skid.

13. Sump Equalizing Compressor

Access for oil check or oil fill on the sump equalizing compressor is poor. This compressor is mounted on the desiccant filter with its oil check and fill port on the rear of the compressor (Fig. 13A). The crewman must crawl "into" the skid to check or add oil (Fig. 14A).

Recommendation

Access to oil check and fill port be improved.

14. Fuses

Sufficient clearance is not provided for replacement of some instrumentation fuses. These fuses are mounted on transformers located over the N₂ turbine inlet line. A cable raceway, directly over four of the six fuse holders, prohibits normal removal of the fuses (Fig. 15A). In order to remove a fuse, it would be necessary to spread the spring holder and pull the fuse out from the end. Replacement of the fuse would be performed similarly which could result in damage to the fuse.

Recommendation

Either the cable raceway or the transformers holding the fuses be relocated and, if possible, the transformers be mounted with the fuses vertical.

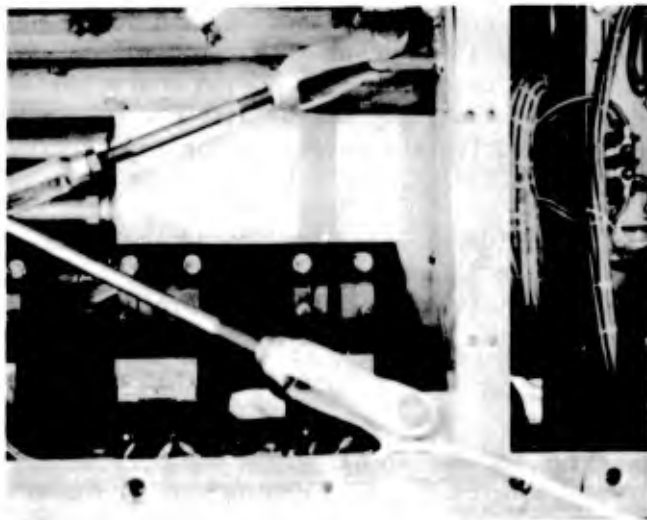


Fig. 15A. FUSES AND CABLE RACEWAY

15. Terminal Board Panels

Supports for the terminal board cover panels are not provided (Fig. 16A). During work on the terminal boards the panels must be supported either by the electrical wiring or some makeshift device. Electrical wires and/or other PCS components should not be utilized as supports, nor should maintenance personnel be required to devise their own supporting structure.

Recommendation

Terminal board panels be hinged at bottom and support rods be provided.

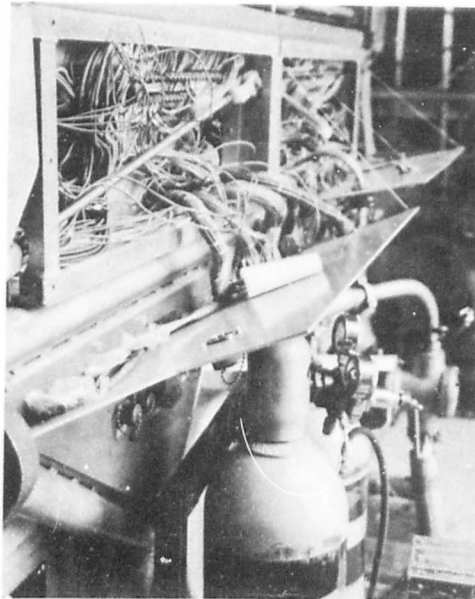


Fig. 16A. TERMINAL BOARD PANELS

16. Terminal Strip Arrangement

Turnbuckle supports, mounted directly in front of some of the terminal strips, hinder maintenance (Fig. 17A).

Recommendation

Terminal strips be rearranged to facilitate work.

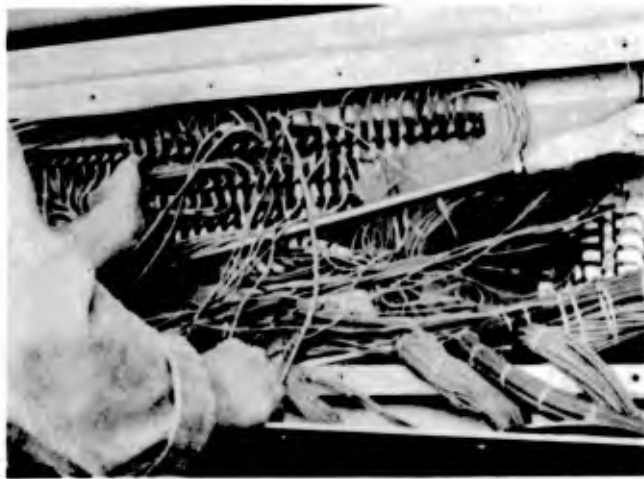


Fig. 17A. TURNBUCKLE SUPPORTS

17. Electrical Circuit Panel

The panel covering the electrical circuits over the desiccant filter is inadequately supported for maintenance (Fig. 18A). Personnel must either improvise a support or rest the panel on their head when performing maintenance on the electrical circuitry or adjusting the precooler cell assembly.

Recommendation

Panel supports be provided to facilitate work.

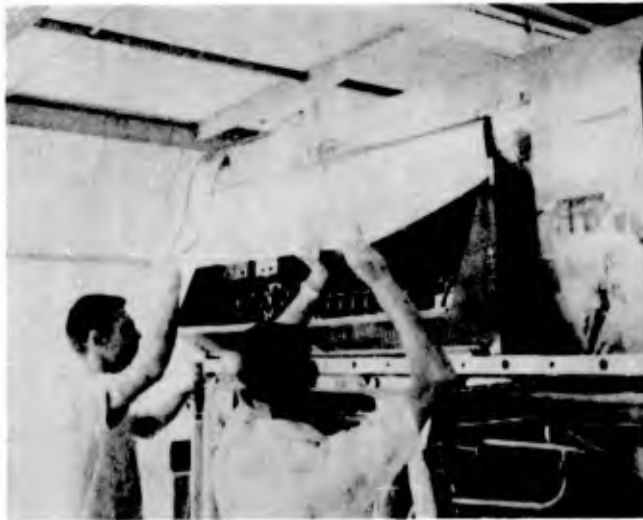


Fig. 18A. ELECTRICAL CIRCUIT PANEL

18. N₂ Filter F-621

Accessibility to the N₂ filter, F-621 is extremely poor. The filter is mounted on the lube rack over the turbine-compressor at the approximate center of the skid (Fig. 19A). Access to the filter by personnel for removal and cleaning is awkward in that they must go "into" (Fig. 14A) the skid to remove the unit.

Recommendation

This filter be relocated to a more accessible position.

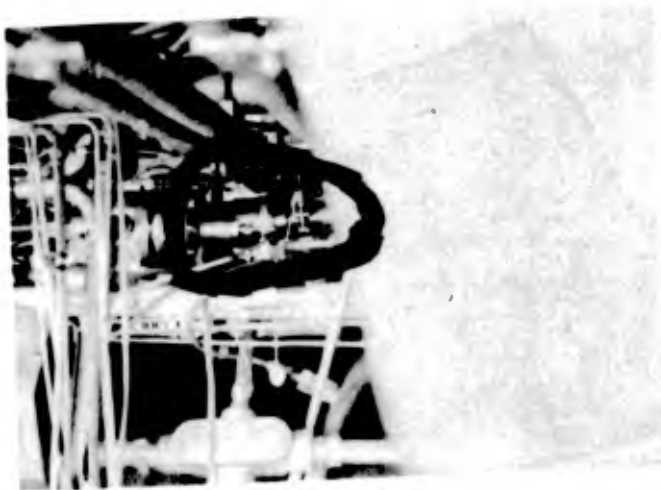


Fig. 19A. N₂ FILTER F-621



Fig. 20A. LUBE OIL FILTER F-601

19. Lube Oil Filter F-601

Removal of the lube oil filter F-601 for cleaning and/or replacement is difficult. The filter is located under the alternator and is mounted to the skid by two clamps (Fig. 20A). Both the rear clamp and the inlet line located at the rear of the filter are awkward to reach.

Recommendation

The filter be relocated to improve accessibility.

20. Oil Sump Heaters

Replacement and/or repair of any of the oil sump heaters can be achieved only by removal of the turbine-compressor from the skid.

Maintenance of small subassemblies, such as heaters, should be performed without major disassembly.

Recommendation

The PCS be redesigned to allow maintenance of the heaters without removal of the turbine-compressor.

21. Recuperator Removal

The task of recuperator removal is inordinately difficult and time consuming. During removal of the recuperator a flange on the recuperator interferes with a flange on the precooler inlet line. The entire precooler must be lifted to alleviate the interference, thereby requiring the associated instrumentation and equipment to be disconnected. Although the task of recuperator removal is performed at a higher echelon of maintenance, it should be performed quickly, easily, and without dismantling the PCS.

Recommendation

The assemblies be redesigned such that removal of the recuperator does not require excessive dismantling of other major items.

22. N₂ Precooler

Maintenance or repair of the inside tubes of the precooler bundle will be difficult to perform. Access to these tubes can only be attained by cutting a hole in the precooler header assuming that the faulty tube can be identified.

Recommendation

"Access ports" be placed in each header so that any tube can be reached for inspection or maintenance.

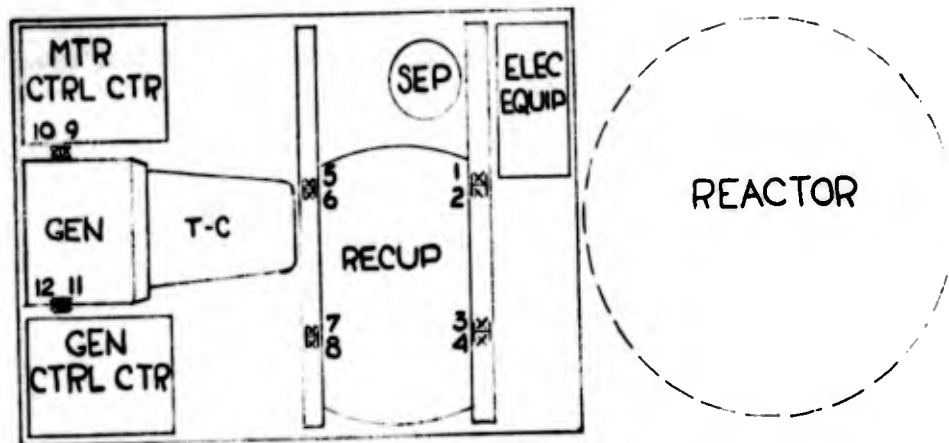


Fig. 21A. LOCATION OF TIE DOWN BOLTS

23. Tie-Down Bolts on Alternator and Recuperator

Access to some of the 12 tie-down bolts (Fig. 21A) on the turbine-compressor set and recuperator is extremely poor. All of these bolts must be tight during transport. Ten of the bolts (1, 2, 5, 6, 7, 8, 9, 10, 11, and 12) must be loose during operation, thus leaving only two (3 and 4) tight. The only bolts which are readily accessible are 3 and 4.

