ANL-7202
Engineering and
Equipment (TID-4500)

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

THE ELECTRICAL DESIGN OF THE EBR-II

by

F. Verber
Reactor Engineering Division

and

H. L. Schmidt
Plant Engineering Division

June 1966

Operated by The University of Chicago
under
Contract W-31-109-eng-38
with the
U. S. Atomic Energy Commission

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

THE ELECTRICAL DESIGN OF THE EBR-II

by

F. Verber and H. L. Schmidt

ABSTRACT

This report summarizes the electrical design of the Experimental Breeder Reactor II Facility (EBR-II). It attempts to gather together and present in reasonable detail the essential features and workings of the completed design, and to present a concise overall view of the system.

The main objective of the EBR-II electrical design was to achieve a high degree of reliability and continuity of power supply commensurate with the desirability of minimizing the number of reactor scrams and consequent thermal shocks to the fuel subassemblies and other components of the reactor.

The order of presentation consists of a simple sequence of main divisions, progressing from general to specific coverage. First, a brief general discussion of the EBR-II is presented, followed by a discussion of physical aspects of the design, including the location and arrangement of electrical equipment in buildings and yard areas. This is illustrated with the use of figures showing electrical equipment layouts. The design features of the underground duct system, grounding system, communication, and alarm systems are then described. Next is presented a brief discussion of the operational characteristics of the electrical system. The remainder of the report, including three Appendices, is devoted to a more detailed technical discussion of the various components and their functions in the system.

Because of the magnitude and many facets of the subject matter involved in the electrical design of the EBR-II, the presentation is necessarily abbreviated. For example, alternative schemes that were investigated and evaluated during the development stages of the design have been omitted; details of controls and instrumentation for most of the electric motor-drive equipment, such as the primary and secondary sodium pumps, have been likewise omitted. Other parts of the design are also presented in a condensed form.

On the other hand, certain areas of the design are treated at considerable length, viz., the 480-V emergency power system, protective relaying, and the turbine-generator.

Notwithstanding the omissions and condensed versions of certain phases of the design, the authors believe this report provides a useful and accurate record of the essential features of the EBR-II electrical design.

I. INTRODUCTION

The Argonne Experimental Breeder Reactor (EBR-II) at the National Reactor Testing Station near Idaho Falls, Idaho, is part of the Atomic Energy Commission's program for the development of power reactors. It is primarily an engineering facility to determine the feasibility of this type of reactor for application in a central power plant. The EBR-II is an integrated nuclear power plant with an unmoderated, heterogeneous, sodium-cooled, fast reactor, with primary and secondary systems for transfer of sodium, a sodium-steam heat exchanger, and a conventional hydrogen-cooled turbine-generator. A fuel-reprocessing plant, in which the irradiated fuel is processed, fabricated, and assembled for return to the reactor, is an integral part of the EBR-II Facility.

The thermal-power capability of the reactor is 62.5 MW, and the gross electric power capability of the plant is 20 MW. The temperature of the sodium at the reactor outlet is 883°F; steam pressure and temperature at the turbine throttle are 1250 psig and 837°F, respectively.

The EBR-II Facility is located on Site 16 of the National Reactor Testing Station (see Fig. 1), along the east line of the NRTS 138-kV power loop between SPERT and ANP Facilities.

Figure 2 gives an aerial view of the EBR-II Facility and an isometric drawing showing the arrangement of the Reactor Plant, Sodium-Boiler Plant, Power Plant, Fuel Cycle Facility, and supporting facilities.

The Reactor Plant houses the reactor system, the primary sodium coolant system, and supporting facilities for these systems, including the high-current power rectifier and floating battery for the primary auxiliary electromagnetic pump. The building is a cylindrical gastight shell of steel plate construction, designed to withstand an internal pressure of 24 psi.

The Power Plant includes the control room for the reactor and power system, the turbine-generator, emergency diesel-generator units, 13.8-kV, 2.4-kV, and 480-V switchgear, motor-control centers, a machine shop, and personnel facilities for the reactor and power-system operating staff. The building is of conventional construction, with pumice block perimeter base wall and sheet metal siding.

The Sodium-Boiler Plant contains the secondary sodium system and the steam generator. The building consists of a "sodium wing" and a "boiler wing," separated by an 18-in.-thick reinforced-concrete wall. The sodium wing houses the pumping, purification, and storage facilities for the secondary system sodium, including the sodium-receiving station. It also contains the motor-generator set for power and control of the a.c. secondary electromagnetic pump, together with instrumentation and control panels. The sodium wing is a single-story structure of fireproof construction. The boiler wing houses the secondary system a.c. linear-induction electromagnetic sodium pump, the sodium surge tank, the steam generator, and associated steam and feedwater piping. The boiler wing is of reinforced-concrete construction.

The Fuel Cycle Facility contains a shielded argon-atmosphere cell and a shielded air-atmosphere cell for disassembly, processing, fabrication, and assembly of fuel elements and subassemblies. The Facility also contains supporting facilities for these operations, including an emergency diesel-generator unit, the inert-gas storage facilities, the sodium equipment cleanup cell, and exhaust ventilation system and stack for the Fuel Cycle Facility, Reactor Plant, and Laboratory and Service Building. The building is of conventional construction with pumice blocks base wall and sheet metal siding.

The Laboratory and Service Building is a one-story pumice block structure, with a basement, containing laboratories, darkroom offices, locker room, and related facilities. The ANL Idaho Division Director, Assistant Business Manager, and staffs have offices in this building.

Special facilities, including low- and high-level counting rooms, fuel storage vaults, junior caves constructed of high-density concrete, disposal systems for contaminated and suspect waste, and related facilities, are also included. The automatic telephone exchange equipment for the entire EBR-II facility area is installed in this building.

Pump House No. 1 is a one-story pumice structure adjacent to the above-ground water-storage tank, housing deep well pump No. 1, three water service pumps, and the diesel-driven fire pump, including all instrumentation, controls, and auxiliaries.

Pump House No. 2 is a one-story pumice block building which houses the deep well pump No. 2 and its instrumentation and control.

The Fuel Oil Tank and Pump House is a pumice block structure built adjacent to the above-ground fuel-oil-storage tank; it houses the oil-pumping equipment, and is complete with piping, controls, instrumentation, and auxiliaries.

The Fire House is a pumice block structure with space for living quarters for the fire protection crew and garage space for one ambulance and one fire truck; it is equipped with electric power-operated doors.

The Guard House is a pumice block structure with counters, storage racks, and turnstile. The short-wave radio system and gate-operation controls are housed in this building.

The Waste Disposal Facilities is a complete system for disposal of sanitary and industrial wastes, and includes lift stations, Imhoff tank, sewage treatment house, metering pit house, and leaching pit. Below-ground installations are of reinforced concrete and above-ground buildings of pumice block. The buildings are electrically heated and house equipment used to operate the system.

The Materials and Service Building is a standard prefabricated steel frame, sheet metal building erected on a concrete slab. It houses the plant services organization.

This report focuses on the principal design elements comprising the EBR-II electric power system.

The design features incorporated in the power system represent an attempt to achieve a high degree of continuity of power supply and thus to minimize the number of reactor "scrams" and consequent thermal shocks to the fuel subassemblies and to other components of the sodium-cooled reactor. Careful consideration was given to various factors affecting the system design with respect to reliability, flexibility, control and instrumentation, safety, maintenance, and economy.

In general, all electrical equipment, such as the 13.8-kV, 2.4-kV, and 480-V switchgear, transformers, motors, and motor-control centers was designed, constructed, and factory tested in accordance with the prevailing applicable standards of the American Standards Association and the National Electric Manufacturers Association.

Several private companies contributed substantially to the electrical design or construction of the EBR-II Facility. The following is a list of some of these companies:

The H. K. Ferguson Co., Cleveland, Ohio	Architect-Engineer (General)
Gibbs and Hill, Inc., Los Angeles, California	Architect-Engineer (138-13.8-kV Outdoor Substation)
Diversified Builders, Inc., Paramount, California	General Construction Contractor
C. L. Electric Company, Pocatello, Idaho	Electrical Construction

Bonberg and Wehrheim Electric Co., Las Vegas, Nevada	Electrical Construction
Fischback and Moore, Inc., Seattle, Washington	Electrical Construction
J. F. Prichard and Co., Kansas City, Missouri	Electrical Construction
General Electric Company, Chicago, Illinois	Generator Transient Stability Study
Sargent and Lundy Engineers, Chicago, Illinois	Protective Relaying Study
Detroit Edison Company, Detroit, Michigan	Design Review

Overall design responsibility for the EBR-II Facility was assigned to the Reactor Engineering Division of the Laboratory. The following is a list of staff personnel who made substantial contributions to the EBR-II electrical design:

L. Barnes
P. E. Brown
D. L. Byers[1]
T. D. Cassidy
S. L. Chapin[2]
R. I. Fabijonas
V. E. Finnegan
J. J. Gregory[3]
J. R. Goodrich
F. B. Hall
H. H. Hooker
R. A. Jaross
H. Kacinskas
L. J. Koch
M. Levenson
A. Lovoff
H. O. Monson
K. J. Moriarty
C. A. Pesce
C. M. Putness
R. L. Ramp
J. R. Simanton
H. L. Schmidt
G. H. Schmuz[1]
W. R. Simmons
T. R. Spalding
D. J. Veith
F. Verber
W. W. White[4]
L. J. Worley[1]

In addition, the members of the Reactor Engineering Division Drafting Department, Scheduling Section, and Secretarial Section contributed very significantly to the project.

The following is a list of the manufacturers of major items of electrical equipment used in the Facility.

---

[1]On loan from Illinois Power Company, Decatur, Illinois.
[2]On loan from Sargent and Lundy Engineers, Chicago, Illinois.
[3]On loan from Commonwealth Edison Company, Chicago, Illinois.
[4]On loan from Detroit Edison Company, Detroit, Michigan.

Federal Pacific Electric Co., Newark, N. J.	Metal Clad Switchgears, Power Transformers, Motor Control Centers
General Electric Co., Schenectady, N. Y.	Turbine-Generator Unit, M-G Set for Secondary Pump, Motor Control Centers
Leeds and Northrup Co., Philadelphia, Pa.	Instrumentation and Control, Control Panels
Electric Machinery Mfg. Co., Minneapolis, Minn.	M-G Sets for Primary Pumps
The Electric Products Co., Cleveland, Ohio	Continuous Power Supply System
Ther Electric and Machine Works, Chicago, Ill.	D.C. Power Supplies
Richardson-Allen Corp., College Point, N. Y.	D.C. Power Supply
Waukesha Motor Co., Waukesha, Wis.	Diesel-Generator Units
Westinghouse Electric Corp., Pittsburgh, Pa.	Main Power Transformers, 138-kV Oil Circuit Breaker and Disconnecting Switches

II. DESIGN SUMMARY

This section of the report is concerned primarily with the physical aspects of the design, with emphasis on the locations and arrangements of electrical equipment in the Main Outdoor Substation, Power Plant, Reactor Plant, Sodium-Boiler Plant, and Fuel Cycle Facility. In addition, the design features of the undergound duct system, grounding system, communications and alarm systems, and yard lighting are described.

A. EBR-II 138-13.8-kV Main Outdoor Substation

The EBR-II substation (see Fig. 3) is comprised of high-voltage equipment including two main power transformers, one 138-kV oil circuit breaker, six disconnecting switches, six coupling capacitor potential devices, six lightning arresters, and porcelain insulators. The support structures for the incoming 138-kV lines from SPERT and ANP and for the disconnecting switches, bus supports, and bus sections consist of galvanized structural steel racks. The power transformers, lightning arresters, and potential devices are mounted on concrete pads. A 176- by 106-ft chain link, galvanized steel fence surrounds the substation. A normally unattended control house is located inside the substation, between the power transformers. The control house contains a duplex relay and control board, a supervisory panel, a 125-V, 60-cell station control battery, battery charger, distribution panels, and a cable pit for interconnection cables to the EBR-II Power Plant and Scoville Substation.

The EBR-II substation is typical of other high-voltage substations on the NRTS loop, except that the secondary circuit breakers are located in the Power Plant Building instead of in the substation control house. The transformers are connected to the circuit breakers by insulated power cables installed in underground ducts.

B. Power Plant

Control of power generation and 13.8-kV, 2.4-kV, and 480-V power distribution is accomplished essentially from control-panel sections E-1 through E-7 in the Main Control Room located on the operating floor of the Power Plant Building (see Fig. 4). West of the Main Control Room is the turbine-generator, the 13.8-kV metal-clad switchgear, the turbine gauge board, and the hydrogen panel.

Located on the mezzanine floor (see Fig. 5) are the generator field amplidyne excitation system cubicle, the battery room containing the 125-V station battery, the 240-V floating battery for the continuous power-supply system, and the Cable Routing Room which houses the continuous power-supply system unit, distribution panels, control-rod relay cubicles, nuclear relay racks, and process shutdown relay racks. A network of cable trays provides for the routing of the numerous control cables between the console and control panels in the Main Control Room above, and the various equipment and devices located in the Power Plant Building, Reactor Plant Building, and other areas of the Facility.

The 2400-V metal-clad switchgear is located on the first floor along the south wall of the building. Approximately 15 ft to the east is the 480-V main switchgear. On the outside of the building wall are located two 2500-kVA and two 2000-kVA askeral-filled power transformers. These are connected to the 2400-V switchgear and 480-V main switchgear, respectively, by metal-enclosed bus ducts (see Fig. 6). Within 40 ft of the 480-V main switchgear are located the 480-V emergency switchgear, the 100-kW and 400-kW emergency diesel-generator units, the 480-V lighting distribution center, and 480-V motor control centers P-1, P-2, R-1, and R-2. These constitute the main distribution centers of the 480-V power system.

The 480-V lighting distribution center consists of circuit-breaker sections for each of the 112-kVA, 480-120/208-V lighting transformers in the Power Plant and Reactor Plant, and the 480-V distribution panel in the 138-13.8-kV substation.

Motor-Control Center (MCC) P-1 feeds the auxiliary loads located in the Power Plant Building; MCC P-2 serves the cooling tower fans, startup boiler feedwater pump, etc; MCC R-1 serves Reactor Plant and Power Plant auxiliaries; MCC R-2 feeds the shield- and thimble-cooling system drives.

Front panel views of the 13.8-kV, 2.4-kV, and 480-V switchgear, showing arrangements of controls, instrumentation, and protective relays, are shown in Figs. 7 through 10.

C. Reactor Plant

The electrical equipment and cables used in the Reactor Plant Building are mainly of standard manufacture, and were installed in accordance with conventional industrial and power-plant practices. Motor-control centers, power rectifiers, instrument panels, safety switches, starters, distribution panels, etc., have general-purpose enclosures. In general, no special insulation or special enclosures were required for protection from exposure of electrical devices and wiring to radioactive radiation. Special consideration, however, was given for the cables and devices used in locations of comparatively high levels of radioactivity; for example, radiation-resistant, 600-V, glass-braid, multiconductor, shielded cables with Mylar tape wrap and silicone jacket were used in certain instrument thimbles in the primary tank.

Cable trays are installed along sections of the wall above the operating floor and on the electrical-equipment balcony for the routing of power, control, and instrumentation cables. Cable trays are similarly used in the shallow depressed area adjoining the primary tank. Steel conduits buried in the concrete walls and floors provide for vertical and horizontal routing of cables. Penetration of the reactor building steel containment shell with electrical circuits is covered in Appendix C. See Appendix A for control modification of building crane.

Figure 11 depicts a vertical cross section of the Reactor Plant Building and plan views, showing the arrangement of equipment on the operating floor, depressed areas, and electrical-equipment balcony. The rectifier and floating battery for the auxiliary primary electromagnetic (EM) pump are located in the shallow depressed area. Instrument centers Nos. 1 and 2 are located nearby on the operating floor; the local control cabinet for the auxiliary pump is mounted on the north side of instrument center No. 1. The main disconnect breaker and 480-V distribution panel for the primary-tank immersion heaters are mounted on the wall behind instrument center No. 2. The fuel-handling control center is located near the personnel air lock.

The rectifier for the fuel-element-rupture-detector EM pump is located in the depressed area east of the primary tank. The rectifier for the sodium-purification-system pump is located on the electrical-equipment balcony, along with motor-control centers Nos. 4 and 5, 480- and 240/120-V distribution panels, starters and variacs for the fuel-handling system, rotating-plug-seal heaters, argon-cooling system, and other loads.

Figure 12 shows the arrangement of various electric-power and control equipment in the basement, and also the shield- and thimble-cooling systems drive equipment in the subbasement.

D. Sodium-Boiler Plant

The 350-kW motor-generator set for the secondary sodium a.c. linear EM pump is located in the electrical room (see Fig. 13) in the sodium wing of the Sodium-Boiler Plant. The electrical room also houses the motor-control center S-1, sodium induction-heating and resistance-heating panels, a Panascan control panel, the sodium plant control panel, and other control panels.

The power transformers for the sodium piping-heating system and for sodium surge-tank heaters are located in the basement under the electrical room. The secondary a.c. linear EM pump is located on the first floor of the boiler wing.

E. Fuel Cycle Facility

Figure 14 is a layout of the Fuel Cycle Facility basement showing the main incoming line circuit breakers, emergency diesel-generator unit, automatic transfer switch, motor-control center, and various auxiliary drives.

Figure 15 is a sectional elevation of the Argon Cell showing the arrangement of the cell cranes and manipulators, as well as their feeder and control cables.

F. Underground Duct System

The underground distribution systems for the EBR-II utilities and services include electrical, water, steam, condensate, fuel oil, demineralized water, sanitary sewers, industrial waste sewers, compressed plant air, compressed instrument air, and suspect gas.

The electrical underground system (see Fig. 16) consists of necessary manholes, handholes, concrete-encased nonmetallic ducts and/or galvanized steel conduit runs, and cables as required for the power, control, alarm, and communication circuits between the buildings.

The following briefly reflects the design criteria for the underground duct system:

Underground nonmetallic ducts and galvanized steel conduits are encased in a red-dyed reinforced-concrete envelope (for ready identification as an electrical duct) with a minimum of 3-in.-covering on all sides. The concrete is mixed with a red dye to produce a distinctive red coloring of the concrete. Reinforcing steel rods for the concrete envelopes are arranged in a manner to avoid forming continuous conducting paths around any one duct or group of ducts, thus preventing the flow of induced circulating currents.

Steel dowels are installed between the concrete envelope of a nonmetallic duct bank and the wall of a building or manhole on which the envelope terminates. The nonmetallic ducts are made of pressed cement-asbestos (Transite Korduct).

Separate manholes and handholes are provided for power and communications underground services. Electric manholes are of reinforced-concrete construction with overall dimensions approximately 72 x 66 x 90 in. deep, with 6-in.-thick walls and ceiling, and an 8-in.-thick floor pad. The manhole is equipped with a cast iron cover assembly, access ladder, sump, grounding cable, supports, and cable-pulling irons. The telephone manholes are of the same type of construction and approximately 66 x 60 x 90 in. deep. The handholes are approximately 66 x 30 x 54 in. deep.

The cables for underground power distribution at 480 V have 1000-V insulation; the cables for power distribution at 2.4 kV have 5-kV insulation; for power distribution at 13.8 kV, 15-kV ungrounded neutral insulation.

G. Grounding System

Because of the poor electrical-grounding characteristics of the surface and underground strata at the EBR-II site, it was necessary to provide a yard grounding network system which is more elaborate and expensive than those usually required in the average industrial or utility plant in this country.

The yard grounding network system (see Fig. 17) is comprised principally of copper grounding plates, grounding electrode inspection and testing wells, and #4/0 and 500 MCM bare, interconnecting copper grounding cables. All splices of grounding cables and copper rod connections to the grounding plates are of the "Cadweld" thermal process-type connections (see Fig. 18). Buried bolted connections were not permitted.

The grounding electrode inspection wells provide for the inspection of grounding connections and watering the earth around the ground electrode plates during the dry season. The connection of the grounding cables from the grounding network to the copper rod that is welded to the ground plate is made with a solderless connector to allow testing of the grounding electrode separate from the network. The grounding electrode wells consist of cast iron boxes of 16-in. inside diameter, 24-in. high, and with a 13-in.-diameter cast iron cover.

The grounding network is connected to building structural steel and to the ground bus-bar systems in buildings. All switchgear enclosures, transformer enclosures, motor and generator frames, bus duct enclosures, distribution cabinets, motor-control centers, control panels, etc., are grounded to their respective ground bus system. Ground connections to equipment that could be removed during the normal life of the facility are made by means of a thermally welded lug, bolted to the equipment.

The overall effectiveness of the grounding system is enhanced substantially by the connection of the above-described grounding network system to the casings of the deep well pumps No. 1 and 2, and to the grounding grid in the 138-13.8-kV Outdoor Substation.

The well casings extend from the yard level to the permanent underground water level, approximately 650 ft below.

The grounding grid in the 138-13.8-kV Outdoor Substation consists of ground rods driven into the ground and interconnected by buried #4/0 bare copper cable; all buried ground connections are "Cadweld" connections. The driven ground rods are spaced approximately 10 ft apart. All electrical equipment, the substation steel structures, overhead static wires, the conduit system, and the substation fence are grounded to the substation ground grid.

The following listed ground-resistance measurements were taken on structural members of buildings at or near the locations indicated:

Location	Ground Resistance, Ω
Outdoor Substation Fence (north center)	1.5
Power Plant (west door)	0.5
Reactor Plant (freight door)	0.4
Sodium-Boiler Plant (sodium wing, south entrance)	0.8
Fuel Cycle Facility (north entrance)	0.7

The measurements were made on June 24, 1965 with an Associated Reasearch Inc. VIBROGROUND, Model 251 Tester (Ser. No. 251877).

The principal ground for the TREAT Facility is established by means of buried copper grounding cables connected to the EBR-II grounding network.

H. Communications and Alarm Systems

1. Telephone and Public Address System

The telephone and public address or paging system is an integrated system. It was designed, furnished, installed, and is being maintained by the Mountain States Telephone and Telegraph Company (MST&T). The system includes all necessary equipment, such as telephone instruments, switchboards, telephone racks, relay racks, telephone terminal boards, amplifiers, loudspeakers, and wire and cable. This equipment is provided by MST&T on an installation and rental basis as adopted for similar equipment and installations in other facilities in the National Reactor Testing Station.

The Laboratory and Service Building is the distribution center for all telephone circuits in the EBR-II area. A 300-line (300-pair) automatic telephone exchange is installed in the basement of that building. This exchange accommodates the needs of EBR-II and TREAT as well as the needs of ZPPR, ITF, and other future additions in the area.

The telephone system is equipped with extensions connecting the EBR-II area with EBR-I and other selected extensions on the NRTS Site, which may be reached directly by dialing. Other extensions on the NRTS Site are reached through the telephone switchboard at NRTS Central Facilities.

The public address system enables one to page in any building and certain yard areas on the EBR-II site. Any phone in the EBR-II telephone system can be used to address the desired EBR-II area by dialing the number listed for that area. There is one unlisted emergency all-call number which is given very limited distribution. When this number is dialed, it overrides any other calls that may be occurring or attempted. Emergency all-call addresses are automatically delivered with increased volume.

A particularized telephone installation is provided between the Console in the Main Control Room and stations in the Cable Routing Room, Reactor Plant, and Sodium-Boiler Plant. A pushbutton station on the Console permits ringing the other stations simultaneously or individually, and also permits connection to the plant telephone system for outside calls; a hold pushbutton is also included. The outlying stations are equipped with pushbuttons and can call the Control Room Console and can also make outside calls. Power for this service is supplied by a rectifier connected to the process generator of the continuous power supply system.

A common talk line is provided in the Fuel Cycle Facility. This consists of a single telephone line to which are connected plug-in jack-type telephone stations located at the viewing windows of the Argon and Air Cells and a two-way speaker located in the control room. By plugging in head or hand phones, any station can communicate with the other stations on the line. Outside calls, one at a time, may also be made from these stations.

A four-channel sound-powered telephone system is installed for communication between the Main Control Room and various operating locations in the Power Plant, Reactor Plant, and Sodium-Boiler Plant. The plug-in, sound-powered telephone sets are U. S. Instrument Company Type A560 hand phones. The locations of the telephone jacks comprising the four channels are as follows:

Channels 1, 2, 3, and 4

a. Control Room (5 locations)
b. Sodium-Boiler Plant Control Panel
c. Instrument Control Center #1
d. Instrument Control Center #2
e. Instrument Control Center #3
f. Corridor Panel
g. Cable Routing Room (2 locations)
h. Fuel Handling Console
i. Datex System (Reactor Basement)

Channels 1 and 3

a. Outside personnel air lock
b. Inside personnel air lock

Channel 1

(Sodium-Boiler Plant -- Boiler Wing)

a. Main floor near EM pump
b. 2nd level, top of stairway
c. Near feedwater valve
d. 3rd level, top of stairway
e. Top level, near surge tank

Channels 1 and 2	
a. At turbine panel	i. North turbine pedestal
b. & c. East and west ends of 13.8-kV switchgear	j. Feedwater pump panel
	k. Demineralizer area
d. Near condensate storage tank	l. South turbine pedestal
e. Near air ejectors	m. Near hydrogen-system manifold
f. Near turbine oil system (mezzanine)	n. On catwalk over pump pit
g. Near flash tanks	o. On generator exciter panel (mezzanine)
h. End of No. 1 heater	

2. Evacuation Alarm System

The evacuation alarm system is designed to alert the entire EBR-II area in the event of a radiation hazard. The main evacuation siren is a Federal Sign and Signal Corp. Model 2T22 siren with a $7\frac{1}{2}$-hp, 440-V, 3-phase motor mounted on top of the Power Plant Building. Small sirens of the same manufacture, Bulletin 111, Model A for 110-V, single-phase operation, are installed in the following locations: one in the cable tunnel, two in the basement of the Laboratory and Service Building, two in the basement of the Fuel Cycle Facility, three in the Reactor Building, and one in each basement wing of the Sodium-Boiler Plant. Electric power for the operation of the sirens originates on the emergency bus section of motor-control center R-1.

The evacuation alarm system can be actuated from a control station located in the Division Director's office, the EBR-II Reactor, the Main Control Room, the Fuel Cycle Facility, and the Guard House. Each control station has a black alert pushbutton which initiates a continuous siren signal, a red evacuate pushbutton which initiates an oscillating siren signal, and indicating lights which indicate the location from where an alarm originates. In addition, indicating light stations are installed in the two wings of the Sodium-Boiler Plant and in the Materials and Services Building. All-clear notification is given by voice over the public address system.

3. Fire and Security Alarm Systems

The EBR-II complex is equipped with a fire and security alarm system, including manual fire alarm, automatic fire alarm, vault and burglar alarm, and watchman tour reporting.

The fire alarm system is an American District Telephone Company (ADT) system of the supervised, noninterfering, coding type. The system includes manual fire alarm stations, automatic fire alarm stations, space indicating cabinets, coding bells and horns, and smoke detectors.

Systems that detect sodium smoke are installed in the Sodium-Boiler Plant and Reactor Plant. The actuation of any fire alarm device results in the sounding of all coding bells within the building in which the device is actuated. The code numbers are assigned so that the first digit of the code indicates the building, the second digit indicates the floor or subdivision of the building, and the third indicates the specific location of the actuated device from which the alarm originates. Fire alarm signals are recorded on a punch-type recorder located in the Fire House. The signals are retransmitted via telephone wires to Central Facilities Area Fire Headquarters.

Ultrasonic burglar-alarm units are installed for protection of the two vaults in the Laboratory and Service Building. The alarm signal is transmitted via telephone wires to burglar-alarm drops located at Central Facilities.

The watchman tour system consists of key-operated mechanical watch tour stations and electrical code-transmitting start, mid-tour, and finish stations. The electric stations are located in the Guard House, Power Plant, and Guard House, respectively. Watchman tour signals are recorded at Central Facilities Area Communications Room via telephone wires.

J. Yard Lighting

1. Security Fence Lighting

The security fence-lighting system is a 120/208-V, 3-phase, 4-wire system consisting of aerial cables carried on a wooden pole line installed 15 ft inside the site perimeter fence. The distance between poles is approximately 130 ft. A die-cast aluminum hood lighting fixture with reflector and 500-W lamp is mounted on each pole. The power feeder circuits to the pole line are run in concrete-encased underground conduits from the Guard House, where two combination starters and four fused safety switches are located for control and protection of the lighting system. A photoelectric control device is used for automatic control of the lighting.

2. Road and Parking-lot Lighting

The road-lighting system consists of aerial wires installed on wooden poles and with a die-cast aluminum hood lighting fixture with reflector and a 200-W lamp mounted on each pole. Lighting fixtures are also mounted on the walls of buildings. The 120-V a.c. power for the lighting circuits is taken from panels located in nearby buildings.

The parking-lot lighting system consists of a series of wooden poles with a die-cast aluminum hood lighting fixture complete with a 6-ft upswing pipe bracket mounted on each pole. Wiring between poles is carried in underground conduit. Power is supplied from the Fire House.

The road-lighting and parking-lot lighting systems are both controlled by photoelectric control devices.

3. Parking-lot Head-bolt Heaters

A wooden rack on which are mounted waterproof power outlets for 2500-W, 120-V tank-type heaters for buses is installed along the west side of the parking lot and a similar rack on which are mounted power outlet cords for 650-W, 120-V head-bolt heaters for passenger cars is installed along the east side of the parking lot. The feeder cables originate in the 120/208-V Parking Lot Power Panel located in the Fire House.

III. OPERATIONAL CHARACTERISTICS

The following brief description of the operational characteristics of the Electric Power System is intended to present a concise overall view and to highlight the major features, particularly in respect to essential interrelationships of its parts. Other characteristics and ratings of equipment comprising the power system are covered in Section IV - MAJOR COMPONENTS.

A. NRTS Electric Power System

The NRTS 138-kV power loop (see Fig. 19) includes substations for Scoville, SPERT, EBR-II, ANP, NRF, MTR/ETR, and CPP. The loop is a 65-mile-long single-circuit line consisting of three 397,500-circular mil ACSR conductors, carried on wood-pole H-frame structures, and protected by two overhead ground wires, each 5/16-in., 7-strand, high-strength, galvanized steel.

Power at 138 kV and 60 cycles is delivered to Scoville through circuit breaker 8B1-1 over the Utah Power and Light Company single-circuit tramsmission line from Goshen Substation, located approximately 45 miles southeast. Provision has been made at the MTR substation for future receipt of 138-kV power through circuit breakers 8B3-2 and 8B3-3 over a single-circuit transmission line from the American Falls Substation of the Idaho Power Company. A Utah Power and Light Company 44-kV single-circuit line from Arco, about 19 miles distant, is connected to Scoville Substation through a power transformer.

The EBR-II 20,000-kW turbine-generator supplies power to the NRTS system on an "as available" basis.

The NRTS high-voltage system is controlled from the control room at Scoville Substation. This control room includes the control, instrument and relay panels for Scoville Substation, power-company billing meters and telemetering equipment, and the dispatching panels of the supervisory control system.

The high-voltage substations are normally unattended and are controlled from Scoville over the supervisory control system. At each substation control switches and indicating lamps are provided for local control, together with a manually operated control-selector switch. In one position of this switch only local control is permitted; in the other position only supervisory control is permitted. Indication of the supervised switches and circuit breakers over the supervisory control system remains effective, whether the control-selector switch is in the local position or the supervisory position. The position of each control-selector switch is also indicated on the supervisory control panels at Scoville.

Normal operation of the 138-kV power system is with the loop closed. Protective relays are provided on the sections of the loop to trip circuit breakers and open motor-operated disconnect switches as required to clear and isolate a faulted line section or power transformer while maintaining continuity of power supply to other parts of the system with a minimum of disturbance.

Protection against phase-to-phase and phase-to-ground faults is provided for each 138-kV loop section between substations by a Westinghouse Corp.-Type HCB high-speed current differential pilot-wire relay at each end of the line. Backup protection is provided by Westinghouse Corp.-Type CR, CR-8 or HCZ (directional overcurrent and directional impedance) relays for phase-to-phase faults, and by Type CR, CRC, CWP or CWC (directional ground) relays for phase-to-ground faults.

The current transformers for the line relays are connected so as to place the power transformers outside the line-section protected zone. Therefore, current surges caused by transformer-energizing currents, loads, or faults outside the protected zone will appear as through currents and will not cause operation of the HCB relays.

The pilot wires used in conjunction with the protective relaying scheme employed between substations are continuously supervised by Westinghouse Corp.-Type PS-13 and PS-3 or PS-23 relays. These relays will detect an open circuit, short circuit, or ground fault of the pilot wires, and cause an alarm to sound. The pilot wires and their supervisory relays are also used for transfer-tripping functions in case of a fault in a step-down power transformer.

When any 138-kV line section, either of the loop system or of the supply lines, is cleared by operation of high-speed pilot wire or carrier-current relays, the oil circuit breakers at each terminal of the faulted line section are automatically reclosed within 20 cycles by reclosing relays. If the fault persists and the breakers trip again, or if they were initially tripped by line-backup relays or transformer-differential relays, the reclosing function is locked out.

B. EBR-II 138-13.8-kV Main Outdoor Substation

Figure 20 is a simplified single-line diagram of the EBR-II electric power system. As indicated, the Main Outdoor Substation has two class OA/FA, 12,000/16,000-kVA, 132-13.8-kV, 3-phase, 60-cycle power transformers with automatic load tap-changing equipment. These transformers tie the 13.8-kV switchgear (located in the Power Plant Building) to the 138-kV power system. This provides duplicate main power interconnections and will permit essentially full-capacity operation of the EBR-II facility in the event one transformer is out of service.

The 138-kV loop-sectionalizing breaker 8B11-1 and the motor-operated line and transformer-disconnecting switches are normally controlled by supervisory equipment from Scoville Substation; they may also be controlled from the control house located in the EBR-II Main Outdoor Substation. Similarly, 13.8-kV incoming line circuit breakers 5B11-1 and 5B11-2 in the Power Plant Building may be tripped (but not closed) from Scoville Substation or from the control house in the EBR-II Main Outdoor Substation.

C. EBR-II Turbine-generator

Control and instrumentation for the EBR-II generator and electric power and distribution system are located principally on panel boards in the Control Room in the Power Plant Building.

Parallel operation of the EBR-II turbine-generator with the NRTS power loop is normally under initial pressure-regulator control (overriding the speed-governor control) to maintain a constant pressure in the steam inlet to the turbine throttle. The load assumed by the generator varies directly with the output of the reactor up to the limit established by the load limit device or speed governor.

Automatic return to speed-governor control of the turbine is provided in the event the connection between the generator and the NRTS loop opens.

The EBR-II generator is of conventional hydrogen-cooled nonsalient pole design, rated 25,650 kVA, 13,800 V, 3-phase, 60-cycles, 0.85 power factor, 3600 rpm, with a direct connected exciter. Excitation control for the generator is maintained by a continuously acting regulating (amplidyne buck-boost) system.

When the EBR-II generator is operating in parallel with the NRTS system, there are three sources of 13.8-kV power at the EBR-II Facility, namely, the two 13.8-kV incoming lines from the main power transformers (eventually to be backed up by a second 138-kV utility power-company transmission line serving the NRTS loop) and the EBR-II generator itself.

The EBR-II auxiliary load during 45 MWt operation of the reactor and with the turbine-generator operating is currently approximately 3.2 MW, including operation of the 800-hp motor-driven boiler feedwater pump. When the motor-driven feedwater pump is not in use, the auxiliary load is approximately 2.7 MW. During plant standby, the EBR-II auxiliary load is approximately 3.2 MW. A 10 to 15 per cent increase in these loads is anticipated when the Facility will be operating at full capacity.

As previously noted, normal operation of the NRTS power system is with the loop closed. It was determined by a transient-stability study that it could be hazardous to operate the EBR-II turbine-generator tied to the NRTS system while the loop is open and an automatic (20-cycle) reclosure of one of the loop sectionalizing breakers in the circuit occurs. The procedure for operation of the turbine-generator therefore requires that the NRTS loop must be closed when the generator is tied to it. It is evident that if automatic (20-cycle) reclosure of a loop-sectionalizing breaker occurs in the closed loop, there is no hazard to the turbine-generator, since the circuit between the generator and the loop is not interrupted.

It was also determined that an automatic reclosure of a breaker in the Utah Power and Light Company 138-kV transmission line from Goshen Substation could similarly prove hazardous to the EBR-II turbine-generator. To prevent this, pilot-wire tripping of the 13.8-kV incoming line circuit breakers 5B11-1 and 5B11-2 is provided when the automatic reclosure of a 138-kV breaker in the utility transmission line is initiated. In this case, the EBR-II turbine-generator supplies the EBR-II Facility loads as a single unit generator, until it is desired to synchronize and return to parallel operation with the NRTS system.

An under-frequency relay is connected to separate the EBR-II system from the NRTS system (by tripping breakers 5B11-1 and 5B11-2) when the turbine-generator is operating and the frequency of the NRTS system drops to 58 cps; another under-frequency relay is provided to drop other loads from the EBR-II generator, as desired, when the frequency drops to 57 cps; a third under-frequency relay is connected to trip generator breaker 5B11-10 when the frequency drops to 56 cps.

D. 13.8-kV System

As shown in Fig. 20, the 138-kV loop-sectionalizing breaker 8B11-1 and the 13.8-kV bus-tie breaker 5B11-12 are normally closed. Incoming line circuit breakers 5B11-1 and 5B11-2 are also normally closed. In the event of a fault in the 138-kV loop on one side of breaker 8B11-1 or in one of the main transformer circuits, protective relays operate to trip appropriate circuit breakers to isolate the faulted zone and maintain continuity of power supply with a minimum of disturbance to the EBR-II system. For example, should a fault occur in the 138-kV loop between EBR-II and SPERT, circuit breakers 8B11-1 and 5B11-1 would open automatically (together with the automatic tripping of the 138-kV tie breaker at SPERT), thus isolating the faulted zone and maintaining continuity of power supply between EBR-II and the 138-kV system via 13.8-kV Incoming Line No. 2.

The 13.8-kV incoming line breakers 5B11-1 and 5B11-2 are equipped with overcurrent and directional overcurrent relays. The overcurrent relays provide overload protection for the power transformers and backup protection for the protective relays on the 13.8-kV feeder breakers. The directional overcurrent relays prevent the flow of current from the NRTS power loop through a 12,000/16,000-kVA transformer to the 13.8-kV bus and back to the NRTS power loop via the other 12,000/16,000-kVA transformer in the event the 138-kV loop-sectionalizing breaker 8B11-1 should be opened.

Two 2500-kVA, 13.8-2.4-kV, 3-phase, 60-cycle power transformers for the 2400-V power system (see Fig. 20) are served by feeders on the 13.8-kV switchgear, one on each side of the bus-tie circuit breaker. The neutrals of the wye-connected primary windings of these transformers are grounded through grounding resistors to establish a grounded neutral for the 13.8-kV system.

Similarly, two 2000-kVA, 13.8-kV, 480-V, 3-phase, 60-cycle power transformers for the 480-V power system are served by feeders from the 13.8-kV switchgear.

The TREAT Facility, approximately one mile northwest of the EBR-II Site, is fed from the 13.8-kV switchgear via a single-circuit pole line.

E. 2400-V System

The 2400-V power system is fed by two 2500-kVA power transformers on the 13.8-kV system. It is an ungrounded delta system. Though a 2400-V grounded neutral system is generally considered to be preferable, the ungrounded delta system has the advantage that the occurrence of an accidental ground on one of the phases does not produce a fault current or cause a reactor "scram;" a ground on the system may therefore be located and cleared during normal plant standby. Ground detection and annunciation are provided.

The two 2400-V incoming-line circuit breakers are provided with one common set of directional overcurrent relays for bus-fault protection and backup protection for the circuit breakers serving the branch circuits. Directional power relays are provided for each of the 2400-V incoming-line breakers to trip their respective breaker if power should flow from the 2400-V bus toward the 13.8-kV bus.

The 2400-V switchgear provides power for the relatively large plant loads, namely, two 300-kW M-G sets for the two 350-hp primary sodium pumps, a 350-kW M-G set for the secondary sodium a.c. linear electromagnetic pump, two 350-hp condenser circulating water pumps, an 800-hp boiler feedwater pump, two 200-hp deep-well pumps, and a feeder serving a 500-kVA, 2.4-kV-240-V, single-phase power transformer for induction heating of the sodium piping and a 250-kVA, 2.4-kV-480-V, single-phase transformer for the secondary system surge-tank heaters.

The present design for the ZPPR Facility and the Inspection and Test Facility calls for a 2400-V pole line feeder originating in a circuit breaker section of the 2400-V switchgear.

F. 480-V System

The 480-V power system (see Fig. 20) is fed by two 2000-kVA power transformers on the 13.8-kV system. It is a solidly grounded neutral system.

The 480-V main switchgear bus is protected against bus faults by a set of directional overcurrent relays which receive the sum of the current into the bus. Coordination with the branch breakers is provided with the use of instantaneous overcurrent relays which are connected and set to prevent operation of the directional overcurrent relays unless the current is large enough to cause tripping of the branch breakers by their short-time-delay elements. Directional power relays are provided for each of the 480-V incoming-line breakers to trip their respective breaker if power should flow from the 480-V bus toward the 13.8-kV bus.

The 480-V-system circuit breakers are equipped with overcurrent devices to provide selective tripping, i.e., the tripping of only the breaker in the circuit nearest the fault to disconnect the faulted circuit from the system.

The 480-V system includes 480-V main switchgear, 480-V emergency switchgear, three emergency diesel-generator units, motor-control centers, and a 480-V lighting distribution center. Four of the motor-control centers have a "normal" and an "emergency" bus section, and a normally open, electrically operated bus-tie breaker. The "normal" bus section is fed directly from the 480-V main switchgear whereas the "emergency" bus section is fed from the 480-V main switchgear via the 480-V emergency switchgear.

In the event of loss of voltage in the "emergency" bus section of a motor-control center, without loss of voltage in the "normal" bus section, the bus-tie breaker closes automatically to restore power to the "emergency" bus section.

With sustained loss of voltage on the 480-V main switchgear, in which case there is sustained loss of voltage on the 480-V emergency switchgear, the three diesel-generator units automatically start and assume their respective emergency loads.

The 100-kW diesel-generator unit supplies emergency power for operation of critical emergency loads in the Reactor Plant, namely, the instrument thimble-cooling-system exhaust turbo-compressors, the shield-cooling-system exhaust fans and damper motors, an instrument air compressor, and auxiliary transformers for control and indicating lights.

The 400-kW diesel-generator unit serves emergency loads in the Reactor Plant, Power Plant, Sodium-Boiler Plant, Laboratory and Service Building, and other areas.

Controls are provided for the 400-kW diesel-generator unit to assume the critical emergency loads of the 100-kW diesel-generator unit should the latter fail to operate.

The 200-kW diesel-generator unit serves the emergency loads of the Fuel Cycle Facility.

Power for emergency lighting is supplied by the 400-kW diesel-generator unit, the 125-V station battery, and by numerous 6-V storage battery emergency lighting units located throughout the Facility.

G. Power Supplies for the Two Primary Sodium Pumps

Each 350-hp, 480-V, 3-phase, 54.5-cps, totally enclosed, fan-cooled, 6-pole, squirrel-cage induction primary pump drive motor receives its electric power from a separate 4-unit motor-generator set consisting of 1) a 400-hp, 2400-V, 3-phase, 60-cps, 1175-rpm, squirrel-cage induction-drive motor, 2) a water-cooled eddy-current type variable slip coupling, 3) a 375-kVA, 480-V, 3-phase, 54.5-cps, 1090-rpm, 0.8-pf synchronous generator, and 4) a 3-kW, 125-V d.c., shunt-wound exciter. The 2400-V circuit breakers serving the M-G set drive motors are part of the 2400-V switchgear, as shown in Fig. 8.

Variable-voltage and variable-frequency output of the synchronous generator is accomplished essentially by controlling the speed of the generator through control of the slip of the coupling between the M-G set drive motor and generator. Variable speed of the pump drive motor from approximately 10 per cent of maximum rated speed is thus achieved.

The main control equipment and instrumentation for the M-G sets are contained in three sections of the Corridor Panel located in front of the M-G sets at the ramp and stairway entrance to the Reactor Plant Building. Startup of the M-G sets is from this panel. Instruments, indicating lights, and annunciation are also located on the Primary Section Panel in the Main Control Room. After startup, all pump control is from the Console in the Main Control Room.

The sodium-flow requirement of each pump is approximately 4670 gpm at 54 psig. The rated maximum capacity of each pump is 5000 gpm at 85 psig.

H. Power Supply for the Secondary Sodium Pump

The power supply for the secondary sodium linear induction electromagnetic pump consists of a 2-unit motor-generator set with a 500-hp, 2400-V, 3-phase, 60-cps, 1185-rpm squirrel-cage induction drive motor and a 438-kVA, 350-kW, 480-V, 3-phase, 60-cps, 1200-rpm, 0.8-pf synchronous generator. The excitation rating of the generator field is 125 V d.c. and 36.6 A. The 2400-V circuit breaker feeding the M-G set drive motor is part of the 2400-V switchgear.

A 1340-kVAR, 460-V, 3-phase, 60-cps capacitor bank is connected across the electromagnetic pump for power-factor correction to prevent the full-load current rating of the generator from being exceeded.

The generator-voltage control system originally consisted of an amplidyne-electronic voltage regulator for control and regulation over a 10 to 1 voltage range. Operating experience, however, revealed the need for improved incremental control of the pump voltage in the region of zero voltage for satisfactory control of the reverse head on the pump. Under certain conditions, i.e., when sodium flow by natural convection is excessive, it is desirable to reduce the flow rate by producing a bucking effect with the pump.

Control of the reverse head on the pump was improved by replacing the amplidyne voltage-regulator scheme with a d.c. power supply consisting of a 4:1 ratio transformer, a motor-operated variable voltage transformer, and a 2:1 ratio transformer cascaded in the input to a single-phase, silicon diode bridge rectifier. The 4:1 ratio transformer is switched out of the input of the rectifier circuit for normal forward operation of the pump.

The M-G set is placed in operation from the Secondary System Panel in the Sodium-Boiler Plant; the generator breaker is controlled from the Secondary System Panel in the Main Control Room. Pumping power (flow rate) is controlled from the Console in the Main Control Room.

The a.c. linear electromagnetic pump is nominally rated at 460 V 3-phase, 60 cps, 350 kW, and 1200-kVA, and is capable of providing a flow of 6500 gpm, at a head of 53 psi, when pumping 700°F sodium.

I. Continuous Power-supply System

A continuous voltage- and frequency-regulated, 120-V, single-phase, 60-cps power-supply unit is provided for the nuclear and process instrumentation and control systems. It consists principally of a magnetic-amplifier type of silicon power rectifier, a floating 240-V storage battery, a 15-kW, d.c.-a.c. M-G set for the nuclear system; a 20-kW, d.c.-a.c. M-G set for the process system; and a 50-kVA 480-120-V, double-secondary, single-phase, reserve transformer for the nuclear and process systems during shutdown of the d.c. power system for maintenance or repair. The output of each generator, as designed, has a voltage regulation of one per cent and a frequency regulation of one cps.

It was determined from operating experience that more stable frequency regulation was needed for proper operation of certain instrumentation on the process system during periods of sudden load changes on the process-system alternator. This need was met by the addition of a flywheel to the process M-G set.

Under normal operation the rectifier supplies power to the M-G sets and maintains the floating battery in a fully charged condition. Upon loss of 480-V a.c. power to the rectifier, the floating battery maintains uninterrupted operation of the M-G sets. The battery is capable of maintaining operation of the M-G sets for 30 min at full load or for a longer period at reduced load. Since the power rectifier is automatically transferred to the 400-kW emergency diesel-generator unit when the normal 480-V power supply is lost, it is unlikely that the storage battery will be called upon to power the M-G sets for more than 15 or 20 sec.

J. Rectifier and Battery Power Supply for the Primary Auxiliary EM Pump

To assure maintained operation of the 500-gpm primary auxiliary d.c. electromagnetic sodium pump, particularly for the period immediately following a reactor shutdown, a 0-15,000-A, 0-1.7-V germanium rectifier and a floating 1.4-V battery are provdied.

Power is normally supplied to the pump by the rectifier during operation and shutdown of the reactor. The rectifier is used to give the battery an equalizing charge and to maintain a trickle charge on the fully charged floating battery. With loss of a.c. power supply to the rectifier, the floating battery maintains uninterrupted operation of the auxiliary pump at a slowly decreasing flow rate, for a period of approximately 30 min. The power rectifier may be manually applied to the 400-kW emergency diesel-generator unit.

IV. MAJOR COMPONENTS

A. EBR-II Main Outdoor Substation

1. General

The EBR-II 138-13.8-kV substation is similar to other substations served by the NRTS 138-kV Power System, except that the secondary switchgear is located in the EBR-II Power Plant Building instead of in the substation control house. This arrangement exists because of the fact that, unlike other facilities on the NRTS System, the EBR-II Facility includes a 20-MW turbine-generator which is operated by ANL personnel and which supplies substantial amounts of power to the NRTS System on an "as available" basis.

The substation (see Figs. 3 and 20) contains two step-down power transformers, one connected on either side of a 138-kV loop-sectionalizing oil circuit breaker. This provides a double-end feed to the substation. The circuit breakers in the secondaries of the transformers comprise a part of the 13.8-kV switchgear assembly in the Power Plant. This provides duplicate main power feeders and will permit essentially full-capacity operation of the EBR-II Facility in the event one transformer is out of service.

Motor-operated horn-gap switches connect each loop line-section to the station and each transformer to its corresponding 138-kV bus. The disconnecting switches on each side of the 138-kV oil circuit breaker 8B11-1 are manually operated.

2. Main Power Transformers

The two main power transformers are Westinghouse Electric Corp. Type SL, 12000/16000-kVA, OA/FA, 132-13.8-kV wye-delta, 3-phase, 60-cycle, 55°C temperature-rise outdoor-type power transformers. The impedance of each transformer is 9 percent at the 12000-kVA rating. The high-voltage windings have four $2\frac{1}{2}$ percent full-capacity taps, two above and two below normal rated voltage. Each transformer is equipped with automatic load tap-changing equipment (Westinghouse Type URT) which operates under load to provide a voltage range of plus or minus 10 percent of normal in thirty-two 5/8 percent steps. The transformers may be paralleled together on both the high- and low-voltage sides without causing hunting of the automatic tap-changing equipment.

The insulation of the high-voltage windings is 115-kV class with a full-wave impulse level of 550 kV, and that of the low-voltage windings is 15-kV class with 110-kV full-wave impulse level.

The secondary of each transformer is connected to its respective 13.8-kV air circuit breaker in the Power Plant Building by two 600-MCM, single-conductor copper cables per phase installed in underground ducts. The cables are shielded, rubber-insulated cables with a 15-kV, ungrounded neutral-system voltage rating.

A 10-kVA, 13,800 Y/7970-V-240/120-V, 3-phase, 60-cycle auxiliary transformer, for operation and control of the load tap-changer mechanism and cooling fans, is mounted on top of the core and coil assembly in the oil compartment of each main transformer.

3. Oil Circuit Breaker and Motor-operated Disconnecting Switches

The 138-kV loop-sectionalizing breaker is a Westinghouse Type GM-5B, 138-kV, 1200-A, 3-pole, outdoor-type oil circuit breaker of the tank type, mechanically and electrically trip-free, complete with a Type AA-10 pneumatic (compressed air) operating mechanism, porcelain bushings, and current transformers.

The voltage and current ratings of the oil circuit breaker are given in Table 1.

TABLE 1. 138-kV Oil Circuit-breaker Rating

Rated voltage	138 kV
Continuous current (60 cps)	1,200 A
Interrupting rating, 3-phase	5,000 mVA
Short-time current rating	
Momentary	36,000 A
Four-second	24,000 A
Interrupting rating	
Amperes at rated voltage	21,000 A
Current limitation	24,000 A
Time in cycles (60-cps basis)	3 cycles
Insulation level	
Withstand test, 60 cps	310 kV
Impulse crest	650 kV
Maximum design kV	145 kV
Maximum kV for rated interrupting mVA	120 kV

The motor-operated horn-gap disconnecting switches are Westinghouse Type V, 161-kV, 600-A, 3-pole, single-throw, group-operated, outdoor-type disconnecting switches.

4. Control, Alarm, and Operating Features

The 138-kV oil circuit breaker and the 138-kV line and transformer horn-gap disconnecting switches are normally controlled by supervisory from Scoville Substation but may be controlled from the substation control house. The transformer 13.8-kV secondary breakers are normally controlled from the EBR-II Power Plant but may be tripped from the substation control house or by supervisory from Scoville Substation. Control switches and indicating lights for local control and indication are provided in the substation control house, together with a control-selector switch. The selector switch permits selection of either local or remote supervisory control. An indication of the position of the selector switch is provided at Scoville Substation by the supervisory equipment. All remote position indications, as well as control functions in the Power Plant, remain effective in both positions of the control-selector switch.

The following circuit breakers and disconnecting switches are controlled either locally or remotely, subject to the position of the control-selector switch:

a) 8B11-1 Oil Circuit Breaker
b) 8H11-1 Transformer 8T11-1 Horn-gap Switch
c) 8H11-2 Transformer 8T11-2 Horn-gap Switch
d) 8H11-3 SPERT Line Horn-gap Switch
e) 8H11-4 ANP Line Horn-gap Switch
f) 5B11-1 Transformer 8T11-1, 13.8-kV Circuit Breaker*
g) 5B11-2 Transformer 8T11-1, 13.8-kV Circuit Breaker*
h) 5B11-12 Switchgear 13.8-kV Bus-sectionalizing Breaker.**

Nominal control voltage for the disconnecting switches, circuit breaker, and the supervisory control system is 125 V d.c. supplied by a 60-cell station battery. The battery operates on a continual floating charge provided by a Rectomatic battery charger. Devices are provided with the supervisory equipment to detect battery-charger failure, sustained abnormally low battery voltage, or a ground on the battery bus; an alarm indication is transmitted to Scoville Substation if any of these conditions occur.

Control voltage for the 13.8-kV switchgear in the EBR-II Power Plant is provided by a separate battery. Interposing relays and control circuits prevent any interconnection between the two batteries.

*Supervision and trip-control only.
**Supervision only.

The supervisory equipment includes provisions for transmitting the following listed alarms:

a) Pilot-wire Alarm, which indicates an open- or short-circuited HCB relay pilot wire between EBR-II and ANP Substations.

b) Control-voltage Failure Alarm, which indicates failure of 125-V d.c. control voltage for tripping either of the main transformer secondary breakers.

c) General Station Alarm, which indicates any of the following listed abnormalities:

1) Transformer No. 1 (8T11-1) or Transformer No. 2 (8T11-2)

Oil Temperature High	
Oil Level Low	Main Tank
Oil Level Low	Tap-changer Selector-switch Compartment
Oil Level Low	Tap-changer Transfer-switch Compartment
Gas Pressure High	Main Tank
Gas Pressure Low	Main Tank
Gas Pressure Low	Storage Cylinder

2) Oil Circuit Breaker (8B11-1)

Air Pressure Low

Compressor Power Failure

3) Control Room Temperature Low

The power transformers are connected to the 138-kV bus through horn-gap disconnecting switches. In order to operate one of these switches safely, the load circuit must be first interrupted by opening the transformer secondary circuit breaker.

The line horn-gap disconnecting switches are provided to isolate a line section while maintaining service to both transformers from the opposite line. In order to safely operate a line horn-gap switch, the load circuit must first be interrupted by removing the associated transformer from service and opening the oil circuit breaker.

To avoid making or breaking load current with any horn-gap switch, each switch is electrically interlocked with other switches and circuit breakers to prevent operation, by either local or supervisory control, under conditions that would cause such an occurrence. All switching procedures must follow a definite sequence as permitted by the preventive interlocks.

Control and interlock circuits are provided to prevent re-energizing a line section, after a transformer differential-relay operation, until the faulty transformer has been disconnected from the line, and to prevent any attempt to return the transformer to service until the hand-reset auxiliary trip and lockout relay has been reset to its normal position.

The closing circuit for the 13.8-kV breaker of each transformer is interlocked with the transformer high-voltage horn-gap switch and with contacts of a Type CV voltage relay, so that the breaker cannot be closed unless the horn-gap switch is closed and the corresponding section of the 138-kV bus is energized.

5. Protective Relaying

The protective relaying scheme is shown in Fig. 21. The following listed Westinghouse Electric Corp. relays are mounted on the substation control house panels and are provided for each 138-kV line section:

a) One Type HCB pilot-wire relay (85) for high-speed phase and ground protection.

b) Three Type HCZ directional-distance impedance relays (21) for backup phase protection.

c) One Type CWC directional current-product relay (67N) for backup ground protection.

Three Westinghouse Type HU differential-current relays (87), together with a hand-reset auxiliary trip and lockout relay, and other auxiliary relays, are provided in the substation control house for differential protection of each 12000/16000-kVA main power transformer.

Check-synchronizing equipment is provided for the 138-kV oil circuit breaker; it consists of a Type CI synchronism-verifier relay (25), a Type CV voltage-timing relay (25X), and two Type SV instantaneous-undervoltage relays (27). The relays are manufactured by the Westinghouse Electric Corp. Check-synchronizing potential is provided by two bushing potential devices, one on each side of the 138-kV oil circuit breaker. When the oil circuit breaker opens, auxiliary-switch contacts establish circuits which apply voltage from the potential devices to the synchronism-verifier and undervoltage relays. If either potential source is de-energized, undervoltage relay contacts complete the breaker closing circuit up to the primary closing control device. If both potential sources are energized, and both voltages are approximately equal and in phase, the breaker closing circuit will be established, after a time delay, by contacts of the CV voltage-timing relay, which is energized through contacts of the synchronism-verifier relay. In either case, the breaker will not close until the closing circuit is completed by either the local control switch or the closing-control relay of the supervisory system.

When 138-kV oil circuit breakers 8B11-1 at EBR-II Substation and 8B5-1 at ANP Substation (see Fig. 19) are tripped by HCB pilot-wire relays (85), the breakers will automatically reclose within 20 cycles. The high-speed reclosing is accomplished through Westinghouse Type SX and SGR-12 relays (79) installed at EBR-II and ANP Substations. Automatic reclosing is similarly provided when 138-kV oil circuit breakers 8B11-1 at EBR-II Substation and 8B10-1 at SPERT Substation are tripped by HCB pilot-wire relays (85). Automatic high-speed reclosure does not occur when tripping has resulted from operation of backup relays, transformer-differential relays, or transferred tripping, or when a breaker has been tripped by supervisory control or by local control switches.

Overcurrent phase relays (51), overcurrent ground relays (50/51N), and directional-overcurrent phase relays (67) are provided in the EBR-II Power Plant on the switchgear sections of 13.8-kV circuit breakers 5B11-1 and 5B11-2. The phase overcurrent relays (51) provide overload protection for the main power transformers and backup protection for the relays on the 13.8-kV branch feeder breakers. The overcurrent ground relays (50/51N) operate only for ground faults in the delta 13.8-kV windings of the main transformers or in the cable between the switchgear and the transformers and have been given a sensitive setting.

The directional-overcurrent phase relays (67) provide backup for the transformer differential relays and prevent NRTS System load-current flow through the power transformers and the secondary switchgear bus in case the 138-kV oil circuit breaker is inadvertently opened. The directional elements are connected so as to close their contacts when current flows from the 13.8-kV bus to the 138-kV system. Since load current normally flows toward the 138-kV system when the turbine-generator is in operation, the current circuits to the overcurrent elements of the phase relays are differentially connected. Thus, with the load balanced between the two transformers, the relays will not operate to close their contacts even though the directional elements recognize current flow in the tripping direction. Any load unbalance or current reversal which results in a differential current in excess of the tap setting of the overcurrent elements, will cause tripping of the transformer 13.8-kV breaker carrying the largest current in the tripping direction, that is, from the 13.8-kV bus to the 138-kV system. In order to prevent tripping when one transformer is out of service or when the switchgear bus is sectionalized, the relay trip circuits are interlocked through breaker auxiliary switches so that the relays are in service only when the 13.8-kV bus-sectionalizing and transformer breakers are all closed.

B. 13.8-kV System

1. General

The 13.8-kV electric power system consists of two buses with a normally closed bus tie breaker. It is a grounded neutral system in which the ground is established by means of resistors connected in the neutrals of the 13.8-kV primary windings of two 2500-kVA power transformers fed from the 13.8-kV switchgear bus (see Fig. 20).

The system includes an indoor-type metal-clad switchgear assembly, a 25,600-kVA turbine-generator (see Section IV-C Turbine-Generator) and interconnecting 15-kV power cables installed in rigid steel conduit and/or in underground ducts encased in concrete. A 13.8-kV, 3-phase wooden pole-line feeder which originates in a section of this switchgear supplies power to the TREAT Facility approximately 4000 ft northwest of EBR-II.

The 13.8-kV system is controlled mainly from control panels in the Main Control Room on the operating floor level of the Power Plant Building.

2. 13.8-kV Switchgear

The 13.8-kV switchgear assembly was manufactured by Federal Pacific Electric Co. and is of the indoor metal-clad type, with front removable air circuit breakers, and with control, protective relays, instruments, and meters mounted on the front door panels of the switchgear sections. The switchgear is complete with bus differential protection, all necessary current and potential transformers, and complete relay protection for the incoming lines, generator, and branch feeders.

The switchgear assembly consists of fourteen sections, namely, ten circuit-breaker sections and four potential-transformers sections, as follows:

Section	Description
1	TREAT (13.8-kV pole-line feeder)
2	Transformer No. 5--2000 kVA, 13.8-0.48 kV
3	Transformer No. 3--2500 kVA, 13.8-2.4 kV
4	Bus Section No. 1--potential transformers
5	Transformer No. 1--12000/16000 kVA, 132-13.8 kV
6	Generator potential transformers
7	25,600-kVA generator
8	Bus transition and potential transformers
9	Bus tie
10	Transformer No. 2--12000/16000 kVA, 132-13.8 kV
11	Bus section No. 2 potential transformers
12	Transformer No. 4--2500 kVA, 13.8-2.4 kV
13	Transformer No. 6--2000 kVA, 13.8-0.48 kV
14	Spare breaker.

The air circuit breakers are Federal Pacific Electric Co. Type DST 15-500, horizontal drawout, rated 13.8 kV, 1200 A, 60 cycle, 3 pole, electrically operated. A summary of circuit breaker data is given in Table 2.

TABLE 2. 13.8-kV Air Circuit Breaker Data

Manufacturer	Federal Pacific Electric Co.
Type	DST 15-500
Rated voltage	13.8 kV
Maximum design voltage rating	15 kV
Continuous 60-cps current	1200 A
Interrupting ratings	
3-phase	500,000 kVA
Current at 13.8 kV	21,000 A rms
Current at 11.5 kV	25,000 A rms
Maximum interrupting time (60-cps basis)	8 cycles
Short-time ratings	
Momentary	40,000 A rms
4-sec	25,000 A rms
Control circuit	
Nominal voltage	125 V d.c.
Closing voltage range	90-130 V d.c.
Closing current (at 125 V d.c.)	100 A
Tripping voltage range	70-140 V d.c.
Tripping current (at 125 V d.c.)	5 A
Tripping time, from energizing trip coil until circuit is interrupted	5 cycles
Closing time, from energizing closing control relay until breaker contacts are fully closed	10-15 cycles
Insulation level withstand test	
Low frequency	36 kV
Impulse crest	95 kV

3. Neutral Grounding Resistors

Typical of the main power transformers at other Facilities on the NRTS 138-kV loop, the 13.8-kV secondaries of the two EBR-II 12000/16000-kVA main power transformers are delta connected. The scheme adopted for establishing a 13.8-kV grounded neutral power system for EBR-II utilizes the neutral points of the wye-connected primary windings of 2500-kVA, 13.8-2.4-kV, 3-phase transformers Nos. 3 and 4. The neutral point of each of these transformers is connected to ground through a 6.66-ohm resistor. The resistors are General Electric Company IC9147-S2 neutral grounding resistors, outdoor type, cast grid, rated 8.4 kV line-to-neutral, 1200 A for 10 sec with a 500°C rise at an elevation of 5120 ft.

Prior to selecting the above method for providing a grounded neutral for the 13.8-kV system, the following methods were investigated:

(a) using wye-wye main power transformers with a delta tertiary winding;

(b) using wye-wye 13.8-2.4-kV transformers with a delta tertiary winding;

(c) using separate neutral grounding transformers on the 13.8-kV bus;

(d) using wye-delta 13.8-2.4-kV transformers and grounding the neutrals of these transformers through grounding resistors.

Item (d) proved to be the most practical, showing a cost savings of approximately $16,000.00.

4. 15-kV Power Cable

The power cables used in the 13.8-kV system have a 15-kV ungrounded neutral rating, which provides a substantial margin of safety against the occurrence of breakdown of cable insulation. The cables are round, single-conductor, class "C" stranding, soft annealed copper cables, shielded, with ozone-resistant butyl rubber compound insulation, corona-, ozone-, moisture-, and heat resistant, and with an outer covering of oil-resistant, thermoplastic polyvinylchloride suitable for a maximum temperature of 80°C, in accordance with Insulated Power Cable Engineers Association (IPCEA) general specifications S-19-81.

5. Control Panels

Controls for the ten 13.8-kV circuit breakers are provided on electrical panels E-5, E-6, and E-7 (see Fig. 22) in the Main Control Room. The switchgear may be seen from the control room. In addition to the main controls located on these panels, there are permissive trip switches on the switchgear cubicle doors for the individual circuit breakers. These switches are not for normal control functions, but will permit tripping of the circuit breaker in their respective cubicles. The closing function of any breaker from the control room can only be initiated if the respective permissive switch is in the "ON" position, but tripping may be accomplished from either location at any time.

Breaker position-indicating lights are located above each of the breaker control switches in the main control room with duplicate indication provided above the individual breaker permissive control switches at the switchgear.

Metering, instrumentation, and annunciation equipment for the individual 13.8-kV feeders are mounted on electrical panels E-5 and E-7. Instrumentation, metering, controls, and automatic synchromizing equipment for the generator are mounted on panel E-6. Electrical panel E-3 (see Fig. 23) contains the metering, instrumentation, and annunciation equipment for the two 13.8-kV incoming lines (ties to the 138-kV system); a 13.8-kV bus recording voltmeter is on panel E-4 (see Fig. 24). An indicating ammeter and ammeter-transfer switch, in addition to those on the main control room electrical panels, are provided on the door of each 13.8-kV switchgear cubicle housing a circuit breaker except the bus-tie cubicle. Also, indicating voltmeters and voltmeter transfer switches are provided on the switchgear for each bus section and incoming 13.8-kV line.

6. Protective Relaying

The design of the protective relaying scheme attempts to achieve a high degree of selective tripping in which a faulted part of the system is automatically disconnected rapidly and with a minimum of disturbance to the remainder of the power system.

The application of relays included consideration of 1) protective zones, 2) reliability, 3) backup protection, 4) relay selection and coordination for minimum tripping times, 5) economics, and 6) simplicity of circuitry. Overlapping of the protective relaying zones involved the selection of appropriate locations of current transformers and potential transformers in the power circuits.

The protective relays employed in the 13.8-kV system are mainly of the flush or semiflush, drawout type.

A list of the principal protective relays used in the system is given in Table 3. The table includes the type, application, location, and function of the relays, with references to single-line and elementary diagrams. All the relays are of General Electric Co. (Relays for the 25,600-kVA generator are listed separately in Section IV-C of this report.)

TABLE 3. Protective Relays for the 13.8-kV System

Feeder	Location (Switchgear unit)	Device No.	Quantity	Relay Type	Function	See Fig.
13.8-kV bus section No. 1	Unit No. 9	87(B1)	3	Bus differential, Type 12PVD11C1A	Trip 13.8-kV bus tie (unit No. 9), TREAT (unit No. 1), Transformer No. 3 (unit No. 3), 13.8-kV line No. 1 (unit No. 5), 13.8-kV generator (unit No. 7)	25 26 27 28
13.8-kV bus section No. 2	Unit No. 9	87(B2)	3	Bus differential, Type 12PVD11C1A	Trip 13.8-kV bus tie (unit No. 9), 13.8-kV line No. 2 (unit No. 10), Transformer No. 4 (unit No. 12), Transformer No. 6 (unit No. 13)	25 26 27 28
13.8-kV line No. 2	Unit No. 10	51(T2)	3	Inverse time overcurrent, Type 121AC51B13A	Trip 13.8-kV line No. 2 (unit No. 10)	21 26
		50/51N	1	Instantaneous and inverse time overcurrent, Type 121AC51B18A	Trip 13.8-kV line No. 2 (unit No. 10)	21 26
		67	3	Directional phase inverse time overcurrent, Type 121BC51E1A	Trip 13.8-kV line No. 2 (unit No. 10)	21 26
		80	1	D.C. undervoltage, Type 13PJV11AK2A	Supervisory system alarm	26
Transformer No. 4	Unit No. 12	50/51	3	Instantaneous and very inverse time overcurrent, Type 121AC53B27A	Trip transformer No. 4, 13.8-kV feeder breaker	25 27
		51N	1	Inverse time ground overcurrent, Type 121AC51B2A	Trip transformer No. 4, 13.8-kV feeder breaker	25 27
		67N	1	Directional ground overcurrent, similar to Type 121BCG51E	Trip transformer No. 4, 13.8-kV feeder	25 27
		87(T4)	3	Percentage differential, Type 12BDD15B1A	Trip transformer No. 4, 13.8-kV and 2400-V breakers	25 27
		50/51G	1	Instantaneous and inverse time ground overcurrent Type 121AC51T16A	Trip 13.8-kV bus tie, 13.8-kV line No. 2, transformer No. 4, 13.8-kV feeder, transformer No. 6, 13.8-kV feeder, and spare feeder	25 27 44
Transformer No. 6	Unit No. 13	50/51	3	Instantaneous and very inverse time phase overcurrent, Type 121AC53B27A	Trip transformer No. 6, 13.8-kV feeder	25 28
		50/51N	1	Instantaneous and inverse time ground overcurrent, Type 121AC51B2A	Trip transformer No. 6, 13.8-kV feeder	25 28
		87(T6)	3	Percentage differential, Type 12BDD15B1A	Trip transformer No. 6, 13.8-kV and 480-V breakers	25 28
TREAT	Unit No. 1	50/51	3	Instantaneous and inverse time phase overcurrent, type 121AC51B13A	Trip 13.8-kV TREAT feeder breaker	25
		50/51N	1	Instantaneous and inverse time ground overcurrent, Type 121AC51B2A	Trip 13.8-kV TREAT feeder breaker	25

TABLE 3 (Contd.)

Feeder	Location (Switchgear unit)	Device No.	Quantity	Relay Type	Function	See Fig.
Transformer No. 5	Unit No. 2	50/51	3	Instantaneous and very inverse time phase overcurrent, Type 121AC53B27A	Trip 13.8-kV transformer No. 5 feeder breaker	25 28
		50/51N	1	Instantaneous and inverse time ground overcurrent, Type 121AC51B2A	Trip 13.8-kV transformer No. 5 feeder breaker	25 28
		87(T5)	3	Percentage differential, Type 12BDD15B1A	Trip transformer No. 5, 13.8-kV and 480-V breaker	25 28
Transformer No. 3	Unit No. 3	50/51	3	Instantaneous and very inverse time phase overcurrent, Type 121AC53B27A	Trip 13.8-kV transformer No. 3 feeder breaker	25 27
		51N	1	Inverse time ground overcurrent, Type 121AC51B2A	Trip 13.8-kV transformer No. 3 feeder breaker	25 27
		87(T3)	3	Percentage differential, Type 12BDD15B1A	Trip transformer No. 3, 13.8-kV and 2400-V breakers	25 27
		67N	1	Directional ground overcurrent, similar to Type 121BCG51E	Trip transformer No. 3, 13.8-kV breaker	25 27
		50/51N	1	Instantaneous and inverse time ground overcurrent, Type 121AC51T16A	Trip 13.8-kV bus tie breaker (unit No. 9), TREAT (unit No. 1), transformer No. 5 (unit No. 2), transformer No. 3 (unit No. 3), 13.8-kV line No. 1 (unit No. 5), 13.8-kV generator (unit No. 7), annunciation	25 27
13.8-kV line No. 1	Unit No. 5	51(T1)	3	Inverse time overcurrent, Type 121AC51B13A	Trip 13.8-kV line No. 1 (unit No. 5)	21 26
		50/51N	1	Instantaneous and inverse time overcurrent, Type 121AC51B18A	Trip 13.8-kV line No. 1 (unit No. 5)	21 26
		67	1	Directional phase inverse time overcurrent, Type 121BC51E1A	Trip 13.8-kV line No. 1 (unit No. 5)	21 26
		80	1	D.C. undervoltage, Type 12PJV11AK2A	Supervisory system alarm	26
Bus transition and potential transformer	Unit No. 8	81(-2)	1	Underfrequency, Type 12CFF12A13A	Spare--for tripping 13.8-kV (unit No. 14), breaker or other circuits	26 40
		81(-3)	1	Underfrequency, Type 12CFF12A13A	Trip 13.8-kV line No. 1 (unit No. 5), trip 13.8-kV line No. 2 (unit No. 10)	26 40

The 13.8-kV incoming-line circuit breakers are provided with induction overcurrent relays (51) which provide overcurrent protection for the main power transformers and backup protection for the relays on the 13.8-kV branch-feeder circuit breakers. The instantaneous trip attachments (50) furnished with these relays have been disconnected to provide coordination with the branch feeders. Overcurrent ground relays with instantaneous trip attachments (50/51N) are provided for sensitive protection against ground faults in the delta windings of the main transformers or in the cable between the switchgear and the transformers.

