Title
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Publication Date
1952-04-01

UNCLASSIFIED UCRL- 1795

UNIVERSITY OF CALIFORNIA — BERKELEY

RADIATION LABORATORY

UCRL-1795

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

Contract No. W-7405-eng-48

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Most manufacturing or industrial plants design their power systems to meet the needs of a carefully planned process. The design is generally based upon years of experience and embodies standardized equipment, well known and readily available. Once built, changes would only be made when justified by plant expansion, change in product, or other economic reason.

In contrast, the research laboratory produces basic scientific knowledge and acts as a proving ground for new ideas. Consequently, laboratory power systems and wiring must frequently be altered as the experimental work progresses. In nuclear research work, a very flexible power system is needed. It should have a wide range of voltage and current levels for single phase, three phase and direct currents.

The operation of experimental equipment and of the various types of particle accelerators will impose loads of widely differing characteristics. Such loads may vary from a few kilowatts applied on a random basis, through steady loads at high power factor, to pulsed loads of several megawatts peak power.

* * * * * *

Bulk power consumption in a large laboratory, can be divided into two broad classes:

<u>Utility Power</u>,	for the shops, offices, chemistry laboratories and the small experimental areas.
<u>Research Power</u>,	for the large experimental loads and operation of the particle accelerators and their associated equipment.

Utility Power-Wiring

In this classification, there is the power used for lighting, heating and ventilating, power-driven tools and machinery, heat treating, pumping, welding, crane operation, alarms and communication equipment, etc. The wiring for such loads is of a "permanent" nature, meets all safety codes, and generally conforms to standard practice for a specific occupancy. Space must be provided for scientists, office workers, engineers and skilled craftsmen. Management recognizes the need for a clean, safe environment in which high-grade personnel will be inspired to do their best.

The word "permanent" however, must not be taken too seriously, because today's office may become tomorrow's shop. Therefore a flexible wiring system is necessary for such alterations are expensive, justified only by the importance of a project and it's timing. In such an area, a large increase in electrical load, due to change in occupancy, presents the problem of having ample power available in the immediate vicinity.

A primary distribution system, e.g. a 12 Kv. radial system, terminating in outdoor transformer yards, provides flexibility in that the various transformers can be changed to suit new power demands. But an inadequate service, from the transformer secondary into a building, may prove to be a bottleneck for future expansion.

The use of standard wiring materials, plus ample feeder capacity into an area, shortens alteration time. For inside wiring the use of Thinwall conduit, flexible conduit, cables placed in troughs, etc. can be adopted where these methods do not conflict with the wiring codes. The power feeder into such areas can be run through rigid conduit somewhat larger than necessary for the immediate load. If the load increases, due to change of building occupancy, a larger service can replace the original feeder. In some cases it may be necessary to remove feeders having the RW or TW insulations, and replace them with the Asbestos or type H insulation for heavier loading on the same size wire.

If the original feeder was a 240 volt line, this can be changed to a 480 volt feeder without replacement, since the insulation will be code-rated at 600 volts for wires in the low voltage class. A few banks of dry step-down transformers located within the building at the load centers, will then double the available building power without changing the service wires, which will be carrying the same rated full load current. In some types of buildings which are used for both office space and small laboratory rooms, it is economical to install overhead bus duct along hallways and in locations where it will not shock the esthetic eye. Where the room occupancy changes frequently, such an installation becomes a very convenient means of increasing or decreasing the service into any room.

If the building contains chemical laboratories, whose work involves the handling of radio-active materials, an emergency power supply will be necessary to carry the ventilation load in case of power failure. This is very important! Failure of ventilation for a sufficient length of time, can result in a difficult and time-consuming decontamination process. The stand-by power can be supplied by small diesel or gasoline engine prime movers. The generators may have ratings just large enough to carry the ventilation load plus a few of the most critical experimental circuits.

Here again, circuit flexibility is needed, so that the non critical loads can be quickly isolated. The use of a careful numbering system, plus a few colored labels, simplifies this problem.

Utility Plugs and Receptacles

With so many voltage and current levels available in the laboratory, a standardized system of plugs and receptacles is a necessity. This will enable laboratory personnel to recognize the voltage, phasing and current rating of an outlet, merely by looking at the shape of the receptacle. The receptacles shown in Fig. 1 show what can be done with standard units, of which there is a wide variety on the market, all having some outstanding advantage for a specific use. Those shown were selected on the basis that the geometrical arrangement of the pins will prevent the insertion of a plug of one voltage or current rating, into a receptacle of some other voltage or current rating. These 9 units will supply 3 circuit ratings without equipment ground, and 6 ratings with equipment ground.

The ability to ground the metal cases of portable devices, is of even greater importance in the research laboratory than in the home, because there is such a variety of test equipment, and so many voltage levels in use. One frequently finds signal generators, scopes, vacuum tube voltmeters, amplifiers and a miscellaneous array of metal chassis-mounted test equipment, all in close proximity to an experimenter.

An accidental contact, internally, between an anode circuit component and a metal case not solidly grounded, becomes a very real hazard to a researcher. In some types of equipment, it is necessary to have the entire instrument floating at a high potential to ground, and this is done safely by mounting the unit on insulators, behind plexiglass windows. But in general, most instrument cases can be grounded. This is recognized as a safety requirement in the California State Electrical Code, which calls for the grounding of all portable appliances.

Since code does not permit the neutral wire to be used as the equipment grounding conductor, a 3 pin plug and 3 conductor cord will be needed for grounding portable test equipment. In this matter, it is unfortunate that the manufacturers of test instruments have not, to date, adopted the use of 3 conductor cords and 3 pin plugs. The replacement of these cords and plugs, for safety purposes, becomes an added task (and expense) for the busy laboratory.

A quick method of changing an office into an experimental room, is to move in a number of standardized test benches, all made uniform as to size and shape, and prewired identically with "Plug-in" strip. Experience has shown that the most reliable and flexible types are those into which the standard receptacles can be snapped, and then connected as in typical race-way wiring. Using this method, the units shown in Fig. 1 maintain the features of standardization and also simplify the stock problem. A group of receptacles in one strip, protected by a circuit breaker to match the receptacle rating, can then be plugged into the nearest wall outlet. Circuit breakers are preferable to fuses, in the laboratory, because they discourage tampering.