Three of the bolts (6, 7, and 9) are extremely difficult to reach with all equipment in place. Bolt 6 is approximately 53 inches in from either side of the skid. Bolt 7 is surrounded by piping and support flanges. Both of these bolts were among those that were not tightened at Azuza previous to shipment. Bolt 9, located behind a flanged support and the Motor Control Center, was tightened; however, the Motor Control Center was not in place when this task was performed.

When the PCS initially arrived at NRTS from AGN at Azuza, approximately one-half of the bolts had not been tightened. During the attempts to couple the PCS to the reactor, it was discovered that the TC unit had shifted on the skid. It could not be determined if this occurred due to vibration when the PCS was being tested at Azuza or due to movement when the PCS was being transported with the bolts improperly tightened.

It is anticipated that the bolts will not be properly tightened when this equipment is transported by field units. The fact that the contractor did not give them proper attention amply supports this premise. Other factors to be considered are that proper torquing is difficult, time consuming, and is not subject to simple verification by supervisory personnel.

Experience has shown that the bolts will undoubtedly be properly tightened during humping and loading tests to be performed in the future. However, if the above premise proves to be valid, the tests will not reflect true field conditions.

Recommendation

Calculations be made to determine the necessity of tightening bolts 1, 2, 6, 7, 8, 9, and 11 -- the "hard to reach" bolts. If tightening of these bolts is found to be necessary, better access must be provided. To further insure proper transport of equipment, emphasis to the task of torquing must be given in all applicable documents such as training manuals, operating instructions, etc.

II. REACTOR

1. Access to Valves

Access to many valves on the reactor is poor. Many valves are located such that personnel must reach around pipes and other components to gain access to the valves. For ease of operation all valves should be readily accessible.

Recommendation

Valves be relocated and/or piping be rerouted such that valves are readily accessible.

2. The labeling of pipes and components on the reactor is poor. These items are identified by plastic tape (Fig. 22A). This type of identification is inadequate for field use.

Recommendation

Items be properly identified, e.g., MOD PUMP, SHLD PUMP, V-201, etc. Labels should be such that field use will not obliterate them. Pipes be color-coded in conformance with Mil-Std-101A, with notice 1, dated 13 August 1961.

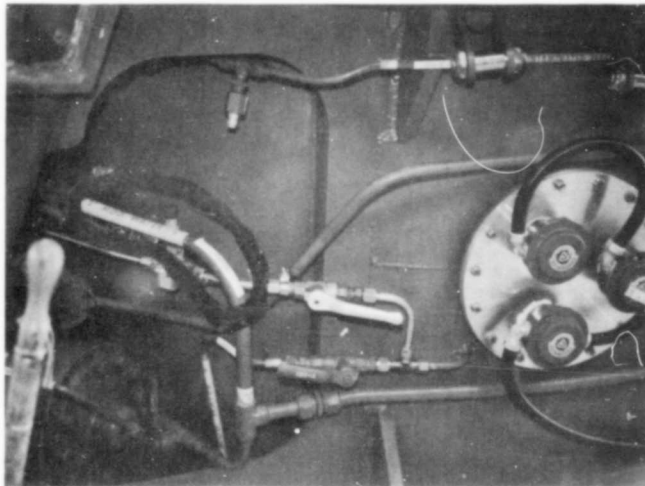


Fig. 22A. PLASTIC-TAPE LABELS

3. Area Protection Switch - Utility Outlets

The lack of proper labeling of the area protection switch and utility outlets creates a safety hazard. The switch positions are labeled "ON" and "OFF"; however, the switch itself is not labeled. The utility outlets, mounted adjacent to the switch, are not labeled. This situation could create the misconception that the key switch provides power to the utility outlets. All components should be labeled with proper descriptive terms.

The area protection switch in the control cab performs a similar function to the area protection switch on the reactor. The labels on both switches should be identical.

Recommendation

The area protection switch be labeled "AREA PROTECTION SWITCH". The switch positions be labeled "SAFE" and "RUN". The utility outlets be labeled "UTILITY OUTLETS" on their protective cap.

4. Tie-Down Stowage

The tie-downs, mounted in the tapered-plug receptacles on the reactor (Fig. 23A), must be unscrewed and removed prior to coupling. However, since stowage space is not provided, the tie-down units will be loose. Loose items should be avoided due to the potentiality of loss.

Recommendation

Stowage locations for the tie-down units be provided in proximity to their normal position.

5. Wrench Access to Tapered Plug Bolt

The insufficient horizontal clearances provided "in the flanged supports" do not permit use of socket wrenches for adjustment of bolts for the full thread range (Fig. 24A and 25A). This limitation could hinder the task of Reactor - PCS coupling if the starter threads were damaged.

In addition, insufficient vertical clearances prohibit the use of open-end wrenches, since this type of wrench cannot be placed around the bolts.

Sufficient space should be provided around the bolts to permit bolt adjustment by all standard wrenches for the full thread range.

Recommendation

Wrench access to tapered-plug bolts be improved.

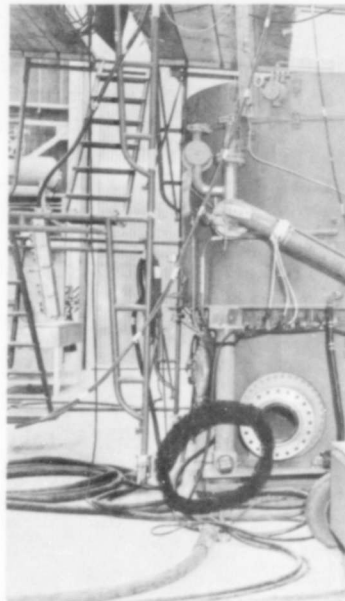


Fig. 23A. TIE DOWN IN POSITION ON REACTOR

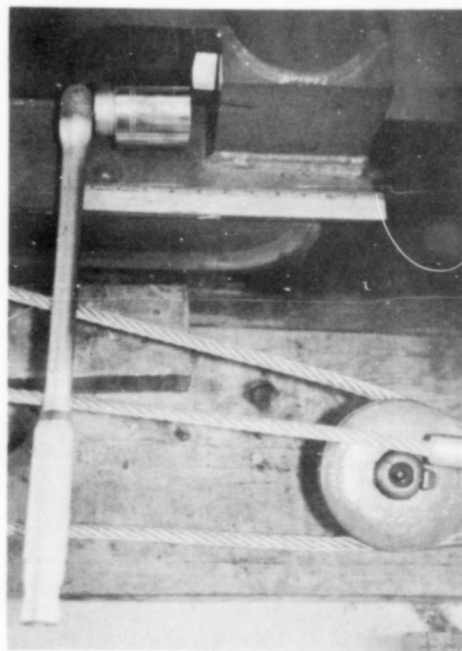


Fig. 24A. POOR ACCESS TO TAPERED-PLUG BOLT

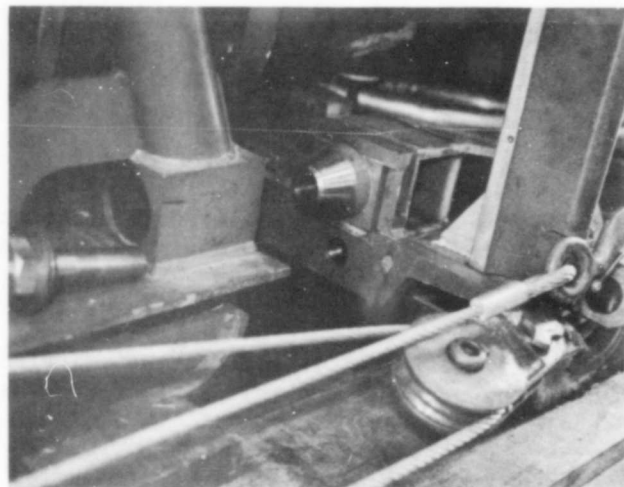


Fig. 25A. SKID CONNECTION LAYOUT

III. GAS STORAGE SKID

1. Component Identification

Component identification on the gas storage skid is poor. Components such as cable connectors, electrical boxes, pumps, filters, pipe connections, etc., are not labeled. Valves are labeled, but only with plastic nameplates wired to the valves. To improve maintenance, decrease set-up time, and minimize errors, all components should be identified such that field use will not obliterate the identification.

Recommendation

All components be properly labeled.

2. Transfer Compressor Oil Fill Cap

The operation of transfer compressor oil fill cap assembly spring is poor. The spring in the assembly presently functions such that the cap will remain in any set position. This presents the problem of foreign particles and water getting into the oil line if the cap is left partially open. To eliminate this problem, the cap should remain fully closed when personnel are not checking or adding oil.

Recommendation

The cap assembly spring be redesigned so that the cap is spring-loaded to the closed position.

3. Transfer Compressor Oil Filter

Accessibility to the transfer compressor oil filter is poor. The filter can be removed for cleaning only by reaching between the fan housing and the fan housing support and approaching the filter from the rear (Fig. 26A). Although this task can be performed, all "user" components should be readily accessible.

Recommendation

In future designs, all "user" components be located such that they are readily accessible.