As described in preceding Section IV-A, directional-overcurrent phase relays (67) are provided to prevent the flow of NRTS-system load current through the power transformers and the 13.8-kV bus in the event oil circuit breaker 8B11-1 is inadvertently opened.

Two sets of bus differential relays (87B) are provided for protection of the two switchgear bus sections connected together by bus tie breaker 5B11-12. For a three-phase, single-phase, or ground-fault internal to a bus section, the appropriate set of relays will operate to trip the tie breaker and all the breakers on the faulted bus section. Additional relays and circuitry are incorporated to trip all the breakers on a bus section in the event a circuit breaker on a 13.8-kV feeder fails to trip under a condition of a ground fault; for example, should an overcurrent ground relay fail to trip its breaker under a ground fault, after a time delay (of 1.7 sec) another initiating circuit will trip all the circuit breakers on the faulted 13.8-kV section, leaving the other bus section in service. This is made selective by having the bus tie breaker trip first, so that only the appropriate bus-lockout relay will then operate to trip the other breakers on the faulted bus section.

Each of the branch feeder circuits is protected by three induction-phase overcurrent relays with instantaneous trip attachments (50/51) and by a ground relay (50/51N).

The feeders for 2500-kVA transformers Nos. 3 and 4 are provided with directional ground overcurrent relays (67N) to see only faults on the 13.8-kV feeders to the 2500-kVA transformers. These relays also provide ground backup protection for the differential relays (87) on transformers Nos. 3 and 4. Ground overcurrent relays (51N) provided on these feeders coordinate with the slowest ground relay on the 13.8-kV system.

Percentage differential relays (87) with harmonic restraint are used for sensitive, high-speed protection of 2500-kVA transformers Nos. 3 and 4 and for 2000-kVA transformers Nos. 5 and 6.

Underfrequency relay (81-3) is used to trip incoming line breakers 5B11-1 and 5B11-2 when the frequency drops to 58 cps. Underfrequency relay (81-3) is a spare which may be used to drop certain loads, such as a future external load that might be served via spare 13.8-kV circuit breaker in unit No. 14 when the generator frequency drops to, say, 57 cps.

C. EBR-II Turbine-generator

1. General

Three-phase electric power is produced at 13,800 V, 60 cycles, by a General Electric Co. conventional 20,000-kW, 3,600-rpm steam turbine generating unit (see Fig. 29). It is located on the Power Plant operating floor, west of the Main Control Room, together with the 13.8-kV metal-clad switchgear assembly, turbine gauge board, and cooling-system-hydrogen control cabinet for the generator (see Fig. 4).

The EBR-II turbine-generator is normally operated under initial pressure-regulator control when connected in parallel with the NRTS electric-power system. Under this control the output of the generator will follow the output of the steam generator. An adjustable load-limit device incorporated in the control of the turbine is set so that the turbine-generator output cannot exceed the steam-generator capacity for a given reactor power level. Control solenoids and interlocks are provided to transfer control of the turbine-generator automatically from initial pressure-regulator control to speed-governor control whenever the generator is disconnected from the NRTS system.

2. Turbine

The turbine is a standard, commercially designed, horizontal-shaft, regenerative machine of the impulse type having sixteen stages with uncontrolled extraction openings at the first, sixth, eleventh, and thirteenth stages. The sixth and thirteenth stage openings are blanked off for possible future use whereas the other two are used for extracting steam for boiler-feedwater heating and have nonreturn valves in their steam lines. Steam extracted from the first and eleventh stage shells has a designed pressure of 665 psia and 29.5 psia, respectively, and heats the boiler feedwater to approximately 485°F. Further heating of the feedwater to 550°F before it enters the boiler is accomplished by steam from the main steam header.

Table 4 lists the manufacturer's guaranteed turbine throttle inlet steam rates for the turbine loads and extraction rates as indicated with 1250-psig and 840°F inlet steam, and with the condenser operating at $1\frac{1}{2}$ in. Hg.

TABLE 4. Turbine Throttle Inlet Steam Rates

		Extraction Rates, lb/kWh	
Turbine Load, kW	Zero	26,000 lb/hr at 665 psia and 17,000 lb/hr at 29.5 psia	30,000 lb/hr at 665 psia and 23,000 lb/hr at 29.5 psia
20,000	8.04	9.66	9.98
15,000	8.02	*	*
10,000	8.30	*	*
5,000	9.19	*	*

*Values not available.

The full design capability of the steam generator (approximately 248,000 lb/hr), less that required for turbine operation, feedwater heating, and the turbine-driven feedwater pump, is bypassed to the condenser. The design of the turbine bypass, the condenser, and related systems was based on the premise that the turbine-generator may be shut down while operating the reactor at full power. When bypassing steam to the condenser with the turbine-generator shut down, the turbine rotor must be maintained on turning gear since no valve or shutoff is provided between the turbine and condenser.

3. Initial Pressure Regulator

An initial pressure-regulator control device is included on the turbine to regulate the turbine steam input according to the available steam supply, i.e., with this device in operation the load on the turbine-generator follows output of the steam generator. Since the output of the steam generator depends on the reactor power level, the electrical load assumed by the synchronous generator becomes a function of the reactor power level. This method of control can only be employed when the turbo-generator is operating in parallel with the utility-company generators. Because of this, electrically tripped mechanical devices have been provided to take the initial pressure regulator out of service and to reset the speed-governor control in the event the connection between the EBR-II generator and the NRTS system is broken.

The elementary diagram of Fig. 30 shows the interlocking and control scheme for automatic transfer of turbine control from initial pressure-regulator control to speed-governor control when the EBR-II generator is disconnected from the NRTS system. The control switch and indicating lights of the control are mounted on the Turbine Gauge Panel (see Fig. 31).

Opening of the generator breaker or any combination of 13.8-kV circuit breakers as listed below will result in separation of the generator from the NRTS system and will cause the operation of transfer devices SRD and SST:

1. generator breaker 5B11-10;
2. circuit breakers 5B11-1 and 5B11-2;
3. circuit breaker 5B11-1 and bus-tie breaker 5B11-12.

The following is a description of the operation of the control scheme as shown in Fig. 30:

(a) The initial condition assumes that circuit breakers 5B11-1, 5B11-2, and 5B11-12 are closed and generator breaker 5B11-10 is open.

(b) Relay TR1 is energized by the auxiliary contact 52b on breaker 5B11-10, and the white "Trip" light is on.

(c) Control switch CS is turned to its "Reset" position. This causes relays TR2 and TR2X to be energized and to be sealed in. A TR2X contact opens the speed reset and control-transfer solenoid (SST and SRD) circuits, and a TR2 contact causes the green "Reset" light to go on.

(d) Solenoids SST and SRD are then manually latched. The turbine-generator is then synchronized, paralleled with the system (by the closing of breaker 5B11-10), and loaded under control of the speed governor. With the closing of breaker 5B11-10, relay TR1 is de-energized. This causes relays TR2 and TR2X to be de-energized, thus placing the automatic tripping circuit for solenoids SST and SRD under the control of the auxiliary contacts of the circuit breakers. The de-energizing of relay TR1 also causes the white "Trip" light to go off.

(e) Initial pressure-regulator control of the turbine-generator is placed in service by raising the setting of the load-limit device and the setting of the speed changer above the control setting of the initial pressure regulator. The power output of the turbine-generator will then follow and match the output of the steam generator.

(f) If the generator becomes separated from the NRTS system due to the opening of 13.8-kV circuit breakers as listed above, the speed-reset solenoid, control-transfer solenoid, and TR1 relay will be energized by the breaker auxiliary switch "b" contacts. Energizing the solenoids rapidly transfers control of the turbine-generator to speed-governor control. The energizing of relay TR1 causes the white "Trip" light to go on and the red "Normal" light to go off.

(g) When the turbine-generator is again paralleled with the NRTS system, the white "Trip" light and the green "Reset" light will go off, and the red "Normal" light will go on.

4. Speed Governor, Load-limit Mechanism, and Load-limit Indicator

The turbine speed governor is an automatic, oil relay type, with a speed regulation of 5%. Turbine speed is controlled by variation of the flow of steam through the turbine control valves. An emergency governor is available which operates on overspeed to trip the turbine main steam stop valve at 110% of rated speed. The speed governor is sufficiently sensitive so that in the case of an instantaneous load change from full to zero load, the turbine speed will not reach the overspeed tripping point. A remotely controlled motor-operated device (commonly referred to as the synchronizing device or speed changer) is provided on the governor mechanism for synchronizing and for load adjustment when the turbine is operated in parallel with another source of power.

Other means provided for tripping the turbine main stop valve are a manual trip lever, an exhaust low-vacuum trip device, and an electrically operated trip solenoid.

Testing of the turbine main steam stop valve can be done by a hydraulic trip test device which functions through operation of the emergency governor to trip the main steam valve, or by a small test valve for testing the freedom of the stop valve. Controls for both of these methods are located on the turbine control casing.

The load-limit mechanism can be operated by either a starting handwheel or by a motor drive controlled from the control room console or Panel E-6. The starting handwheel is employed during turbine startup to open the steam-inlet valves to bring the unit up to approximately synchronous speed. At this time, the turbine control is transferred to the motor-operated synchronizing device (speed changer). With the synchronizing device controlling the turbine, the starting handwheel or motor attachment is used to preset the load-limit mechanism at the maximum load for which the turbine is to operate.

The starting handwheel, a tachometer, and a load-limit indicator are located on the front end of the turbine. Selsyn indicators are remotely mounted near the load-limit motor controls for indication of load-limit setting. A turbine speed indicator is mounted on the Graphic Panel in the Main Control Room.

5. <u>Other Turbine Auxiliaries</u>

In addition to the previously mentioned equipment, the following turbine auxiliary equipment is included in the design.

a. An atmosphere-relief diaphragm is mounted on the upper half of the turbine exhaust casing to protect the exhaust hood and condenser from excessive steam pressure. In normal operation of the turbine, this diaphragm is dished inward against a supporting grid due to the partial vacuum on the inside and atmospheric pressure on the outside. A loss of condenser vacuum for any reason and an increase of the internal exhaust hood pressure to approximately 5 psig will rupture the diaphragm and allow the steam to pass into the atmosphere.

b. A self-contained turning gear, complete with motor, controls, interlocks, etc., is provided for rotating the turbine-generator shaft at 3 to 5 rpm to prevent its bowing. A control panel mounted adjacent to the turning gear between the turbine and generator contains the motor controls and indicating lamps. The turning gear-clutch control is located on this panel.

c. A steam sealing system around the turbine shaft is provided to prevent the inleakage of air or outward leakage of steam; an automatic regulator maintains steam pressure on the seals.

d. A complete lubricating system for the entire turbine-generator unit is provided; included are pumps, tanks, pressure regulators, oil coolers, valves, gauges, strainers, etc. There are three oil pumps supplied with this system, namely, a main lubricating-oil pump driven from the turbine shaft, a steam-driven auxiliary oil pump, and a motor-driven turning gear oil pump.

e. A turbine gauge panel (see Fig. 31) contains the pressure and temperature gauges for the turbine-generator unit and controls and indicating lights.

6. Generator

The EBR-II Generator (serial No. 8287203) is a Type ATB-2 nonsalient two-pole, three-phase, 60-cycle, 3600-rpm, hydrogen-cooled, synchronous generator rated 25,600 kVA (21,760 kW), 13,800 V, and 0.85 power factor.

Table 5 lists the guaranteed and expected performance requirements of the generator and exciter.

TABLE 5. EBR-II Generator and Exciter Data

(All data represent expected values except where indicated otherwise)

A. Guaranteed Capability Rating of Generator

21,760 kW	13,800 V
25,600 kVA	3-phase
0.85 Power Factor	60 cycles

B. Generator Design Capability*

Hydrogen Pressure, psig	Max kVA	Max kVA with One Cooler Out	Rated Armature, A	Rated Field, A
0.5	20,480	16,384	857	268
15.0	23,529	18,823	984	291
30.0	25,600	20,480	1071	309
Air	12,288	-	514	-

TABLE 5 (Contd.)

C. Generator Losses (At rated voltage and power factor), kW

1. 50% Rated Load 195
2. 75% Rated Load 258
3. 100% Rated Load 339

(Losses do not include bearing, hydrogen seal, and excitation losses.)

D. Total Temperatures (At rated kVA, power factor, voltage, and hydrogen pressure), °C

1. Generator Armature. 91
2. Generator Collector Rings. 125
3. Exciter Commutator. 95
4. Generator Field. 125
5. Exciter Windings 80

E. Expected Operating Temperatures, °C*

Hydrogen Pressure, psig	Max kVA	Temperature of Coil Resistance Detectors	Gas to Cooler Temperature	Gas Temperature from Cooler
0.5	20,480	73	55	40
15.0	23,529	69	51	42
30.0	25,600	68	50	43

F. Generator Data

1. Short-circuit Ratio. . . . . 0.64 (Guaranteed)
2. Synchronous Impedance (On generator-rated kVA base). 169%
3. Voltage Regulation at Unit Power Factor 26%
4. Voltage Regulation at 0.85 Power Factor 34%
5. Excitation at Rated Load at 0.85 Power Factor at 95% Rated Voltage
   a. Field, A. 306
   b. Collector Ring, V . . . . 234.5 V @125°C
6. Excitation at Rated Load at 0.85 Power Factor at 100% Rated Voltage
   a. Field, A. 309
   b. Collector Ring, V . . . . 236.5 V @125°C
7. Excitation at Rated Load at 0.85 Power Factor at 105% Rated Voltage
   a. Field, A. 316.5
   b. Collector Ring, V . . . . 242.5 V @125°C

TABLE 5 (Contd.)

G. Excitation Data (Guaranteed)

1. Exciter Capacity . . . . 85 kW @5100 ft
2. Rated Voltage . . . . 250 V
3. Rated Current . . . . 340 A @5100 ft
4. Speed of Response of Excitation System is not less than . . . . 0.5 per Unit

H. Generator Reactance Values (On generator-rated kVA base)

1. Direct-axis Synchronous (At rated current 169%
2. Transient (At rated current) 40%
3. Subtransient (At rated voltage) 16%
4. Negative Sequence (At rated voltage) . 16%
5. Zero Sequence (At rated current) . . . 6%

I. Resistances

1. Field @25°C . . . . 0.550 ohms (test)
2. Armature, Average, One Phase, Line to Neutral at 25°C . . . . 0.0166 ohms (test)
3. Positive Sequence (On generator-rated kVA base). . . . . 0.60% @100°C
4. Negative Sequence (On generator-rated kVA base). . . . . 2.9% @100°C
5. Armature Insulation (All phases to ground) . . . . 3600 megohms (test) @24°C
6. Field insulation . . . . 540 megohms (test) @24.5°C

J. Time Constants, sec

1. Transient Short Circuit (3-phase) . . . 1.65
2. Transient Open Circuit 7.13
3. Subtransient Short Circuit 0.038
4. Direct Current (3-phase and L-L). . . 0.160

K. Telephone Interference Factors . . . . . . 1935 weighting

1. Line to Line--50 (Guaranteed) . . . . . 15 (expected)
2. Line to Neutral . . . . 20 (expected)

TABLE 5 (Contd.)

L. Weights, lb

1.	Complete Unit	302,500
2.	Turbine Rotor	12,000
3.	Generator Rotor	21,300
4.	Generator Stator	125,000
5.	Heaviest Piece	
	During Erection	151,960
	After Erection	39,400

*Hydrogen pressures must be increased 2.5 psig to correct for operation at 5100-ft altitude.

The wye-connected stator winding has all six leads brought out through hydrogen-tight bushings to terminals located at the bottom of the stator frame. The neutral terminals are metal-enclosed and are connected together to form the generator neutral. The neutral point of the generator winding is ungrounded. Grounding of the 13.8-kV system is established by a 6.66-ohm grounding resistor in the primary winding, neutral of each of the two 2500-kVA, 13.8-2.4-kV power transformers serving the 2400-V power system.

Protection of the generator is provided by three G. E. Co. Model No. 9LA1H053 15-kV ungrounded-neutral, Thyrite Magne-valve lightning arresters and three G. E. Co. Cat. No. 18F451, 15-kV, 0.25-microfarad capacitors connected to the generator line terminals.

The generator output is fed into the 13.8-kV switchgear bus with three 600-MCM cables per phase and a 1200-A, 500-mVA interrupting capacity air circuit breaker. Solderless pressure-type cable connectors are used to connect the cables.

A total of four 1200/5-A bushing current transformers are mounted on the neutral bushings. One set of three current transformers is mounted on the neutral bushings for differential relaying with the remaining transformer mounted on the B-phase neutral bushing terminal for use with the automatic voltage regulator.

Twelve resistance-type temperature detectors are imbedded in the generator stator windings at points of probable highest temperatures. In addition, eight resistance-type detectors sense the temperatures of the gas entering and leaving the four hydrogen coolers; also, there is one detector in the exciter air intake and one in the exhaust. The temperature-detector lead wires are connected to terminal boards on the machine. One of the temperature detectors on each of the stator phase windings and the detectors on the exciter air intake and exhaust are connected to a temperature indicator through a selector switch which are located on Panel E-4 in the Main Control Room. Several of the other detectors are fed into a data-logger in the Main Control Room.

7. Excitation System

The excitation system consists of a main exciter directly connected to the main generator, an electrically operated generator-field circuit breaker, a generator-field discharge resistor, a main-exciter motor-operated field rheostat, a rotating-amplifier motor-generator set, and complete voltage-regulating and -control equipment of the static-magnetic type, including reactive-ampere lower-limit control, a motor-operated voltage-adjusting rheostat, and paralleling equipment.

The main exciter is a General Electric Co. Type EDF-4, sheet metal-enclosed, 3600-rpm, shunt-wound exciter rated at 85 kW, 250 V d.c. for operation at an altitude of 5100 ft. The housing is provided with access doors and observation windows, as well as illumination lighting. Intake of filtered cooling air is from beneath the operating floor; the air is circulated through the exciter and exhausted below the floor. The hot exhaust air is prevented from re-entering the exciter by means of a baffle plate installed at the air outlet under the floor.

The excitation and control circuits are shown in Fig. 32. The generator-excitation cubicles are shown in Fig. 33.

The armature leads of the main exciter are connected to the generator field through a General Electric Co. Type AKF-IC-6, 1600-A frame, 500-V d.c., 2-pole single-throw, electrically operated air circuit breaker. When the circuit breaker is tripped, one of its contacts closes and connects the field-discharge resistor across the generator field, thus limiting the voltage produced by collapse of the magnetic field to a safe value.

Control of field excitation for regulation of the terminal voltage of the synchronous generator may be either manual or automatic. A motor-operated rheostat connected in series with the shunt field of the main exciter is used for manual control from Panel E-6 in the Main Control Room (see Fig. 22).

Automatic regulation of the terminal voltage of the synchronous generator is accomplished with a General Electric Co. CR7931-NA101 voltage-regulator equipment and an amplidyne generator. The amplidyne output is connected in series with the field of the main exciter and the motor-operated field rheostat. Depending upon whether the voltage signal from the potential transformers on the output of the terminals of the synchronous generator is low or high, the amplidyne generator output will boost or buck the voltage applied to the shunt field of main exciter.

The excitation system is arranged so that loss or failure of the amplidyne rotating amplifier will automatically adjust the excitation to the setting of the motor-operated field rheostat and will not cause loss of excitation. The EBR-II operating procedure is to place the automatic voltage-regulator equipment in service after the desired kilowatt and reactive kVA loads have been established. This provides a setting of the motor-operated field rheostat which requires zero "buck" or "boost" voltage from the amplidyne generator and hence will prevent a sudden change in excitation should the amplidyne unit fail.

8. Hydrogen Cooling System

The following discussion of the advantages of hydrogen cooling is taken from General Electric Co. Instructions GEI-46139-D, dated January 1956.

"Hydrogen is used in place of air as the cooling agent principally because of its low density and its superior cooling properties. Since its density is approximately one-fourteenth the density of air at a given temperature and pressure, the use of hydrogen reduces the windage friction losses of a rotating machine to a small fraction of the losses encountered when running in air. For a high speed machine such as a turbine generator, this results in an increase in full load efficiency of between one-half and one percent. Hydrogen has a thermal conductivity of nearly seven times that of air, and its ability to transfer heat through forced convection is about fifty percent better than that of air. This permits a reduction of nearly twenty percent in the amount of active material required in the construction of a generator of given output, and for a given temperature rise of the windings.

"The life of the generator is increased by operating in hydrogen. This is due to the fact that the enclosed construction keeps out dirt and moisture from the windings and ventilation passages. Also, with hydrogen, there is practically no deterioration of the armature insulation because of corona.

"Since additional kva output may be obtained by increasing the hydrogen pressure, the presently built hydrogen-cooled generators have a maximum hydrogen pressure rating of 30 PSIG. At increased pressures the hydrogen becomes more dense, and this improves its capacity to absorb and remove heat. As a result, additional load may be carried with no increase in the temperature rise of the windings. Also, increasing the hydrogen pressure permits operation at normal load with the temperature of the water supplied to the gas cooler in excess of normal. In general, an increase in kva output of about one percent may be obtained for every one pound increase in hydrogen pressure up to 15 psig, while for pressure between 15 and 30 psig, an increase in output of about one-half percent per pound increase in pressure may be obtained. For operation at rated output with temperatures of the cooling water in excess of normal, it is permissible to increase the inlet water temperature by approximately 1°F for each one pound increase in hydrogen pressure up to 15 psig. For hydrogen pressures from 15 to 30 pounds, an increase of about 1/2°F in water temperature per pound increase in pressure is permissible."

Hydrogen gas, under pressure, is used as the cooling medium in the EBR-II generator. The generator-cooling system is a closed system with fans mounted on the shaft to circulate the hydrogen gas through the generator. The heat absorbed by the hydrogen as it passes over the stator and rotor is removed as it continues over the finned tubes of four water-cooled gas coolers located in the generator stator frame. A carbon dioxide system is provided for purging the generator casing to avoid an explosive mixture of air and hydrogen. A seal-oil system and a hydrogen-scavenging system provide an effective seal against hydrogen leakage at the generator-shaft bearings. Other components of the hydrogen system are: (1) a gas dryer, (2) hydrogen and CO_2 manifolds, valves, regulators, and gauges, (3) purging control valves, (4) a hydrogen-control cabinet, including controls and indicators, (5) a seal-oil control unit, (6) one a.c. and one d.c. motor-driven seal-oil pump, (7) an oil-storage tank, and (8) a portable gas analyzer.

Table 6 gives design data of the generator hydrogen system for a gas purity of 98 percent.

The flow diagram for the hydrogen and carbon dioxide systems is shown in Fig. 35.

During normal operation the functions of the hydrogen system are essentially automatic, and only routine inspections and adjustments are necessary. Instrumentation, controls for adjusting scavenging rate, and a system annunciator are located on the Hydrogen Panel (see Fig. 34). Controls for the vapor extractor, gland exhauster, and a.c. and d.c. seal-oil pump motors are on the Turbine Gauge Panel (Fig. 31), located near the turbine on the operating floor.

TABLE 6. Design Data for the EBR-II Generator Hydrogen System

Gas volume of generator casing	815 cu ft
Hydrogen purity	98%
CO_2 required to purge air (on turning gear or standstill)	1000 cu ft
CO_2 required to purge H_2 (on turning gear or standstill)	1630 cu ft
H_2 required to fill casing to 90% purity at $\frac{1}{2}$ psi (on turning gear or standstill)	1400 cu ft
Cooling-gas flow through generator	29,000 cfm
Water flow through gas coolers	110 gpm
H_2 requirement (generator in normal operation):	
At $\frac{1}{2}$ psi	70 cu ft/day
At 15 psi	110 cu ft/day
At 30 psi	170 cu ft/day
H_2 required to increase casing pressure from:	
$\frac{1}{2}$ to 15 psi	815 cu ft
15 to 30 psi	1630 cu ft
Seal-oil flow to both shaft seals for inlet temperature of 110°F:	
At $\frac{1}{2}$ psi H_2	4.4 gpm
At 15 psi H_2	13.4 gpm
At 30 psi H_2	22.7 gpm
Gas-side seal-oil flow from both seals	0.4 gpm
Differential pressure between seal-oil and casing pressure:	
Collector end	~4.5 psi
Turbine end	~4.5 psi

9. Turbine-generator Load Operation

The output of the 20,000-kW turbine-generator is fed into 13.8-kV switchgear bus section No. 1 (see Fig. 20) via generator air circuit breaker 5B11-10 and is operated in parallel with the NRTS 138-kV system through the 12000/16000-kVA main power transformers. In a demonstration run between 1330 August 13 and 0800 August 17, 1964, the reactor operated continuously at 30 MWt with an average electrical output of 7.5 MW. Since then, the reactor and turbine-generator have operated for extended periods of time at 37.5 MWt and 11.8 MWe, respectively, and at 45 MWt and 14 MWe, respectively. As of the week ending April 13, 1966, the total accumulated reactor thermal power production was 151,010 MWh and the electrical power production was 41,805 MWh. The total generator-on-time was 1,644 hr.

This operation of the EBR-II reactor and turbine-generator demonstrates the feasibility of this type of power-generating system for central power-plant application. It also demonstrates its feasibility for operation as a base-loaded plant.

When the Initial Pressure Regulator was first placed in service, the speed changer was set at its high-speed position (i.e., 3780 rpm at no load or 3600 rpm at full load). This corresponds to the governor 5% speed regulation. To prevent excessive speed increase when the generator is separated from the NRTS system, an electromechanical arrangement is incorporated whereby the Initial Pressure Regulator and Speed Reset devices are simultaneously tripped to place the turbine on Speed Governor Control and instantly change the speed-changer mechanism to a preset (reset) position. Since the plant auxiliary load is approximately 3MW, this setting corresponds to a machine speed of 3600 rpm at that load. Should the load be dropped by the opening of the generator circuit breaker, the speed would increase to 3627 rpm. When other loads are added to the EBR-II side of the EBR-II-NRTS interconnection, it may become necessary to change the setting of the speed-reset device to correspond to a machine speed of 3600 rpm at the new load in the event of separation of EBR-II from the NRTS system.

Separation of the turbine-generator from the NRTS system results in an inverse speed change of approximately 9 rpm (0.15 cps) for each MW change of load on the generator. Whenever the turbine-generator is automatically transferred from Initial Pressure Regulator Control to Speed Governor Control, the speed and frequency of the generator should be noted and the speed changer should be operated to restore the generator to 3600 rpm (60 cps), if necessary.

With the occurrence of one of the following abnormalities, it is possible for the kW load imposed on the EBR-II turbine-generator to become greater than the available steam supply:

(a) The tripping of 13.8-kV incoming-line breakers 5B11-1 and 5B11-2 when the EBR-II generator is supplying only a part of the total load on the EBR-II side of the EBR-II-NRTS interconnection.

(b) The tripping, without reclosing, of two 138-kV loop-sectionalizing breakers on both sides of EBR-II, but one of which is beyond the next facility in the loop circuit.

In the case of abnormality (a), the turbine-generator control automatically transfers to speed-governor control, as previously explained, and any deficiency in the amount of steam required by the additional load imposed on the generator results in a reduction of machine speed and frequency.

In the case of abnormality (b), the turbine-generator would remain under initial pressure regulator control and, again, any deficiency in the amount of steam required by the additional load imposed on the generator results in a reduction of machine speed and frequency.

To maintain operation of the EBR-II generator under such conditions as those outlined above, an underfrequency relay is incorporated in the design to trip breakers 5B11-1 and 5B11-2 when the frequency drops to 58 cps. This would drop that part of the generator load in the 138-kV loop in the case of abnormality (b). Another underfrequency relay is provided for dropping loads not necessary for the operation of the generator, such as TREAT and other external loads which might be served by EBR-II in the future. This could relieve the load on the generator sufficiently to maintain operation of the EBR-II Facility under its own power. If sufficient steam still were not available, a third underfrequency relay is connected to trip generator breaker 5B11-10 when the frequency drops to 56 cps.

The most likely condition to exist following the separation of EBR-II from the NRTS system, however, is an excess of available steam, since the EBR-II generator is normally delivering power to the NRTS system. In this case, the control of the turbine is automatically transferred from initial pressure-regulator control to speed-governor control and any excess steam is automatically bypassed to the condenser.

It has been established from a Transient Stability Study (see Appendix B) that it would be hazardous to operate the EBR-II generator in parallel with the 138-kV system in the event of a 20-cycle reclosure of a loop-sectionalizing breaker when the 138-kV loop is open. Therefore, the operating procedure requires that all 138-kV loop-sectionalizing oil circuit breakers be closed when the generator is tied to the loop. It has also been established that an automatic 20-cycle reclosure of the 138-kV oil circuit breakers in the Utah Power and Light Co. transmission line from Goshen Substation (see Fig. 19) could prove hazardous to the generator. Therefore, pilot-wire tripping (see Fig. 21) of the 13.8-kV incoming-line air circuit breakers 5B11-1 and 5B11-2 is provided whenever automatic reclosure of oil circuit breaker 8B1-1 at Scoville is initiated by a line fault between Goshen and Scoville.

Close liaison between the EBR-II operator and Scoville Substation operator is maintained. The Scoville Substation operator has panel-board indication of the position of every 138-kV oil circuit breaker in the system as well as position indication for the EBR-II 13.8-kV incoming-line breakers 5B11-1 and 5B11-2 and generator breaker 5B11-10. He also has supervisory tripping control for breakers 5B11-1 and 5B11-2. Should the EBR-II generator already be in parallel operation with the 138-kV system and a section of the loop is lost for any reason (except for a successful single-shot reclosure), the Scoville operator will trip the EBR-II incoming-line circuit breakers 5B11-1 and 5B11-2 and notify the EBR-II operator. The EBR-II generator will then be supplying the EBR-II Facility loads without benefit of connection to the NRTS system. After the lost section of the 138-kV loop is restored, the

Scoville operator will notify the EBR-II operator, who may then synchronize the EBR-II generator with the 138-kV system and resume parallel operation.

With operation of the EBR-II generator in parallel with the 138-kV closed loop, an automatic reclosure of a 138-kV loop-sectionalizing breaker entails no danger to the generator since the connection between the generator and the 138-kV supply will not have been momentarily disconnected.

The two 12000/16000-kVA 132-13.8-kV power transformers in the Main Outdoor Substation are equipped with mechanisms for automatically changing the low-voltage taps under load. However, when the EBR-II generator is connected to the system with its amplidyne voltage-regulator system in service, the transformer tap changers must be placed under manual control to prevent hunting. The transformers are also provided with current balance-paralleling equipment to maintain the tap changers in "step" when the transformers are operating in parallel under automatic control. If one transformer is out of service the balance-paralleling feature is automatically deactivated and the remaining transformer can "step" independently.

Two curves (see Figs. 36 and 37) have been prepared to serve as guides in the operation of the EBR-II Generator. Figure 36 shows the complete operating range of the generator in terms of kilowatts and reactive kVA.

As the kW load is increased on the generator, increased field current is necessary to maintain terminal voltage and to carry a reasonable portion of the reactive kVA associated with the load. With the EBR-II generator operating in parallel with the NRTS power system, voltage and reactive kVA are interrelated and cannot be controlled independently. Changes in generator field current result primarily in changes in voltage on the 13.8-kV switchgear and in the reactive kVA loading of the generator. Increasing the excitation causes the generator to deliver more lagging reactive kVA while decreasing the excitation has the opposite effect.

The operating range of the EBR-II generator will normally be within the boundaries of the points designated as OBFEO in Fig. 36. Within this area, the field current should be of such magnitude as to hold approximately 13,800 V on the generator bus. This voltage can go as high as 14,490 V when the machine is carrying full load and should not drop below 13,110 V at light load. (This represents the ±5% voltage tolerance that the manufacturer allows for the operation of this machine.)

The limits of operation are also shown in Fig. 36; the limit indicated by the curve A to B is imposed by the design limits of the generator field (rotor). This is determined by the manufacturer. Operation within the area OABO is permissible, but normally not necessary unless low-voltage conditions exist on the NRTS loop, and it is desired to use the EBR-II generator to help boost the voltage. The limits indicated by the curve BFC are imposed by the design limits of the generator armature (stator). This also is determined by the manufacturer. The limits indicated by the curve C to D are imposed by design limits of the rotor iron and are also determined by the manufacturer in the design of the machine.

The curve HJEF was determined as the limit to be imposed by considerations of system stability. These considerations take into account the electrical characteristics of the generator and the system to which it is connected. The points at which the EBR-II generator would pull out of synchronism are designated by the curve HG.

Stability may be explained briefly as follows: a synchronous generator connected to a power system can be made to pull out of synchronism in one of two ways, or a combination of the two: (1) by holding the field current constant and increasing the kW loading until the machine pulls out; and (2) by holding the kW constant but decreasing the field current until the machine pulls out. For any value of kW loading there is then a minimum value of field current that must be maintained to hold the machine in synchronism with the system. As the kW loading of the generator is increased, the angle of the rotor advances with respect to the angle of the large system to which the generator is connected. Electrically, this angle must not exceed 90°, because beyond this point, the generator will pull out of synchronism and this would result in serious voltage disturbances to the power system and possible serious damage to the generator.

A 20% margin (Power Limit to Operating Limit ratio of 1.2) of safety was used in establishing the stability operating limit curve HJEF. Operation of the EBR-II generator with its output above this curve avoids loss of synchronism by allowing the wide margin to curve HG for system disturbances and other abnormal conditions, such as low voltage. It will be noted that the limit imposed by armature core and heating intersects the stability curve HJEF at point J and therefore the generator is not operated in the area below curve DJEF when manual excitation control is used.

Operating within the area OEJD is normally not necessary, but is permissible if the NRTS system voltage is high and it is desired to reduce the voltage by using the generator to do so.

The line RS represents the underexcited reactive-amperes limit start-line characteristics of the amplidyne generator-voltage regulator equipment, as provided to limit minimum excitation. The underexcited reactive current to which the voltage-regulator equipment responds is automatically readjusted as a function of the power output of the generator.

Figure 37 shows the pull-out limit and the recommended limit of operation in terms of generator output in kW and field current in amperes. The "pull-out limit" on this figure corresponds to the curve HG of Fig. 36, and the recommended limit under manual control of excitation corresponds to the curve DJEF. The "reactive-ampere limit start" line corresponds to line RS in Fig. 36.

Controls, instrumentation, and meters for synchronizing the EBR-II generator and for controlling the generator field excitation are located on Generator Indicating Panel E-4 (see Fig. 24) and the Synchronizing Panel E-6 (see Fig. 22) in the Main Control Room.

There are four circuit breakers in the 13.8-kV switchgear assembly at which the generator can be synchronized and paralleled with the NRTS power system. These are as follows:

(1) 13.8-kV incoming-line No. 1 circuit breaker 5B11-1;

(2) 13.8-kV incoming-line No. 2 circuit breaker 5B11-2;

(3) 13.8-kV bus-tie breaker 5B11-12;

(4) generator breaker 5B11-10.

The synchronizing control circuits are shown in Fig. 38.

Synchronizing and paralleling of the EBR-II generator may be performed either by manual or automatic synchronizing procedures. A "MAN-OFF-AUTO" synchronizing selector switch and a synchronizing transfer switch are provided on Panel E-6 (see Fig. 22) for selection of the synchronizing method and the specific circuit breaker to be used.

10. Protective Relaying

A list of the principal relays incorporated in the design for protection of the generator is given in Table 7. All the relays function to trip generator breaker 5B11-10 and all are located in the generator breaker unit of the 13.8-kV switchgear, except for the loss-of-field relay (40), which is located in the generator-excitation cubicle. The relays are of General Electric Co. manufacture.

A block diagram of the tripping scheme for the EBR-II turbine-generator is shown in Fig. 39. A single-line diagram (Fig. 40) and an elementary diagram of generator breaker 5B11-10 control scheme (see Fig. 41) show the application of the relays and the interlocking circuits used in the design.

High-speed differential relays (87G) are used for effective protection of the generator against phase-to-phase and phase-to-ground faults. The protected zones of these relays include the generator power cable leads between the first set of three current transformers on the load side of the generator breaker and the set of three current transformers nearest the neutral connection of the generator.

The power directional relay (32) provides protection against motoring of the generator in the event of loss of steam to the turbine. The primary protection is against overheating the turbine blading in the event the generator should drive the turbine.

The voltage-restrained overcurrent relay (51V) provides backup protection for the faults on the system that are not cleared by other relays and circuit breakers.

The induction-overcurrent ground relay (50-51N) provides generator line-to-ground fault protection and backup protection for the generator differential relays (87G).

The loss-of-field relay (40) is provided to protect the generator against loss of excitation and quickly to trip the generator breaker automatically when this occurs. Loss of field can occur as a result of accidental tripping of the field-circuit breaker, short circuits in the field circuits, loss of excitation to the main exciter, open circuits, or high-resistance contact of the brushes on the commutator of the exciter (see Fig. 32).

Underfrequency relay (81-1) operates when the frequency drops to 56 cps. As mentioned earlier, underfrequency relay (81-3) operates to trip breakers 5B11-1 and 5B11-2 when the frequency drops to 58 cps, and underfrequency relay (81-2) is a spare for shedding other loads as desired.

TABLE 7. Protective Relays for the EBR-II Generator

Device No.	Quantity	Relay Type
87G	3	High-speed differential Type 12CFD12B2A
32	1	Power directional Type 12GGP53B1A
51V	3	Overcurrent with voltage restraint Type 12IJCV51A1A
50/51N	1	Instantaneous and inverse time ground overcurrent G. E. Type 12IAC51B18A
40	1	Loss-of-field current Type IC 2820A100AA253E
81-1	1	Underfrequency Type 12CFF12A13A

D. 2400-V System

1. General

The 2400-V power system is an ungrounded delta system consisting of a single main bus which is fed by two parallel-operated 13.8-2.4-kV power transformers, one connected on each bus section of the 13.8-kV switchgear (see Fig. 20). The 2400-V system is used principally for large individual motor drives (200-800 hp) and for large single-phase loads.

The system includes an indoor-type metal-clad switchgear assembly (see Fig. 8), metal-enclosed bus ducts for throat connection to the power transformers, and 5-kV power cables installed in rigid steel conduit, cable trays, and/or underground ducts.

The main 2400-V bus is controlled from panels in the Main Control Room. The branch feeders are controlled from the Main Control Room and/or from local control panels.

2. 2400-V Switchgear

The 2400-V switchgear is an indoor-type, metal-clad, double-ended, single-bus-constructed switchgear assembly. It consists of eleven unit-type constructed cubicles housing eleven front-removable, horizontal drawout, air circuit breakers and all necessary potential transformers, current transformers, protective relays, meters, and control devices to make it functional.

The main busses and all current-carrying parts are copper, with all joints and connections silver-plated and tightly bolted to insure maximum conductivity. Terminations of the main busses are made and arranged at each end of the switchgear in a manner to permit the addition of future units. A ground bus extends throughout the length of the switchgear, with connections to each unit and to the frame of each circuit breaker and potential-transformer assembly. Spring-loaded contacts are provided to assure a positive ground connection whenever circuit breakers are in the "Operate" or "Test" position.

The air circuit breakers are Federal Pacific Electric Co. Type DST5-150, horizontal drawout, rated 2.4 kV, 1200 A, 60-cycle, 3-pole, and electrically operated. A summary of circuit breaker data is given in Table 8.

TABLE 8. Data for 2400-V Air Circuit Breaker

Manufacturer	Federal Pacific Electric Co.
Type	DST5-150
Rated voltage	2.4 kV
Maximum design voltage rating	4.76 kV
Continuous 60-cps current	1200 A
Interrupting ratings:	
3-phase kVA 2400 V	100,000 kVA
Current at 2400 V	21,000 A
Maximum tripping time (60 cps basis)	8 cycles
Short-time ratings:	
Momentary	40,000 A
4-sec	25,000 A
Control circuit:	
Nominal voltage	125 V d.c.
Closing voltage range	90-130 V
Closing current (at 125 V d.c.)	100 A
Tripping voltage range	70-140 V
Tripping current (at 125 V d.c.)	5 A
Tripping time, from energizing trip coil until circuit is interrupted	5 cycles
Closing time, from energizing closing control relay until breaker contacts are fully closed	10-15 cycles
Insulation level withstand test:	
Low frequency	19 kV
Impulse crest	60 kV

3. Power Transformers

The two power transformers (see Figs. 6 and 20) serving the 2400-V system are Federal Pacific Electric Co. Type LCA, each rated at 2500 kVA, 13,800 V wye primary to 2400 V delta secondary, 3-phase, 60 cycle, 5.5 percent impedance, askeral immersed, self-cooled, 55°C temperature rise, for outdoor installation. Four $2\frac{1}{2}$ percent full-capacity taps are provided on the primary winding, two above and two below the 13.8-kV tap; the desired tap is selected by means of an externally operated no-load manual tap switch, with provisions for padlocking.

There are no exposed live parts on the transformers. The neutral of the transformer primary winding is brought out to a porcelain terminal bushing in the high-voltage terminal box. A 600-5-A multi-ratio current transformer is provided on the neutral bushing. The neutral of each transformer is grounded through a 6.66-ohm resistor, as previously described.

The delta secondary leads of each transformer are brought out to 2400-V terminal bushings for throat connection to a metal-enclosed bus duct.

Each transformer is equipped with the following listed accessories:

Liquid-level gauge	Drain valve
Thermometer with alarm contacts	Vacuum pressure control and test connections
Vacuum pressure gauge	Filter-press connection
Manual tap changer	Liquid-sampling device
Relief vent	

4. 2400-V Bus Duct

The secondary connection between each transformer and the switchgear is made by means of a metal-enclosed, 3-pole, nonsegregated bus duct rated at 2400 V, 1200 A, 60 cycle, and suitably braced to withstand a momentary short-circuit current of 40,000 rms asymmetrical amperes. Each bus bar is insulated for 5 kV with flame-retardant insulation. Connections to the transformer terminals are made with strip laminated flexible connectors. Flanges and vapor-tight barriers are installed to seal the wall opening at the point of the bus duct where it enters the building.

5. 5-kV Power Cable

The power cables used in the 2400-V system have a 5-kV rating to provide a good margin of safety against the breakdown of cable insulation. The cables are round, single-conductor, class "C" stranding, soft-annealed copper cables, unshielded, insulated with ozone-resistant butyl rubber compound, and with an outer covering of oil-resistant, thermoplastic polyvinylchloride suitable for a maximum temperature of 80°C.

6. Control Panels

Controls for the 2400-V incoming power feeders and branch load feeders are located on panels as listed below:

Circuit Breaker Cubicle No.	Load	Location of Controls
1	Primary Pump No. 1 M-G Set	Corridor Panel (See Fig. 42)
2	Primary Pump No. 2 M-G Set	Corridor Panel (See Fig. 42)
3	Transformer No. 3 Secondary	13.8-kV Feeder Panel E-5 (Main Control Room) (See Fig. 22)
4	Pump House No. 1	2400-V Electrical Panel E-2 (Main Control Room) (See Fig. 22)
5	Pump House No. 2	Pump House No. 2 (See Fig. 43)

Circuit Breaker Cubicle No.	Load	Location of Controls
6	Secondary Sodium Pump	Control Panel (Sodium-Boiler Plant) (See Fig. 43)
7	Circulating Water Pump No. 1	Steam Panel (Main Control Room)* (See Fig. 43)
8	Circulating Water Pump No. 2	Steam Panel (Main Control Room)* (See Fig. 43)
9	Transformer No. 4 Secondary	13.8-kV Feeder Panel E-7 (Main Control Room) (See Fig. 22)
10	Induction and Resistance Heating	Induction and Resistance Heating Panel (Sodium-Boiler Plant) (See Fig. 43)
11	Boiler Feedwater Pump	Steam Panel (Main Control Room)* (See Fig. 43)

*Duplicate controls are located on the local startup panel.

Breaker-position indication is provided at each control location and also above the permissive trip switches located on the front door of the respective circuit breaker switchgear cubicle. An indicating ammeter and ammeter switch are mounted on the front door panel of the switchgear for each of the switchgear circuits; an ammeter and ammeter switch are also provided on Panel E-2 (see Fig. 43) in the Main Control Room for each load feeder. Bus voltage may be read from either an indicating voltmeter on Panel E-2 or the indicating voltmeter provided on the switchgear.

7. Protective Relaying

The protective relaying scheme for the 2400-V system is indicated in Figs. 44 and 45.

The relays are mainly of the flush or semiflush, drawout type, and are located on the front door panels of the switchgear, except for the relays for the 200-hp pump-drive motor in Pump House No. 1.

A list of the principal protective relays, all of General Electric Co. manufacture, is given in Table 9.

TABLE 9. Protective Relays for the 2400-V System

Feeder	Location on Switchgear	Device No.	Quantity	Relay Type	Function
Primary sodium pump No. 1, M-G set motor	Unit No. 1	49/50	2	Thermal overcurrent, with instantaneous overcurrent unit, Type 12TMC11B94A	Trip unit No. 1, 2.4-kV breaker
Primary sodium pump No. 2, M-G Set Motor	Unit No. 2	49/50	2	Thermal overcurrent, with instantaneous overcurrent unit, Type 12TMC11B94A	Trip unit No. 2, 2.4-kV breaker
Incoming lines No. 1 and No. 2 (transformers No. 3 and No. 4)	Unit No. 3	67	3	Directional phase overcurrent, inverse time, Type 12IBC51E1A	Trip incoming lines No. 1 and No. 2 (transformers No. 3 and No. 4), 2.4-kV breakers and alarm
Incoming lines No. 1 and No. 2 (transformers No. 3 and No. 4)	Unit No. 3	50	1	Instantaneous overcurrent, similar to Type 12PJC31C67A	Establishes pickup of (67) at 2400 A, 10,000 kVA via 50X

TABLE 9. (Contd.)

Feeder	Location on Switchgear	Device No.	Quantity	Relay Type	Function
Incoming line No. 1 (transformer No. 3)	Unit No. 3	32	1	Instantaneous directional power, 3-phase, Type CCP-13D	Trip incoming line No. 1 (transformer No. 3), 2.4-kV breaker via device No. 62
Incoming line No. 1 (transformer No. 3)	Unit No. 3	62	1	D.C. timing relay, Type 12RPM13A12A	Auxiliary to device 32
2.4-kV bus	Unit No. 4	64	1	A.C. overvoltage, Type 12IAV51A7A	Annunciates 2.4-kV bus ground
Pump house No. 1	Unit No. 4	51	3	Overcurrent, extremely inverse time, Type 121AC77B4A	Trip pump house No. 1, 2.4-kV feeder breaker
Well pump No. 2	Unit No. 5	49/50	2	Thermal overcurrent, with instantaneous overcurrent unit, Type 12TMC11B2A	Trip well pump No. 2, 2.4-kV breaker
Well pump No. 2	Unit No. 5	WP2		Automanual selector relay	Permissive control (manual automatic) of 2.4-kV well pump No. 2 breaker
Secondary sodium pump	Unit No. 6	49/50	2	Thermal overcurrent, with instantaneous overcurrent unit, Type 12TMC11B6A	Trip secondary sodium pump 2.4-kV breaker
Condenser circulating water pump No. 1	Unit No. 7	49/50	2	Thermal overcurrent, with instantaneous overcurrent unit, Type 12TMC11B8A	Trip condenser circulating water pump No. 1 breaker
Condenser circulating water pump No. 2	Unit No. 8	49/50	2	Thermal overcurrent, with instantaneous overcurrent unit, Type 12TMC11B8A	Trip condenser circulating water pump No. 2 breaker
Incoming line No. 2 (transformer No. 4)	Unit No. 9	32	1	Instantaneous directional power, 3-phase, Type CCP-13D	Trip incoming line No. 2 (transformer No. 4), 2.4-kV breaker via device 62
Incoming line No. 2 (transformer No. 4)	Unit No. 9	62	1	D.C. timing relay, Type 12RPM13A12A	Auxiliary to device 32
2.4-kV bus	Unit No. 9	27	2	A.C. undervoltage, Type 12PCV12B1	Reactor scram and alarm
Induction and resistance heating	Unit No. 10	50/51	3	Overcurrent, extremely inverse time, with instantaneous overcurrent unit, Type 121AC77B4A	Trip induction and resistance heating 2.4-kV breaker
Boiler feedwater pump	Unit No. 11	49/50	2	Thermal overcurrent, with instantaneous overcurrent unit, Type 12TMC11B6A	Trip boiler feedwater pump 2.4-kV breaker
Deep well pump No. 1 motor	On 2.4-kV starter at pump house No. 1	49/50	2	Thermal overcurrent, with instantaneous overcurrent unit, Type TMC11B42A	Open motor starter
Deep well pump No. 1 motor	On 2.4-kV starter at pump house No. 1	46	1	Current balance; Type 121JC51B3A	Open motor starter

Since the 2400-V system is an ungrounded system, a ground fault on only one of the lines will not cause operation of any protective relay. To provide annunciation of the occurrence of a line-to-ground fault, an overvoltage "ground alarm" relay (64) is connected in the open corner of the delta secondary of a set of 2400-120-V potential transformers, connected wye-broken delta.

The 2400-V incoming-line circuit breakers are provided with one common set of three directional overcurrent relays (67) to provide bus-fault protection and also backup protection for the relays on the branch feeder circuit breakers. These relays receive the sum of the current flowing into the 2400-V bus. In order to provide coordination with the relays on the branch-feeder circuit breakers, instantaneous overcurrent relays (50) are connected to prevent operation of the directional overcurrent relays (67), except when the total current is large enough to operate the instantaneous elements on the branch-feeder circuit breakers.

Instantaneous directional power relays (32) are provided for each of the 2400-V incoming-line breakers. These relays will trip their respective circuit breaker if power should flow from the 2400-V bus toward the 13.8-kV bus. They are set to operate on a very low power flow in the reverse direction; however, time-delay relays (62) are incorporated to provide time delay before tripping an incoming-line circuit breaker.

Each of the motor-feeder circuit breakers is provided with two thermal overcurrent relays with instantaneous trip elements (49/50) for motor overload and short-circuit protection. The thermal overcurrent relay (49) settings are between 110 and 120 percent of the motor full-load current.

In addition to overload and short circuit protection, the 200-hp deep well pump motor in pump house No. 1 is protected against single-phase operation by a current-balance relay (46). This motor is controlled by an industrial motor controller (Limitamp) equipped with current-limiting fuses.

The feeder circuit breaker for the 500-kVA single-phase induction heating transformer and the 250-kVA surge-tank heating transformer is provided with induction-type overcurrent relays with instantaneous trip attachments (50/51) for overload and short-circuit protection. The line-feeder circuit breaker for pump house No. 1 is similarly provided with overcurrent relays (51); instantaneous elements furnished with the latter relays were disconnected since they could not be coordinated with the motor starter and transformer fuses.

Two plunger-type undervoltage relays are connected to the 2400-V bus through two 2400-120-V potential transformers for reactor scram and annunciation in the event of an undervoltage condition.

E. 480-V System

1. General

The 480-V power system is a wye-connected system with the neutrals of two 2000-kVA, 13.8-kV-480-V delta-wye power transformers solidly grounded. One transformer is connected to the 13.8-kV bus on one side of the bus tie breaker, and one is connected to the bus on the other side of the bus tie breaker (see Fig. 20).

The system includes 480-V main and emergency indoor-type, metal-enclosed, switchgear assemblies, three automatic-starting emergency diesel-generator units, a 480-V lighting distribution center, motor-control centers, lighting and distribution transformers, power and lighting distribution panels, and control panels.

The 480-V main switchgear assembly has a single bus which is throat-connected to the two power transformers by metal-enclosed bus ducts.

The 480-V emergency switchgear is normally fed by a feeder from the 480-V main switchgear. Four of the motor-control centers have a "normal" and an "emergency" bus section, with a normally open bus tie breaker between them. The "normal" bus section is fed directly from the 480-V main switchgear whereas the "emergency" bus section is fed from the 480-V main switchgear via the 480-V emergency switchgear. Under emergency conditions, i.e., when the normal power supply is lost, the 480-V emergency switchgear bus is automatically disconnected from the 480-V main switchgear and receives its power from the 400-kW automatic-starting diesel-generator unit (see Fig. 20).

When the normal power supply is lost, the "emergency" bus section of three of the motor-control centers receives power from the 400-kW diesel-generator unit; the fourth motor-control center, F1, receives power from the 200-kW unit. Concurrently with the starting of the 400-kW diesel-generator unit, the 100-kW unit starts automatically to serve the critical loads on motor-control center R2.

When voltage is lost on the "emergency" bus section of a motor-control center but not on the "normal" bus section, the bus tie breaker closes automatically to energize the "emergency" bus.

1000-V-insulation, single-conductor cables are used for heavy 480-V power feeders and 600-V-insulation, single-conductor and/or multi-conductor cables are used for light power circuits, lighting, and control. Cables are routed in galvanized rigid steel conduit, galvanized electrical metallic tubing, cable trays, and/or in underground duct runs encased in concrete.

2. 480-V Main Switchgear.

The 480-V main switchgear is of Federal Pacific Electric Co. manufacture and consists of a single-bus, indoor-type, metal-enclosed, double-ended, drawout switchgear assembly with six rigid, self-supporting steel frames containing individually isolated compartments for fourteen drawout-type air circuit breakers. Instruments, protective relays, and permissive control switches are mounted on hinged front-panel sections over the incoming-line circuit breakers (see Fig. 9).

The main busses are copper with a continuous current rating of 3000 A; their entire length, including contact surfaces of all bolted connections, are silver-plated. These busses are mounted in high-impact, heavy phenolic base supports in each cell and are braced to withstand stresses induced by a maximum momentary asymmetrical short-circuit current of 75,000 A.

A ground bus extends the entire length of the assembly and connects to ground stabs provided in each breaker cell. The ground bus has a continuous rating exceeding 1000 A, and a momentary rating equivalent to that of the largest circuit breaker. Ground connections to the circuit-breaker frames are made at all times when the circuit breakers are in service.

The two incoming-line (transformer secondary) circuit breakers are General Electric Co. Type AK-1-75, 600-V a.c., 3000-A, 60-cps, 3-pole, electrically operated, trip-free, drawout air circuit breakers with an interrupting capacity of 75,000 rms amperes at 480 V. The circuit breakers are not equipped with integral series overcurrent devices as fault protection is provided by means of separate protective relays connected to energize the breaker shunt trip device. The motor-operated closing mechanisms provided have an operating range of 90 to 130 V d.c. and the shunt trip devices have an operating range of 70 to 140 V d.c.

The branch-feeder circuit breakers are Federal Pacific Electric Co. Type DMB-50, 600-V a.c., 1600-A frame, 3-pole, electrically operated, trip-free, drawout air circuit breakers, with an interrupting capacity of 50,000 rms amperes at 480 V. Each circuit breaker is equipped with three series overcurrent trip devices of the time-delay mechanical-escapement type with long time-delay and short time-delay mechanisms with factory-set time bands of minimum, intermediate, or maximum--for selective tripping of circuit breakers in the system. The long-time delay mechanisms are field adjustable from 80 to 160 percent of rated current, and the short-time delay mechanisms are field adjustable to calibrated pickup settings of 500,700 and 1000 percent of rated current. The breaker-closing mechanisms have an operating range of 90 to 130 V d.c. and the shunt trip devices have an operating range of 70 to 140 V d.c.

3. Power Transformers

The two power transformers (see Figs. 6 and 20) serving the 480-V system are Federal Pacific Electric Co. Type LCA, each rated 2000-kVA, 13,800-V delta primary, 480-V wye secondary, 3-phase, 60 cycle, 11.75 percent impedance, askeral-immersed, self-cooled, 55°C temperature rise, for outdoor installation. Four $2\frac{1}{2}$ percent full-capacity taps are provided on the primary windings, two above and two below the 13.8-kV tap; the desired tap is selected by means of an externally operated no-load manual tap switch, with provisions for padlocking. There are no exposed live parts on the transformers. The primary leads are brought out to porcelain terminal bushings in the high-voltage terminal box mounted on the front of the transformer. The secondary leads, including the neutral connection, are brought out to porcelain terminal bushings at the rear of the transformer. The neutrals of the transformers are solidly grounded to the EBR-II ground grid system. The 480-V secondary terminals of each transformer are throat-connected to a metal-enclosed bus duct.

Each transformer is equipped with the following listed accessories:

- Liquid-level gauge
- Thermometer with alarm contacts
- Vacuum pressure gauge
- Manual tap changer
- Relief vent
- Drain valve
- Vacuum pressure control and test connections
- Filter press connection
- Liquid-sampling device

4. 480-V Bus Duct

The secondary connection between each transformer and the switchgear is made by means of a metal-enclosed, 3-wire, nonsegregated bus duct rated at 480 V, 3000 A, 60 cycles, and suitably braced to withstand a momentary short-circuit current of 75,000 rms asymmetrical amperes. Connections to the transformers terminals are made with strip laminated flexible connectors. Flanges and vapor-tight barriers are installed at the point of the bus duct where it enters the building.

5. 480-V Emergency Switchgear

The 480-V emergency switchgear is of Federal Pacific Electric Co. manufacture and consists of a single-bus, indoor-type, metal-enclosed, switchgear assembly containing individually isolated compartments housing seven drawout-type air circuit breakers, one 1200-A nonautomatic incoming-line disconnect switch, and a 3-phase current-limiting line reactor. Protective relays, control switches, and indicating lights are mounted on the front of the equipment (see Fig. 10).

The main busses are copper with a continuous-current rating of 600 A, and braced to withstand the stresses induced by a momentary as-symetrical rms short-circuit current of 35,000 A. All bus joints and connections are silver-plated and tightly bolted to insure maximum conductivity. A ground bus extends the length of the switchgear, with a connection to each switchgear unit and to each circuit-breaker frame. Grounding of a circuit-breaker frame is in effect at all times when the breaker is in the operating position.

The circuit breakers are Type DMB-25, 600-V a.c., 600-A frame, 3-pole, trip-free, drawout air circuit breakers with an interrupting capacity of 35,000 asymmetrical rms amperes at 480 V. Each breaker is equipped with three series overcurrent trip devices of the time-delay mechanical-escapement type with long-time and short-time delay tripping mechanisms. The long-time-delay mechanisms are adjustable from 80 to 160 percent of rated current, and the short-time-delay mechanisms have adjustable pickups calibrated at 500, 750, and 1000 percent of rated current.

The 400-kW diesel-generator breaker has a 125-V d.c. closing mechanism, with an operating range of 90 to 130 V. All circuit breakers in this gear have 125-V d.c. shunt trip devices with an operating range of 70 to 140 V. The closing and tripping potential is supplied by the station 125-V battery.

The current-limiting line reactor is a Westinghouse-type MSP shielded reactor, rated 600 V, 1000 A, 3-phase, 60-cycle, 0.01 ohm per phase. The reactor limits the short-circuit current on the switchgear bus to approximately 23,600 assymetrical rms amperes.

6. 480-V Lighting Distribution Center

The 480-V lighting distribution center consists of three vertical sections joined together to form a rigid, free-standing, dead-front, indoor metal-enclosed assembly. All busses in the assembly are braced to withstand a short-circuit current of 25,000 rms amperes. The distribution center is normally fed from the 480-V main switchgear through a 600-A, manually operated, nonautomatic, L-frame air circuit breaker and a 3-phase, 600-A current-limiting reactor. A normally open feeder circuit breaker in the 480-V emergency switchgear is included in the design to provide power to the lighting distribution center from the 400-kW emergency diesel-generator unit.

The distribution center contains a total of nine manually operated, K-frame branch molded case circuit breakers, four of which are spares. The distribution center serves lighting and auxiliary loads in the Power Plant, Reactor Plant, Main 138-13.8-kV Outdoor Substation, Guard House, Fire Station, and Yard Lighting.

7. 480-V Emergency Power System

Emergency power for the 480-V, 3-phase emergency power system is supplied by one 400-kW and one 100-kW automatic-starting emergency diesel-generator unit (see Fig. 20). The 400-kW generator output is fed into the 480-V emergency switchgear, and the 100-kW generator output is fed into motor-control center R2. Table 10 lists the loads which are automatically applied to the 400-kW unit and Table 11 the loads which may be manually applied. Table 12 shows the critical emergency loads served by the 100-kW unit via motor-control center R2. Table 13 shows the loads which are automatically disconnected and locked out during a power outage.

TABLE 10. Emergency Power System Loads Automatically Applied to the 400-kW Diesel Generator

Load No.	Description	hp	Delay (sec)
RM-45	Argon Blower 1	5	0
RM-46	Argon Blower 2	5	0
PPS	Pump Pit Sump Pump	$\frac{1}{2}$	0
PM-77	Turning Gear Oil Pump	5	0
PM-90	Instrument Air Compressor 1	50	0
PM-91*	Instrument Air Compressor 2	50	0
PM-94	Continuous Power Supply	115	0
PC-383	Annunciator	10	0
PF-74	Control Power System	10	0
PM-74	Hydrogen Seal Oil Pump	2	0
PM-119	Duplex Condensate Pump	3	0
PM-120*	Duplex Condensate Pump	3	0
RF-11	Emergency Lighting Panel RE-1	5	0
PF-63	Sodium-Boiler Plant	0.3	0
PM-64	Demineralizer Service Pump 1 (make up)	7.5	0
PM-65*	Demineralizer Service Pump 2 (make up)	7.5	0
RF-14	Refueling Machine	10.75 5.2 kW	0
PF-11	Guard House and Fire House Emergency Feeder	11.5	0
PM-59	Emergency Instrument Air Compressor	2	10
PF-96	Station Battery Charger	5	10
PM-115	Cooling Water Pump 1	15	10
PM-116	Cooling Water Pump 2	15	10
RM-48	Shield Air Recirculating Fan 1	20	10
RM-49*	Shield Air Recirculating Fan 2	20	10
RM-54**	Refrigeration Compressor 3	40	20
RM-62**	Refrigeration Compressor 1	20	20
RM-63	Refrigeration Compressor 2	20	20
PF-31	Laboratory and Service Building		
L11M-311A	Main Exhaust Fan (West)	20	
L11M-311B*	Main Exhaust Fan (East)	20	
LM-707A	Process Water Pump (South)	3	
LM-707B*	Process Water Pump (North)	3	

TABLE 10. (Contd.)

Load No.	Description	hp	Delay (sec)
RM-52†	Thimble Cooling Compressor 1	60	50
RM-53*†	Thimble Cooling Compressor 2	60	50
PF-67†	Pilot Light Transformers	2.0	50
RF-13†	Shield Cooling Supply Fan Dampers		
	RM-99	0.25	50
	RM-100	0.25	50
RF-13C†	Shield Cooling Supply Filters Dampers		
	RM-101	0.25	50
	RM-102	0.25	50
RM-68†	Emergency Instrument Air Compressor (Reactor Plant)	1.5	50
RM-50†	Shield Cooling Exhaust Fan 2	30	70
RM-51*†	Shield Cooling Exhaust Fan 1	30	70
PF-34	Emergency Lighting Panel PE-1	15.0	45 (min)

*Standby operation--only one motor for this service will operate at one time.
**Compressors RM-62 and RM-63 will operate simultaneously as a standby for RM-54, but not at the same time as RM-54.
†Applied to 400-kW generator if 100-kW generator fails.

TABLE 11. Emergency Power System Loads Manually Applied to the 400-kW Diesel Generator

Load No.	Description	hp
RF-10	Rotary Bridge Crane	67
RM-60	Air Supply Fan	30
RM-66	Purge Exhaust Fan	5
RF-69	Personnel Air Lock	1
RF-71	Equipment Air Lock	1
RM-73	Equipment Air Lock Cart	0.75
RF-14	Large Rotating Plug Seal Heaters	38 kW
PM-50	Auxiliary Boiler 1 Forced Draft Fan	10
PM-53	Auxiliary Boiler 2 Forced Draft Fan	10
PM-56*	Auxiliary Boiler Feed Water Pump	40
PM-57	Diesel Oil Pump	2
PM-58	Fuel Oil Pump	5.25
PM-76	Turning Gear	1.5
PM-94M1**	Continuous Power Supply	50
RF-35A	Auxiliary Primary Sodium Pump	50
	Evacuation Siren	10
	Acid Storage Tank Heaters (1 Phase)	5.5 kW

*PM-56 operation on standby service is rejected; however, starting is permitted under manual operation.
**PM-94M1 is standby for PM-94 and will not operate when PM-94 is in service.

TABLE 12. Emergency Power System Loads Automatically Applied to the 100-kW Diesel Generator

Load No.	Description	hp	Delay (sec)
RM-50	Shield Cooling Exhaust Fan 2	30	20
RM-51*	Shield Cooling Exhaust Fan 1	30	20
RM-52	Thimble Cooling Compressor 1	60	0
RM-53*	Thimble Cooling Compressor 2	60	0
RM-67	Pilot Light Transformers	2	0
RM-68	Emergency Instrument Air Compressor	1.5	0
RF-13	Shield Cooling Supply Fan Dampers		
	RM-99	0.25	0
	RM-100	0.25	0
RF-13C	Shield Cooling Supply Filters Dampers		
	RM-101	0.25	0
	RM-102	0.25	0

*Standby operation--only one motor for this service will operate at one time.

TABLE 13. Loads Automatically Disconnected from Emergency System during Power Outage

Load No.	Description	hp
PM-10	Heating and Ventilation Unit Fan (North)	5
PM-11	Heating and Ventilation Unit Filter (North)	1/6
PM-12	Heating and Ventilation Unit Fan (South)	5
PM-13	Heating and Ventilation Unit Filter (South)	1/6
PM-36	Data Logger Refrigeration Compressor	1.5
PM-75	Vapor Extractor	0.75
PF-33	Cooling Tower	10
PM-171	Silicone Pump 1	15
PM-172	Silicone Pump 2	15
PM-56*	Auxiliary Boiler Feed Water Pump	40
PF-30**	Fuel Cycle Facility Emergency Feeder	

*PM-56 operation on standby service is rejected; however, starting is permitted under normal operation.

**See Table 15 (Emergency Power System loads applied to 200-kW Diesel-generator).

In the original design of the emergency power system, the 400-kW diesel-generator unit served all the emergency loads in the Reactor Plant, Power Plant, Sodium-Boiler Plant, Laboratory and Service Building, and Yards (see Fig. 20). In the event of failure of the 400-kW unit to operate, the 100-kW diesel-generator unit was arranged to assume automatically the critical loads on motor-control center R2.

With the gradual addition of loads to the emergency system as time went on, it became apparent that optimum utilization of the diesel-generator units was not being realized, since the 100-kW unit would normally be unused during an emergency condition in which normal electric power is lost. Therefore, to improve the utilization of the emergency power-generating equipment, the design was revised to provide for the 100-kW unit to supply power to motor-control center R2 immediately upon sustained loss of the normal electric power supply. Further, if the 100-kW unit should fail to operate, the motor-control center R2 loads will be picked up automatically by the 400-kW unit; the revision also includes means for shedding certain nonessential loads from the 400-kW unit before picking up the critical motor-control center R2 to prevent overloading the 400-kW unit.

The application of emergency loads to the diesel-generator units in time-delayed steps (instead of all at once) was incorporated in the design to prevent the dropout of loads due to excessive drop in generator terminal voltage and consequent voltage drop on the contactor coils of starters during the motor starting periods.

The following listed Cases illustrate the design objectives and operational functions of the 100-kW and 400-kW emergency diesel-generator units in the 480-V emergency power system. All of the events indicated, namely, diesel-generator set starting, circuit-breaker closing, or circuit-breaker tripping, are accomplished automatically. The devices and circuits involved are shown in Figs. 57, 58, and 59 (see pp. 178-180).

Case I

Assumed Conditions

1. Loss of voltage on 480-V emergency switchgear bus and motor-control center (MCC) R2 bus.
2. No voltage on MCC R1-A (normal bus).
3. 100-kW and 400-kW diesel-generators start and come up to rated voltage within approximately 50 sec.

Equipment Response

1. MCC R1 to MCC R2 tie breaker 15C trips.
2. 480-V main switchgear breaker 3B trips.
3. 400-kW generator connects to 480-V emergency switchgear (breaker 3D closes).
4. 100-kW generator connects to MCC R2 bus (breaker 1A closes).

Case II

Assumed Conditions

1. Loss of voltage on 480-V emergency switchgear and MCC R2 busses.
2. No voltage on MCC R1-A (normal bus).
3. 100-kW and 400-kW diesel-generators start and come up to rated voltage within approximately 50 sec, but the 100-kW diesel-generator fails to continue operating.

Equipment Response

1. MCC R1 to MCC R2 tie breaker 15C trips.
2. 480-V main switchgear breaker 3B trips.
3. 100-kW generator connects to MCC R2 bus (breaker 1A closes) and 400-kW generator connects to the emergency switchgear bus (breaker 3D closes).
4. On failure of the 100-kW diesel-generator, the 100-kW generator is disconnected from MCC R2 (breaker 1A opens).
5. After approximately 50 sec, MCC R1 to MCC R2 tie breaker 15C recloses. This places MCC R2 loads on the 400-kW diesel-generator. Excess loads on the 400-kW unit will be shed as preselected.
6. In the event the 100-kW diesel-generator restarts (automatically or manually), it will not reconnect to MCC R2 bus. Manual operation is required for further control of the loads.

Case III

Assumed Conditions

Loss of voltage on 480-V emergency switchgear only.

Equipment Response

1. 480-V emergency switchgear breaker 2B (emergency supply feeder to MCC R1) trips.
2. MCC R1-B breaker 16A (emergency supply feeder to MCC R1) trips.
3. MCC R1 bus tie breaker 8A closes. MCC R1-B (emergency bus) and MCC R2 are energized from the normal source via MCC R1-A (normal bus).
4. 100-kW diesel-generator starts and comes up to rated voltage, but does not connect to MCC R2 bus.
5. 400-kW diesel-generator starts and comes up to rated voltage.
6. 480-V main switchgear breaker 3B trips.
7. 400-kW generator connects to 480-V emergency switchgear bus (breaker 3D closes).

Case IV

Assumed Conditions

Loss of voltage on MCC R2 bus only.

Equipment Response

1. MCC R1 to MCC R2 tie breaker 15C trips.
2. 100-kW diesel-generator starts, comes up to rated voltage and connects to MCC R2 (breaker 1A closes).

Case V

Assumed Conditions

1. Loss of voltage on 480-V emergency switchgear and MCC R2.
2. No voltage on MCC R1-A (normal bus).
3. 400-kW diesel-generator starts and comes up to rated voltage.
4. 100-kW diesel-generator fails to start or to come up to rated voltage within approximately 50 sec.

Equipment Response

1. MCC R1 to MCC R2 tie breaker 15C trips.
2. 480-V main switchgear breaker 3B trips.
3. 400-kW generator connect to 480-V emergency switchgear bus (breaker 3D closes).
4. After approximately 50 sec, MCC R1 to MCC R2 tie breaker 15C closes. This places MCC R2 loads on the 400-kW unit. Excess loads on the 400-kW diesel-generator will be shed as preselected.
5. In the event the 100-kW diesel-generator starts after approximately 50 sec, it will not connect to MCC R2 bus. Manual operation is required for further control of loads or for shutdown of the unit.

The following examples provide a detailed description of the theory of operation of the automatic transfer scheme to provide 480-V emergency power for the critical emergency loads on motor-control center R2 from (Example A) the 100-kW diesel-generator unit, or (Example B) from the 400-kW unit in the event of failure of the 100-kW unit. The devices and circuit actions described are shown in Figs. 57, 58, and 59.

Example A

a) Assume that the 100-kW diesel-generator is in standby and that the normal electric power supply is lost.

b) Initial circuit conditions:
   1. Breaker 15C in MCC-R1 is closed.
   2. 100-kW generator breaker 1A is open.
   3. 100-kW generator "MAN.-STANDBY-OFF" selector switch CS/GEN is in the "STANDBY" position; its No. 2, 4, and 8 contacts are closed; its No. 1, 3, 5, 6, and 7 contacts are open.
   4. Breaker 15C control switch CS is in its "normal-after-close" position; its No. 2 and 3 contacts are open: its No. 5 and 10 contacts are closed.
   5. The voltage on the MCC-R2 bus is zero; a.c. time-delay relays 27, 62D, 62L and 62T are de-energized and start to time out. (Relay 62T contact in series with CS/GEN contact No. 4 is closed.)

6. Time-delay relay 62GV and auxiliary relay 59X are de-energized. (Relay 62GV TDO contact is open and its TDC contact is closed.)

c) The circuit actions that follow automatically to delivery 480-V power to the MCC-R2 bus are as follows (all time delays indicated are from the instant of loss of MCC R2 bus voltage):

1. After 3 sec, relay 27 TDC contact closes and energizes relay 27X; its N.O. contact in the trip circuit of breaker 15C closes, causing breaker 15C to trip. The 27X N.O. contact in the trip circuit of breaker 1A also closes.
2. At the same time, the relay 27 N.O. contact in the 100-kW Diesel Starting Control Circuit opens and initiates cranking of the diesel engine.
3. After the generator terminal voltage rises to normal (approximately 490 V), relay 59 picks up and its N.O. contact energizes its seal in coil and relay 62GV.
4. The relay 62GV TDC contact in the trip circuit of generator breaker 1A opens immediately, and the relay 62GV TDO contact in series with relay 59X closes immediately.
5. Relay 59X is thus energized and its N.O. contact in the closing control circuit of generator breaker 1A closes to cause breaker 1A to close and deliver 480-V power to the MCC-R2 loads. (Relay 27 picked up, causing 27X to be de-energized, opening its N.O. contacts in the trip circuits of breakers 1A and 15C.)
6. With the closing of breaker 1A, its "b" contact de-energizes 59X and 62GV. After one second, relay 62GV TDC contact, in series with the open 27X contact, closes and the 62GV TDO contact in series with 59X opens.
7. Relay 62L picks up before it has timed out and prevents 94L from picking up to shed the selected loads, if any.
8. Relay 62D picks up before it has timed out and prevents 62DX from picking up.