Utility Circuits

In an office building, or one in which there are many small single phase, 120 volt experimental circuits, the conventional 3 phase 4 wire Y system can be used to best advantage because it places such a well balanced load upon the area supply system. A few 3 phase 3 wire 240 volt loads, such as elevators, ventilators, etc. can then be supplied by means of small dry transformers, connected Y-Δ to transform from the 120/208 volt system to 240 volts for the special 3 phase loads. If then the building occupancy changes, so that most of the new loads are 3 phase 3 wire 240 volts, the transformer bank feeding the building can have its secondary reconnected for 3 phase 4 wire Δ with one leg of the delta, center-tapped for a neutral. This will then provide 3 phase 240 volts, and 1 phase 240/120 volts for lights, receptacles, control circuits, etc. For this reason, it is desirable to install transformers having the 240/120 volt secondary windings.

Where one large transformer bank supplies a group of buildings, the choice of secondary connection must be based upon the prevalence of 240 volt 3 phase loads as compared to 120 volt 1 phase loads for lighting, etc.. Using the 4 wire delta system mentioned above, a point may be reached where the phase loads become badly unbalanced. A simple, though somewhat awkward, solution for such a situation is shown in Fig. 2, using standard filament and dry step-down transformers. Here, the 208 volts from B phase to neutral, is stepped up to 228.8 volts, using a 1.75 KVA. filament transformer, having a 10:1 voltage ratio. This 228.8 volts is then supplied to a standard 240-240/120 volt dry transformer of suitable KVA. rating, and stepped down to 228.8/114.4 volts, 3 wire, single phase. The method loads B phase and helps restore a balanced load condition on the main transformer bank, but leaves much to be desired from an efficiency viewpoint. In addition to the excitation losses, 2 transformers are required, plus the space and labor of mounting them. A simpler solution would be the use of a 208-240/120 volt transformer, but these are not always available on short time schedules.

Good voltage regulation must be maintained for the experimental areas in which accuracte measurements are made. Good regulation is also needed for the various types of radioactivity counters, scalers and monitoring equipment. This is especially true where these devices are designed and serviced. At present, many of the later types of radioactivity monitoring instruments, have built-in voltage regulation so that their operation is satisfactory if the building supply voltage is regulated to within ± 1.25 percent. For this purpose the conventional tap-changing auto transformer regulator, having the standard 5/8 percent taps and a 30 second time delay to prevent excessive contact wear, will be satisfactory. But for experimental development work, such regulation is totally inadequate and must be supplemented with additional regulators of the resonant circuit-high leakage reactance type, or the saturable reactor type which embodies a rectifier controlled by a voltage sensitive wheatstone bridge. Harmonic distortion of several percent will be noticeable in the output of both types.

Where small amounts of direct current are needed, the portable rectifier is convenient. Such units can supply as much as 1300 watts D.C. from the standard 120 volt, 15 amp. single phase wall outlet. For values of direct current up to 6 kilowatts, a portable 3 phase full wave rectifier plugged into a 240 volt, 20 ampere 3 phase wall outlet can be used. For D.C. up to approximately 18 kilowatts, portable motor-generator sets are used. These can be plugged into the 240 volt, 60 ampere 3 phase outlets. All of these wall receptacles are shown in Fig. 1. These portable M-G sets are completely assembled units, equipped with circuit breakers, motor starting contactors, self-contained regulators, meters, overload relays, pilot lights, toggle switches for local or remote operation, etc. The regulators can hold the output current constant to within 0.05 percent if needed. These M-G sets can also be equipped with field reversing contactors, so that there will be a rapid decay of current in circuits having large inductance, such as experimental magnets. Fig. 3 shows a portable 20 K.W. motor generator set. Where it becomes necessary to fully load, or overload these machines, they are generally wired in solidly, rather than through plugs and cables.

Research Power

Several service feeders at 12 K.V. or higher, are required for the large experimental loads and for Particle Accelerator operation. This provides some flexibility so that new units can be constructed without interfering with the operation of existing equipment. With several main services, plus an adequate switching structure, service continuity is assured.

The public utility which serves a large laboratory, may well be concerned with the types of load placed upon its system. These vary over a wide range, from ideal to undesirable. In the ideal group, a large Cyclotron is the best example, requiring about 1000 kilowatts for an average of 500 hours per month. Of this 1000 kilowatts, about 850 will be at 80 percent leading power factor, for operation of an M.G. set which supplies magnet power, a very steady load.

In the undesirable class, there will be the pulsating loads which vary over a wide range in peak power, length of pulse, pulse repetition rate, and duty cycle.

The two principal methods of reducing the annoyance of such loads are:

1. Scheduling operations for the hours of Midnight to 8:00 AM.
2. Use of large motor-generator sets equipped with flywheels, or use of stored energy in large capacitor banks.

Of the first method, about all that can be said is that it transfers the unhappiness of the utility onto the researcher!

The second method is the most promising. Flywheels have been in use for many years, and there is a wealth of practical knowledge concerning their ability to smooth out pulsating loads.

One finds an interesting example, in the case of the cloud chamber generator. Cloud chambers are used in the research laboratory as a means of photographing highly accelerated particles. These particles, traveling at high sppeds through a vaporized chamber, are deflected from their line of travel by a magnetic field applied for a few seconds. Such a magnet may require a D.C. pulse of 4000 amperes at 200 volts. This 800 kilowatt load rises to its peak in approximately 2-1/4 seconds at which time the generator field is automatically deenergized. The current then decays to about 200 amperes in the next 10 seconds at which time it is safe to open the main D.C. circuit breaker. These pulses are repeated about 30 times per hour.

The cloud chamber generator which furnishes this power is shown in Fig. 4. The generator has an intermittent rating of 3000 amperes at 180 volts, or 540 kilowatts. It is driven by a 150 H.P. 480 volt 3 phase induction motor, squirrel cage type. Between the generator and the motor, there is a 3.8 ton flywheel. A 300 H.P. hydraulic coupling is used between the motor and the flywheel. This permits easy reduced-voltage starting of the motor which then brings the flywheel-generator combination up to speed (1170 R.P.M.) in several minutes. At full idling speed, this motor draws 30 kilowatts from the line. At the peak of the (800 kilowatt) D.C. pulse, the motor draws approximately 330 kilowatts from the line. There is a 13 percent reduction in flywheel speed as it gives up some of its stored energy, while the motor decreases its speed approximately 5.5 percent. A selective control system is provided so that pulse power, time and repetition rate can be varied to suit the needs of the moment. With this equipment, the 60 cycle system sees only 41 percent of the peak power taken by the cloud chamber magnet.