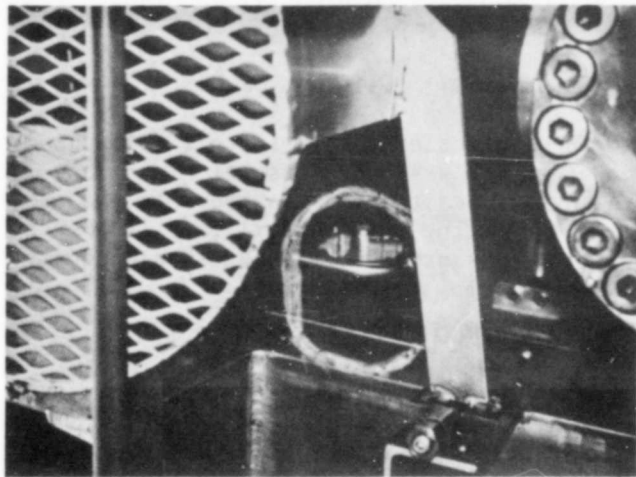


Fig. 26A. TRANSFER COMPRESSOR OIL FILTER

APPENDIX B

RECOMMENDED LAYOUT OF THE ML-1A CONTROL CONSOLE AND CAB

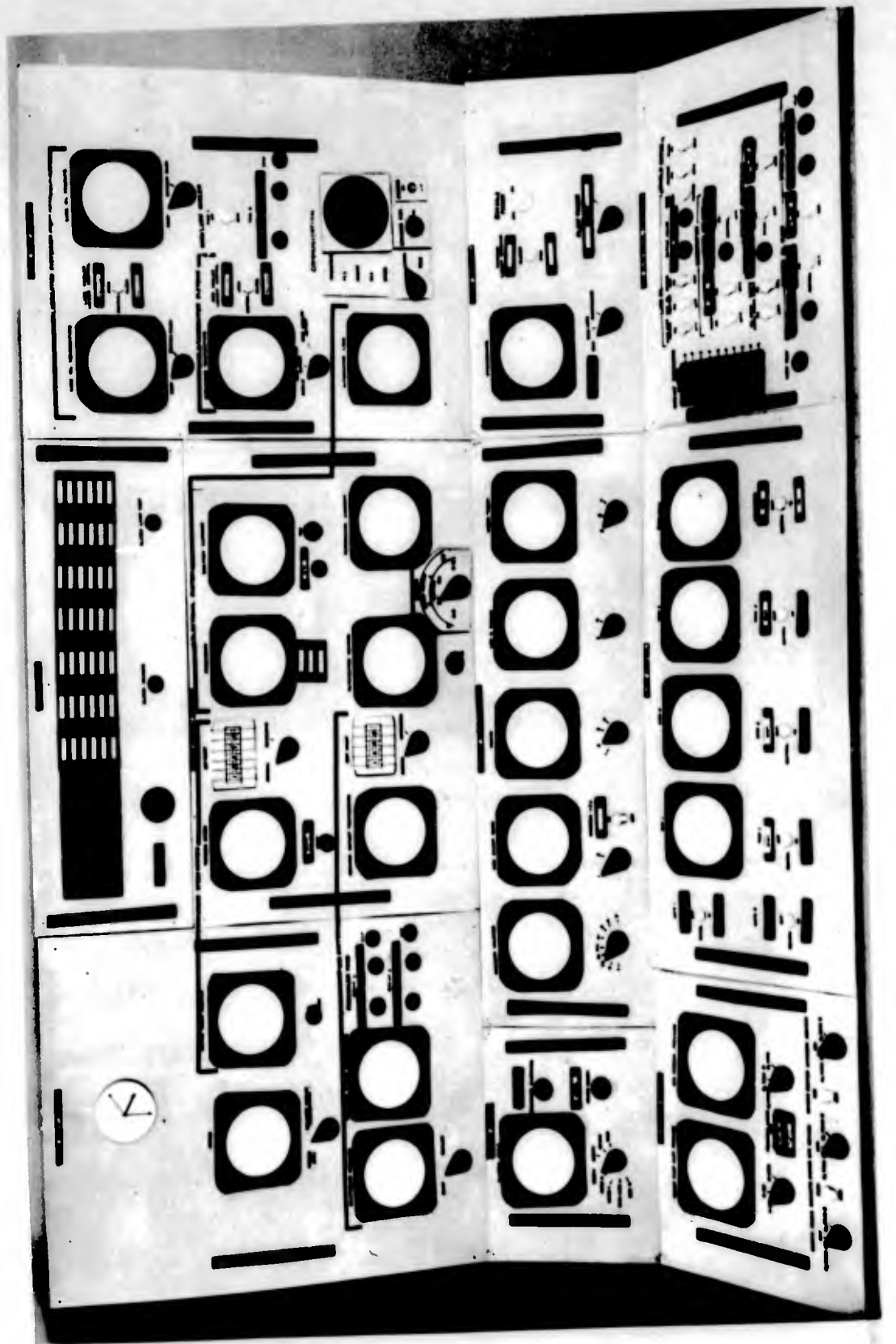
- I. Components and Labeling on Control Console**
- II. Recommended Control Console Layout**
 - (1) Photographs of Recommended Control Console for ML-1A**
 - (2) Description of Recommended Control Console for ML-1A**
- III. Control Cab Layout**
- IV. Gas Handling Schematic**

I. COMPONENTS AND LABELING ON CONTROL CONSOLE

1. All components and labeling should adhere to Appendix A, HEL TM 8-62, "A Human Engineering Evaluation of the ML-1 Mobile Low Power Nuclear Power Plant".
2. All indicators should be similar to MARCO, VM 261, Style A. This indicator provides maximum space for information, occupies minimum panel space, and is designed for ease of bulb replacement.
3. All two-position toggle switches should be similar to "Pull-to-Unlock 'TL' Toggle Switches, Configuration D", as shown in Micro Switch Catalog 73e.
4. All two-position, spring-loaded-to-bottom toggle switches should be similar to "Pull-to-Unlock 'TL' Toggle Switches, Configuration F or G", as shown in Micro Switch Catalog 73e.
5. All three-position, spring-loaded-to-center lock toggle switches should be similar to "Pull-to-Unlock 'TL' Toggle Switches, Configuration E", as shown in Micro Switch Catalog 73e.
6. All automatic set point controls should be similar to DIGISWITCH, Series 7300, The Digitron Co.

II. RECOMMENDED CONTROL CONSOLE LAYOUT

The recommended control console layout for the ML-1A is illustrated by the following photographs and descriptions.



UPPER LEFT CONTROL



ERROR

BYPASS VALVE POSITION

TURBINE SPEED

REACTOR OUTLET TEMPERATURE

OPEN

COMPRESSOR PRESSURE

PRECOOLER OUTLET TEMPERATURE

PRECOOLER FANS

GROUP 1

SLOW FAST STOP

GROUP 2

SLOW FAST STOP

INLET

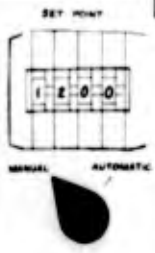
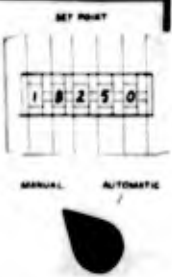
OUTLET

GAS SYSTEM

CENTRAL CONTROL




TURBINE SPEED SYSTEM UPPER CENTER CONTROL ELECTRICAL SYSTEM




UPPER RIGHT CONTROL

LUBRICATION SYSTEM

LUBE OIL TEMPERATURE



LUBE OIL PRESSURE



LUBE COOLER LOUVER CONTROL

WILL OPEN


OPEN

NEUTRAL

CLOSE


WILL CLOSE

LUMP **BEARING INLET**



SHIELD/MODERATOR SYSTEMS

SHIELD/MOD TEMPERATURE



MOD COOLER LOUVER CONTROL

WILL OPEN


OPEN

NEUTRAL

CLOSE

WILL CLOSE

MOD REACTOR **SHIELD OUTLET** **MOD COOLER OUTLET**




MOD/LUBE COOLER

FAN 1 ON

OFF

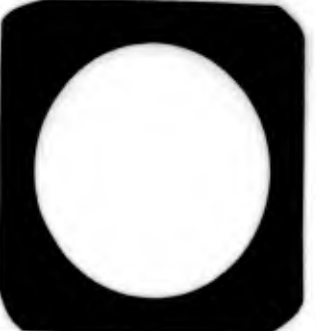
FAN 2

SLOW **FAST** **STOP**



COMMUNICATION

ALTERNATOR LOAD



OPERATIONS

PCS

MAINT

ALL

SPARE

LISTEN

TALK


SPEAKER VOL.

INC.