<u>Example B</u>

a) Assume that normal electric power supply is lost, the 400-kW diesel-generator is serving its loads, and the 100-kW diesel-generator is serving the motor control center R2 loads, when the 100-kW diesel engine stops as a result of low lube oil pressure, water overtemperature, overspeed, or other reasons.

b) Initial circuit conditions:

1. Breaker 15C in MCC-R1 is open.
2. 100-kW generator breaker 1A is closed.
3. 100-kW generator "MAN.-STANDBY-OFF" selector switch is in its "STANDBY" position; its No. 2, 4, and 8 contacts are closed; its No. 1, 3, 5, 6 and 7 contacts are open.

4. Breaker 15C control switch CS is in its "normal-after-close" position; its No. 2 and 3 contacts are open; its No. 5 and 10 contacts are closed.
5. The voltage on the MCC-R2 bus is zero; a.c. time-delay relays 27, 62D, 62L, and 62T are de-energized and start to time out. Relay 59 is de-energized.
6. Time-delay relay 62GV had been timed out, since its coil is in series with a "b" contact of breaker 1A. For the same reason, the seal-in coil of relay 59 is de-energized.

c) The circuit actions that follow automatically to deliver 480-V power to the MCC-R2 bus are as follows (all time delays indicated are from the instant of loss of 100-kW generator terminal voltage):

1. After 3 sec, relay 27 TDC contact closes and energizes relay 27X; its N.O. contact, in series with the already closed 62GV TDC contact, closes to cause breaker 1A to trip. At the same time, the 27X N.O. contact in series with CS/GEN contact No. 4 (in the trip circuit of breaker 15C) has closed; note that, although the relay 62T contact is closed, the trip coil is de-energized because of the open "a" contact of breaker 15C.
2. After 40 sec, the relay 62T contact opens, thus disconnecting battery "+" line from the trip coil of breaker 15C.
3. After 48 sec, relay 62L TDC contact closes and causes shedding of loads from the 400-kW generator via relay 94L, as preselected.
4. After 50 sec, relay 62D, TDC contact closes and energizes relay 62DX; the N.O. 62DX contact in the closing circuit of breaker 15C closes and causes breaker 15C to close and energize the MCC-R2 bus and the loads thereon from the 400-kW diesel-generator.
5. The following circuit changes then occur:
   a. Relays 62T, 27, 62L, and 62D are energized.
   b. The 1-sec time delay on pickup of relay 62T prevents its open contact from closing before the 27X contact in the trip circuit of breaker 15C has opened.

The 400- and 100-kW diesel-generator units are located on the first floor of the Power Plant Building (see Fig. 6).

The diesel engines are full-compression ignition engines capable of starting cold from the heat of compression and operating on No. 2 fuel oil without the need of auxiliary heating devices. Exhaust from the engines passes through exhaust silencers connected to the engines by flexible connections and is vented to the outside. Each is equipped with a radiator and a belt-driven fan for cooling. The cooling air is taken from inside the building and blown through the radiator and a duct to outside of the building.

Relays, indicating lights, pushbuttons, and associated circuits are included on an automatic start panel (see Fig. 46) for each diesel-engine. The automatic start cycle is initiated when loss of normal voltage occurs. The start circuits incorporate engine crank and rest cycles with an automatic overcrank lockout and alarm at the end of 90 sec. The crank and rest periods are each adjustable up to 30 sec. Alarms are provided for high water temperature, low oil pressure, and overspeed.

A generator field cubicle (see Fig. 46) is located adjacent to each diesel-generator unit. Each cubicle includes a manually operated generator air circuit breaker, a field rheostat, a field-disconnect switch and discharge resistor, a voltage regulator, and indicating meters. A storage battery and charger is located at each unit to supply power to the starting motors.

A summary of ratings and related data for the 100-kW and 400-kW diesel-generator units are given in Table 14.

TABLE 14. 100-kW and 400-kW Diesel-generator Units--Ratings and Related Data

400-kW Diesel-generator		
Engine:	Type	Waukesha Motor Model VLRDBS 12 cylinder, 1200 rpm
	Brake horsepower (5100 ft altitude)	590 BHP continuous 650 BHP emergency full load
	Fuel consumption--$\frac{1}{2}$ load	0.73 lb/kW hr
	$\frac{3}{4}$ load	0.67 lb/kW hr
	full load	0.675 lb/kW hr
Generator:		Kato Engineering Co. Model 400 MPS6 1200 rpm rated for 5100 ft altitude 480 V, 3 phase, 60 cycle wye connected 500 kVA, 0.8 power factor 18% transient impedance 9$\frac{1}{2}$% subtransient impedance 40°C continuous temperature rise
	Exciter:	Kato Engineering Company Model 45XUG2 5 kW, 125 V d.c. direct connected
	Governor:	Woodward Governor Co. Type UG-8 governor and solenoid shutdown device
Battery:		NIFE Inc., nickel-cadmium battery, Type KB-18, 36 V, 185 A-hr at 8-hr rate to 1.14 V per cell

TABLE 14. (Contd.)

Battery charger:		La Marche Manufacturing Co., constavolt Type A-5, 36 V, 10 A
100 kW Diesel-generator		
Engine: Type		Waukesha Motor Model WAKDB-7E 6 cylinder, 1800 rpm
Brake horsepower (5100 ft altitude)		160 BHP continuous 175 BHP emergency full load
Fuel consumption--	$\frac{1}{2}$ load	0.84 lb/kW hr
	$\frac{3}{4}$ load	0.76 lb/kW hr
	full load	0.745 lb/kW hr
Generator:		Electric Machinery Manufacturing Co. Serial No. 1P01231 1800 rpm rated for 5100 ft altitude 480 V., 3 phase, 60 cycle wye connected 125 kVA, 0.8 power factor 19% transient impedance 11% subtransient impedance 50°C continuous temperature rise-armature 60°C continuous temperature rise-field
Exciter:		Electric Machinery Manufacturing Co. Frame HC-2 direct connected
Governor:		Woodward Governor Co. Type SG
Battery:		NIFE Inc., nickel-cadmium battery, Type KB-8, 24 V, 82 A-hr at 8-hr rate to 1.14 V per cell
Battery charger:		La Marche Manufacturing Co., constavolt Type A-5, 24 V, 10 A

The emergency loads in the Fuel Cycle Facility are automatically applied to the emergency 200-kW diesel-generator unit (see Table 15). Whenever the normal power supply is lost, feeder circuit breaker 1A in the 480-V emergency switchgear (see Fig. 57) is automatically tripped and locked out.

Table 16 shows the nameplate data of the 200-kW diesel-generator unit.

TABLE 15. Emergency Power System Loads Automatically Applied to 200-kW Diesel-generator

Load No.	Description	hp	Delay Sequence (sec)
FM-56	Stack Exhaust Fan 1	60	0
FM-58*	Stack Exhaust Fan 2	60	0
FM-66	Emergency Instrument Air Compressor	3	0
FF-67	Instrument Power	10	0
FM-14	Sodium Cleanup Exhauster	40	2
FM-15	Suspect Exhaust Fan 1	60	1
FM-16	Suspect Exhaust Fan 2	60	1
FM-43	Sodium Cleanup Pump	2	0
FM-116	Freight Elevator	5	0
FF-18	Emergency Lighting	15	0
FF-23	Stack Feeder	4.5	0

*Standby operation--only one motor for this service will operate at one time.

TABLE 16. 200-kW Diesel-generator Unit--Nameplate Data

	Generator
Diesel Engine	
General Motors MOD 12201	General Electric Type AT1
Unit No. 12-1249	No. 6784431
Equipment Type	250 kVA
Gear Box 32	1200 rpm
Generator Battery 55	Form BL
Cover Rocker 14	220/440 V
Shutoff or Alarm SL-100	656/328 Armature Amperes
Starting Motor SL-102	0.8 pF
Throttle Control SL-101	200 kW
Engine Base 61	3-phase, 60 cycle
Twin-671 1600 rpm	125 V, Exciter
Power Transfer Gear	22.4 A, Field
Part No. 5172721	Frame 965Z
Ratio 1.33 to 1.0	Temperature Rise 50°C Continuous
Serial No. SS1172	

8. Motor-control Centers

The 480-V plant auxiliary loads are fed mainly from motor-control centers designated P1, P2, R1, R2, R3, S1, and F1 (see Fig. 20). These control centers, with the exception of R3, have two busses and a bus-tie breaker. Motor-control centers P1, R1, S1 and F1 have a "normal" and "emergency" bus section, and a normally open, electrically operated bus-tie breaker. As previously indicated, their "normal" bus sections are fed directly from the 480-V main switchgear while the "emergency" bus sections are fed from the 480-V main switchgear via the 480-V emergency switchgear. Both bus sections of motor control center P2 are fed directly from the 480-V main switchgear; the bus-tie breaker is manually operated and is normally open. Power is fed to motor-control center R2 via a branch feeder on the "emergency" bus section of motor-control center R1.

The arrangement of compartments comprising the motor-control centers in the Power Plant Building are shown in Figs. 47 through 52.

Each control center consists of vertical sections with compartments joined together to form a NEMA Class I, Type B, metal-enclosed, rigid, floor-mounted, indoor assembly. The control centers are of back-to-back construction, except for R2, which is assembled in a single row.

The main horizontal busses in all motor-control centers are rated 600 A continuous, except for motor-control center P2, which is rated 1000 A. Distribution of power to individual control units is by 300-A, silver-plated vertical busses. Busses and all main current-carrying parts in the motor-control centers are braced to withstand 25,000 rms amperes short-circuit current. A copper ground bus extends the full length of each motor-control center.

The assemblies of motor-control centers (except for S1 and F1) are equipped with incoming-line current-limiting reactors (see Fig. 60, p. 181) to limit the short-circuit currents to values permitting the use of less expensive circuit breakers (with lower interrupting ratings) and other components than would otherwise have been required. A separately mounted current-limiting reactor is installed in the incoming-line feeder to the "normal" bus section of motor-control center F1.

The motor-control centers are equipped with combination starters or circuit breakers rated for the loads being served. The smallest circuit breakers used have a minimum short-circuit interrupting rating of 15,000 A, except for those in motor-control center P2, which have a minimum rating of 25,000 A. Each starter is provided with an individual 480-120-V control transformer.

Motor-control-center compartments containing a combination starter have a red pilot light mounted on the compartment door. The light ON indicates that the load is energized.

In addition to the motor-control centers described above, numerous control centers and distribution cabinets are provided throughout the Facility for supplying power to individual lighting circuits, small motors, and other loads.

9. Continuous 120-V A.C. Power Supply System

The continuous power supply system provides voltage- and frequency-regulated single-phase power: 120 V (±1%), 60 cycle (±1 cycle), for essential nuclear and process system instrumentation and control. The system consists of a power magnetic amplifier (rectifier) that feeds a 240-V d.c. bus. Connected to the bus are one 25-hp d.c. motor-15-kW a.c. generator, 0.8 power factor, 1800-rpm M-G set for the nuclear instrumentation and control system, and one 30-hp d.c. motor-20-kW a.c. generator, 0.8 power factor, 1800-rpm M-G set for the process instrumentation and control system. A 240-V battery is "floated" on the bus to provide uninterrupted operation of the M-G sets in the event of loss of a.c. power supply to the power rectifier. A 50-kVA, 480-120-V, single-phase, 60-cycle double-secondary reserve or auxiliary transformer provides power directly from the plant electric power system in the event that the continuous power supply units are out of service for maintenance or repair.

The continuous power supply equipment is a package unit (see Fig. 53) housed in a metal enclosure located in the cable routing room (see Fig. 5) in the Power Plant. Controls and instrumentation are mounted on front panel sections of the enclosure; voltmeters and frequency meters for the two generators are duplicated on the Utilities Control Panel (see Fig. 55) in the Main Control Room. The 240-V floating battery is located in the battery room adjacent to the cable routing room.

The battery provides for emergency full-load operation of the two M-G sets for approximately 30 min or for a correspondingly longer duration under reduced load. Extended battery operation is achieved by dropping continuous power loads, except the more critical loads fed from panels 1A, 2A, and S4 after the first 15 to 20 min of battery operation (see Fig. 54). This load shedding is accomplished by contactors controlled by manually operated key switches on the control room console.

10. Power and Control Cables

The cables used for power distribution are mainly 1000-V and 600-V, stranded, tinned-copper, round, single-conductor and three-conductor cables covered with corona-, ozone-, moisture- and heat-resistant, rubber compound insulation. The 1000-V cable has an outer sheath of oil-resistant, thermoplastic polyvinylchloride composition suitable for a minimum temperature of 80°C; the temperature rating of the copper is 85°C. The outer jacket on the 600-V cables are generally either polyvinychloride or neoprene suitable for 75°C operation.

When high-temperature operation, small cable diameter, and/or flexibility were requirements of the design, special cables were specified for power and control circuits: these consisted essentially of (1) "KEL-F" cables, insulated for 175°C copper operation, with a polyvinychloride jacket suitable for 105°C ambient, (2) silicone-rubber-tape-insulated cables with asbestos braid jacket for 125°C operation, and (3) glass-insulated cables for high-temperature applications such as heater-terminal connections. The application of the first two cable types are principally inside the Reactor Plant or in the cable tunnel between the Power Plant and Reactor Plant, where the cables are connected to the bulkhead-type pressure connectors in the Reactor Building Containment shell.

Conductor sizes were specified for the design in accordance with the National Electrical Code. Multiconductor cables used in the design are color coded to aid in making terminal connections and tracing of circuits.

11. Control Panels

The 480-V main-switchgear incoming-line circuit breakers are controlled from the Main Control Room panels E-5 and E-7 (see Fig. 22), and the branch-feeder circuit breakers are controlled from panel E-1 (see Fig. 56). Selector switches, "start" pushbuttons, indicating lights, and instrumentation for the 100-kW and 400-kW emergency diesel-generator units are mounted on panel E-1.

A permissive control switch for each of the 480-V incoming-line circuit breakers is mounted on the 480-V main switchgear (see Fig. 9) together with incoming-line ammeters, a bus voltmeter, and protective relays.

The branch circuit breakers of the 480-V emergency power system are manually operated at the switchgear (see Fig. 10). A permissive control switch for the 400-kW generator breaker, breaker-position indicating lights, and protective relays are mounted on the switchgear.

The control stations for the numerous loads served by the motor-control centers are located locally at the respective load and/or on the motor-control center.

12. Protective Relaying and Circuit-breaker Coordination

The design of the 480-V electric power system includes the application of circuit breakers in series which are so coordinated as to provide selective overcurrent tripping, i.e., to provide for the automatic opening of the circuit breaker nearest the fault, without other circuit breakers opening.

The arrangements of circuit breakers, busses, and protective relays in the 480-V emergency power system and in the 480-V main or normal power system are shown in the single-line diagrams of Figs. 57 and 60, respectively. The circuitries of the protective relaying and control schemes for these systems are shown in Figs. 58, 59, and 61.

The 480-V main-switchgear incoming-line circuit breakers (see Figs. 60 and 61) are not equipped with series tripping devices; instead, a set of three directional overcurrent relays (67) connected to receive the sum of currents flowing into the 480-V bus provides protection against bus faults and backup protection for the branch circuit breakers (see Table 17). To achieve coordination between the directional overcurrent relays (67) and the branch circuit breakers, instantaneous overcurrent relays (50) are connected to prevent operation of the directional overcurrent relays unless the current is large enough to cause the branch circuit breakers to be tripped by their short-time-delay elements.

TABLE 17. Bus-fault Protective Relays for the 480-V Main Switchgear

Feeder	Relay Location on Switchgear	Device No.	Quantity	Relay Type	Function
Incoming line No. 1 (transformer No. 5)	Unit No. 1A	32	1	Instantaneous directional power, Type 12CCP13D1A	Trip incoming line No. 1 breaker via device 62
Incoming line No. 1 (transformer No. 5) and incoming line No. 2 (transformer No. 6)	Unit No. 1A	67	3	Inverse time and instantaneous directional overcurrent, Type 12IBC51E1A	Trip incoming line No. 1 and No. 2 breakers via device 86
Incoming line No. 1	Unit No. 1A	62	1	D.C. timing relay, Type 12RPM13A12A	Auxiliary to device 32
Incoming line No. 1 and No. 2	Unit No. 1A	50	1	Instantaneous overcurrent similar to Type 12PJC31C67A	Energize relay device 67
Incoming line No. 2 (transformer No. 6)	Unit No. 6A	32	1	Instantaneous directional power, Type 12CCP13D1A	Trip incoming line No. 2 breaker via device 62
Incoming line No. 2	Unit No. 6A	62	1	D.C. timing relay	Auxiliary to device 32

Individual instantaneous directional power relays (32) are provided to trip either of the incoming-line circuit breakers if power should flow from the 480-V bus toward the 13.8-kV bus. These relays are set to pick up on very low power in the reverse direction, and timing relays (62) are therefore used to provide some delay before a reverse power relay trips the respective incoming-line circuit breaker.

The 400-kW generation breaker 3D (see Figs. 57 and 59) has no instantaneous or short-time-delay tripping devices. Although the breaker is equipped with a long-time-delay element, it is given its maximum setting to prevent tripping under any overload conditions. Generator-overload protection is provided by overcurrent relays with voltage restraint (51V) which will allow the generator to be operated at 133% of its rating continuously provided that the generator terminal voltage is normal. Under fault conditions the voltage will be reduced and the relays will operate at lower currents to protect the generator.

The branch circuit breakers in the 480-V main and emergency switchgear assemblies should coordinate with the molded-case branch circuit breakers on the motor-control center busses and the 480-V lighting distribution center bus (see Figs. 20, 57, and 60). The molded-case circuit breakers are equipped with thermal long time and magnetic instantaneous tripping devices.

The series tripping device settings of the branch circuit breakers in the 480-V main switchgear and 480-V emergency switchgear are shown in Tables 18 and 19, respectively.

TABLE 18. Tripping Device Settings for 480-V Main Switchgear

ACB No.	Service	Trip Coil Continuous Current Rating, A	Tripping Device Settings: Long Time Delay: Pickup	Long Time Delay: Time Band	Short Time Delay: Pickup	Short Time Delay: Time Band
2A	E-2 Lighting Distribution Center	600	100% 600 A	Intermediate	500% 3000 A	Minimum
2B	MCC P2-A Power Plant	1000	100% 1000 A	Intermediate	500% 5000 A	Minimum
2C	MCC R1 Reactor Plant	600	100% 600 A	Intermediate	750% 4500 A	Intermediate
3A	MCC P1 Power Plant	400	100% 400 A	Intermediate	500% 2000 A	Minimum
3B	E-1 Emergency Switchgear	1000	140% 1400 A	Intermediate	750% 7500 A	Maximum
3C	MCC P2-B Power Plant	1000	100% 1000 A	Intermediate	500% 5000 A	Minimum
4A	MCC R3 Reactor Plant	400	160% 640 A	Intermediate	1000% 4000 A	Minimum
4B	Laboratory Bus Ducts B and D	400	160% 640 A	Intermediate	1500% 6000 A	Instantaneous
4C	MCC F1-A Fuel Cycle Facility	600	160% 960 A	Intermediate	1000% 6000 A	Minimum

TABLE 18. (Contd.)

ACB No.	Service	Trip Coil Continuous Current Rating, A	Tripping Device Settings: Long Time Delay Pickup	Long Time Delay Time Band	Short Time Delay Pickup	Short Time Delay Time Band
5A	MCC S1-A Sodium-Boiler Plant	400	100% 400 A	Intermediate	500% 2000 A	Minimum
5B	Bus Duct in Fuel Cycle Facility	600	100% 600 A	Intermediate	500% 3000 A	Minimum
5C	Primary-tank Immersion Heaters	800	100% 400 A	Intermediate	1000% 8000 A	Instantaneous

TABLE 19. Tripping Device Settings for 480-V Emergency Switchgear

ACB No.	Service	Trip Coil Continuous Current Rating, A	Tripping Device Settings: Long Time Delay Pickup	Long Time Delay Time Band	Short Time Delay Pickup	Short Time Delay Time Band
1A	MCC F1-B Fuel Cycle Facility	600	160% 960 A	Minimum	750% 4500 A	Minimum
1B	Laboratory	400	100% 400 A	Minimum	500% 2000 A	Minimum
1C	No ACB					
1D	No ACB					
2A	Spare ACB	400	160% 640 A	Minimum	1000% 4000 A	Minimum
2B	MCC R1-B Reactor Plant	600	160% 960 A	Minimum	750% 4500 A	Intermediate
2C	MCC P1-B Power Plant	400	100% 400 A	Minimum	500% 2000 A	Minimum
2D	E-2 Lighting Distribution Center	600	100% 600 A	Minimum	500% 3000 A	Minimum
3	400-kW Diesel Generator	600	160% 960 A	Intermediate	No Short Time or Instantaneous Trip Devices	

The 800-A circuit breaker 5C (see Fig. 60) feeding the primary-tank immersion heaters is provided with an instantaneous trip device; therefore coordination with the molded-case circuit breakers in the distribution cabinet cannot be assured.

The bus-tie breakers in motor-control centers P1 and R1 (see Fig. 60) should coordinate with breakers 3A and 2C, respectively, in the 480-V main switchgear. The series tripping device settings of the bus-tie breakers is shown in Table 20.

TABLE 20. Miscellaneous 480-V Breaker Tripping Device Setting

ACB No.	Service	Location	Trip Coil Continuous Current Rating, A	Tripping Device Settings			
				Long Time Delay		Short Time Delay	
				Pickup	Time Band	Pickup	Time Band
9A	Bus Tie	MCC P1	225	160% 360 A		1000% 2250 A	Instantaneous
8A	Bus Tie	MCC R1	400	120% 480 A		1000% 4000 A	Instantaneous
15C	MCC R2 Feeder	MCC R1	225	100% 225 A		1000% 2250 A	Instantaneous
1A	100-kW, Generator Breaker	MCC R2	150	160% 240 A		1000% 1500 A	Instantaneous
	400-kW Generator Breaker	400-kW Generator Field Cubicle	600	600 A (20-sec delay at 3000 A)		4800 A	

The emergency bus section for motor-control center R1 is normally fed via emergency switchgear circuit breaker 2B (see Table 19). Motor-control center R1 branch feeder breaker 15C (see Table 20 and Fig. 57) feeds motor control center R2. Breaker 2B settings provide coordination with the 200-A branch breakers on motor-control center R2 and the 150-A branch circuit breakers on motor-control center R1; however, there will be the possibility of simultaneous tripping with breaker 15C for fault currents below approximately 3000 A (see Fig. 66). Fault currents of this low value could probably occur only when the 400-kW diesel-generator is serving motor-control center R2. This, however, assumes the unlikely conditions in which the normal power supply has been lost and the 100-kW emergency diesel-generator unit has failed to operate; under such circumstances a fault anywhere between the 400-kW generator and motor-control center R2 would result in sustained loss of power for motor-control center R2.

Typical overcurrent coordination curves for the EBR-II power system are shown in Figs. 65 and 66.

F. Station Battery and 125-V D.C. Distribution System

1. General

The 125-V station battery and d.c. distribution system (see Fig. 62) is an ungrounded system. A 16-circuit, 125-V d.c. distribution panel located in the cable routing room (see Fig. 5) provides control power for electrically operated air circuit breakers, isolation valves, emergency lighting, and essential turbine-generator auxiliaries and controls.

2. Battery and Battery Charger

The 125-V station battery is a 60-cell lead-plate storage battery with a discharge capacity of 40 A for 8 hr or 430 A for one minute to 1.75 V per cell at an ambient temperature of 77°F. The battery is an Electric Storage Battery Co. Type EMP-17, Exide-Manchex battery with seventeen (17) Plante positive plates per cell.

When fully charged the specific gravity of the electrolyte is 1.200 to 1.220 at 77°F, and the voltage is approximately 2.15 V per cell, giving a battery voltage of approximately 129 V.

The station battery and the continuous power supply system battery are installed on battery racks in the battery room (see Fig. 5). The arrangement of this room provides for ease of battery servicing and for adequate ventilation. There are no receptacles installed inside the room, and all lighting fixtures are of the explosion-proof type.

An Electric Products Co. Model "UR" rectifier (silicon diode) battery charger with a maximum rated output of 12 A d.c. at 120-140 V maintains the 125-V station battery in a fully charged condition. The charger supplies the essentially constant d.c. load current plus a battery trickle charging current. A manually operated timer located on the charger is provided for placing the battery on an equalizing charge at the periods desired.

3. Metering and Annunciation

An ammeter and voltmeter located on the battery charger provide indication of the charger output. Indication of the load current is provided by a second ammeter located adjacent to the charger and connected to a shunt in the main feed to the d.c. distribution cabinet. The battery charging or discharging current can be determined readily from these ammeter readings.

A ground developing anywhere on the d.c. system will be annunciated on Control Room Panel E-1 and will be indicated by ground-indicating lights on the d.c. distribution cabinet. Low battery voltage (below 100 V) is also annunciated on Panel E-1. A separate bell sounds an alarm for a loss of a.c. power input to the battery charger or for a blown fuse at the charger output.

4. Emergency 125-V D.C. Battery Source

In case the station battery is damaged or lost, its load can be transferred for emergency operation to a 125-V tapped section of the continuous power system 240-V battery. A manually operated transfer switch is provided for this purpose (see Fig. 62).

G. Short-circuit Study

The short-circuit currents required to establish relay settings and circuit-breaker coordination for the EBR-II electrical system (see Fig. 20) were calculated with the use of the net-per-unit imepdance values on a 100-MVA base, as shown in Fig. 63. The short circuit current and MVA values shown are 3-phase, symmetrical, balanced, values.

The impedance of the fault is assumed to be zero in all cases. Subtransient reactance values, X"d, of rotating machines are used. The subtransient reactance of 2300-V and 440-V motors are assumed to be 20 percent and 25 percent, respectively. Cable and bus impedances are neglected in the calculation of fault currents at the 13.8-kV, 2400-V, and 480-V main busses, whereas reactance and/or resistance values are included in the calculations involving power feeders in the 480-V system.

Table 21 lists the system elements and per unit impedance values used in the short-circuit calculations for the 13.8-kV, 2400-V, and 480-V main busses. The per unit values on a 100-MVA base are shown in the impedance diagram (see Fig. 64) made for calculation of a 13.8-kV system fault.

TABLE 21. System Impedances

Rated System Element	Per Unit X on Rated kVA Base	Per Unit X on 100 MVA Base
138-kV system	1.0	0.37
25600-kVA Generator	0.16	0.625
12000-kVA Transformer	0.09	0.75
2500-kVA Transformer	0.055	2.2
2000-kVA Transformer	0.1175	5.9
3000-kVA 440-V Motors	0.25	8.35
5000-kVA 2400-V Motors	0.2	4.0
480-V Current-limiting Reactors	0.13	5.65

The series and parallel combinations of impedances in the diagram combine to give an equivalent per unit impedance of 0.314 at the fault, from which the short-circuit current I_{sc} and MVA are calculated:

$$I_{sc} = \frac{10^8}{13{,}800\sqrt{3}\ \ 0.314} = 13{,}350 \text{ rms amperes (symmetrical)};$$

$$\text{MVA} = \frac{13{,}800\sqrt{3}\ \ 13{,}350}{10^6} = 319 \text{ MVA}.$$

Typical overcurrent coordination curves for the electrical system are shown in Figs. 65 and 66. Since the short-circuit current value at any system voltage is directly proportional to the short-circuit MVA, the abscissas of the curves are expressed in mVA. Amperes per MVA referred to 13.8 kV, 2400 V, and 4800 V are 41.8, 240, and 1200 A, respectively.

H. Annunciation

Multiwindowed annunciator cabinets are mounted on electrical control panels E-1 through E-7 in the Main Control Room, except for Synchronizing Panel E-6.

These provide visual and audible alarms when an important part of the electric power system is in an "off-normal" condition and also when the "off-normal" condition returns to "normal." The visual alarms employ both flashing and sustained illuminated windows, which are marked to identify the "off-normal" condition.

The annunciator cabinets have an audible automatic ringback operating sequence in which the "off-normal" visual alarms are white lamps flashing behind the corresponding annunciator windows. The audible alarms are provided by a bell.

Each control panel is provided with three pushbuttons: "Test," "Reset," and "Silence." In addition, the Control Console is equipped with a master silence pushbutton which may be used to silence any annunciator in the Control Room, except the Control Console annunciator.

An "off-normal" condition covered by an annunciator causes the alarm to sound and the window or windows associated with the "off-normal" point to flash. When the "Silence" button is pushed on the panel containing the flashing window, the sound will shut off and the window will be continuously lighted. After the "off-normal" condition has been corrected, a bell will ring and the window will start flashing again. The flashing will continue until the "Reset" pushbutton is depressed. Then the window light will go off.

The "Test" pushbutton is used to check for lamp burnout. When this pushbutton is depressed all windows become lighted, except those with a burned out lamp.

The following is a list of the major electrical alarms showing the legends as appearing on the annunciator windows:

<u>480 Volt Panel E-1</u>

Emerg. Sw'gr. E-1 Feeder Trip
Emerg. Lighting Dist. Ctr. E-2 Ftr. Trip

Power Plant MCC P-1 Trip
Power Plant MCC P-2A Trip
Power Plant MCC P-2B Trip
Reactor Plant Feeder Trip
Primary Tank Immersion Heater Trip
Sodium Boiler Bldg. Feeder Trip
Fuel Cycle Process Feeder 1 Trip
Fuel Cycle Process Feeder 2 Trip
Laboratory Feeder 1 Trip
Fuel Handling and Sodium Purif. Feeder Trip
125 Volt D. C. Station Battery Low Voltage
125 Volt D. C. Battery Bus Grounded
Rod Drive Power Off
400 KW Diesel Gen Fail to Start
400 KW Diesel Gen 480 V Circuit Bkr. Closed
400 KW Diesel Gen Water High Temp.
400 KW Diesel Gen Oil Low Press.
400 KW Diesel Gen Overspeed
100 KW Diesel Gen Oil Low Press.
100 KW Diesel Gen Overspeed
100 KW Diesel Gen Fail to Start
100 KW Diesel Gen 480 V Circuit Bkr. Closed
100 KW Diesel Gen Water High Temp.
480 Volt Emergency Bus E-1 Undervoltage
480 Volt Emergency Bus MCC R2A Undervoltage

<u>2400 Volt Panel E-2</u>

Primary Sodium Pump 1 Feeder Trip
Primary Sodium Pump 2 Feeder Trip
Pipe Induction Heating Feeder Trip
Sec. Sodium Pump Feeder Trip
Pump House 1 Feeder Trip
2400 V Bus Undervoltage
2400 V Bus Ground

<u>Incoming Lines Panel E-3</u>

138 KV OCB Trip

<u>Generator Panel E-4</u>

Amplidyne M-G Set Off-Trip

<u>13.8 KV Feeder Panel E-5</u>

Treat Feeder Trip
Transformer No. 5 13.8 KV Primary Trip
Transformer No. 5 480 V Secondary Trip

Transformer No. 5 High Temperature
Transformer No. 3 13.8 KV Primary Trip
Transformer No. 3 2400 V Secondary Trip
Transformer No. 3 High Temperature
Transformer No. 1 13.8 KV Secondary Trip
Generator 13.8 KV Breaker Trip
Generator Differential Trip
13.8 KV Bus No. 1 Undervoltage
13.8 KV Bus Section No. 1 Ground
13.8 KV Bus Section No. 1 Lockout

13.8 KV Feeder Panel E-7

Transformer No. 2 13.8 KV Secondary Trip
Transformer No. 4 13.8 KV Primary Trip
Transformer No. 4 2400 V Secondary Trip
Transformer No. 4 High Temperature
Transformer No. 6 13.8 KV Primary Trip
Transformer No. 6 480 V Secondary Trip
Transformer No. 6 High Temperature
13.8 KV Bus No. 2 Undervoltage
13.8 DV Bus Section No. 2 Ground
13.8 KV Bus Section No. 2 Lockout
13.8 KV Bus Tie Trip
Pilot Wire Trip out of Service

APPENDIX A

Control Modification for the Reactor Building 75/5-ton Rotary Bridge Crane to Prevent Traverse of a Crane Load across the Reactor during Reactor Operation

1. Introduction

At the request of the Atomic Energy Commission, a system of interlocks was designed and installed in the control circuits of the reactor building 75/5-ton rotary bridge crane to prevent traverse of a crane load across the reactor during reactor operation.

This requirement of crane operation enhances reactor safety by reducing the possibility of collision with and damage to the reactor control-rod mechanism and other vital components mounted on top of the primary tank.

The crane control scheme as modified (see Figs. A-1 and A-2) provide the following listed modes of operation:

a. Restricted Operation. This mode restricts operation and location of the crane hoists from the area above the primary sodium tank during reactor operation.

b. Administrative Permissive Operation. This mode of operation is performed only under strict administrative control, and provides for the operation and location of the crane hoists in the area above the primary sodium tank during reactor operation, when authorized. The key needed to use this mode of operation is kept in the custody of the control room operator.

c. Unrestricted Operation. This mode permits unrestricted operation of the crane whenever the reactor is shut down.

2. Description of Controls for the Three Modes of Operation

The following describes the functioning of control circuits as modified to accomplish the above indicated modes of operation:

a. Restricted Crane Operation

The control circuits for restricted operation of the crane are established only when the reactor can be started, i.e., only when reactor scram relay, CP, is energized (see Fig. A-2). In order for this relay to be energized, it is necessary for the crane bridge and trolly to be in the position indicated in Fig. A-1.

The following is a description of the operation of the control scheme for the restricted mode of crane operation:

1) The key-operated Administrative selector switch, SS, is placed in the "ON" (Restricted Operation) position, the normal position for this switch. The switch and red indicating light are located in the hinged cover of a control box mounted on the wall of the reactor building, adjacent to the crane power disconnect switch.

2) The position shown for contacts LS1 through LS5 of the limit switches (see Fig. A-2) are for the location of the crane bridge and trolley as indicated in Fig. A-1.

3) The closed contacts of limit switches LS1 and LS5 cause relay coil CX to become energized, and the normally open CX contact in the scram string circuit closes, energizing reactor scram relay CP. (It is assumed that all the other series contacts in the CP coil circuit were already closed.) The normally open CP contact then closes and energizes relay CP1.

4) Since the crane must be in its predetermined position before reactor scram relay CP can be energized, annunciation is provided in the main control room. It is initiated when the crane is not properly positioned for reactor startup.

5) The normally closed CP1 contact opens and de-energizes relays BX and TX. This, in turn, causes the normally open BX and TX contacts to open, thus placing starter contactor coils T_F, B_{CW}, and B_{CCW} for the trolley and bridge travel drives under control of limit switches LS2, LS3, and LS4, respectively.

6) Limit switch LS2 opens and de-energizes contactor coil T_F, thus stopping the travel of the trolley when the position of the auxiliary hoist hook approaches close to the restircted area. Limit switch LS3 opens and de-energizes contactor coil B_{CW}, thus stopping the clockwise rotation of the crane bridge when it approaches close to the restricted area. Similarly, limit switch LS4 opens and de-energizes contactor coil B_{CCW}, thus stopping the counterclockwise rotation of the crane bridge when it approaches close to the restircted area.

b. Administrative Permissive Operation

1) The key-operated selector switch SS is placed in the "OFF" position for this mode of operation. In this position the SS contact is parallel with the CP1 contact (see Fig. A-2) is closed.

2) This causes auxiliary relays BX and TX to remain energized, since the parallel contact of the CP1 relay is maintained open as a result of the reactor being in operation.

3) With auxiliary relays BX and TX energized, normally open BX and TX contacts close to bypass limit switches LS2, LS3, and LS4, thus providing full range operation of the crane while the reactor is operating.

c. Unrestricted Operation

In this mode of operation, the reactor is shut down, and the CP and CP1 relays are de-energized. The normally closed CP1 contact maintains relays BX and TX energized, and causes limit switches LS2, LS3, and LS4 to be bypassed, thus providing unrestircted operation of the crane.

3. Considerations of Overtravel and Load Swing

The design included consideration of overtravel of the crane bridge and trolley due to their momentum and that of the load. The swing of hoisted loads was also considered.

Tests were performed with "source coffin," which weighs approximately 10 tons, to check the design and installation, particularly in respect to location of the brackets for actuation of travel-limit switches.

A maximum load swing of 18 in. was measured in the tests. This occurred when the bridge was rotated at maximum speed and suddenly stopped. The trolley was positioned near the end of the bridge, and the tests were performed for both clockwise and counterclockwise rotations of the bridge. Maximum overtravel of the bridge under the loaded condition was found to be 5 in.

It was recognized that crane handling of loads of unusual shape and size, such as machines, steel beams, floor plates, and long cylinders, must receive special precaution and supervision to insure safety.

APPENDIX B

Transient Stability of EBR-II 20,000-kW Generator*

1. Introduction

This report presents the results of a study whose purpose was to determine if any hazard to the EBR-II 20,000-kW generator might exist due to the application of automatic reclosing to either the 138-kV circuit breaker in the NRTS electric power loop or to those in the 138-kV tie between Scoville and the Goshen station of the Utah Power and Light Company.

2. The Problem

Figure B-1 shows the one-line diagram of the system studied. The interconnection between the EBR-II generator and the NRTS 138-kV power loop is indicated, as is the tie to the Utah Power and Light Company. Table B-1 includes the various system and EBR-II generator constants used in the study. The power and reactive loads for each of the substations supplied from the NRTS loop are given in Table B-2. (Fig. B-1, and Tables B-1 and B-2 are based on information supplied by Messrs. Verber and Koch, Argonne National Laboratory, in letters of October 16 and November 20, 1961, to J. M. Henderson, of General Electric Company.)

TABLE B-1. System Data

	% R	% X
138-kV Lines		
Scoville-SPERT	0.083	0.280
EBR-II--ANP	0.470	1.577
ANP-NRF	0.437	1.469
NRF-MTR/ETR	0.122	0.410
MTR/ETR-CPP	0.051	0.172
CPP-Scoville	0.061	0.205
Utility System Equivalent	1.120	6.410
EBR-II Step-up Transformers (2 in parallel)	0.000	7.500
EBR-II Generator		
Transient Reactance, X'_d	0.000	31.250
EBR-II Turbine-generator		
Inertia Constant, H		4.494

NOTE: The above impedances are all expressed in percent on a 20-MVA base. The turbine-generator inertia constant is in per unit on the 20-MVA base.

*By: J. M. Henderson, Electric Utility Application Engineer, General Electric Company, Chicago, Illinois--March 19, 1962.

TABLE B-2. Results of Load Flow Study

	Voltage, %	Load MW	Load MVAR	Load Z	Load θ*
Load Buses					
EBR-II (13.8 kV)	102.5	2.00	0.98	9.431	26.10°
EBR-II (138 kV)	100.0	-	-	-	-
ANP	99.1	2.00	0.56	9.458	15.64°
NRF	98.4	7.50	2.16	2.480	16.07°
MTR/ETR	98.3	9.00	2.58	2.063	16.00°
CPP	98.3	2.00	0.56	9.297	15.64°
Scoville	98.3	1.50	0.42	12.400	15.64°
SPERT	98.3	3.00	0.86	6.179	15.98°
Generation (Behind Transient Reactance)					
EBR-II	120.8	20.00	15.32		
Utility Equivalent	99.2	7.19	1.83		

	Flows** MW	Flows** MVAR
Circuits		
Scoville-SPERT	3.00	0.86
EBR-II-ANP	18.00	6.00
ANP-NRF	15.92	5.16
NRF-MTR/ETR	8.36	2.78
MTR/ETR-CPP	-0.65	0.19
CPP-Scoville	-2.65	-0.37
Scoville-Utility	-7.16	-1.65
EBR-II (13.8-138 kV)	18.00	7.35

*Equivalent shunt impedance per unit on 20-MVA base.

**Indicated flows are measured at the source end, that is, at the first mentioned bus. Positive flows are away from the bus.

From Fig. B-1, it is apparent that the analysis required to determine the effect of automatic circuit-breaker reclosing involves a transient stability study of a two-machine system--one machine being the EBR-II generator, and the second an equivalent representing the generation by the Utah Power and Light Company. Whether or not automatic breaker reclosing can be applied without hazard to the EBR-II generator depends on the ability of the two machines to stay in synchronism with one another following a system disturbance in which transmission tie circuit breakers are first opened and then reclosed. A loss of synchronism would result in severe transient power swings between the EBR-II generator and the utility system and would, no doubt, result in considerable damage to the EBR-II unit.

3. Conclusions

The writer has drawn the following conclusions from the results of this study:

1. For faults in the NRTS 138-kV loop, automatic reclosing should not be permitted when the loop is broken, that is, when one of the section breakers is open. This follows from the fact that stability between EBR-II and the utility system is in serious jeopardy following reclosure for cases where the remaining load on the isolated EBR-II unit is not within a few megawatts of the initial load on the EBR-II unit (see case 2).

2. Automatic reclosures on the 138-kV interconnection to Utah Power and Light Company can also be hazardous to the EBR-II unit. This is true in cases where a material unbalance exists between the EBR-II generation and the load on the NRTS 138-kV loop. Of particular concern are modes of operation in which the Utility System supplies the bulk of the NRTS demand while the EBR-II unit is lightly loaded (see cases 6 and 8).

3. When and if the EBR-II transmission system shown in Fig. B-1 is materially revised, additional transient stability studies should be conducted to see if the above limitations still exist.

4. Results

Transient stability runs were computed for the conditions outlined in Table B-3. The results of these runs are plotted in Figs. B-2, B-3 and B-4; they are also tabulated in Table B-4.

TABLE B-3. Summary of Transient Stability Studies

	Initial Operation					Description of Disturbance				
	System Load,	EBR-II		Utility Tie					EBR-II Accelerating	
Case No.	MW	MW	% E'	MW	% E'	Fault Location*	Clearing Time, Cycles	Reclosing Time, Cycles	Power, MW**	Comments
(1)	27.2	20.0	120.8	7.2	99.2	EBR-II--ANP	9	21	17.30	Unstable
(2)	27.2	20.0	120.8	7.2	99.2	NRF-MTR	9	21	5.74	Unstable
(3)	27.2	20.0	120.8	7.2	99.2	Scoville-Utility	9	21	-4.20	Stable
(4)	27.9	4.0	106.4	23.9	102.9	Scoville-Utility	9	21	-14.76	Stable
(5)	27.9	4.0	106.4	23.9	102.9	Scoville-Utility	9	27	-14.76	Stable
(6)	27.9	4.0	106.4	23.9	102.9	Scoville-Utility	0	24	-14.76	Unstable
(7)	27.9	4.0	106.4	23.9	102.9	Scoville-Utility	9	24	-23.90	Stable
(8)	27.9	4.0	106.4	23.9	102.9	Scoville-Utility	6	24	-23.90	Unstable

*In each case, a 3-phase fault is assumed at the source end of the indicated line section. The fault is cleared in the indicated time with the opening of the circuit breakers at each end of the line section.
**This condition exists from the time the fault is cleared until the line breakers are reclosed.

TABLE B-4. Rotor Angle vs. Time for EBR-II

Time, sec	Rotor Angle, Degrees for Case Nos. 1-8							
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
0	18.31	18.31	18.31	-0.53	-0.53	-0.53	-0.53	-0.53
0.05	20.86	20.86	20.86	-0.38	-0.38	-2.74	-0.38	-0.38
0.10	28.52	28.52	28.52	0.07	0.07	-9.39	0.07	0.07
0.15	41.29	41.29	41.29	0.82	0.82	-20.48	0.82	-2.93
0.20	59.21	57.47	55.98	-0.52	-0.52	-36.00	-1.88	-13.14
0.25	82.33	75.37	69.41	-6.27	-6.27	-55.95	-11.79	-30.56
0.30	110.65	95.00	81.58	-16.46	-16.46	-80.34	-28.91	-55.19
0.35	144.16	116.35	92.48	-31.08	-31.08	-109.16	-53.24	-87.03
0.40	178.80	134.82	98.18	-44.62	-50.13	-142.42	-84.78	-126.08
0.45	218.54	148.55	94.92	-49.13	-73.62	-173.63	-113.38	-163.24
0.50	272.32	160.26	82.58	-43.89	-93.06	-202.62	-129.68	-195.93
0.55		172.59	61.12	-29.74	-99.31	-235.79	-135.47	-231.37
0.60		188.49	32.00	-9.27	-92.48	-278.99	-131.59	-276.22
0.65				13.15	-72.46		-117.47	

In all cases the total NRTS loop load plus that of the EBR-II facility is essentially constant--27.2 MW for cases 1-3 and 27.9 MW for cases 4-8. The first three cases are concerned with system disturbances with the EBR-II generator operating at its rated 20-MW output; in the latter five cases, the EBR-II unit output is 4 MW, or 20% of rating.

Normal Operation--Load Flow and Voltage Distribution. In conducting a transient stability study it is, of course, necessary to determine the initial operating conditions. This was done for the system of Fig. B-1 by means of the computer load flow program outlined in Ref. 1. The results--bus voltages, circuit megawatt and megavar flows, and the shunt impedance equivalent of the load at each bus--are shown in Table B-2. Of these data, the most significant--as far as the transient stability studies are concerned--are the power output and voltage behind transient reactance of each of the machines as well as the load shunt impedance equivalents. The use of these data in determining transient stability performance is described in the appendix.

Automatic Reclosing for Faults in the NRTS Loop. During normal operation, with the EBR-II generator operating in parallel with the utility system and with all NRTS 138-kV loop circuit breakers closed, short circuits on the 138-kV loop when cleared in approximately 9 cycles (0.15 sec) will not result in system instability, i.e., synchronism will be retained.

However, when one of the loop section breakers is open, a fault on the remaining tie between the EBR-II facility and the utility interconnection point--Scoville--results in isolating the two generation sources. This latter mode of operation exists, of course, until the circuit breakers protecting the

[1] Automatic Digital Computer Solution of Load Flow Studies, J. M. Henderson. AIEE Transactions, Pt. III (Power Apparatus and Systems), February 1955, pp. 1696-1701.

faulted section are reclosed. After reclosure, the system may be unstable, depending on the location of the fault, the load on the loop, and the load on the EBR-II generator.

Figure B-2--cases 1 and 2--shows the transient angular swing of the EBR-II generator with respect to the utility generation for two different 3-phase fault conditions of the NRTS loop. In each case, the line section breaker at SPERT is open. In each case, although the fault is removed in 9 cycles and a successful reclosure is effected in 21 cycles, system stability is lost. This is evidenced by the increasing positive angular displacement between EBR-II and the utility generation.

The difference between the swing curves for cases 1 and 2 is due solely to the difference in fault location. Faults close to the EBR-II facility result in a faster acceleration. This is particularly pronounced in the interval between the fault removal and the line reclosure. As indicated in Table B-3, the accelerating power on EBR-II during this interval is 17.3 MW for the close-in fault (case 1) and 5.74 MW for the more remote fault (case 2).

Case 3--also plotted in Fig. B-2--provides an interesting comparison with those discussed above. This case, differing from the other two only in the location of the fault, is stable. The reason stability is maintained is due principally to the decelerating effect of the loop load during the period EBR-II is isolated from the utility generation. From Table B-3 the decelerating power during this interval is 4.20 MW.

Automatic Reclosing for Faults on the Utility Tie Line. Faults on the 138-kV tie line between the Scoville Substation and the Utah Power and Light Company isolate the EBR-II generator along with the entire NRTS loop load from the Utility System. Case 3 (see Fig. B-2) indicates stability is maintained for 9-cycle fault clearing and 21-cycle reclosing for a condition where the initial EBR-II generation (20 MW) and the loop load (27 MW) are in relatively close balance.

Figures B-3 and B-4 indicate the EBR-II swing with respect to the utility generation for 3-phase faults on the utility tie. In all of the cases shown the initial NRTS loop load (27.9 MW) is considerably in excess of the initial EBR-II generation (4 MW). This results, as the curves illustrate, in a negative angular swing, that is, the EBR-II rotor angle retreats or slows down with respect to that of the utility generation.

In cases 4, 5, and 6 the NRTS loop loads were represented--as they were in cases 1-3--as constant shunt impedances. With this assumption the total megawatt load on the EBR-II unit after the fault is cleared and prior to reclosing is 18.76 MW. This output with the turbine input of 4 MW produces, as indicated in Table B-3, a net decelerating power on the EBR-II unit of 14.76 MW.

As indicated by cases 4 and 5 of Fig. B-3, this decelerating load is not sufficient to produce an unstable condition for 9-cycle fault switching and line-reclosing times in the range from 21 to 27 cycles.

Case 6 may be somewhat academic since, in the strictest sense, fault-clearing times of zero cycles are impossible. Practically speaking, this case may be interpreted as depicting system performance for a false trip on the utility tie followed by a 24-cycle reclosure. As indicated in Fig. B-3, an occurrence of this nature would result in loss of synchronism between the EBR-II generator and the utility system.

The swing curves of Fig. B-4 are based on constant-power, rather than constant-impedance, representation of the NRTS loop loads during the interval in which EBR-II is isolated from the utility and required to carry the entire system load. For such a transient condition, the net decelerating power acting on the EBR-II generator is (27.9-4.0) = 23.9 MW. The data of Fig. B-4 indicate stability is maintained for fault clearing and line reclosing times of 9 and 24 cycles respectively (case 7). Where the tie line fault is cleared at the Scoville end in 6 cycles (case 8), synchronism is lost following a 24-cycle reclosure.

Whether or not the NRTS loop is closed has only a minor effect on system stability for faults on the utility tie line. This is due to the fact that the synchronizing power between the two generators--after the tie line fault is removed and the breakers are reclosed--is essentially the same for either broken or closed loop operation. Therefore, the results of cases 3-8, which are predicated on the SPERT section breaker being open, would also apply for closed loop operation.

5. Appendix

The method of analysis employed in this study is covered in detail in Ch. 5 of Ref. 2. Therefore, only a brief description is in order.

Assumptions. The following assumptions, commonly made in transient stability studies, were employed in this analysis:

1. Transient saliency was neglected ($X_d' = X_q$).

2. Flux linkages were held constant, corresponding to the voltage back of the transient reactance (X_d').

3. Damping torques and subtransient effects were neglected.

4. Mechanical-shaft torques of synchronous machines were taken to be constant.

[2] S. B. Crary, Power System Stability, Vol. II, John Wiley and Sons. Inc., New York (1947).

5. Loads were represented by constant shunt impedances.

6. System-network impedances were taken to be constant, corresponding to normal frequency.

7. Stability was determined by the first swing.

Procedure. The procedure used in the swing curve calculation includes the following steps:

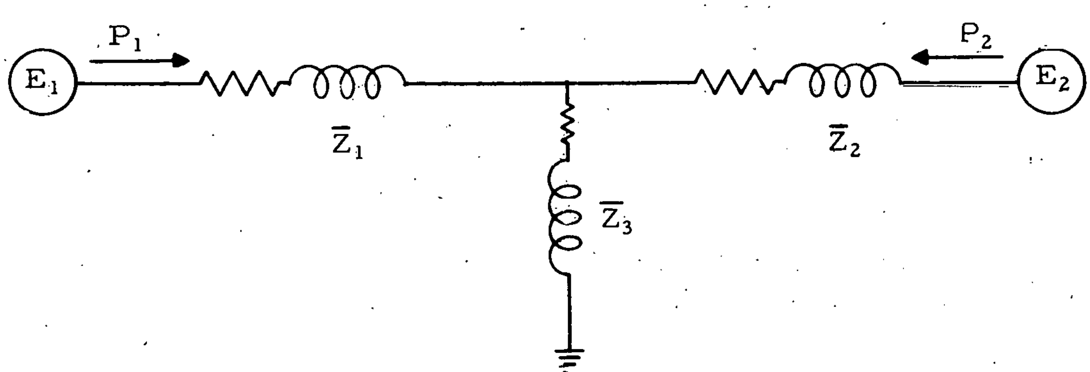
1. The system network is reduced to a simple equivalent

2. Transfer and driving point impedances for circuit conditions of transient (fault on, fault off, etc.) are determined.

3. Initial conditions and power flow equations for subsequent transient conditions are determined.

4. Calculations are carried out for assumed system disturbance until it is apparent that system is stable or unstable.

System Equivalent and Power Flow Equations. Using techniques described in Ch. 1 of Ref. 3, and with loads represented as constant shunt impedances, the system of Fig. B-1 was reduced to the following equivalent:



where

E_1 = Voltage behind the transient reactance of the EBR-II generator.

E_2 = Voltage behind the transient reactance of the equivalent utility generation.

P_1 = Power output of EBR-II generator.

P_2 = Power output of equivalent utility generation.

[3]S. B. Crary, Power System Steam Stability, Vol. I, John Wiley and Sons, Inc., New York (1945).

$\overline{Z}_1 = 0.4120\underline{|88.80^\circ}$ per unit on 20 MVA.

$\overline{Z}_2 = 0.0788\underline{|79.04^\circ}$ per unit on 20 MVA.

$\overline{Z}_3 = 0.6856\underline{|16.00^\circ}$ per unit on 20 MVA.

The transfer and driving point impedances of the equivalent circuit are:

$$\overline{Z}_{11} = \overline{Z}_1 + \frac{\overline{Z}_2\overline{Z}_3}{\overline{Z}_2 + \overline{Z}_3} = Z_{11}\underline{|90 - a_{11}} = 0.4842\underline{|86.47^\circ}; \quad (1)$$

$$\overline{Z}_{22} = \overline{Z}_2 + \frac{\overline{Z}_1\overline{Z}_3}{\overline{Z}_1 + \overline{Z}_3} = Z_{22}\underline{|90 - a_{22}} = 0.3907\underline{|66.05^\circ}; \quad (2)$$

$$\overline{Z}_{12} = \overline{Z}_1 + \overline{Z}_2 + \frac{\overline{Z}_1\overline{Z}_2}{\overline{Z}_3} = Z_{12}\underline{|90 - a_{12}} = 0.5119\underline{|92.03^\circ}. \quad (3)$$

In terms of these impedances, which are defined in Ref. 3, the generator power outputs are

$$P_1 = \frac{E_1^2}{Z_{11}} \sin a_{11} + \frac{E_1E_2}{Z_{12}} \sin (x_{12} - a_{12}); \quad (4)$$

$$P_2 = \frac{E_2^2}{Z_{22}} \sin a_{22} - \frac{E_1E_2}{Z_{12}} \sin (x_{12} + a_{12}), \quad (5)$$

where Z_{11}, Z_{22}, and Z_{12} are the absolute values of the impedances and a_{11}, a_{22}, and a_{12} are the complements of the impedance angles; x_{12} is the phase-angle difference between the rotors of the two generators.

Thus, for cases 1-3, for which $E_1 = 1.208$ and $E_2 = 0.992$, the per unit electrical power output of EBR-II, when interconnected with the utility, equals

$$0.186 + 2.342 \sin (x_{12} + 2.03^\circ). \quad (6)$$

For cases 4-8 (E_1 and E_2 are 1.064 and 1.029, respectively), the EBR-II per unit electrical power is

$$0.144 + 2.139 \sin (x_{12} + 2.03^\circ). \quad (7)$$

The initial operating conditions given in Table B-3 for cases 1-3 correspond to x_{12} equal to 18.31°; those for cases 4-8 result from an angle of -0.53°.

The Swing Equation. The step-by-step procedure used to determine the transient angular swing of the EBR-II unit with respect to the utility generation is described in Ch. 5 of Ref. 2 (Vol. II) and is illustrated in Table B-5. The latter data apply specifically to case 3.

TABLE B-5. Swing Curve Calculation Data

GENERAL ELECTRIC CO.-A.C. NETWORK ANALYZER

STEP-BY-STEP SWING CURVE CALCULATION

GEN. NO. ______
BOX NO. ______

PAGE NO. ______

DATE ______

STUDY NO. ______

CASE NO. III

KVA BASE 20,000

FOR Argonne National Laboratory

Inertia Constant, $H = \dfrac{(0.231)\,(WR^2)\,(RPM)^2\,(10)^{-6}}{\text{Base KVA}} = 4.4942$

Acceleration Constant, $k = \dfrac{180\,f(\Delta t)^2}{H} =$ 6.0077 Δt = .05 Sec.

______ Δt = ______ Sec.

$E_{gen.}$ in p.u. 1.208

$X_{gen.}$ in p.u. .3125

Fault

Type Three-phase

Location Utility tie at Scoville

Time in Sec. t	Power Input to Rotor: Reading	Mult.	T_1 in °/1				
0-			1.000				

Time in Sec. t	Power Out to System: Reading	Mult.	T_0 in °/1	Acceler. Torque $T_a = T_1 - T_0$	kT_a	$\Delta\delta_n = \Delta\delta_{n-1} + kT_a$	Angular Displacement δ_a in degrees $\delta_a = \Delta\delta_n + \delta_{n-1}$
0+			.150	.850 x ½	2.553	— — — —	18.31
.05			.150	.850	5.107	2.553	20.86
.10			.150	.850	5.107	7.660	28.52
.15-			.150	.850	-	12.767	41.29
Fault Cleared			(Average)	.320	-	-	-
.15+			1.210	-.210	1.922	-	-
.20			1.210	-.210	-1.262	14.689	55.98
.25			1.210	-.210	-1.262	13.427	69.41
.30			1.210	-.210	-1.262	12.165	81.58
.35-			1.210	-.210	-	10.903	92.48
Line Reclosed			(Average)	-.866	-	-	-
.35+			2.521	-1.521	-5.203	-	-
.40			2.491	-1.491	-8.957	5.700	98.18
.45			2.511	-1.511	-9.078	-3.257	94.92
.50			2.518	-1.518	-9.120	-12.335	82.58
.55			2.276	-1.276	-7.666	-21.455	61.12
.60						-29.121	32.00

The indicated procedure provides the solution to the following equation of angular motion of a synchronous machine:

$$\frac{d^2x}{dt^2} = \frac{180\, f(T_m - T_e)}{H}, \qquad (8)$$

where

f = frequency (cps)

t = time (sec)

x = generator angular displacement (degrees)

T_m = mechanical shaft torque per unit

T_e = electrical torque per unit

H = generator per unit inertia constant.

Since machine speed does not vary appreciably from synchronous speed during the transient swing, per unit torque and per unit power can be assumed equal and therefore used interchangeably. Thus, in terms of Eq. 8, the acceleration of the generator angle at a particular instant in time equals a constant times the accelerating power acting at that same instant. With the mechanical power input assumed constant, the accelerating power is a function only of the electrical output.

For the EBR-II unit, the electrical power output during short-circuit conditions of the NRTS loop or of the utility tie was assumed to be 15% of nameplate rating. (This is typical for 3-phase faults electrically close to the terminals of the generator step-up transformer).

With the fault removed and the two generators isolated from one another, the EBR-II power output is

$$P_1 = \frac{E_1^2}{Z_{11}} \sin a_{11},$$

where Z_{11} and a_{11} vary depending on the shunt impedance loads remaining on the EBR-II unit. The following table shows these data and P_1, expressed in per unit on 20 MVA, for cases 1-8:

Case	E_1	Z_{11}	A_{11}, degrees	P_1
1	1.208	9.572	62.21	0.135
2	1.208	1.784	60.56	0.713
3	1.208	0.898	48.02	1.210
4-6	1.064	0.898	48.02	0.938
7-8	(Constant Power Loads)			1.395

After the fault is cleared and the breakers reclosed, the EBR-II electrical output is a function of the angular displacement between it and the utility generation. Eqs. 6 and 7 define this relationship.

Throughout this analysis, the phase angle of the equivalent utility generation was assumed to be unaffected by disturbances in or near the NRTS loop. This is thought to be reasonable since the inertia constant of the utility generation is large compared to that of EBR-II; furthermore, the accelerating power acting on the equivalent utility generation would be quite small for faults in the NRTS loop area.

APPENDIX C

Electrical Penetrations of the Reactor Building Containment Vessel

1. Introduction

Containment of the EBR-II is provided to preclude release of fission products and/or plutonium from the Reactor Building in the unlikely event of a major nuclear accident.

A large number of openings through the Reactor Building containment vessel are required for personnel and equipment, for electrical conductors, ventilating air, sodium pipes, instrument and utility compressed air lines, and other utilities. All openings employ gas-tight seals, either of the metal-to-metal type or of an organic type suitably protected against possible high-temperature gases generated in a postulated incident involving a sodium-air reaction. All openings are designed so as not to detract from the strength of the building shell and so as to be capable of sustaining the same building pressure as the maximum containable by the shell itself.

The necessary electrical circuits are brought into the Reactor Building through leak-tight pressure connectors mounted in pressure chambers (penetrations) installed in the building containment shell. These are located at the north end of the cable tunnel below the corridor between the Reactor Building and the Power Plant Building. Cables leaving the penetrations inside the Reactor Building are routed to equipment via conduit embedded in the concrete walls of the containment vessel.

The design of the electrical penetrations permits pressure and leak-testing of bulkhead-type connector assemblies prior to their installation onto pressure chambers installed in the containment vessel. After installation, each connector assembly is retested for possible leakage. The design permits convenient leak-rate testing of the individual pressure chamber without pressurizing of the entire building. Periodic leak-rate testing of the penetrations is performed as part of the plant maintenance program.

As shown in Table C-1, 34 electrical pressure chambers are provided. Thirty chambers contain electrical connectors, consisting of Cannon Electric Company Type TBF connectors, Amphenol Electronics Corporation Type 100X Coaxial connectors, and specially constructed mineral-insulated (MI) cable connectors of ANL design. One electrical pressure chamber (No. 26) was used for the installation of a low-pressure relief valve which opens for a predetermined low-pressure condition inside the building to limit the pressure differential on the building containment shell. Three chambers are blanked off and sealed as spares. This arrangement provides a total of 4212 connector pins or circuit penetrations; approximately 15 percent of these are spares. In addition, 48 coaxial cable connectors are provided.

TABLE C-1. Electrical Penetrations in Reactor Building Containment Vessel

Pressure Chamber (penetration) No.	Pressure Chamber (penetration) IPS, in.	Type of Pressure Connector (receptacle)	Pressure Connectors (receptacle) No.	Pressure Connectors (receptacle) Type (see Fig. C-6)	Number of Connector Pins
1	10	Cannon TBF	7	R-5	259
2	10	Cannon TBF	7	R-5	259
3	10	Cannon TBF	6	R-5	222
			1	R-3	14
4	10	Cannon TBF	6	R-5	222
			1	R-3	14
5	10	Cannon TBF	6	R-2	18
			1	R-3	14
6	10	Cannon TBF	5	R-1	15
			1	R-2	3
			1	R-3	14
7	10	Cannon TBF	5	R-1	15
			2	R-2	6
8	10	Cannon TBF	4	R-4	104
			2	R-2	6
			1	R-3	14
9	10	Cannon TBF	7	R-5	259
10	10	Cannon TBF	7	R-5	259
11	10	Cannon TBF	6	R-5	222
			1	R-5A	37
12	10	Cannon TBF	6	R-5	222
			1	R-5A	37
13	10	Cannon TBF	7	R-3	98
14	10	Cannon TBF	4	R-5	148
			2	R-4	52
			1	R-2	3
15	10	Cannon TBF	4	R-1	12
			2	R-2	6
			1	R-3	14
16	10	Cannon TBF	6	R-4	156
			1	R-3	14
20	6	MI Cable	1	(Fig. C-2)	6
21	6	Cannon TBF	1	R-7	6
22	6	MI Cable	1	(Fig. C-2)	6
23	6	MI Cable	1	(Fig. C-2)	6
24	6	Spare	-	-	-
25	6	Spare	-	-	-
26	6	Containment Vessel Low-pressure Relief	-	-	-

TABLE C-1 (Contd.)

Pressure Chamber (penetration)		Type of Pressure Connector (receptacle)	Pressure Connectors (receptacle)		Number of Connector Pins
No.	IPS, in.		No.	Type (see Fig. C-6)	
27	6	Spare	-	-	-
28	6	Cannon TBF	1	R-5	37
29	6	Cannon TBF	1	R-5	37
30	16	Cannon TBF	10	R-5B	370
			2	R-5	74
31	8	Cannon TBF	5	R-3	70
32	8	Cannon TBF	4	R-5	148
			1	R-5B	37
33	16	Cannon TBF	7	R-5	259
			3	R-3	42
			2	R-2	6
34	16	Amphenol 100X (Coaxial)	14	R-6A	-
			10	R-6B	-
35	16	Amphenol 100X (Coaxial)	22	R-6A	-
			2	R-6B	-
36	8	Cannon TBF	5	R-5	185
37	8	Cannon TBF	5	R-5B	185
				Total Pins	4212

Note: Penetrations Nos. 17, 18, 19 do not exist.

The Cannon Type TBF and Amphenol Type 100X Coaxial connectors are bulkhead-type pressure connectors with solid through-conductors with terminals at each end. Where conductor sizes larger than 1/0 AWG are required, special MI cable penetration assemblies provide leak-tight through-conductors with terminals at both ends.

Cabinet enclosures for the electrical connector assemblies are installed in the concrete wall opposite the end of the tunnel at the Reactor Building. The enclosures are made of 1/8-in.-thick steel plate for protection against mechanical injury and the inside surfaces of the doors of the enclosures are provided with a 3/4-in.-thick layer of thermal insulation.

2. Pressure Chambers

The pressure-chamber designs shown in Figs. C-1 and C-2 for penetrations Nos. 1 through 16, 20, 22, and 23 are typical of the design used for all electrical penetrations. Basically, a penetration consists of short lengths of standard carbon steel pipes (5, 10 or 16 in., Schedule 40 pipe, or 8-in. Schedule 160 pipe) inserted in the wall openings and welded to the containment vessel shell. A $1\frac{1}{2}$-in. carbon steel reinforcing ring is welded to the external side of the shell at all penetrations to relieve the stresses, except for penetrations Nos. 31, 32, 36, and 37 which consist of Schedule 160 carbon steel pipe. Welded to each end of the pipe is a pipe flange (see Figs. C-1 and C-2). Carbon steel terminal plates (terminal plates used on penetrations 20 and 22 are stainless steel) are gasketed and bolted to the outside pipe flanges.

To permit leak-rate testing of penetrations without disconnecting the circuits involved, several additional terminal plates mounted with hermetically sealed Cannon Type BFH receptacles are installed on the reactor building ends of pressure chambers. A short length of cable inside the pressure chamber, with plug connectors on both ends, connects the receptacle on the outside plate with the corresponding receptacle on the inside plate. At present, inside plate assemblies are installed on pressure chambers 9, 10, 13, 29, 31, and 37. Other pressure chambers will similarly be equipped with inside plate receptacle assemblies in the future to enhance reactor operation time.

Leak-rate testing of the individual pressure chamber (except chambers 9, 10, 13, 29, 31, and 37) is accomplished by disconnecting all its cables on the inside of the pressure chamber, removing the fiber ring, and then installing the test head. The test head is provided with fittings for pressurizing the chamber, and attaching a manometer and a thermocouple probe. Chambers 9, 10, 13, 29, 31, and 37, however, do not require use of the test head for leak-rate testing since terminal plates and connectors have been installed on the inside flange of these chambers.

A leak-rate test was run continuously for a minimum of 48 hr on each of the pressure chambers after all pressure connectors were installed. These tests were made under ambient temperature conditions with pressures of 60 psig on chambers with the Amphenol coaxial connectors and with pressures of 30-34 psig on those with the Cannon TBF connectors.

Leak-rate testing of the pressure chambers is presently being conducted at 24 psig on a yearly schedule with a random selection of penetrations to be tested. Penetrations which have been worked on or disturbed for any reason are tested immediately.

3. Bulkhead-type Pressure Connectors

Figures C-3 and C-4 show construction and mounting details of the Cannon Electric Company Type TBF and Amphenol Borg Electronic Corporation coaxial cable pressure connectors, respectively. Figure C-4 also shows the coaxial connector assembly and gasketing of the parts for mounting the connector. The socket-and-plug arrangement facilitates disconnecting of cables from the bulkhead fittings for ease of maintenance and testing.

Figure C-6 is a diagram of the pin arrangement in the various pressure connectors, and Fig. C-5 shows the arrangement of the pressure connectors on the pressure chamber terminal plates. These two diagrams in conjunction with Table C-1 show the number and type of pressure connectors and their arrangement on each terminal plate.

a. Cannon Type TBF Connectors. The Cannon Electric Company TBF pressure connectors are of the through-bulkhead type (see Figs. C-3 and C-6) rated for 30 psi at 250°F continuously, with a leakage rate of not more than one cubic inch per hour. The Cannon Electric Company catalog numbers are shown on Fig. C-6. Connector shells are equipped with a polarizing key to prevent any misalignment of mating pins and sockets. These shells are all size 28 except for the one Type R-7 connector which has three 1/0 and three No. 12 pins. The Type R-7 connector has a size 36 shell and is used in pressure chamber No. 21. The connector pins are embedded in a pressurized resilent insert to provide solid leak-tight through conductors.

b. Amphenol Coaxial Connectors. The Amphenol Borg Electronic Corporation coaxial cable connectors are also of the bulkhead type. The coaxial connectors, Amphenol assembly No. 100X-3875-1, consist of Type UG-30 C/U pressurized bulkhead adapters and Type UG-630 A/U mating plugs for Amphenol 21-804 (RG-71/U) cable or Type UG-21/DU mating plugs for Amphenol 21-467 cable. The tapered connector pin is embedded in a pressurized resilent insert to provide a solid leak-tight through conductor.

The Amphenol connector assembly was subjected to a pressure of 50 psig and 300°F continuously for one week at Argonne National Laboratory. No detectable leakage was observed. The electrical resistance of this connector measured 10 megohms. A voltage breakdown test on four samples gave the following results:

Sample	Breakdown, V
1	4,500
2	3,100
3	4,300
4	3,000

4. MI Cable Penetrations

Special copper-jacketed, copper-conductor, magnesium-oxide-insulated (MI, mineral-insulated) cable penetration assemblies are provided for the three-phase, 480-V power circuits feeding the two 350-hp, squirrel-cage induction motors for the primary pumps, the primary-tank immersion heaters, and the Reactor Plant motor-control center R-3.

The penetration assemblies (see Fig. C-2) consist of short lengths of MI cable brazed to nozzle plates, and mounted on pressure chambers Nos. 20, 22, and 23 with gaskets between the penetration steel flange and the nozzle plate. A fiber cable support is included at the opposite end of the chamber. The enlarged view of the cable end shows the method used to seal the cable insulation. The magnesium oxide insulation between the cable sheath and the copper conductor is reamed out to a depth of one-half inch at both ends of the cable and the void thus created is filled with an epoxy resin sealing compound.

A test set-up (see Fig. C-7) was made to determine the leakage through a piece of 500-MCM MI cable, 15 in. in length, sealed at one end as described above. Heat was applied to the cable in order to determine the ability of the epoxy resin to maintain a satisfactory seal at 30 psi and at a temperature of approximately 240°F. As the end of the cable was heated to 240°F, the pressure in the vessel was bled off to maintain 30 psi. After achieving 240°F, the vessel was sealed and the temperature and pressure readings were taken for a period of 48 hr. The initial and final conditions were as follows:

Initial	Final
695 cu in.	695 cu in.
30 psi (vessel)	30.5 psi (vessel)
240°F (end of sealed MI cable)	250°F (end of sealed MI cable)

It is estimated that the accuracy of these readings are 0.25 psi for the pressure gauge and 1°F for the temperature.

Calculations made from these data indicated no leakage through the MI cable. Also, a Freon leak-test performed with the vessel at 30 psi indicated no leakage.

After installation of these special MI cable penetration assemblies, leak-rate tests were performed on each completely assembled pressure chamber with the leak-rate well within the design requirements. The results of these tests and the field maintenance testing has proved that the design is satisfactory and reliable.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the review, comments and criticisms by J. H. Monaweck. The helpful advice and assistance with the graphic arts portions of the report by M. R. Sims, J. R. Korn, and J. M. Flagg are also gratefully acknowledged.

Acknowledgement of the various contributors to the EBR-II electrical design is included in the Introduction.

BIBLIOGRAPHY

1. Koch, L. J., H. O. Monson, W. R. Simmons, M. Levenson, F. Verber, E. Hutter, R. A. Jaross, T. R. Spalding, J. R. Simanton, and A. Lovoff, *Construction Design of EBR-II; an Integrated Unmoderated Nuclear Power Plant,* Proceedings Second International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland 9, 323 (1958).

2. Koch, L. J., H. O. Monson, D. Okrent, M. Levenson, W. R. Simmons, J. R. Humphreys, J. Haugsnes, V. Z. Jankus, and W. B. Loewenstein, *Hazard Summary Report, Experimental Breeder Reactor II (EBR-II),* ANL-5719 (1957).

3. Koch, L. J., W. B. Loewenstein, and H. O. Monson, *Addendum to Hazard Summary Report, Experimental Breeder Reactor II (EBR-II),* ANL-5719 (Addendum) (1962).

4. Loewenstein, W. B., *The Physics Design of the EBR-II,* ANL-6383 (1961).

5. Barnes, A. H., F. A. Smith, and G. K. Whitham, *Electromagnetic Pump for Liquid Metals,* ANL-4317 (1949).

6. Hutter, E., and G. Giorgis, *Design and Performance Characteristics of EBR-II Control Rod Drive Mechanisms,* ANL-6921 (1964).

7. EBR-II Project Staff, *EBR-II Operating Manual,* Volume Nos. 1-5.

8. Gibbs and Hill, Inc., *Operating Instructions--High Voltage Electrical System at National Reactor Testing Station,* (May 1958; Revised Jan 1964).