An example of an Accelerator using the stored energy in a large capacitor bank, is the Electron synchrotron, which accelerates electrons to an energy level of 335 MEV. The electrons travel around a circular orbit in the vacuum chamber of a magnet constructed similar to a transformer. The magnet winding acts as the primary, while the electron stream in the evacuated acceleration chamber acts as the transformer secondary. A constant frequency of 47.7 megacycles, at 3.5 K.V. is maintained across the accelerating gap, while the electrons are held in synchronism by a rapid rise in magnetic field strength to approximately 11.5 kilogauss. This is accomplished by discharging a large capacitor through the magnet winding.

The capacitor and magnet form an L-C circuit resonant at 32 cycles, at which frequency the capacitor is rated 29,200 KVAR. The peak current and voltage at time of discharge is 3060 amperes at 19000 volts. This discharge lasts 1 full cycle (of 32 cycle frequency) or 1/32 of a second, while the pulse repetition rate is 6 per second.

The capacitor is divided into two banks of 1636 mfds. each, in series with the magnet and charged during the pulse interval from a 3 phase full wave rectifier having a 100 K.W. 480 volt 60 cycle source. Pulsing is accomplished by firing two sets of Ignitrons, connected back-to-back, momentarily connecting the two capacitor banks in series and forming a discharge path through the magnet. The simplified circuit is shown in Fig. 5.

A pair of Diode Limiter tubes, plus a 60 Henry choke, limit the rectifier current to a safe value during the Ignitron firing period. With the capacitor banks connected in series, total capacitance is 818 mfds. providing stored energy of 148 KW. seconds, derived from:

$E = 1/2\, C\, V^2$ with C in Farads and V in volts.

During each pulse, the energy dissipated in the L-C circuit is 12.3 KW. secs or 8.3 percent of the stored energy. With a 1 cycle pulse, the power dissipated in this circuit will be:

$12.3 \div 1/32$ or 394 KW. pulse peak power

The duty cycle will be $(6 \times 100) \div 32 = 18.75$ percent which results in averaged power dissipation of 74KW. over the full 1 second period, itemized approximately:

135 Ton Magnet iron loss	8KW.
1.75 Ton Magnet copper loss	8KW.
Capacitor losses	32KW.
Ignitron losses	26KW.
	74KW.

To the averaged power of 74KW. should be added 13KW. capacitor Bleeder losses, and 10KW. losses in the Diode Limiters, making a total of 97KW. averaged power taken from the high voltage rectifier. Adding the several small components of power losses in the rectifier, plate transformers, induction voltage regulator, etc. will result in a total average load of approximately 100KW. on the 60 cycle system with relatively small variations during pulse and pulse interval periods.

Flywheels are used for obtaining large values of stored energy for the excitation of the Bevatron Magnet. The Bevatron, to be used for accelerating Protons to approximately 6 BEV, is now nearing completion. It's magnet is 120 ft. in diameter, weighs 10,000 tons, and requires 733,000 ampere-turns per quadrant excitation for maximum magnetic field of [redacted] 16 Kilogauss. This magnet will be pulsed at about 100MW. peak power and will require nearly 550,000 CFM of air cooling, provided by two 327 RPM, 250 H.P. Synchronous motors.

Magnet excitation is provided by two 46,000 KVA. 12 phase 5500 volt generators, driven by 3600 H.P. 12 KV. wound rotor motors, each equipped with a 67 ton flywheel. The windings of the magnet and the generators are so arranged that the total voltage across the magnet will be 18 KV although the voltage to ground at any point will not exceed 4500 volts. Eight groups of continuously pumped, thyratron controlled Ignitrons rectify the (55 cycle) generator currents, and provide peak currents of 8333 amperes, pulsed at a repetition rate of 10 per minute. This pulse wave shape is triangular, rising to crest in 1.85 seconds, decaying in 1.85 seconds during inversion, followed by pulse off-time of 1.4 seconds. The magnet, having an inductance of approximately 2.4

Henrys at full current, will store magnetic energy of 83 MW. secs,. again derived from the conventional:

$E = 1/2 L I^2$ with L in Henrys and I in amperes.

Each flywheel gives up approximately 40 M.W. secs. of stored energy during pulse rise time, and this energy is returned from the magnet during current decay and off-time. The 60 cycle system is thus protected from the 100 M.W. peak pulses, and will supply only the losses of the magnet and it's excitation equipment. This will average approximately 7 MW. with load swings of about 3 MVA. due to 7 percent speed fluctuations of the M.G. sets.

These motor-generator sets require 6 minutes starting time during which period the average power input is 2250 KW. each. With such large flywheels, the total inertia of each machine is more than 1,800,000 lbs. ft. squared. Dynamic braking is used to stop them, and the same grid resistors in the wound rotor circuit which are used for starting, are also used to absorb the power generated in the rotor during the braking period. A totalizing demand meter installation is used as a guide in the operation of these machines to soften the financial shock of the billing demand charges.

Selective D.C. Sources

In the research power class, one can include various motor-generator sets, in sizes from 30 to 1250 KW. which are used for supplying D.C. to magnetic research areas. These machines have no flywheels because their loads are constant, but an assortment of voltage and current levels will be needed to cover the range of experimental design work. Here again, flexibility is essential, so that the generators may be easily and quickly switched from one test area to another.

Fig. 6 shows a group of 5 D.C. terminal boards, each containing the output terminals, controls, overload relays and metering of their respective generators. Each set of links connects a generator to cables serving a test area. Busbar jumpers, cut to size and ready for use, can connect any machine to any set of load cables. For remote control, starting, etc. a standardized control panel is mounted in each of these test areas. These panels are connected to the main generator room with multiconductor control cables, terminating on a cross-connect board, arranged so that any remote control station can be plugged into any motor-generator control circuit.

Each remote magnet or other load device has it's own overload relay, set to protect it against overload. Each generator has it's own relay which is set to a reasonable overload value. In this manner both machine and it's load, large or small, is adequately protected, consequently the switching of loads and/or machines requires but a few moments. In large magnets, the current decays so slowly, that caution must be used when opening the connecting links. Circuit breakers or switches cannot be used and the load circuit is de-energized by removing the generator field excitation, thus permitting load current to die out.

Accelerator Auxiliaries

Of smaller load but equal importance in the operation of Particle Accelerators, are the various auxiliary devices such as Vacuum pumps, R. F. supply, Ion sources, Injectors, Deflectors, etc. with their associated control, timing and metering equipment, for the Accelerators cannot operate without them. In this class, the larger components of load are the vacuum pumping system and the R.F. supply which will be described very briefly.