POWER

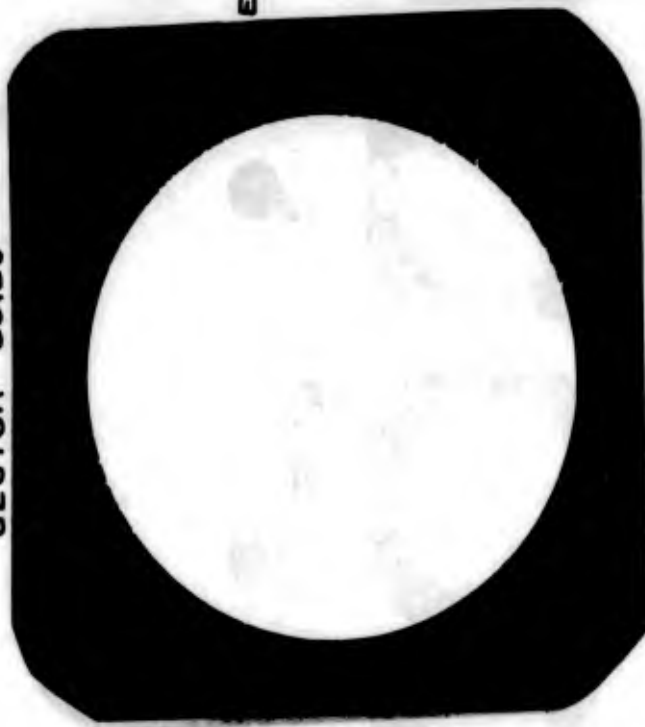
ON

OFF



CLUTCH POWER

CLUTCH COILS



CLUTCH PWR
AVAILABLE

ENERGIZE CLUTCHES



SCRAMS
BYPASSED

POWER RESET



SHIM 1 SHIM 2 SHIM 3
SAFE 2 REG
SAFE 1
BUS CUR
BUS V



LINEAR POWER



LOG N POWER



RESOLUTION TEST CHART
1951-O



RES-100



LOG COURT RATE

COURT RATE

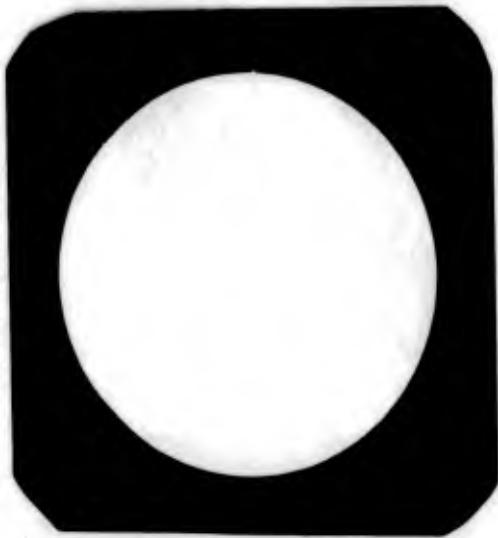


CHARGE VOLTAGE



POWER TRANSFER

SYNCHROSCOPE



AUX PCS-GEN CUSTOMER



OUTGOING CIRCUIT BREAKER



CLOSED



OPEN



POWER

OFF ON



PLANT POWER



GAS HANDLING MONITOR

VACUUM PUMP INLET PRESSURE



GAS STORAGE PRESSURE



0-10 | 0-100



TRANSFER COMPR N₂ TANK A
AND
VACUUM PUMPS



EMPTY TANKS EVACUATE SYSTEM GAS RETURN OXYGEN ADDITION NITROGEN ADDITION

OFF

N₂ TANK A



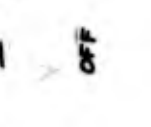
EVAC

N₂ TANK B



OFF

N₂ TANK A



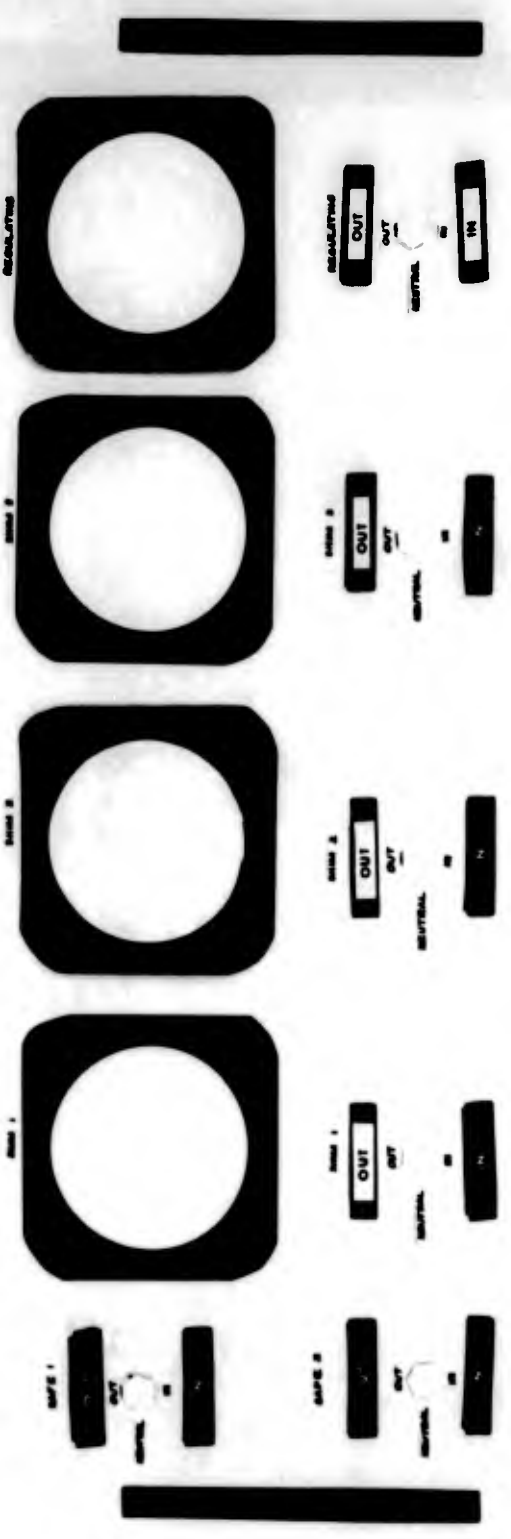
ADD

N₂ TANK B

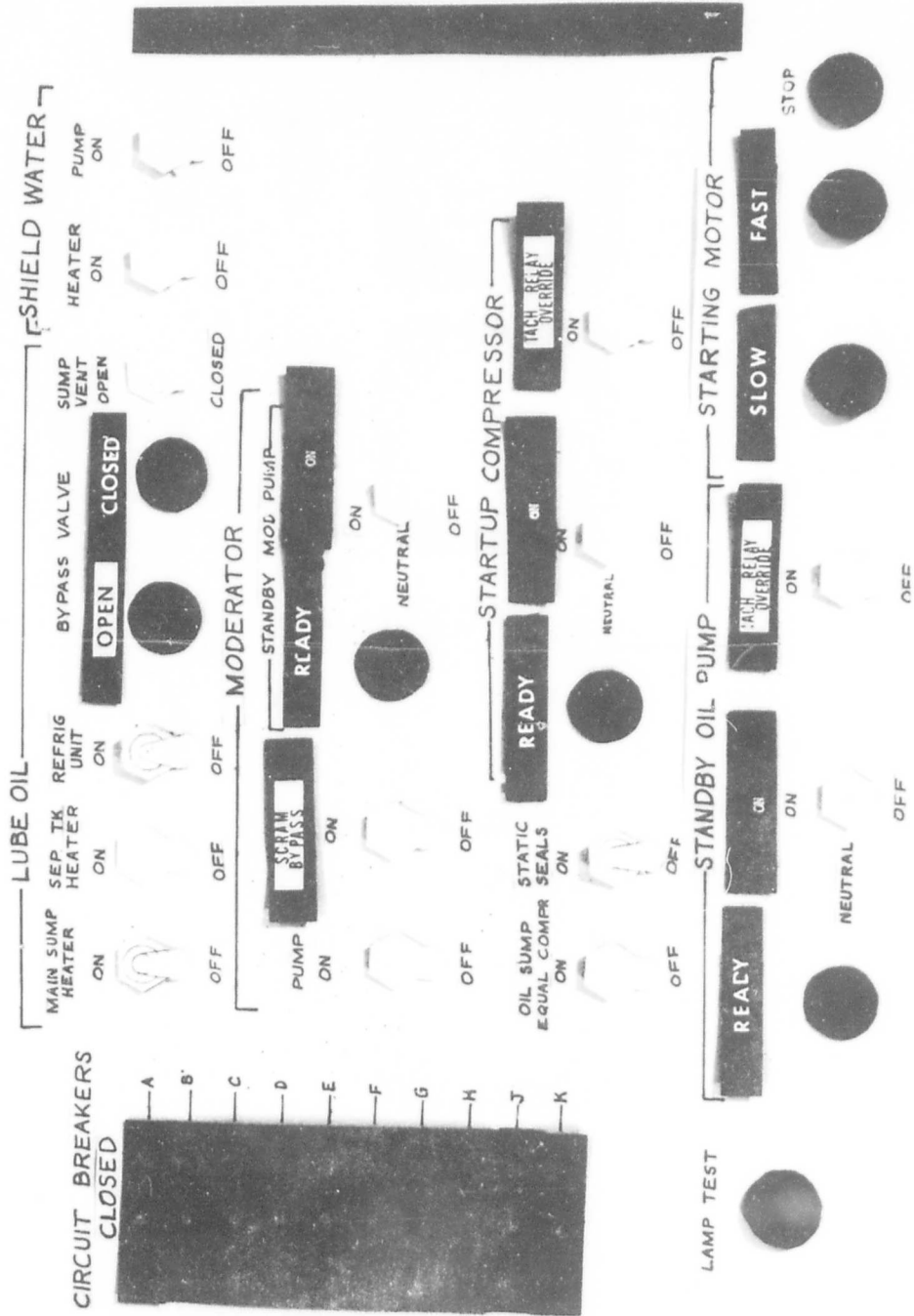


OFF

TAPE CONTROL



AUX ELECTRICAL EQUIPMENT



DESCRIPTION OF RECOMMENDED CONTROL CONSOLE FOR ML-1A

Error System

1. Error Meter and Control
 - a. The Error Meter should be labeled ERROR.
 - b. The control should be a two-position selector switch; and be labeled left to right:
 - (1) TURBINE SPEED
 - (2) REACTOR OUTLET TEMPERATURE

Speed Control System

1. The Speed Control System should be labeled TURBINE SPEED SYSTEM.
2. By-pass Valve Position Meter and Control.
 - a. The By-pass Valve Position Meter should be labeled BY-PASS VALVE POSITION.
 - b. The control should be a round adjust knob and be labeled OPEN with a clockwise arrow.
3. Turbine Speed Meter and Controls.
 - a. The Turbine Speed Meter should be labeled TURBINE SPEED.
 - b. The Set Point Control should be a five-digit counter and be labeled SET POINT.
 - c. The Mode Selector should be a two-position selector switch and be labeled left to right:
 - (1) MANUAL
 - (2) AUTOMATIC
 - d. The indicator below the Turbine Speed Meter should be amber and be labeled OVERSPEED VALVE OPEN.
 - e. The control below the Overspeed Valve indicator should be a momentary push button and be labeled RESET.

Gas System

1. The gas system should be labeled GAS SYSTEM.
2. Compressor Pressure Meter and Control.
 - a. The Compressor Pressure Meter should be labeled COMPRESSOR PRESSURE.
 - b. The control should be a two-position selector switch and be labeled left to right:
 - (1) INLET
 - (2) OUTLET
3. Precooler Outlet Temperature Meter and Fan Control Group.
 - a. The Precooler Outlet Temperature Meter should be labeled PRECOOLER OUTLET TEMPERATURE.
 - b. The Fan Controls should be labeled PRECOOLER FANS.
 - c. The Fan Group 1 controls should be labeled GROUP 1.
 - d. The slow control should be a black momentary push button.
 - e. The slow indicator should be green and labeled SLOW.
 - f. The fast control should be a black momentary push button.
 - g. The fast indicator should be green and labeled FAST.
 - h. The stop control should be a black momentary push button and labeled STOP.
 - i. The Fan Group 2 controls should be labeled GROUP 2.
 - j. The slow control should be a black momentary push button.
 - k. The slow indicator should be green and labeled SLOW.
 - l. The fast control should be a black momentary push button.
 - m. The fast indicator should be green and labeled FAST.
 - n. The stop control should be a black momentary push button and labeled STOP.

4. Reactor Outlet Temperature Meter and Controls.

a. The Reactor Outlet Temperature Meter should be labeled REACTOR OUTLET TEMPERATURE.

b. The set point control should be a four-digit counter and be labeled SET POINT.

c. The Mode Selector should be a two-position selector switch and be labeled left to right:

(1) MANUAL

(2) AUTOMATIC

Electrical System

1. The electrical system should be labeled ELECTRICAL SYSTEM.

2. FREQUENCY METER and INDICATORS.

a. The Frequency Meter should be labeled FREQUENCY.

b. The indicators should be white and be labeled top to bottom:

(1) AUXILIARY

(2) PCS-GEN

(3) CUSTOMER

3. Exciter Current Meter and Controls.

a. The Exciter Current Meter should be labeled EXCITER CURRENT.

b. The on control should be a black momentary push button.

c. The on indicator should be green and be labeled ON.

d. The off control should be a black momentary push button and be labeled OFF.