9. General Electric Company, *Steam Turbine Generator Manual Experimental Breeder Reactor II,* GEI-67217.

10. Seim, O. S., and R. A. Jaross, *Characteristics and Performance of 5000-gpm AC Linear Induction and Mechanical Centrifugal Sodium Pumps,* Proceedings Second International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland 7, 88 (1958).

11. Monaweck, J. H., and E. S. Sowa, *Summary Report on Irradiation of Prototype EBR-II Fuel Elements,* ANL-6010 (1960).

12. Hesson, J. C., M. J. Feldman, and L. Burris, *Description and Proposed Operation of the Fuel Cycle Facility for the Second Experimental Breeder Reactor (EBR-II),* ANL-6605 (1963).

13. Sargent and Lundy, Engineers, *Protective Relay Settings--EBR-II Facility,* (Jan 1960; Revised June 1962 and Dec 1964).

14. Koch, L. J., *Fast Reactor Fuel Handling,* ANS National Topical Meeting, Detroit, Michigan, ANS-100 (April 1965), p. 333.

15. H. O. Monson, *EBR-II Initial Operation--Highlights,* London Conference on Fast Breeder Reactors (May 1966).

16. J. D. Cochran, H. O. Monson, J. E. Owens, *Operating Experience with Large Sodium-Cooled Reactor Plants,* American Power Conference (April 1966).

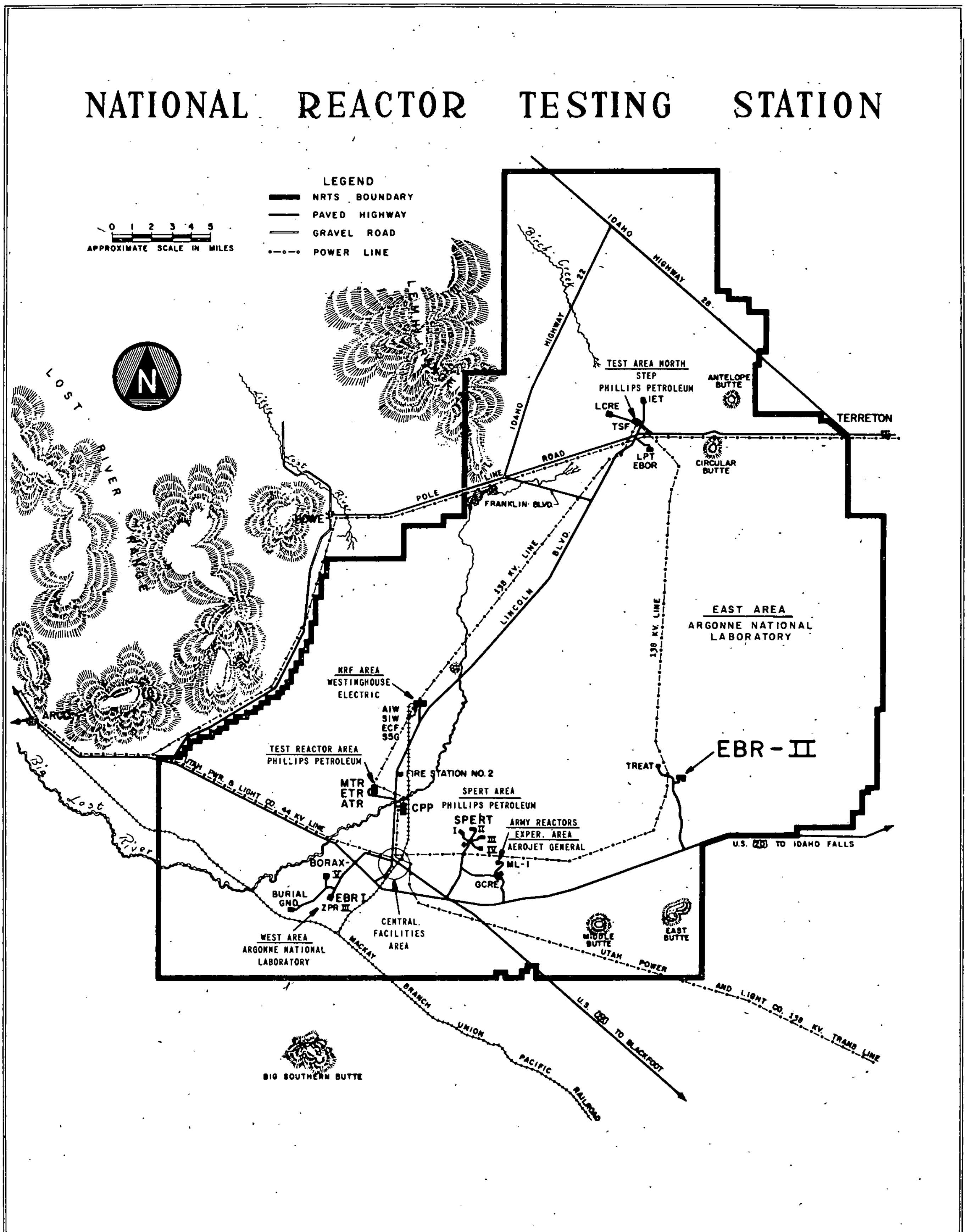


Fig. 1. Overall Site Plan of National Reactor Testing Station

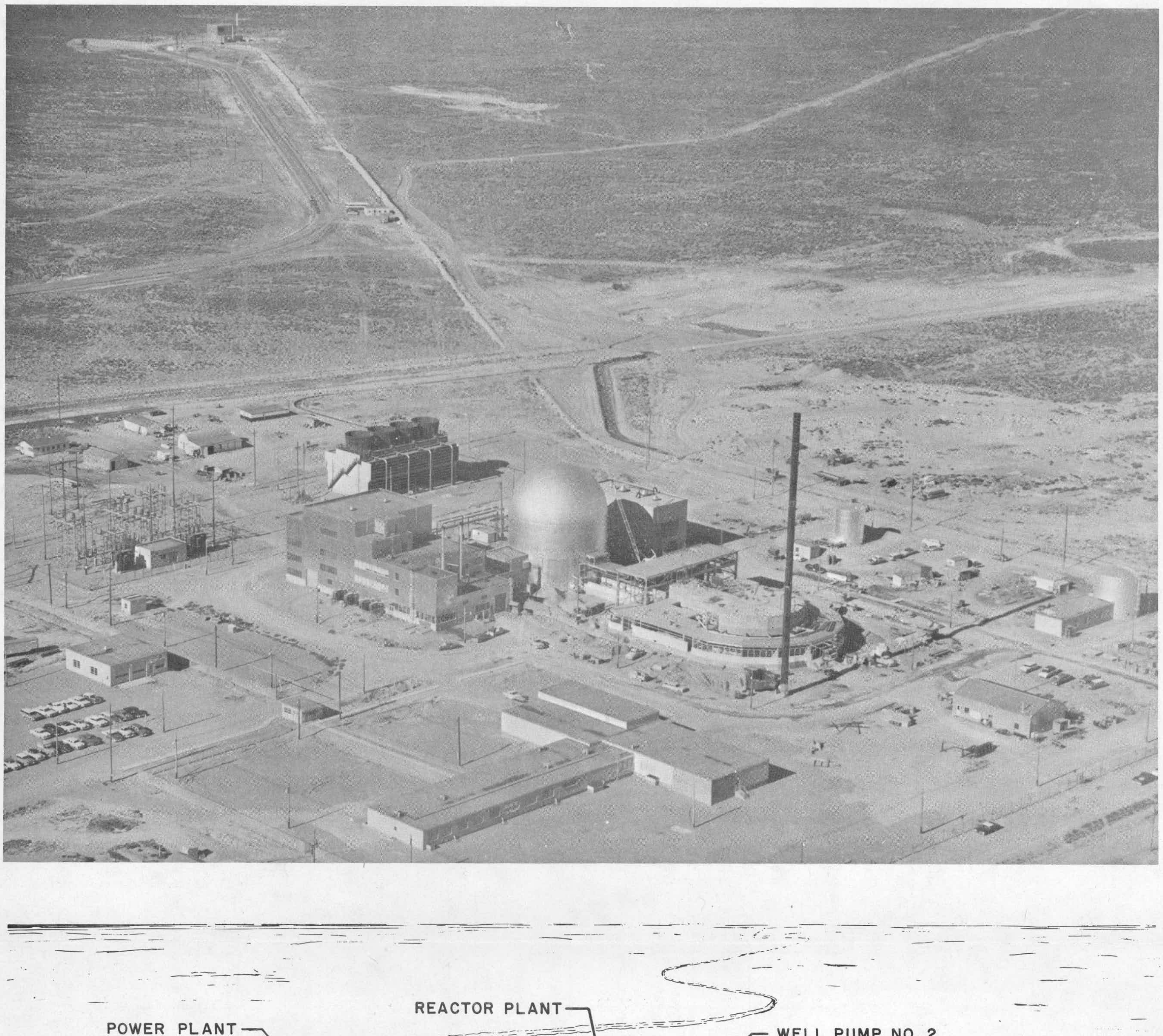
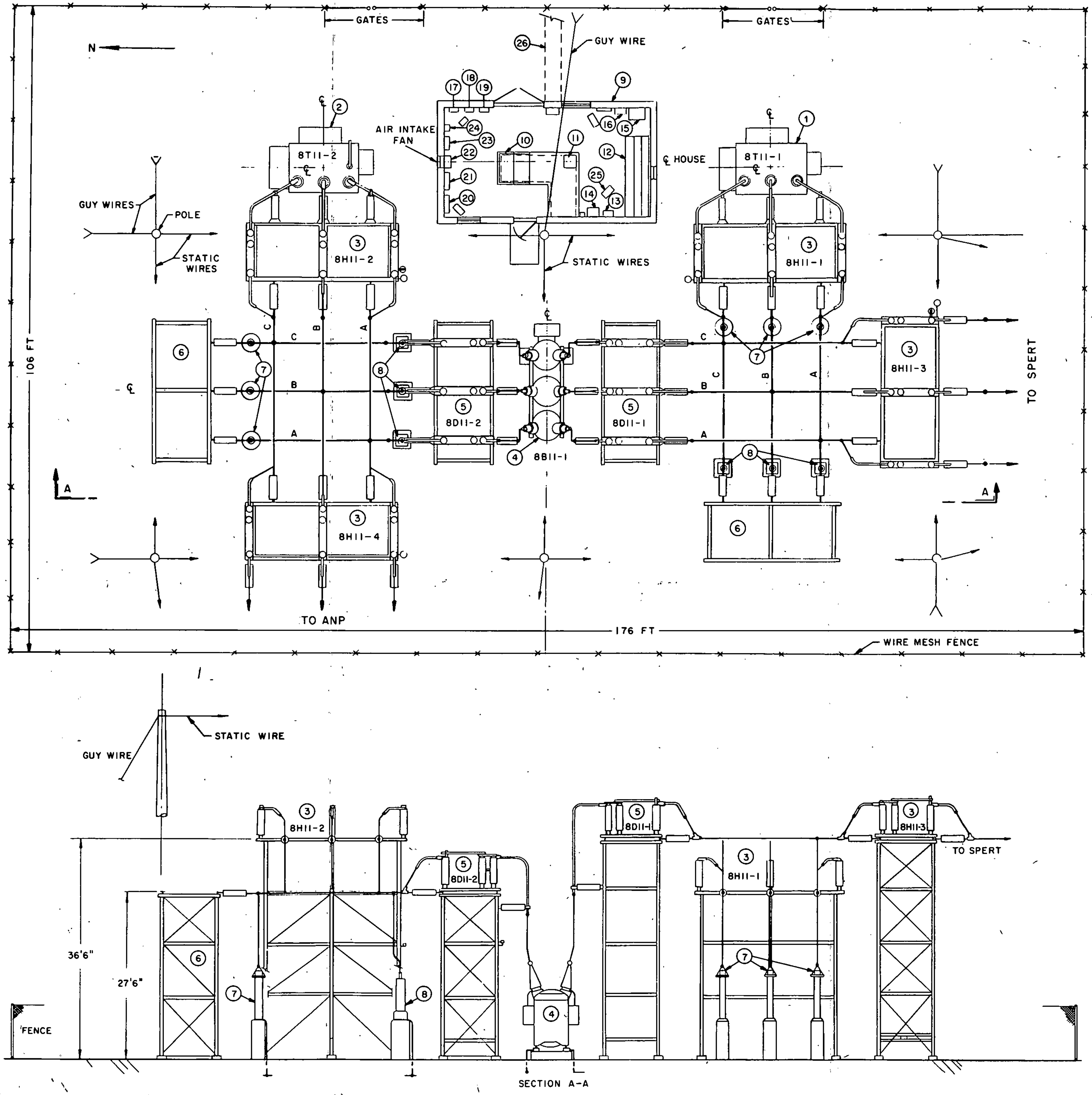


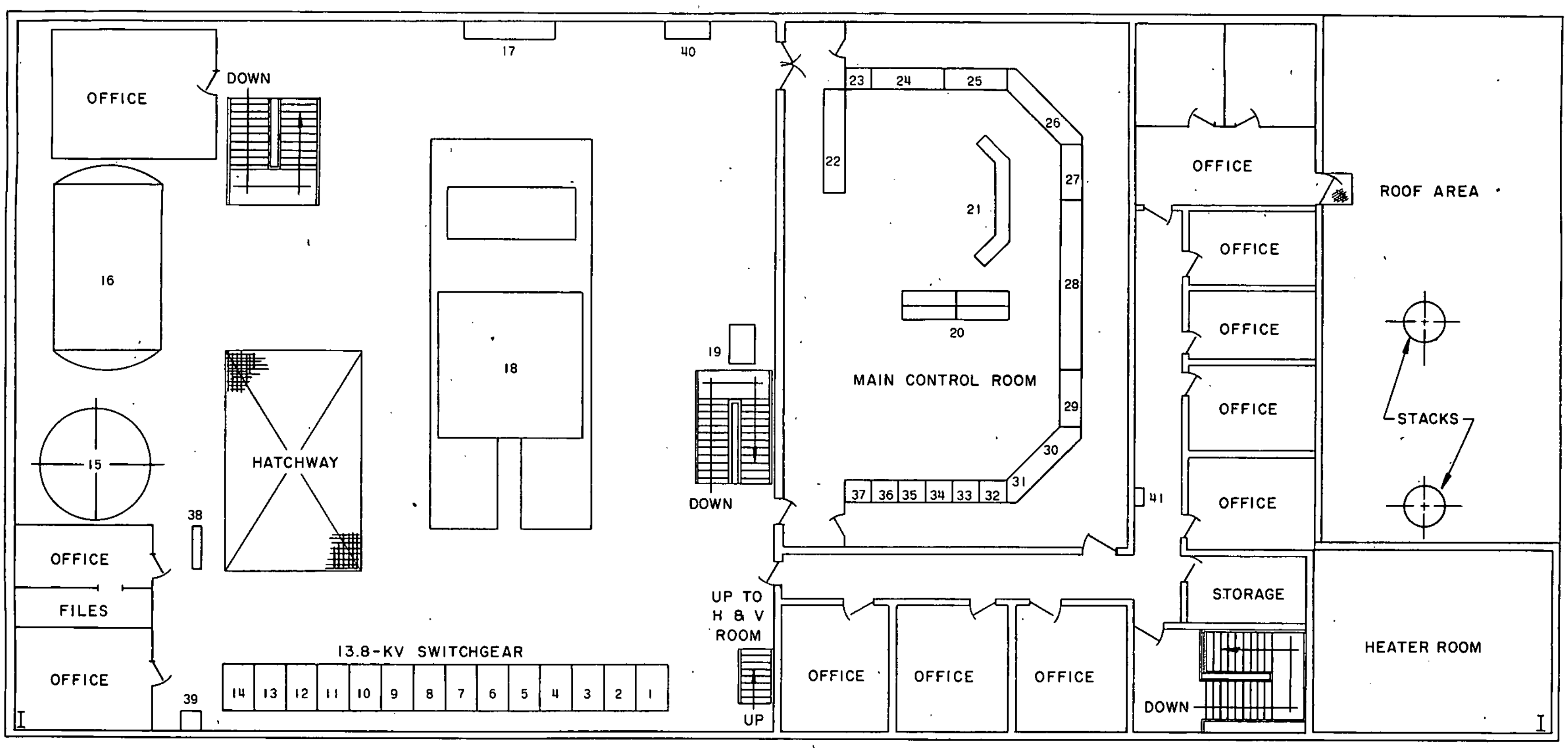
Fig. 2. EBR-II Plant Arrangement



LEGEND

1. 12000/16000-KVA TRANSFORMER NO. 1
2. 12000/16000-KVA TRANSFORMER NO. 2
3. 138 KV-3 PST HORN GAP DISCONNECT SWITCH (MOTOR OPERATED)
4. 138-KV OIL CIRCUIT BREAKER
5. 138 KV-3 PST DISCONNECT SWITCH (MANUALLY OPERATED)
6. DEAD-END RACK
7. 121 KV-SINGLE POLE LIGHTNING ARRESTER
8. COUPLING CAPACITOR POTENTIAL DEVICE
9. SUBSTATION CONTROL HOUSE
10. CONTROL PANELS
11. SUPERVISORY PANEL
12. 125-V VATTERY (60-CELL)
13. D-C SAFETY SWITCH
14. BATTERY CHARGER
15. 25-KVA TRANSFORMER
16. 440-V PANEL
17. PILOT WIRE CABINET
18. FIRE ALARM CABINET
19. TELEPHONE CABINET
20. EMERGENCY AC-DC DISTRIBUTION PANEL
21. A-C PANEL
22. AC-DC CONTACTOR
23. D-C PANEL
24. A-C SAFETY SWITCH
25. SPACE HEATER
26. UNDERGROUND DUCT RUN

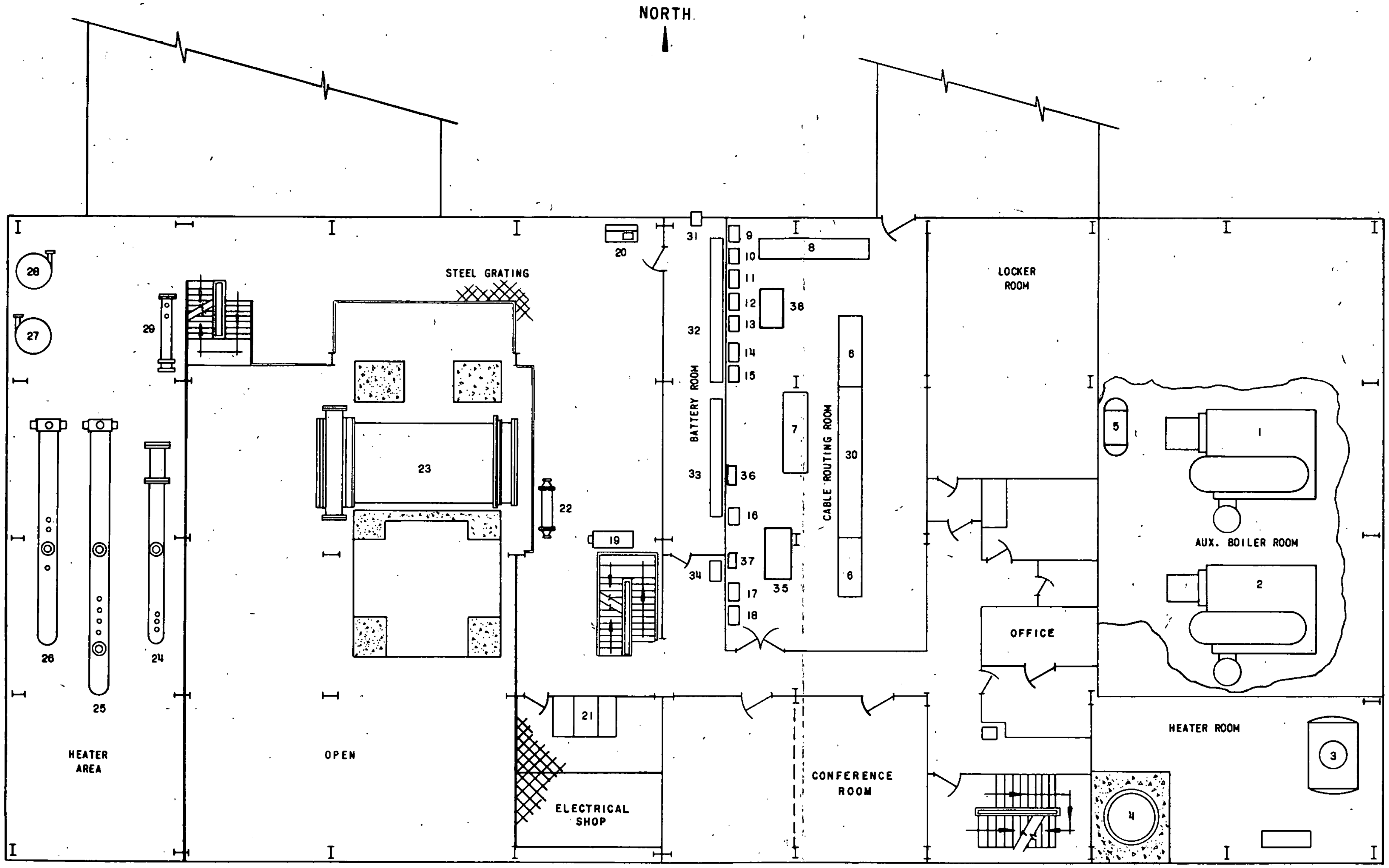
Fig. 3. Arrangement of EBR-II Main Outdoor Substation



LEGEND

1. TREAT FEEDER
2. TRANSFORMER NO. 5 (13.8 KV-0.48 KV)
3. TRANSFORMER NO. 3 (13.8 KV-2.4 KV)
4. POTENTIAL TRANSFORMERS
5. INCOMING LINE NO. 1
6. POTENTIAL TRANSFORMERS
7. GENERATOR
8. POTENTIAL TRANSFORMERS
9. BUS TIE
10. INCOMING LINE NO. 2
11. POTENTIAL TRANSFORMERS
12. TRANSFORMER NO. 4 (13.8 KV-2.4 KV)
13. TRANSFORMER NO. 6 (13.8 KV-0.48 KV)
14. SPARE
15. CONDENSATE TANK
16. FEEDWATER HEATER NO.2
17. TURBINE GAUGE PANEL
18. TURBINE GENERATOR (20 MW)
19. HYDROGEN CONTROL CABINET
20. TYPEWRITER TABLES
21. CONSOLE
22. DATA LOGGER
23. MONITORING SECTION
24. AUXILIARY SECTION
25. SECONDARY SECTION
26. PRIMARY SECTION
27. NUCLEAR SECTION
28. GRAPHIC SECTION
29. STEAM SECTION
30. UTILITIES SECTION
31. 480-VOLT FEEDER SECTION E1
32. 2400-VOLT SECTION E2
33. INCOMING LINE SECTION E3
34. GENERATOR INDICATING SECTION E4
35. 13.8-KV FEEDER SECTION E5
36. SYNCHRONIZING SECTION E6
37. 13.8-KV FEEDER SECTION E7
38. 13.8-KV BREAKER TEST PANEL
39. CRANE FEEDER DISCONNECT SWITCH
40. HEAT. AND VENT. CONTROL PANEL
41. HEAT. AND VENT. CONTROL PANEL (OFFICE AREA)

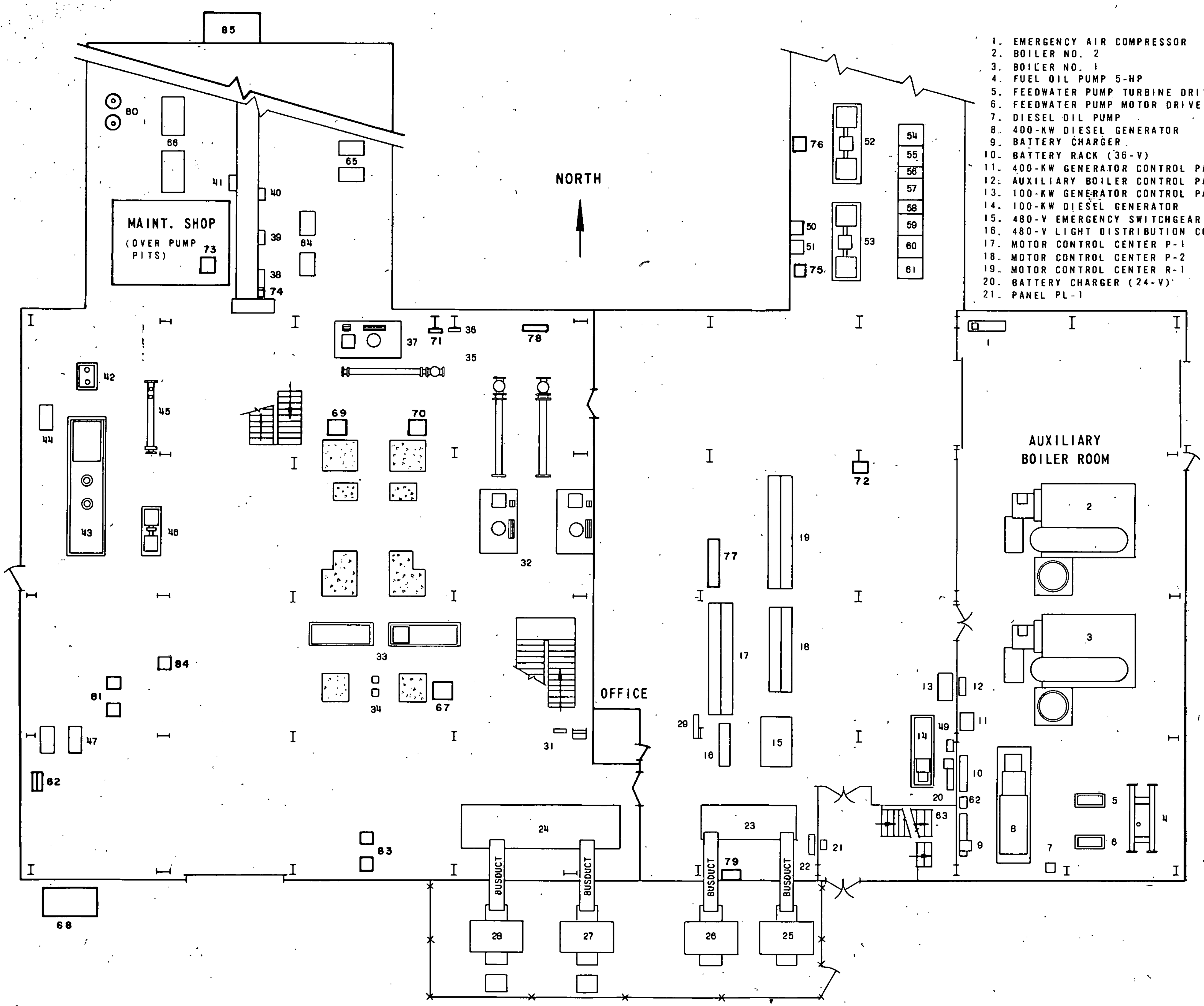
Fig. 4. Arrangement of Equipment on Operating Floor of Power Plant



LEGEND

1. BOILER NO. 2
2. BOILER NO. 1
3. FEEDWATER HEATER
4. AUXILIARY CONDENSATE STORAGE TANK
5. HOTWATER HEATER
6. NUCLEAR RELAY RACK
7. PROCESS SHUTDOWN RELAY RACK
8. CONTINUOUS POWER SUPPLY UNIT
9. 10-KVA TRANSFORMER
10. SAFETY SWITCH
11. CONTINUOUS POWER PANEL 2A
12. CONTINUOUS POWER PANEL 2B
13. 120V A-C DISTRIBUTION PANEL
14. CONTINUOUS POWER PANEL 1A
15. CONTINUOUS POWER PANEL 1B
16. 125V D-C DISTRIBUTION PANEL
17. DISTRIBUTION PANEL PC-1A
18. DISTRIBUTION PANEL PC-1B
19. REFRIGERATION COMPRESSER
20. REFRIGERATION COMPRESSER UNIT
21. GENERATOR FIELD CUBICLE
22. AIR EJECTOR
23. CONDENSER
24. HEATER NO. 1
25. HEATER NO. 3
26. HEATER NO. 4
27. LOW PRESSURE FLASH TANK
28. HIGH PRESSURE FLASH TANK
29. BLOWDOWN COOLER
30. CONTROL ROD RELAY CUBICLES
31. EXHAUST FAN
32. 240-V BATTERY (120 CELL)
33. 125-V BATTERY (60 CELL)
34. RECTIFIER BATTER CHARGER
35. ANALOG COMPUTER
36. DP DT 125-V D-C TRANSFER SWITCH
37. DISCONNECT SWITCH FOR 125-V BATTERY
38. CARD PUNCH

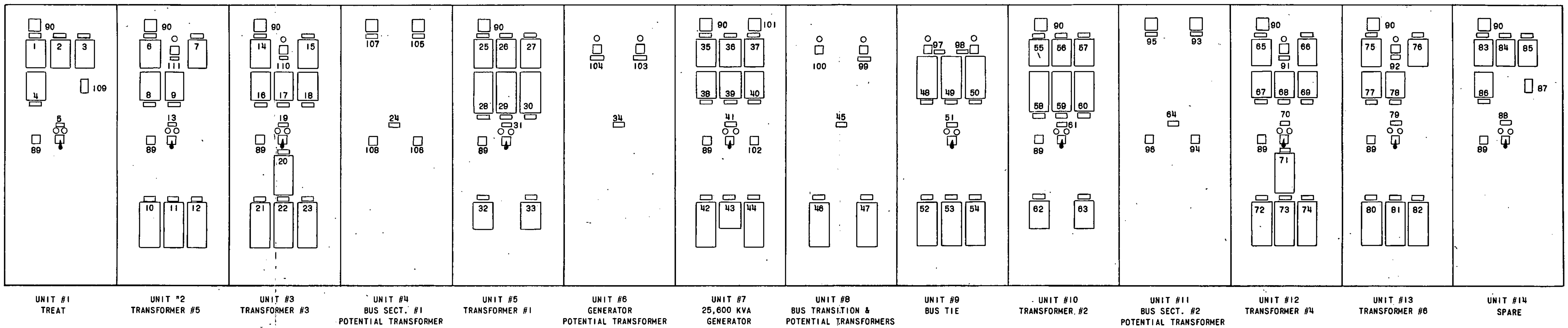
Fig. 5. Arrangement of Equipment on Mezzanine Floor of Power Plant



LEGEND

1. EMERGENCY AIR COMPRESSOR
2. BOILER NO. 2
3. BOILER NO. 1
4. FUEL OIL PUMP 5-HP
5. FEEDWATER PUMP TURBINE DRIVE
6. FEEDWATER PUMP MOTOR DRIVE
7. DIESEL OIL PUMP
8. 400-KW DIESEL GENERATOR
9. BATTERY CHARGER
10. BATTERY RACK (36-V)
11. 400-KW GENERATOR CONTROL PANEL
12. AUXILIARY BOILER CONTROL PANEL
13. 100-KW GENERATOR CONTROL PANEL
14. 100-KW DIESEL GENERATOR
15. 480-V EMERGENCY SWITCHGEAR E-1
16. 480-V LIGHT DISTRIBUTION CENTER E-2
17. MOTOR CONTROL CENTER P-1
18. MOTOR CONTROL CENTER P-2
19. MOTOR CONTROL CENTER R-1
20. BATTERY CHARGER (24-V)
21. PANEL PL-1
22. PANEL PLD-1
23. 480-V SWITCHGEAR
24. 2400-V SWITCHGEAR
25. 2000-KVA TRANSFORMER NO. 5
26. 2000-KVA TRANSFORMER NO. 6
27. 2500-KVA TRANSFORMER NO. 3
28. 2500-KVA TRANSFORMER NO. 4
29. 2400-V BREAKER TEST CABINET
30. PANEL PE-1
31. AUTO TRANSFER AC/DC SWITCH
32. INSTRUMENT AIR COMPRESSORS
33. CONDENSATE PUMPS
34. HYDROGEN SEAL OIL PUMPS
35. AFTER COOLERS
36. PANEL PL-2
37. PLANT AIR COMPRESSOR
38. CONDENSER PUMP CONTROL PANEL
39. PLANT SERVICE COOLING WATER PUMP PANEL NO. 2
40. REACTOR PLANT AUXILIARY COOLING WATER PUMP PANEL NO. 3
41. CONDENSER CIRCULATING WATER PUMP NO. 4 CONTROL PANEL NO. 1
42. TURBINE DRIVEN FEEDWATER PUMP
43. FEEDWATER PUMP
44. BOILER FEED CONTROL PANEL
45. BLOWDOWN AFTER COOLER
46. STARTUP FEEDWATER PUMP
47. MAKE-UP WATER PUMPS
48. WATER TREATMENT CONTROL PANEL
49. ENGINE-MATIC CONTROL PANEL
50. BREAKER (PRIMARY Na PUMP NO. 2 GENERATOR)
51. BREAKER (PRIMARY Na PUMP NO. 1 GENERATOR)
52. MOTOR GENERATOR SET (PRIMARY Na PUMP NO. 2)
53. MOTOR GENERATOR SET (PRIMARY Na PUMP NO. 1)
54. BLANK (CABLE ROUTING)
55. AUXILIARY AND SPACE COOLING PANEL
56. THIMBLE COOLING PANEL
57. SHIELD COOLING PANEL
58. AUXILIARY PRIMARY PUMP PANEL
59. PRIMARY PUMP NO. 2 PANEL
60. DYNAMATIC CONTROL PANEL
61. PRIMARY PUMP NO. 1 PANEL
62. BATTERY CHARGER (36-V)
63. BATTERY RACK (24-V)
64. PLANT SERVICE COOLING PUMPS
65. REACTOR PLANT COOLING WATER PUMPS
66. CONDENSER CIRCULATING WATER PUMPS
67. CHLORIDE ANALYZER
68. ACID STORAGE TANK
69. OIL TRANSFER PUMP
70. OIL FILTER PUMP
71. PANEL PL-2A
72. 3PDT SWITCH FOR EMERGENCY POWER TO PANEL R3A
73. WATER TEST LOOP PUMP
74. SUBASSEMBLY DRYER
75. CLUTCH COOLING WATER SUMP PUMP NO. 1
76. CLUTCH COOLING WATER SUMP PUMP NO. 2
77. MOTOR CONTROL CENTER R-2
78. PANEL PLD-2
79. AOT PANEL
80. SUMP PUMPS
81. CHEMICAL INJECTION PUMPS - CIRC. WATER SYSTEM
82. DISCONNECT SWITCH AND TRANSFORMER FOR ACID STORAGE TANK HEATERS
83. CHEMICAL INJECTION PUMPS - FEEDWATER SYSTEM
84. pH ANALYZER - CIRCULATING WATER SYSTEM
85. H_2 AND CO_2 MANIFOLD HOUSE

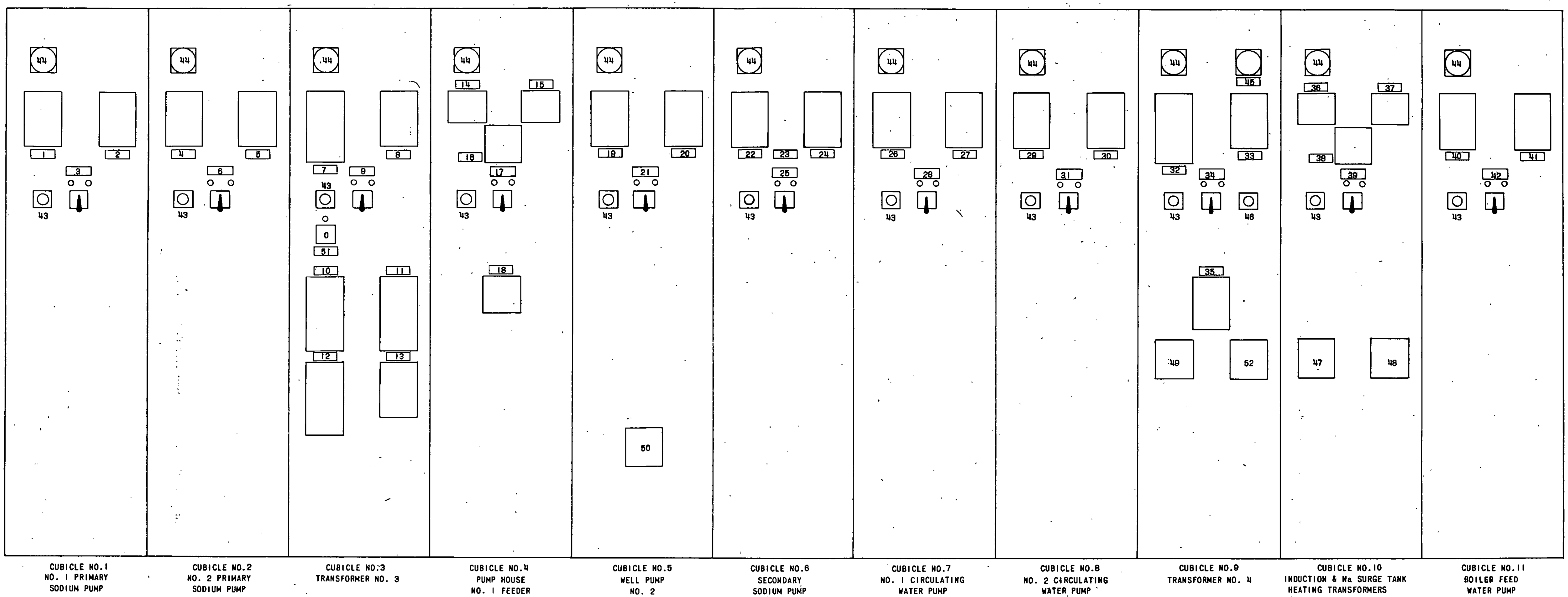
Fig. 6. Arrangement of Equipment on First Floor of Power Plant



1 OVERCURRENT PHASE A
2 OVERCURRENT PHASE B
3 OVERCURRENT PHASE C
4 GROUND OVERCURRENT
5 TREAT FEEDER (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
6 OVERCURRENT PHASE A
7 OVERCURRENT PHASE B
8 GROUND OVERCURRENT
9 OVERCURRENT PHASE C
10 TRANSFORMER DIFF. PHASE A
11 TRANSFORMER DIFF. PHASE B
12 TRANSFORMER DIFF. PHASE C
13 480 VOLT TRANSFORMER NO. 5 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
14 OVERCURRENT PHASE A
15 OVERCURRENT PHASE B
16 GROUND OVERCURRENT
17 OVERCURRENT PHASE C
18 NEUTRAL GROUND OVERCURRENT
19 2400 VOLT TRANSFORMER NO.3 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
20 DIRECTIONAL GROUND OVERCURRENT
21 TRANSFORMER DIFF. PHASE A
22 TRANSFORMER DIFF. PHASE B
23 TRANSFORMER DIFF. PHASE C
24 POTENTIAL TRANSFORMERS (BUS SECTION NO.1 & INCOMING LINE NO.1)
25 OVERCURRENT PHASE A
26 OVERCURRENT PHASE B
27 OVERCURRENT PHASE C
28 DIRECTIONAL OVERCURRENT PHASE A
29 DIRECTIONAL OVERCURRENT PHASE B
30 DIRECTIONAL OVERCURRENT PHASE C
31 INCOMING LINE NO.1 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
32 GROUND OVERCURRENT
33 D.C. UNDERVOLTAGE
34 POTENTIAL TRANSFORMERS(GENERATOR)
35 OVERCURRENT PHASE A
36 OVERCURRENT PHASE B
37 OVERCURRENT PHASE C
38 GENERATOR DIFF. PHASE A
39 GENERATOR DIFF. PHASE B
40 GENERATOR DIFF. PHASE C
41 GENERATOR (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
42 REVERSE POWER
43 GROUND OVERCURRENT
44 UNDER FREQ.- GENERATOR
45 BUS TRANSITION & P.T'S. (TOTALIZING METERS AND DIR. RELAYS P.T'S.)
46 UNDER FREQ. TREAT (NOT CONNECTED)
47 UNDER FREQ. INCOMING LINES 1 & 2
48 BUS DIFF. BUS NO.1 PHASE A
49 BUS DIFF. BUS NO.1 PHASE B
50 BUS DIFF. BUS NO.1 PHASE C
51 BUS TIE (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
52 BUS DIFF. BUS NO.2 PHASE A
53 BUS DIFF. BUS NO.2 PHASE B
54 BUS DIFF. BUS NO.2 PHASE C
55 OVERCURRENT PHASE A
56 OVERCURRENT PHASE B
57 OVERCURRENT PHASE C
58 DIRECTIONAL OVERCURRENT PHASE A
59 DIRECTIONAL OVERCURRENT PHASE B
60 DIRECTIONAL OVERCURRENT PHASE C
61 INCOMING LINE NO.2 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
62 GROUND OVERCURRENT
63 D.C. UNDERVOLTAGE
64 POTENTIAL TRANSFORMERS (BUS SECTION NO.2 & INCOMING LINE NO.2)
65 OVERCURRENT PHASE A
66 OVERCURRENT PHASE B
67 GROUND OVERCURRENT
68 OVERCURRENT PHASE C
69 NEUTRAL GROUND OVERCURRENT
70 2400 VOLT TRANSFORMER NO.4 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
71 DIRECTIONAL GROUND OVERCURRENT
72 TRANSFORMER DIFF. PHASE A
73 TRANSFORMER DIFF. PHASE B
74 TRANSFORMER DIFF. PHASE C
75 OVERCURRENT PHASE A
76 OVERCURRENT PHASE B
77 GROUND OVERCURRENT
78 OVERCURRENT PHASE C
79 480 VOLT TRANSFORMER NO.6 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
80 TRANSFORMER DIFF. PHASE A
81 TRANSFORMER DIFF. PHASE B
82 TRANSFORMER DIFF. PHASE C
83 OVERCURRENT PHASE A
84 OVERCURRENT PHASE B
85 OVERCURRENT PHASE C
86 GROUND OVERCURRENT
87 (AUTOMATIC RECLOSING RELAY)
88 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
89 (AMMETER SWITCH)
90 (AMMETER)
91 TRANSFORMER NO.4 DIFF. LOCKOUT (WITH WHITE INDICATING LAMP)
92 TRANSFORMER NO.6 DIFF. LOCKOUT (WITH WHITE INDICATING LAMP)
93 13.8 KV INCOMING LINE NO.2 VOLTS
94 (VOLTMETER SWITCH - 13.8 KV INCOMING LINE NO.2)
95 BUS NO.2 VOLTS
96 (VOLTMETER SWITCH - BUS NO.2)
97 13.8 KV BUS NO.1 DIFF. LOCKOUT (WITH WHITE INDICATING LAMP)
98 13.8 KV BUS NO.2 DIFF. LOCKOUT (WITH WHITE INDICATING LAMP)
99 INC. LINES 1 & 2 UNDER FREQ. LOCKOUT (WITH WHITE INDICATING LAMP)
100 (SPARE LOCKOUT RELAY - WITH WHITE INDICATING LAMP)
101 (VOLTMETER)
102 (VOLTMETER SWITCH)
103 GENERATOR LOCKOUT (WITH WHITE INDICATING LAMP)
104 GENERATOR DIFF. LOCKOUT (WITH WHITE INDICATING LAMP)
105 13.8 KV INCOMING LINE NO.1 VOLTS
106 (VOLTMETER SWITCH - 13.8 KV INCOMING LINE NO.1)
107 BUS NO.1 VOLTS
108 (VOLTMETER SWITCH - BUS NO.1)
109 (AUTOMATIC RECLOSING RELAY)
110 TRANSFORMER NO.3 DIFF. LOCKOUT (WITH WHITE INDICATING LAMP)
111 TRANSFORMER NO.5 DIFF. LOCKOUT (WITH WHITE INDICATING LAMP)

NOTE: DESCRIPTION IN PARENTHESIS ( ), DOES NOT APPEAR ON NAMEPLATES

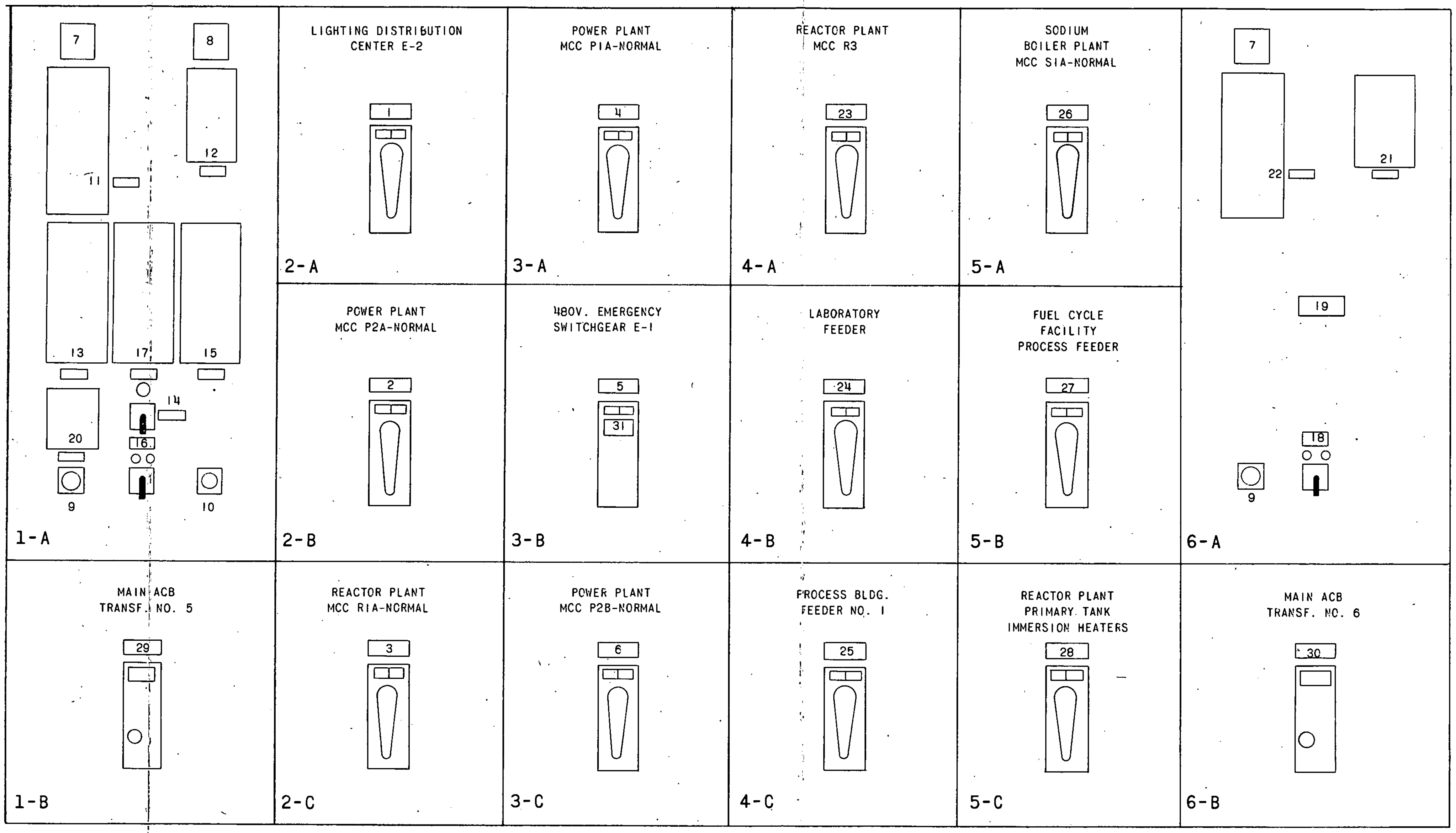
Fig. 7. Front Panel Arrangement of 13.8-kV Switchgear



1 OVERCURRENT PHASE A
2 OVERCURRENT PHASE C
3 PRIMARY Na PUMP NO.1 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
4 OVERCURRENT PHASE A
5 OVERCURRENT PHASE C
6 PRIMARY Na PUMP NO.2 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
7 REVERSE POWER
8 TIME DELAY TRIP D.C.
9 INCOMING FEEDER NO.1 - 2400V 3 PH. 60 CYC. (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
10 DIR. OVERCURRENT PHASE A
11 DIR. OVERCURRENT PHASE B
12 DIR. OVERCURRENT PHASE C
13 DIRECTIONAL OVERRIDE
14 OVERCURRENT PHASE A
15 OVERCURRENT PHASE B
16 OVERCURRENT PHASE C
17 PUMP HOUSE NO.1 FEEDER (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
18 GROUND PROTECTIVE RELAY
19 OVERCURRENT PHASE A
20 OVERCURRENT PHASE C
21 PUMP HOUSE NO.2 FEEDER (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
22 OVERCURRENT PHASE A
23 2400 VOLT SWITCHGEAR
24 OVERCURRENT PHASE C
25 SECONDARY Na PUMP (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
26 OVERCURRENT PHASE A
27 OVERCURRENT PHASE C
28 CIRCULATING WATER PUMP NO.1 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
29 OVERCURRENT PHASE A
30 OVERCURRENT PHASE C
31 CIRCULATING WATER PUMP NO.2 (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
32 REVERSE POWER
33 TIME DELAY TRIP D.C.
34 INCOMING FEEDER NO.2 - 2400V. 3 PH. 60 CYC. (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
35 D.C.UNDERVOLTAGE (NOT USED)
36 OVERCURRENT PHASE A
37 OVERCURRENT PHASE B
38 OVERCURRENT PHASE C
39 INDUCTION & Na SURGE TANK HEATING TRANSFORMERS (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
40 OVERCURRENT PHASE A
41 OVERCURRENT PHASE C
42 BOILER FEEDWATER PUMP (PERMISSIVE SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
43 (AMMETER SWITCH)
44 (AMMETER)
45 BUS VOLTS (VOLTMETER)
46 (VOLTMETER SWITCH)
47 (SODIUM BOILER PLANT FIRE PROTECTION AUXILIARY RELAY - RESET PUSHBUTTON INSIDE OF CUBICLE)
48 (SODIUM BOILER PLANT EMERGENCY AUXILIARY RELAY - RESET PUSHBUTTON INSIDE OF CUBICLE)
49 (AUXILIARY RELAY - NOT CONNECTED)
50 (AUTO.-MAN. SELECTOR AUXILIARY RELAY)
51 DIR. OVERCURRENT LOCKOUT (WITH WHITE INDICATING LIGHT)
52 (BUS UNDERVOLTAGE AUXILIARY RELAY)
53 (BUS UNDERVOLTAGE RELAYS - INSIDE CUBICLE 9)

NOTE: DESCRIPTION IN PARENTHESIS ( ), DOES NOT APPEAR ON NAMEPLATES

Fig. 8. Front Panel Arrangement of 2400-V Switchgear



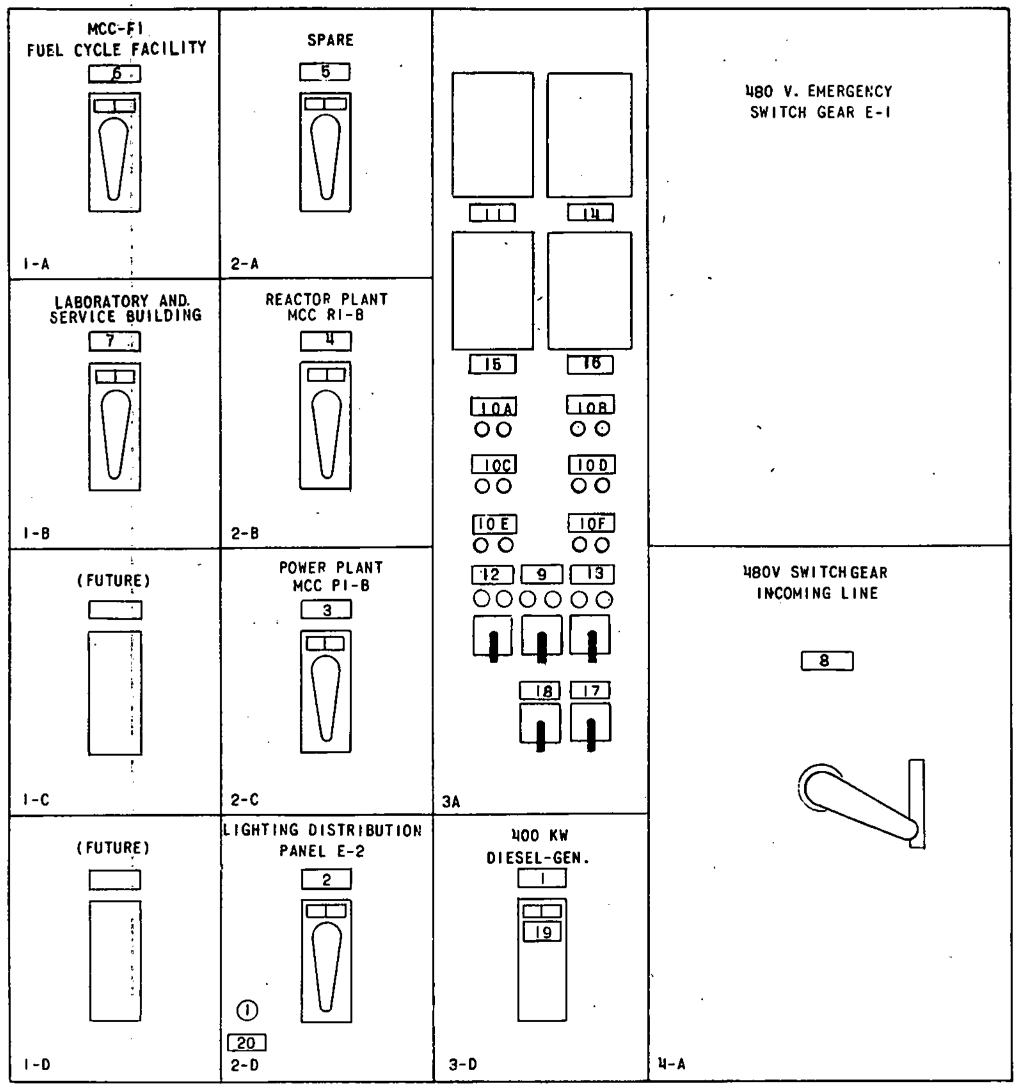
1 LIGHTING DISTRIBUTION CENTER E-2 (AIR CIRCUIT BKR.2-A - ELECT. OP.)
2 POWER PLANT MCC P2A-NORMAL (AIR CIRCUIT BKR. 2-B - ELECT. OP.)
3 REACTOR PLANT MCC R1A-NORMAL (AIR CIRCUIT BKR. 2-C - ELECT. OP.)
4 POWER PLANT MCC P1A-NORMAL (AIR CIRCUIT BKR. 3-A - ELECT. OP.)
5 480V. EMERGENCY SWITCHGEAR E-1 (AIR CIRCUIT BKR. 3-B - ELECT. OP.)
6 POWER PLANT MCC P2B-NORMAL (AIR CIRCUIT BKR. 3-C - ELECT. OP.)
7 (AMMETER)
8 (VOLTMETER-BUS)
9 (AMMETER SWITCH)
10 (VOLTMETER SWITCH - BUS)
11 REVERSE POWER (TRANSF. NO. 5)

NOTE: DESCRIPTION IN PARENTHESIS ( ) NOT ON NAMEPLATES

12 TIME DELAY TRIP D.C. (TRANSF. NO. 5 480V BKR.)
13 DIRECTIONAL OVERCURRENT PHASE A
14 DIR. OVERCURRENT LOCKOUT (WITH WHITE INDICATING LAMP)
15 DIRECTIONAL OVERCURRENT PHASE C
16 PERMISSIVE CONTROL MAIN ACB (SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS - TRANSF. NO. 5 480V BKR.)
17 DIRECTIONAL OVERCURRENT PHASE B
18 PERMISSIVE CONTROL MAIN ACB (SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS - TRANSF. NO. 6 480V BKR.)
19 480V (NORMAL) MAIN SWITCHGEAR
20 DIRECTIONAL OVERRIDE (INCOMING LINES)

21 TIME DELAY TRIP D.C. (TRANSF. NO. 6 480V BKR.)
22 REVERSE POWER (TRANSF. NO. 6)
23 REACTOR PLANT MCC R3 (AIR CIRCUIT BKR. 4-A - ELECT. OP.)
24 LABORATORY FEEDER (AIR CIRCUIT BKR. 4-B - ELECT. OP.)
25 PROCESS BLDG. FEEDER NO. 1 (AIR CIRCUIT BKR. 4-C - ELECT. OP.)
26 SODIUM BOILER PLANT MCC S1A-NORMAL (AIR CIRCUIT BKR. 5-A - ELECT. OP.)
27 FUEL CYCLE FACILITY PROCESS FEEDER (AIR CIRCUIT BKR. 5-B - ELECT. OP.)
28 REACTOR PLANT PRIMARY TANK IMMERSION HEATERS (AIR CIRCUIT BKR. 5-C - ELECT. OP.)
29 MAIN ACB - TRANSF. NO. 5 (AIR CIRCUIT BKR. 1-B - ELECT. OP.)
30 MAIN ACB - TRANSF. NO. 6 (AIR CIRCUIT BKR. 6-B - ELECT. OP.)
31 THIS BREAKER TO BE OPERATED IN CONTROL ROOM ONLY

Fig. 9. Front Panel Arrangement of 480-V Main Switchgear



1 400 KW DIESEL GENERATOR (AIR CIRCUIT BKR. 3-D - ELECT. OP.)
2 LIGHTING DISTRIBUTION PANEL E-2 (AIR CIRCUIT BKR. 2-D - MAN. OP.)
3 POWER PLANT MCC PI-B (AIR CIRCUIT BKR. 2-C - MAN. OP.)
4 REACTOR PLANT MCC RI-B (AIR CIRCUIT BKR. 2-B - MAN. OP.)
5 SPARE (AIR CIRCUIT BKR. 2-A MAN. OP.)
6 MCC-FI FUEL CYCLE FACILITY (AIR CIRCUIT BKR. 1-A - MAN. OP.)
7 LABORATORY AND SERVICE BUILDING (AIR CIRCUIT BKR. 1-B - MAN. OP.)
8 480V SWITCHGEAR INCOMING LINE (DISCONNECT SWITCH)
9 PERMISSIVE CONTROL GENERATOR ACB (SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
10 (BKR. POSITION INDICATING LAMPS - RED & GREEN)
 A - (BLANK - FUTURE BKR. 1-C)
 B - (BLANK - FUTURE BKR. 1-D)
 C - MCC-FI FUEL CYCLE FACILITY (BKR. 1-A)
 D - MCC RI-B (BKR. 2B)
 E - LABORATORY AND SERVICE BUILDING (BKR. 1-B)
 F - MCC PI-B (BKR. 2-C)
11 GENERATOR OVERVOLTAGE
12 AUTOMATIC TRIP SPARE (BKR. 2-A AUTO. TRIP SELECTOR SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
13 AUTOMATIC TRIP LIGHTING DIST. CENTER E-2 (BKR. 2-A AUTO. TRIP SELECTOR SWITCH WITH RED & GREEN BKR. POSITION INDICATING LAMPS)
14 GENERATOR OVERCURRENT PHASE A
15 GENERATOR OVERCURRENT PHASE B
16 GENERATOR OVERCURRENT PHASE C
17 LOAD REJECTION RELAY
18 OVERCURRENT LOCKOUT RELAY (400 KW GENERATOR)
19 THIS BREAKER TO BE OPERATED IN CONTROL ROOM ONLY
20 KEY INTERLOCK WITH BKR 2B IN 480V MAIN SWGR.

NOTE: DESCRIPTION IN PARENTHESIS ( ) NOT ON NAMEPLATES.

Fig. 10. Front Panel Arrangement of 480-V Emergency Switchgear

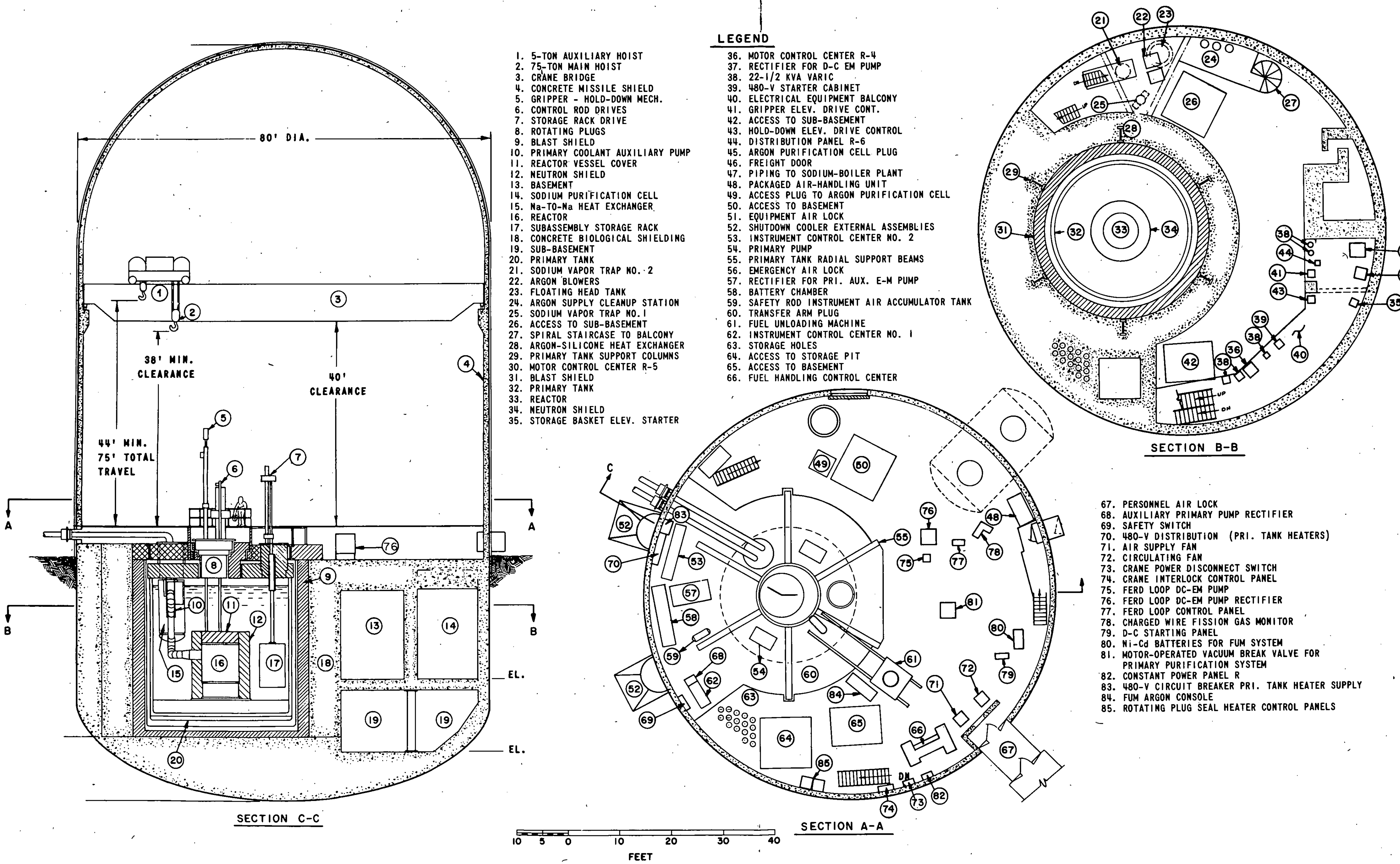
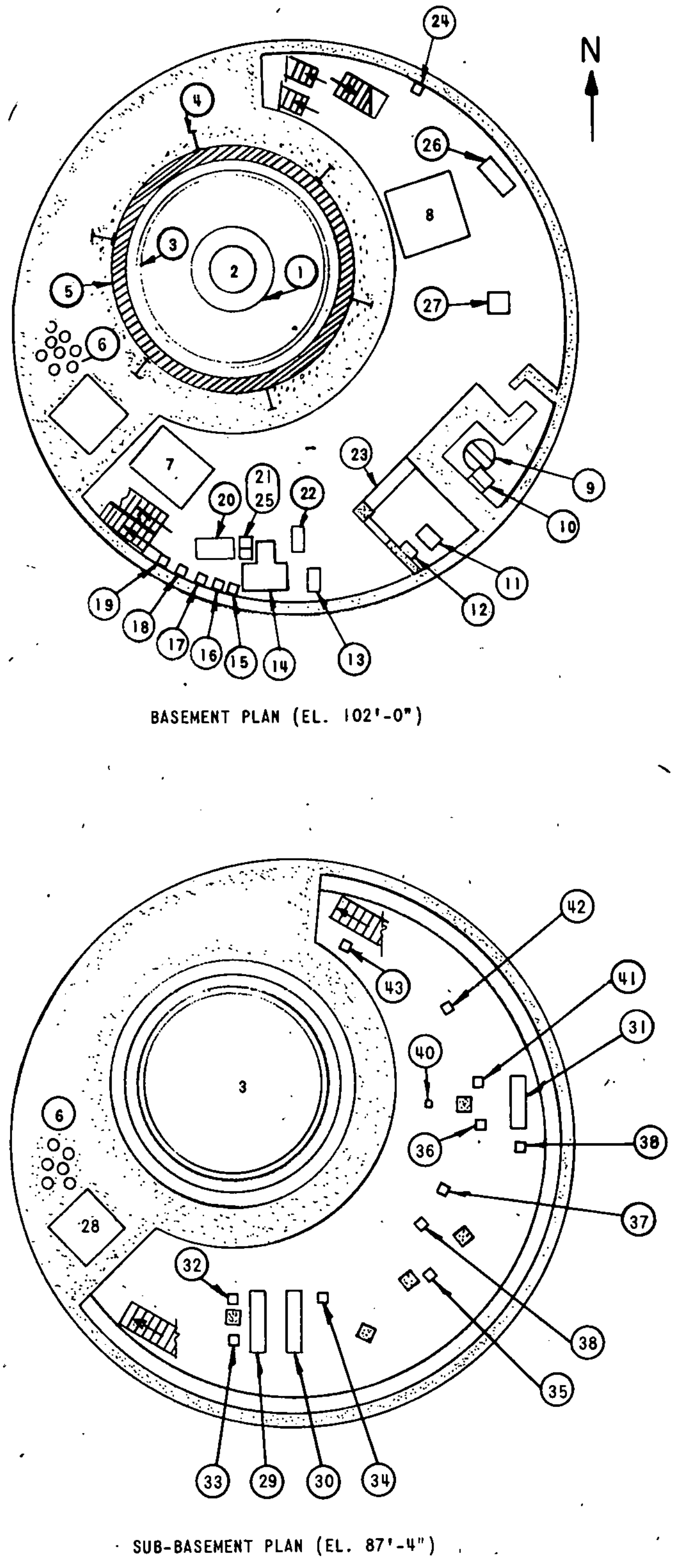


Fig. 11. Arrangement of Equipment on Operating Floor and Balcony of Reactor Plant



LEGEND

1. RADIAL NEUTRON SHIELD
2. REACTOR VESSEL GRID AND CONTENTS
3. PRIMARY TANK
4. PRIMARY TANK SUPPORT COLUMNS
5. BLAST SHIELD
6. STORAGE HOLES
7. ACCESS TO SUB-BASEMENT
8. ACCESS TO SUB-BASEMENT
9. SODIUM COLD TRAP ASSEMBLY
10. D-C ELECTROMAGNETIC PUMP
11. NaK SILICONE HEAT EXCHANGER
12. NaK A-C ELECTROMAGNETIC PUMP
13. MOTOR CONTROL CENTER R-7
14. AIR COOLING UNIT
15. 30 KVA - 480-120-V 3 ϕ 60 ~ TRANSFORMER
16. 10 KVA - 480-120/290-V 1 ϕ 60 ~ EMERGENCY LIGHTING TRANSF.
17. EMERGENCY LIGHTING PANEL RE-1
18. LIGHTING PANEL RL-1
19. EMERGENCY LIGHTING PANEL RE-2
20. MOTOR CONTROL CENTER R-3
21. 480-V EMERGENCY POWER DISTRIBUTION PANEL RE-3
22. FUEL HANDLING SYSTEM DIGITAL CONTROL CABINET
23. INSTRUMENT CENTER NO. 3
24. LIGHTING PANEL RL-2
25. MOTOR CONTROL CENTER R-3
26. INSTRUMENT AIR COMPRESSOR
27. SUBASSEMBLY DISTILLATION APPARATUS
28. STORAGE PIT
29. AEC FILTER UNIT NO. 2
30. AEC FILTER UNIT NO. 1
31. AEC FILTER UNIT NO. 3
32. SHIELD COOLING EXHAUST FAN NO. 2
33. COMPRESSOR NO. 2
34. SHIELD COOLING EXHAUST FAN NO. 1
35. SHIELD COOLING COMPRESSOR NO. 3
36. SHIELD COOLING SUPPLY FAN NO. 2
37. SHIELD COOLING SUPPLY FAN NO. 1
38. COMPRESSOR NO. 1
39. EXHAUST TURBO COMPRESSOR NO. 2
40. CONTROL PANEL
41. EXHAUST TURBO COMPRESSOR NO. 1
42. ARGON COMPRESSOR
43. AIR COOLING UNIT