Particle acceleration occurs in tanks, tubes or chambers under high vacuum. These vacua are produced by combinations of Oil Diffusion Pumps, and rotary mechanical pumps. Diffusion pumps range in sizes up to 32" I.D. and can draw a vacuum in 3 stages to 10^{-6}mm. of mercury. (10^{-3} Microns).

They operate on the principal of molecular diffusion of a gas into a vapor which in this case is oil vapor emerging in several pressure stages inside the pump, directed downwards and drawing air molecules from the intake manifold connected to the top of the pump. The manifold is connected to the acceleration chamber or tank of the Accelerator. Oil boilers at the base of these pumps use heating elements rated from 6 to 9 KW. at 240 or 480 volts, 1 phase. Oil vapor is condensed by means of water cooling coils around the outside of the Diffusion pump, and returns to the boiler tank, completing it's cycle. The main pump exhausts into a smaller unit of similar construction, called a booster pump. The combination will only work into a fore pressure of about 1 mm. of mercury, consequently a fore-pump must be used between the Diffusion pumps and atmospheric pressure. For this purpose, a rotary, oil sealed mechanical pump (such as Kinney or the Beach Russ) is associated with each Diffusion pump and it's Booster.

The Bevatron, whose magnet is wound in Quadrants, will have 6 of the 32" Diffusion pumps (plus their 8" boosters) grouped in the vacuum chamber gap between each quadrant. These are rated 10.5 KW, 480 volts, 1 phase each, including the booster, and will be connected into two 3 phase groups, making a 63 KW. load at each quadrant gap, or a total of 252 KW. for the 24 pumps. Fore or primary pumping will be provided by connecting these units with 8" pick-up lines terminating in a 10" suction line run to the mechanical pump room, containing 8 of the 310 CFM size and 6 of the 105 CFM size Kinney pumps. For roughing and finishing purposes there will be an additional 16" suction line run directly into a tangent tank.

Of these, the larger units have 15 H.P. motors, while the smaller units are driven by 5 H.P. motors. Allowing 1 K.W. per H.P. of motor output, this total pumping load will be 402 KW. at 480 volts, three phase. The 8 larger size Kinney pumps will be used for reducing tank pressure (roughing) to approximately 200 Microns, after which the 24 diffusion pumps will be used with these 8 mechanical pumps to hold a tank vacuum of 10^{-2} microns.

As mentioned above, the R.F. supply equipment places a moderate load on the 60 cycle system. The high voltage rectifier for the R. F. equipment of the Linear Accelerator, is rated 15 amperes at 20,000 volts, or 300KW. This rectifier charges an 18 mfd. capacitor through a 33 Henry choke. When operating at 18 KV., the capacitor's stored energy will be 2.92 KW - secs. and when pulsed for a period of 600 microseconds, the pulse peak power will be 4870 KW. One side of this capacitor is grounded. The other side contains a series circuit of sphere gap and specially wound pulse transformer having a 1:2 ratio. The remaining primary terminal is grounded. When the sphere gap breaks down, triggered by a timing bias circuit, the capacitor discharges to half voltage or 9 KV. This is stepped up in the pulse transformer to 18 KV. and appears as equal plate voltage to 9 oscillators arranged along the length of the 40 ft. Linear Accelerator tank. The oscillators are tuned to generate a frequency of 203 megacycles, and deliver their output to the series of drift tubes inside the tank.

Conclusion

The modern research laboratory contains so many lethal devices, that a persistant safety campaign must be carried on at all times. Highly trained personnel, absorbed in creative work, tend to become unconcerned about the hazards surrounding them, consequently circuits and equipment must be carefully planned so that accidents will be avoided.

High voltage equipment is screened, gates and doors kept locked, and interlocks are wired into control circuits so that voltage will be removed if doors are inadvertently opened. All outdoor transformer banks, fused cutouts, etc. are connected with lead cable-wiped joints instead of the conventional open wiring. Fig. 7 shows a main transformer yard, in which everything that is energized, is surrounded by steel plates, steel caging, or lead sheath, and solidly grounded.

Cages containing high voltage equipment are equipped with numerous grounding hooks, placed just inside the door, where the maintenance man can reach them and hook them onto each point of danger. Equipment which emits rays having high penetrating power, such as the gamma and the X-rays, must be shielded with lead or concrete.

Magnetic materials must not be placed near magnets where the application of the field might slam the material against another object or person. Wiring devices, subject to radioactive contamination, must be expendible, e.g. buried in concrete and dumped into the ocean. Sensitive instruments must be shielded against powerful stray fields and protected from corrosive fumes and acids. Water cooled high voltage equipment, must use very low conductivity water, plus removable electrolysis anodes, to prevent the disintegration of the plumbing system.

These are some of the items which must be considered when planning circuits and designing the electrical power supply for the nuclear research laboratory.

Carl T. Grauer
April 21, 1952

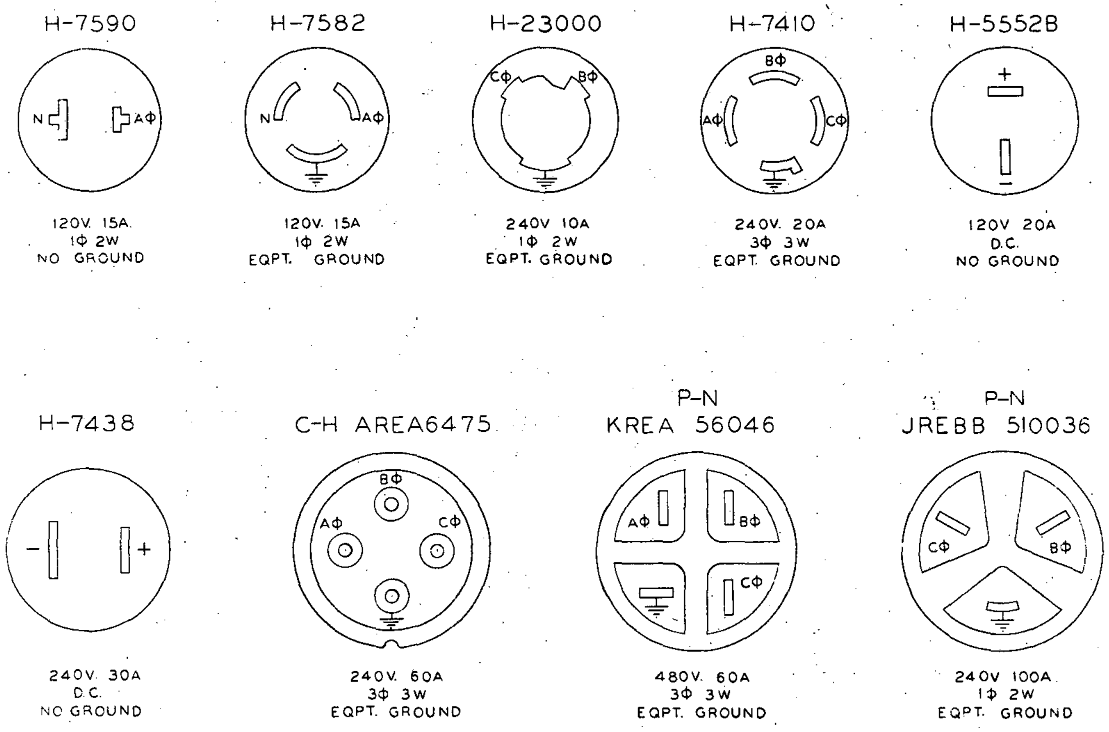


FIG.1 —— POWER RECEPTACLES —— U.C.R.L.