4. Alternator Voltage Meter, Alternator Current Meter and Controls.

a. The Alternator Voltage meter should be labeled ALTERNATOR VOLTAGE.

b. The Alternator Voltage adjust knob should be labeled INC with a clockwise arrow on panel.

c. The Alternator Current meter should be labeled ALTERNATOR CURRENT.

d. The Ammeter - Voltmeter Selector switch should be a four position switch with labels as on photographs.

5. Alternator Load.

a. The Alternator Load meter should be labeled ALTERNATOR LOAD.

Lubrication System

1. The lubrication system should be labeled LUBRICATION SYSTEM.

2. Lube Oil Temperature Meter and Control.

a. The Lube Oil Temperature Meter should be labeled LUBE OIL TEMPERATURE.

b. The control should be a two-position selector switch and be labeled left to right:

(1) SUMP

(2) BEARING INLET

3. Lube Cooler Louver Controls.

a. The louver controls should be labeled LUBE COOLER LOUVER CONTROLS.

b. The indicator above the toggle switch should be amber and be labeled FULL OPEN.

c. The indicator below the toggle switch should be amber and be labeled FULL CLOSED.

d. The control should be a three-position, spring-loaded-to-center-lock toggle switch with the center position labeled NEUTRAL.

4. Lube Oil Pressure Meter and Control.

a. The Lube Oil Pressure Meter should be labeled LUBE OIL PRESSURE.

b. The control should be a two-position selector switch and be labeled left to right:

(1) SUMP

(2) BEARING INLET.

Shield/Moderator Systems

1. The Shield/Moderator Systems should be labeled SHIELD/MODERATOR SYSTEMS.
2. Temperature Meter and Control.
 - a. The Shield/Moderator Temperature Meter should be labeled SHIELD/MOD TEMPERATURE.
 - b. The control should be a three-position selector switch and be labeled left to right:
 - (1) SHIELD
 - (2) MOD REACTOR OUTLET
 - (3) MOD COOLER OUTLET
3. Louver Position Control and Indicators.
 - a. The louver position control and indicators group should be labeled MOD COOLER LOUVER CONTROLS.
 - b. The indicator above the toggle switch should be amber and be labeled FULL OPEN.
 - c. The indicator below the toggle switch should be amber and be labeled FULL CLOSED.
 - d. The control should be a three-position, spring-loaded-to-center-lock toggle switch with the center position labeled NEUTRAL.

Mod/Lube Cooler Fans

1. The Mod/Lube Cooler Fans should be labeled MOD/LUBE COOLER FANS.
2. The Fan 1 control should be labeled FAN 1.
3. The Fan 1 control should be a two-position toggle switch and be labeled from top to bottom:
 - a. ON
 - b. OFF
4. The Fan 2 controls should be labeled FAN 2 and the individual controls should be left to right:
 - a. The slow control should be a black momentary push button.

- b. The slow indicator should be green and labeled SLOW.
- c. The fast control should be a black momentary push button.
- d. The fast indicator should be green and labeled FAST.
- e. The stop control should be a black momentary push button labeled STOP.

Clutch Power

- 1. Clutch Coils Meter and Control.
 - a. The Clutch Coils Meter should be labeled CLUTCH COILS.
 - b. The control should be an eight-position selector switch and be labeled left to right:
 - (1) BUS V
 - (2) BUS CUR
 - (3) SAFE 1
 - (4) SAFE 2
 - (5) SHIM 1
 - (6) SHIM 2
 - (7) SHIM 3
 - (8) REG
- 2. Clutch Power.
 - a. The Energize Clutch Control should be a momentary push button and labeled ENERGIZE CLUTCHES.
 - b. The indicator above the push button should be green and be labeled CLUTCH PWR AVAILABLE.
 - c. The power reset control should be a momentary push button and be labeled POWER RESET.
 - d. The indicator should be amber and be labeled SCRAMS BYPASSED.

Nuclear Instrumentation

- 1. Chamber Volts Meter and Control.
 - a. The Chamber Volts Meter should be labeled CHAMBER VOLTAGE.

b. The control should be a nine-position selector switch and be labeled left to right:

- (1) 1
- (2) 2
- (3) 3+
- (4) 3-
- (5) 4+
- (6) 4-
- (7) 5
- (8) 6
- (9) 7

2. Log Count Rate Meter and Control.

a. The Log Count Rate Meter should be labeled LOG COUNT RATE.

b. The control should be a two-position selector switch and be labeled left to right:

- (1) 1
- (2) 2

3. Channels 1 and 2.

a. The control should be a two-position toggle switch labeled CHANNELS 1 and 2.

b. The switch positions should be labeled top to bottom:

- (1) ON
- (2) OFF

c. The indicator should be white and be labeled ON.

4. Period Meter.

a. The Period Meter should be labeled PERIOD.

b. The control should be a four-position selector switch and be labeled left to right:

- (1) 1
- (2) 2
- (3) 3
- (4) 4

5. Log N Power Meter and Control.

a. The Log N Power meter should be labeled LOG N POWER.

b. The control should be a two-position selector switch and be labeled from left to right:

(1) 3

(2) 4

6. Linear Power Meter and Control.

a. The Linear Power Meter should be labeled LINEAR POWER.

b. The control should be a three-position selector switch and be labeled from left to right:

(1) 5

(2) 6

(3) 7

Power Transfer System

1. Synchroscope, Indicator and Control.

a. The synchroscope should be labeled SYNCHROSCOPE.

b. The indicator should be red and be labeled A-C-B PHASE SEQUENCE.

c. The selector switch should be a three-position switch and be labeled left to right:

(1) AUX

(2) PCS-GEN

(3) CUSTOMER

2. Outgoing Circuit Breaker Indicator and Control.

a. The indicator and control group should be labeled OUTGOING CIRCUIT BREAKER.

b. The indicator above the control should be green and be labeled CLOSED.

c. The indicator below the control should be green and labeled OPEN.

d. The control should be a three-position spring-loaded-to-center lock toggle switch.

3. Plant Power Transfer Indicator and Control.

- a. The Plant Power Transfer Indicators and Control group should be labeled PLANT POWER.
- b. Both indicators should be white and be labeled left to right:
 - (1) AUX
 - (2) PCS-GEN
- c. The control should be a two-position selector switch.

4. Power Key Switch

- a. The Power Key Switch should be labeled CONSOLE POWER.
- b. The two positions for the key switch should be labeled left to right:
 - (1) OFF
 - (2) ON
- c. The key switch should be one that cannot be turned to either ON or OFF with the key removed. The key should not be removable in the ON position.

Gas Storage System

1. Vacuum Pump Inlet Pressure Meter and Control.

- a. The Vacuum Pump Inlet Pressure Meter should be labeled VACUUM PUMP INLET PRESSURE.
- b. The control should be a three-position selector switch and be labeled left to right:
 - (1) 0-10
 - (2) 0-100
 - (3) 0-1000

2. Gas Storage Meter and Control.

- a. The Gas Storage Meter should be labeled GAS STORAGE PRESSURE.
- b. The control should be a three-position selector switch and be labeled left to right:

(1) N₂ TANK A

(2) N₂ TANK B

(3) O₂ TANK

3. Gas Handling Indicator and Controls.

a. The indicator should be amber and be labeled TRANSFER COMPR AND VACUUM PUMP on the panel and AUTO STOP on the light.

b. The pressurizing control should be a three-position selector switch, be labeled NITROGEN ADDITION, and the switch positions be labeled left to right on the panel:

(1) N₂ TANK A

(2) OFF

(3) N₂ TANK B

c. The Oxygen Addition control should be a two-position, spring-loaded-to-the-bottom toggle switch. The switch should be labeled OXYGEN ADDITION, and the switch positions be labeled top to bottom:

(1) ADD

(2) OFF

d. The gas return control should be a three-position selector switch and be labeled GAS RETURN. The switch positions should be labeled left to right:

(1) N₂ TANK A

(2) OFF

(3) N₂ TANK B

e. The evacuation control should be a two-position, lock-in-both-positions toggle switch and be labeled EVACUATE SYSTEM. The switch positions should be labeled top to bottom:

(1) EVAC

(2) OFF

f. The empty tanks control should be a three-position selector switch and be labeled EMPTY TANKS. The switch positions should be labeled left to right:

(1) N₂ TANK A

(2) OFF

(3) N₂ TANK B

Blade Control System

1. Safe 1 Control and Indicator Group.

a. The Safe 1 control and indicator group should be labeled SAFE 1.

b. The control should be a three-position, spring-loaded-to-center-lock position toggle switch with the center position labeled NEUTRAL.

c. The indicator above the control should be green and be labeled OUT.

d. The indicator below the control should be green and be labeled IN.

2. Safe 2 Control and Indicator Group.

a. The Safe 2 control and indicator group should be labeled SAFE 2.

b. The control should be a three-position, spring-loaded-to-center-lock position toggle switch with the center position labeled NEUTRAL.

c. The indicator above the control should be green and be labeled OUT.

d. The indicator below the control should be green and be labeled IN.

3. Shim 1 Meter, Control and Indicator

a. The Shim 1 Meter control and indicator group should be labeled SHIM 1.

b. The Shim 1 control should be a three-position, spring-loaded-to-center-lock position toggle switch with the center position labeled NEUTRAL.

c. The indicator above the control should be amber and be labeled OUT.

d. The indicator below the control should be green and labeled IN.

4. Shim 2 Control and Indicator.

- SHIM 2.**
- a. The Shim 2 control and indicator group should be labeled
 - b. The control should be a three-position, spring-loaded-to-center-lock position toggle switch with the center position labeled NEUTRAL.
 - c. The indicator above the control should be amber and be labeled OUT.
 - d. The indicator below the control should be green and be labeled IN.

5. Shim 3 Control and Indicator.

- SHIM 3.**
- a. The Shim 3 control and indicator group should be labeled
 - b. The control should be a three-position, spring-loaded-to-center-lock position toggle switch with the center position labeled NEUTRAL.
 - c. The indicator above the control should be amber and be labeled OUT.
 - d. The indicator below the control should be green and be labeled IN.

6. Regulating Blade Control and Indicator.

- a. The Regulating Blade control and indicator group should be labeled REGULATING.
- b. The control should be a three-position, spring-loaded-to-center-lock position toggle switch with the center position labeled NEUTRAL.
- c. The indicator above the control should be amber and be labeled OUT.
- d. The indicator below the control should be amber and be labeled IN.