Fig. 12. Arrangement of Equipment in Basement and Subbasement of Reactor Plant

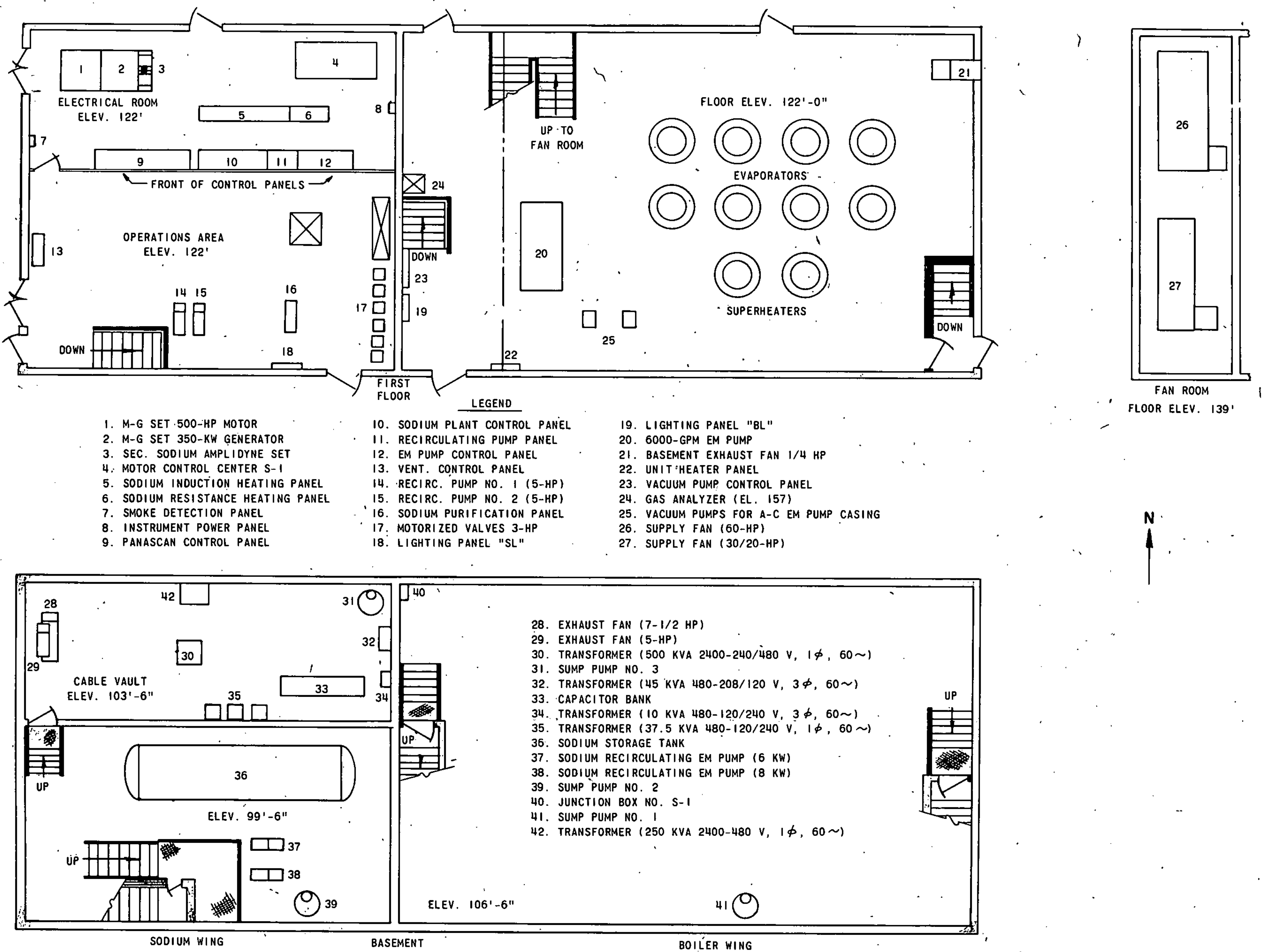


Fig. 13. Arrangement of Equipment in Sodium-Boiler Plant

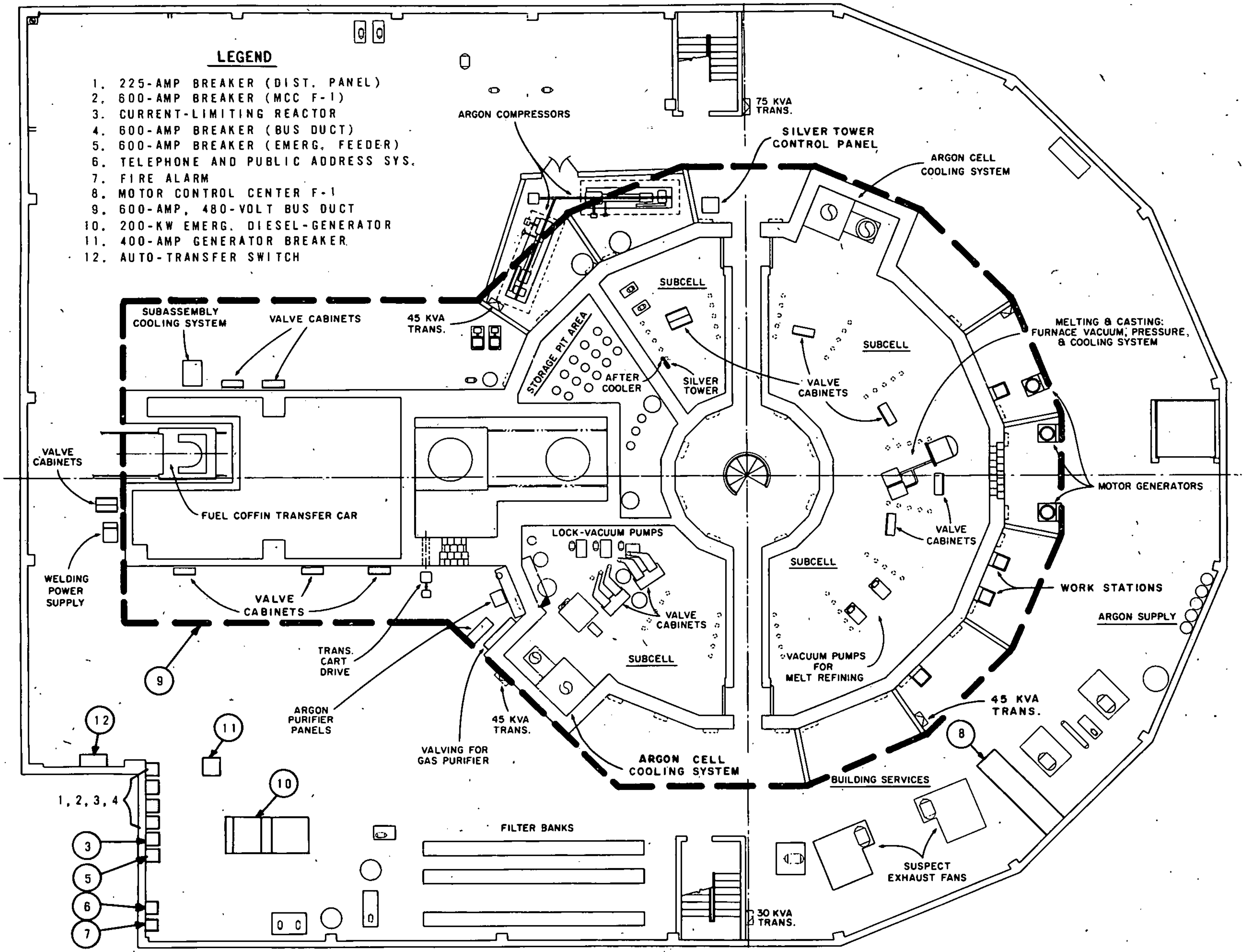


Fig. 14. Arrangement of Equipment in Basement of Fuel Cycle Facility

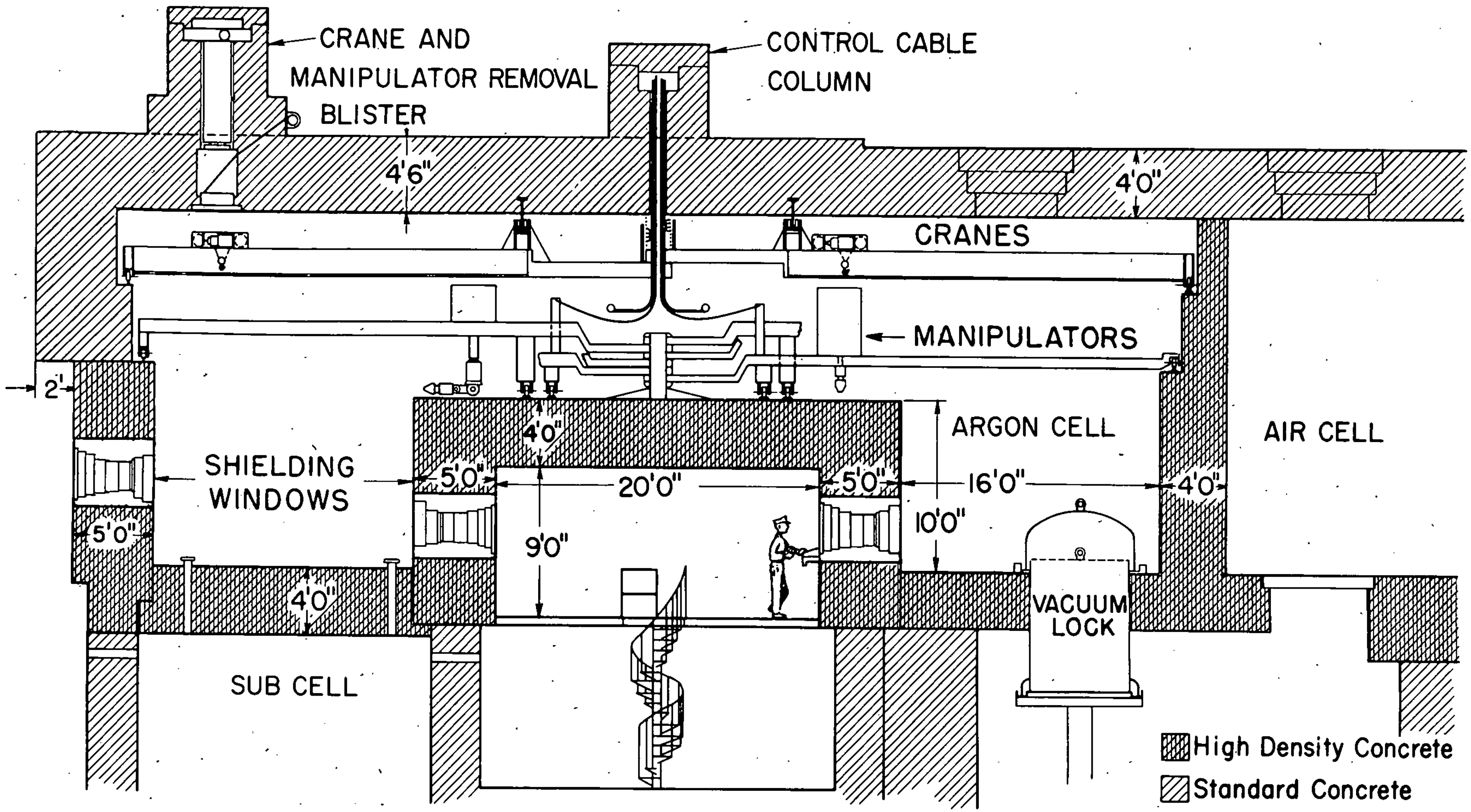
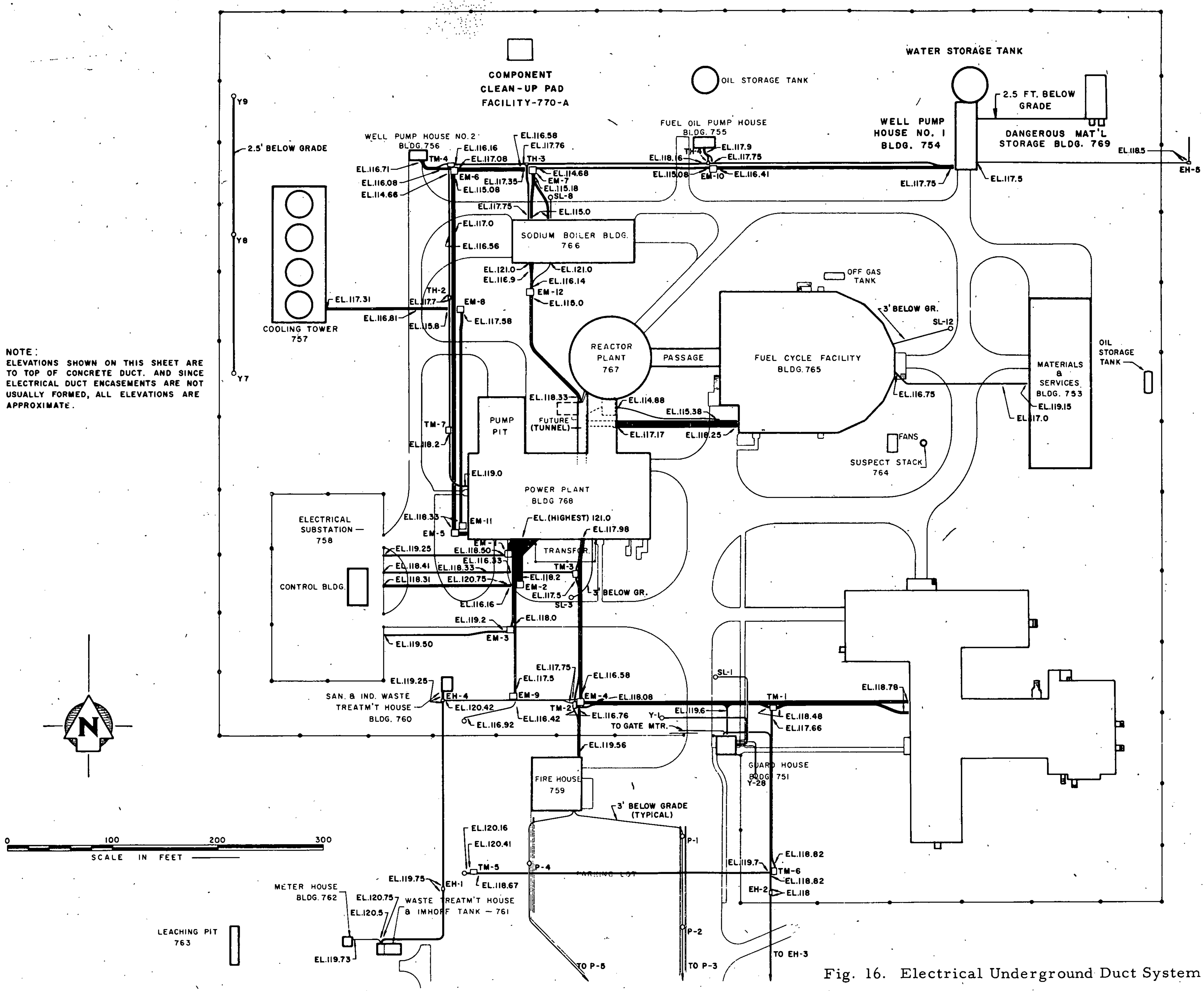


Fig. 15. Sectional Elevation of Argon Cell in Fuel Cycle Facility



NOTE: ELEVATIONS SHOWN ON THIS SHEET ARE TO TOP OF CONCRETE DUCT. AND SINCE ELECTRICAL DUCT ENCASEMENTS ARE NOT USUALLY FORMED, ALL ELEVATIONS ARE APPROXIMATE.

Fig. 16. Electrical Underground Duct System

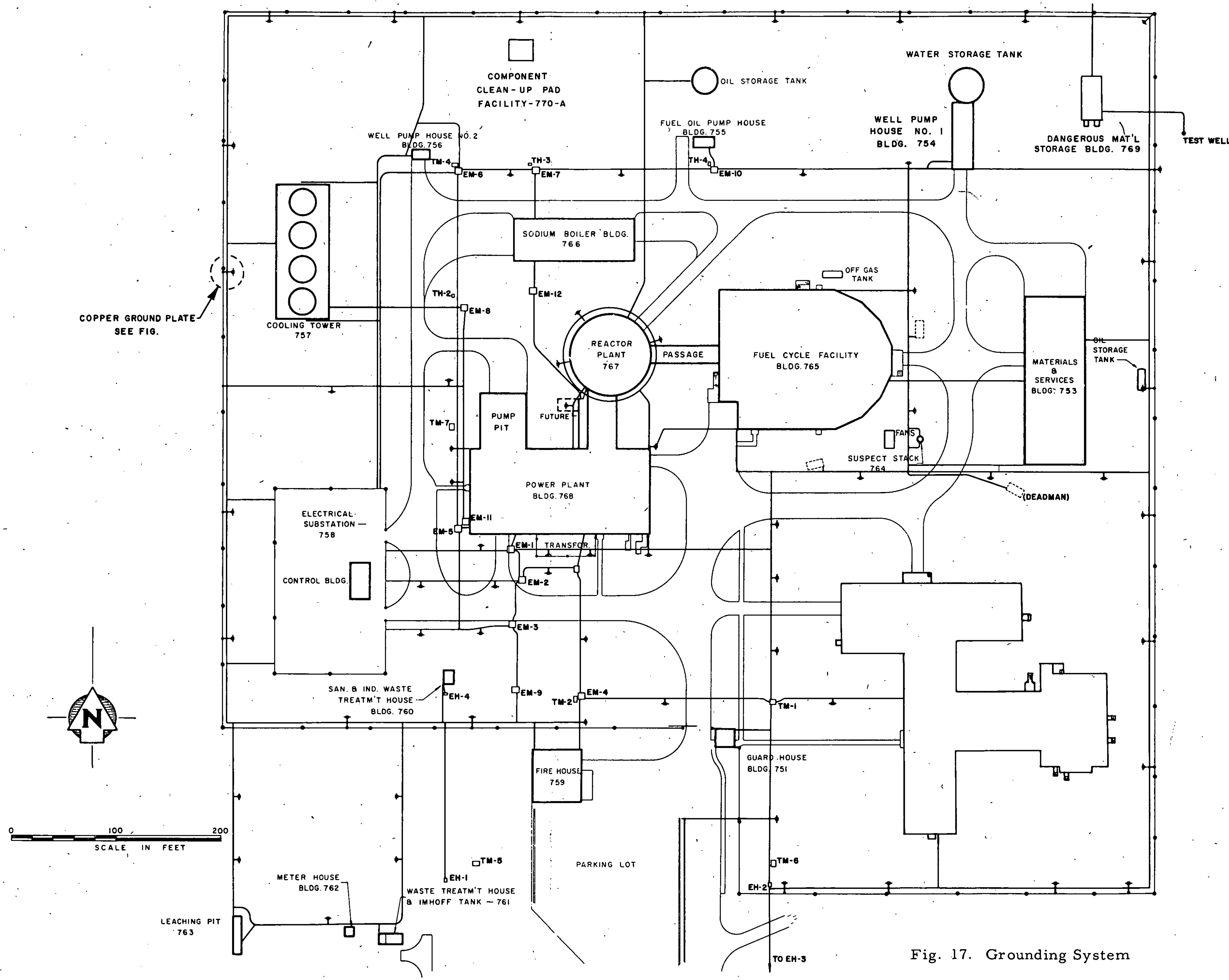


Fig. 17. Grounding System

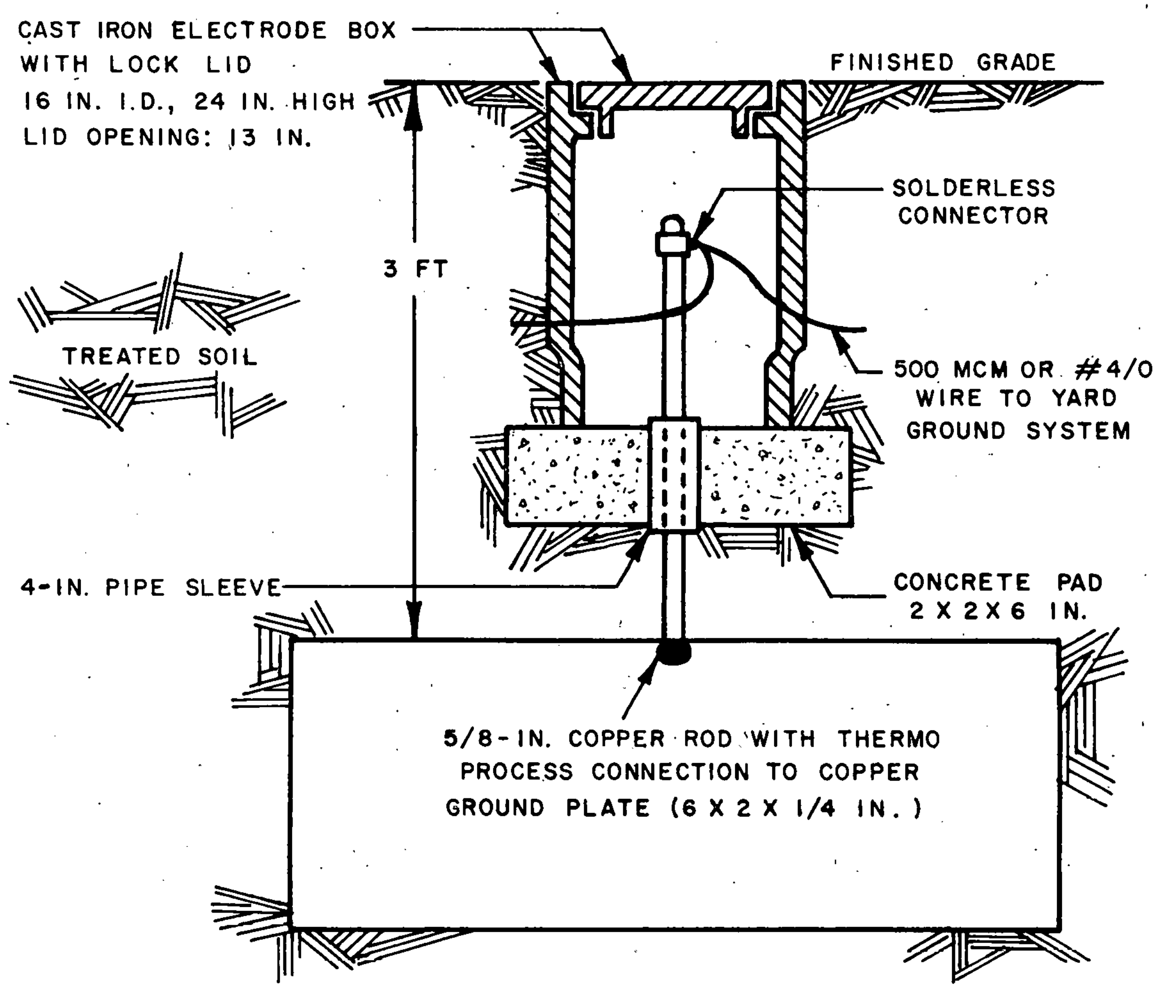


Fig. 18. Typical Test Well and Grounding Plate

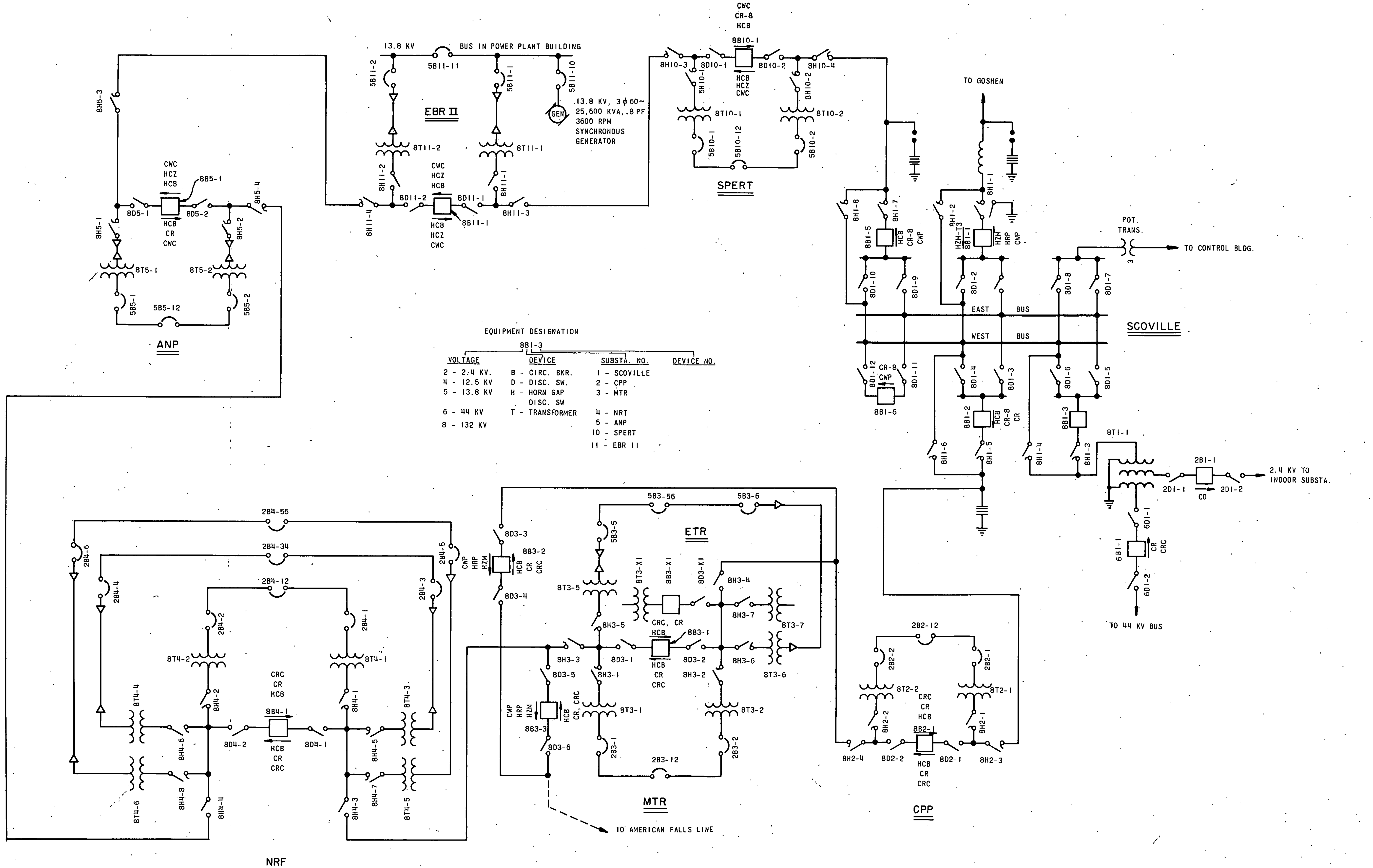


Fig. 19. Simplified Single Line Diagram of NRTS 138-kV Electric Power System

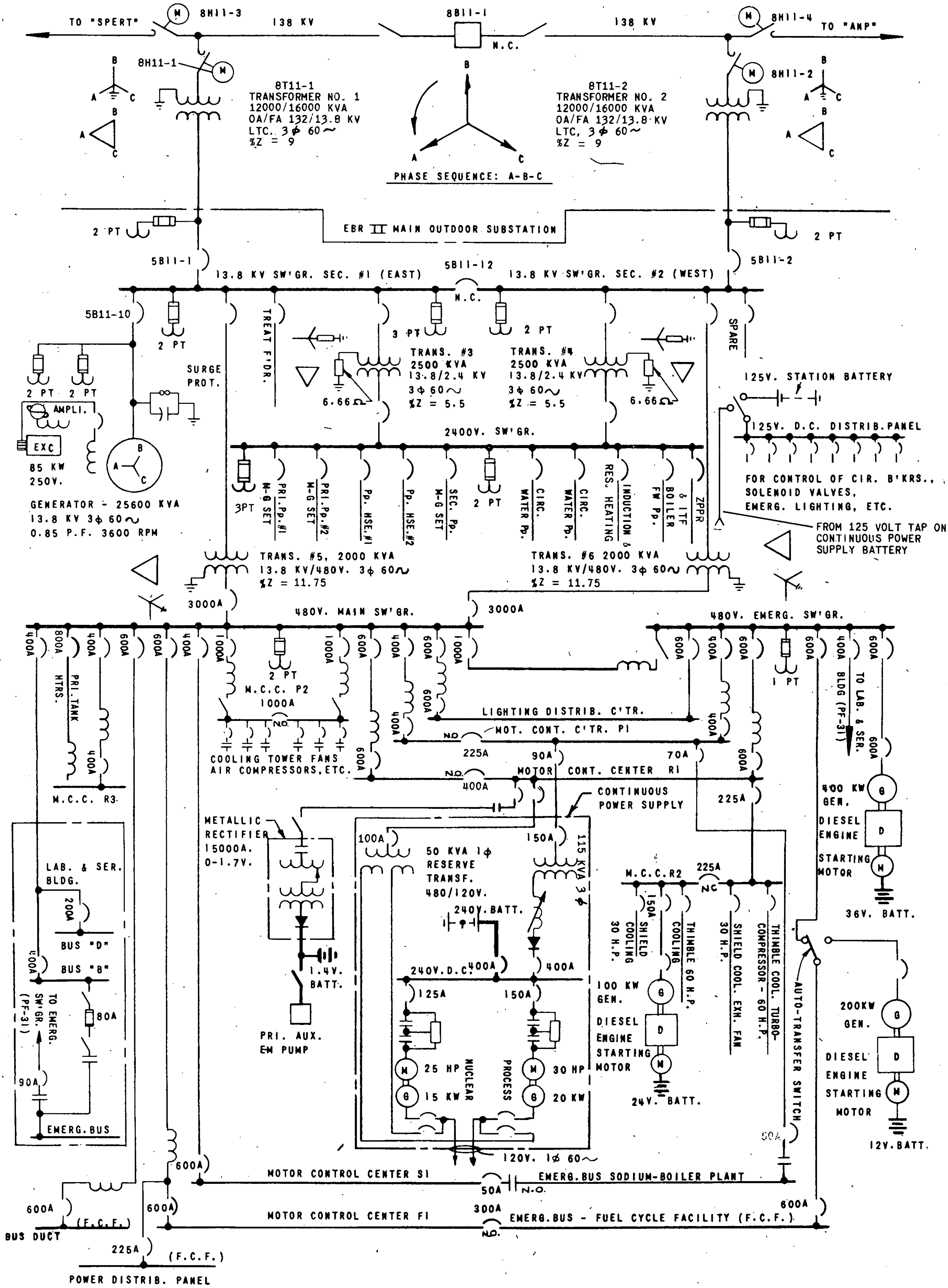
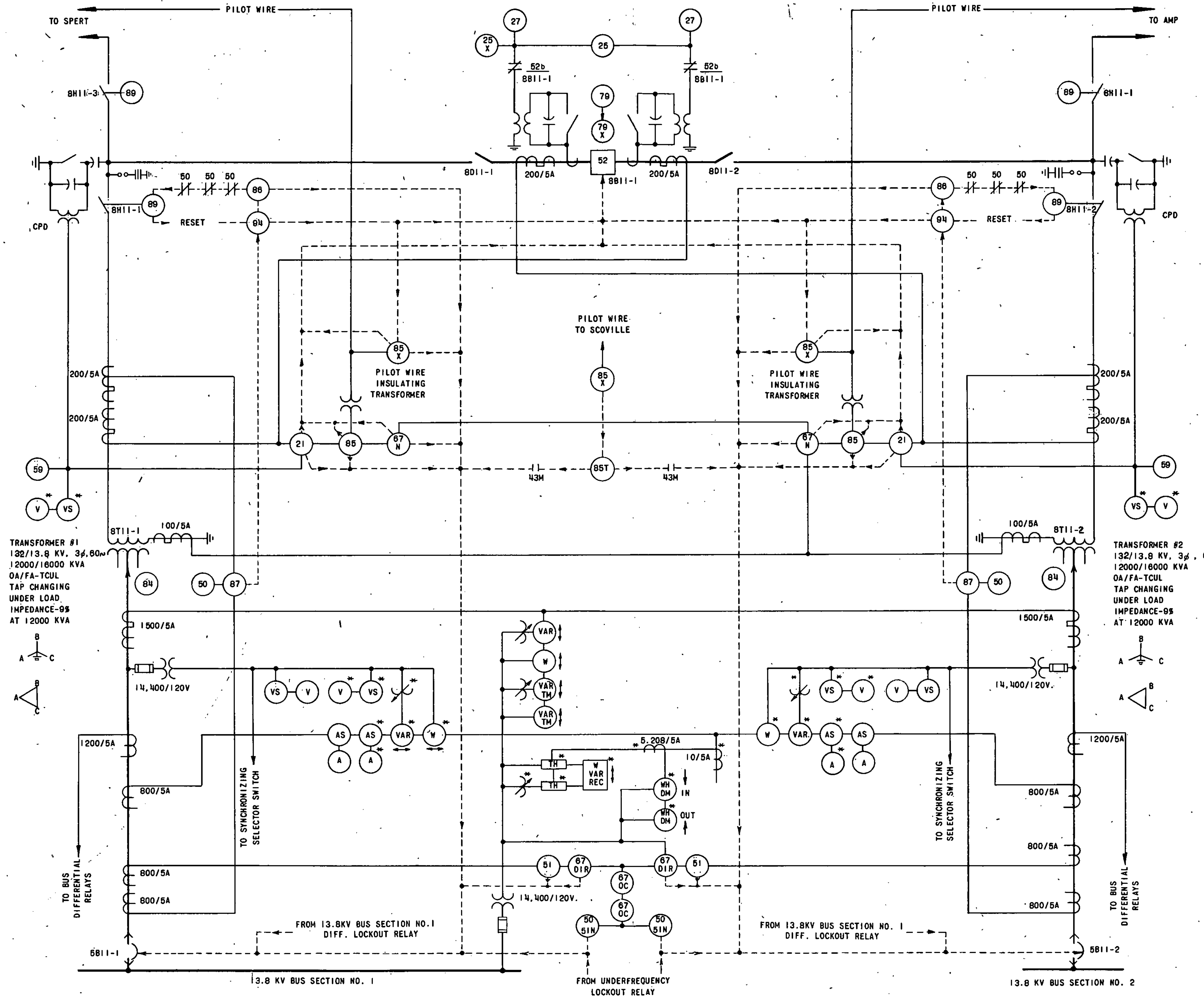


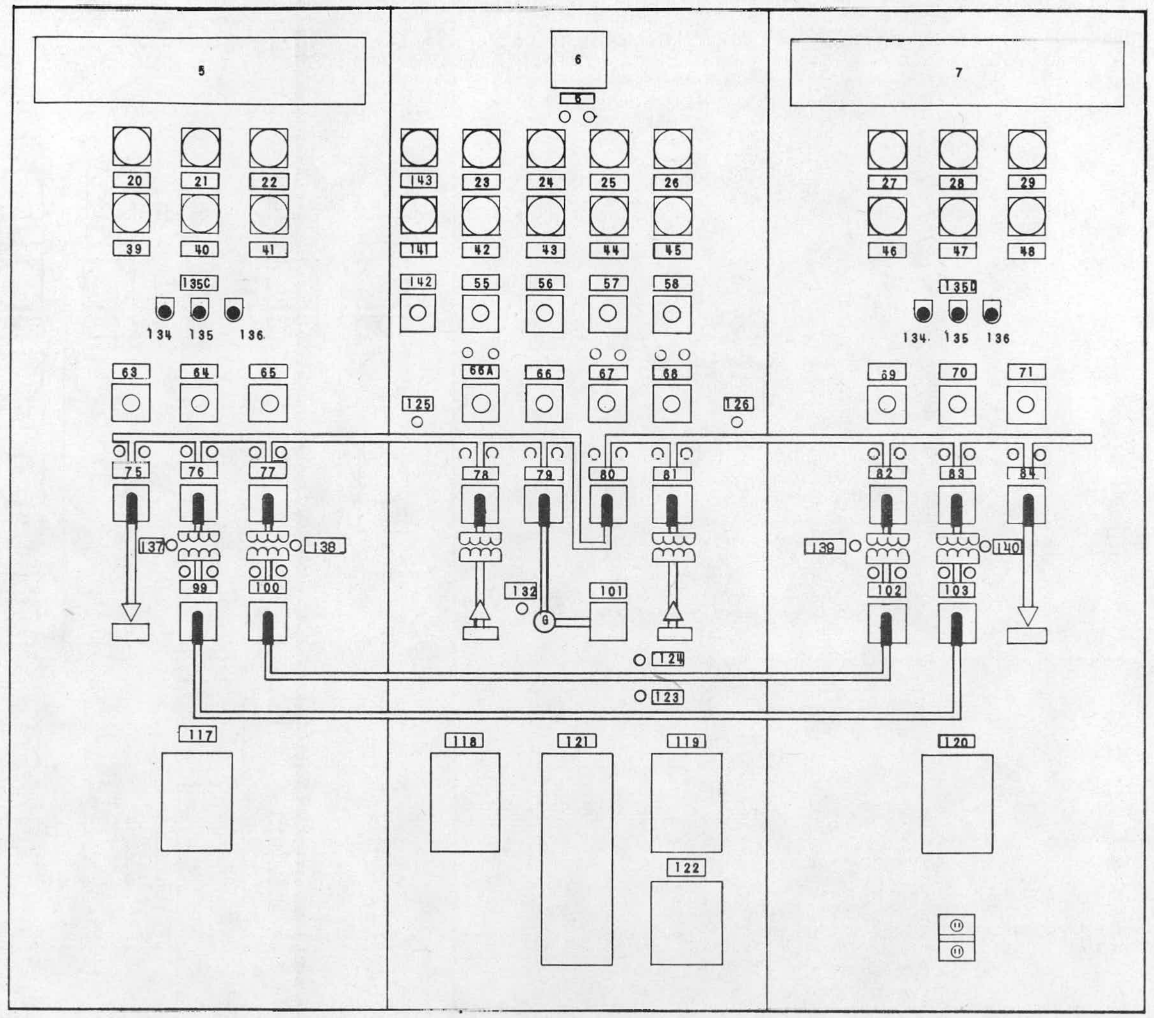
Fig. 20. Simplified Single Line Diagram of EBR-II Electric Power System



LEGEND

ITEM NO.	TITLE
21	DIRECTIONAL DISTANCE IMPEDANCE RELAY
25	SYNCHRONIZING RELAY
25X	AUXILIARY TO SYNCHRONIZING RELAY
27	UNDERVOLTAGE RELAY
50	SHORTCIRCUIT SELECTIVE RELAY
51	OVERCURRENT RELAY
51N	RESIDUAL OVERCURRENT RELAY
52	OIL CIRCUIT BREAKER
59	VOLTAGE CHECK RELAY
67N	DIRECTIONAL OVERCURRENT GROUND FAULT RELAY
79X	AUXILIARY TO RECLOSING RELAY
79	RECLOSING RELAY
84	TAP CHANGER UNDER LOAD OPERATING MECHANISM
85	PILOT WIRE RECEIVER
85X	TRANSFER TRIP AUXILIARY RELAY
86	LOCKOUT RELAY
89	MOTOR OPERATED LOAD BREAK SWITCH
94	TRIPPING RELAY
DIR	DIRECTIONAL ELEMENT
OC	OVERCURRENT ELEMENT
A	AMMETER
AS	AMMETER SWITCH
V	VOLTMETER
VS	VOLTMETER SWITCH
W	WATTMETER
VAR	VARMETER
TH	THERMAL CONVERTER
REC	RECORDER
WHDM	WATTHOUR DEMAND METER
CPD	CAPACITOR POTENTIAL DEVICE
TM	TELEMETER
85T	PILOT WIRE TRIPPING RELAY
43M	ON-OFF SELECTOR SWITCH
*	LOCATED IN MAIN CONTROL ROOM

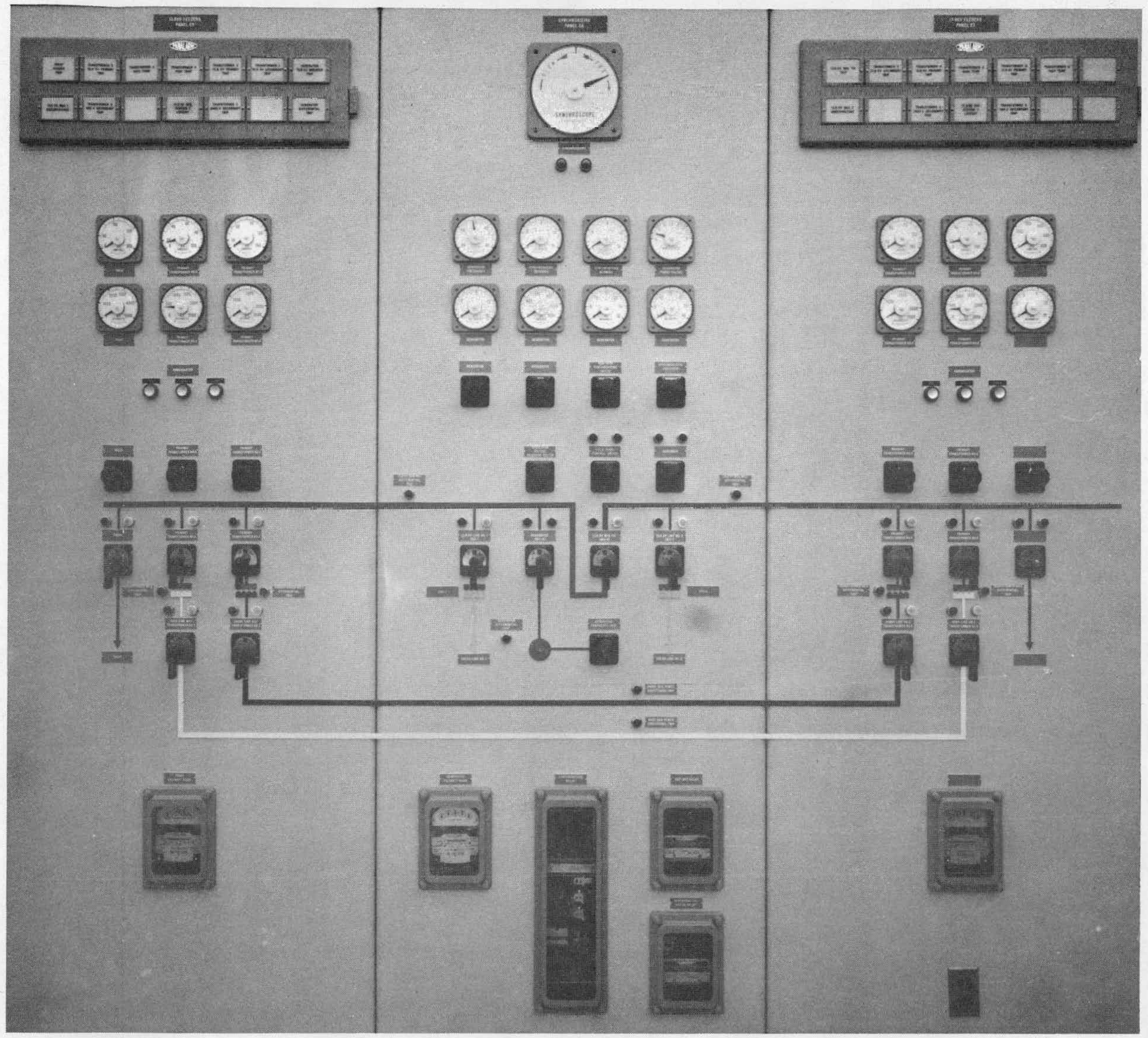
Fig. 21. Single-line Diagram of EBR-II 138-13.8-kV Outdoor Substation



E5
13.8-KV FEEDERS

E6
SYNCHRONIZING PANEL

E7
13.8-KV FEEDERS



E5
13.8-KV FEEDERS

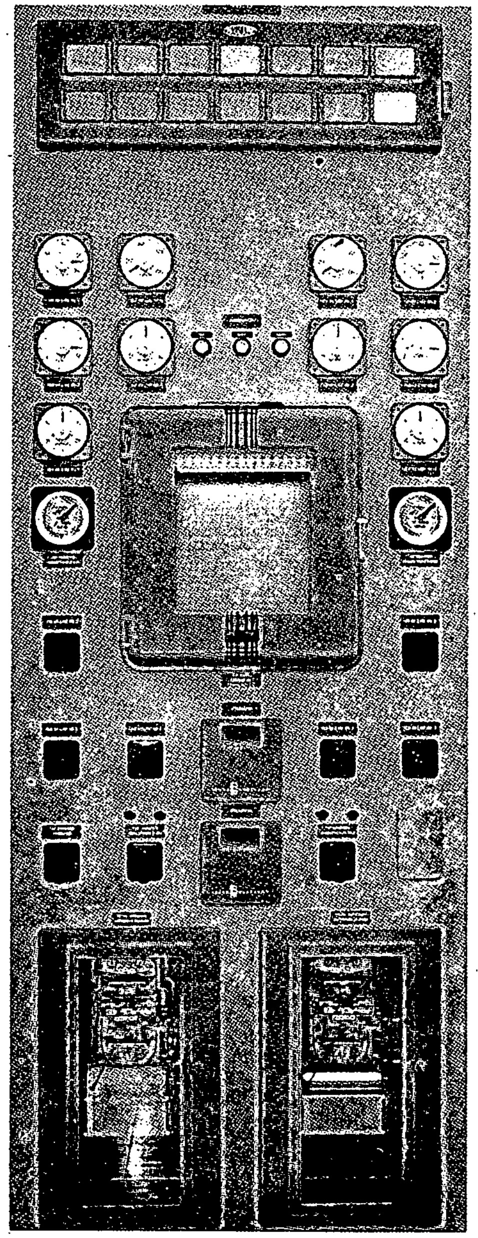
E6
SYNCHRONIZING PANEL

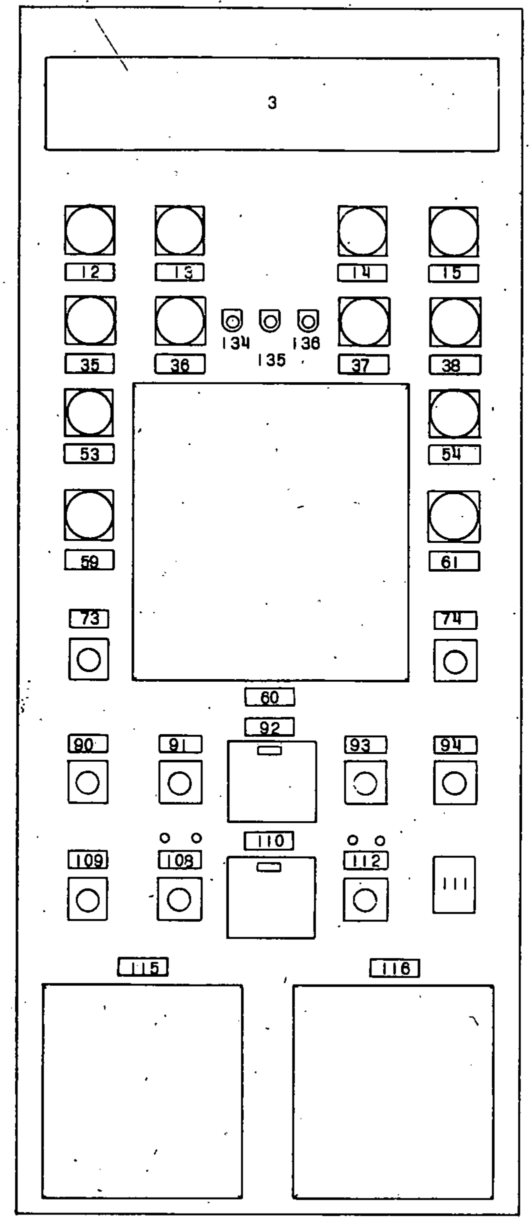
E7
13.8-KV FEEDERS

5. (13.8-KV FEEDERS PANEL ANNUNCIATOR)
6. SYNCHROSCOPE (INDICATING LIGHTS - CLEAR)
7. (13.8-KV FEEDERS PANEL ANNUNCIATOR)
20. TREAT (AMMETER)
21. PRIMARY TRANSFORMER NO. 5 (AMMETER)
22. PRIMARY TRANSFORMER NO. 3 (AMMETER)
23. GENERATOR FREQUENCY (METER)
24. SYNCHRONIZING INCOMING (VOLTMETER)
25. SYNCHRONIZING RUNNING (VOLTMETER)
26. GENERATOR POWER FACTOR
27. PRIMARY TRANSFORMER NO. 4 (AMMETER)
28. PRIMARY TRANSFORMER NO. 6 (AMMETER)
29. (SPARE AMMETER)
39. TREAT (WATTMETER)
40. PRIMARY TRANSFORMER NO. 5 (WATTMETER)
41. PRIMARY TRANSFORMER NO. 3 (WATTMETER)
42. GENERATOR (VOLTMETER)
43. GENERATOR (AMMETER)
44. GENERATOR (WATTMETER)
45. GENERATOR (VARIMETER)
46. PRIMARY TRANSFORMER NO. 4 (WATTMETER)
47. PRIMARY TRANSFORMER NO. 6 (WATTMETER)
48. (SPARE WATTMETER)
55. GENERATOR (VOLTMETER SWITCH)
56. GENERATOR (AMMETER SWITCH)
57. MAN-AUTO. SYNCHRONIZING SWITCH
58. SYNCHRONIZING TRANSFER (SWITCH)
63. TREAT (AMMETER SWITCH)
64. PRIMARY TRANSFORMER NO. 5 (AMMETER SW.)
65. PRIMARY TRANSFORMER NO. 3 (AMMETER SW.)
66. REGULATOR VOLTAGE ADJUSTER SWITCH
66A PILOT WIRE TRIP 13.8-KV LINES 1 & 2 (SWITCH & INDICATING LIGHTS - RED & GREEN)
67. FIELD RHEOSTAT CONTROL SWITCH
68. GOVERNOR (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
69. PRIMARY TRANSFORMER NO. 4 (AMMETER SWITCH)
70. PRIMARY TRANSFORMER NO. 6 (AMMETER SWITCH)
71. (SPARE AMMETER SWITCH)
75. TREAT (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
76. PRIMARY TRANSFORMER NO. 5 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
77. PRIMARY TRANSFORMER NO. 3 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
78. 13.8-KV LINE NO. 1 5B11-1 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
79. GENERATOR 5B11-10 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
80. 13.8-KV BUS TIE 5B11-12 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
81. 13.8-KV LINE NO. 2 5B11-2 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
82. PRIMARY TRANSFORMER NO. 4 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
83. PRIMARY TRANSFORMER NO. 6 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
84. (SPARE CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
99. 480-V LINE NO. 1 TRANSFORMER NO. 5 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
100. 2400-V LINE NO. 1 TRANSFORMER NO. 3 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
101. GENERATOR EMERGENCY TRIP (CONTROL SWITCH)
102. 2400-V LINE NO. 2 TRANSFORMER NO. 4 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
103. 480-V LINE NO. 2 TRANSFORMER NO. 6 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
117. TREAT KILOWATT HOUR (METER)
118. GENERATOR KILOWATT HOUR (METER)
119. CUT-OFF RELAY
120. (SPARE KILOWATT HOUR METER)
121. SYNCHRONIZING RELAY
122. SYNCHRONIZING CHECK RELAY
123. 480-V BUS POWER DIRECTIONAL TRIP (INDICATING LIGHT - AMBER)
124. 2400-V BUS POWER DIRECTIONAL TRIP (INDICATING LIGHT - AMBER)
125. 13.8-KV BUS NO. 1 DIFFERENTIAL TRIP (INDICATING LIGHT - AMBER)
126. 13.8-KV BUS NO. 2 DIFFERENTIAL TRIP (INDICATING LIGHT - AMBER)
132. GENERATOR DIFFERENTIAL TRIP (INDICATING LIGHT - AMBER)
134. TEST (ANNUNCIATOR PUSHBUTTON)
135. RESET (ANNUNCIATOR PUSHBUTTON)
136. SILENCE (ANNUNCIATOR PUSHBUTTON)
137. TRANSFORMER NO. 5 DIFFERENTIAL TRIP (INDICATING LIGHT - AMBER)
138. TRANSFORMER NO. 3 DIFFERENTIAL TRIP (INDICATING LIGHT - AMBER)
139. TRANSFORMER NO. 4 DIFFERENTIAL TRIP (INDICATING LIGHT - AMBER)
140. TRANSFORMER NO. 6 DIFFERENTIAL TRIP (INDICATING LIGHT - AMBER)
141. TURBINE LOAD LIMIT INDICATOR
142. TURBINE LOAD LIMIT SWITCH RAISE-OFF-LOWER
143. GENERATOR OPERATING TIME

NOTE: DESCRIPTIONS IN PARENTHESIS () NOT ON NAMEPLATES

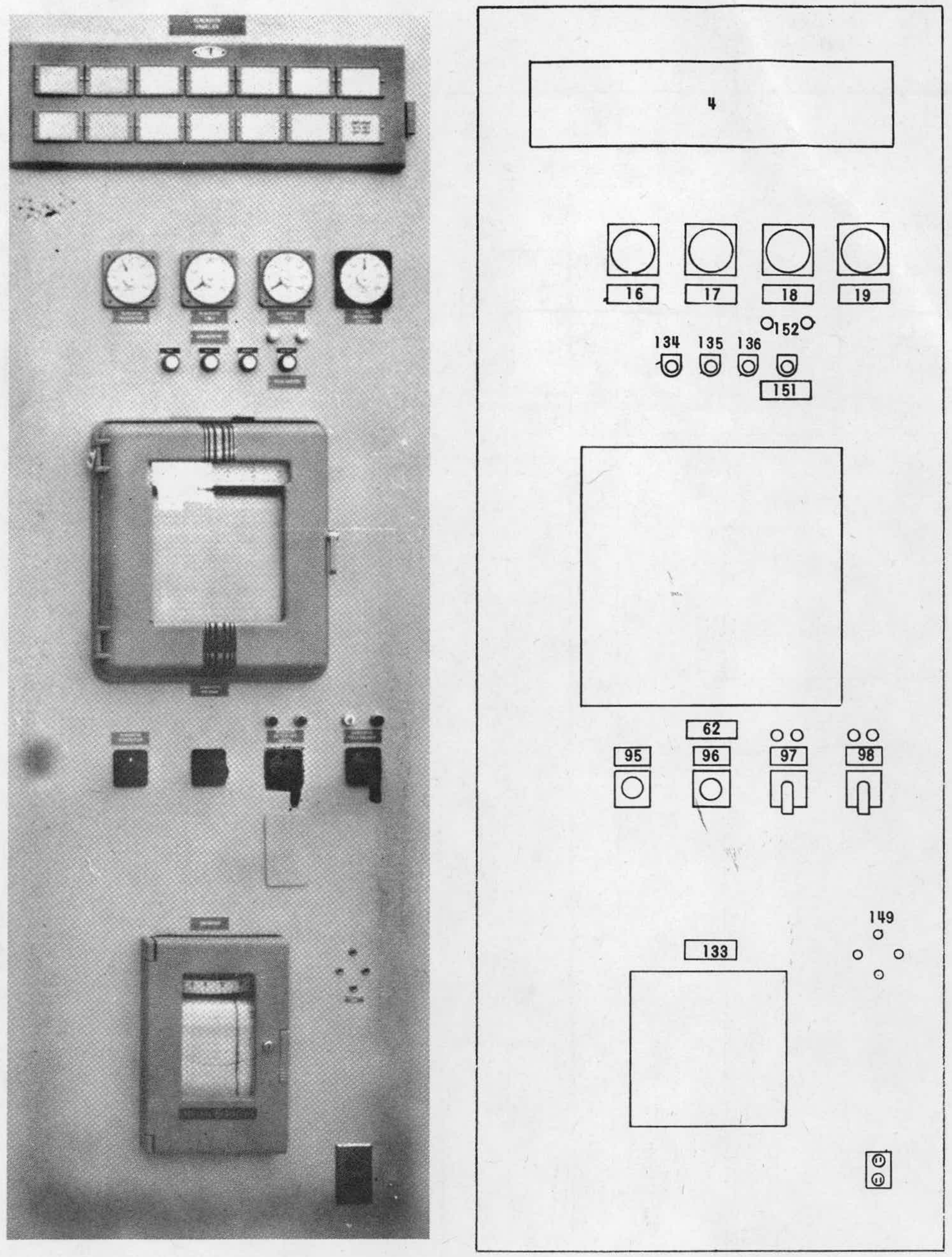
Fig. 22. Electrical Control Panels E-5, E-6, and E-7





3 - INCOMING LINES PANEL ANNUNCIATOR
12 - 138 KV LINE NO. 1 VOLTMETER
13 - 13.8 KV LINE NO. 1 AMMETER
14 - 13.8 KV LINE NO. 2 AMMETER
15 - 138 KV LINE NO. 2 VOLTMETER
35 - 13.8 KV LINE NO. 1 VOLTMETER
36 - 13.8 KV LINE NO. 1 WATTMETER
37 - 13.8 KV LINE NO. 2 WATTMETER
38 - 13.8 KV LINE NO. 2 VOLTMETER
53 - 13.8 KV LINE NO. 1 VARMETER
54 - 13.8 KV LINE NO. 2 VARMETER
59 - TAP POSITION TRANSFORMER NO. 1 INDICATOR
60 - KW-KVAR TOTALIZING RECORDER TRANSFORMER NO. 1 & 2
61 - TAP POSITION NO. 2 INDICATOR
73 - 138 KV LINE NO. 1 VOLTMETER SWITCH
74 - 138 KV LINE NO. 2 VOLTMETER SWITCH
90 - 13.8 KV LINE NO. 1 VOLTMETER SWITCH
91 - 13.8 KV LINE NO. 1 AMMETER SWITCH
92 - INTEGRATOR
93 - 13.8 KV LINE NO. 2 AMMETER SWITCH
94 - 13.8 KV LINE NO. 2 VOLTMETER SWITCH
108 - TAP CHANGER SWITCH TRANSFORMER NO. 1 AND INDICATING LIGHTS (AMBER-RED)
109 - TAP CHANGING TRANSFER SWITCH
110 - INTEGRATOR
111 - COVER PLATE
112 - TAP CHANGER SWITCH TRANSFORMER NO. 2 AND INDICATING LIGHTS (AMBER-RED)
115 - TOTAL INCOMING WATTHOUR DEMANDMETER
116 - TOTAL OUTGOING WATTHOUR DEMANDMETER
134 - ALARM TEST ANNUNCIATOR PUSHBUTTON
135 - ALARM RESET ANNUNCIATOR PUSHBUTTON
136 - ALARM SILENCE ANNUNCIATOR PUSHBUTTON

Fig. 23. Incoming Lines Electrical Control Panel E-3



4 - GENERATOR INDICATING PANEL ANNUNCIATOR
16 - GENERATOR TEMPERATURE INDICATOR
17 - GENERATOR FIELD AMMETER
18 - GENERATOR FIELD VOLTMETER
19 - AMPLIDYNE OUTPUT VOLTMETER
62 - KW-KVAR RECORDER
95 - TEMPERATURE SELECTOR SWITCH
96 - BUS NO. 1 & NO. 2 VOLTAGE TRANSFER SWITCH
97 - REGULATOR ON-TEST-OFF SWITCH & INDICATING LIGHTS (RED & GREEN)
98 - GENERATOR FIELD BREAKER CONTROL SWITCH & INDICATING LIGHTS (RED & GREEN)
133 - RECORDING VOLTMETER
134 - ANNUNCIATOR ALARM TEST PUSHBUTTON
135 - ANNUNCIATOR ALARM RESET PUSHBUTTON
136 - ANNUNCIATOR ALARM SILENCE PUSHBUTTON
149 - SOUND POWER PHONE JACK
151 - FIELD EXCITER GROUND TEST PUSHBUTTON
152 - FIELD EXCITER GROUND LIGHT (WHITE)

Fig. 24. Generator Indicating Panel E-4

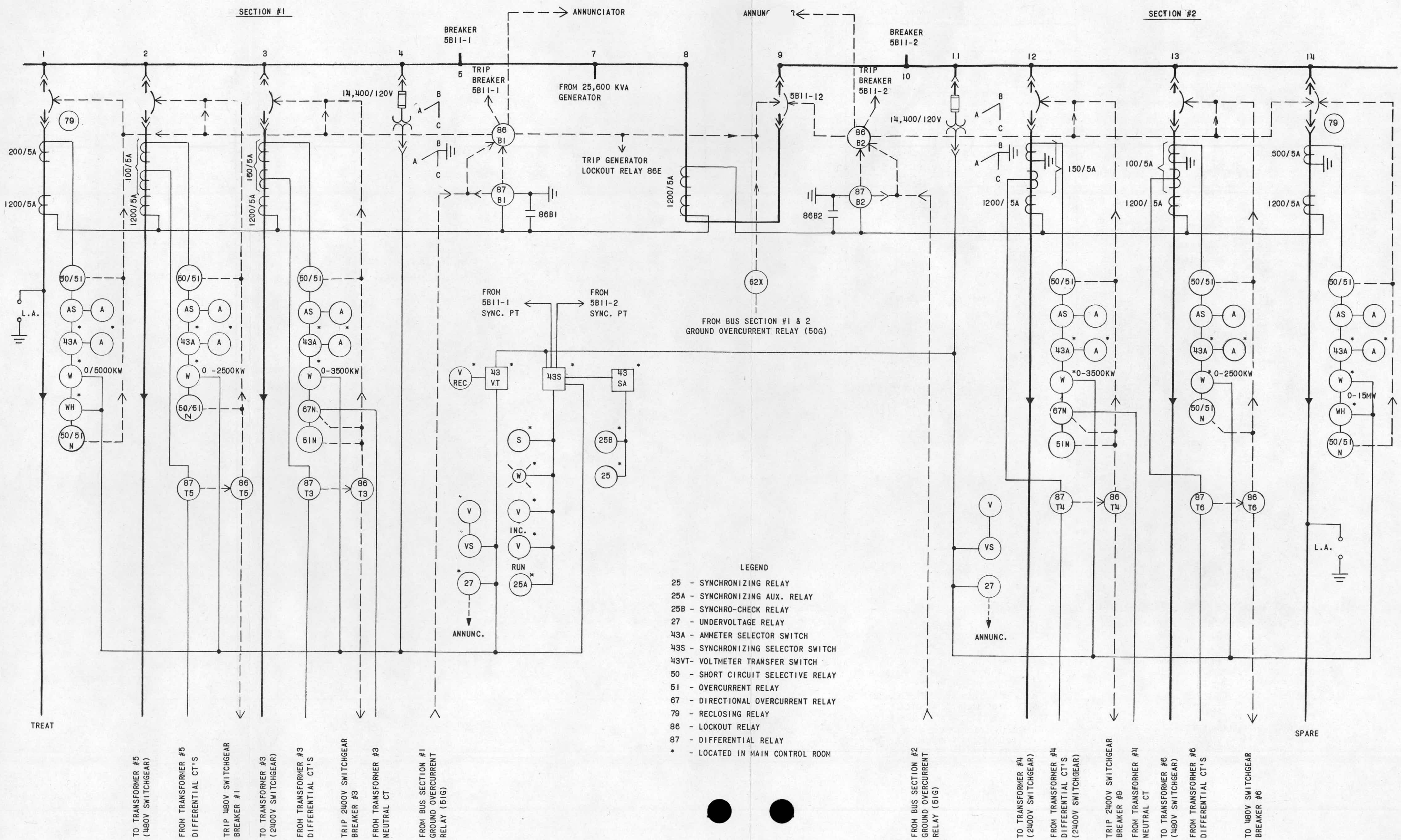
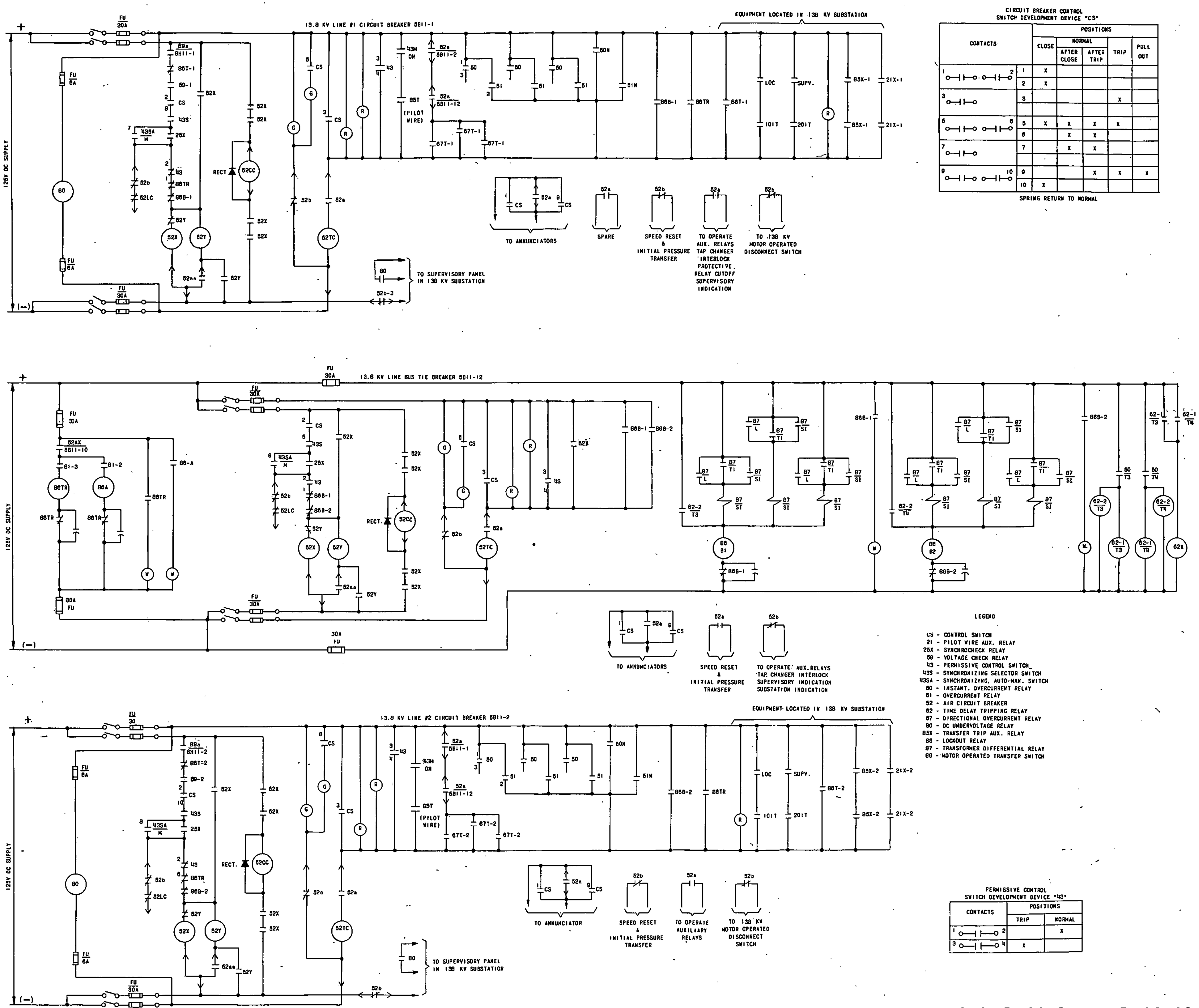


Fig. 25. Protective Relaying--13.8-kV Single-line Diagram



CIRCUIT BREAKER CONTROL SWITCH DEVELOPMENT DEVICE "CS"

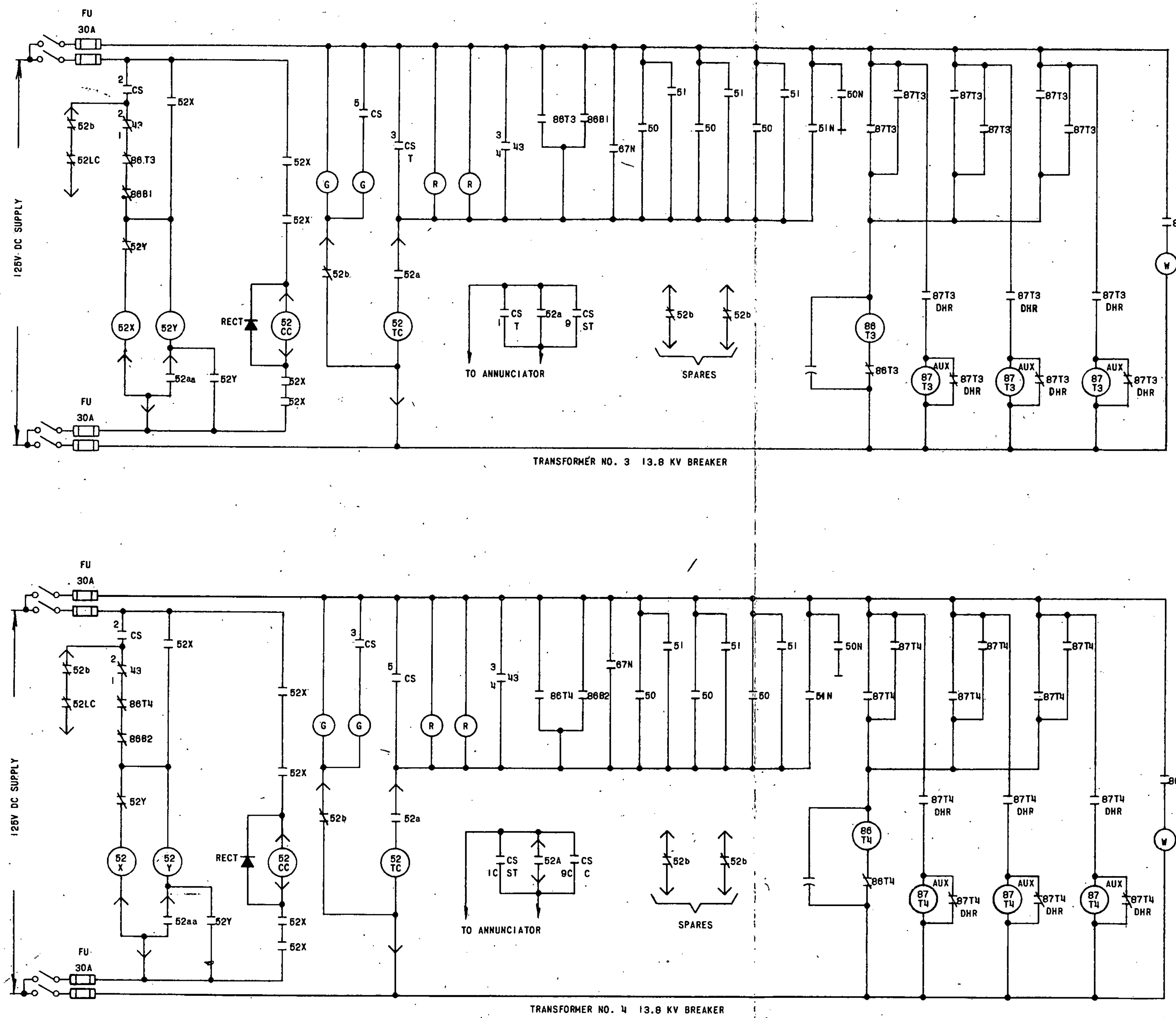
CONTACTS		CLOSE	NORMAL AFTER CLOSE	NORMAL AFTER TRIP	TRIP	PULL OUT
1–2	1	X				
	2	X				
3	3				X	
5–6	5	X	X	X	X	
	6		X	X		
7	7		X	X		
9–10	9			X	X	X
	10	X				

SPRING RETURN TO NORMAL

PERMISSIVE CONTROL SWITCH DEVELOPMENT DEVICE "43"

CONTACTS	TRIP	NORMAL
1–2		X
3–4	X	

Fig. 26. Elementary Diagram--13.8-kV Breakers 5B11-1, 5B11-2, and 5B11-12



CS - CONTROL SWITCH
43 - PERMISSIVE SWITCH
50 - INSTANT. OVERCURRENT RELAY
51 - OVERCURRENT RELAY
52 - AIR CIRCUIT BREAKER
67N - DIRECTIONAL OVERCURRENT RELAY
86B - BUS DIFF. RELAY
86T - TRANSFORMER AUX. LOOKOUT RELAY
87T - TRANSFORMER DIFF. RELAY

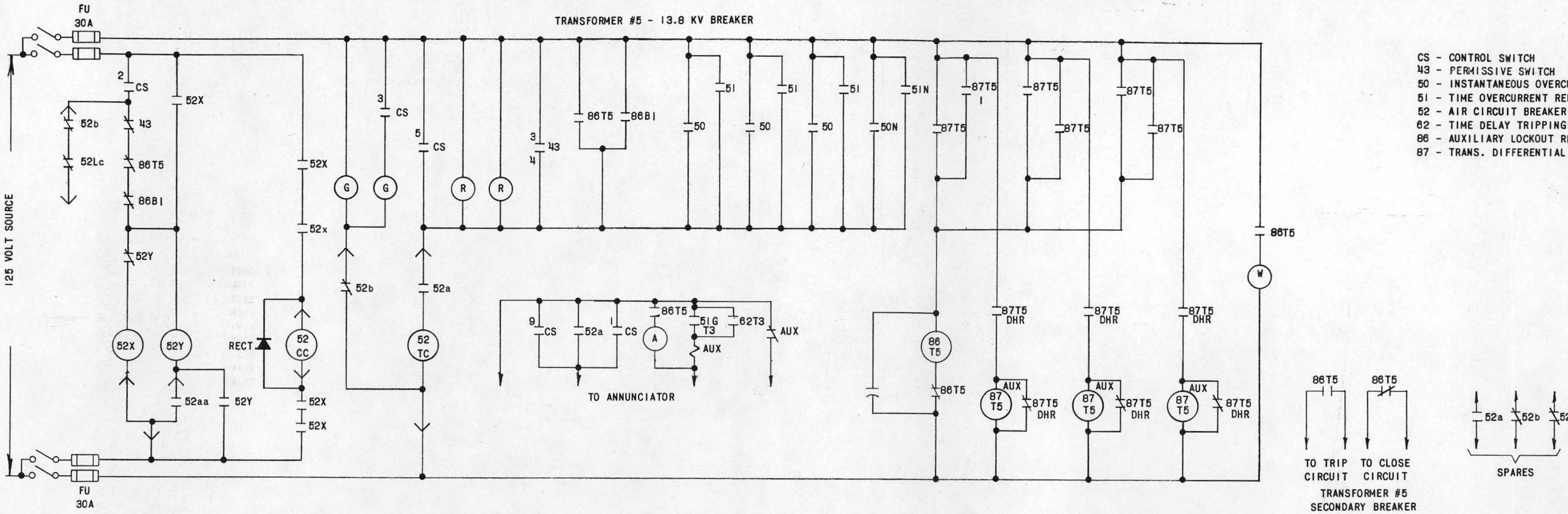
CIRCUIT BREAKER CONTROL
SWITCH DEVELOPMENT DEVICE "CS"

CONTACTS		POSITIONS				
		CLOSE	NORMAL AFTER CLOSE	NORMAL AFTER CLOSE	TRIP	PULL OUT
1 — 2	1	X				
	2	X				
3	3				X	
5 — 6	5	X	X	X	X	
	6		X	X		
7	7		X	X		
9 — 10	9			X	X	X
	10	X	X			

PERMISSIVE CONTROL
SWITCH DEVELOPMENT "43"

CONTACTS		POSITIONS	
		TRIP	NORMAL
1 — 2			X
3 — 4		X	

Fig. 27. Elementary Diagram--13.8-kV Breakers for Transformers No. 3 and 4



CS - CONTROL SWITCH
43 - PERMISSIVE SWITCH
50 - INSTANTANEOUS OVERCURRENT RELAY
51 - TIME OVERCURRENT RELAY
52 - AIR CIRCUIT BREAKER
62 - TIME DELAY TRIPPING RELAY
86 - AUXILIARY LOCKOUT RELAY
87 - TRANS. DIFFERENTIAL RELAY

CIRCUIT BREAKER CONTROL SWITCH DEVELOPMENT DEVICE "CS"

CONTACTS		CLOSE	NORMAL AFTER CLOSE	NORMAL AFTER TRIP	TRIP	PULL OUT
1–2	1	X				
	2	X				
3	3				X	
5–6	5	X	X	X	X	
	6		X	X		
7	7		X	X		
9–10	9			X	X	X
	10	X	X			

SPRING RETURN TO NORMAL

PERMISSIVE CONTROL SWITCH DEVELOPMENT "43"