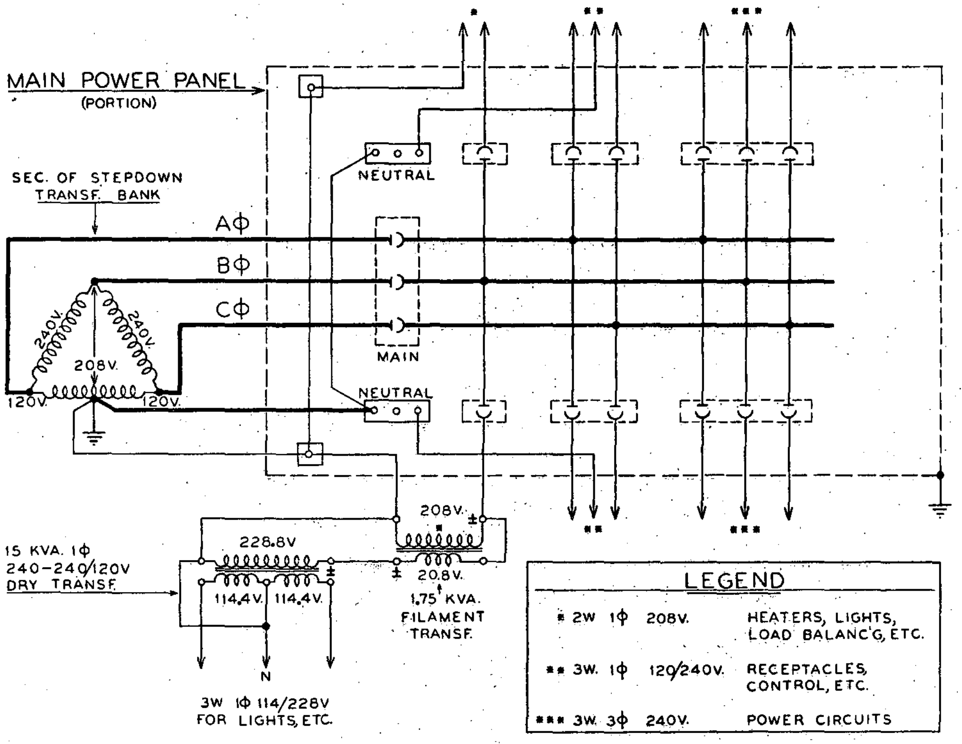
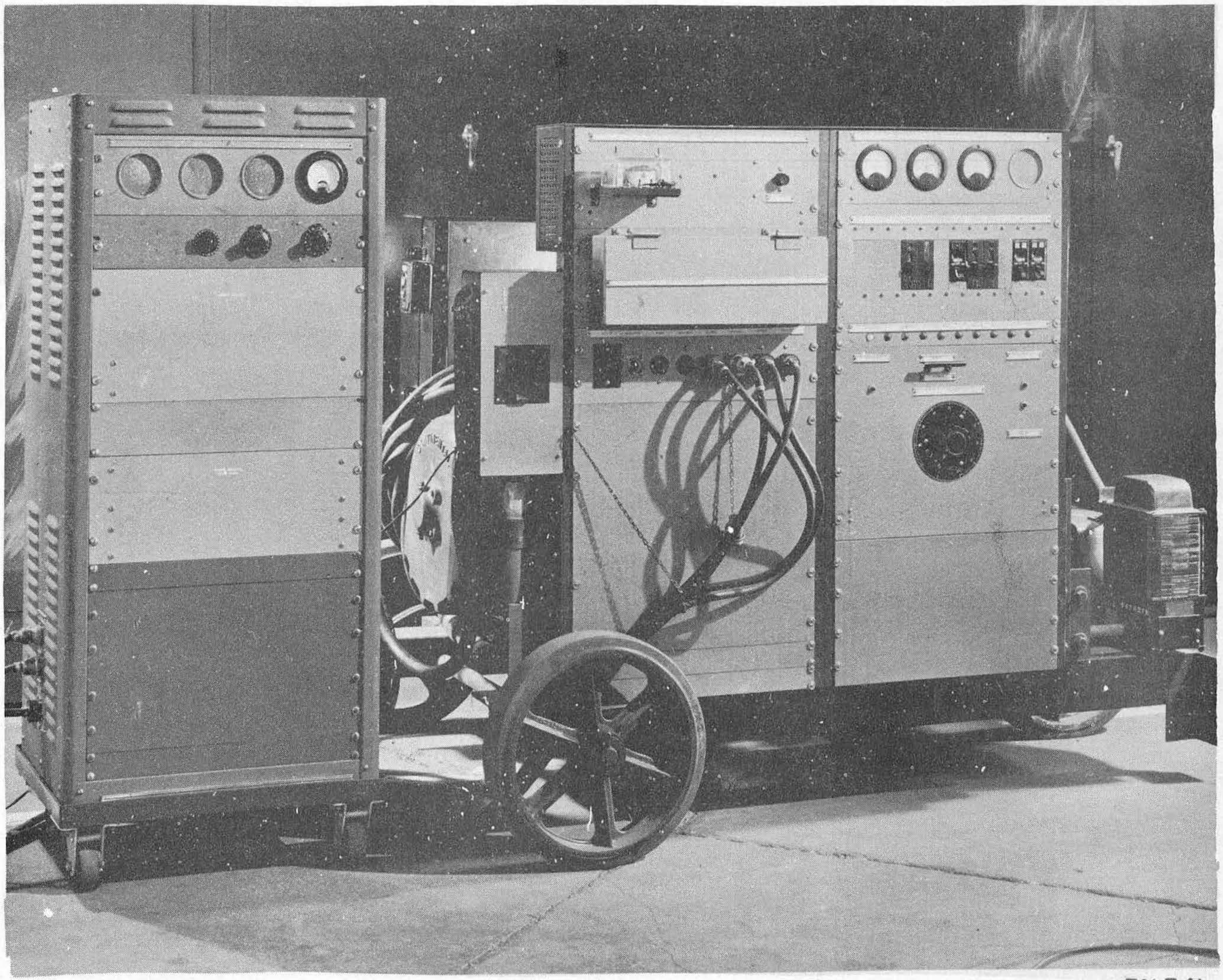