Auxiliary Electrical Equipment

1. Lubrication System.

- a. The Lubrication System should be labeled LUBE OIL.
- b. The Lube Oil Sump Heater control should be a two-position toggle switch labeled MAIN SUMP HEATER, and the switch positions be labeled top to bottom:

(1) ON

(2) OFF

c. The Separator Tank Heater control should be a two-position toggle switch labeled SEP TK HEATER, and the switch positions labeled top to bottom:

(1) ON

(2) OFF

d. The Refrigeration Unit control should be a two-position toggle switch labeled REFRIG UNIT, and the switch positions labeled top to bottom:

(1) ON

(2) OFF

e. The Bypass Valve controls should be momentary push buttons and should have the following left to right indicators above them:

(1) Amber -- labeled OPEN.

(2) Green -- labeled CLOSED.

f. The Main Lube Oil Sump Vent control should be a two-position toggle switch, labeled SUMP VENT with the switch positions labeled top to bottom:

(1) OPEN

(2) CLOSED

2. Shield Water System

a. The Shield Water system should be labeled SHIELD WATER.

b. The Shield Water Heater control should be a two-position toggle switch labeled HEATER, with the switch positions labeled top to bottom:

(1) ON

(2) OFF

c. The Shield Water Pump control should be a two-position toggle switch labeled PUMP, with the switch positions labeled top to bottom:

(1) ON

(2) OFF

3. Moderator System.

- a. The Moderator system should be labeled MODERATOR.
- b. The Moderator Pump control should be a two-position toggle switch labeled PUMP, with the switch positions labeled top to bottom:
 - (1) ON
 - (2) OFF
- c. The Scram Bypass control should be a two-position toggle switch with switch positions labeled top to bottom:
 - (1) (UNLABELED)
 - (2) OFF
- d. The Scram Bypass indicator should be amber and be labeled SCRAM BYPASS.
- e. The Standby Moderator Pump control group be labeled STANDBY MOD PUMP.
- f. The Ready control should be a black momentary push button, and the indicator above the control should be green and be labeled READY.
- g. The manual control should be a three-position, spring-loaded-to-center-lock toggle switch, with the switch positions labeled top to bottom:
 - (1) (UNLABELED)
 - (2) NEUTRAL
 - (3) OFF
- h. The indicator above the toggle switch should be green and be labeled ON.

4. Oil Sump Equalizing Compressor

- a. The Oil Sump Equalizing Compressor control should be a two-position toggle switch labeled OIL SUMP EQUAL COMPR, with the switch positions labeled top to bottom:
 - (1) ON
 - (2) OFF

5. Static Seals

a. The Static Seals control should be a two-position toggle switch labeled STATIC SEALS, with the switch positions labeled top to bottom:

(1) ON

(2) OFF

6. Start-up Compressor System.

a. The Start-up Compressor system should be labeled START UP COMPRESSOR.

b. The Ready control should be a black momentary push button and the indicator above the control should be green and labeled READY.

c. The manual control should be a three-position spring-loaded-to-center-lock toggle switch with the switch positions labeled top to bottom:

(1) (UNLABELED)

(2) NEUTRAL

(3) OFF

d. The indicator above the toggle switch should be green and be labeled ON.

e. The Tach Relay Override control should be a two-position toggle switch labeled top to bottom:

(1) (UNLABELED)

(2) OFF

f. The indicator above the control should be amber and be labeled TACH RELAY OVERRIDE.

7. Standby Oil Pump System

a. The Standby Oil Pump System should be labeled STANDBY OIL PUMP.

b. The ready control should be a black momentary push button, and the indicator directly above the control should be green and labeled READY.

c. The manual control should be a three-position, spring-loaded-to-center-lock position toggle switch, with the switch positions labeled top to bottom:

(1) (UNLABELED)

(2) NEUTRAL

(3) OFF

d. The indicator above the control should be green and be labeled ON.

e. The Tach Relay Override control should be a two-position toggle switch labeled top to bottom:

(1) (UNLABELED)

(2) OFF

f. The indicator above the control should be amber and be labeled TACH RELAY OVERRIDE.

8. Starting Motor System

a. The Starting Motor system should be labeled STARTING MOTOR.

b. The slow control should be a black momentary push button, and the indicator above the control should be green and be labeled SLOW.

c. The fast control should be a black momentary push button, and the indicator above the control should be green and be labeled FAST.

d. The stop control should be a black momentary push button, and be labeled STOP on the panel.

9. Lamp Test

a. The lamp test control should be a black momentary push button, and be labeled LAMP TEST.

b. All indicators, except annunciator indicators, on the console should be on the lamp test circuit.

10. Circuit Breaker System

a. The circuit breakers closed indicators should all be green and be labeled to the right of the indicators:

- (1) A
- (2) B
- (3) C
- (4) D
- (5) E
- (6) F
- (7) G
- (8) H
- (9) J
- (10) K

b. On the ML-1A system, the circuit breakers, with the exception of the main circuit breaker mentioned prior, should be closed, by personnel at the PCS, in alphabetical order. The sequence of equipment operation will thus indicate the arrangement of the circuit breakers on the skid and the appropriate lettering.

Communications

1. The communications system should be of two types:

- a. Headset
- b. Standard commo set

2. The standard communications set should have the following elements:

a. A two-position toggle switch labeled POWER, with the switch positions labeled top to bottom:

- (1) ON
- (2) OFF

b. The speaker volume control should be labeled SPEAKER VOL.

c. The knob should have a clockwise arrow and the label INC on the panel.

d. The listen-talk control should be a two-position selector switch spring loaded to the top position with the switch positions labeled top to bottom:

- (1) LISTEN
- (2) TALK

e. The station selectors should be labeled top to bottom:

- (1) OPERATIONS
- (2) PCS
- (3) MAINT
- (4) ALL
- (5) SPARE

3. The headset jack receptacles and volume control should be located below the rest table.

Clock

1. The clock should be a standard eight-day clock currently carried in military supply channels.

Annunciator System

1. Annunciator

a. The annunciator should be labeled ANNUNCIATOR.

b. The annunciator should be grouped as follows:

(1) 1st Row - Red

(a) FAST PERIOD
CHANNEL 1

(b) FAST PERIOD
CHANNEL 2

(c) FAST PERIOD
CHANNEL 3

(d) FAST PERIOD
CHANNEL 4

(e) (Blank)

(f) (Blank)

(2) 2d Row - Red

(a) HIGH POWER
CHANNEL 5

- (b) HIGH POWER
CHANNEL 6
 - (c) HIGH POWER
CHANNEL 7
 - (d) (Blank)
 - (e) (Blank)
 - (f) (Blank)
- (3) 3rd Row - Red
- (a) TURBINE SPEED
HIGH
 - (b) REACTOR OUTLET
TEMP HIGH
 - (c) MOD LOW FLOW
 - (d) FAST PRESSURE LOSS
 - (e) PRECOOLER FAN
POWER LOSS
 - (f) MANUAL SCRAM
- (4) 4th Row - Amber
- (a) REACTOR OUTLET
TEMP HIGH
 - (b) REACTOR OUTLET
TEMP ERROR
 - (c) REACTOR POWER
LOW FOR AUTO
 - (d) CHANNEL 1 & 2
SATURATION
 - (e) COUNT RATE
CHANNEL 1 LOW
 - (f) TURBINE COMPR
VIBRATION HIGH

(5) 5th Row - Amber

- (a) SHIELD WATER
LEVEL LOW
- (b) SHIELD WATER
CONDUCTIVITY LOW
- (c) SHIELD WATER
TEMP LOW
- (d) MOD WATER
LEVEL LOW
- (e) MOD WATER
CONDUCTIVITY HIGH
- (f) (Blank)

(6) 6th Row - Amber

- (a) MOD WATER PRECOOLER
OUTLET TEMP LOW
- (b) MOD WATER PRECOOLER
OUTLET TEMP HIGH
- (c) MOD WATER REACTOR
OUTLET TEMP HIGH
- (d) COMPR OUTLET
PRESSURE HIGH
- (e) CAB RADIATION
HIGH
- (f) SKID RADIATION
HIGH

(7) 7th Row - Amber

- (a) OIL FILTER DIFF
PRESSURE HIGH
- (b) BEARING TEMP HIGH
- (c) BEARING DIFF
PRESSURE LOW
- (d) OIL SEP TANK
OVERFLOW

- (e) OIL SEP TANK
LEVEL HIGH
- (f) OIL SEP TANK
LEVEL LOW
- (8) 8th Row - Amber
 - (a) REG BLADE
TRAVEL LIMIT
 - (b) GAS STORAGE
PRESSURE HIGH
 - (c) TRANSFER COMPRESSOR
DIAPH PRESSURE HIGH
 - (d) TRANSFER COMPRESSOR
GAS OUT TEMP HIGH
 - (e) VACUUM PUMP
OIL LEVEL LOW
 - (f) STANDBY OIL
PUMP ACTIVATION
- (9) 9th Row - Amber
 - (a) SUMP EQUAL
COMPR OVERLOAD
 - (b) STARTUP COMPR OVERLOAD
 - (c) START MOTOR OVERLOAD
 - (d) MOD PUMP
OVERLOAD
 - (e) MOD/LUBE FANS
OVERLOAD
 - (f) PRECOOLER FANS
OVERLOAD
- (10) 10th Row - White
 - (a) OXYGEN MAKE UP
PRESSURE LOW
 - (b) INVERTER VOLTS LOW

- (c) COMPRESSOR OUTLET
PRESSURE LOW
- (d) COMPRESSOR INLET
TEMP HIGH
- (e) TRANSFER COMPRESSOR
OIL PRESSURE LOW
- (f) MAIN LUBE OIL
SUMP LEVEL LOW

2. Standby Moderator Pump Indicator

a. The Standby Moderator Pump Indicator should be green and be labeled STANDBY MOD PUMP.

b. The indicator should be a true feedback of the standby Moderator Pump. The circuit for this indicator should be energized by inverter power and not by the manual operation of the pump.

3. Alarm Silence, Alarm Lamp Test, and Scram Controls

a. The Scram control should be a red push button and be labeled SCRAM on the control.