CONTACTS	TRIP	NORMAL
1–2		X
3–4	X	

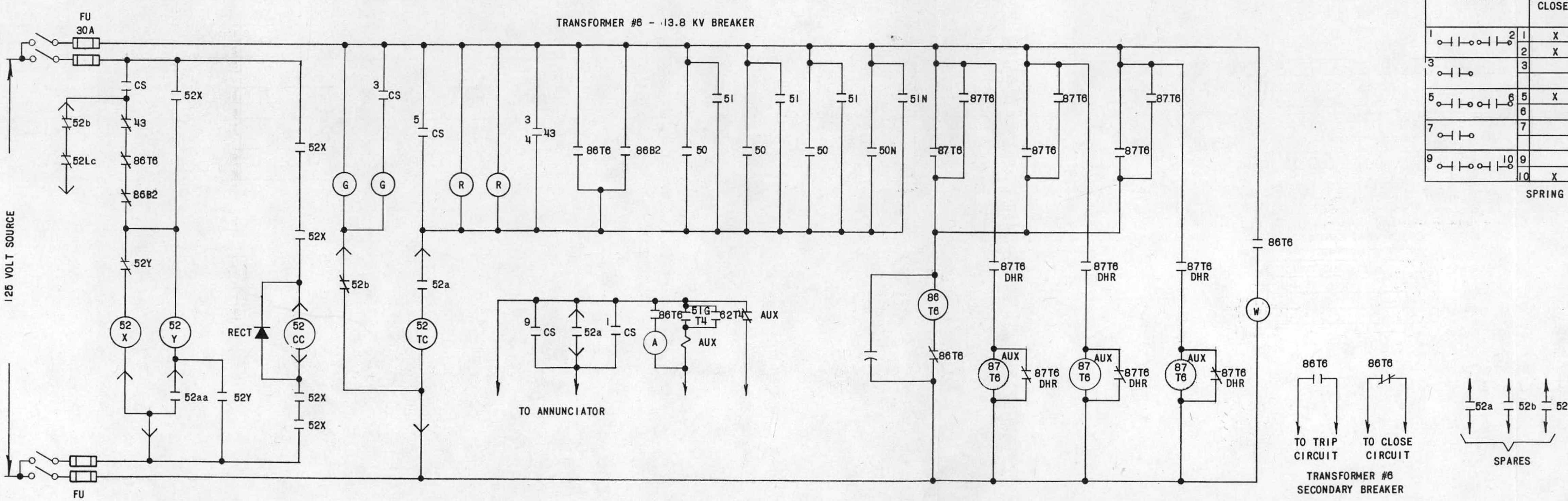


Fig. 28. Elementary Diagram--13.8-kV Breakers for Transformers No. 5 and 6

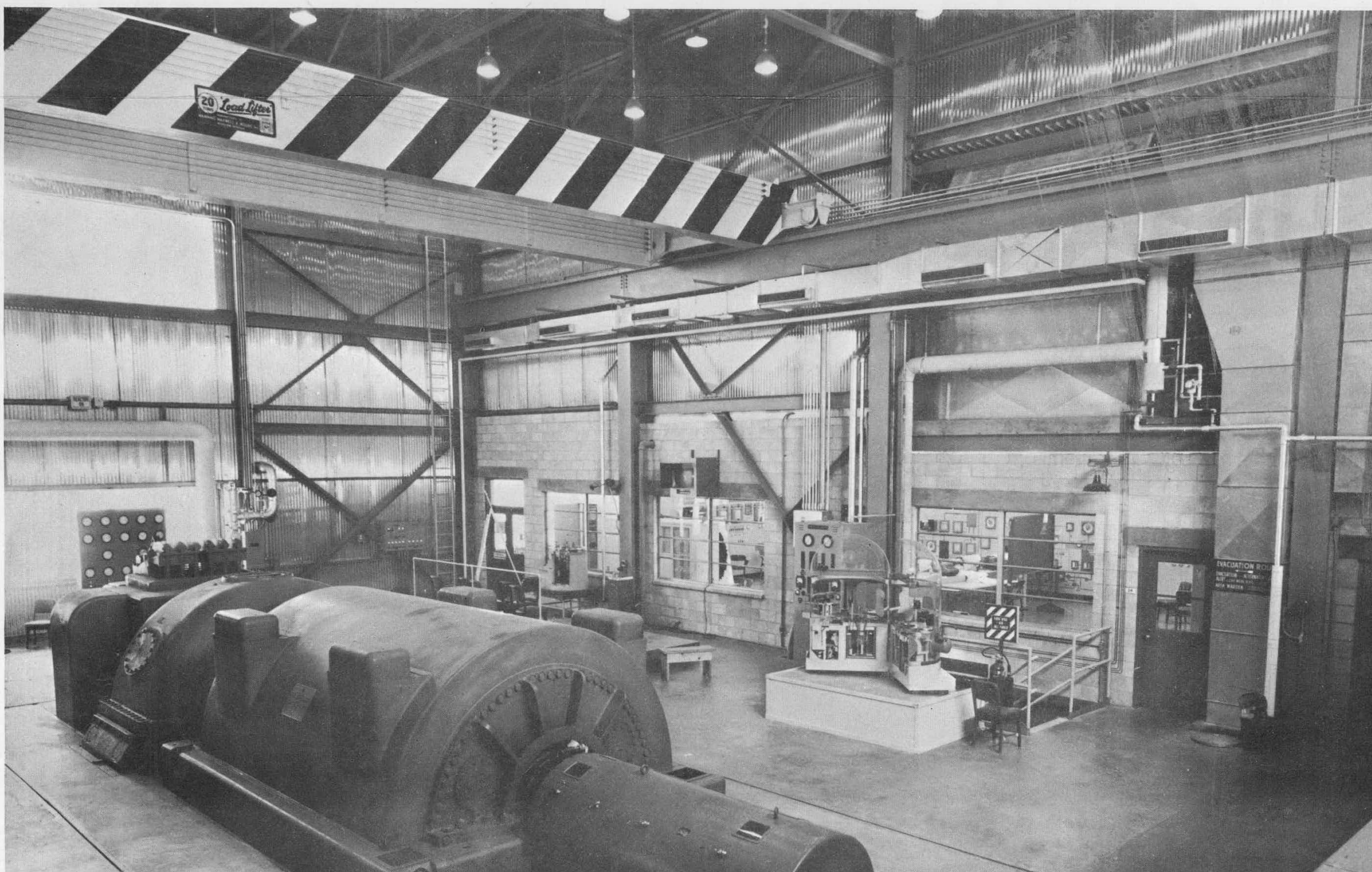


Fig. 29. EBR-II 20,000-kW Turbine-generator

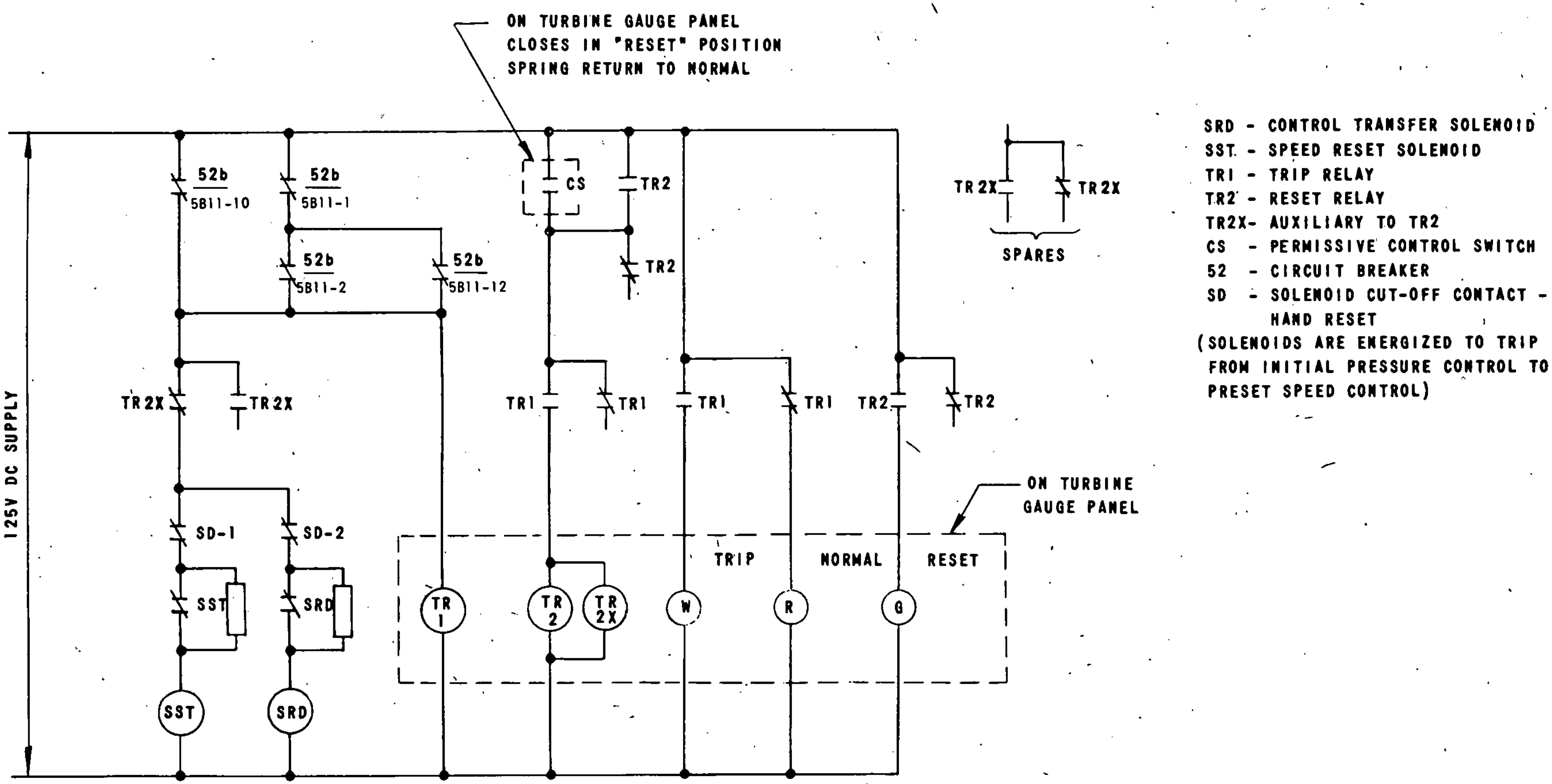
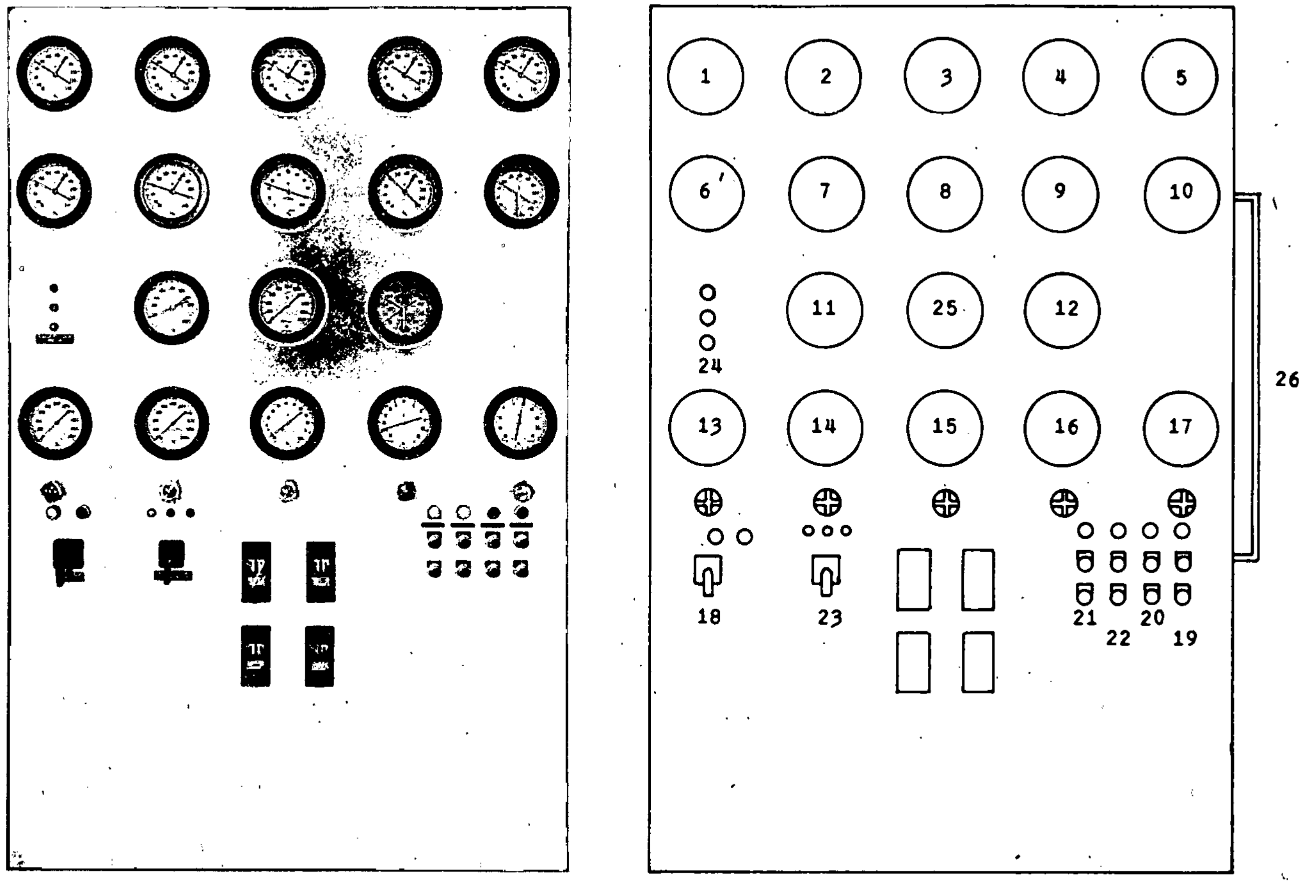
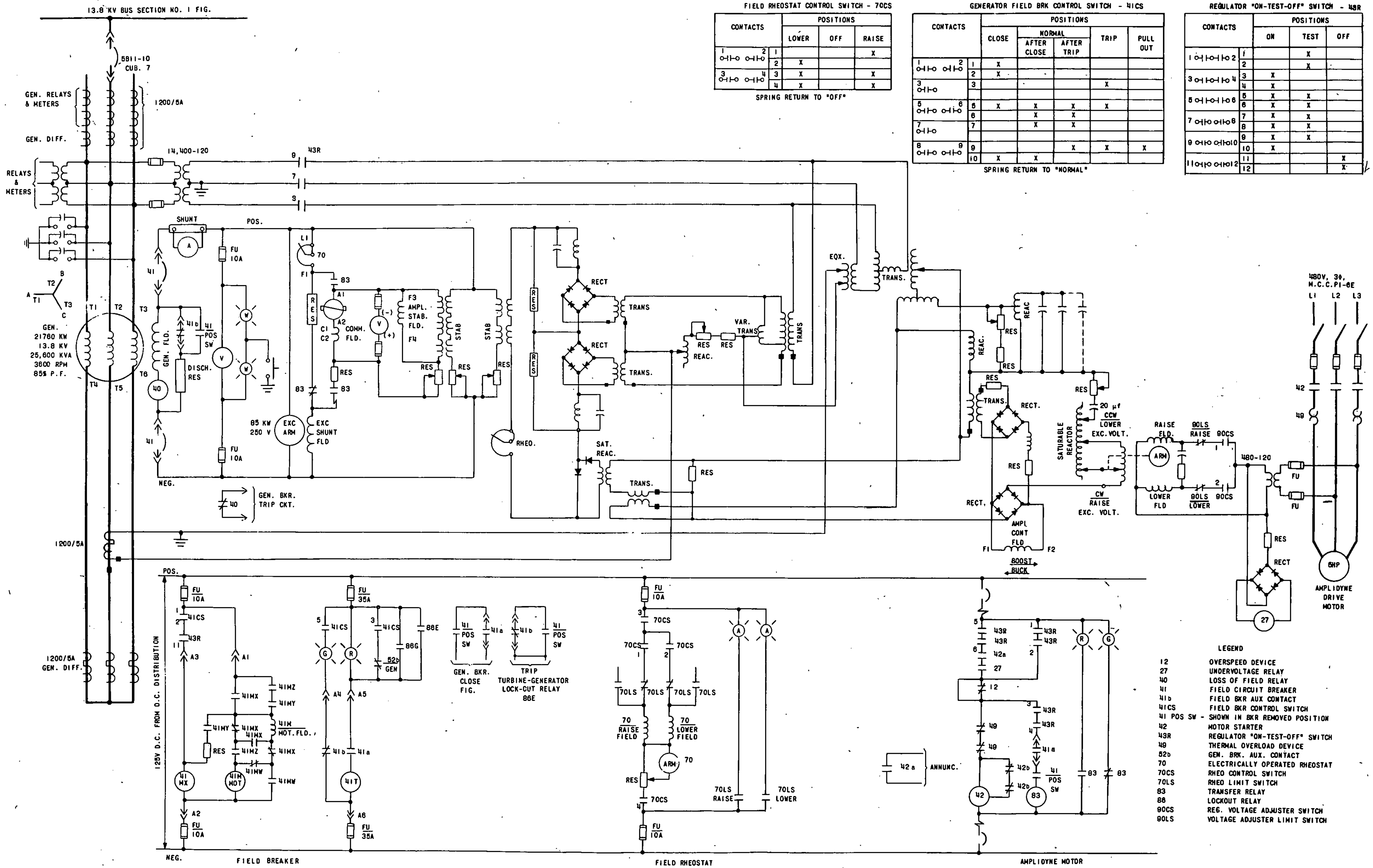


Fig. 30. Elementary Diagram of Turbine Governor Autotransfer Scheme



1. TURBINE THRUST BEARING TEMP.
2. HIGH PRESSURE BEARING TEMP.
3. MAIN BEARING TEMP.
4. GENERATOR #1 BEARING TEMP.
5. GENERATOR #2 BEARING TEMP.
6. EXCITER BEARING TEMP.
7. EXCITER BEARING TEMP.
8. EXCITER AIR DISCHARGE TEMP.
9. TURBINE OIL COOLER INLET TEMP.
10. TURBINE OIL COOLER OUTLET TEMP.
11. TURBINE THROTTLE TEMP.
12. TURBINE EXHAUST TEMP.
13. TURBINE THROTTLE PRESS.
14. FIRST STAGE EXTRACTION STEAM PRESS.
15. 15# STAGE EXTRACTION STEAM PRESS.
16. TURBINE EXHAUST STEAM PRESS.
17. GLAND SEAL PIPING SYSTEM STEAM PRESS.
18. VACUUM TRIP RESET SOLENOID SELECTOR SWITCH & IND. LMPS.
19. AC H_2 SEAL OIL PUMP - P.B. & IND. LMP.
20. DC H_2 SEAL OIL PUMP - P.B. & IND. LMP.
21. VAPOR EXTRACTOR - P.B. & IND. LMP.
22. GLAND EXHAUSTER - P.B. & IND. LMP.
23. INITIAL PRESSURE GOVENOR - RESET SWITCH
24. TURBINE STOP VALVE POSITION IND. LIGHTS
25. STEAM HEADER PRESS.
26. BAROMETER

Fig. 31. Turbine Gauge Panel



REGULATOR VOLTAGE ADJUSTER - 90CS
FIELD RHEOSTAT CONTROL SWITCH - 70CS

CONTACTS		POSITIONS		
		LOWER	OFF	RAISE
1 ○┤├○ ○┤├○ 2	1			X
	2	X		
3 ○┤├○ ○┤├○ 4	3	X		X
	4	X		X

SPRING RETURN TO "OFF"

GENERATOR FIELD BRK CONTROL SWITCH - 41CS

CONTACTS		POSITIONS				
		CLOSE	NORMAL AFTER CLOSE	NORMAL AFTER TRIP	TRIP	PULL OUT
1 ○┤├○ ○┤├○ 2	1	X				
	2	X				
3 ○┤├○	3				X	
5 ○┤├○ ○┤├○ 6	5	X	X	X	X	
	6		X	X		
7 ○┤├○	7		X	X		
8 ○┤├○ ○┤├○ 9	9			X	X	X
	10	X	X			

SPRING RETURN TO "NORMAL"

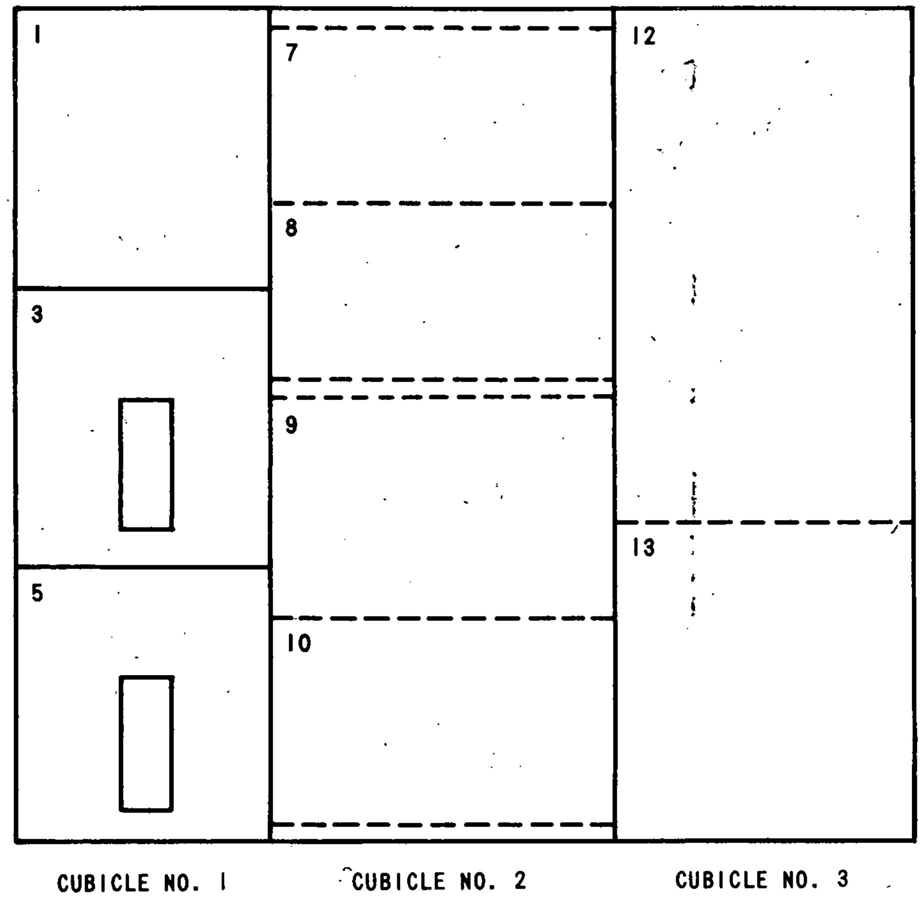
REGULATOR "ON-TEST-OFF" SWITCH - 43R

CONTACTS		POSITIONS		
		ON	TEST	OFF
1 ○┤├○┤├○ 2	1		X	
	2		X	
3 ○┤├○┤├○ 4	3	X		
	4	X		
5 ○┤├○┤├○ 6	5	X	X	
	6	X	X	
7 ○┤├○ ○┤├○ 8	7	X	X	
	8	X	X	
9 ○┤├○ ○┤├○ 10	9	X	X	
	10	X		
11 ○┤├○ ○┤├○ 12	11			X
	12			X

LEGEND

12	OVERSPEED DEVICE
27	UNDERVOLTAGE RELAY
40	LOSS OF FIELD RELAY
41	FIELD CIRCUIT BREAKER
41b	FIELD BKR AUX CONTACT
41CS	FIELD BKR CONTROL SWITCH
41 POS SW -	SHOWN IN BKR REMOVED POSITION
42	MOTOR STARTER
43R	REGULATOR "ON-TEST-OFF" SWITCH
49	THERMAL OVERLOAD DEVICE
52b	GEN. BRK. AUX. CONTACT
70	ELECTRICALLY OPERATED RHEOSTAT
70CS	RHEO CONTROL SWITCH
70LS	RHEO LIMIT SWITCH
83	TRANSFER RELAY
86	LOCKOUT RELAY
90CS	REG. VOLTAGE ADJUSTER SWITCH
90LS	VOLTAGE ADJUSTER LIMIT SWITCH

Fig. 32. Elementary Diagram for Excitation and Control



1. FUSE COMPARTMENT
2. FIELD DISCHARGE RESISTOR (IN REAR SECTION OF CUBICLE NO. 1)
3. MAIN EXCITER CIRCUIT BREAKER COMPARTMENT
4. SHUNT (IN REAR SECTION OF CUBICLE NO. 1)
5. SPARE COMPARTMENT (RESERVE EXCITER CIRCUIT BREAKER)
6. LOSS OF FIELD RELAY (IN REAR SECTION OF CUBICLE NO. 1)
7. D-C CONTROL PANEL
8. A-C CONTROL PANEL
9. REACTIVE - AMPERE LIMIT PANEL
10. VOLTAGE - REGULATOR PANEL
11. AUXILIARY EQUIPMENT PANEL (IN REAR SECTION OF CUBICLE NO. 2)
12. EXCITER FIELD RHEOSTAT COMPARTMENT
13. AMPLIDYNE MOTOR - GENERATOR COMPARTMENT

Fig. 33. Generator-excitation Cubicles

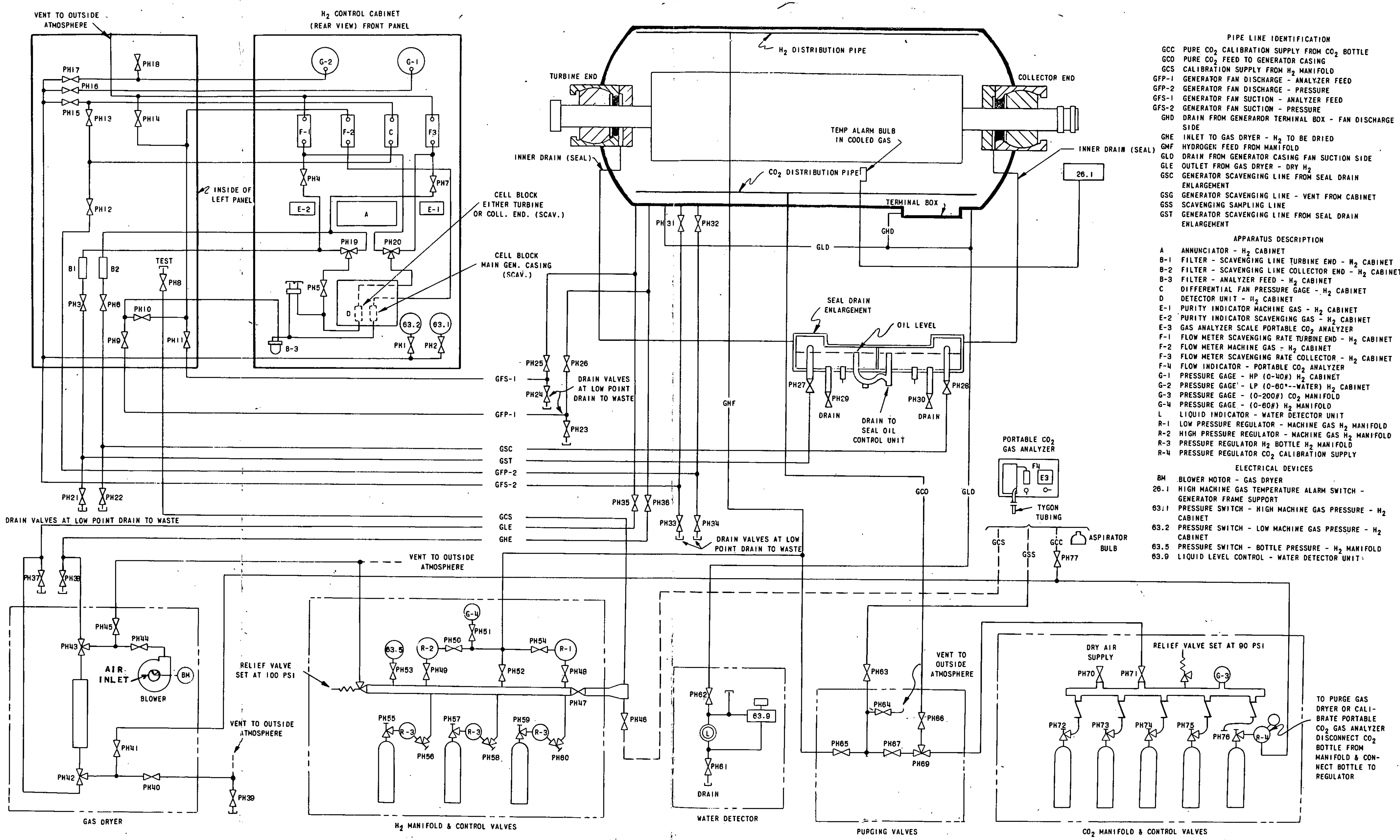
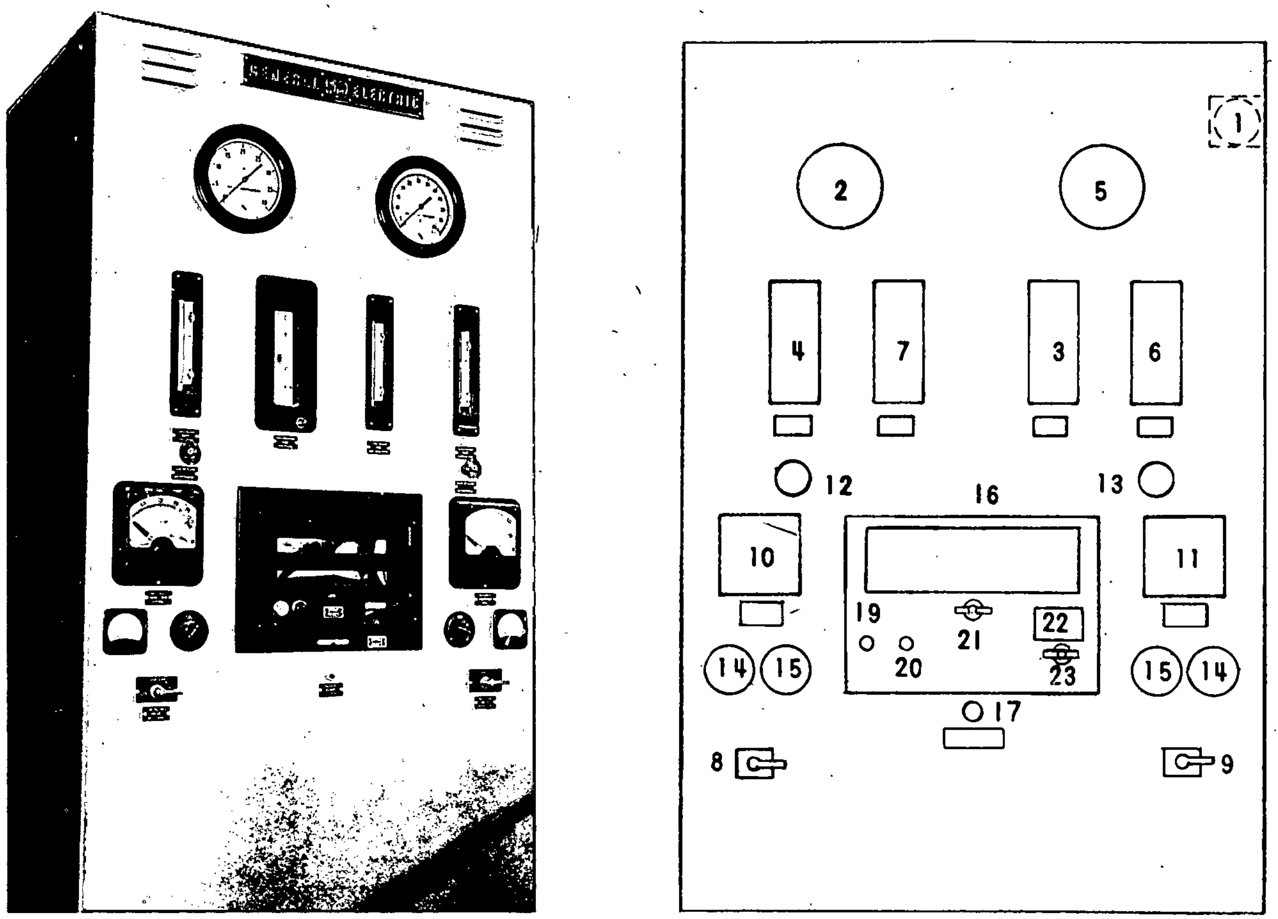


Fig. 35. Flow Diagram for CO_2 and Hydrogen

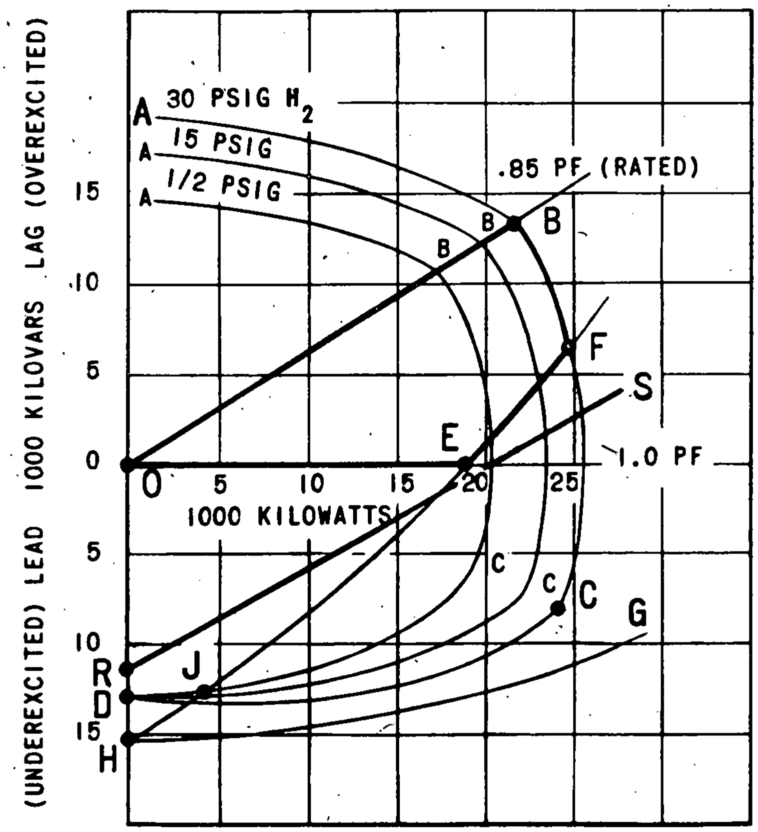


1. HORN
2. MACHINE GAS PRESSURE (INDICATOR-HIGH)
3. FLOWMETER FOR GAS ANALYZER
4. SCAVENGING RATE COLL. END (ROTAMETER)
5. MACHINE GAS PRESSURE (INDICATOR-LOW)
6. SCAVENGING RATE TURBINE END (ROTAMETER)
7. DIFFERENTIAL FAN PRESSURE (INDICATOR)
8. SELECTOR VALVE SCAV. GAS
9. SELECTOR VALVE SCAV. GAS
10. H_2 PURITY, GENERATOR CASING (METER)
11. H_2 PURITY, SCAVENGED GAS (METER)
12. RATE OF FLOW ADJUSTMENT (COLLECTOR END)
13. RATE OF FLOW ADJUSTMENT (TURBINE END)
14. MILLIAMETER
15. POTENTIOMETER AND SWITCH
16. ANNUNCIATOR
17. REMOTE ALARM CUT-OUT (PUSHBUTTON)
19. D.C. PILOT LAMP
20. ALARM LAMP
21. DROP RESET
22. SIGNAL RESET
23. SIGNAL RESET

Fig. 34. Hydrogen Panel

REACTIVE CAPABILITY CURVES

FOR STEAM TURBINE-GENERATOR UNIT
ATB-2-POLE - 25600 KVA - 3600 RPM -
13800 VOLTS - .85 PF 30 PSIG H_2,
1070 ARMATURE AMPS - 250 VOLTS EXCITATION



MANUAL CONTROL
OF GENERATOR EXCITATION

1. OPERATION OF THE GENERATOR SHOULD BE ABOVE CURVE "DJEF", THE LIMIT IMPOSED BY SYSTEM STABILITY AND ARMATURE CORE END HEATING.
2. AREA "O B F E O" IS THE NORMAL OPERATING RANGE OF THE GENERATOR.
3. CURVE "A B" INDICATES THE DESIGN LIMITS OF THE GENERATOR FIELD (ROTOR) HEATING.
4. CURVE "B F C" INDICATES THE DESIGN LIMITS OF THE GENERATOR ARMATURE (STATOR) HEATING.
5. CURVE "C D" INDICATES THE DESIGN LIMITS OF THE ARMATURE CORE END HEATING.
6. OPERATION OF THE GENERATOR IN AREA "O A B O" COULD BE USED WHEN LOW VOLTAGE CONDITIONS EXIST ON THE NRTS SYSTEM AND IT IS DESIRED TO USE THE GENERATOR TO HELP RAISE THE VOLTAGE.
7. OPERATION OF THE GENERATOR IN AREA "OEJDO" COULD BE USED WHEN HIGH VOLTAGE CONDITIONS EXIST ON THE NRTS SYSTEM AND IT IS DESIRED TO USE THE GENERATOR TO HELP LOWER THE VOLTAGE.
8. CURVE "HG" IS THE LOCUS OF POINTS AT WHICH THE GENERATOR WILL PULL OUT OF SYNCHRONISM.
9. LINE "RS" INDICATES THE REACTIVE-AMPERE LIMIT START LINE SETTING OF THE VOLTAGE REGULATOR EQUIPMENT.

Fig. 36. Curves of EBR-II Generator Reactive Capability

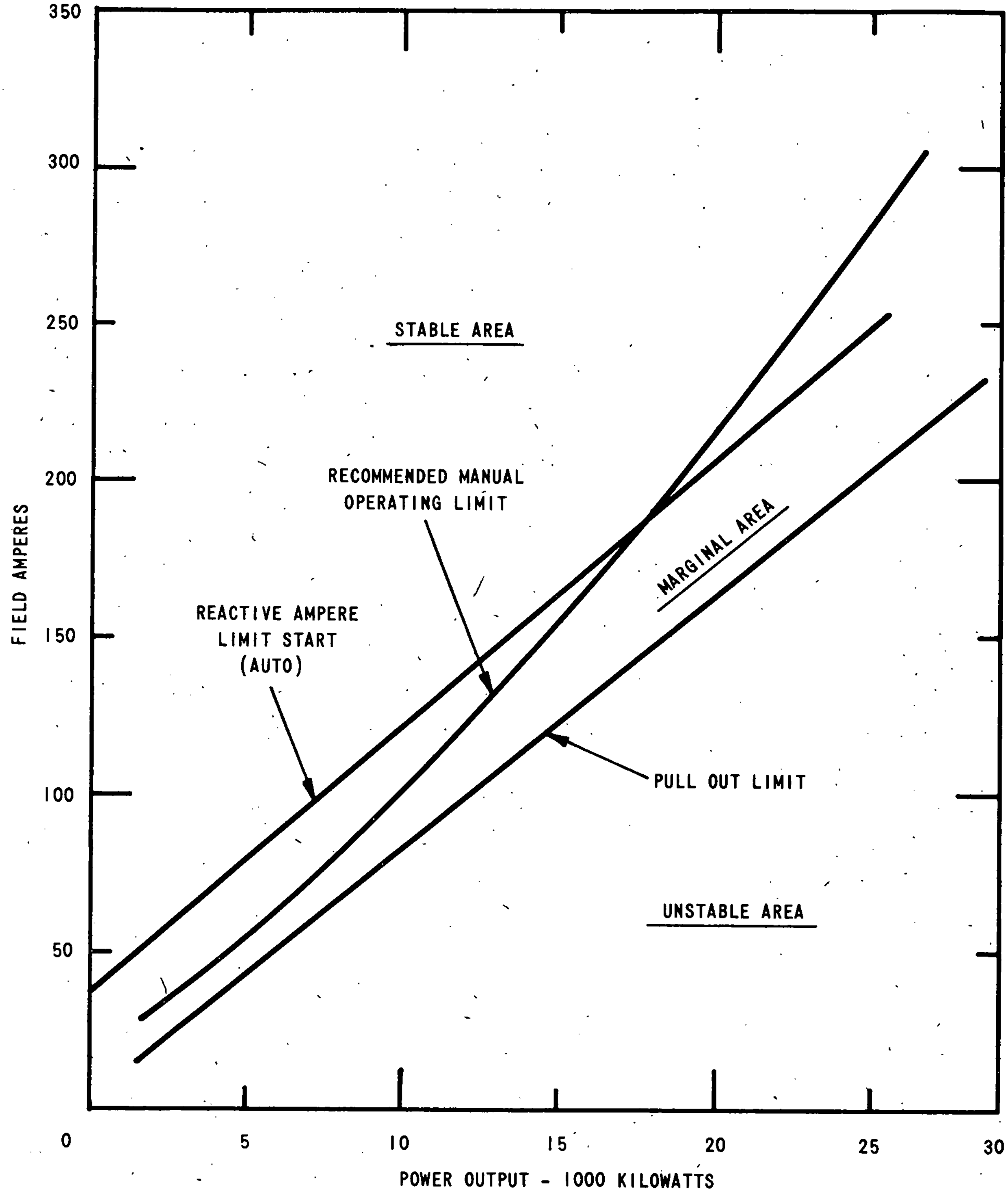
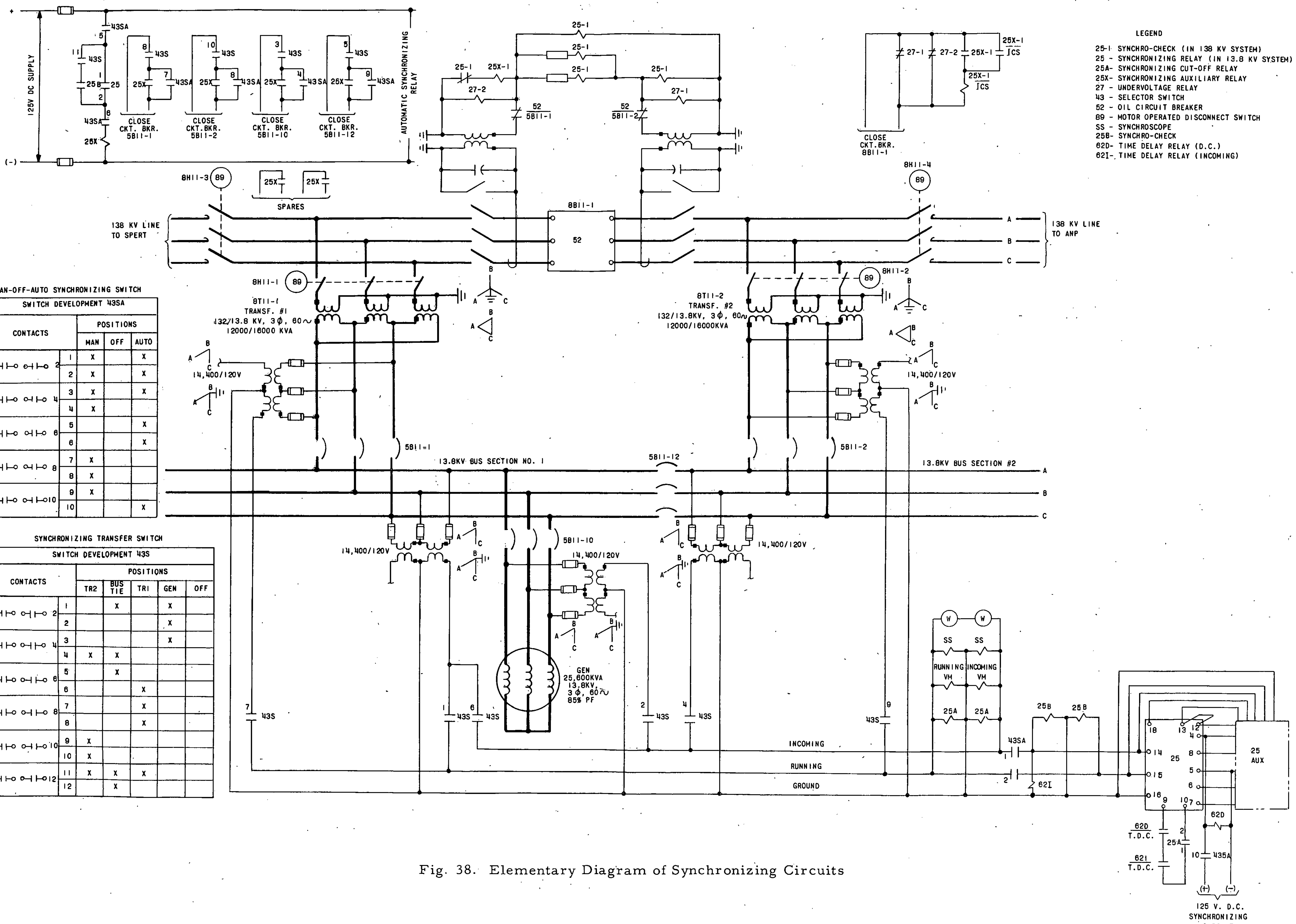


Fig. 37. EBR-II Generator Pull-out Limit and Operating Limit



MAN-OFF-AUTO SYNCHRONIZING SWITCH

SWITCH DEVELOPMENT 43SA				
CONTACTS		POSITIONS		
		MAN	OFF	AUTO
1 o-| |-o o-| |-o 2	1	X		X
	2	X		X
3 o-| |-o o-| |-o 4	3	X		X
	4	X		
5 o-| |-o o-| |-o 6	5			X
	6			X
7 o-| |-o o-| |-o 8	7	X		
	8	X		
9 o-| |-o o-| |-o 10	9	X		
	10			X

SYNCHRONIZING TRANSFER SWITCH

SWITCH DEVELOPMENT 43S						
CONTACTS		POSITIONS				
		TR2	BUS TIE	TR1	GEN	OFF
1 o-| |-o o-| |-o 2	1		X		X	
	2				X	
3 o-| |-o o-| |-o 4	3				X	
	4	X	X			
5 o-| |-o o-| |-o 6	5		X			
	6			X		
7 o-| |-o o-| |-o 8	7			X		
	8			X		
9 o-| |-o o-| |-o 10	9	X				
	10	X				
11 o-| |-o o-| |-o 12	11	X	X	X		
	12		X			

Fig. 38. Elementary Diagram of Synchronizing Circuits

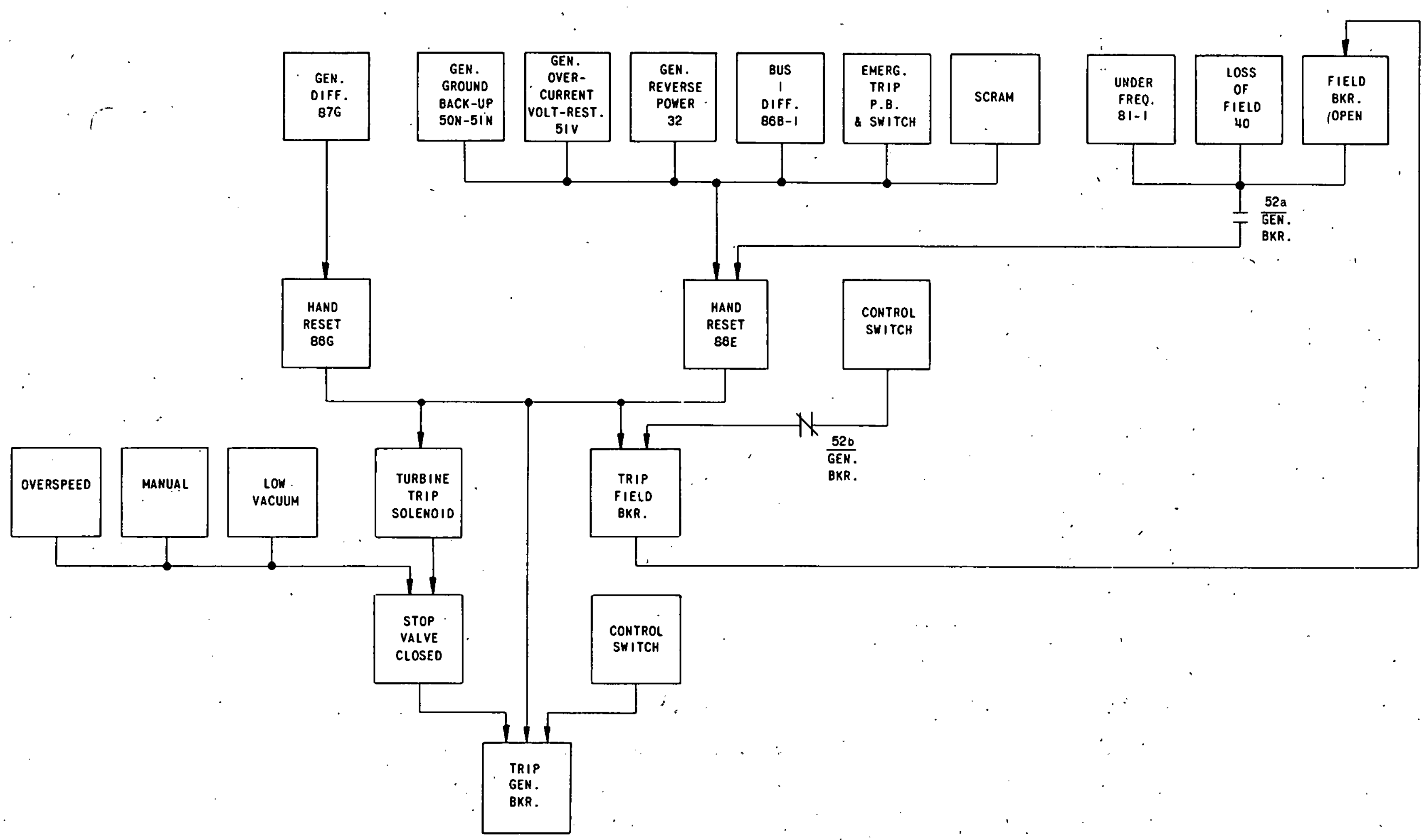
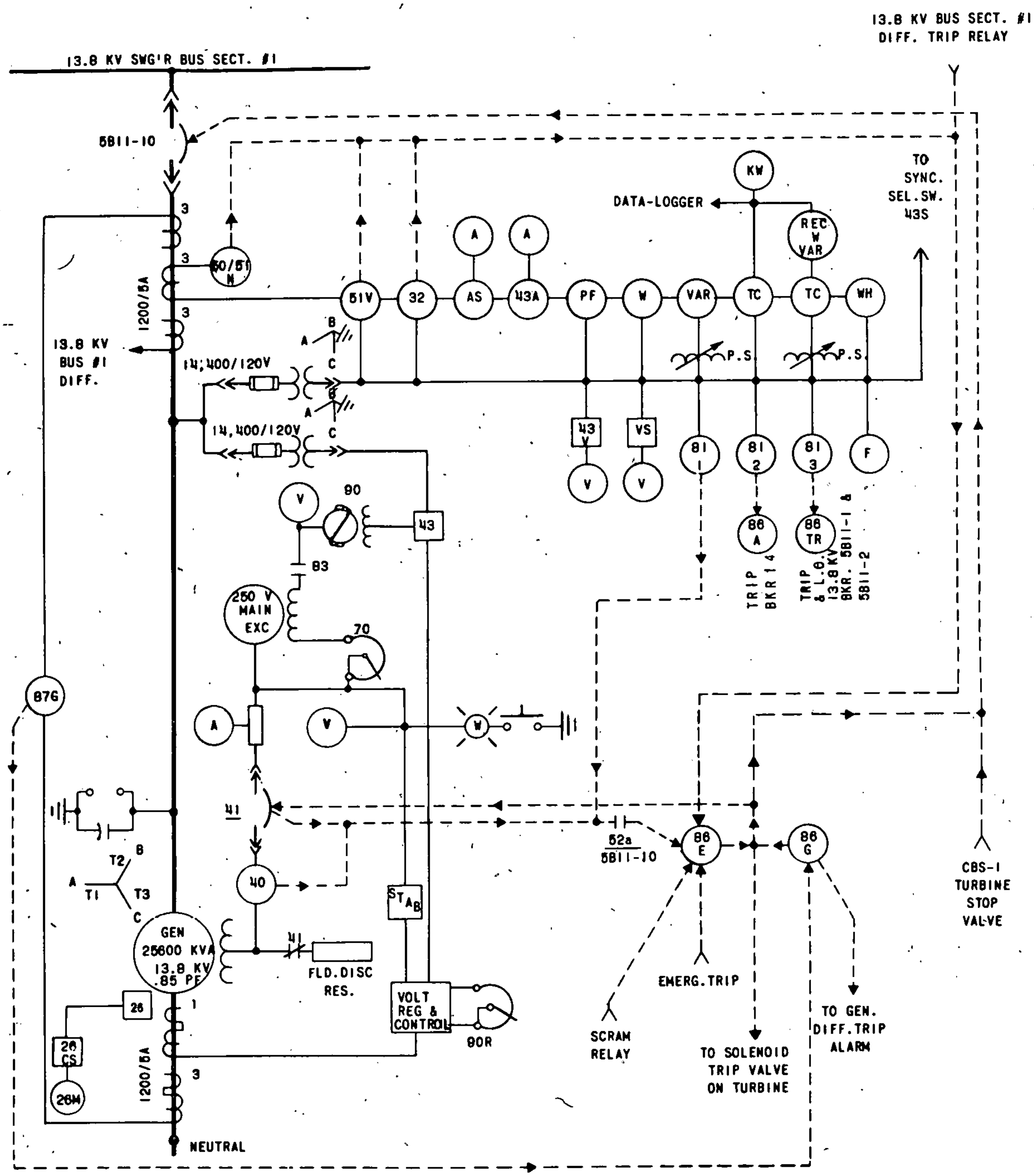


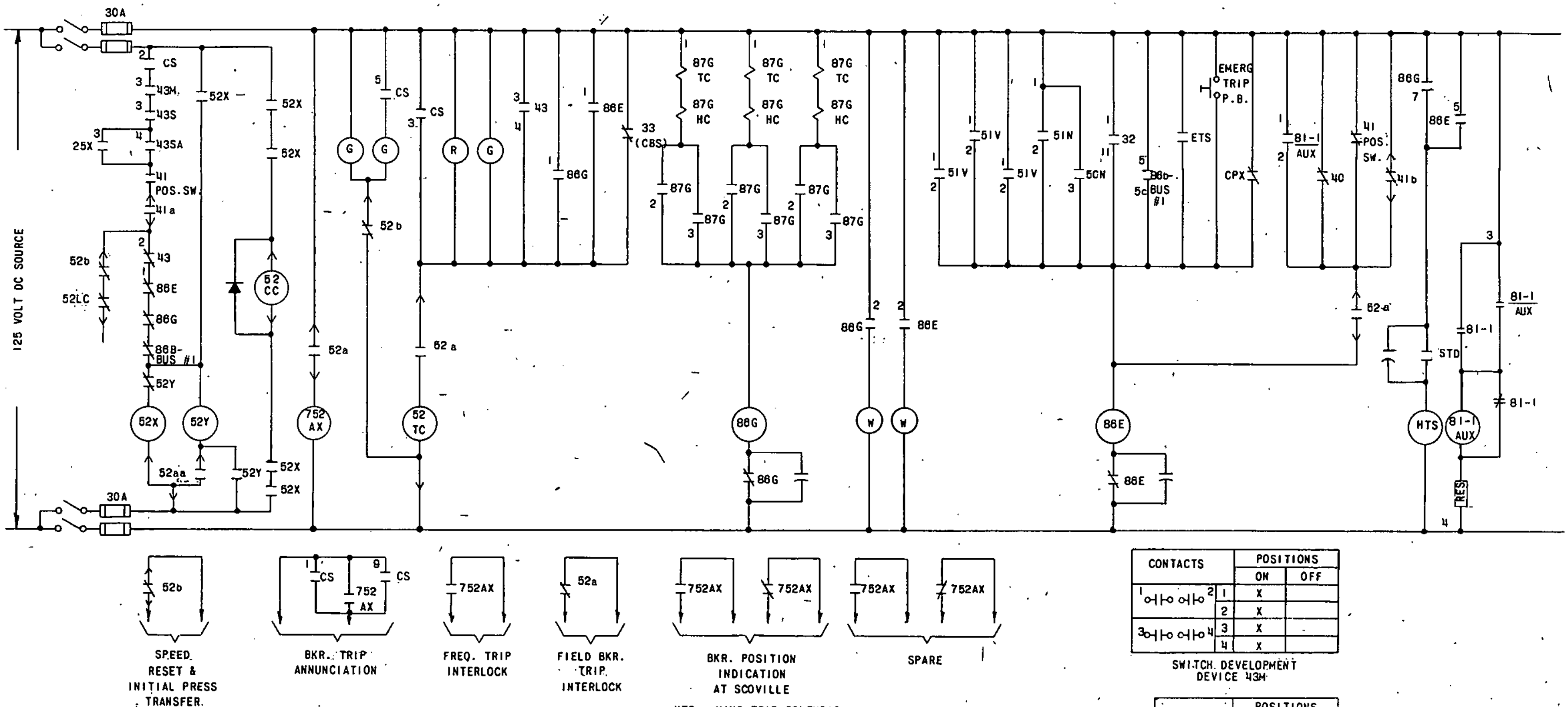
Fig. 39. Tripping Block Diagram for the EBR-II Turbine-generator



LEGEND

26 - TEMPERATURE INDICATOR
32 - DIRECTIONAL POWER RELAY
40 - LOSS OF FIELD RELAY
41 - FIELD BREAKER
43 - SELECTOR SWITCH
50/51N - GROUND OVERCURRENT RELAY
51V - OVERCURRENT RELAY
70 - EXCITER FIELD RHEOSTAT
81 - UNDERFREQUENCY RELAY
83 - TRANSFER RELAY
86 - LOCKOUT RELAY
87G - GENERATOR DIFFERENTIAL RELAY
90 - VOLTAGE REGULATOR

Fig. 40. Single-line Diagram for EBR-II Generator



CONTACTS		ON	OFF
1 – 2	1	X	
	2	X	
3 – 4	3	X	
	4	X	

SWITCH DEVELOPMENT
DEVICE 43M

CONTACTS	TRIP	NORMAL
1 – 2		X
3 – 4	X	

SWITCH DEVELOPMENT
DEVICE 43

CONTACTS	TRIP	NORMAL
1 – 2: 1	X	
2	X	

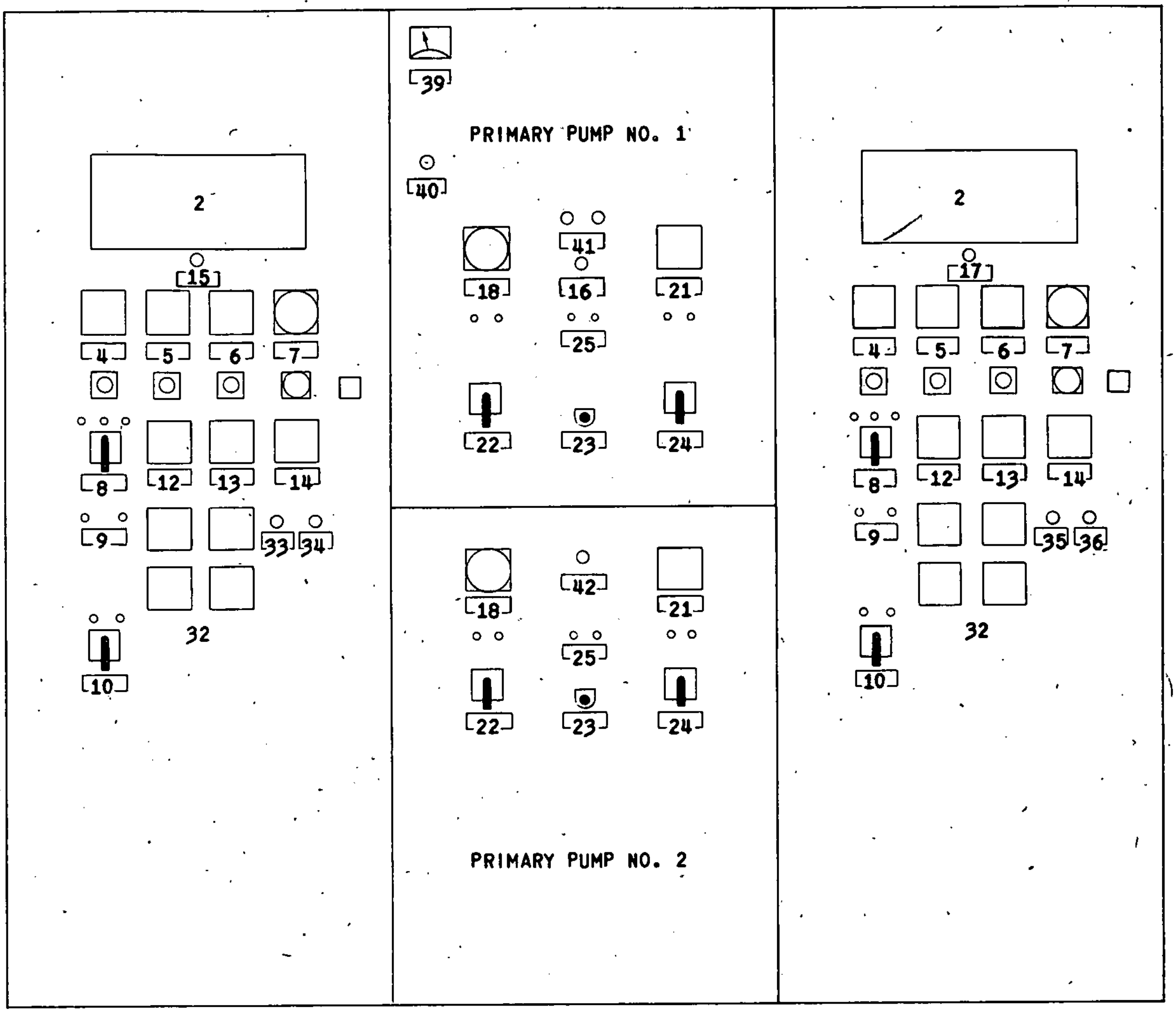
SWITCH DEVELOPMENT
SPRING RETURN TO NORMAL
DEVICE ETS

HTS - HAND TRIP SOLENOID
STD - SOLENOID TRIP DEVICE
CS - CONTROL SWITCH
25X - AUX. TO SYNCHRO CHECK RELAY
32 - REVERSE POWER-RELAY
40 - LOSS OF FIELD RELAY
41 - FIELD CIRCUIT BREAKER
43 - TRANSFER SWITCH
50 - INSTANT. OVERCURRENT RELAY
51 - OVERCURRENT RELAY
52 - CIRCUIT BREAKER
52AX - AUX. TO DEVICE 52
81 - UNDERFREQUENCY RELAY
87 - DIFFERENTIAL RELAY
CPX - REACTOR OPERATING SHUTDOWN AUX. RELAY
86 - LOCKOUT RELAY
ETS - EMERGENCY TRIP SWITCH
33(CBS) - STOP VALVE POSITION SWITCH
43S - SYNCHRONIZING TRANSFER SWITCH
43SA - MAN-AUTO SYNCHRONIZING SWITCH
43M - PILOT WIRE TRIP SELECTOR SWITCH

CONTACTS		CLOSE	AFTER CLOSE	AFTER TRIP	TRIP	PULL OUT
1 – 2	1	X				
	2	X				
3	3				X	
5 – 6	5	X	X	X	X	
	6		X	X		
7	7		X	X		
9 – 10	9			X	X	X
	10	X	X			

SWITCH DEVELOPMENT
SPRING RETURN TO NORMAL
DEVICE CS

Fig. 41. Elementary Diagram of 13.8-kV Generator Breaker



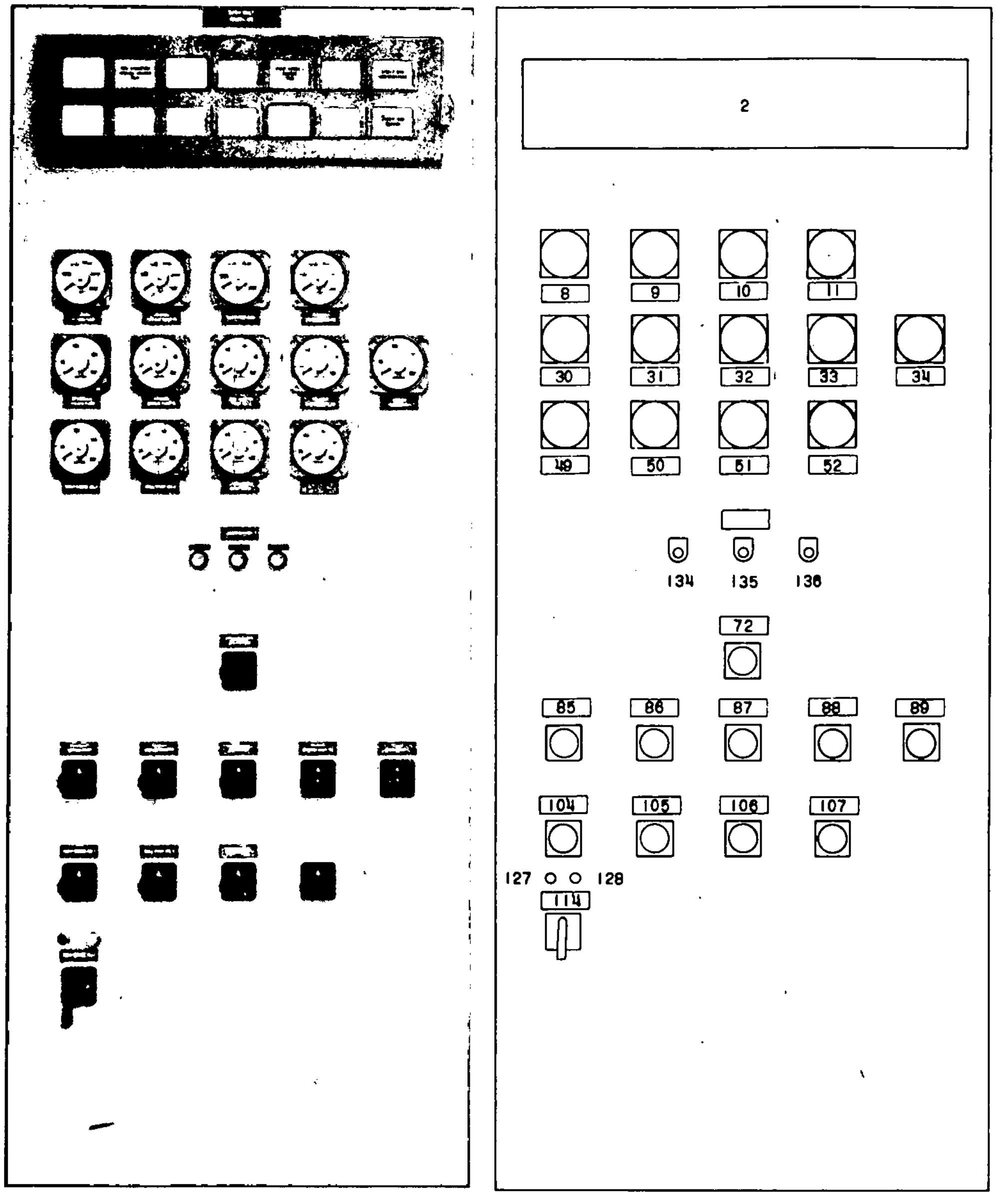
PRIMARY PUMP NO. 1 M-G SET CONTROL PANEL

PUMP CONTROL PANEL

PRIMARY PUMP NO. 2 M-G SET CONTROL PANEL

1. RUNNING HOUR METER - M.G. SET NO. 1
2. RUNNING HOUR METER - M.G. SET NO. 2
3. ANNUNCIATOR
4. M-G MOTOR AMMETER & AMMETER SWITCH
5. GENERATOR VOLTMETER & VOLTMETER SWITCH
6. GENERATOR AMMETER & AMMETER SWITCH
7. GENERATOR FREQUENCY METER
8. MOTOR CONTROL SWITCH & INDICATING LIGHTS
9. GENERATOR BREAKER INDICATING LIGHTS (GREEN, RED)
10. BLOWER CONTROL SWITCH & INDICATING LIGHTS (GREEN, RED)
12. GENERATOR WATTMETER
13. EXCITER AMMETER
14. EXCITER VOLTMETER
15. ANNUNCIATOR RESET & SILENCE
16. REFERENCE VOLTAGE RESET
17. ANNUNCIATOR RESER & SILENCE
18. CLUTCH FIELD AMMETER
21. TACHOMETER
22. CLUTCH EXCITATION CONTROL SWITCH & INDICATING LIGHTS (BLUE, RED)
23. BRAKE RESET PUSHBUTTON
24. CONTROL POWER SUPPLY CONTROL SWITCH & INDICATING LIGHTS (GREEN, RED)
25. SPARE THYRATRON "ON" - INDICATING LIGHTS (CLUTCH RED, BRAKE RED)
32. EDISON MONITORING SYSTEM
33. PUMP MOTOR A Φ UNDERCURRENT (RED INDICATING LIGHT)
34. PUMP MOTOR C Φ UNDERCURRENT (RED INDICATING LIGHT)
35. PUMP MOTOR A Φ UNDERCURRENT (RED INDICATING LIGHT)
36. PUMP MOTOR C Φ UNDERCURRENT (RED INDICATING LIGHT)
37. TOTAL HOURS RUN PUMP NO. 1
38. TOTAL HOURS RUN PUMP NO. 2
39. CLUTCH COOLING WATER DISCHARGE TEMPERATURE
40. WATER DISCHARGE TEMPERATURE SELECTOR
41. PRIMARY PUMPS EXCITATION POWER SUPPLIES - START, STOP
42. TEST LIGHT PANEL

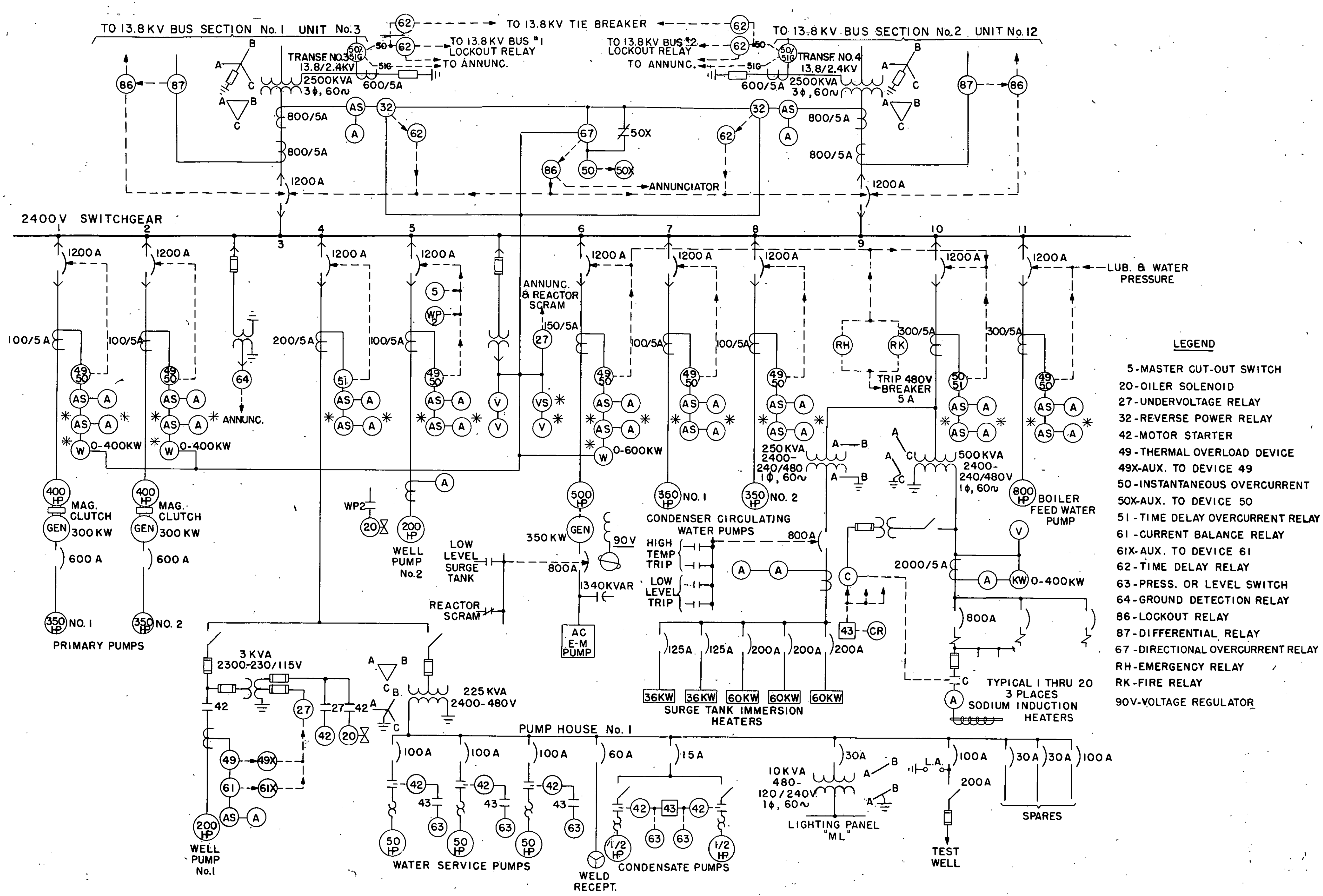
Fig. 42. Primary Pump Control Sections of Corridor Panel



2 - (2400V PANEL ANNUNCIATOR)
8 - SECONDARY PUMP (WATTMETER)
9 - PRIMARY SODIUM PUMP NO. 1 (WATTMETER)
10 - 2400V BUS (VOLTMETER)
11 - PRIMARY SODIUM PUMP NO. 2 (WATTMETER)
30 - SECONDARY SODIUM PUMP (AMMETER)
31 - PRIMARY SODIUM PUMP NO. 1 (AMMETER)
32 - CIRCULATING PUMP NO. 1 (AMMETER)
33 - PRIMARY SODIUM PUMP NO. 2 (AMMETER)
34 - BOILER FEED PUMP (AMMETER)
49 - PUMP HOUSE NO. 1 (AMMETER)
50 - WELL PUMP NO. 2 (AMMETER)
51 - CIRCULATING PUMP NO. 2 (AMMETER)
52 - (SPARE AMMETER)
72 - 2400V BUS (VOLTMETER SWITCH)
85 - SECONDARY Na PUMP (AMMETER SWITCH)
86 - PRIMARY Na PUMP NO. 1 (AMMETER SWITCH)
87 - CIRCULATING PUMP NO. 1 (AMMETER SWITCH)
88 - PRIMARY Na PUMP NO. 2 (AMMETER SWITCH)
89 - BOILER FEED PUMP (AMMETER SWITCH)
104 - PUMP HOUSE NO. 1 (AMMETER SWITCH)
105 - WELL PUMP NO. 2 (AMMETER SWITCH)
106 - CIRCULATING PUMP NO. 2 (AMMETER SWITCH)
107 - INDUCTION HEATING (3W, AMMETER)
114 - PUMP HOUSE NO. 1 (CONTROL SWITCH)
127 - (INDICATING LIGHT - GREEN)
128 - (INDICATING LIGHT - RED)
134 - TEST (PUSHBUTTON - ANNUNCIATOR)
135 - RESET (PUSHBUTTON - ANNUNCIATOR)
136 - SILENCE (PUSHBUTTON - ANNUNCIATOR)