MAIN POWER PANEL
(PORTION)
SEC. OF STEPDOWN TRANSF. BANK
AΦ
BΦ
CΦ
240V.
240V.
208V.
120V.
120V.
NEUTRAL
MAIN
NEUTRAL
*
**
***
208V.
±
20.8V.
±
1.75 KVA. FILAMENT TRANSF.
228.8V
114.4V.
114.4V.
±
15 KVA. 1Φ 240-240/120V DRY TRANSF.
N
3W 1Φ 114/228V FOR LIGHTS, ETC.
LEGEND
* 2W 1Φ 208V. HEATERS, LIGHTS, LOAD BALANC'G, ETC.
** 3W. 1Φ 120/240V. RECEPTACLES, CONTROL, ETC.
*** 3W. 3Φ 240V. POWER CIRCUITS

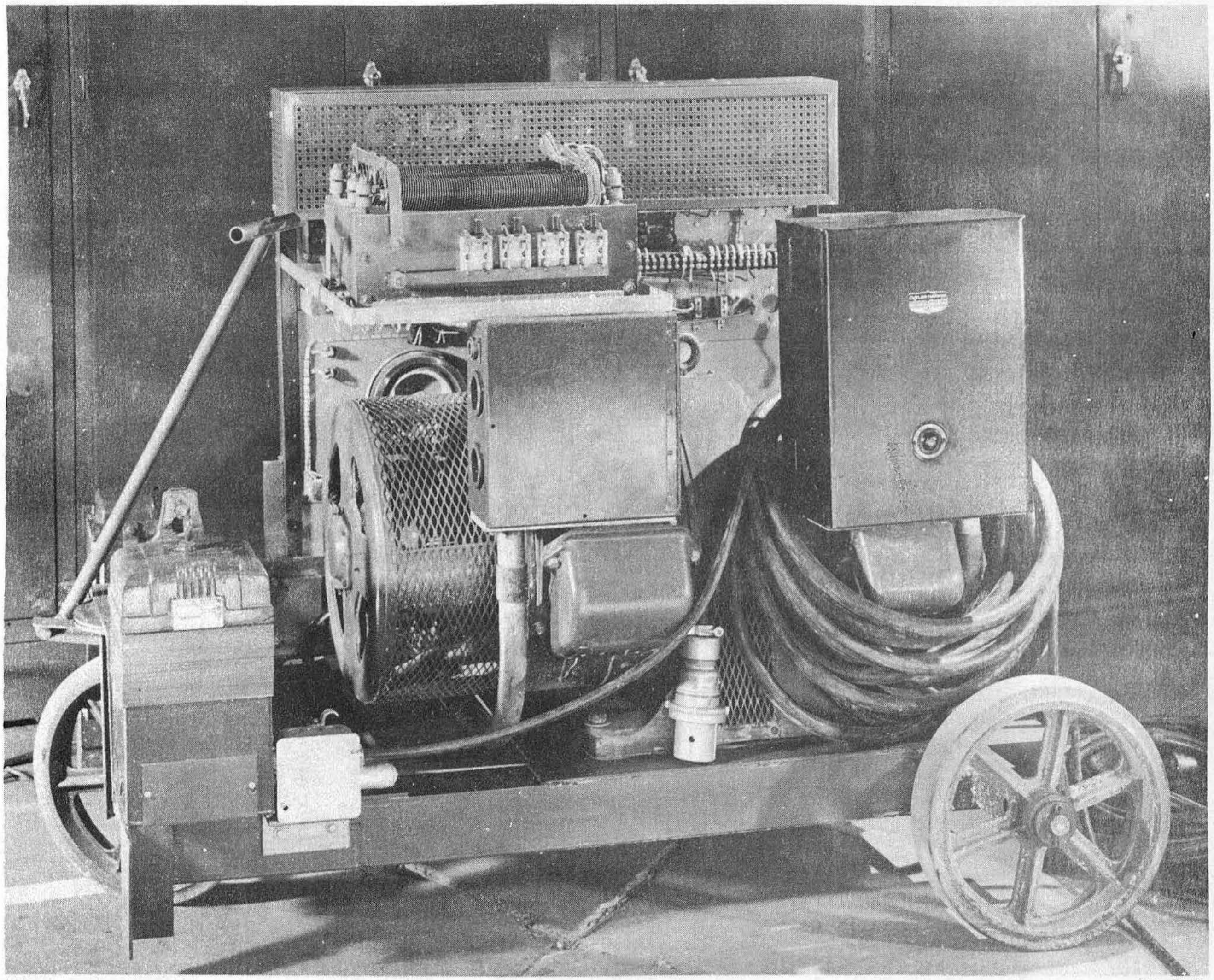
FIG. 2

MU 3839



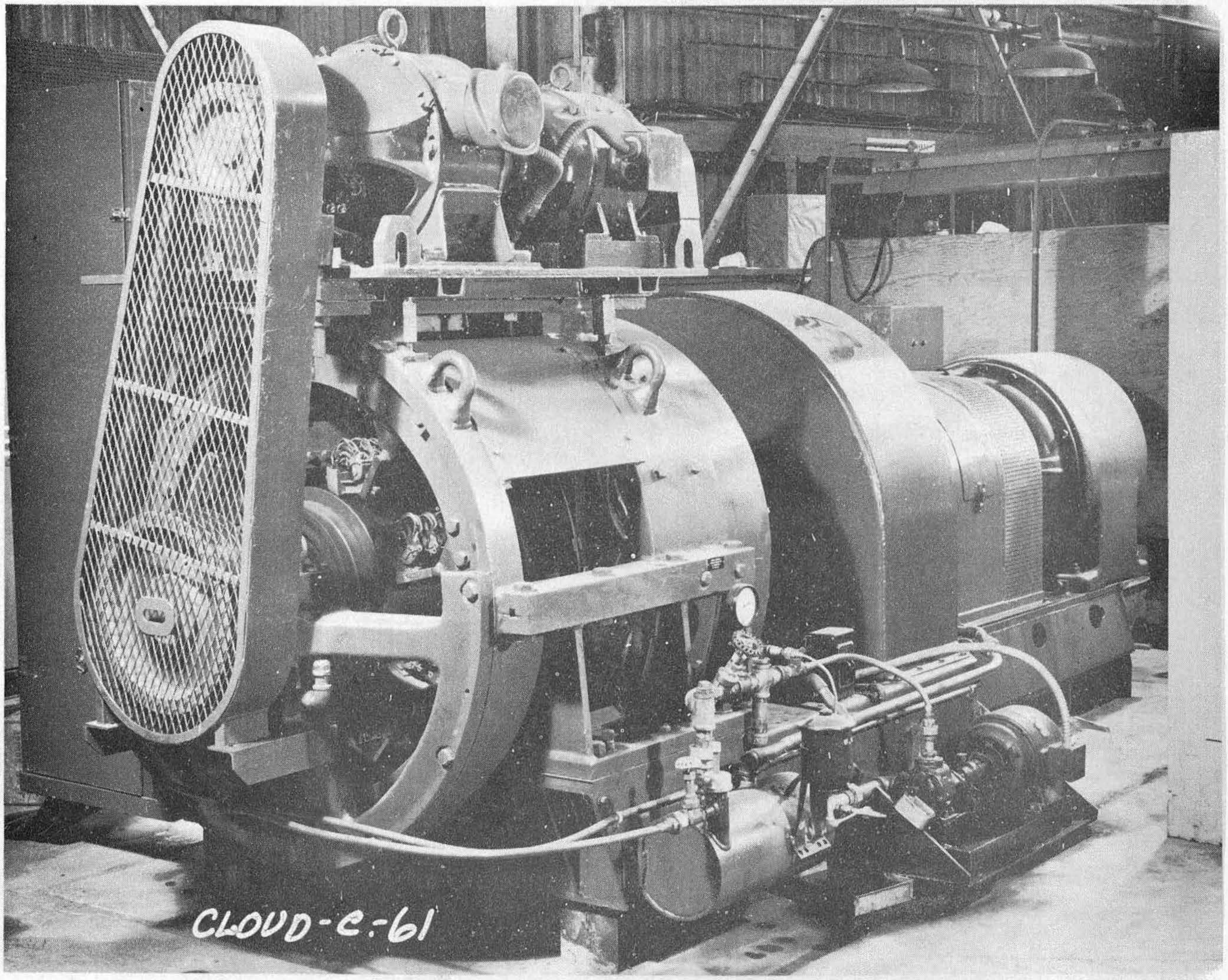
ZN 341

Fig. 3A - Front view, 20 KW. Portable Generator With Regulator



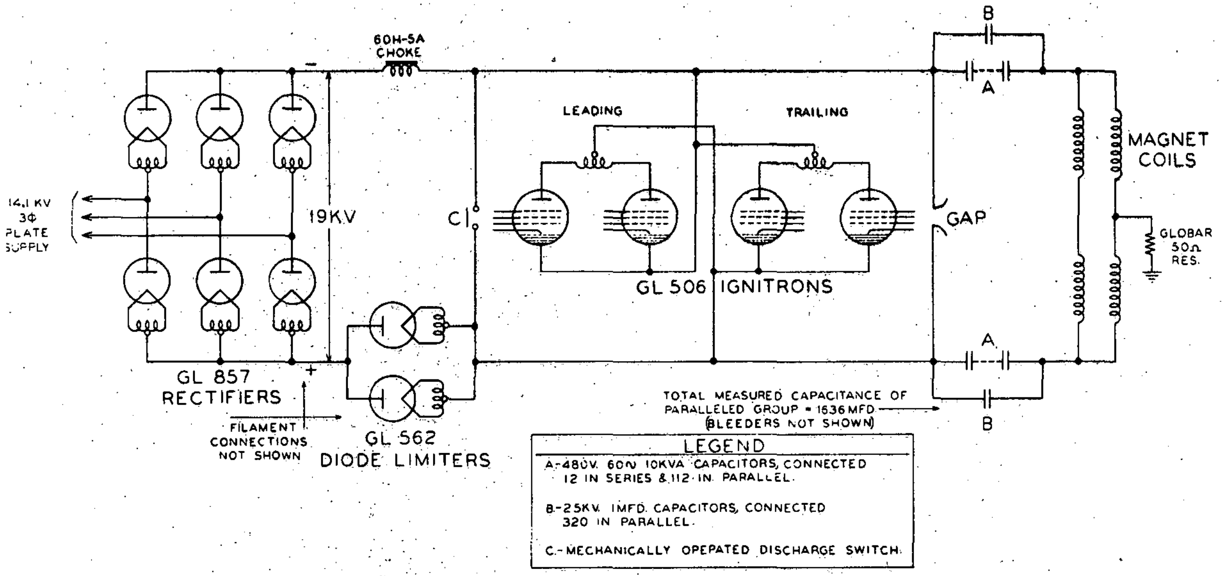
ZN34