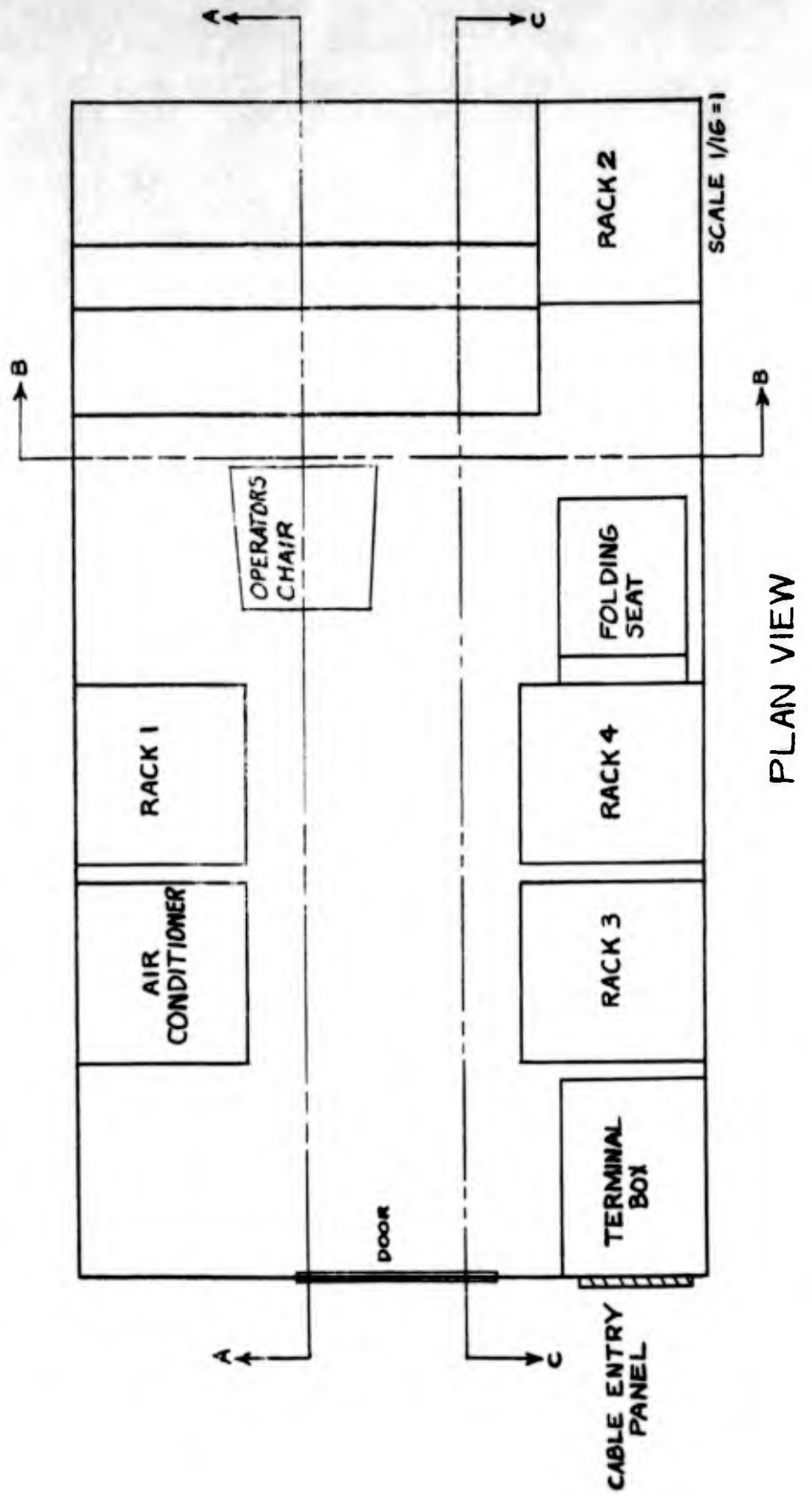
b. The Alarm Silence control should be a black momentary push button and be labeled ALARM SILENCE on the panel.

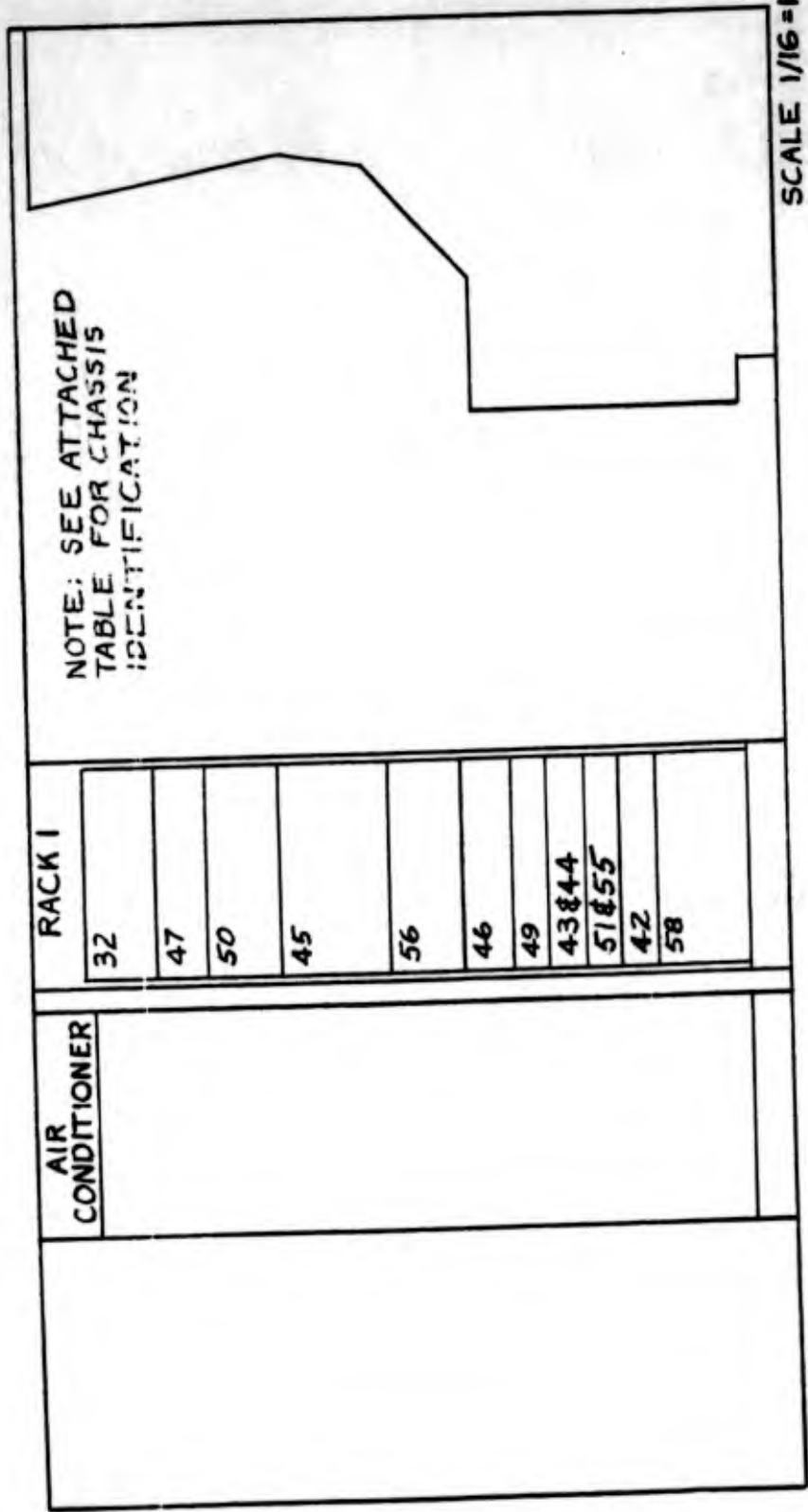
c. The Alarm Lamp Test control should be a black momentary push button and be labeled ALARM LAMP TEST on the panel.



III. CONTROL CAB LAYOUT

PROPOSE LAYOUT - ML-1A CONTROL CAB





NOTE: SEE ATTACHED
TABLE FOR CHASSIS
IDENTIFICATION

RACK I

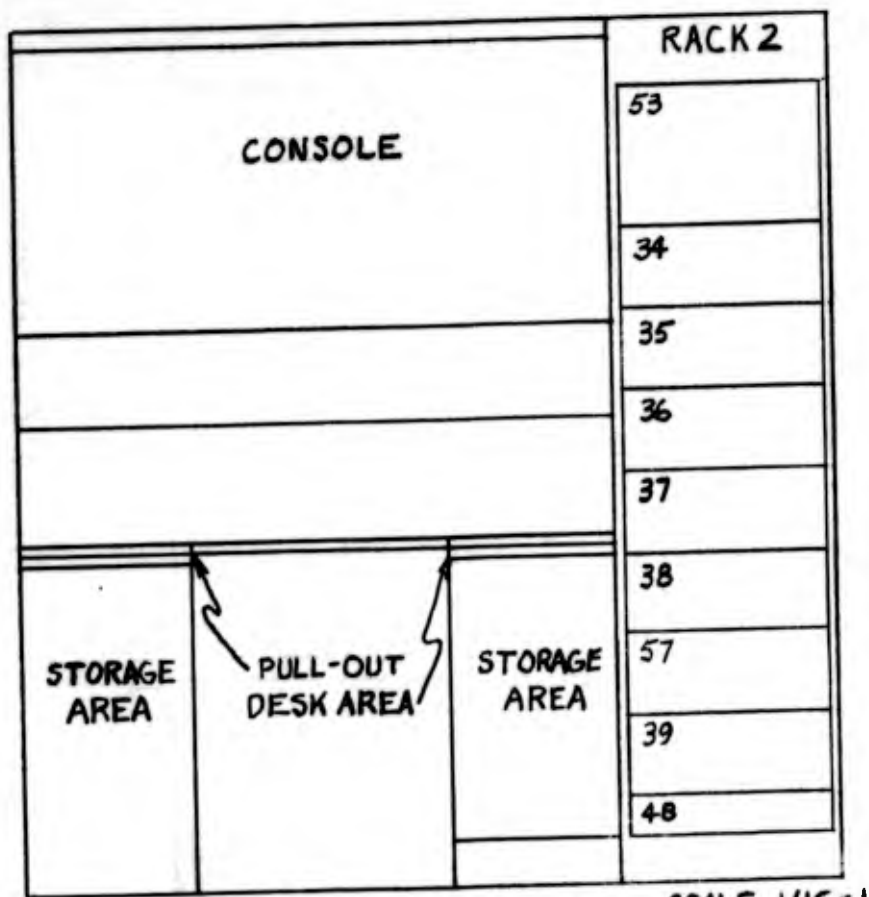
AIR
CONDITIONER

32
47
50
45
56
46
49
43844
51855
42
58

SCALE 1/16"=1"