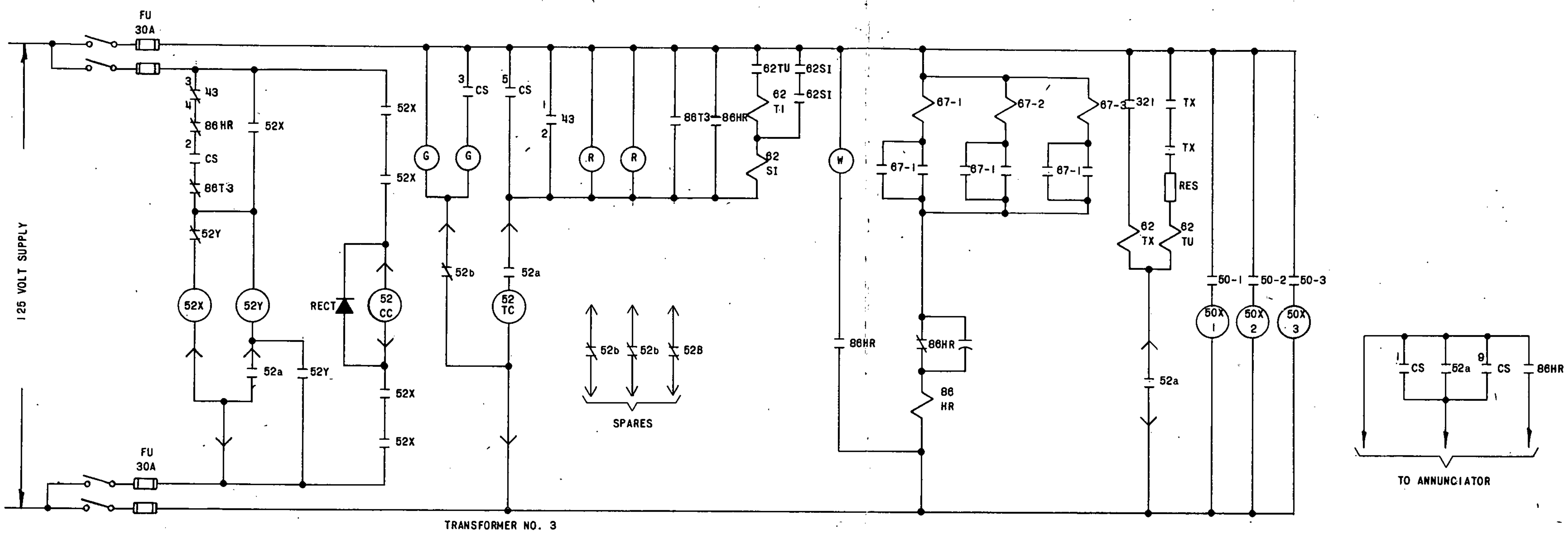
NOTE: DESCRIPTIONS IN PARENTHESIS ( ) NOT ON NAMEPLATES

Fig. 43. 2400-V Electrical Panel E-2

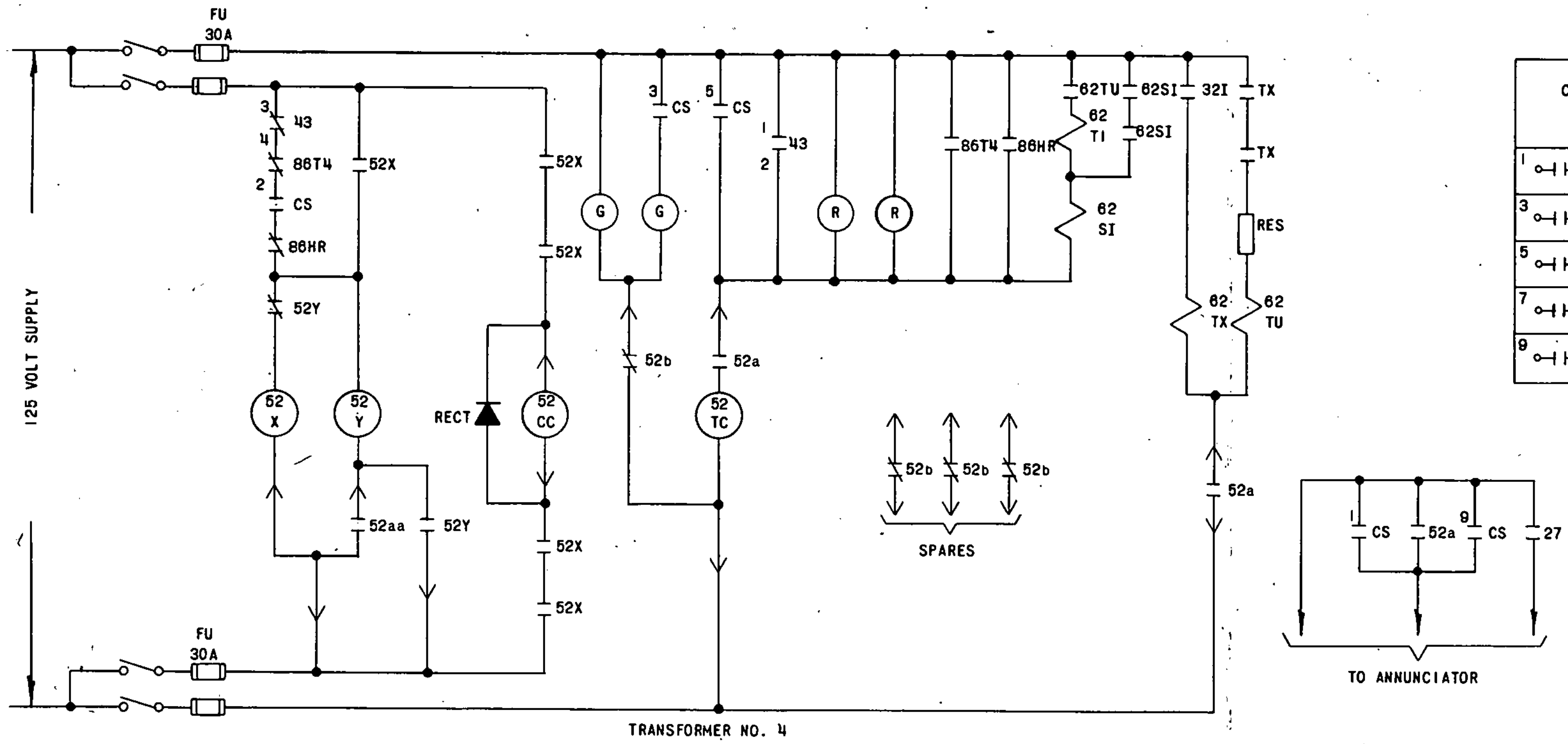


*- LOCATED IN MAIN CONTROL ROOM

Fig. 44. 2400-V Single-line Diagram for Protective Relaying



CS - CONTROL SWITCH
32 - REVERSE POWER RELAY
43 - SELECTOR SWITCH
50 - INSTANT. OVERCURRENT RELAY
52 - AIR CIRCUIT BREAKER
62 - TIME DELAY
67 - DIRECTIONAL OVERCURRENT RELAY
86 - LOCKOUT RELAY



SWITCH DEVELOPMENT DEVICE "CS"

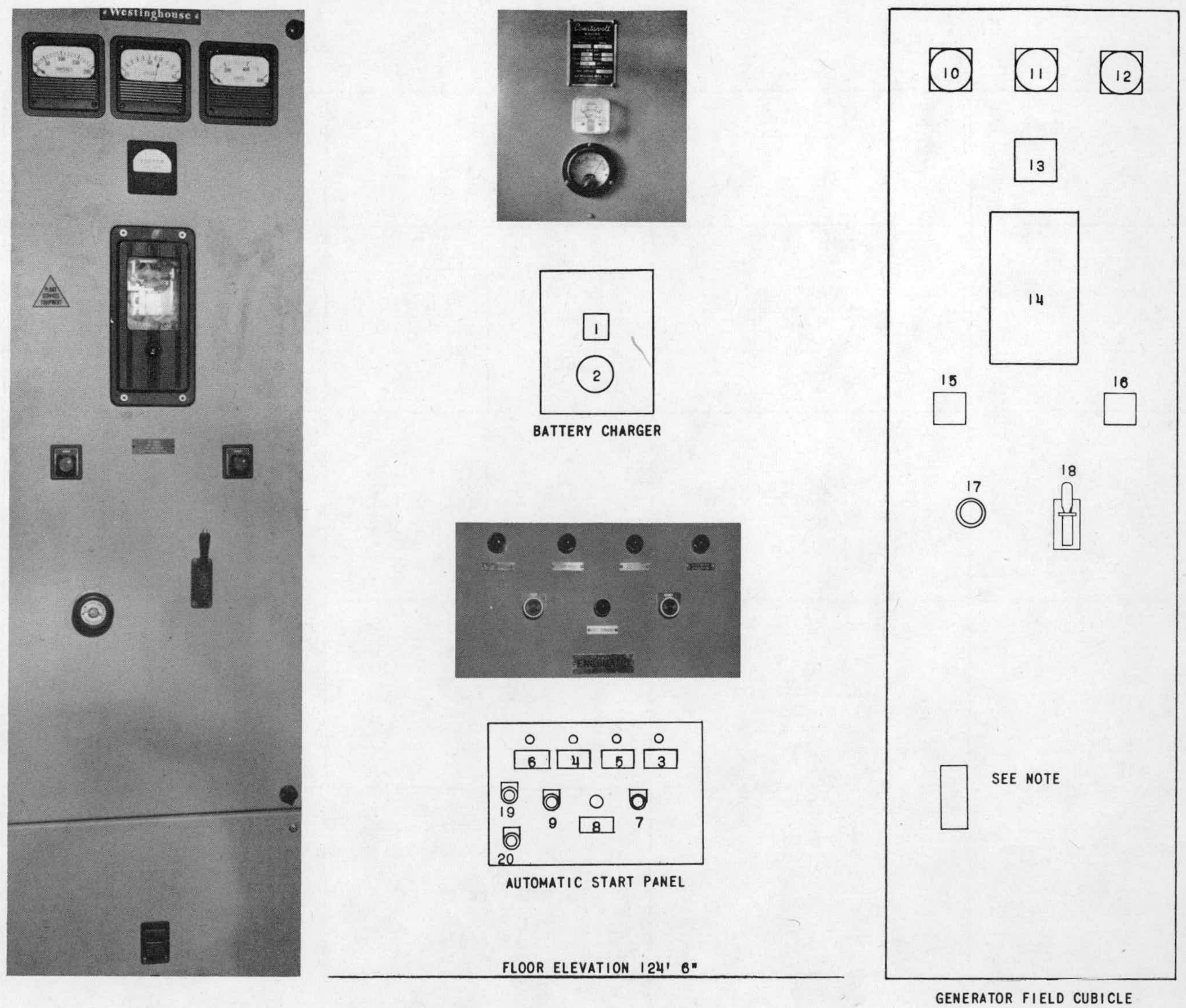
CONTACTS		POSITIONS				
		CLOSE	NORMAL AFTER CLOSE	NORMAL AFTER TRIP	TRIP	PULL OUT
1–2	1	X				
	2	X				
3	3				X	
5–6	5	X	X	X	X	
	6					
7	7		X	X		
9–10	9			X	X	X
	10	X	X			

SPRING RETURN TO NORMAL

SWITCH DEVELOPMENT "43"

CONTACTS	POSITIONS	
	NORMAL	TRIP
1–2		X
3–4	X	
5–6		X
7–8	X	

Fig. 45. Elementary Diagram for 2400-V Circuit Breakers for Transformers No. 3 and 4



1. (AMMETER)
2. (VOLTMETER)
3. HIGH WATER TEMPERATURE (INDICATING LIGHT)
4. OVERSPEED (INDICATING LIGHT)
5. LOW LUBE OIL PRESSURE (INDICATING LIGHT)
6. OVERCRANK (INDICATING LIGHT)
7. RESET ALARM (PUSHBUTTON)
8. UNIT RUNNING (INDICATING LIGHT)
9. TEST (PUSHBUTTON- DIESEL)
10. (AC AMMETER)
11. (FREQUENCY METER)
12. (AC VOLTMETER)
13. (ELAPSED TIME INDICATOR)
14. (VOLTAGE REGULATOR)
15. (AMMETER SWITCH)
16. (VOLTMETER SWITCH)
17. (RHEOSTAT)
18. (FIELD SWITCH)
19. START (PUSHBUTTON)
20. STOP (PUSHBUTTON)

NOTE: 400 KW GENERATOR FIELD CUBICLE EQUIPPED WITH 600A CIRCUIT BREAKER, 100 KW EQUIPPED WITH 200A CIRCUIT BREAKER

Fig. 46. Auxiliary Panels for 100- and 400-kW Diesel-generator Units

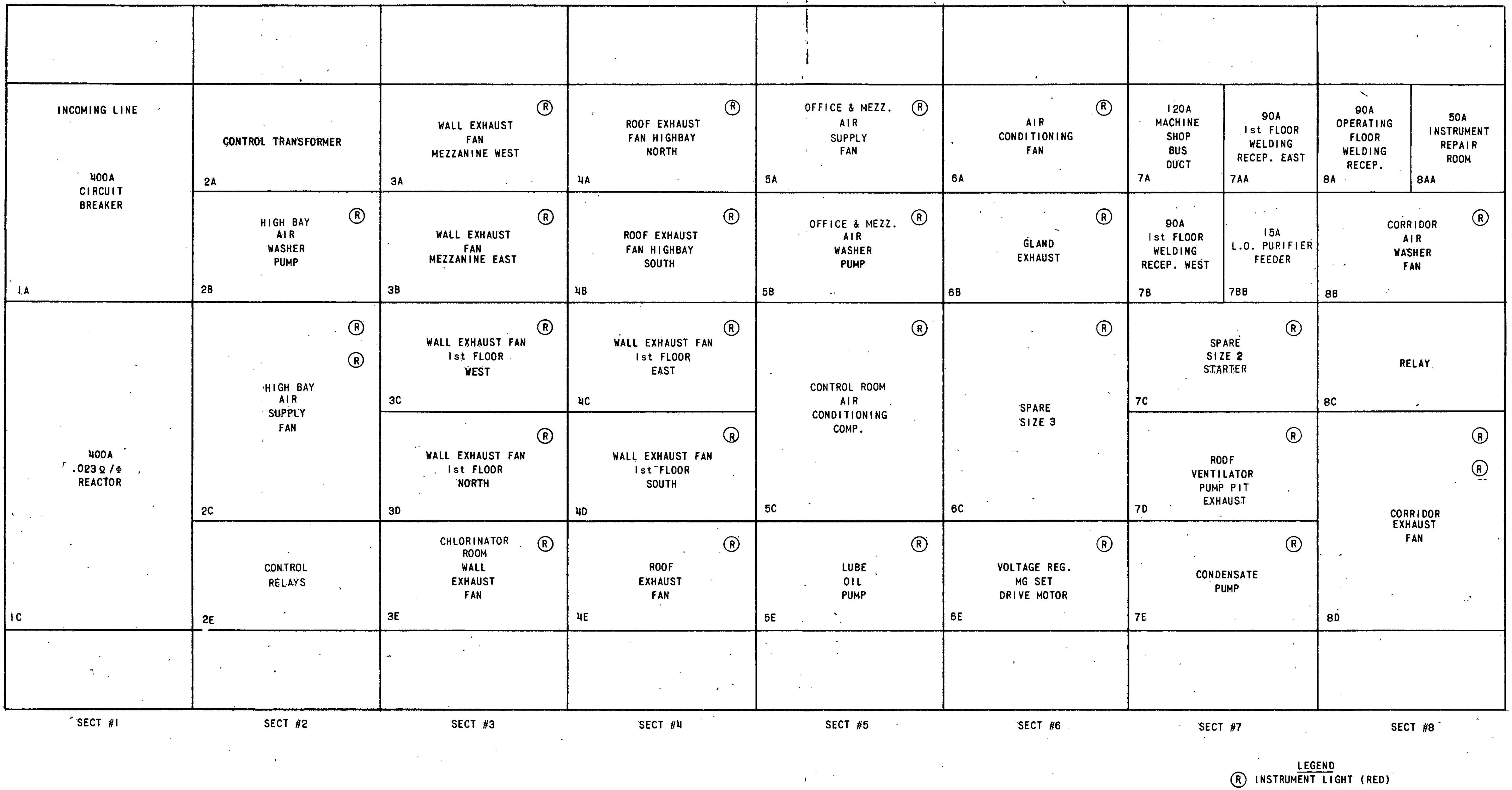
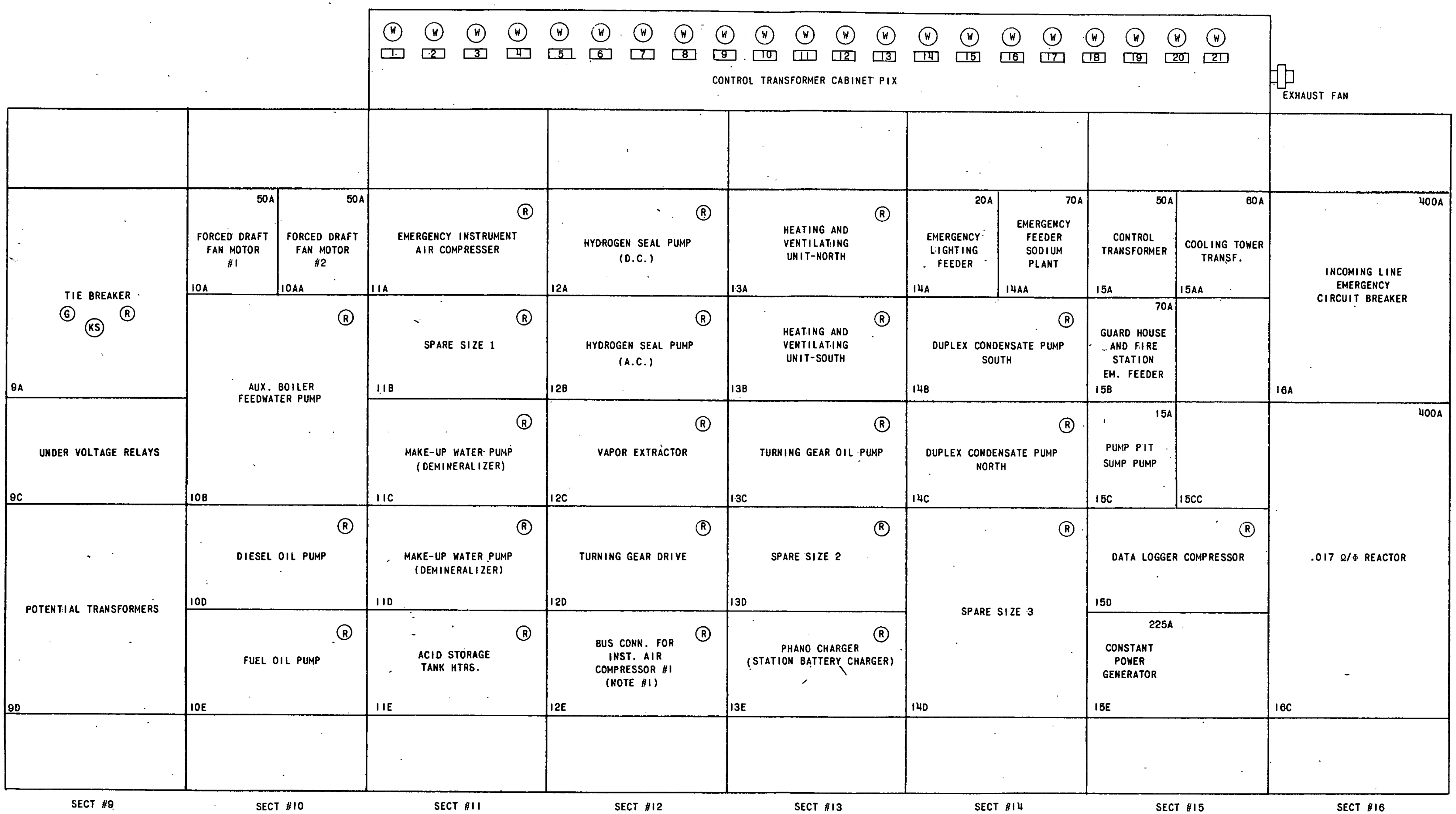


Fig. 47. Normal Bus Section of Motor-control Center P1



NOTES:

1 - POWER CONNECTIONS TO CIRCUIT BKR. AND STARTER IN COMPARTMENT 2A OF M.C.C. P2 FOR INSTR. AIR COMPRESSOR #1

NAME PLATES

1. 6A AIR CONDITIONING FAN
2. 6B GLAND EXHAUST
3. 8B CORRIDOR AIR SUPPLY FAN
4. 10D DIESEL OIL PUMP
5. 10E FUEL OIL PUMP
6. 11A EMERG. INST. AIR COMP.
7. 11C MAKEUP WATER PUMP
8. 11D DEMIN. SERVICE PUMP
9. 11E ACID STORAGE TANK HTRS.
10. 12B HYDROGEN SEAL PUMP (AC)
11. 12C VAPOR EXTRACTOR
12. 12D TURNING GEAR DRIVE
13. 12E
14. 13A H & V UNIT - NORTH
15. 13B H & V UNIT - SOUTH
16. 13C TURNING GEAR OIL PUMP
17. 13D
18. 13E STATION BATTERY CHARGER
19. 14B DUPLEX COND. PUMP - SOUTH
20. 14C DUPLEX COND. PUMP - NORTH
21. 15D DATA LOGGER REFRIG. COMP.

LEGEND

(R) --INDICATING LIGHT (RED)

(G) --INDICATING LIGHT (GREEN)

KS --"AUTO TRANSF. - MAN TRANSFER-TRIP" KEY OPERATED SELECTOR SWITCH

(W) --INDICATING LIGHT (WHITE)

Fig. 48. Emergency Bus Section of Motor-control Center P1

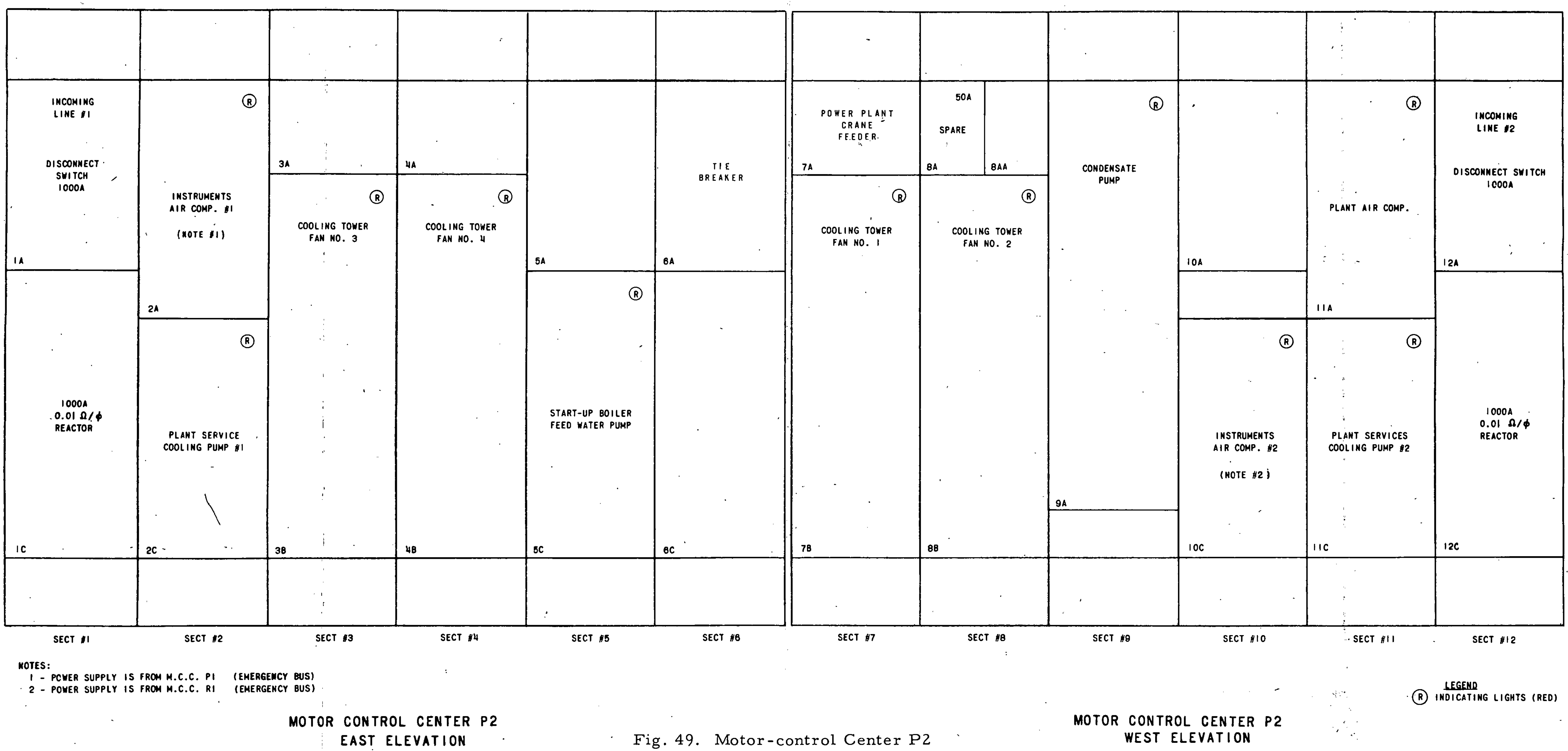


Fig. 49. Motor-control Center P2

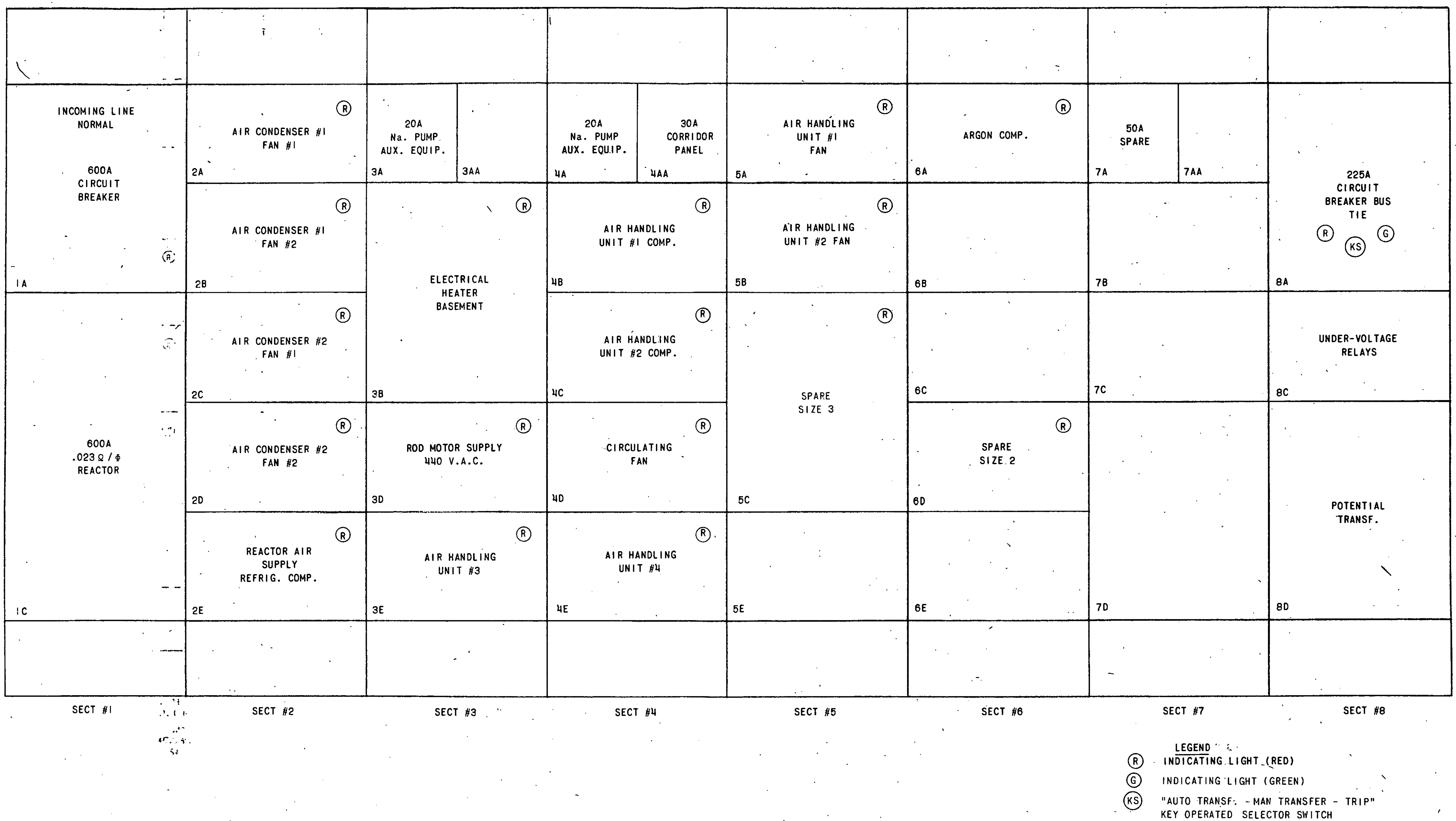
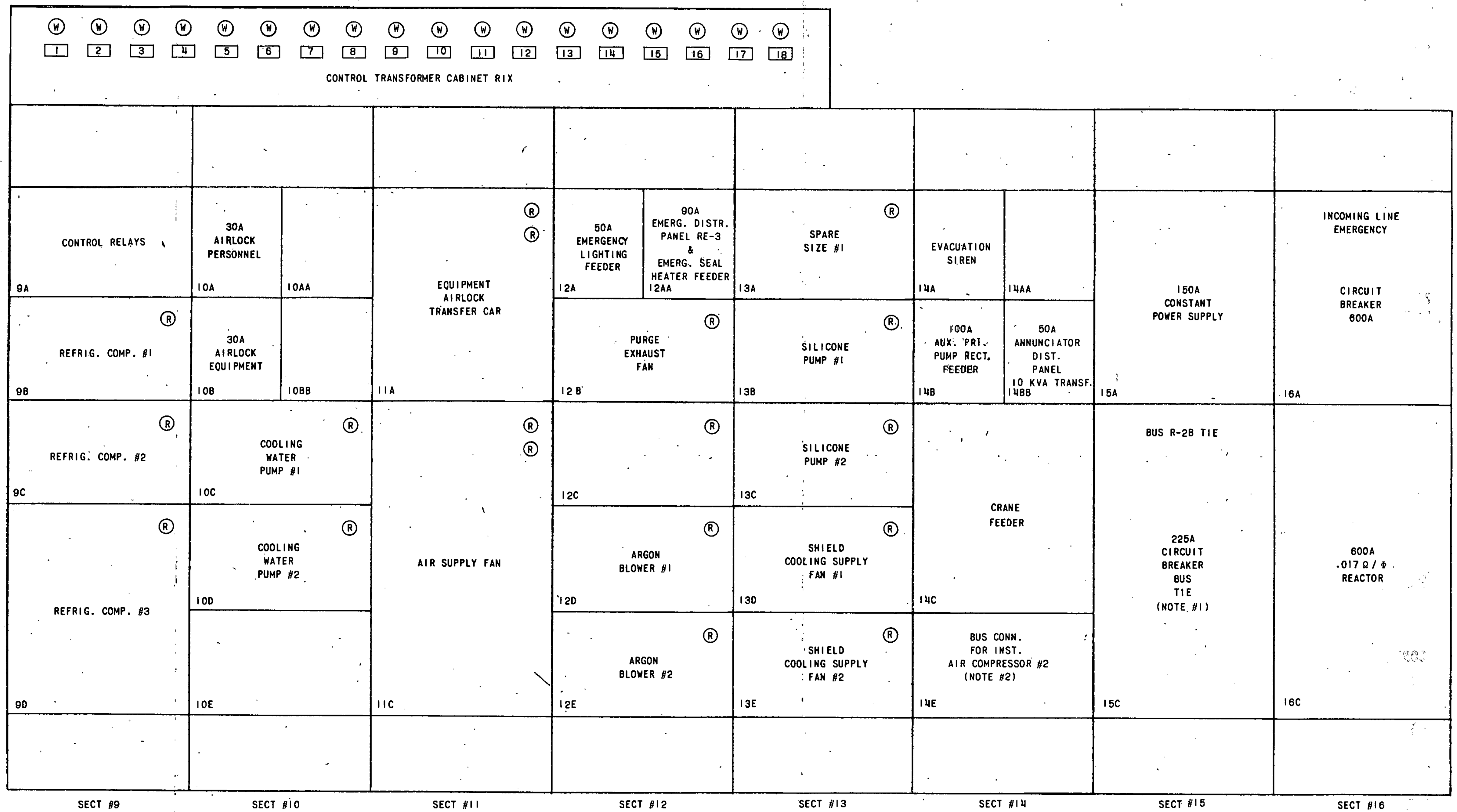


Fig. 50. Normal Bus Section of Motor-control Center R1



NOTES:

1 - HANDLE REMOVED FROM COMPARTMENT AND HUNG ON SOUTH END OF M.C.C. R2

2 - POWER CONNECTIONS TO CIRCUIT BKR. AND STARTER IN COMPARTMENT 10C OF M.C.C. P2 FOR INSTR. AIR COMPRESSOR #2

NAME PLATES

1 - 9B REFRIG. COMP #1
2 - 9C REFRIG. COMP #2
3 - 10C COOLING WATER PUMP #1
4 - 10D COOLING WATER PUMP #2
5 - 12D ARGON BLOWER #1
6 - 12E ARGON BLOWER #2
7 - 13D SHIELD COOLING SUPPLY FAN #1
8 - 13B SILICONE PUMP #1
9 - 13C SILICONE PUMP #2
10 - 4E AIR HANDLING UNIT #4
11 - 3E AIR HANDLING UNIT #3
12 - 4D CIRCULATING FAN
13 - 5B AIR HANDLING UNIT #2 FAN
14 - 4C AIR HANDLING UNIT #2 COMP.
15 - 5A AIR HANDLING UNIT #1 FAN
16 - 4B AIR HANDLING UNIT #1 COMP.
17 - 6A ARGON COMPRESSOR
18 - 11C AIR SUPPLY FAN

LEGEND

Ⓡ INDICATING LIGHT (RED)

Ⓦ INDICATING LIGHT (WHITE)

Fig. 51. Emergency Bus Section of Motor-control Center R1

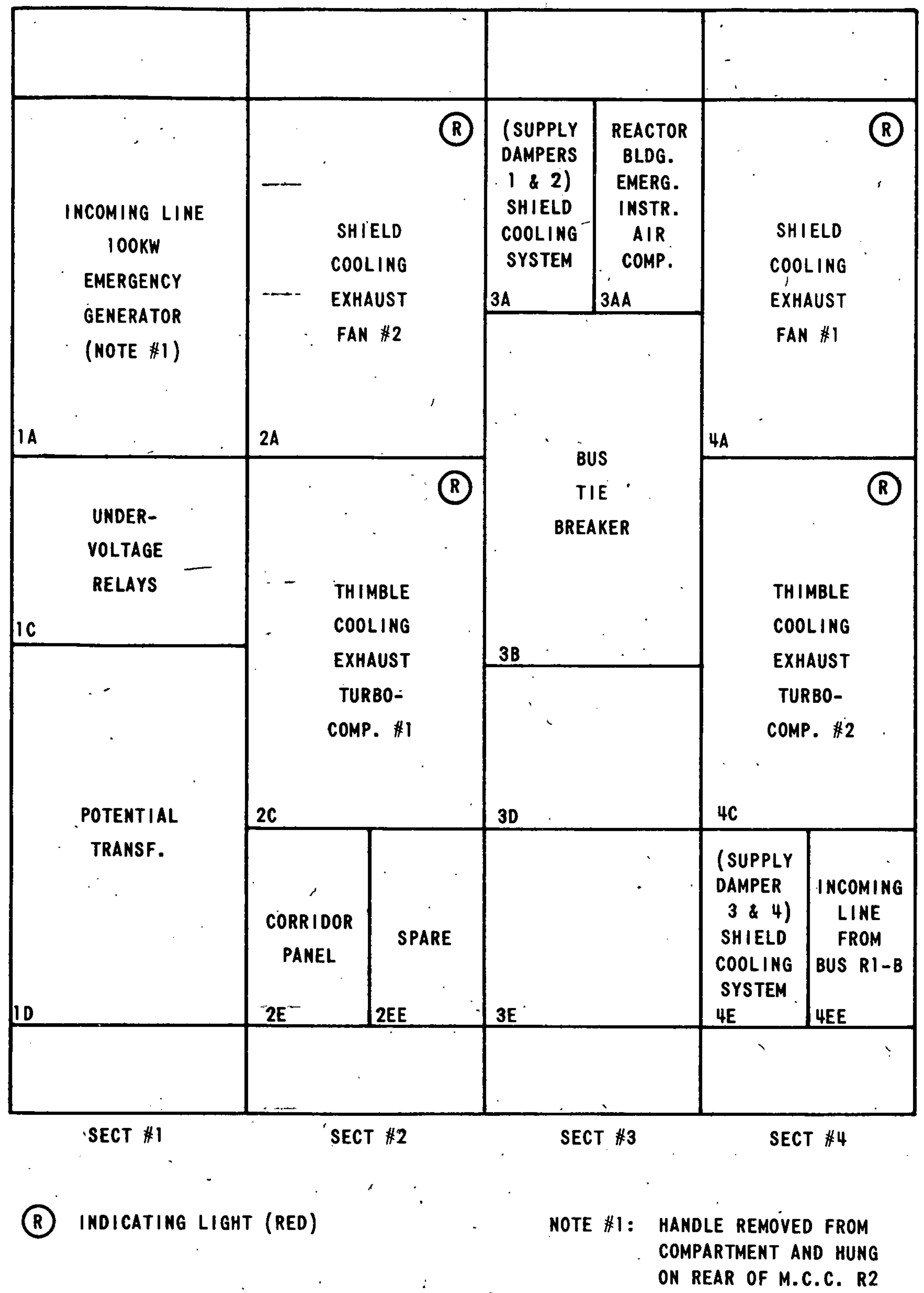
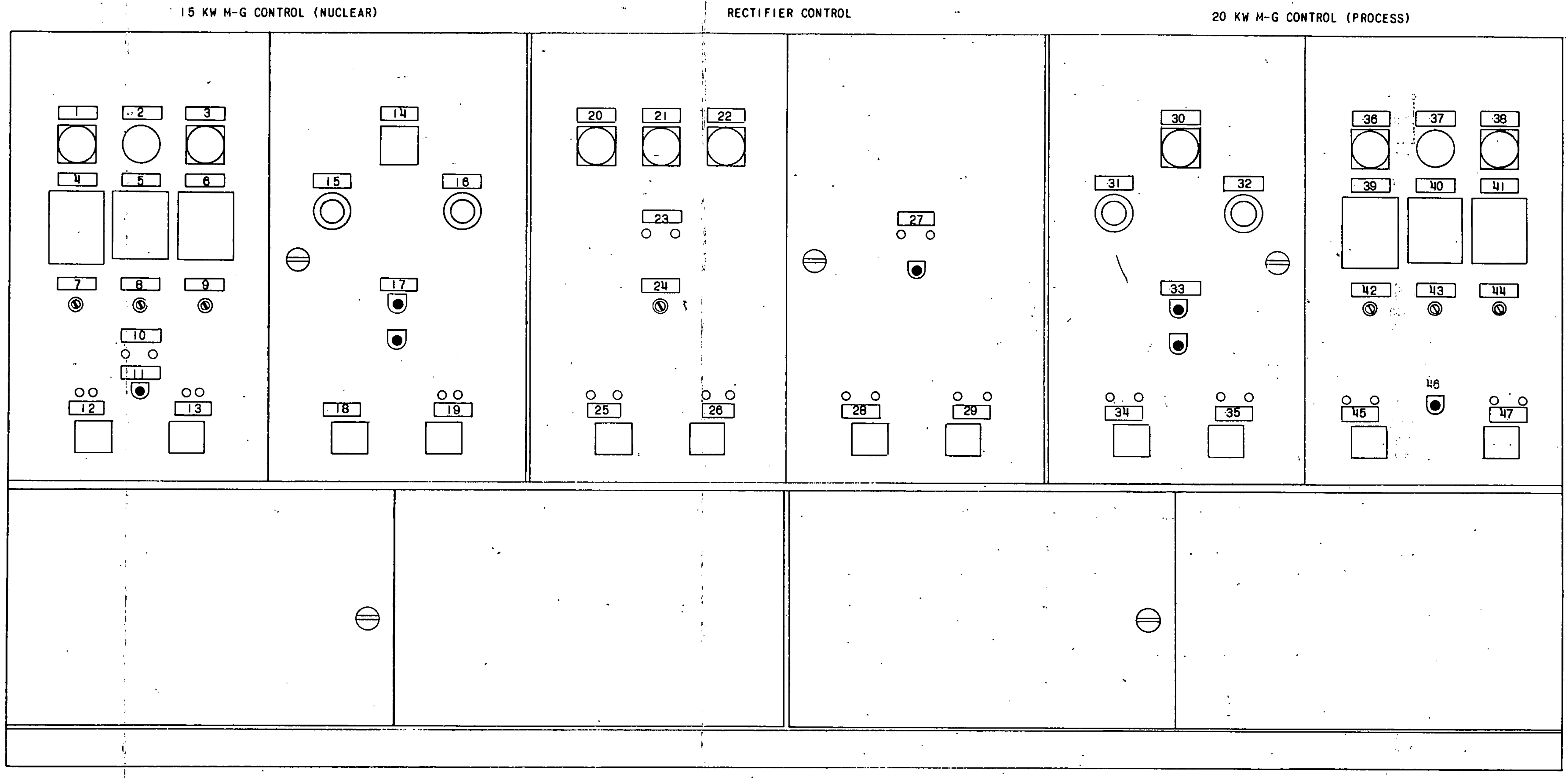


Fig. 52. Motor-control Center R2



1 - ALTERNATOR VOLTMETER
2 - ALTERNATOR FREQUENCY METER
3 - AC OUTPUT AMMETER
4 - UNDERFREQUENCY RELAY
5 - OVERFREQUENCY RELAY
6 - VOLTAGE CHECK RELAY
7 - SPEED REGULATOR ADJUSTMENT SWITCH
8 - REGULATOR CONTROL SWITCH
9 - VOLTAGE REGULATOR ADJUSTMENT SWITCH
10 - OUTPUT GROUND DETECTOR LIGHTS (CLEAR)
11 - RESET PUSHBUTTON (AC UNDERVOLTAGE RELAY)
12 - NORMAL AC OUTPUT CIRCUIT BREAKER & IND. LTS. (RED, GREEN)
13 - AUXILIARY AC OUTPUT CIRCUIT BREAKER & IND. LTS. (RED, GREEN)
14 - MOTOR AMMETER
15 - MOTOR FIELD RHEOSTAT
16 - ALTERNATOR FIELD RHEOSTAT
17 - MOTOR CONTROL PUSHBUTTONS (START, STOP)
18 - CONTROL CIRCUIT BREAKER
19 - MOTOR CIRCUIT BREAKER & IND. LIGHTS (RED, GREEN)
20 - BATTERY AMMETER
21 - RECTIFIER VOLTMETER
22 - RECTIFIER AMMETER
23 - GROUND DETECTOR LIGHTS (CLEAR)
24 - CONTROL VOLTAGE REGULATOR ADJUSTMENT SWITCH
25 - BATTERY CIRCUIT BREAKER & IND. LIGHTS (RED, GREEN)
26 - RECTIFIER CIRCUIT BREAKER & IND. LIGHTS (RED, GREEN)
27 - FAN MOTOR PILOT LIGHTS (RED, GREEN) AND FAN CONTROL SWITCH
28 - AUXILIARY AC INPUT CIRCUIT BREAKER AND IND. LIGHTS (RED, GREEN)
29 - AC INPUT CIRCUIT BREAKER AND IND. LIGHTS (RED, GREEN)
30 - MOTOR AMMETER
31 - MOTOR FIELD RHEOSTAT
32 - ALTERNATOR FIELD RHEOSTAT
33 - MOTOR CONTROL PUSHBUTTONS (START, STOP)
34 - CONTROL CIRCUIT BREAKER
35 - MOTOR CIRCUIT BREAKER AND IND. LIGHTS (RED, GREEN)
36 - ALTERNATOR VOLTMETER
37 - ALTERNATOR FREQUENCY METER
38 - AC OUTPUT AMMETER
39 - VOLTAGE CHECK RELAY
40 - OVERFREQUENCY RELAY
41 - UNDERFREQUENCY RELAY
42 - VOLTAGE REGULATOR ADJUSTMENT SWITCH
43 - REGULATOR CONTROL SWITCH
44 - SPEED REGULATOR ADJUSTMENT SWITCH
45 - NORMAL AC OUTPUT CIRCUIT BREAKER AND IND. LTS. (RED, GREEN)
46 - RESET PUSHBUTTON (AC UNDERVOLTAGE RELAY)
47 - AUXILIARY AC OUTPUT CIRCUIT BREAKER AND IND. LIGHTS (RED, GREEN)

Fig. 53. 120-V A.C. Continuous Power Supply Assembly.

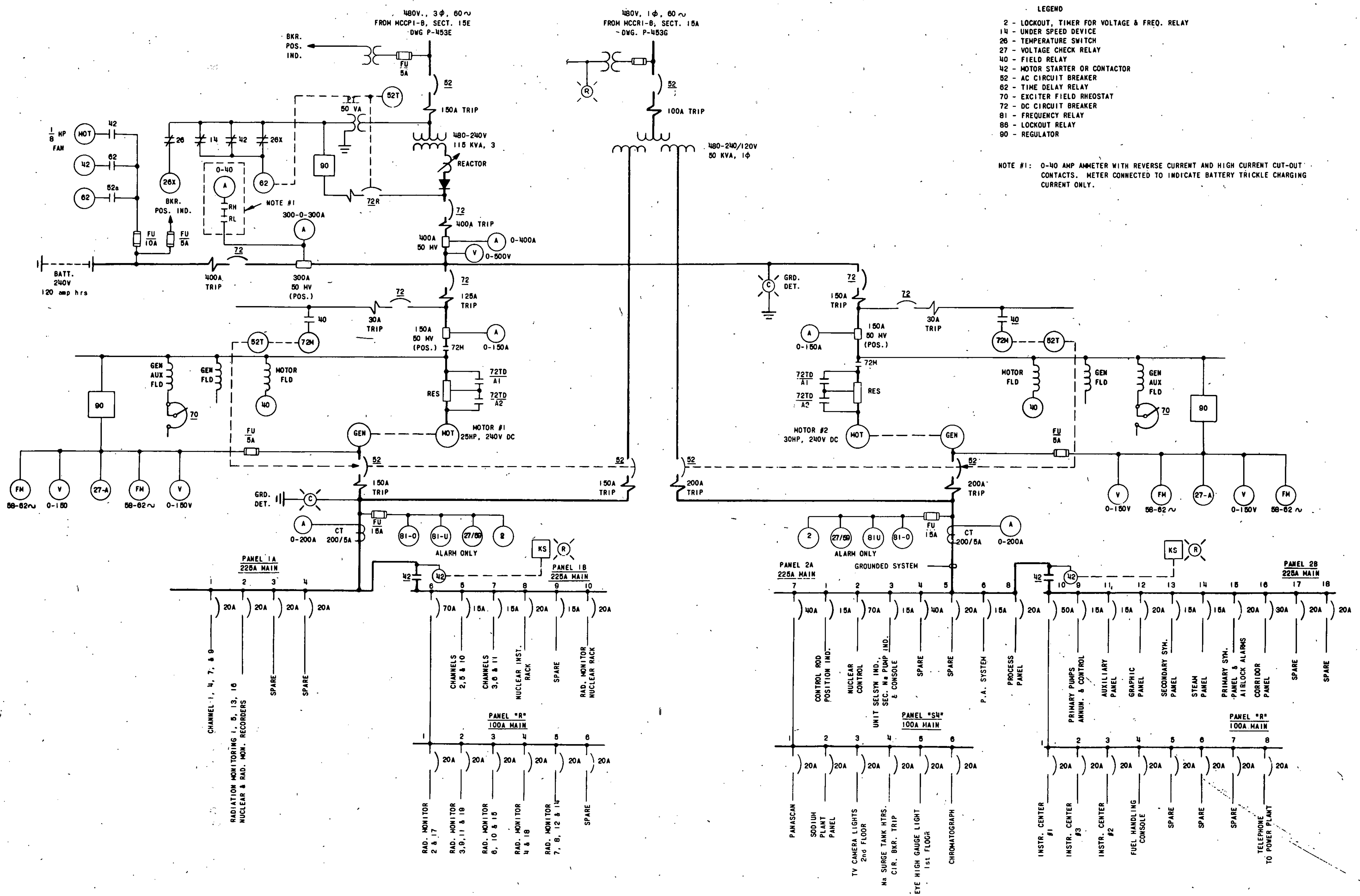
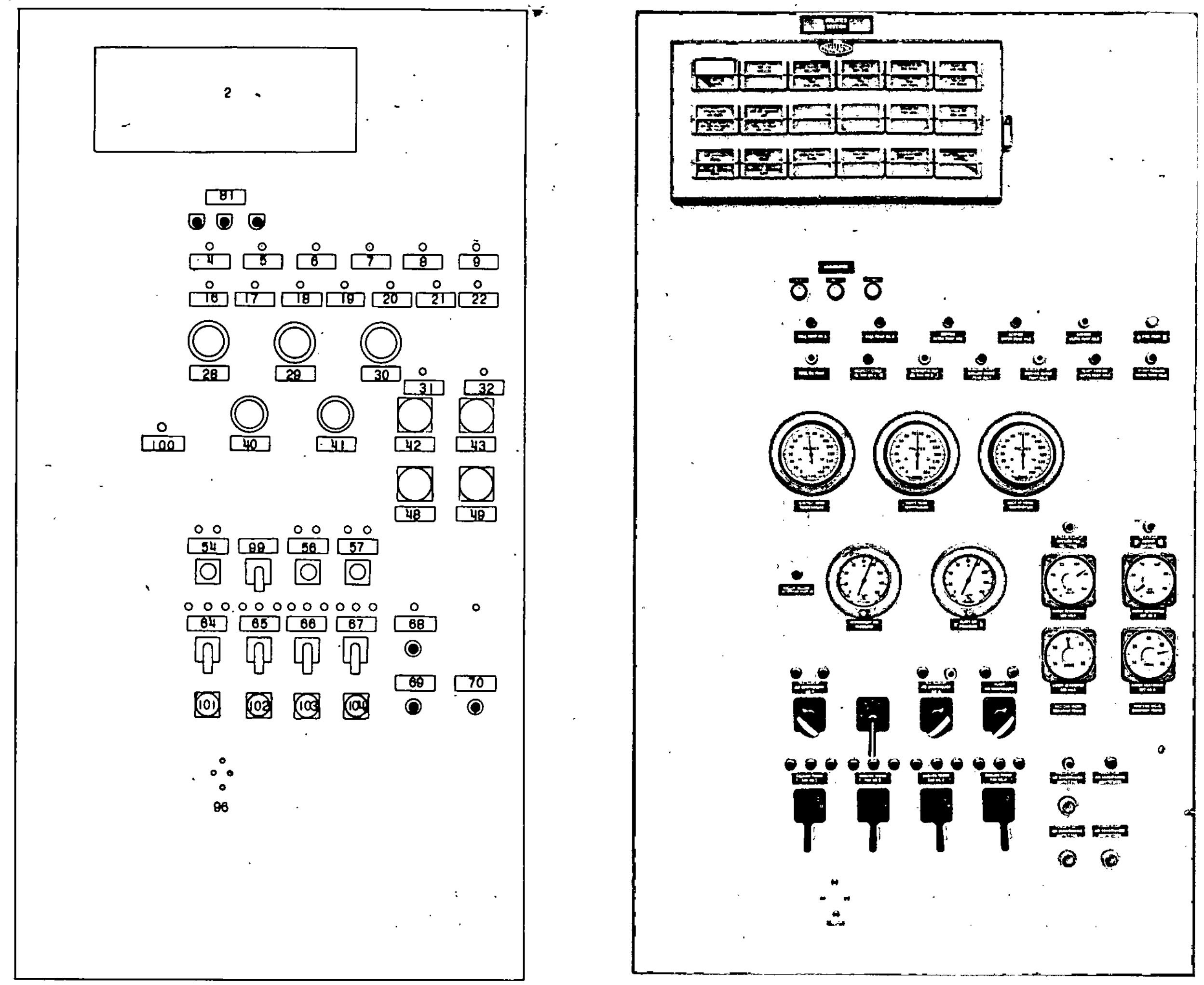
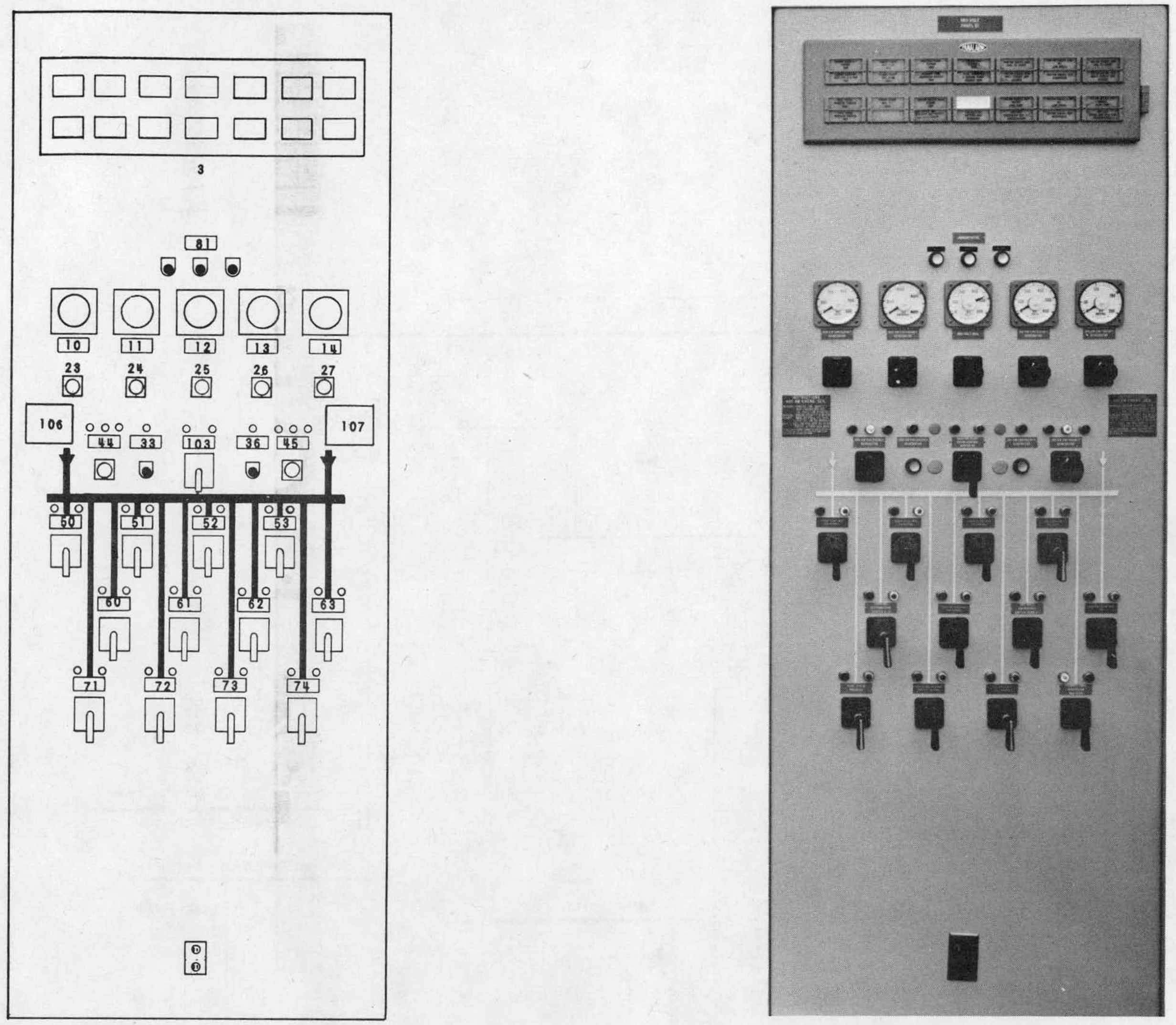


Fig. 54. Single-line Diagram for the Continuous Power Supply Distribution



2 - UTILITY SECTION ANNUNCIATOR
4 - WELL PUMP NO. 1 INDICATING LIGHT (RED)
5 - WELL PUMP NO. 2 INDICATING LIGHT (RED)
6 - SERVICE WATER PUMPS NO. 1 INDICATING LIGHT (RED)
7 - SERVICE WATER PUMPS NO. 2 INDICATING LIGHT (RED)
8 - SERVICE WATER PUMPS NO. 3 INDICATING LIGHT (RED)
9 - FIRE PUMP INDICATING LIGHT (RED)
16 - FUEL OIL PUMP INDICATING LIGHT (RED)
17 - SUSPECT STACK FAN NO. 1 INDICATING LIGHT (RED)
18 - SUSPECT STACK FAN NO. 2 INDICATING LIGHT (RED)
19 - REACTOR PLANT AUXILIARY CW PUMP NO. 1 INDICATING LIGHT (RED)
20 - REACTOR PLANT AUXILIARY CW PUMP NO. 2 INDICATING LIGHT (RED)
21 - PLANT COOLING WATER PUMP NO. 1 INDICATING LIGHT (RED)
22 - PLANT COOLING WATER PUMP NO. 2 INDICATING LIGHT (RED)
28 - CONTROL ROOM TEMPERATURE
29 - CABLE ROOM TEMPERATURE
30 - BACK OF PANEL TEMPERATURE
31 - 3Φ SUPPLY BREAKER TO RECTIFIER INDICATING LIGHT (RED)
32 - RECTIFIER OUTPUT BREAKER INDICATOR LIGHT (RED)
40 - INSTRUMENT AIR PRESSURE
41 - PLANT AIR PRESSURE
42 - MOTOR GENERATOR SET NO. 1 VOLTMETER
43 - MOTOR GENERATOR SET NO. 2 VOLTMETER
48 - MOTOR GENERATOR SET NO. 1 FREQUENCY METER
49 - MOTOR GENERATOR SET NO. 2 FREQUENCY METER
54 - INSTRUMENT AIR COMPRESSOR NO. 1 CONTROL SWITCH
56 - INSTRUMENT AIR COMPRESSOR NO. 2 CONTROL SWITCH
57 - PLANT AIR COMPRESSOR CONTROL SWITCH
64 - COOLING TOWER FAN NO. 1 SELECTOR SWITCH AND INDICATING LIGHTS (RED)
65 - COOLING TOWER FAN NO. 2 SELECTOR SWITCH AND INDICATING LIGHTS (RED)
66 - COOLING TOWER FAN NO. 3 SELECTOR SWITCH AND INDICATING LIGHTS (RED)
67 - COOLING TOWER FAN NO. 4 SELECTOR SWITCH AND INDICATING LIGHTS (RED)
68 - AIR CONDITIONING FAN PUSHBUTTON START
69 - AIR CONDITIONING FAN PUSHBUTTON STOP
70 - AIR CONDITIONING COMPRESSOR PUSH BUTTON STOP AND INDICATING LIGHT (RED)
81 - ANNUNCIATOR PUSHBUTTONS
96 - PHONE JACK
99 - INSTRUMENT AIR COMPRESSOR SELEFTOR SWITCH
100 - REACTOR BLDG. AUX. INST. AIR COMP. ON - INDICATING LIGHT
101 - RUNNING HOUR METER C-TWR-FAN NO. 1
102 - RUNNING HOUR METER C-TWR-FAN NO. 2
103 - RUNNING HOUR METER C-TWR-FAN NO. 3
104 - RUNNING HOUR METER C-TWR-FAN NO. 4

Fig. 55. Utilities Control Panel



3 - (480 PANEL ANNUNCIATOR)
10 - 400 KW EMERGENCY GENERATOR (VOLTMETER)
11 - 400 KW EMERGENCY GENERATOR (AMMETER)
12 - 480V BUS (VOLTMETER)
13 - 100 KW EMERGENCY GENERATOR (VOLTMETER)
14 - 100 KW EMERGENCY GENERATOR (AMMETER)
23 - (400 KW EMERGENCY GENERATOR VOLTMETER SWITCH)
24 - (400 KW EMERGENCY GENERATOR AMMETER SWITCH)
25 - (480V BUS VOLTMETER SWITCH)
26 - (100 KW EMERGENCY GENERATOR VOLTMETER SWITCH)
27 - (100 KW EMERGENCY GENERATOR AMMETER SWITCH)
33 - 400 KW EMERGENCY GENERATOR (START PUSHBUTTON & INDICATING LIGHT - RED)
36 - 100 KW EMERGENCY GENERATOR (START PUSHBUTTON & INDICATING LIGHT - RED)
44 - 400 KW EMERGENCY GENERATOR (CONTROL SELECTOR SWITCH & INDICATING LIGHTS - RED, AMBER & GREEN)
45 - 100 KW EMERGENCY GENERATOR (CONTROL SELECTOR SWITCH & INDICATING LIGHTS - RED, AMBER & GREEN)
50 - POWER PLANT MCC P2A - NORMAL (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
51 - POWER PLANT MCC P1A-NORMAL (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
52 - POWER PLANT MCC P2B-NORMAL (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
53 - LABORATORY & SERVICE BUILDING (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
60 - LIGHTING DISTRIBUTION CENTER E-2 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
61 - REACTOR PLANT MCC R1A-NORMAL (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
62 - 480V EMERGENCY SWITCHGEAR E-1 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
63 - REACTOR PLANT MCC R-3 (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
71 - FUEL CYCLE PROCESS (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN) (BUS DUCT)
72 - SODIUM BOILER PLANT MCC S1A-NORMAL (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
73 - FUEL CYCLE MCC F1A-NORMAL (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
74 - PRI. TANK IMMERSION HEATERS (CONTROL SWITCH & INDICATING LIGHTS - RED & GREEN)
81 - ANNUNCIATOR, TEST-RESET-SILENCE (PUSHBUTTONS)
103 - REACTOR PLANT MCC-R2 (FEEDER CONTROL SWITCH AND INDICATING LIGHTS - RED & GREEN
106 - INSTRUCTIONS - 400 KW EMERG. GEN.
107 - INSTRUCTIONS - 100 KW EMERG. GEN.

NOTE: DESCRIPTIONS IN PARENTHESIS ( ) NOT ON NAMEPLATES.