Fig 3B - Rear view, 20 KW. Portable generator



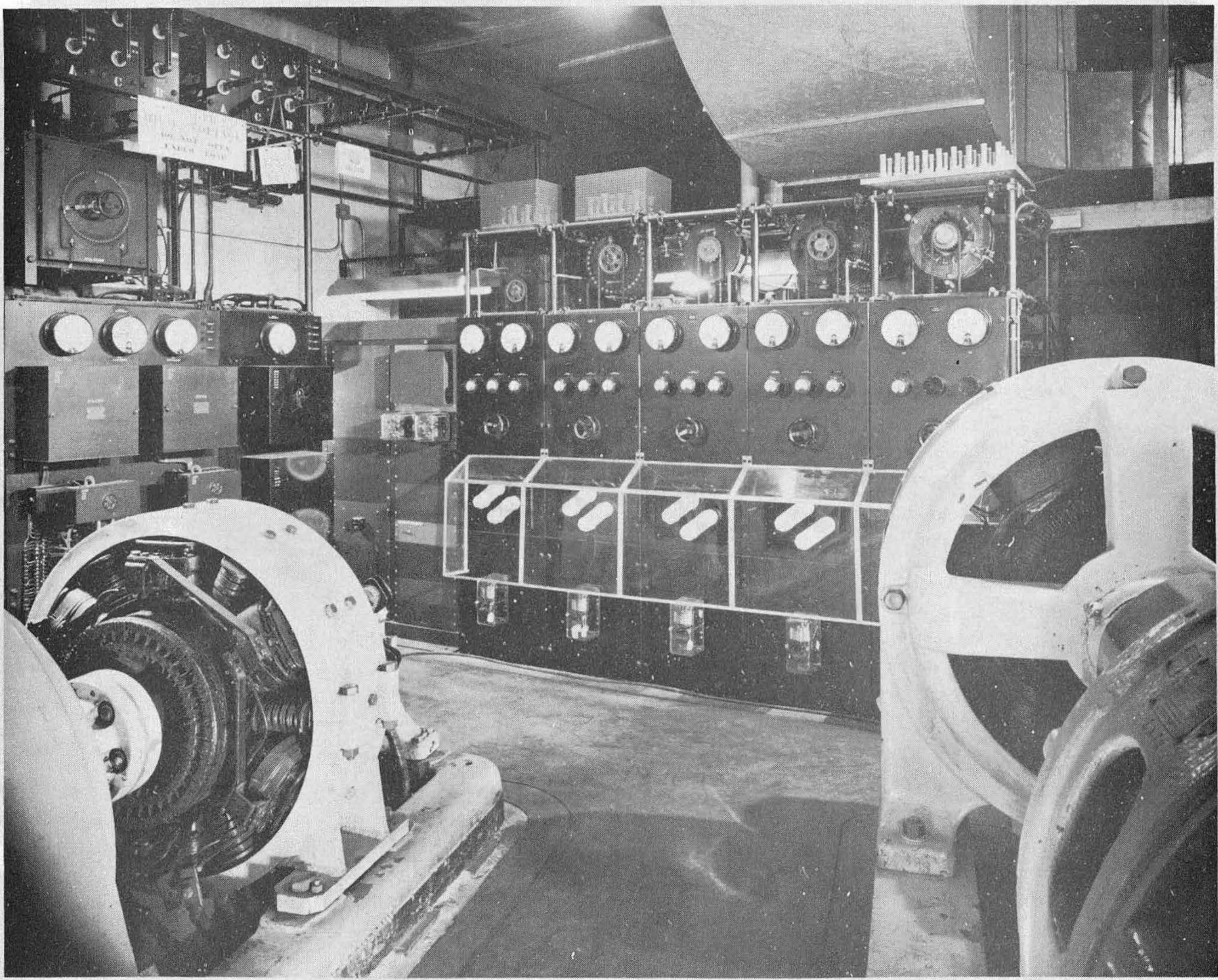
ZN340

Fig 4 - Cloud Chamber Generator



MU 3840

FIG.5-SYNCHROTRON BASIC H.V. CIRCUIT



ZN 343

Fig 6. - D.C. Terminal and Control Boards

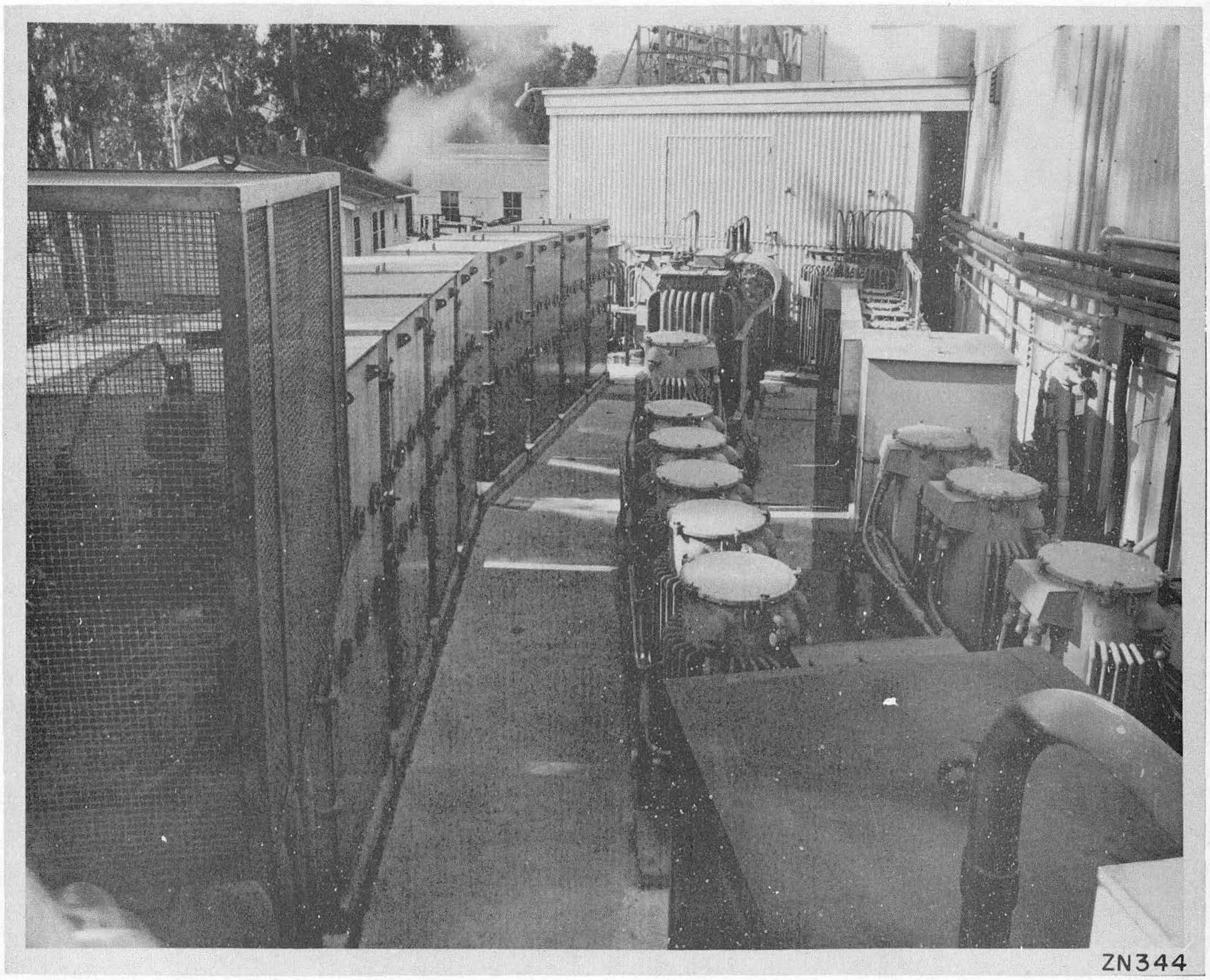

ZN344

Fig 7 - Main Transformer Yard