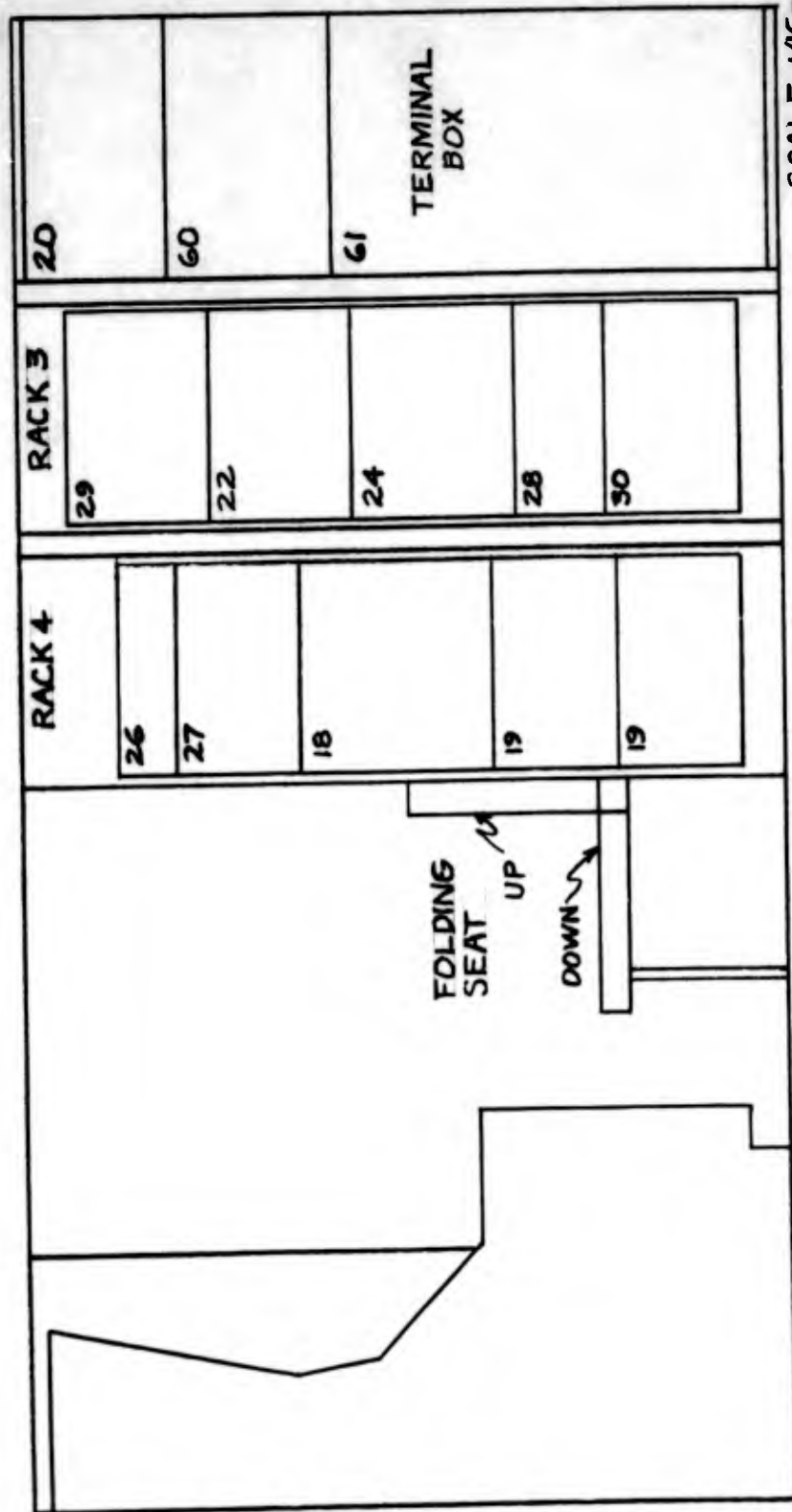
SECTION A-A

PROPOSED LAYOUT - ML-1A CONTROL CAB



SCALE 1/16 = 1

SECTION B-B
 ROTATED 90° CCW



SCALE 1/16"=1'

SECTION C-C
 ROTATED 180° CW

TABLE OF CHASSIS TITLES

The following is a list of chassis titles as referenced on drawings.

Rack 1

- 32. Annunciator and Power Supply
- 47. Shield & Moderator Conductivity
- 50. Bearing Temperature & Liquid Level
- 45. Reactor Outlet Temperature & Turbine Speed Control Amplif.
- 56. Vibration Chassis
- 46. Temperature Instrumentation
- 49. Process Temp System
- 43. Compressor Pressure
- 44. Lube Oil Sump Press System
- 51. Transfer Compr. Oil Press & Oxy Storage Pressure
- 55. Storage Sphere Pressure
- 42. Evacuation Pressure and Fast Pressure Loss
- 58. Storage Drawer

Rack 2

- 53. Sam System
- 34. Source Range Channel 1
- 35. Source Range Channel 2
- 36. Intermediate Range Channel 3
- 37. Intermediate Range Channel 4
- 38. Power Range Channels 5, 6, & 7
- 57. Turbine Overspeed Bypass
- 39. Scram Logic Chassis
- 48. Reactor Outlet High Temp Scram

Rack 3

- 29. Meter Transformer Assembly
- 22. Transfer Relay Panel
- 24. Static Inverter
- 28. Rod Control Relay Chassis
- 30. 7-1/2 KVA Transformer

Rack 4

- 26. Relay Lockout & Personnel Protection
- 27. Static Current Relay
- 18. Battery Charger
- 19. Batteries

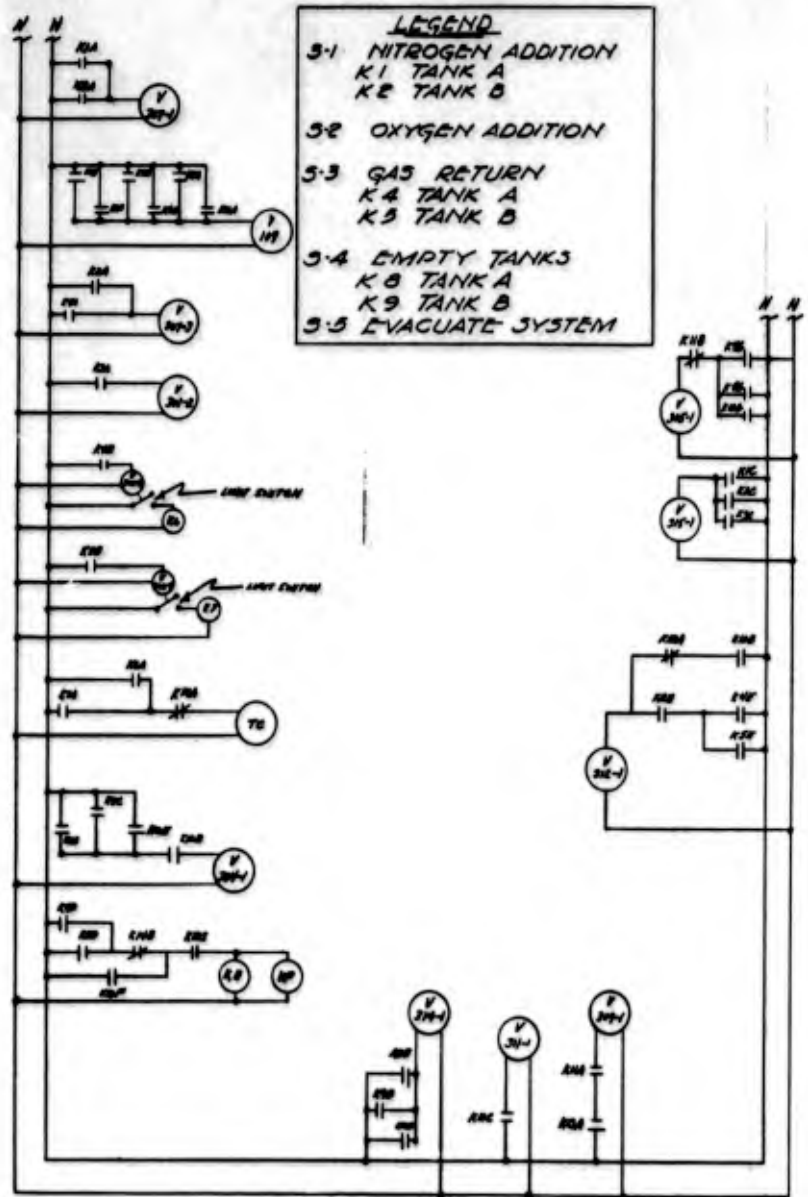
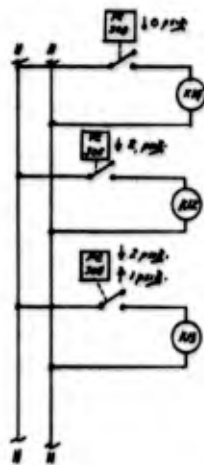
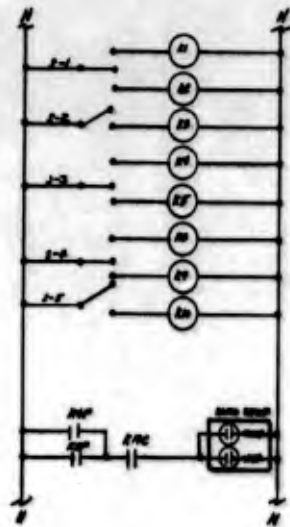
Terminal Box

- 20. Circuit Breakers
- 60. Meter Cabinet
- 61. Terminal Boards

These numbers were used on a control cab layout diagram prepared by the contractor. This diagram had no title or reference.

IV. GAS HANDLING SCHEMATIC

The following drawing is a simplified electrical schematic of the gas handling controls.



PROPOSED CONCEPT OF AL-1A GAS HANDLING SYSTEM / HUMAN ENG. LABS

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UNCL

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2. Nuclear Power Plant

AD

U. S. Army Human Engineering Laboratories
Aberdeen Proving Ground, Maryland
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B. Lawrence Sova, Jr., Marlin E. McCahan, & Richard H. Dewey

Technical Memorandum 19-63 ANOMS Code 5010.21.81902

Unclassified

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Technical Memorandum 19-63 ANOMS Code 5010.21.81902

Unclassified

This report is a continuation of the U. S. Army Human Engineering Laboratories' human engineering evaluation of the M-1 Mobile Nuclear Power Plant and is being conducted at the request of the U. S. Army Corps of Engineers. It covers the period 1 April 1962 to 30 April 1963 and includes a simultaneous task analysis of the M-1 start-up procedures, a review of the layout and operation of the reactor, Power Conversion Skid, and Gas Storage Skid, the monitoring of the contractor's product improvement program, a proposed layout of the M-1A Control Cab, a review of the preliminary M-1A Performance Specification, and a review of the training simulator design. Recommendations are made for improving the operation and maintenance of this system. A brief description of the reactor plant is also included.

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