Fig. 56. 480-V Electrical Control Panel E-1

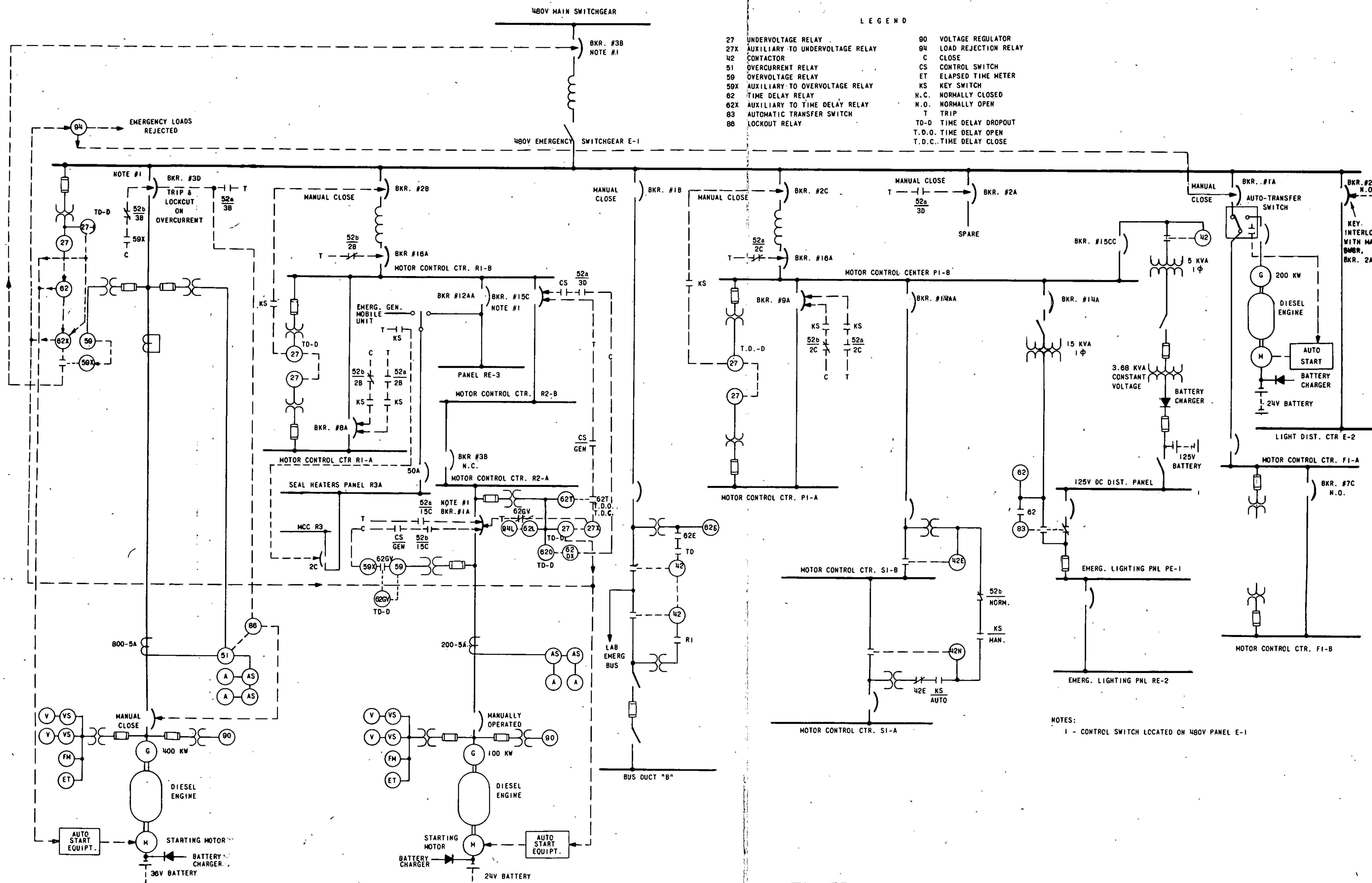


Fig. 57. Single-line Diagram for 480-V Emergency Power System

LEGEND

27 - UNDERVOLTAGE RELAY (GEN)
27x- AUXILIARY TO UNDERVOLTAGE RELAY
52 - OIL CIRCUIT BREAKER
59 - OVERVOLTAGE RELAY
59x- AUXILIARY TO OVERVOLTAGE RELAY
CS CONTROL SWITCH
CR CONTROL RELAY
TDR TIME DELAY RELAY
WTS WATER TEMPERATURE SWITCH
OPS OIL PRESSURE SWITCH
OSS OVERSPEED SWITCH
SM STARTING MOTOR
FU FUSE
62L TIME DELAY RELAY (MCC R2 BUS LOSS OF VOLTAGE)
62D TIME DELAY RELAY (MCC R2 BUS LOSS OF VOLTAGE)
62GV TIME DELAY RELAY (GENERATOR LOSS OF VOLTAGE)
62T TIME DELAY RELAY (MCC R2 BUS RELAY)
T.D.O. TIME DELAY OPEN
T.D.C. TIME DELAY CLOSE

CONTROL SWITCH (CS)

CONTACTS		POSITIONS: CLOSE	NORMAL: AFTER CLOSE	NORMAL: AFTER TRIP	TRIP	PULL OUT
1–2	1	X				
	2	X				
3	3				X	
5–6	5	X	X	X	X	
	6					
7	7		X	X		
9–10	9			X	X	X
	10	X	X			

SPRING RETURN TO NORMAL FROM CLOSE AND TRIP

EMERGENCY GENERATOR CONTROL SWITCH CS GEN

CONTACTS HANDLE END		POSITIONS: MANUAL	STANDBY	OFF
1–2	1			X
	2	X	X	
3–4	3			X
	4		X	
5–6	5	X		
	6	X		
7–8	7			X
	8	X	X	

SPRING RETURN FROM NORMAL TO STANDBY

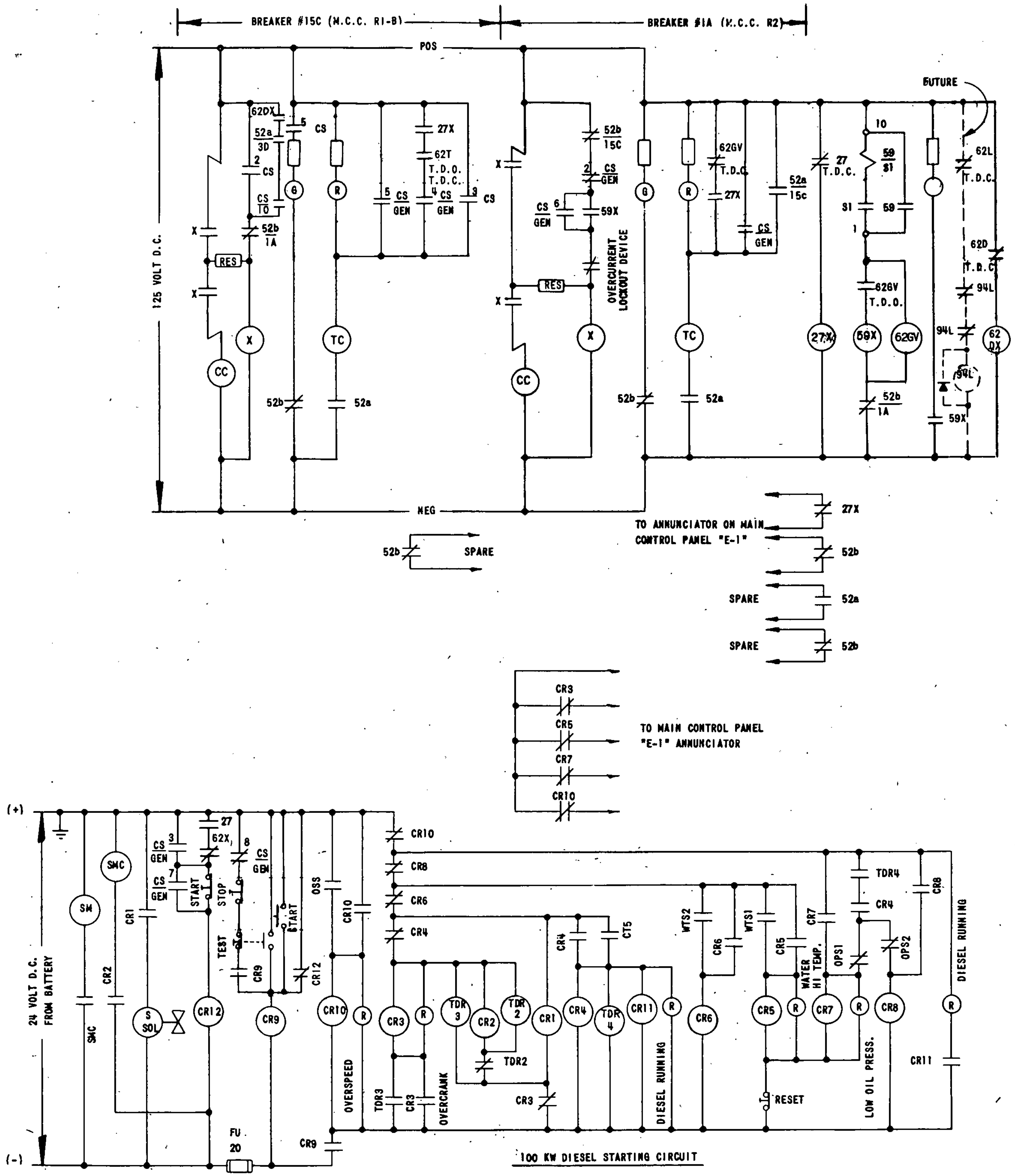
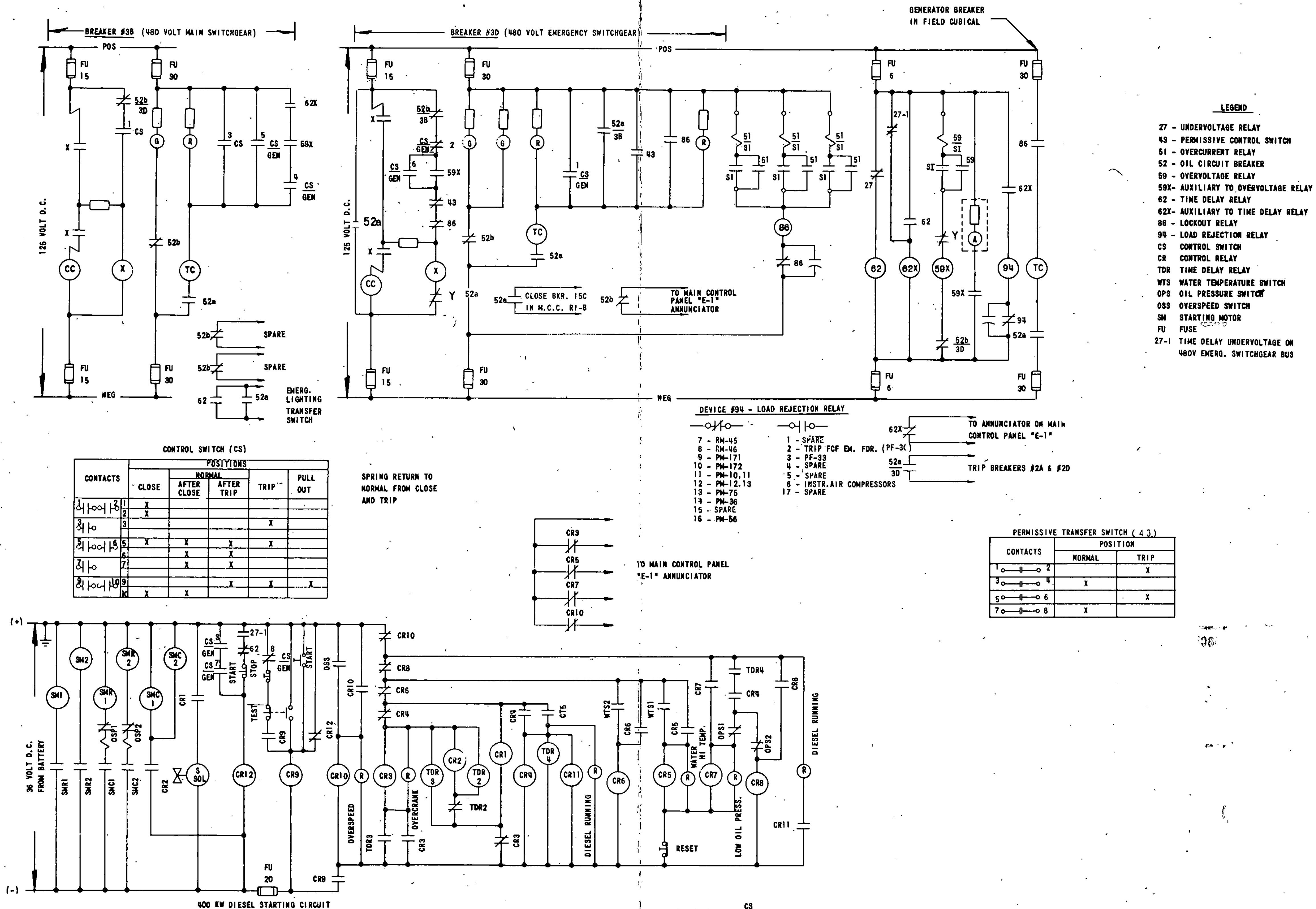


Fig. 58. Elementary Diagram for 100-kW Emergency Diesel-generator



CONTROL SWITCH (CS)

CONTACTS		POSITIONS: CLOSE	NORMAL: AFTER CLOSE	NORMAL: AFTER TRIP	TRIP	PULL OUT
1–2	1	X				
	2	X				
3	3				X	
5–6	5	X	X	X	X	
	6		X	X		
7	7		X	X		
9–10	9			X	X	X
	10	X	X			

PERMISSIVE TRANSFER SWITCH (43)

CONTACTS	POSITION: NORMAL	POSITION: TRIP
1–2		X
3–4	X	
5–6		X
7–8	X	

EMERGENCY GENERATOR CONTROL SWITCH CS/GEN

CONTACTS HANDLE END		POSITIONS: MANUAL	STANDBY	OFF
1–2	1			X
	2	X	X	
3–4	3			X
	4		X	
5–6	5	X		
	6	X		
7–8	7			X
	8	X	X	

Fig. 59. Elementary Diagram for 400-kW Emergency Diesel-generator

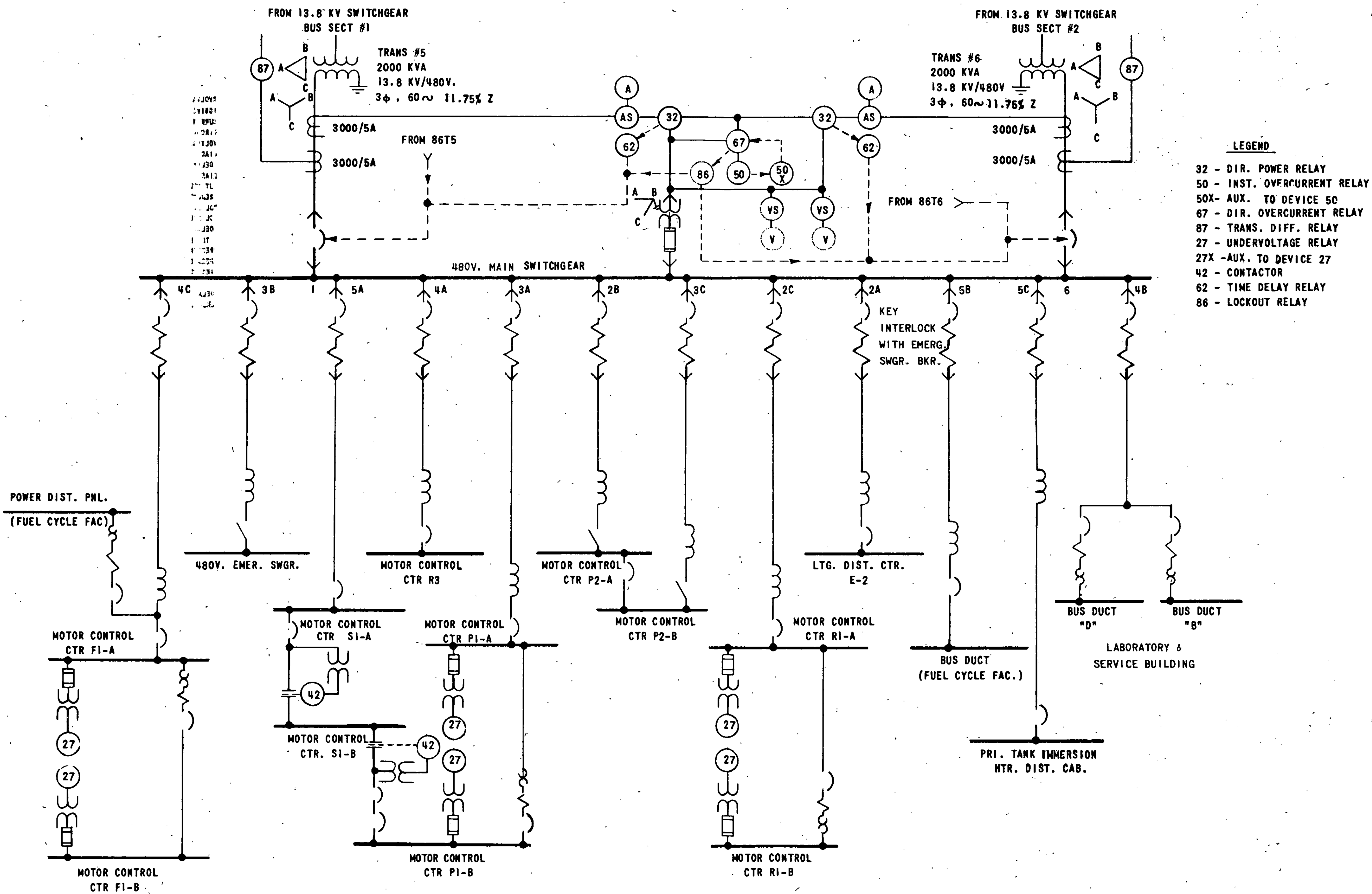
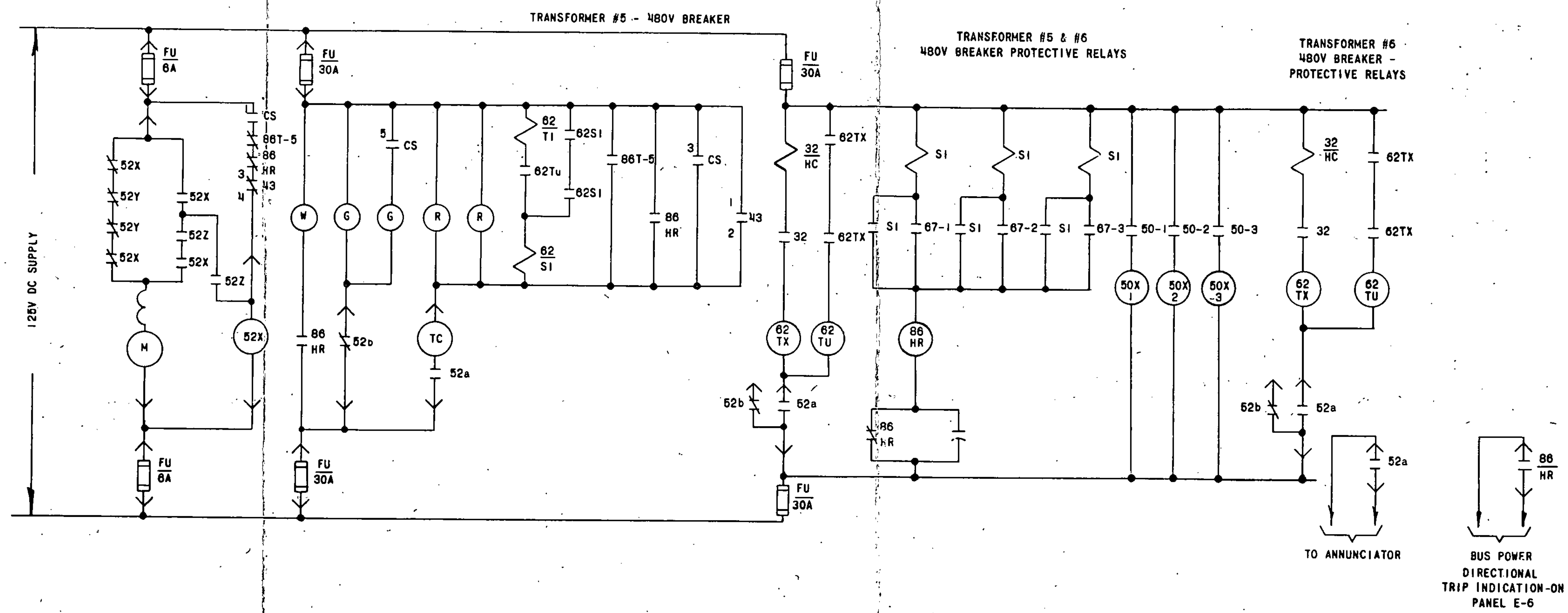
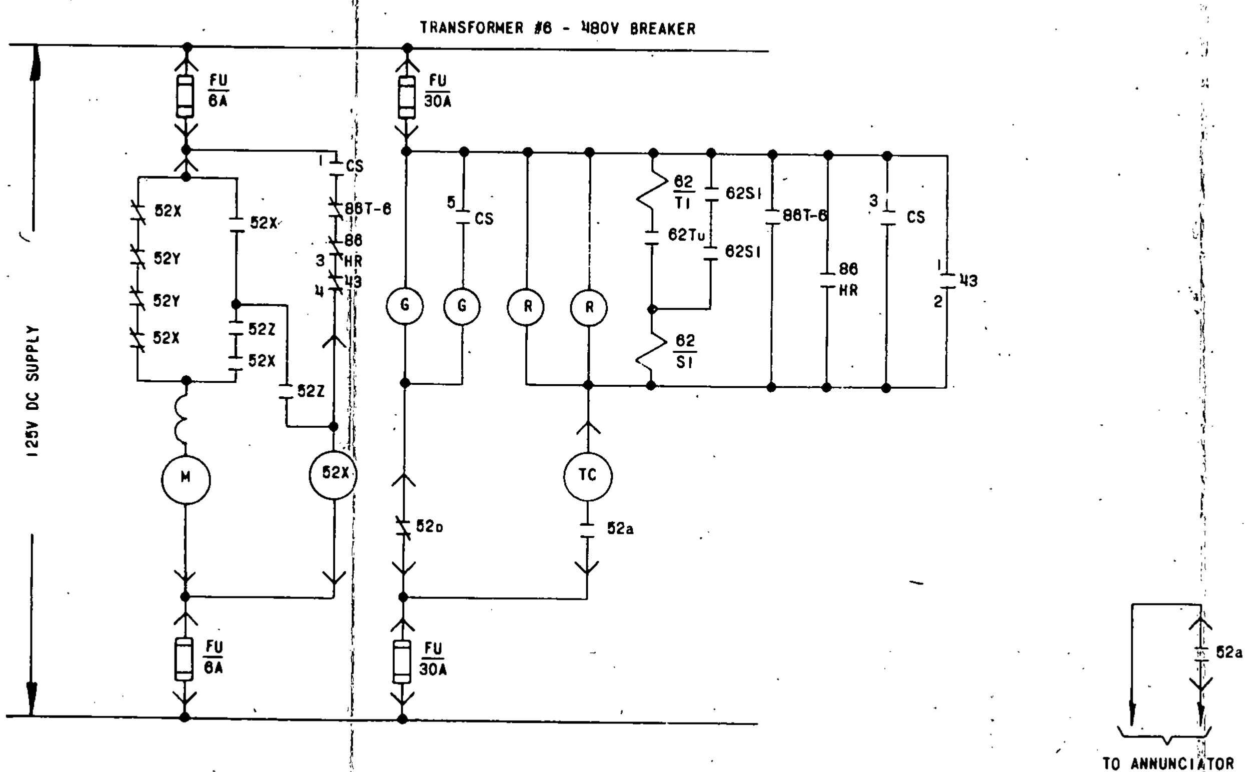


Fig. 60. Single-line Diagram for 480-V Normal Power System





CIRCUIT BREAKER CONTROL
SWITCH DEVELOPMENT DEVICE "CS"

CONTACTS		POSITIONS				
		CLOSE	NORMAL AFTER CLOSE	NORMAL AFTER TRIP	TRIP	PULL OUT
1–2	1	X				
	2	X				
3	3				X	
5–6	5	X	X	X	X	
	6		X	X		
7	7		X	X		
9–10	9			X	X	X
	10	X	X			

SPRING RETURN TO NORMAL

PERMISSIVE CONTROL
SWITCH DEVELOPMENT "43"

CONTACTS		POSITIONS NORMAL	POSITIONS TRIP
1–2			X
3–4		X	
5–6			X
7–8		X	

CS - CONTROL SWITCH
SI - SEAL-IN RELAY
32 - REVERSE POWER RELAY
43 - PERMISSIVE TRANSFER SWITCH
50 - SHORT CIRCUIT SELECTIVE RELAY
52 - AIR CIRCUIT BREAKER
62 - TIME DELAY RELAY
67 - DIRECTIONAL OVERCURRENT RELAY
86 - LOCKOUT AUXILIARY RELAY

Fig. 61. Elementary Diagram for 480-V Breakers for Transformers No. 5 and 6

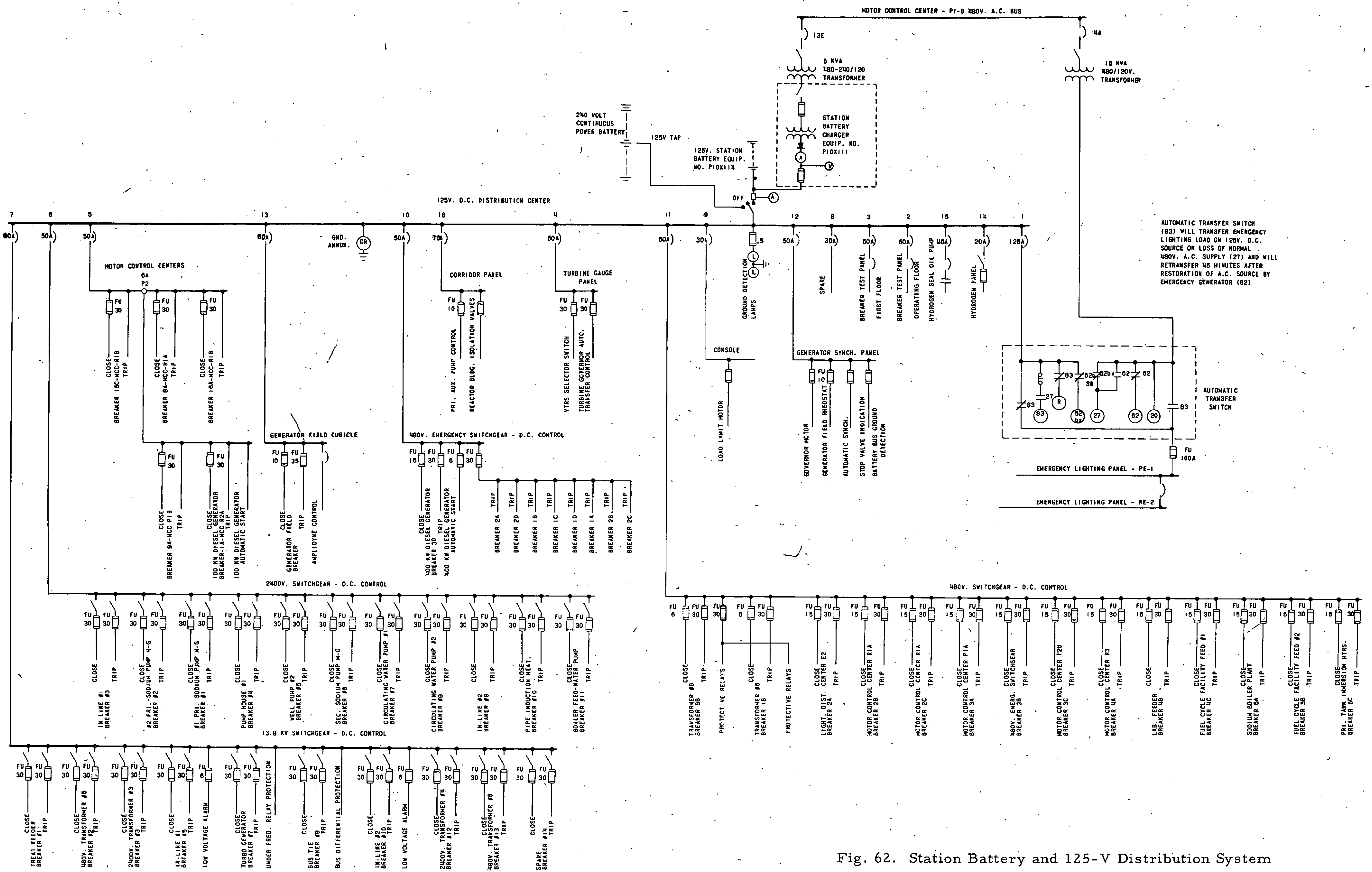


Fig. 62. Station Battery and 125-V Distribution System

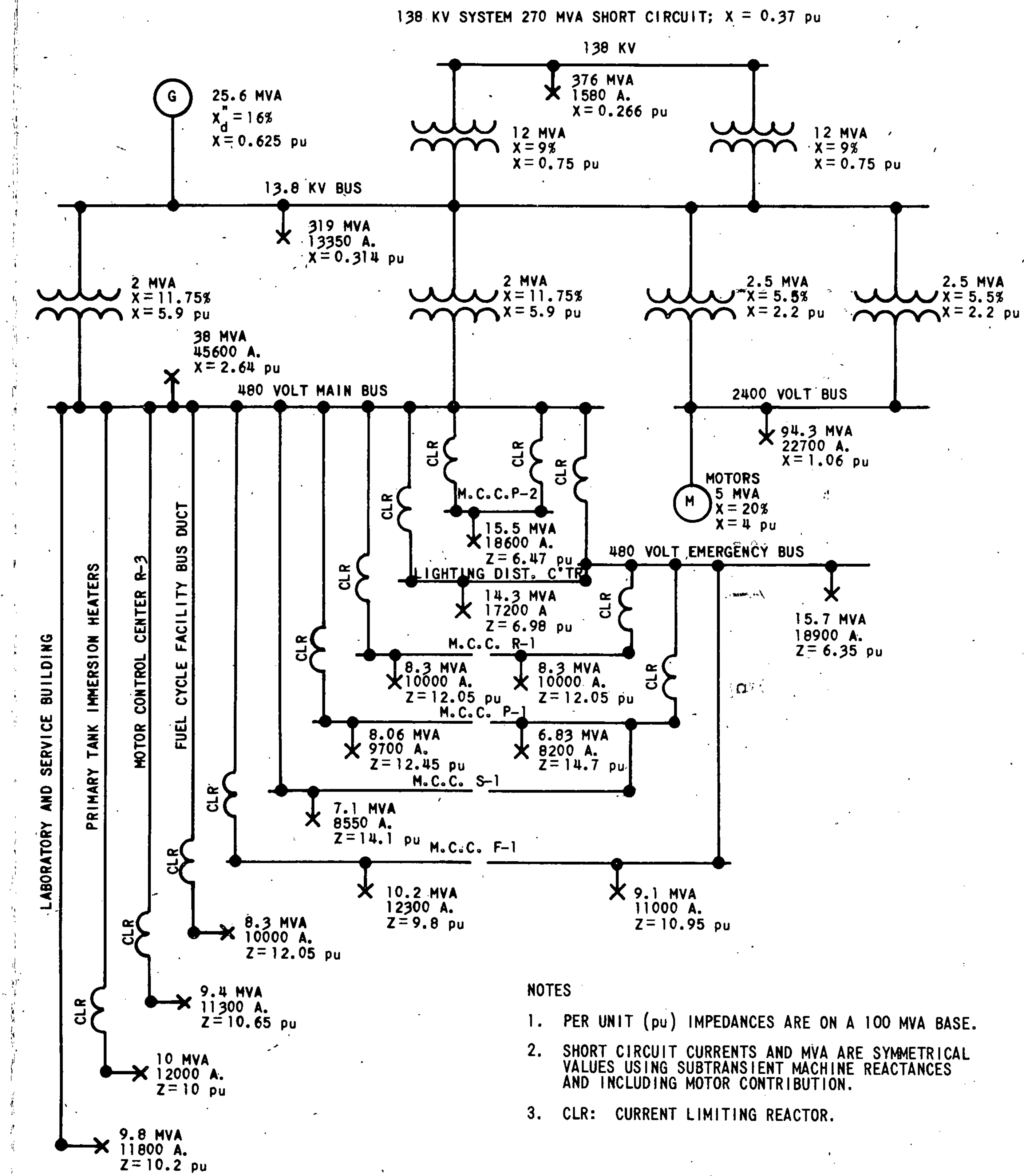


Fig. 63. Impedance Diagram and 3-phase Short-circuit Currents and MVA

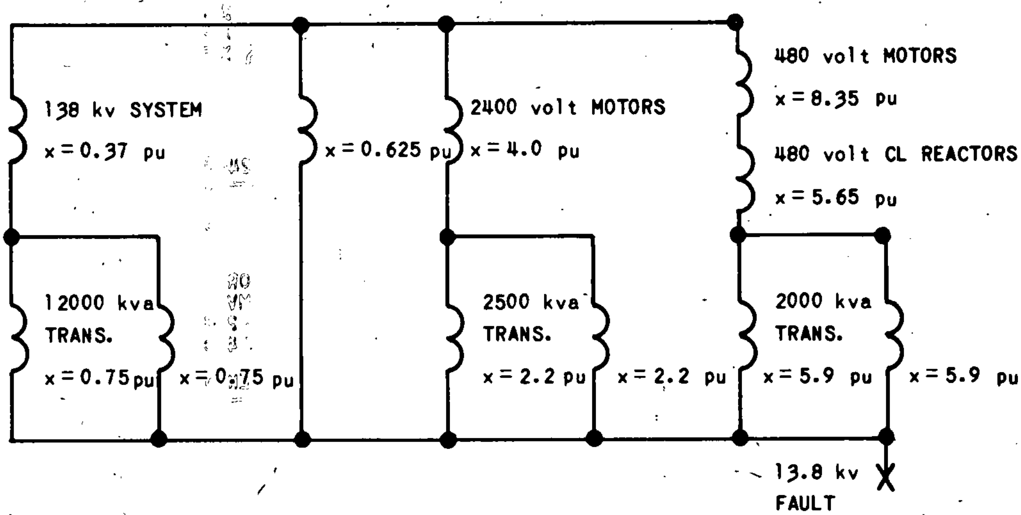


Fig. 64. Impedance Diagram for a 13.8-kV System Fault

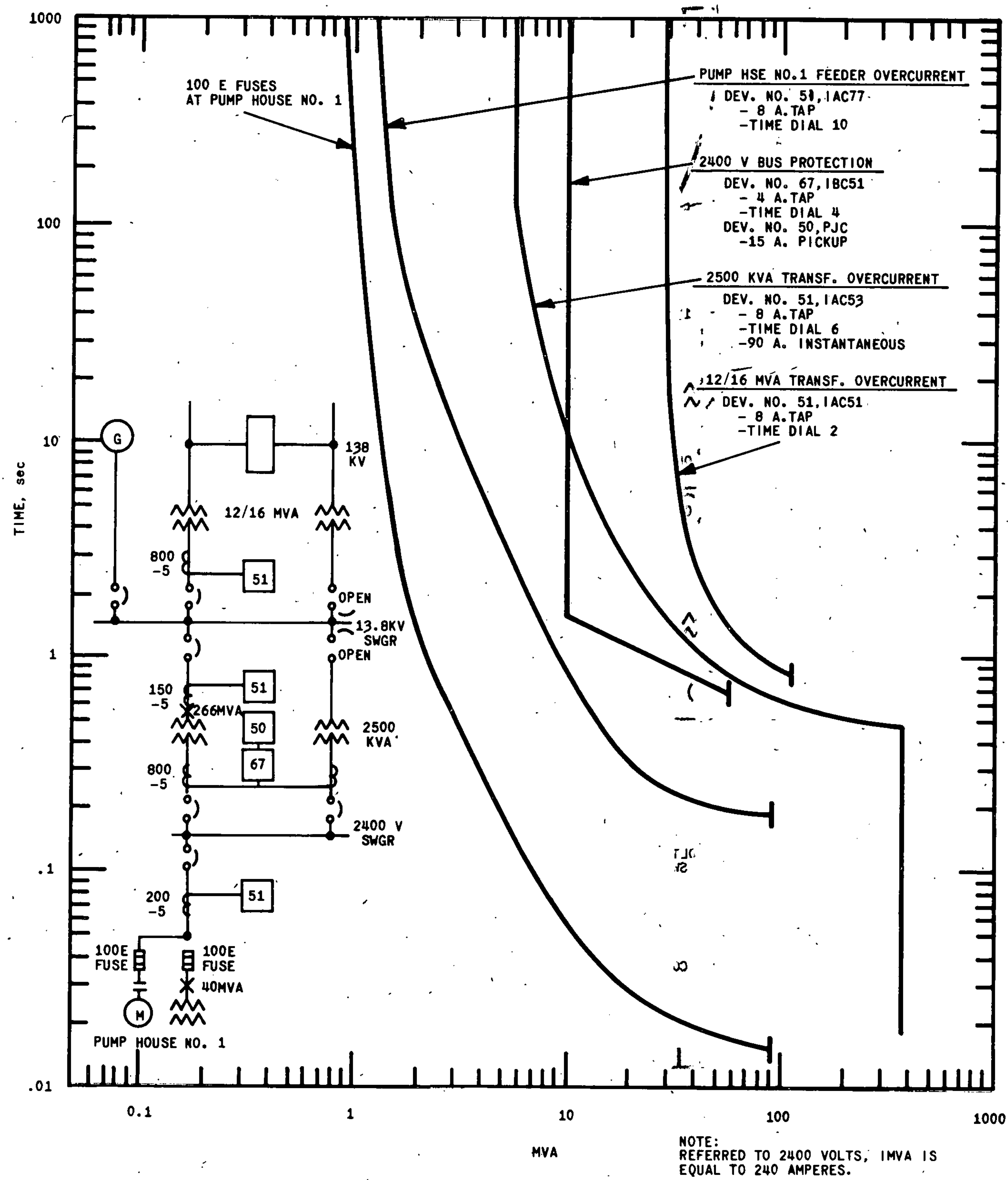
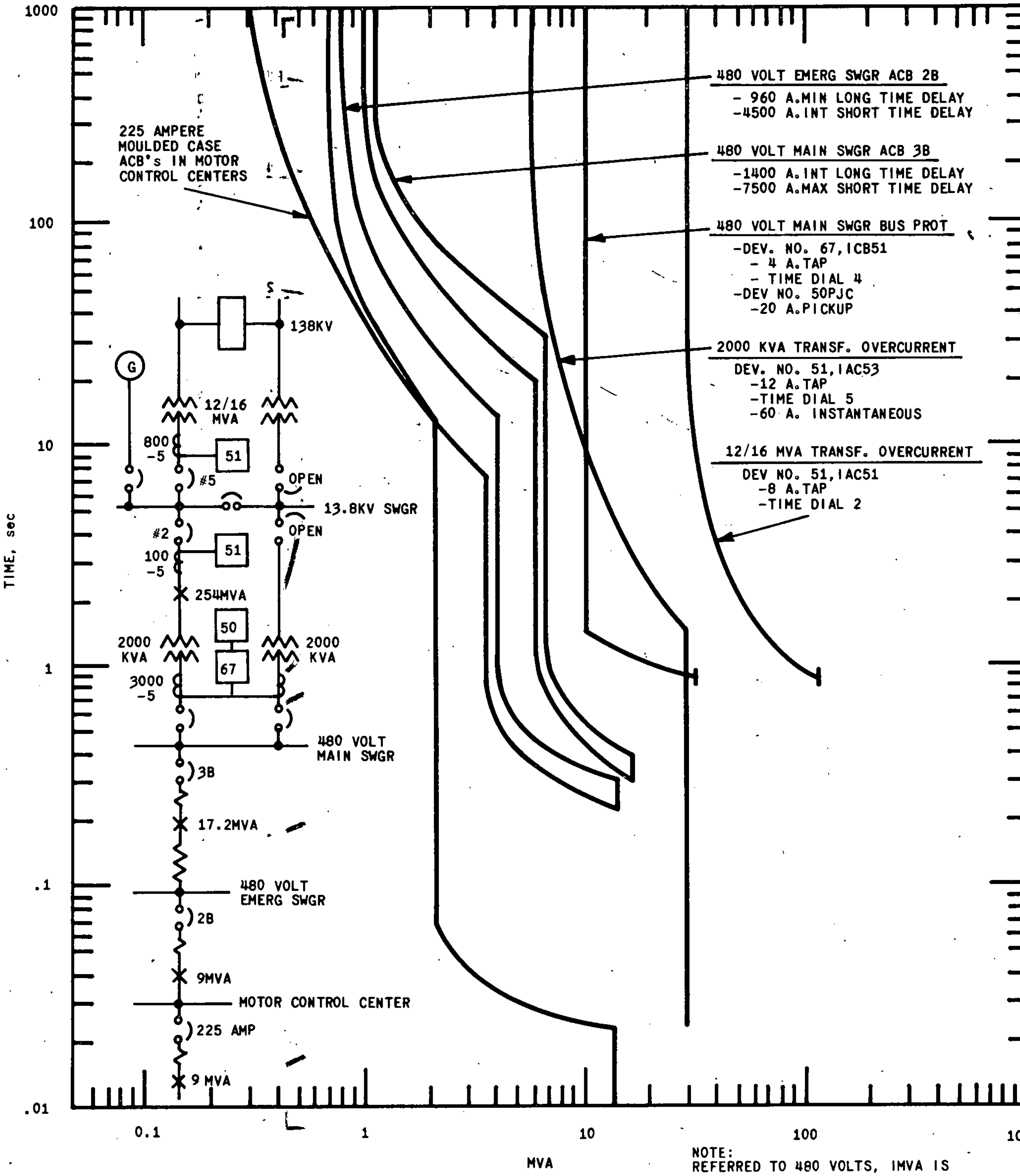
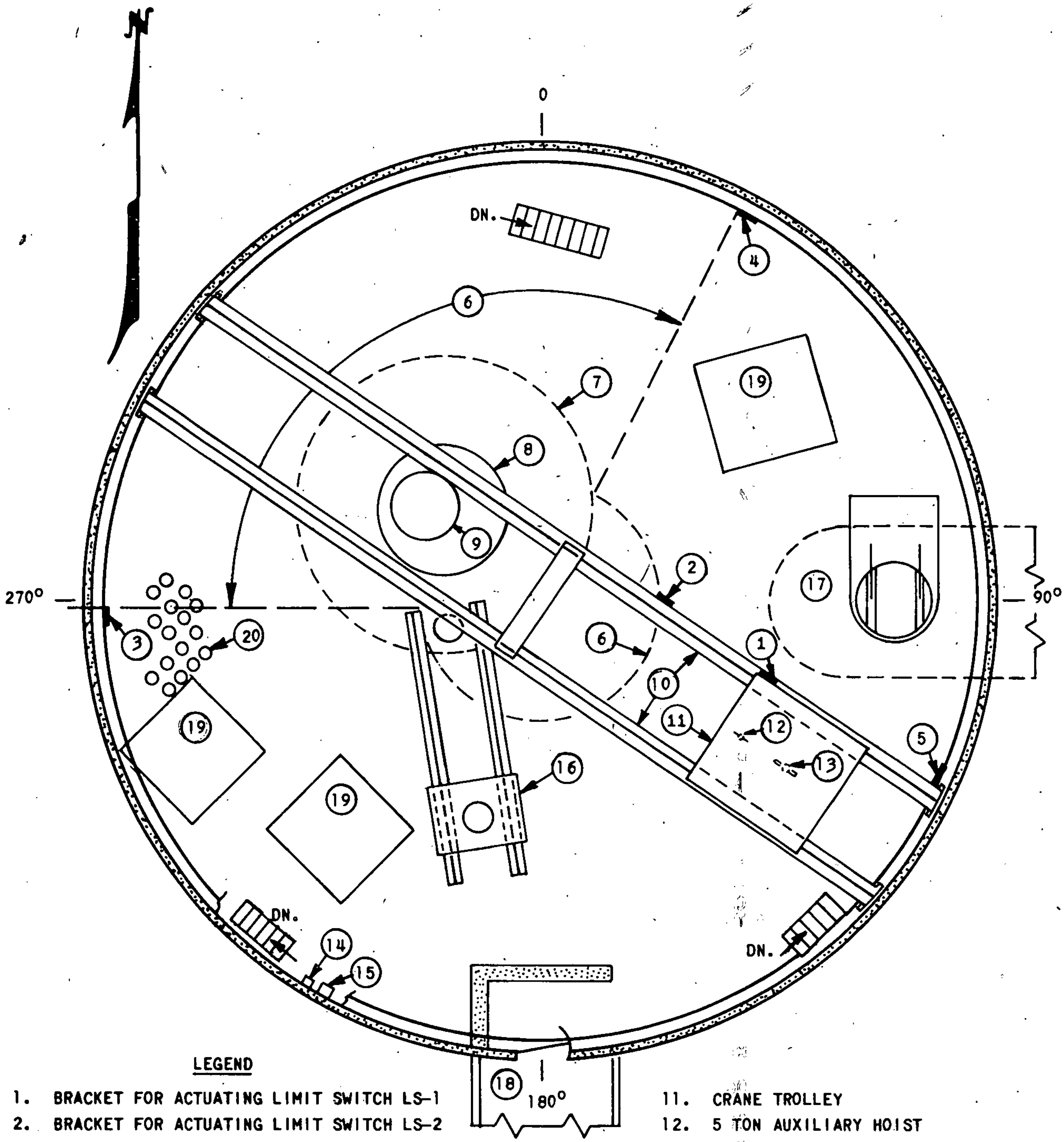


Fig. 65. Typical Overcurrent (MVA) Coordination Curves - 138-kV, 13.8-kV, and 2400-V Systems



NOTE:
REFERRED TO 480 VOLTS, 1MVA IS EQUAL TO 1200 AMPERES.

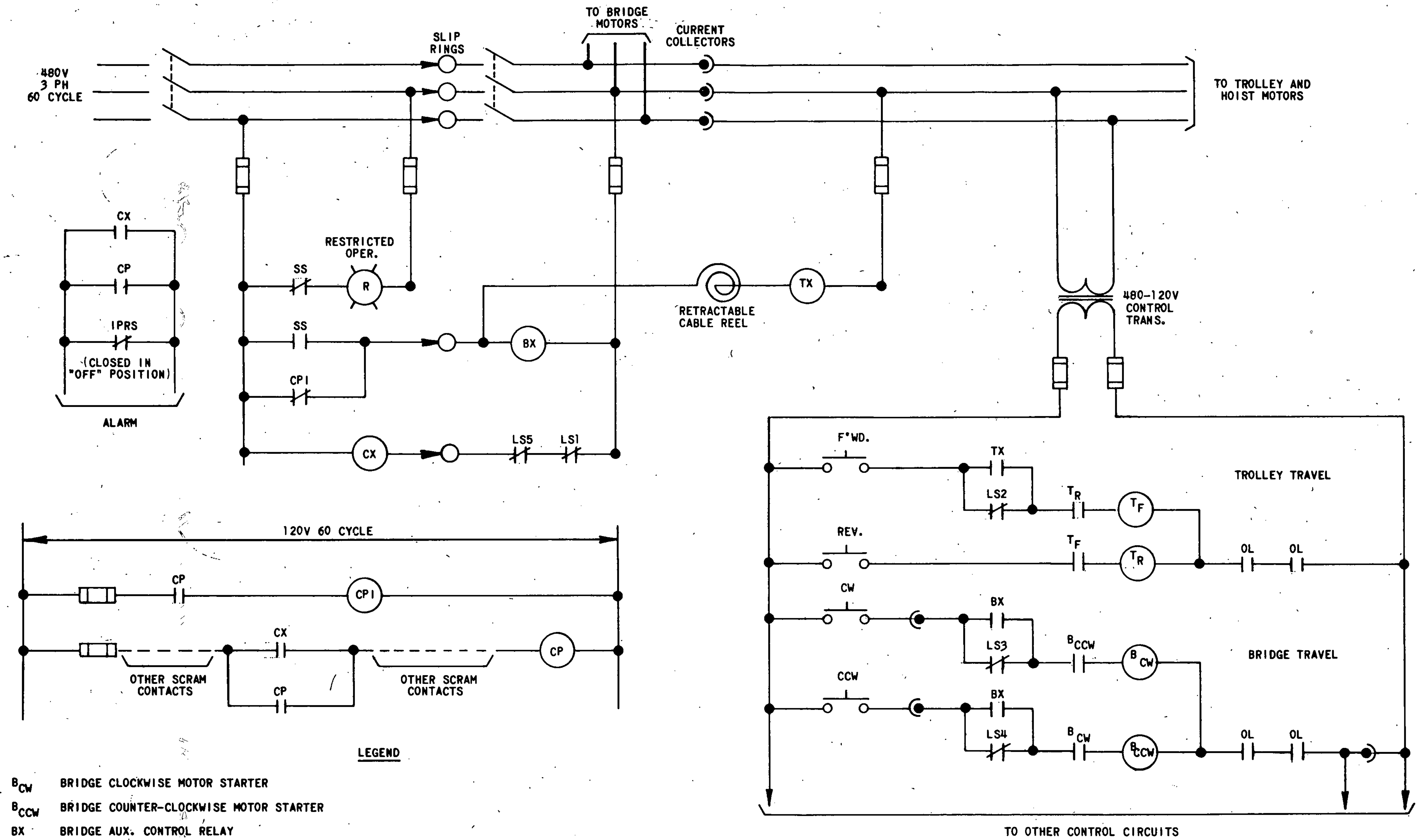
Fig. 66. Typical Overcurrent (MVA) Coordination Curves-138-kV, 13.8-kV, and 480-V Systems



LEGEND

1. BRACKET FOR ACTUATING LIMIT SWITCH LS-1
2. BRACKET FOR ACTUATING LIMIT SWITCH LS-2
3. BRACKET FOR ACTUATING LIMIT SWITCH LS-3
4. BRACKET FOR ACTUATING LIMIT SWITCH LS-4
5. BRACKET FOR ACTUATING LIMIT SWITCH LS-5
6. RESTRICTED CRANE OPERATING AREA
7. PRIMARY TANK
8. LARGE ROTATING PLUG
9. SMALL ROTATING PLUG
10. CRANE BRIDGE
11. CRANE TROLLEY
12. 5 TON AUXILIARY HOIST
13. 75 TON MAIN HOIST
14. KEY SWITCH AND RELAY BOX
15. CRANE POWER DISCONNECT SWITCH
16. FUEL UNLOADING MACHINE
17. EQUIPMENT AIRLOCK
18. PERSONNEL AIRLOCK
19. HATCHWAY
20. STORAGE HOLES

Fig. A-1. Layout of Rotary Bridge Crane in Reactor Building



LEGEND

B_{CW}	BRIDGE CLOCKWISE MOTOR STARTER
B_{CCW}	BRIDGE COUNTER-CLOCKWISE MOTOR STARTER
BX	BRIDGE AUX. CONTROL RELAY
CX	BRIDGE AND TROLLEY POSITION AUX. RELAY FOR REACTOR STARTUP
CP	REACTOR SCRAM RELAY
CPI	REACTOR SCRAM AUX. RELAY
IPRS	REACTOR STARTUP KEY SWITCH
LS1	LIMIT SWITCH (TROLLEY POSITION ON BRIDGE FOR REACTOR STARTUP) CONTACT CLOSED WHEN SWITCH IS ACTUATED.
LS2	LIMIT SWITCH(LIMITS TROLLEY TRAVEL) CONTACT OPENS WHEN SWITCH IS ACTUATED.
LS3	LIMIT SWITCH (LIMITS BRIDGE CLOCKWISE ROTATION) CONTACT OPENS WHEN SWITCH IS ACTUATED.
LS4	LIMIT SWITCH (LIMITS BRIDGE COUNTER-CLOCKWISE ROTATION) CONTACT OPENS WHEN SWITCH IS ACTUATED.
LS5	LIMIT SWITCH (BRIDGE POSITION FOR REACTOR STARTUP) CONTACT CLOSED WHEN SWITCH IS ACTUATED.
SS	KEY OPERATED SELECTOR SWITCH (SHOWN IN "ON" POSITION FOR RESTRICTED OPERATION)
T_F	TROLLEY FORWARD MOTOR STARTER
T_R	TROLLEY REVERSE MOTOR STARTER
TX	TROLLEY AUX. CONTROL RELAY

Fig. A-2. Elementary Diagram of Control Scheme for Restricted Crane Operation

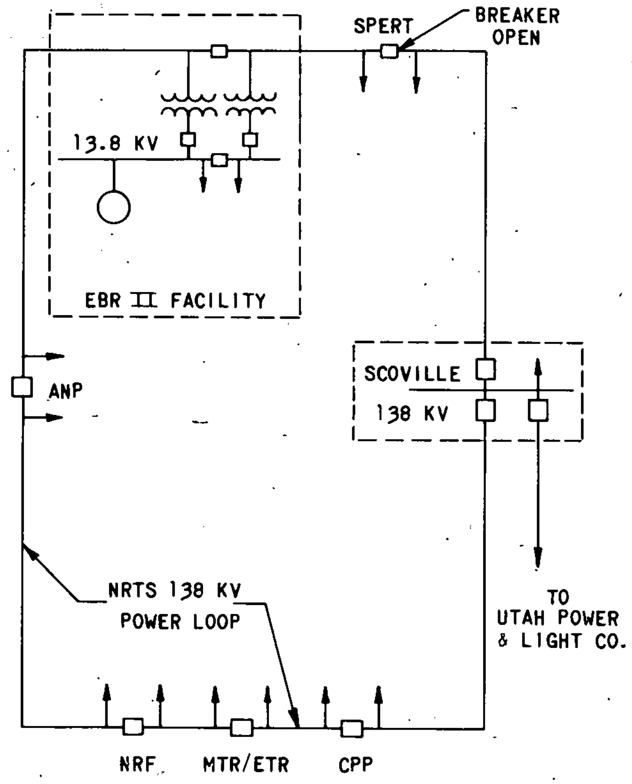


Fig. B-1. System One-line Diagram

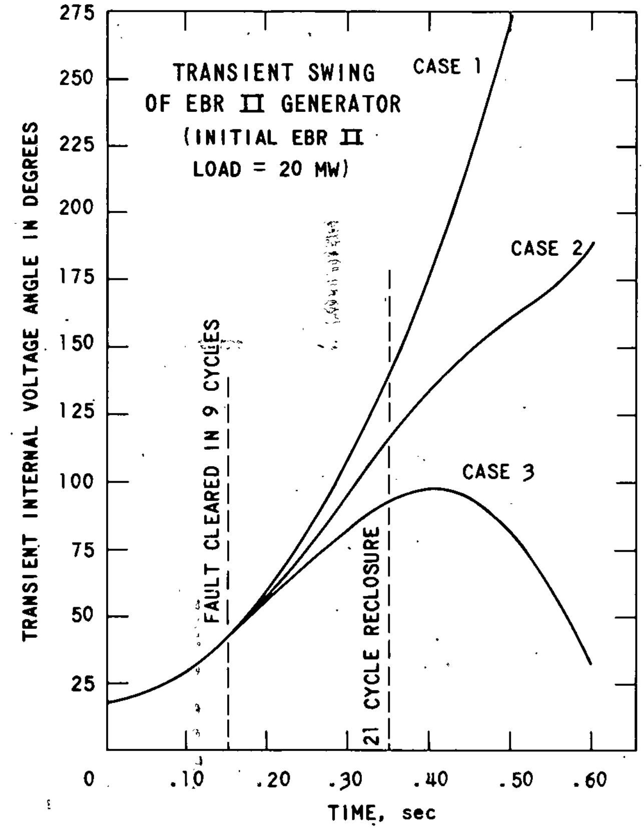


Fig. B-2. Transient Swing of EBR-II Generator (Cases 1, 2, and 3)

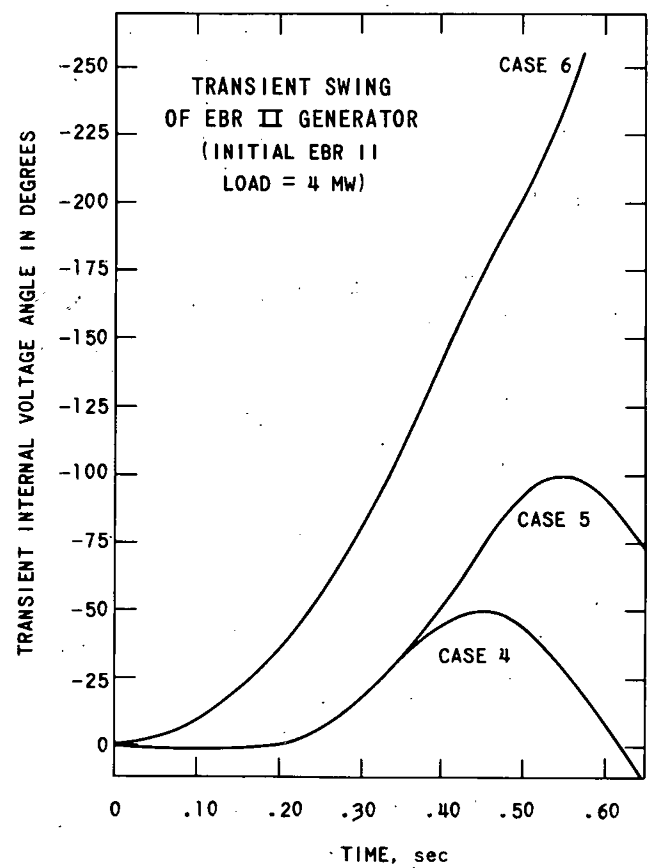


Fig. B-3. Transient Swing of EBR-II Generator (Cases 4, 5, and 6)

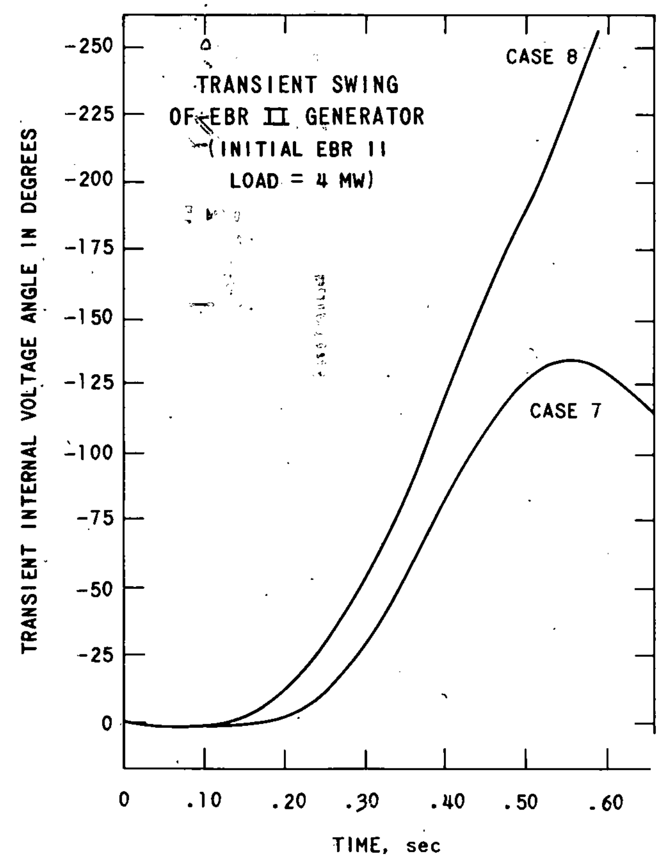


Fig. B-4. Transient Swing of EBR-II Generator (Cases 7 and 8)

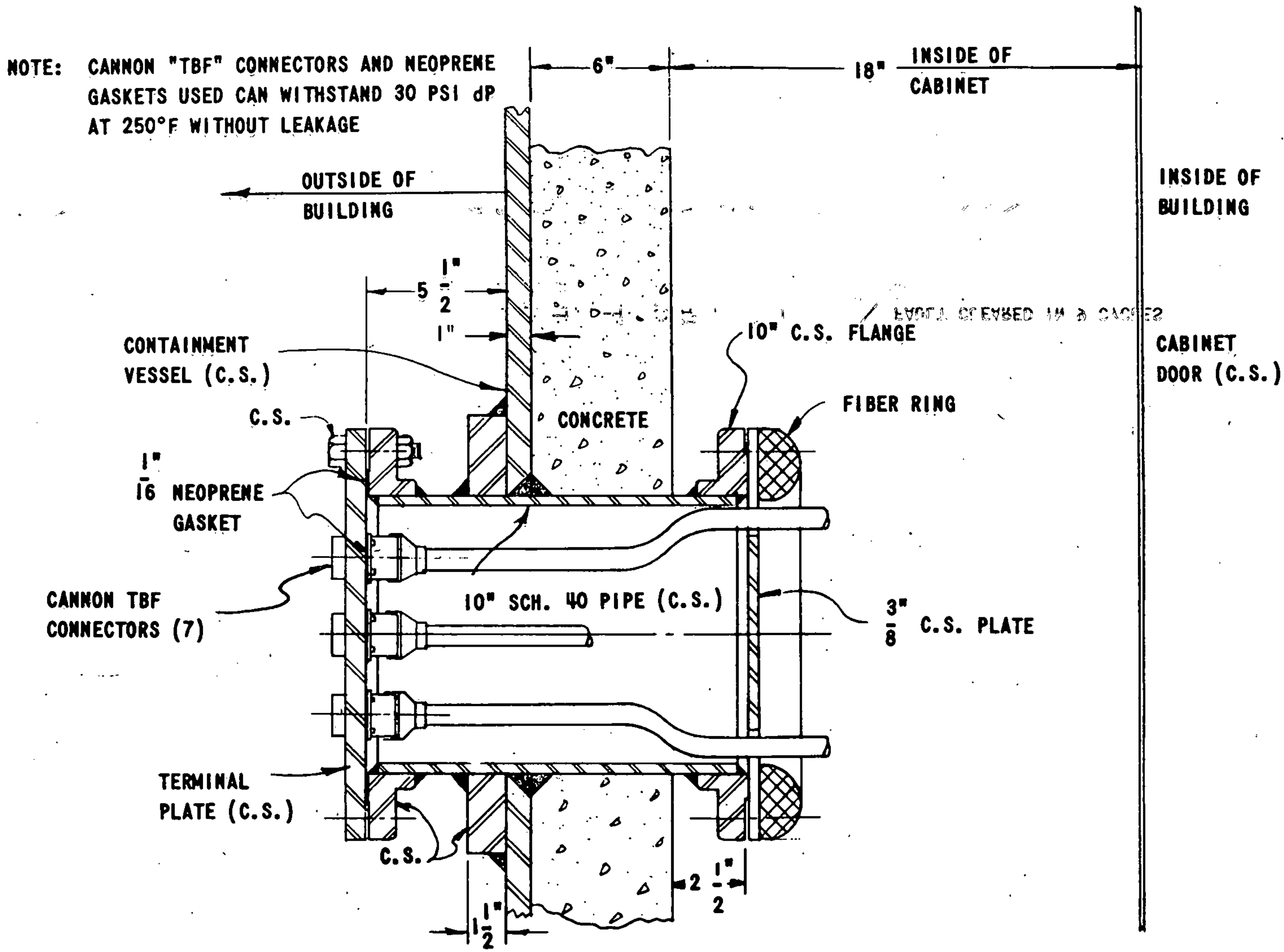


Fig. C-1. Electrical Penetration--Nos. 1 through 16

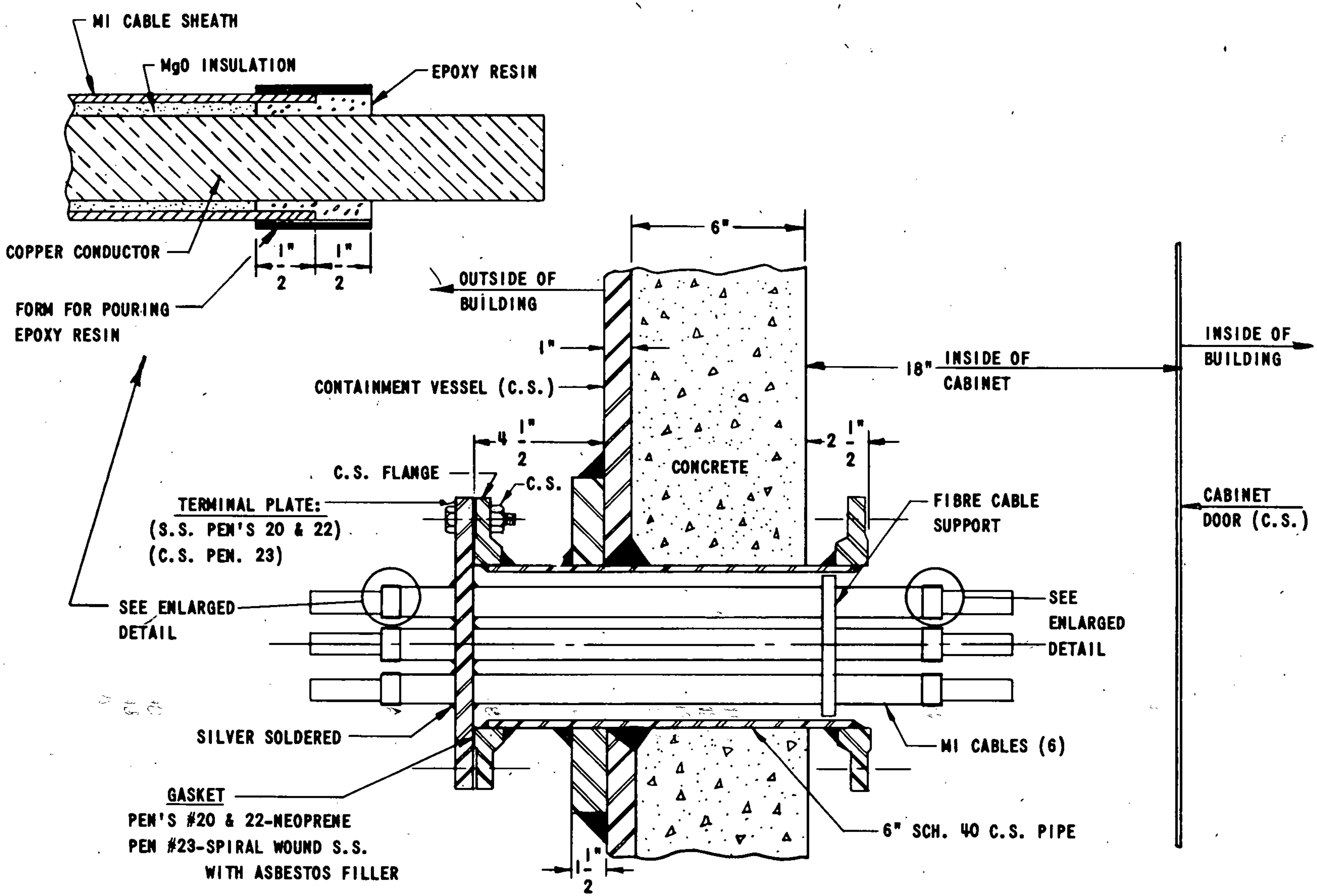


Fig. C-2. Electrical Penetration--Nos. 20, 22, and 23

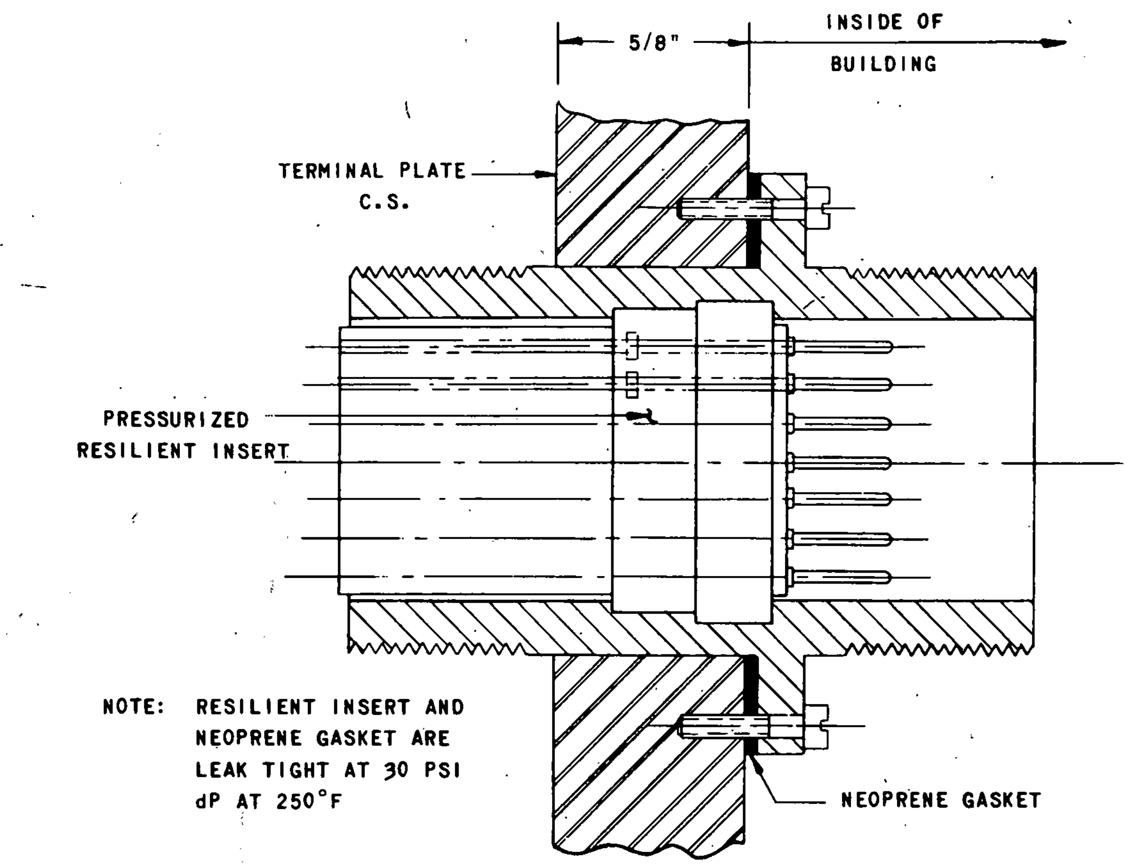


Fig. C-3. Cannon Type "TBF" Connector

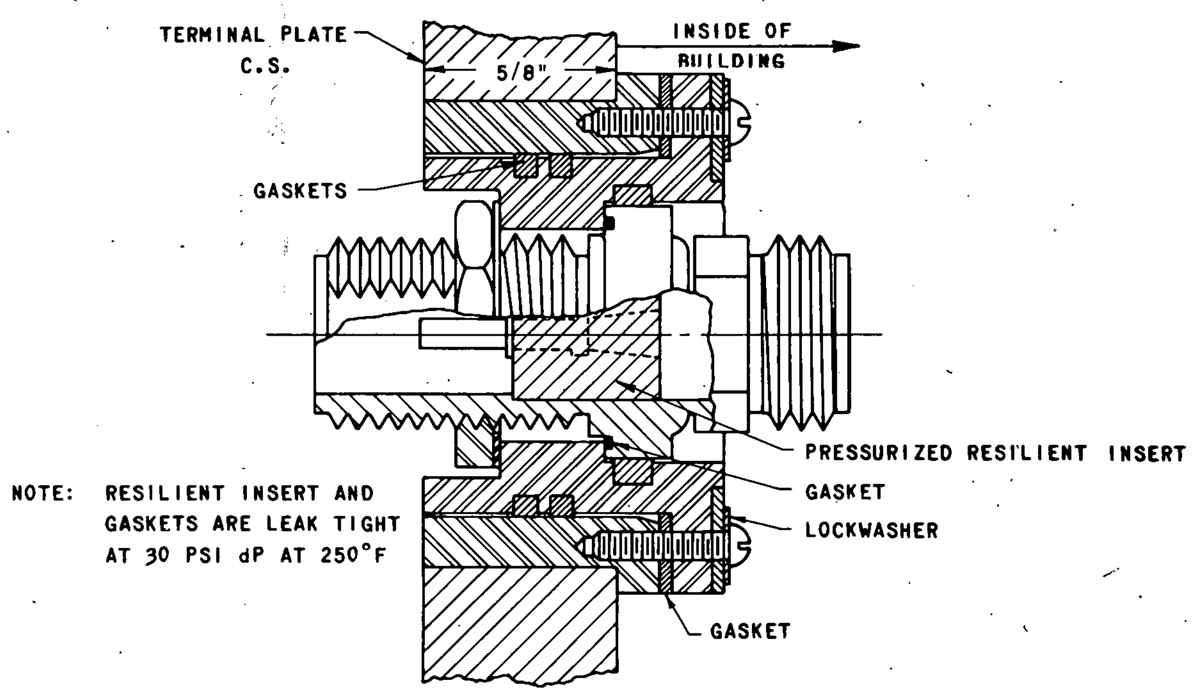


Fig. C-4. Amphenol No. 100X-3875-1 Coaxial Connector

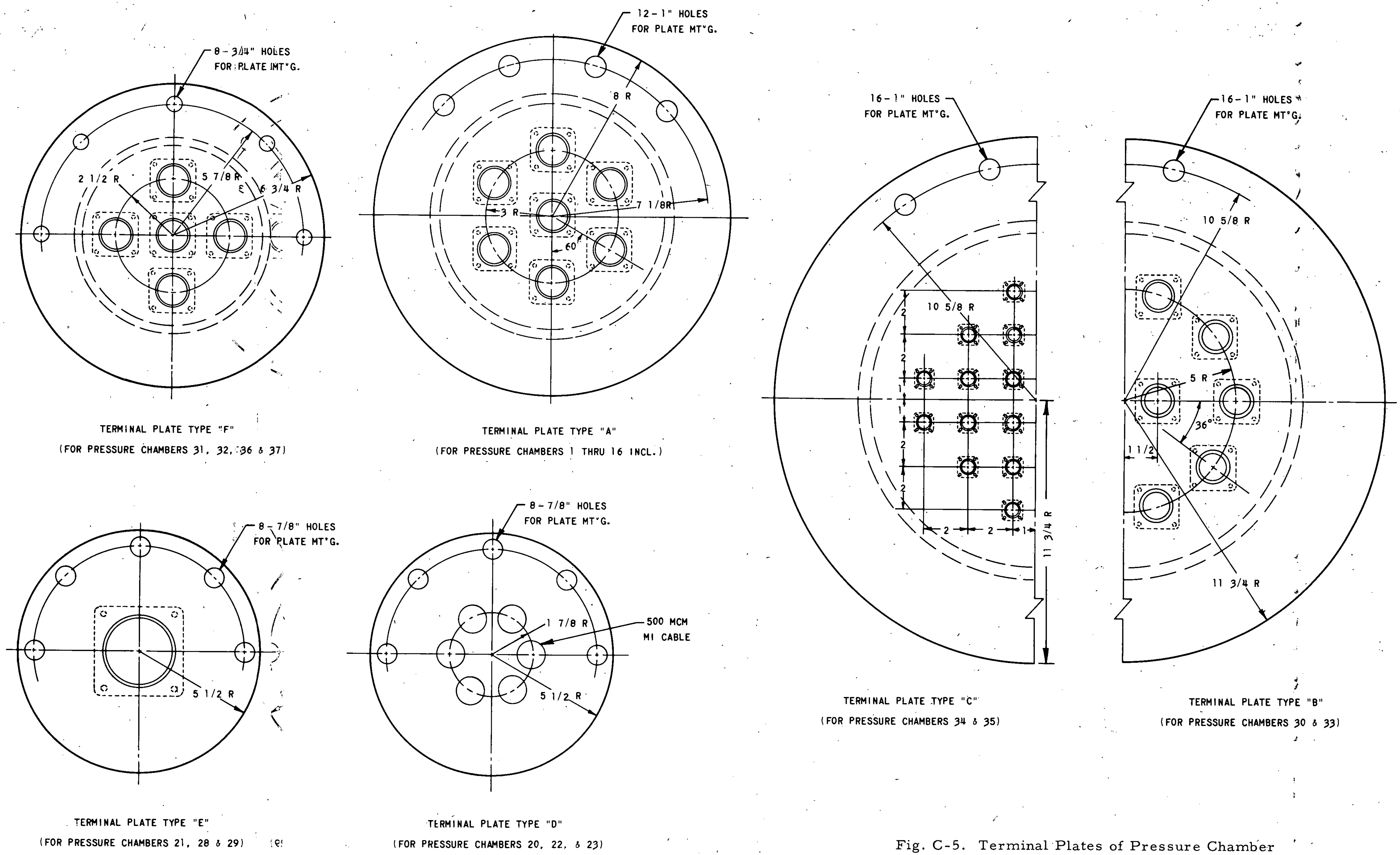
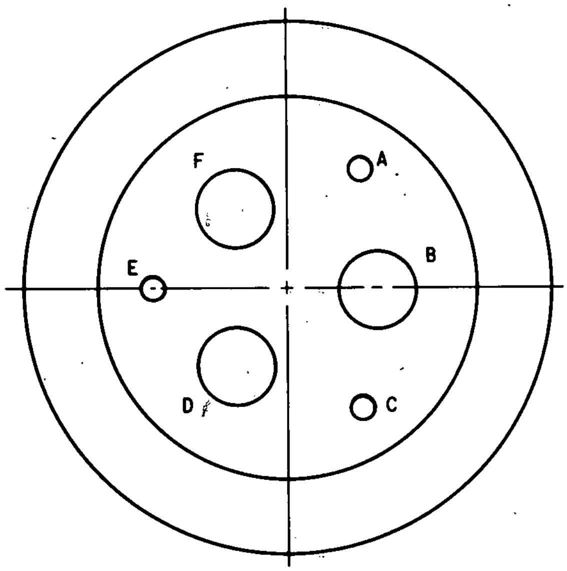


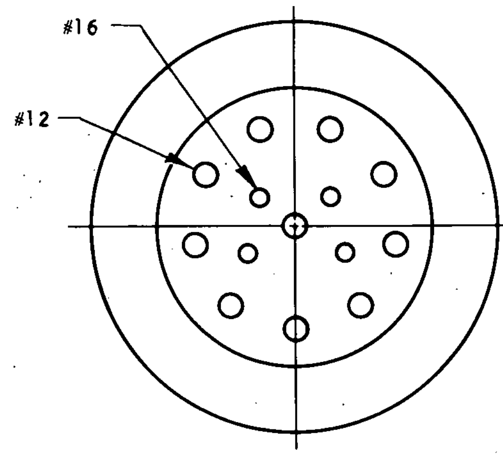
Fig. C-5. Terminal Plates of Pressure Chamber



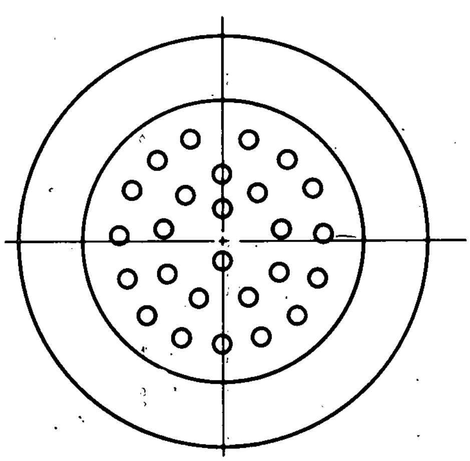
TYPE R-1 (CANNON CATALOG NO. TBF-28-3PS)
(3 #8 COPPER CONTACTS)

TYPE R-2 (CANNON CATALOG NO. TBF-28-6PS)
(3 #4 COPPER CONTACTS)

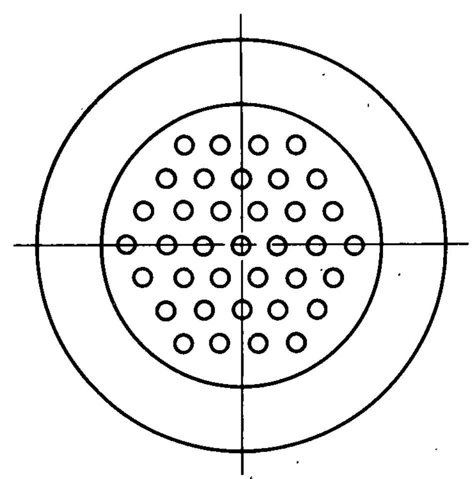
TYPE R-7 (CANNON CATALOG NO. TBF-36-3PS)
(3 #1/0 AND 3# 12 COPPER CONTACTS)
(PINS A, C & E ON CONNECTOR R-7 ONLY)



TYPE R-3 (CANNON CATALOG NO. TBF-28-20PS)
(10 #12 AND 4 #16 COPPER CONTACTS)



TYPE R-4 (CANNON CATALOG NO. TBF-28-12PS-A115)
(26 #16 GOLD PLATED CONTACTS)



TYPE R-5 (CANNON CATALOG NO. TBF-28-12PS-A115)
(37 #16 GOLD PLATED CONTACTS)

TYPE R-5A (CANNON CATALOG NO. TBF-28-21PS-F9)
(37 #16 CHROMEL AND ALUMEL CONTACTS)

TYPE R-5B (CANNON CATALOG NO. TBF-36-12PS-A115)
(37 #16 GOLD PLATED CONTACTS)
(12 SHIELDED PAIR CABLE)

Fig. C-6. Cannon Type "TBF" Connector Pin Arrangements

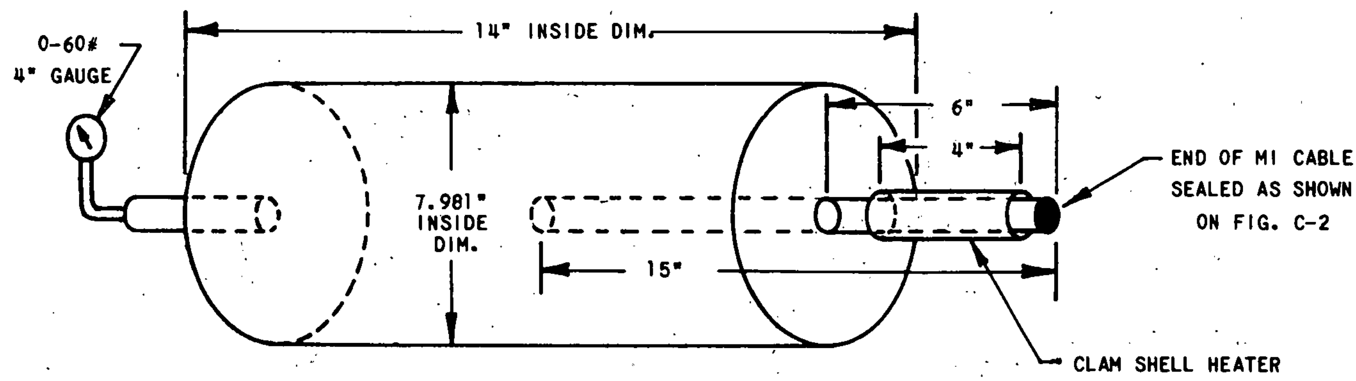


Fig. C-7. MI Cable Test Set-up